Land use and traffic generation in urban areas, with particular reference to Perth

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'LAND USE AND TRAFFIC GENERATION IN

URBAN AREAS, WITH PARTICULAR REFERENCE

TO PERTH'

A thesis presented to the Department of Geography, University of Durham, for the degree of Doctor of Philosophy.

M. E. Eliot Hurst.

PREFACE

This thesis owes its origin to many sources. The introduction to traffic studies began with a two week visit to the Road Research Laboratory, and advice continued over the following three years. It was made financially possible with a D.S.I.R. Research Studentship, and through the Department of Geography, University of Durham, and the Burgh of Perth. The willing help of the Burgh Surveyor's Department of Perth, and later the Scottish Development Department, ensured the successful completion of the field work.

The list of helpful people and organisations is too long to itemise individually. However mention must be made of the Burgh Surveyor of Perth and his staff, numerous citizens and firms in Perth, and Perth local press, the Scottish Development Department, and the Joint Urban Planning Group. In Durham constant help was available from my supervisor, Professor W.B. Fisher, from Mrs. E. Templeton and Dr. Horgood of the Computer Unit, and from Dr. E. Sunderland. In Vancouver, financial help was available from the Department of Geography, Simon Fraser University in the final preparation of the thesis. Finally, and not least, thanks must go to my wife, who has given me constant encouragement and advice.

M.E. Eliot Hurst,
Department of Geography,
Simon Fraser University.
1966.

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I N T R O D U C T I O N

INTRODUCTION

This thesis attempts to show to what extent relationships may be held to exist for urban areas between land use and the amount of traffic generated, and to try to erect simple mathematical relationships to explain those correlations that are demonstrated. Land use is measured in terms of space, category and location; traffic is thought of as the number of journeys generated or induced by particular land use types. Residential areas are examined as the main generators, and commercial, industrial, etc. areas as the main inductors or attractors. Finally, the suggested relationships are tested by mapping residuals and erecting models to show how such relationships operate over the whole urban area.

The basic tenent of the thesis is "traffic as a function of land use". This has been investigated in general terms in the United States, and in isolated studies in Britain. For some time geographers and others have been describing the relationships between transport and the development of towns, but it is only in the last few years that accurate quantitative data have been collected. No city can wholly exemplify a theory. However closely it appears to conform to the "norm" for cities of its size and type, there are always unique facets of its personality, which enable it to retain its individuality. Perth is no exception. A long and varied history has differentially affected the rate and type of developments. Present day patterns though not to be thought of as historical relicts, nevertheless, are influenced to greater or lesser extent by older developments. However, in many ways Perth does fulfill the predicted norm for a medium sized county town and market and route centre with a population at the 1961 census of 41,199 and 14,202 households. Further this town represents a relatively stable and independent regional centre, with a more or less self contained urban area, small enough to permit intensive investigation in its entirety, yet large enough to provide sufficient variation in land use and family/dwelling unit characteristics to make the study valid.

Any model has only a limited correspondence to the real world. The normative concepts dealt with in this thesis are no exception. Traffic and land use are basically examined as a set of relationships within a closed system, whose applicability depends on the specifications and assumptions made in the first place. Perth's individuality, or explicit geographic personality and regional relations, are important to the traditional approach, but not to the macrogeographer, who is searching for broad generalisations which can help elucidate spatial structures within many medium-sized towns. The concern is not with the uniqueness of geographic distributions, but with normative, model, and theoretical approaches. Perth remains vague and shadowy through this thesis, since Perth itself is not the main concern; that remains as traffic - land use relationships.

Although Perth is fairly small, the number of surveys necessary to carry out the study were costly and numerous. It could not have been undertaken without the financial and physical aid mentioned in the preface.

To collect the basic information the following surveys were undertaken:-

1) Land Use Survey, including square foot areas and land rental areas.
2) Origin and Destination Traffic Surveys, both as internal and external cordons.
3) Employment Survey.
4) Generation by use, linked with the first three survey types.
   A number of surveys fall into this category:
   Questioning employers, employees, goods vehicle and taxi operators, and interviews at the home itself. Various types of traffic movement are included - for example, movements generated by employees, customers, visitors; by service vehicles; and by individual household activity.

5) Pedestrian counts, parking surveys, facility user surveys, etc.

In conjunction with the 1961 census data (at enumeration district level), rateable value, rental information, and additional data as to vehicle ownership and so on, obtained at the home interview, it was possible to link traffic generation with socio-economic status, house and vehicle ownership, housing types, and to some extent land values.

The zoning system used was devised first for the origin and destination survey, and maintained through subsequent surveys for uniformity. Each zone without the central area represents the catchment area of a major road, with minor modifications of the boundaries to take account of land use and enumeration district boundaries. The zones in the central area of Perth were divided according to major shopping areas and centro-peripheral areas of mixed land use. These zones like comparable areas in most Scottish towns contain a fairly high resident population. Two further zones on the periphery of the central area were marked by a distinctive land use; the railway station, and the principal cattle market.

The thesis falls into three basic parts:

I. Residential Trip Generation,

II. Industrial/commercial Trip Generation, and

III. The Formulation of a Theory and Model.

Information concerning the surveys undertaken, methods used, questionnaires, results, and statistical techniques are to be found in the Appendices. The results of the Journey-to-work survey, printed out by the Elliott 803 computer, are bound separately in Volume II.

PART 1.

PART I.

RESIDENTIAL TRIP GENERATION

INTRODUCTION

The prodigious growth in the use of motor vehicles is one of the oustanding features of the present century, and made its first impact soon after the First World War. At first treated as just another new form of recreation, it soon began to demand alterations to the pre-Twentieth Century road pattern, and in turn started to influence the actual sitings of development. Main road frontages for instance were discovered to be desirable building sites, and in consequence tentacles of development reached out from the towns. The tendency towards more open lower density residential planning which had already begun[1] was greatly facilitated by the flexibility of bus services and delivery vans, which led in time to the growth of vast suburban tracts. There was not however the same tendency for the dispersal of employment, and so the daily movement into and out of town centres was intensified.

Although it has been recognised that travel in urban areas is related to land use activities, little research has been carried out into the inter-relations of traffic generation and differing kinds of land usage until recently. The studies include those by J. Douglas Carroll,[2] Mitchell,[3] Harper,[4] and Schuldiner,[5] in North America; and by Medhurst,[6] Hall,[7] and others[8] in Britain. For long "buildings", the urban fabric, and "traffic", the human response have remained from the point of view of planners, traffic engineers, and geographers, quite separate.

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1. For example, Ebenezer Howard's Garden City Movement.
2. J. Douglas Carroll was study-director of the Chicago Area Transportation Study 1957-1960.
3. R.E. Mitchell and C. Rapkin. "Urban Traffic: A function of Land Use". New York 1954 Columbia University Press.
4. B.C.S. Harper and H.M. Edwards "Generation of Person Trips within the C.B.D." Highway Research Board Bulletin 253. 1960 pp. 44-61.
5. P.W. Schuldiner and W.Y. Oi. "An Analysis of Urban Travel Demands". Evanston Northwestern University Press. 1962.
6. F. Medhurst "Traffic Induced by Central Area Functions" Town Planning Review Vol. 34 No. 1, April 1963 pp. 50-59.
7. P. Hall "Worship St. Survey". Unpub. manuscript.
8. Please see next page.

Residential trip generation is affected by a number of factors, each of which was subjected to regression analysis:

1) Household Size It was found that the mean number of from-home trips/household increases as household size increases,[9] though at a decreasing rate where $R^2 = 0.62$ (the coefficient of determination). Eliminating the effect of adults/children ratio (age, work/non-work trip ratio, and car ownership), a partial household size effect remained indicating some kind of "economy of scale".

2) Car Ownership All traffic studies to date report a high degree of correlation in this category. Perth is no exception, except in one of degree. A unit increase in car ownership increased the average daily trip generation by 2.25 from-home trips ($R^2 = 0.31$).

The data was also examined with one or the other of the two variables held constant. It was found that the larger the car ownership class, the faster trip generation rates rose with increasing family size.

3) Other Variables were examined, such as distance from the central area, density of population, socio-economic status, and certain social area indices.

In the regression analyses the most powerful influence were found to be distance (R^2 0.66), family size, and car ownership.[10]

The analysis up to this point assumed that all journeys were alike, irrespective of mode, purpose, length, time, or destination. The material was therefore further analysed according to journey mode, journey purpose, time (particularly peak-hour departure), and time-distance. Naturally there was an internal differentiation, a function of distance from the central area, distance

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8. For example, E.M. Stone "Traffic Generated by a Wilmslow Specialty Store" - Town Planning Review Vol.34 No.2 July 1963 pp.119-145;
   E.G. Sibbert "Traffic Generated by Different Land Uses" - Journal of the Town Planning Institute Sept./Oct.1960 pp.238-240;
   T.E.H. Williams et al "Road Traffic Generated by Households and Factories" 7th Intern. Study Week in Traf. Eng. London W.T. & A.O. 1964;
   and I. Boileau "Traffic and Land Use" Town Planning Review Vol. XXIX April 1958. pp. 27-42.
9. From -home trips = the one way journey from the home to a destination.
10. The results of multivariate analysis are found in Appendix 6.e.

to work, distance to school, car-ownership, which for example influenced the choice of mode. Also some variables were interrelated, and it was difficult to isolate any particular factor. Thus with choice of mode, not only family size and car-ownership had to be taken into account, but also age structure, and dispersion of family size about the mean. Similarly in the analysis of purpose (by work, business, school, shopping, and social), time, and time-distance, it was difficult to isolate the effect of any particular variable.

Certain other relationships were then studied. Car ownership was studied as a function of social class, mean family income, miles of public bus service in a zone, percentage of male workers, and percentage of families of more than two members; percentage of population as car drivers as a function of social class, age, mean income, bus miles and the percentage of transit users.

The analyses in these sections, and in subsequent parts, were largely dealt with by simple or multiple linear regression. This method assumes a linear relationship of the data, and various tests were used (such as fractile diagrams) to establish this fact. Where data were found to be distributed in a curvilinear fashion, these were transformed by the use of logarithms, e.g. population density was transformed by using Naperian logarithms. But in most the distribution of the results was such that a basic linearity was upheld. Other difficulties included colinearity, where there was significant correlation between "independent" variables, and heteroscadascity, where values of the independent variable do not have a constant variance. But despite these difficulties the various forms of multi-variate analysis proved invaluable.

Finally, some of the theoretical and empirical studies of transport inputs at residential sites are reviewed, and an attempt is made to compare the results obtained in Perth with a number of European and North American empirical studies.

SECTION I HOUSEHOLD SIZE

The mean number of from-home trips per household increases as household size increases, though at a decreasing rate. This indicates some kind of "economy of scale"[1]. The convexity of the curve is consistent with this, but it probably also reflects changing age composition as household size increases. As large households most frequently means more children, the convexity of Graph 1:1 may reflect merely a differential rate of trip generation between adults and children.

Using data collected in the home interview survey[2], the least square relationship between family size and trip frequency is, assuming a linear relationship:-

$$X_1 = 0.24 + 1.12\, x_2$$

X_1 = from-home trips $r^2 = 0.53$ [3]

X_2 = household size

From this equation, trip generation is estimated for a family of 2, as 2.48 trips, and 4.72 trips for a family of 4, against average zonal values of 2.65 and 5.40 respectively. The regression line is plotted on Graph 1:1.

Not only does Graph 1:1 conceal age differences, but also zonal differences. For example, one person households in all Perth generates 0.90 from-home trips per day, whilst the zonal variation is from 0.25 to 1.12 from-home trips/day, for the same household size. Graphs 1:2, 1:3 and 1:4 illustrate this

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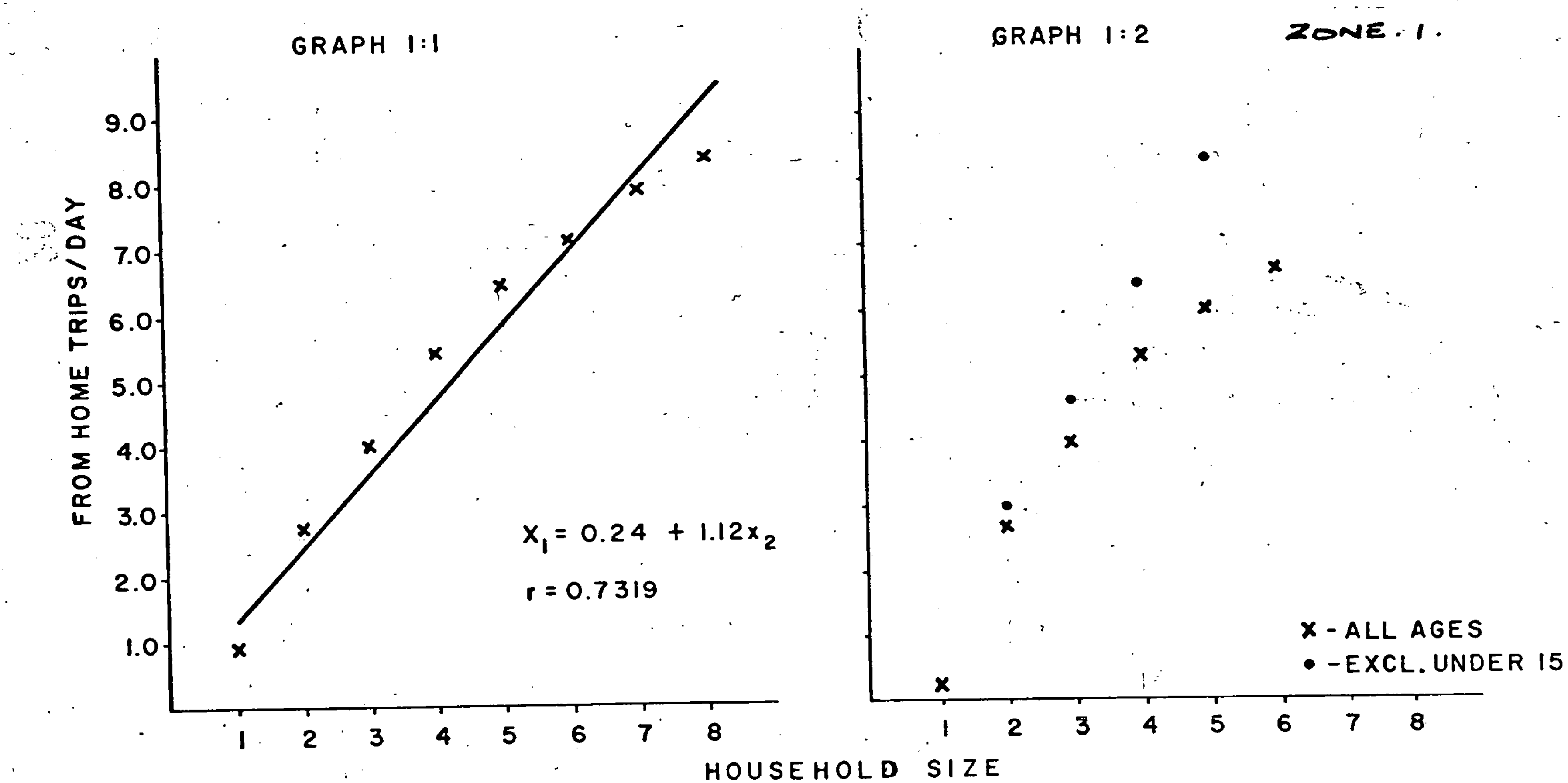
(1) A similar effect was noted by Schuldiner and Oi in their analysis of results for Modesto. Schuldiner and Oi. Op. cit. pp.82-86.

(2) The home interview survey is described in Appendix 3a; the validity of the data was upheld by Bartlett's test (Appendix 6d), and the results are fully analyzed in Appendix 6e.

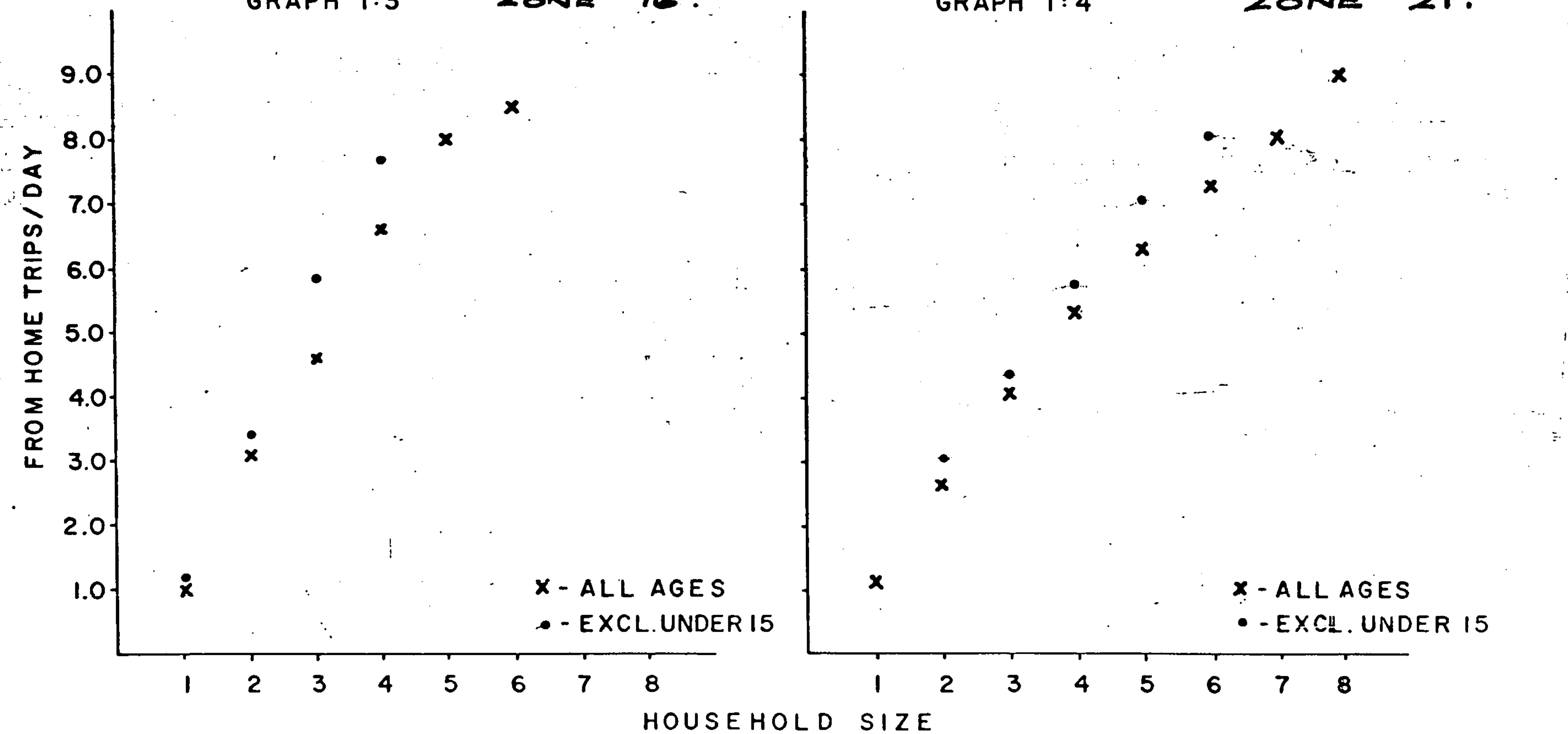
(3) One could also use values for, r = 0.7319
Oe= 9.5303
CV= 0.5303
X = 3.86

But these are largely unnecessary, giving a superficial impression of accuracy.


GRAPH 1:1
GRAPH 1:2
ZONE. 1.
FROM HOME TRIPS/DAY
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
$X_1 = 0.24 + 1.12x_2$
r = 0.7319
1 2 3 4 5 6 7 8
HOUSEHOLD SIZE
X - ALL AGES
• - EXCL. UNDER 15

GRAPH 1:3 ZONE 16.

GRAPH 1:4 ZONE 21.



point - zone 1 is part of the Central Area, zone 16 a high income suburb and zone 21 a large local authority housing estate. Trip generation in zone 1 is consistently lower than the average for Perth; zone 16, higher; and zone 21 similar.

The linear regressions[(4)] are:-

Zone 1 $X_1 = -0.35 + 1.39\ X_2 \quad r^2 = 0.60$

Zone 16 $X_1 = 0.08 + 1.58\ X_2 \quad r^2 = 0.44$

Zone 21 $X_1 = -0.29 + 1.43\ X_2 \quad r^2 = 0.59$

These regressions must be treated with some reserve, for with all Perth the regression is to some extent violated by the average regressions. In this case the square root of Household Size would have been more useful. Also the zonal figures average out random variations and tend to produce a more precise estimate than the high degree of uncertainty in the underlying relationships would seem to indicate. Further difficulty occurs in the areas of individual zones, in that heteroscadascity occurs, i.e. the dispersion about the mean increases as family size increases, so that the function is not strictly a linear one. Despite these reservations, the regressions introduced here are a useful guide. Functions introduced later in the thesis try to overcome some of these difficulties to a much greater effect.

In an attempt to eliminate the effects of age composition, a trip generation rate was calculated taking account of only those members of the family over 15 years of age. This is plotted on Graphs 1:2, 1:3 and 1:4. The exclusion of younger members steepens the curve and reduces its convexity. The differential between the two generation rates should be most marked, if age has an effect, in the larger household sizes. Thus in Zone 1, household size one shows no difference, but the rate for household size five, is 6.0 from-home trips/day for all ages,but 8.3 from-home trips/day for adult membership only.

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(4) The Student 't' test gave 5.62, 6.20, 19.32 respectively, all significant to the 0.1% level.

The regressions are

Zone 1 $X_1 = -0.59 + 1.52\ X_4 \quad r^2 = 0.55$

Zone 16 $X_1 = -0.63 + 1.99\ X_4 \quad r^2 = 0.47$

Zone 21 $X_1 = 1.25 + 0.71\ X_4 \quad r^2 = 0.13$

X_4 = Household size, eliminating those under 15. (all significant to the 0.1% level)

Even though the effect of age composition can be more or less eliminated through the exclusion of the younger age groups, there is still a marked difference in trip generation rate between the two. That is, the difference must be due to an association between household size, and/or other factors affecting trip generation rates. For the moment, household size is of the greatest interest, and the affect of other factors such as car ownership, distance from the central area, and so on will be apparent in later sections. At this first stage of analysis it suffices to attempt to isolate a partial household size effect. This can be carried out crudely by examining zonal variations. For the three zones, 1, 16 and 21, and for all Perth, it is possible to compare trip generation rates for family sizes one to seven, cross-classified by car-ownership classes, zero, one, and two. Eight person households were excluded, since the number in the sample were statistically insignificant. The results are shown in Table 1:1. In all cases, without exception, large households show higher mean from-home trip generation rates, allowing both for zonal variation and car-ownership. More powerful statistical tests were undertaken, and are referred to in the next section.

Map 1:1(5) and Graph 1:5 illustrate the zonal difference in trip generation rates, taking into account differences in family size alone.

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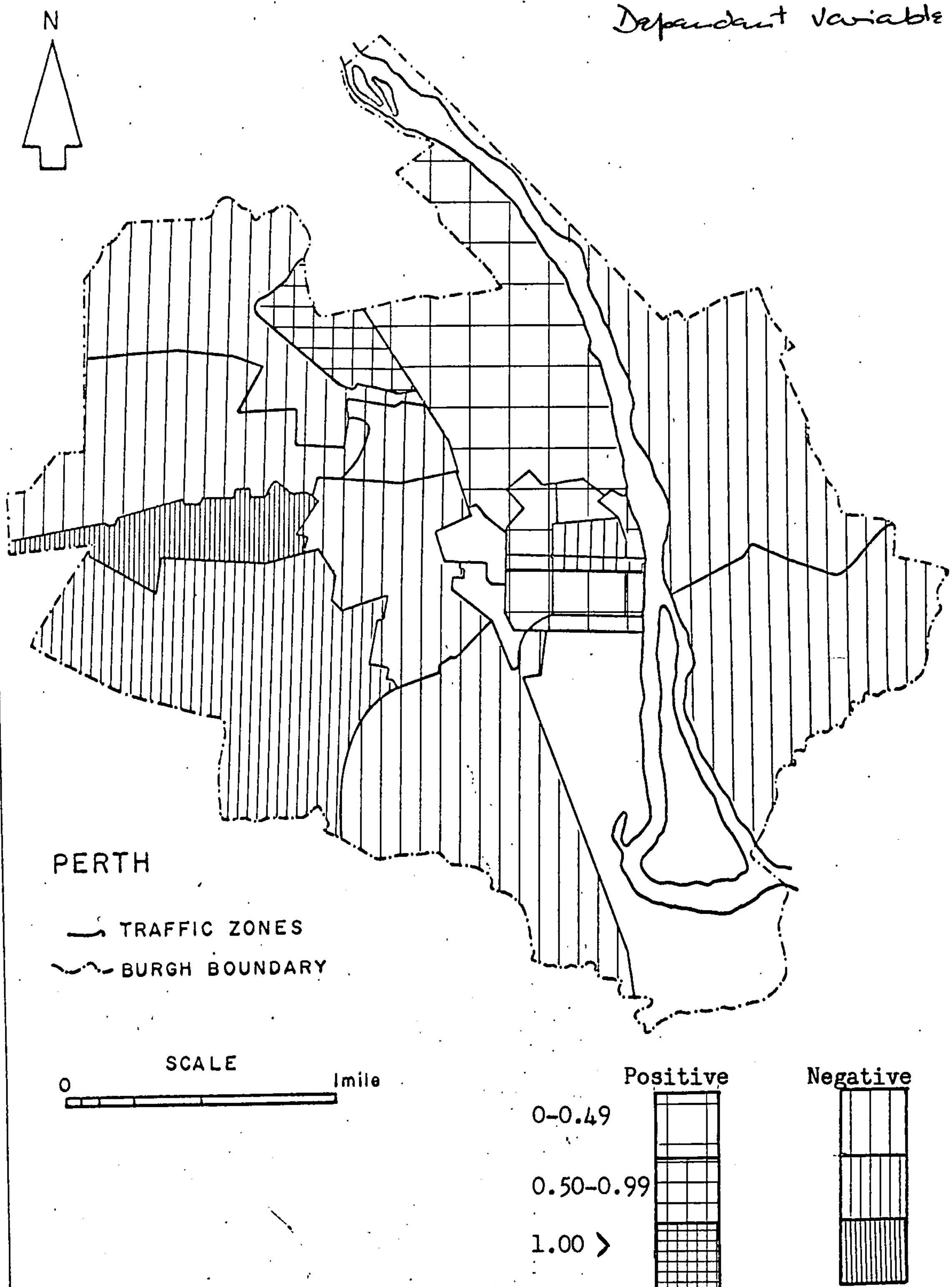
(5) The construction of the maps of residuals from regression throughout this thesis follow, E.N. Thomas 'Maps of Residuals from Regression: Their Characteristics and Uses in Geographic Research' paper No.2, Department of Geography, State University of Iowa, Iowa City. 1960. The expression used is $(y_{cn}-y_n)/S_{yc}$, where y_{cn} represents the computed value of y for the nth unit area; y_n represents the observed value for that unit; and s_{yc} the standard error of estimate. See Thomas pp. 21-24.

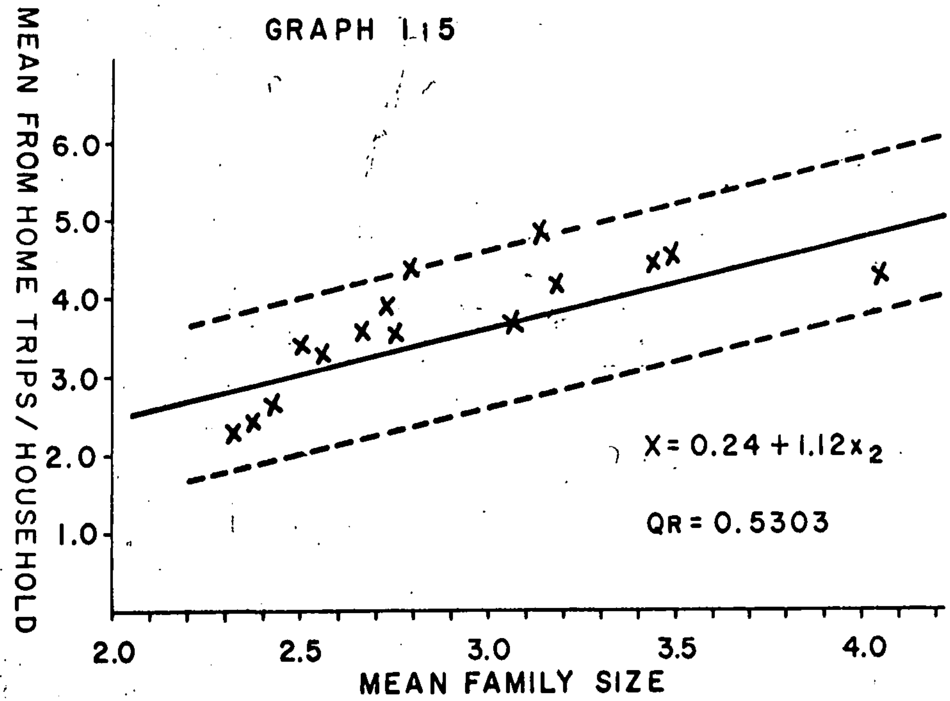
MAP 1:1

Residuals from regression.

From-home trips.
Dependant variable: family size.



GRAPH 1.15



GRAPH 1:6

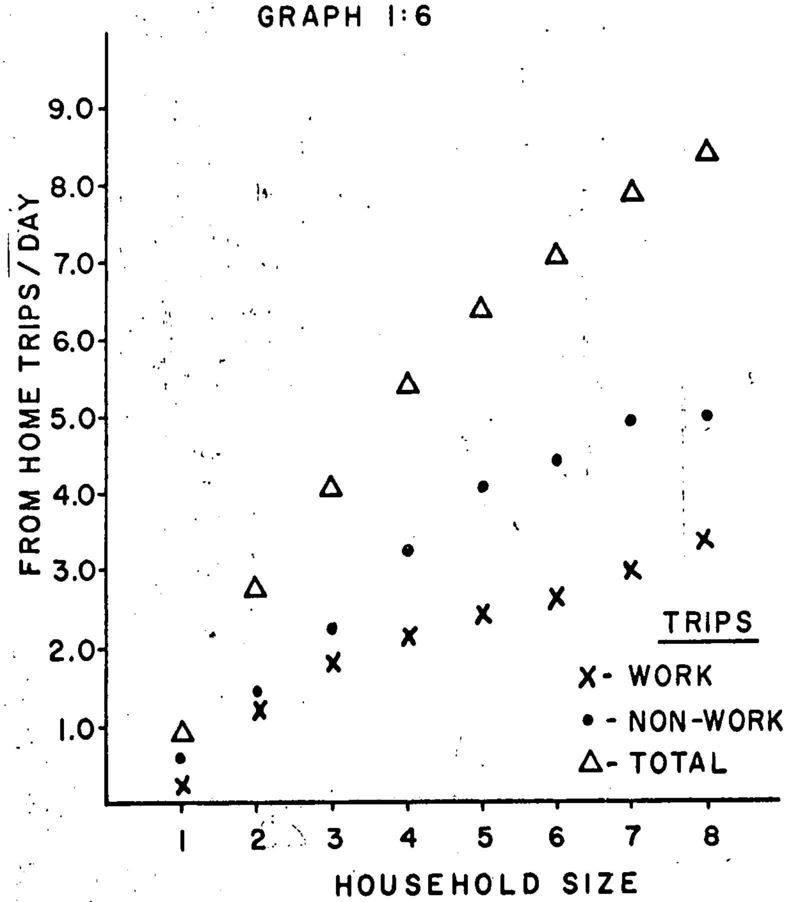


Table 1:1

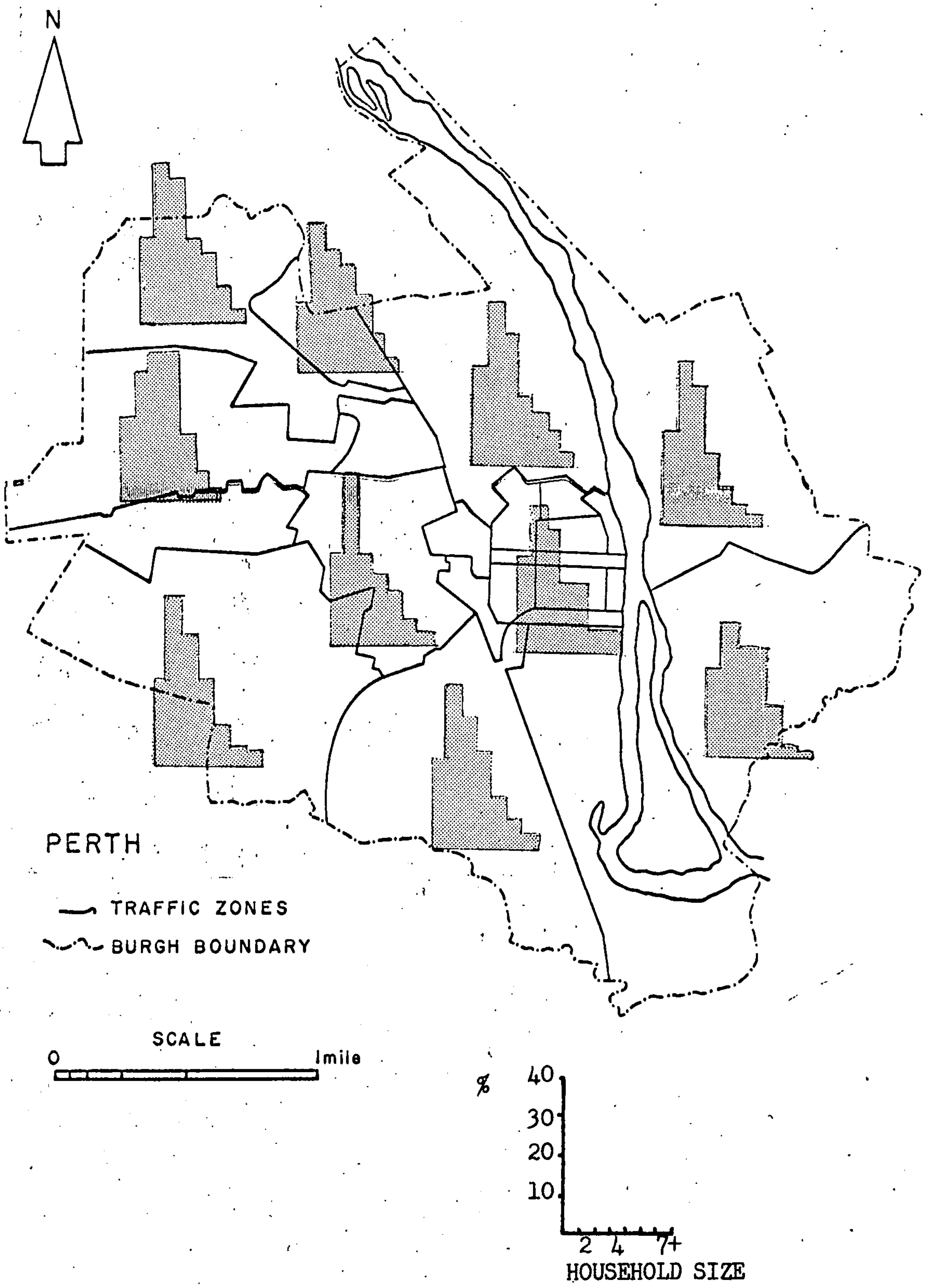
Car Ownership	Fam.size	All Perth	Zone 1	Zone 16	Zone 21
Zero	1	0.83	0.17	0.43	0.82
	2	2.39	2.48	2.07	1.65
	3	3.41	3.50	3.21	3.24
	4	4.77	4.85	4.71	3.99
	5	5.58	6.00	5.81	4.78
	6	6.69	6.60	6.73	5.95
	7+	7.74	-	-	6.89
	All	3.40	3.09	2.54	3.86
One	1	2.07	0.91	2.00	2.61
	2	3.40	3.66	3.49	3.71
	3	5.21	5.50	4.92	6.10
	4	6.82	6.02	6.94	7.91
	5	8.10	-	8.14	8.91
	6	9.57	-	10.27	10.01
	7+	11.00	-	-	11.59
	All	4.92	4.11	5.17	5.72
Two	2	5.01	-	5.20	-
	3	7.34	-	7.36	-
	4	10.25	-	10.52	-
	5	12.16	-	12.72	-
	6	-	-	-	-
	T	7.30	-	6.65	-
All Households		3.86	3.22	4.40	4.52

Zonal variation in family size itself is shown in Map 1:2. Family size leads to a good prediction in 11 out of 15 zones. The exceptions are zones 12, 16, and 20, which have car/person ratios of 0.18, 0.27 and 0.21 respectively,(6) well above the average rates for Perth and Britain as a whole; and zone 23, which has an above average family size.(7) In Graph 1:6 another differential is analyzed, and trips have been classified into 'work' and 'non-work' categories. Work trips increase at a slower rate, by family size, than do non-work trips. The former level off at family size three, the latteraat around seven. Again in fact this is a feflection of the change in age composition. Taking into account these variables, some household effect still remains. It is the simple relationship between increases in family size and an increase in the trips generated,though at a decreasing rate.

(6) Perth average car/person ratio, 0.097. U.K. average 0.162 car/person.
(7) Average family size in zone 23 is 4.19. The Perth average is 3.02. The next zone in size is zone 21 with 3.46.

MAP 1:2

HOUSEHOLD SIZE



SECTION II CAR OWNERSHIP

All traffic studies to date have reported a high degree of correlation between trip generation and car ownership, and car ownership has proved to be an even more important explanatory variable than family size.(1) Most of these studies have been carried out in North America, where car ownership is much greater than in Britain.(2) In Perth, where vehicle ownership is lower, it is however, still of importance. Insufficient studies have been undertaken in Britain to know whether at car ownership levels as low as those in Perth similar correlation would be found. In the multiple regression analysis to follow, carried out on an Elliott 803 computer, an 'elimination' factor (Student's 'F' test) was built in to the programme to reject any variables which were not significant at 10.0%, 5.0%, 1.0% and 0.1% levels. When car ownership was used with family size the computer retained both values to the 0.1% level, in the estimation of trips per household.

Car ownership gives a household a means of transport which is convenient, readily available, and flexible though subject to some limitation by costs of fuel, etc., allowing a maximum satisfaction of travel "needs". Without a car, a family is limited by the existing means of transportation (bus schedules, frequency, nearness to bus routes, etc.), though in a small town like Perth where few houses are far from a bus route and where distances are short, this factor is less meaningful.

However the assumed causal relationship between car ownership and increasing trip generation must be viewed carefully. Car ownership is not an isolated independent variable; it is interdependent and cross correlatable with other variables. Some of these are measurable, like residential density,

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(1) For example: W.L. Mertz and L.B. Hamner, "A Study of Factors Related to Urban Travel". Public Roads Vol. 19, No.7. April 1, 1957. pp. 170-174; and Schuldiner and Oi. Op cit. pp. 86-95.

(2) Car ownership in the United States is 0.403 vehicles/head and 0.162 in Britain. These figures are from R.J. Smeed "The Traffic Problem in Towns". Manchester Statistical Society. February 1961.

family size, type of dwelling unit, social rank, occupation, income; others either cannot be measured directly or are not susceptible to quantitative analysis, for example, the condition of the economy, social attitudes, attitudes towards the use of hire purchase, and so on. Many of these attendent variables have their own effect on trip generation as a whole. Because of this cross correlation it is difficult at the present level of investigation into travel behaviour, and at existing stages of computer technology, to isolate the precise causal relationships. However the effect is distinct enough to be capable of some analysis.

Allowing as far as possible for the effect of these indirect variables, a relationship between trips generated and cars owned, per household, is shown in Graph 2:1. Multiple car ownership is small in Perth, so that these results should be treated with caution. Households with one car generate 1.51 more from-home trips, than do zero-car households, on average, and the addition of a second car increases from-home trips by a factor of 2.39. The intensity of car use can be measured in a similar way. The addition of one car increases car driver trip rates from 0.04 from-home trips/day with zeroocar ownership, to 1.917 for one car, and 4.666 for two; an increase of 1.91 and 2.75 respectively. Since the addition of a second car has an equal if not greater effect than the first car, this relationship can be expressed in linear terms with more confidence than household size alone. Traffic studies to date are not very clear here. Detroit and Chicago report linear functions, but Modesto non-linear functions.(3)

$X_1 = 3.02 + 2.25\ X_5$ $\qquad r = 0.56$

where X_5 = car ownership. $\qquad r^2 = 0.32$

Thus a unit increase in car ownership will increase the average trip generation rate by 2.25 from-home trips. The constant 3.02 represents that part of the regression which is not explained by car ownership alone, in the case of Perth it is as high as 68% of the total trip generation rate.

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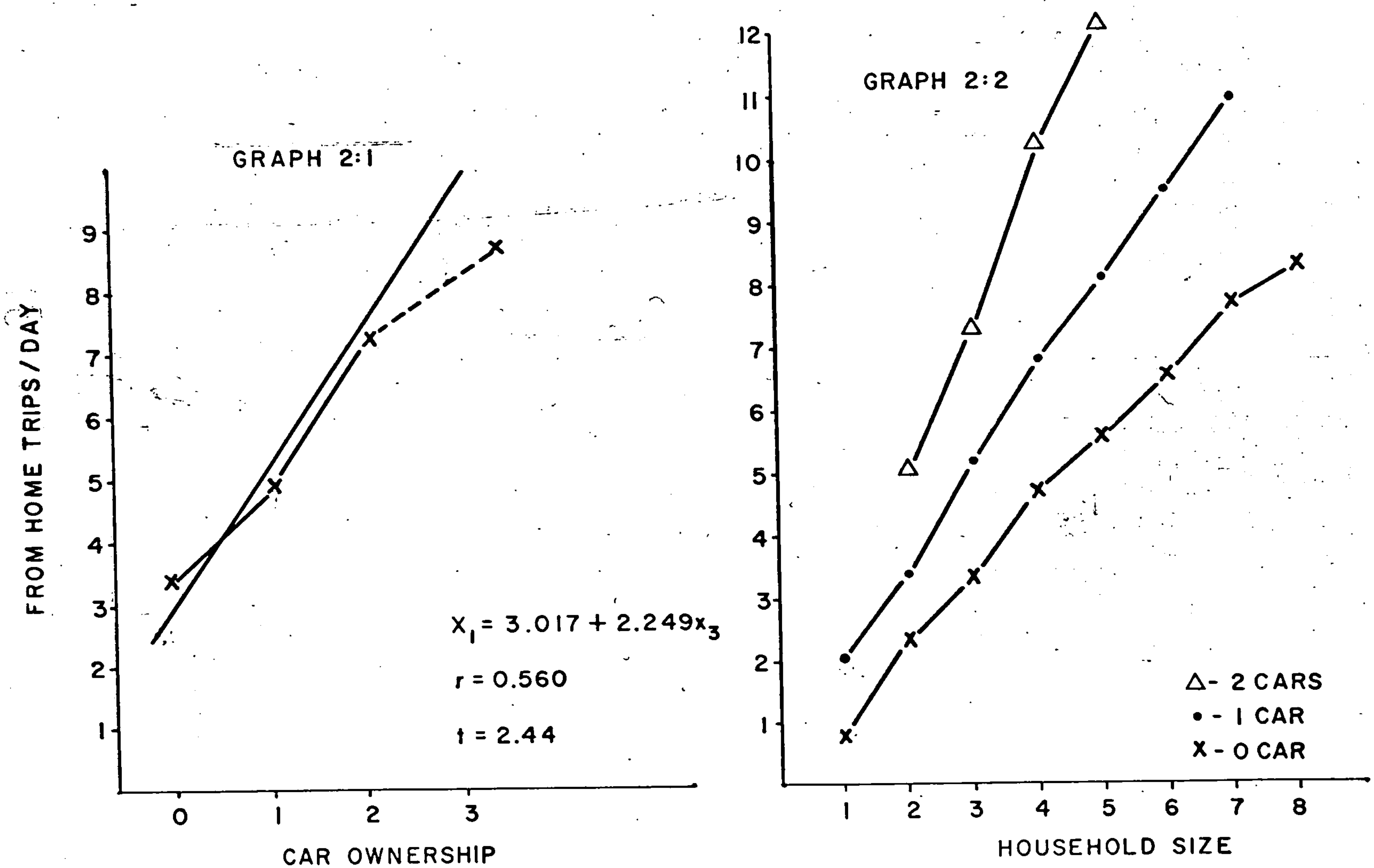
(3) Detroit Area Transportation Survey; Chicago Area Transportation Survey; The Modesto results are to be found in Schuldiner & Oi. Op. cit. pp.86-95, and 197-218.


GRAPH 2:1
FROM HOME TRIPS / DAY
9
8
7
6
5
4
3
2
1
0
1
2
3
CAR OWNERSHIP
X1 = 3.017 + 2.249x3
r = 0.560
t = 2.44
GRAPH 2:2
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
HOUSEHOLD SIZE
Δ - 2 CARS
• - 1 CAR
X - 0 CAR

When considered alone, family size and car ownership have a considerable effect on the number of from-home trips/family, and therefore also on total trips. To examine the partial effect of each, whilst holding the other one fixed, the data has been cross classified by both variables in Graph 2:2. Each line represents a particular car ownership group, and the slope of the line indicates the increase due to family size, holding car ownership fixed. The larger the car ownership class, the faster trip generation rates rise with increasing family size, i.e. the slopes steepen from zero to 1, and 1-2 car ownership. Thus a doubling of family size from two to four persons is accompanied by an increase in from-home trips of 2.38, 3.43 and 5.24, for zero, one, and two car ownership respectively. The explanation of this increase may be accountable by the increased satisfaction of traffic "needs" with personal transport, as well as by the effect of changing age composition, since most multi-car-ownership families include a higher number of adults than one car families.(4)

Graph 2:3 and Diagram 2:1 illustrate this cross correlation again, trip generation rising with family size and car ownership, when one holds in this case car ownership constant. Thus the greater trip generation potential found in larger families is only realised with maximum car ownership.

The "car ownership/family size" pattern can be subjected to more detailed analysis, considering (a) the proportion of residents who normally make a daily trip, to total residents. This category therefore excludes children under 5 years, retired persons, and those housewives who do not make daily journeys; and (b) total trips /daily traveller. Table 2:1 sets out these two factors, cross correlated with household size and car ownership.

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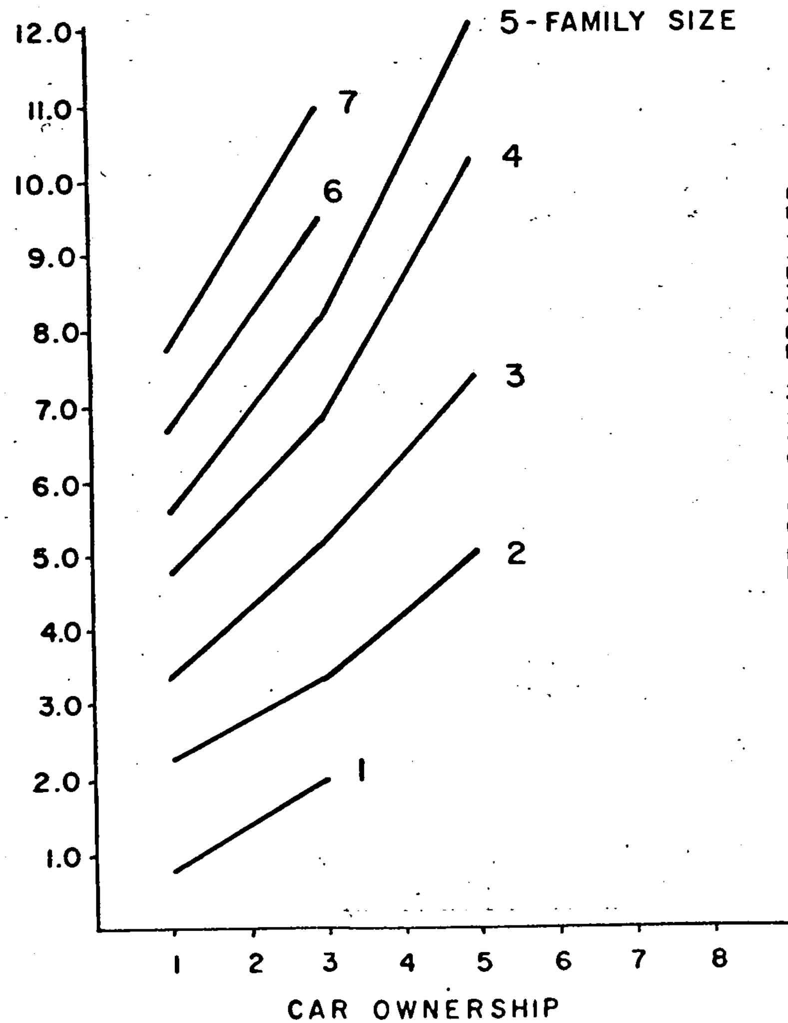
(4) The analysis of multi-car ownership is covered in J.D. Orzeske "Auto Usage in Multi-car Households". <u>C.A.T.S. Research News</u>. Vol. 4 No.7 Nov. 1962. pp.11-16.

GRAPH 2:3



GRAPH 2:4

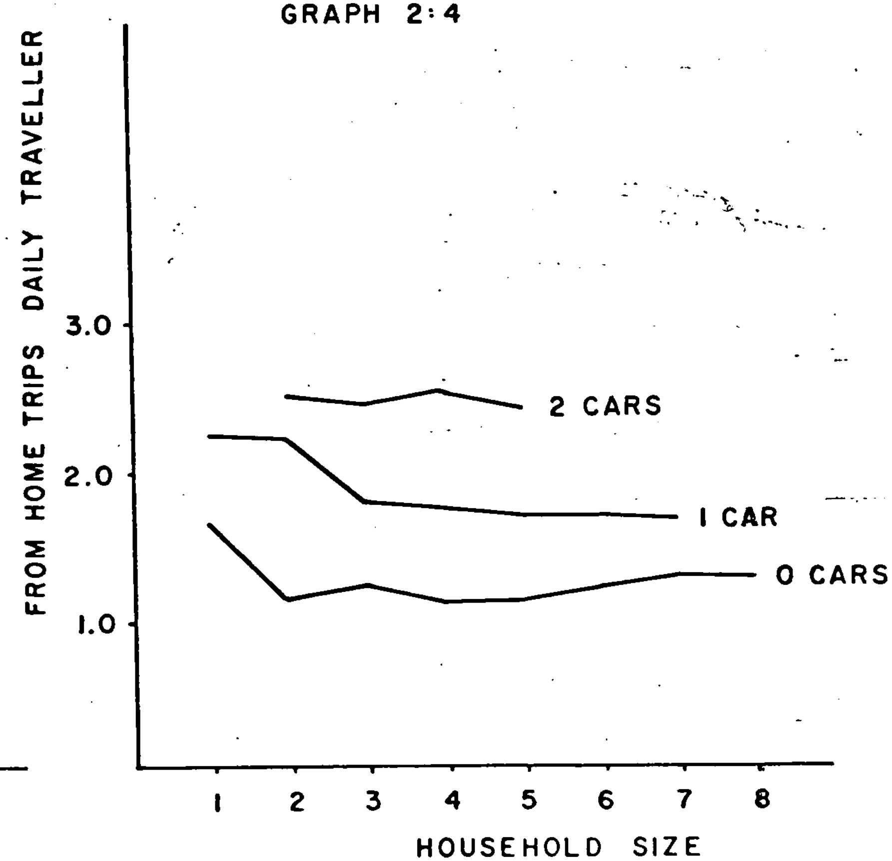
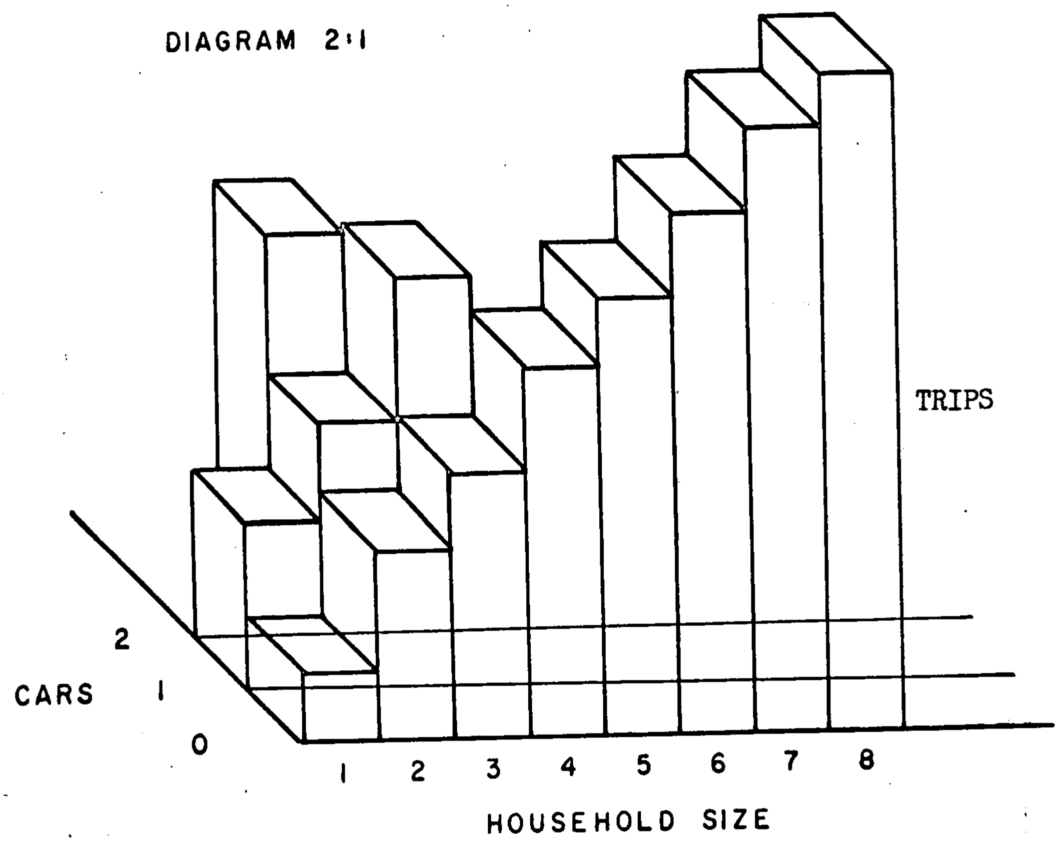


DIAGRAM 2:1



STATISTICAL RELATIONSHIP - $X_1 = X_2 + X_3$

Table 2:1

Household Size	1	2	3	4	5	6	7	8	All
0 cars from home trips/hse.	0.84	2.39	3.41	4.77	5.59	6.70	7.75	8.34	
% daily travel-lers to residents	50.0	86.4	90.6	89.9	87.5	86.0	82.2	75.0	91.0
F.H. trips/ daily travel	1.69	1.15	1.25	1.11	1.14	1.25	1.34	1.37	1.26
1 car from home trips/hse.	2.07	3.40	5.21	6.82	8.11	9.57	11.00	-	
% daily travel-lers to residents	92.3	92.5	96.0	95.5	94.4	92.9	89.3	-	94.4
F.H. trips/ daily travel	2.25	2.23	1.81	1.78	1.71	1.72	1.69	-	1.84
2 cars from home trips/hse.	-	5.01	7.34	10.25	12.17	-	-	-	
% daily travel-lers to residents	-	100	100	98.2	91.0	-	-	-	99.0
F.H. trips/ daily travel	-	2.50	2.44	2.56	2.40	-	-	-	2.49

Car ownership seems to operate in two ways on trip generation:-

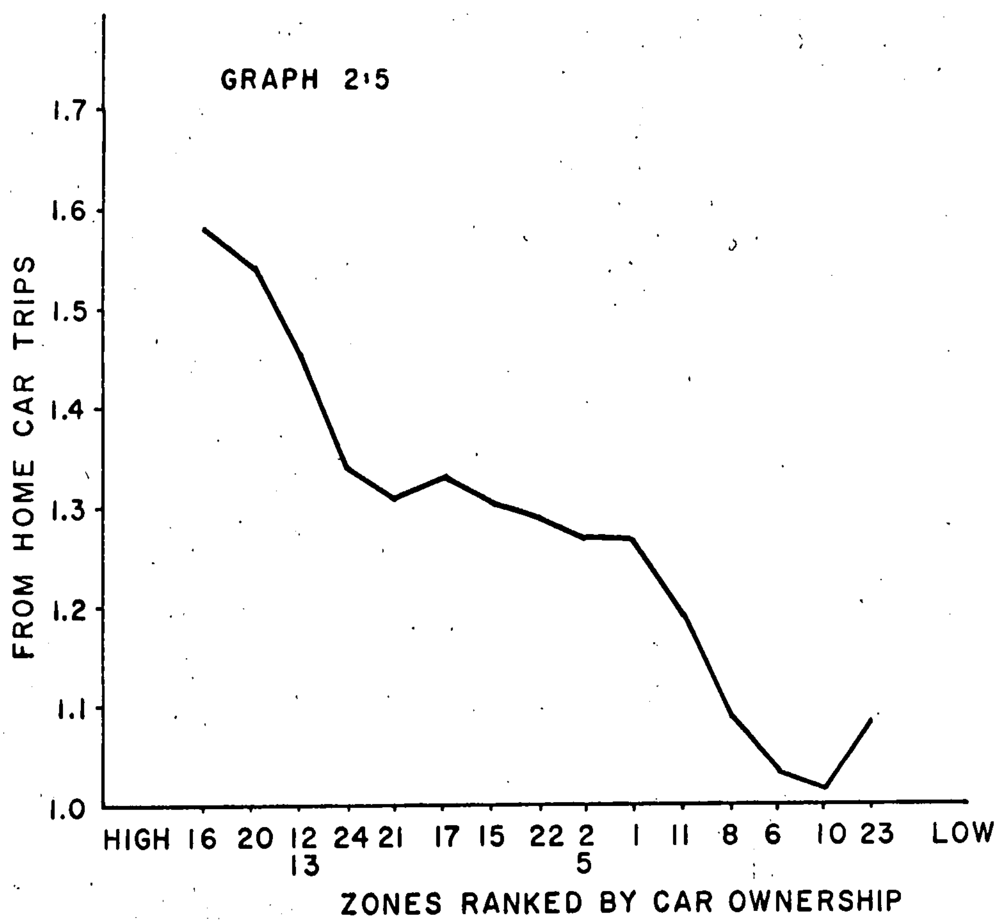
1. The varying proportion of residents who are trip makers. 91.0% for zero car ownership; 94.4% for one car, and 99.0% for two cars. This does in part seem to be a reflection of age structure - there are fewer children in two car households.

2. Increasing car ownership heightens the intensity of travel - 1.25 from-home trips/person for zero car ownership, to 2.49 for multi car ownership.

These two factors complement one another, to produce the relationship shown in Graph 2:1. Holding car ownership fixed, household size shows its impact on the proportion of trip makers. The increase is particularly marked for zero car ownership. As family size one, 50% of the household make no regular trip, largely a function of the high proportion of people over 65 in this size category. Above family size three in all cases, the proportion of children of non school age increases and concommitently the proportion of non trip making housewives increases, so that the proportion of daily travellers declines. The intensity of travel, however, by each daily traveller, in terms of from-home trips/regular traveller, remains fairly constant within each ownership class, with the exception of the small households already mentioned. This is illustrated in Graph 2:4.

The slope of the line in Graph 2:1 is thus largely a result of the overall decline in the proportion of regular daily travellers as family size increases to three and up. Since the decline of daily travellers/resident is most marked when no cars are owned, this group has the most convex line.

As with household size, car ownership can be looked at in terms of zonal variations within Perth. Zonal average person trips/car, ranked by the rate of car ownership, are shown in Graph 2:5. Holding other variables constant, a distinct trend would be expected from high to low car ownership rates, and this is in fact borne out by the graph. Those zones with low ownership rates report a more than 50% decline in trips over those with high ownership rates. This spatial variation is an important parameter when considering total movements. Implicit in the ranking, there is in fact, a distance effect which is analyzed in the next section.


GRAPH 2·5
FROM HOME CAR TRIPS
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
HIGH 16 20 12 13 24 21 17 15 22 2 5 1 11 8 6 10 23 LOW
ZONES RANKED BY CAR OWNERSHIP

SECTION III THE INFLUENCE OF OTHER VARIABLES

3:1 Distance to the Central Area

Most American studies[(1)] have suggested some relationship between dwelling location and trip generation. In American terms this has usually meant reference to the Central Business District (C.B.D.), though it could be interpreted in terms of residential density, social area, and so on, which will be considered in subsequent subsections.

In terms of Perth it is feasible to ask does the proximity of the central area have any effect on trip generation, considering that few dwellings are of further walking distance than 30 minutes, and that a fairly high percentage of the population lives within the central area. Graph 3:1:1 shows as a simple correlation, from-home trips/person (as an attempt to eliminate the effects of family size) and rank distance, measured as the distance from the residential midpoint of a zone to High Street. No startling conclusions can be claimed for this correlation, although a general tendency seems evident on the graph. The correlation coefficient is 0.68. Much of the variation would seem to come through car ownership, so that zones 12, 20 and 16 have the highest rates of ownership, and zones 10, 6, 8 and 23 the lowest. The central area itself (zones 1 and 2) shows a trip generation rate as high as that of three zones of medium distance and average car ownership (zones 17, 24, 15, 22 and 21), even though these central zones have a low rate of ownership.

Graph 3:1:2 is an attempt to hold car ownership steady plotting from-home journeys/person, at zero, one and two car ownership levels. Eliminating the effect of car ownership, the influence of distance is more obvious. Again the central area seems anomolous.

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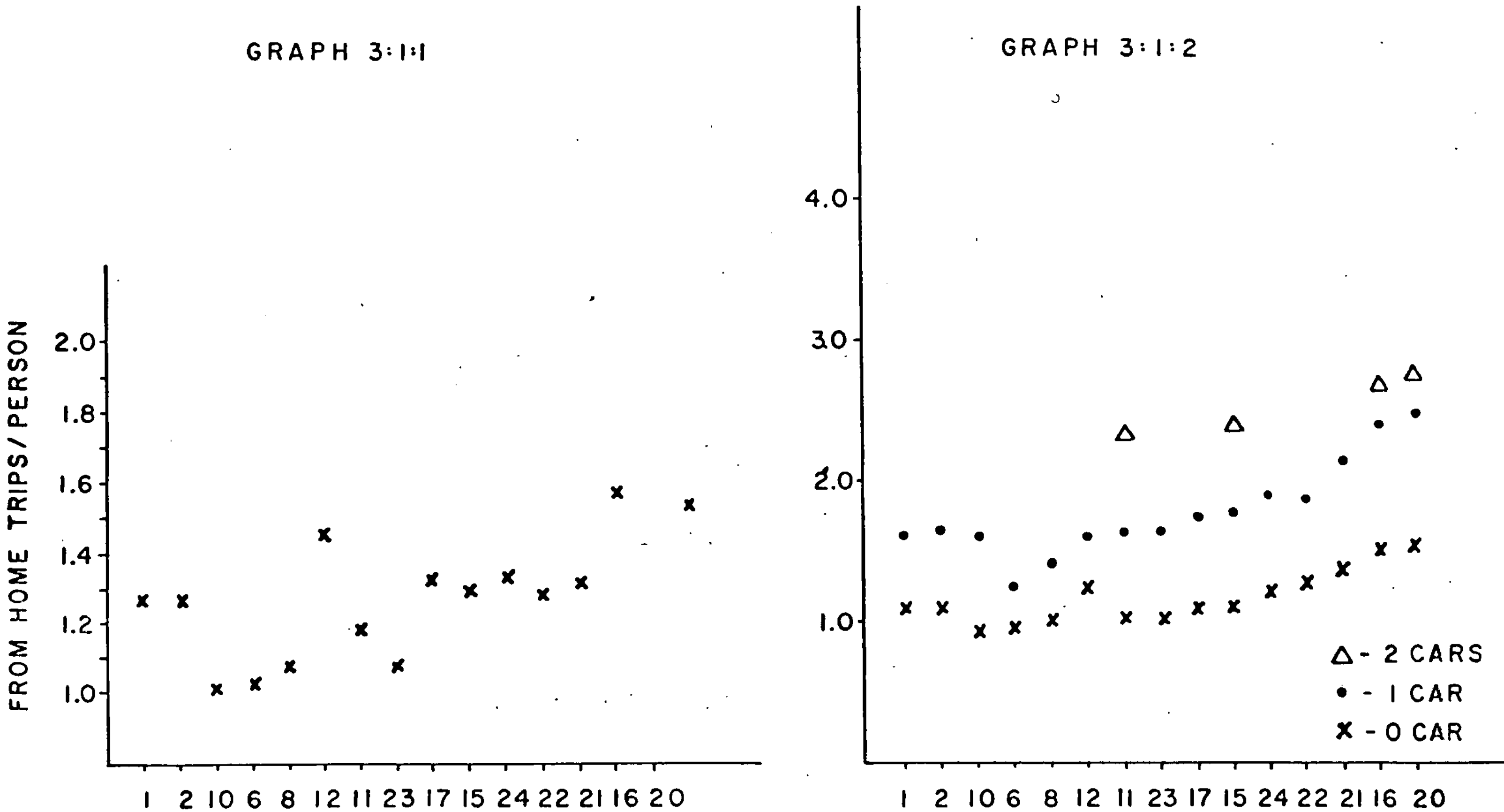
(1) For example, Chicago, Detroit, Modesto, op. cit.; Mertz and Hamner op. cit.

GRAPH 3:1:1

GRAPH 3:1:2



ZONES, RANKED BY DISTANCE FROM CENTRAL AREA

Graph 3:1:3 plots the simple regression, with the confidence limits of the relationship shown, of from-home trips/household against ranked distance.

$$X_1 = 2.68 + 1.39\ X_6$$

where X_6 is distance from the central area

$$r^2 = 0.66$$

Similar relationships can be found in many American studies. In the case of Perth, despite initial reservations, distance seems to be an important factor. Graph 3:1:4 shows the results of holding family size constant. A general trend can again be seen, but as one would expect, is more diffuse.

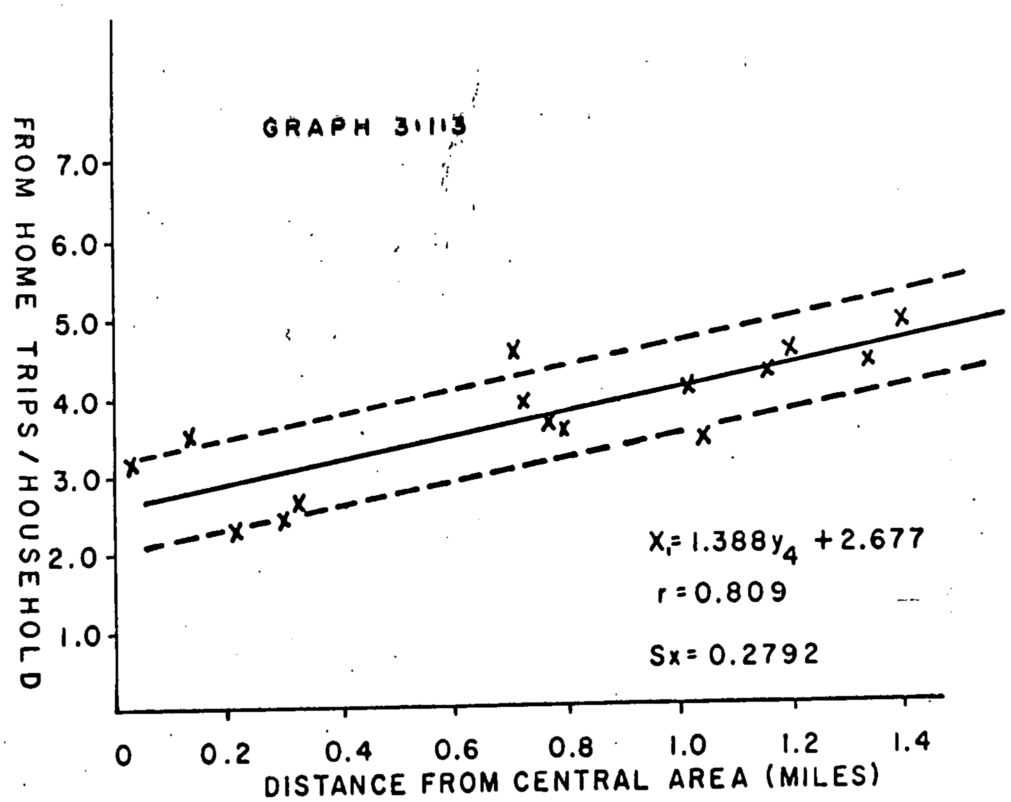
Earlier observations indicate that at least one, and possibly more, variables are at work too. Graph 3:1:5(2) shows that in fact both car ownership and family size tend to be positively correlated with distance, though family size much less so. Therefore the increase in trip generation with distance from the central area could be apparent rather than real, since car ownership especially increases as one moves away from the central area. So far the relationships have been examined on a very simple level, and one cannot put too much reliance on the implied linear relationship between say family size and trips, distance and trips, alone. This colinearity rules out multiple regression analysis of trips, distance and car ownership, but not that for trips, family size and distance.

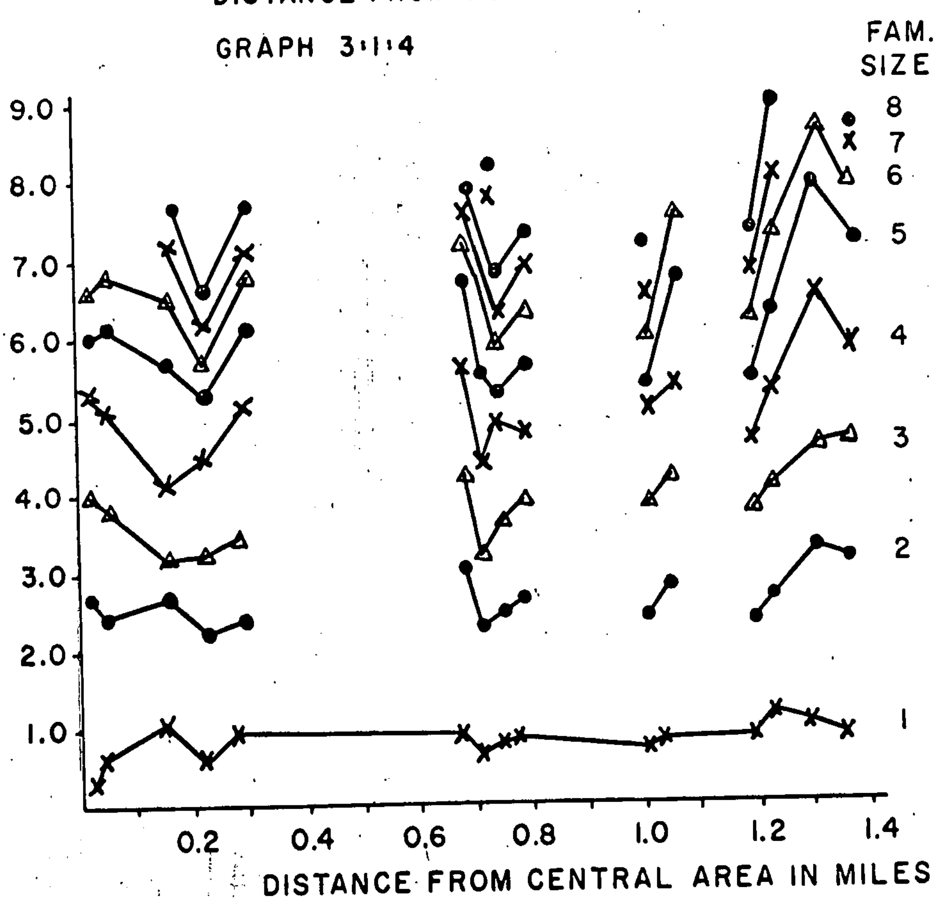
$$X_1 = 0.72 + 0.79 = 0.96\ X_6$$
$$r^2 = 0.85$$

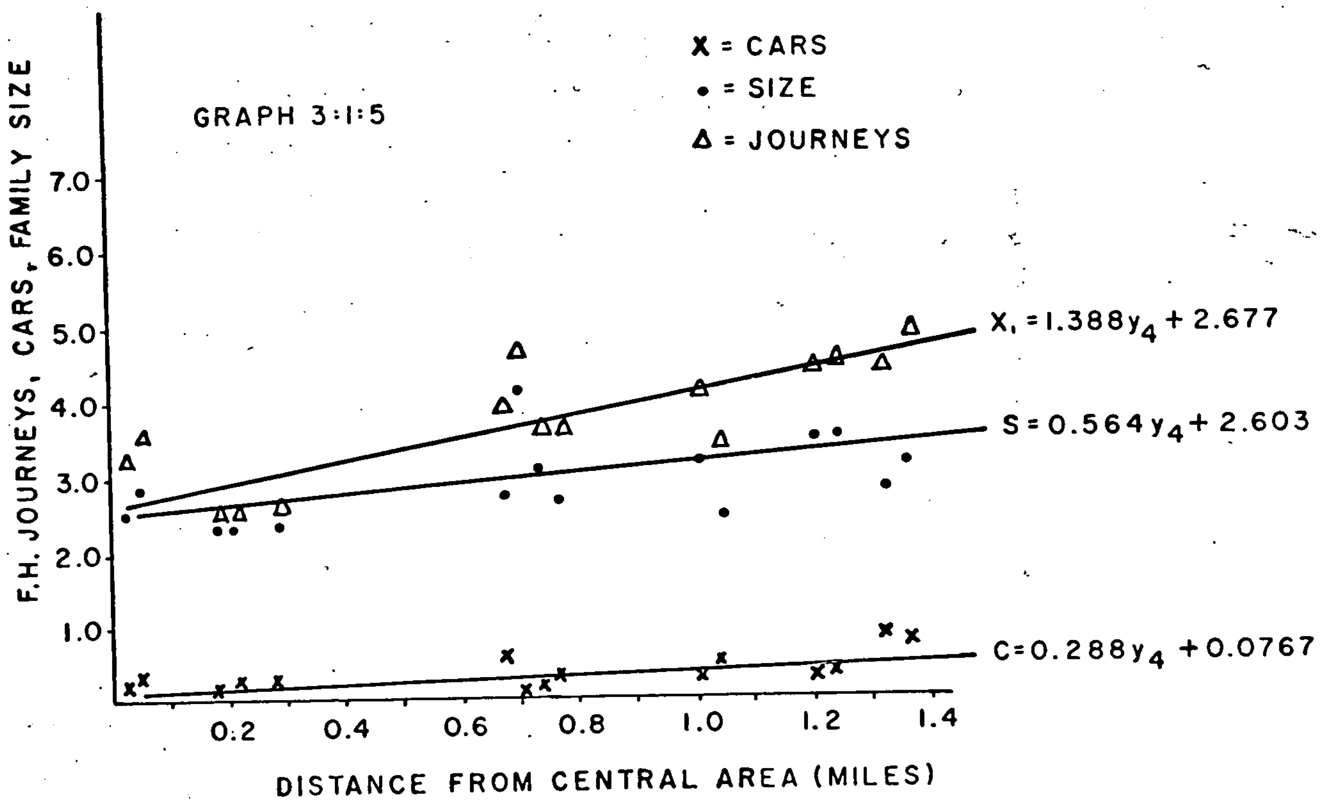
The relationship with distance is further analyzed in Table 3:1:1. For families of identical sizes and car ownership, mean from-home trip generation rates are given as distance varies. For each family size/car ownership

---

(2) The other regressions are House Size = $2.603 + 0.564\ X_6$ $r = 0.493$
Car/hse = $0.077 + 0.288\ X_6$ $r = 0.676$


GRAPH 3:1:3
FROM HOME TRIPS / HOUSEHOLD
7.0
6.0
5.0
4.0
3.0
2.0
1.0
X₁= 1.388y₄ + 2.677
r = 0.809
Sx = 0.2792
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISTANCE FROM CENTRAL AREA (MILES)


GRAPH 3:1:4
FAM. SIZE
8
7
6
5
4
3
2
1
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISTANCE FROM CENTRAL AREA IN MILES


GRAPH 3:1:5
X = CARS
• = SIZE
Δ = JOURNEYS
F.H. JOURNEYS, CARS, FAMILY SIZE
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
DISTANCE FROM CENTRAL AREA (MILES)
X₁ = 1.388y₄ + 2.677
S = 0.564y₄ + 2.603
C = 0.288y₄ + 0.0767

combination a correlation coefficient between trip frequency and distance was computed. In no case was there a significant coefficient. Furthermore these are negative. These results indicate that in detail there is no striking relationship between distance and trip frequency, once family size and car ownership are rigidly controlled. Holding only car ownership constant, a significant correlation does result.

Table 3:1:1

From Home Trips

Dis-tance	All sizes 0 car	All sizes 1 car	Fam. Size 1 0 car	Fam. Size 1 1 car	Fam. Size 2 0 car	Fam. Size 2 1 car	Fam. Size 3 0 car	Fam. Size 3 1 car
(miles)								
0.03	3.09	4.11	0.17	0.90	2.48	3.66	3.50	5.50
0.15	3.21	4.58	0.29	2.00	2.17	3.49	3.09	5.51
0.18	2.26	3.74	1.00	2.40	2.07	3.70	2.38	5.41
0.22	2.29	3.01	9.24	2.06	1.56	3.51	2.79	5.50
0.28	2.48	3.50	0.51	2.40	2.04	3.60	3.00	5.66
0.69	3.52	4.42	0.59	2.38	2.38	3.65	3.00	4.72
0.72	4.40	5.90	0.62	-	2.07	3.61	2.71	4.85
0.75	3.21	5.47	0.33	3.33	1.76	4.48	3.07	5.64
0.78	2.75	5.72	0.66	2.10	1.87	3.63	3.10	5.69
1.06	3.66	5.67	0.57	2.11	1.75	3.16	3.42	4.50
1.09	2.52	4.65	0.40	2.10	2.43	3.31	3.53	5.10
1.22	3.91	6.05	0.83	-	2.01	3.20	3.37	4.72
1.24	3.86	5.72	0.82	2.61	1.65	3.71	3.24	6.10
1.34	2.54	5.17	0.43	2.00	2.07	3.49	3.21	4.92
1.35	2.95	5.92	0.33	2.11	1.99	3.50	3.21	5.13
Means 0.74			0.60	2.07	2.09	3.40	3.20	5.21
r	0.26	0.75	0.20	0.26	0.19	0.21	0.44	0.54

A further controlled test was carried out by the technique, analysis of variance. One car families were cross classified by family size and distance. The data used are set out in Table 3:1:2 and the results in Table 3:1:3. The linear hypothesis implicit in this test can be expressed as:

$Xij = X_1 + X_2 + X_6 + R$

where Xij = mean number of trips for family size i, at distance j.

X_1 = from home trips/household

X_2 = family size

X_6 = distance

R = a residual random effect.

Table 3:1:2

	FAMILY SIZE					
Dist. (miles)	1	2	3	4	5	Mean
0.03	0.90	3.66	5.50	6.00	6.50	4.11
0.15	2.00	3.49	5.50	7.72	8.51	5.01
0.18	2.40	3.52	5.50	7.02	8.01	3.01
0.22	2.05	3.70	5.41	7.01	7.91	3.74
0.28	2.40	3.60	5.66	7.12	8.11	3.50
0.69	2.20	3.65	4.72	6.32	8.65	4.42
0.72	2.40	3.61	4.85	6.93	10.00	5.90
0.75	3.30	4.48	5.64	6.95	8.16	5.47
0.78	2.10	3.63	6.09	8.00	10.03	5.72
1.06	2.11	3.16	4.50	6.11	8.63	5.67
1.09	2.10	3.31	5.10	6.78	8.61	4.65
1.22	2.50	3.20	4.72	6.20	8.51	6.05
1.24	2.61	3.71	6.10	7.91	8.91	5.72
1.34	2.00	3.49	4.92	6.94	8.14	5.17
1.35	2.11	3.50	5.13	6.82	8.72	5.92
Mean	2.07	3.40	5.21	6.82	8.10	4.92

Table 3:1:3

Source of Variation	o F	Sum of Squares	Variance	F ratio
Household size	4	379.61	94.9	412.6
Distance	14	9.83	0.70	3.0
Residual	56	13.38	0.23	
Total variance	74	402.84	5.44	

A total of 75 observations were analyzed. The significance of the results were tested by the F-ratio. The household size effect is significant at the 1.0% and 0.1% levels; distance is significant at the 1.0% level, but barely so at the 0.1% level.[3]

In summary, the distance effect is in Perth largely masked by the influence of car ownership. Car ownership is itself positively correlated with distance, a reflection of the distribution of higher income car owning families. When car ownership, and the other major influence, family size, are held constant, a distance effect is recognisable, but only weakly.

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(3) F ratio for household size with N_1 4, and N_2 56, is in the range 3.65-3.83 for the 1.0%, 5.31-5.70 for the 0.1% level. Distance, with N_1 5, is in the range 2.12-2.66 at the 1.0%, and 2.69-3.64 at the 0.1% level. Source, Table II p.25-27 "Statistical Formulae and Tables for use in the Behavioural Sciences". Department of Psychology, University of Durham, 1964.

3:2 Population Density

It is usual in traffic studies to think of population density as a determinant of trip generation, with a negative relationship, using the log base of population density [1] (an exponential, not an arithmetic relationship). Residential density is an important measure of the urban structure; it measures the intensity of residential land use or the physical proximity of people to one another at their place of residence. To explore this density effect a number of statistical tests were taken:

(i) Simple and multiple linear regression. The simple regression between population density and trip generation was negative, and also non-significant.

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(1) B.J.L. Berry, Simmons and Tennant.
"Urban Population Densities, Structure and Change".
Geogr. Review. 1963. No.53 pp. 388-405.
Schuldiner and Oi. Op.cit. pp. 100-104.
J.R. Hamburg "A Comparison of Car Ownership and Density - Chicago and Detroit". C.A.T.S. Research News Vol. 2 No.15, Oct. 1958. pp.3-7.

(ii) An attempt was made to isolate the two important variables, family size (with population density, r = +0.43) and car ownership (with population density, r = -0.73), from any density effect. Table 3:2:1 was set up, in which car ownership was held constant (at one-car), cross classified by density and family size. There are 60 possible cells, though only 48 were used. Density was expressed as the log e of persons per 1,000 sq. feet, and each trip generation rate by a ratio, computed between the mean trip generation for that family size and the trip generation of that particular cell (family size x density).

Table 3:2:1

One-Car Households

Household size											Mean Trip Generation
1	0.96	1.01	1.05	1.00	1.01	1.01	0.98	1.05			2.08
2	1.02	0.97	1.06	1.06	1.03	0.93	1.04	1.01	0.94	1.06	3.40
3	0.94	0.97	0.90	0.97	0.98	0.86	1.05	0.97	0.90	0.93	5.21
4	1.01	0.99	0.92	0.87	0.96	0.89	1.00	0.97	0.90	0.95	6.83
5	1.00		1.06	0.99	0.98	0.99		0.95	0.95	0.94	8.11
6	1.07		1.02								9.57
Density	0.79	0.83	0.92	0.99	1.13	1.28	1.41	1.46	1.65	2.04	

These ratios were then tested by the 'sign test'. In this simple test each value is given a positive sign if 1.0 or above, negative if below 1.0. If there is no relationship between population density and trip generation, then the signs will be equally distributed. The matrix that resulted is shown in Table 3:2:2. Since in fact there were twenty positive, and twenty eight negative, signs, and more than half the positive signs appear in the first four columns (representing low population density), there is an indication that some relationship exists.

Table 3:2:2

Fam. size incr. ↓										
	-	+	+	+	+	+	-	+		
	+	-	+	+	+	-	+	+	-	+
	-	-	-	-	-	-	+	-	-	-
	+	-	-	-	-	-	+	-	-	-
	+		+	-	-	-		-	-	-
	+		+							

Population Density increasing →

(iii) The relative trip generation rates in Table 3:2:1 were correlated with log e density. The correlation coefficients were:-

Family size 1	-0.41
Family size 2	+0.02
Family size 3	-0.27
Family size 4	-0.28
Family size 5	-0.85

Like the regression analysis a negative correlation was found, though in this case with the exception of two-person households.

These three tests indicate that, if influential variables are isolated, density has a negative correlation with trip generation, however small.

3:3 Socio-Economic Status

This subsection is concerned with measures of status or income. Actually income is the preferred measure, but there are difficulties in obtaining such information,[1] though most American studies have used income.[2] The following measures were considered:-

(i) gross rateable value.

(ii) Land values (from the Register of Sassines).

(iii) Home ownership.

(iv) Socio-economic status.[3]

An indication of income or status can be obtained by studying property values. Two measures were used, and are plotted on Maps 3:3:1 and 3:3:2. The first is a measure of rental value, the average gross annual rate for a household.[4] The second, land value, is the average price per square foot of floor space of residential property sold in the 12 months prior to the survey.[5] Thirdly, the distribution of homes by tenure is indicated in Map 3:3:3. There is a reasonable homogeneity within each traffic zone, since these factors were borne in mind when the zones were devised.[6] However, only the fourth measure could be conveniently quantified for each zone. This final measure was based on the Registrar General's classification, with some amendment, and seven status groups were used.[7] Table 3:3:1 shows the

---

(1) An attempt was made to ask for this information in a pilot survey, but a low response rate resulted. Therefore this question was dropped from the full home interview survey.

(2) Mertz and Hamner, op. cit., The Detroit Study, The Chicago Study, Modesto.

(3) Registrar General's definition.

(4) This is a hypothetical annual rate, assessed in Scotland by a valuation officer, employed by each local authority. Adjustments were made to allow for the possession of garages, etc.

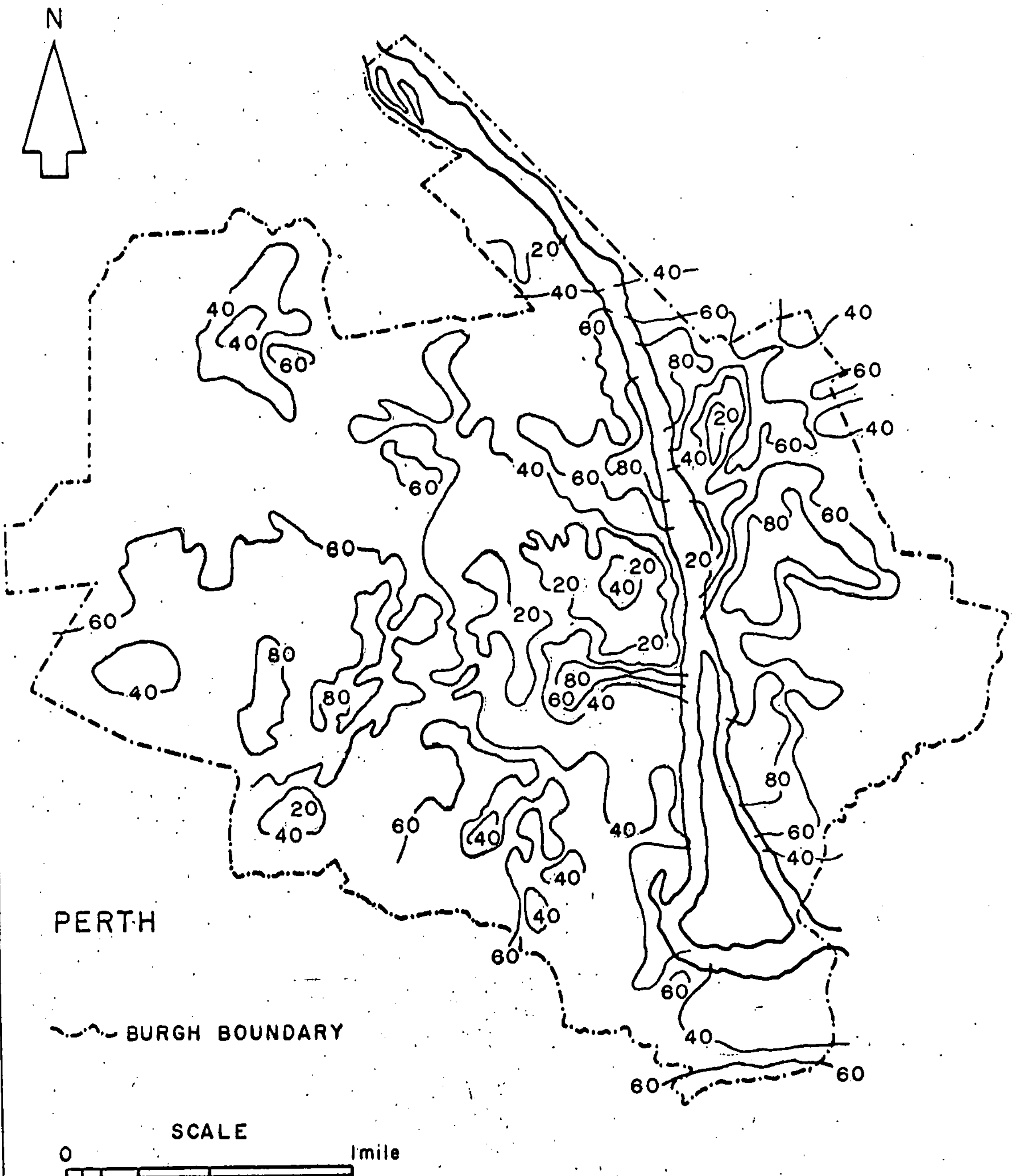
(5) 1962-3. Obtained from the Register of Sassines.

(6) See Appendix 1. The main criterion was the catchment area of a particular route, but other criteria included compatability with enumeration district boundaries, uniformity of land use, socio-economic status, etc.

(7) The Registrar General uses 13 groups. 'Classification of Occupation 1960' H.M.S.O. 1961 pp. XI-XII

1. Professional	- Reg. General's Groups	1, 2, 3, 4.
2. Intermediate	- "	5, 6, 7, 11
3. Manual (skilled)	"	8
4. Manual (semi-skilled)	"	9
5. Manual (unskilled)	"	10
6. Others	"	13, 14, 15, 16
7. Retired, etc.	- no equivalent.	

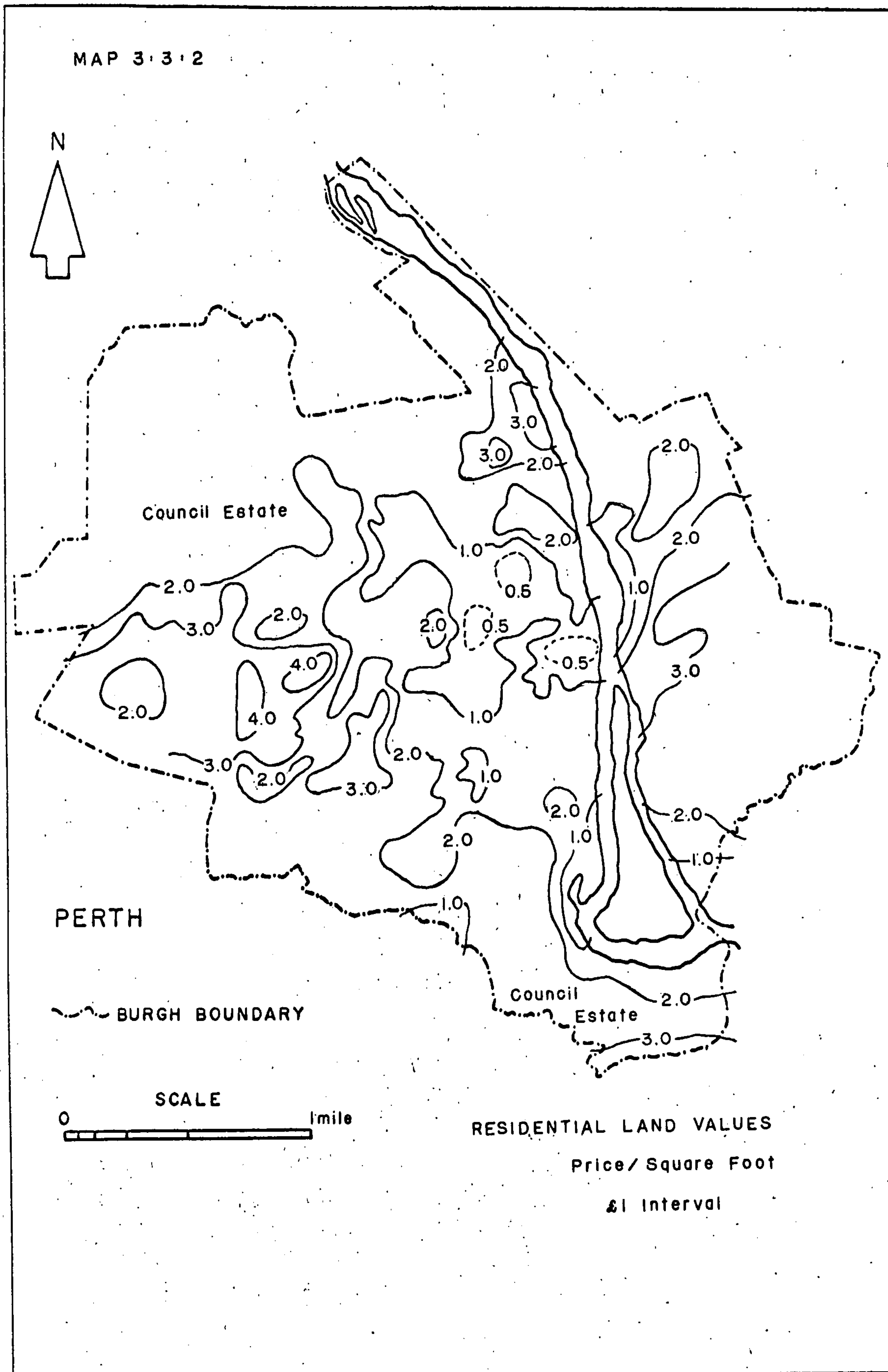
MAP 3·3·1



RESIDENTIAL GROSS ANNUAL VALUE

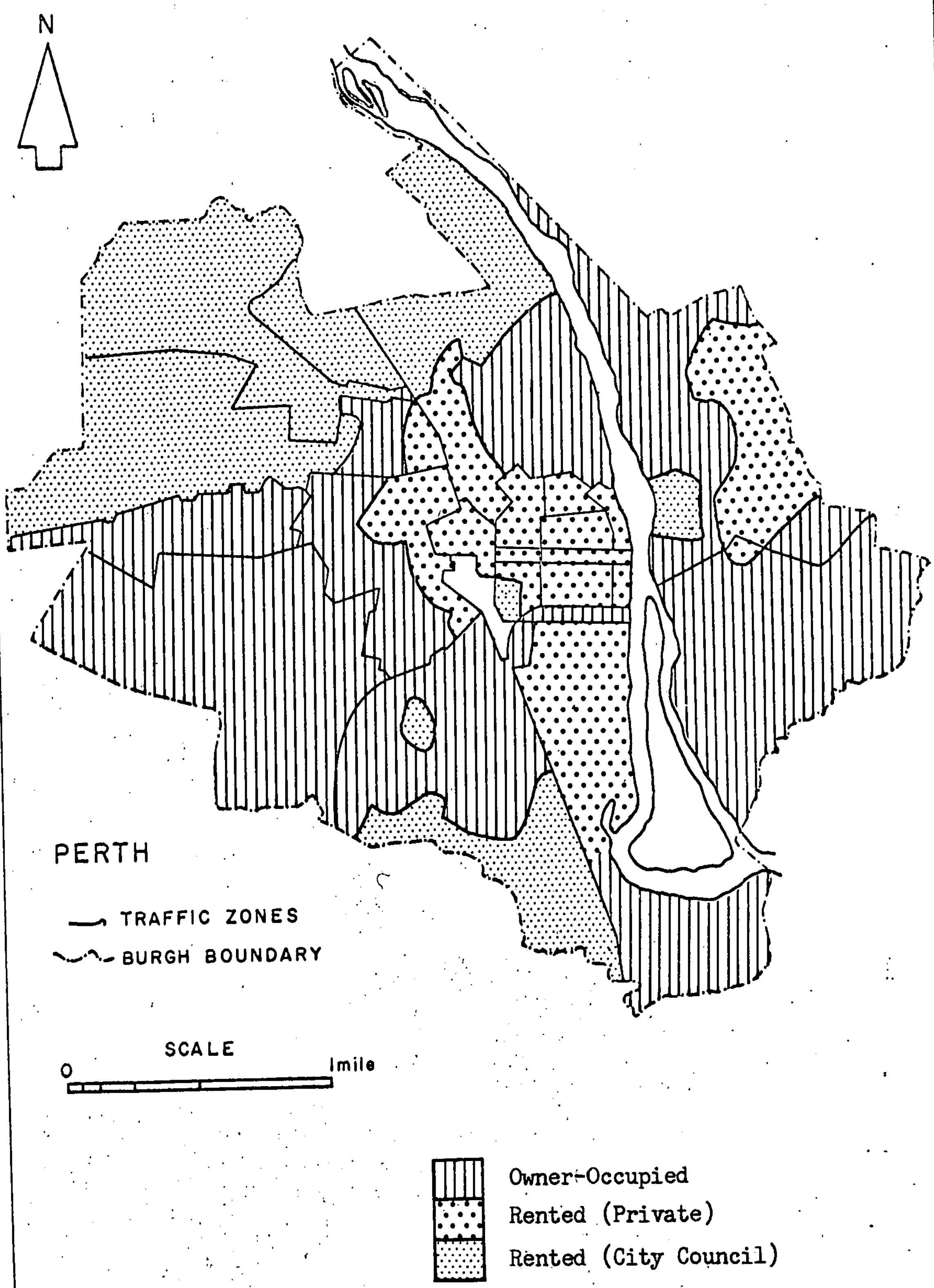
(£'s) PRICE/SQ. FOOT

Source: Register of Sassines


MAP 3·3·2
N
Council Estate
PERTH
BURGH BOUNDARY
SCALE
0
1mile
RESIDENTIAL LAND VALUES
Price/Square Foot
£1 Interval
Council
Estate
0.5
1.0
2.0
3.0
4.0

MAP 3:3:3

TENURE



percentages of the total sample in the various socio-economic classes. The occupation of the head of the household, obtained through the home-interview survey, was used as an indication of the socio-economic status of the household as a whole. Group 7 is a category for those not engaged in any occupation, e.g. widows and retired persons, the unemployed, and others for whom there was insufficient information. Table 3:3:1 seems to indicate that higher socio-economic class corresponds with small family size, but higher car ownership, and higher numbers of from-home journeys per person. Obviously then, if there is spatial variation in the distribution of socio-economic groups, then there should be a corresponding variation in trip generation. Table 3:3:2 indicates that the general axiom is operative.

TABLE 3:3:1 All Perth

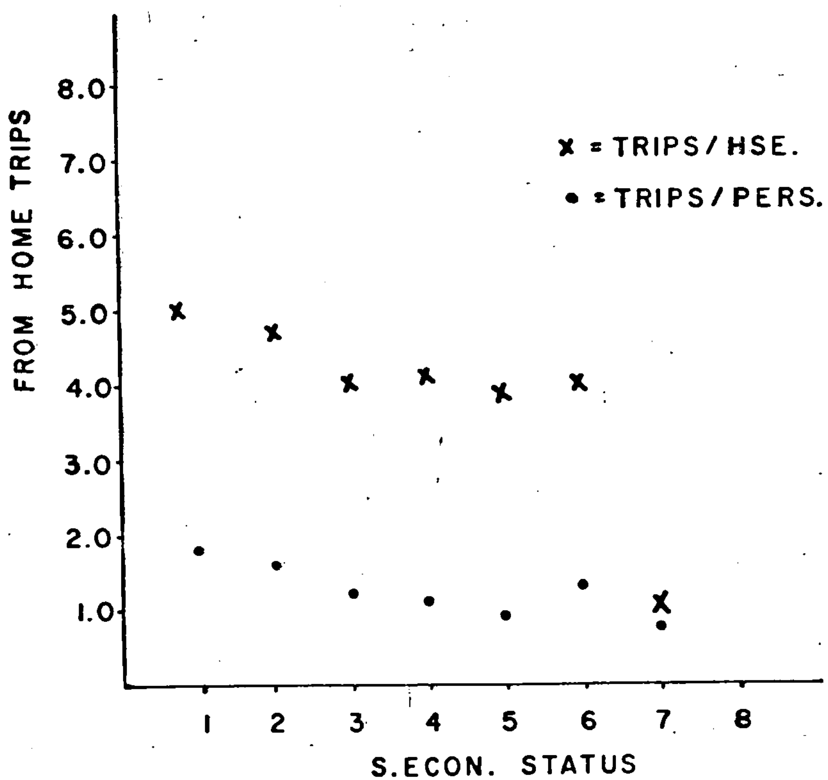
Socio Economic Group	% of Sample	Mean Household Size	Mean car Ownership /Hsehld	From home journeys	
				/person	/household
1. Professional	10.8	2.71	0.94	1.85	5.02
2. Intermediate	7.3	2.86	0.63	1.65	4.74
3. Manual (skilled)	50.0	3.22	0.21	1.24	4.01
4. Manual (semi-skilled)	13.6	3.56	0.14	1.16	4.14
5. Manual (unskilled)	6.5	3.98	0.04	0.98	3.91
6. Others	0.8	3.09	0.45	1.32	4.09
7. Retired	11.0	1.31	0.09	0.79	1.03
	1385 Hsehld.	3.02	0.29	1.27	3.85

Table 3:3:2 Perth: Zonal Variation

Zone	% in Sec. 1 & 2	Mean Household Size	Mean No Car /Hsehld	From Home /Person	Journeys /Hsehld
1	9	2.54	0.18	1.27	3.21
5	12	2.75	0.23	1.27	3.51
6	9	2.32	0.15	1.03	2.58
8	4	2.39	0.16	1.08	2.64
10	5	2.32	0.12	1.01	2.30
11	10	3.06	0.18	1.19	3.64
12	15	3.15	0.25	1.30	4.09
15	33	2.73	0.51	1.45	3.95
16	70	2.75	0.75	1.58	4.40
17	28	2.65	0.25	1.33	3.52
21	11	3.46	0.36	1.31	4.53
22	10	3.42	0.25	1.29	4.38
23	4	4.19	0.09	1.08	4.52
24	31	2.45	0.43	1.34	3.29

Table 3:3:3 shows the matrix of correlation coefficients obtained from correlating status with several variables. Status here was measured as the percentage of heads-of-households in Groups 1 and 2. Significant correlations were obtained with person trips, car ownership, distance, and negatively with density. No significant relationship was in fact accorded to household size ($r = -0.11$). It is probable however that as status is highly correlated with car ownership, etc. that its effect on trip frequencies is linear, and is entirely captured by these other explanatory variables. In fact there is a low correlation with from-home trip generation ($r = 0.45$). Variation in from-home trips, family size, and car ownership with the seven socio-economic groups are shown in Graphs 3:3:1 and 3:3:2.

GRAPH 3:3:1



GRAPH 3:3:2

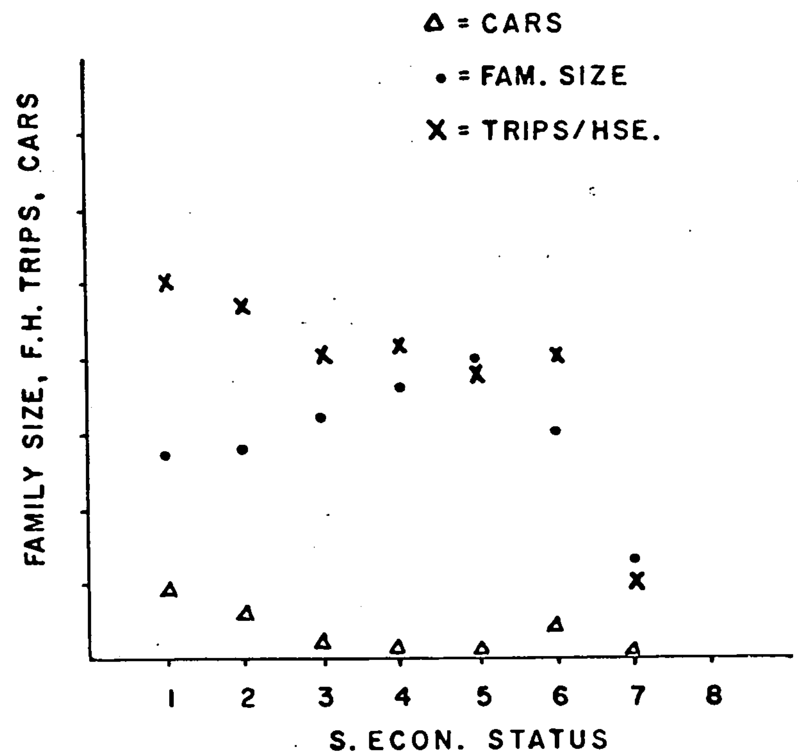


Table 3:3:3

Correlation of STATUS with Certain Variables

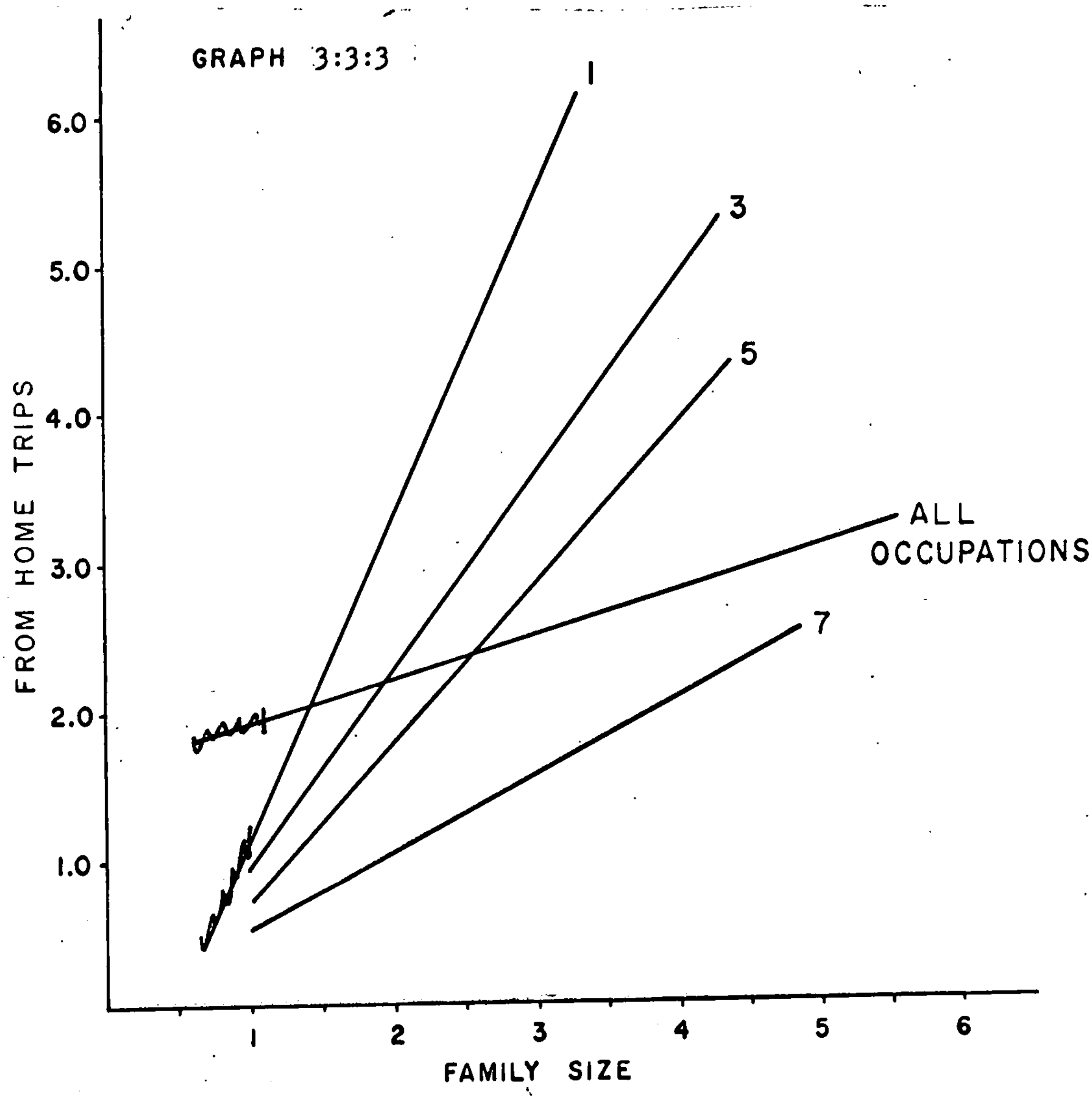
From-home Trips/person	0.86
From-home Trips/household	0.45
All Trips/person	0.89
All Trips/household	0.54
Car ownership	0.92
Distance	0.52
Density	-0.73
Household Size	-0.11
Social Rank Index	0.89
House Type	0.89

As a further test, mean trip generation rates were computed for each status group, as in Graph 3:3:3, and these were submitted to an analysis of variance. Status groups 6 and 7, because of smallness of sample, etc., were eliminated from this test. The analysis of variance was then used to test whether the difference in trip generation rates were significant. The F ratio for 4 and 14 degrees of freedom was 12.1 (Table 3:3:4), which is highly significant. This test establishes that a classification of households by five socio-economic groups does isolate significant differences in trip generation rates.

However in the summary of the 1385 households, Table 3:3:1, it can be seen that movement up the status hierarchy is associated not only with higher trip generation rates, but also with higher car ownership rates and a variation in family size. In the simple analysis of variance just noted, these differences were ignored.

Further analysis was therefore undertaken to try to isolate these effects. These fall into four groups.

1. An analysis of variance was carried out, as above, but on trips per person. An F ratio of 33.7 was obtained, again highly significant.


GRAPH 3:3:3
FROM HOME TRIPS
6.0
5.0
4.0
3.0
2.0
1.0
FAMILY SIZE
1
2
3
4
5
6
1
3
5
ALL OCCUPATIONS
7

2. In earlier sections the importance of household size and car ownership were stressed, so that these are now to be rigidly controlled. The information was therefore cross classified by these variables:-

(a) Family size, 1-7[7]

(b) Car ownership 0, 1, and 2

(c) One socio-economic status by groups 1-5 and 7.

Table 3:3:4

Analysis of Variance

(i) Correlation of group status and trip generation per household.

	SUM OF SQUARES	o of F	MEAN SQUARES	F TEST
Total Variance	63.859	74	0.863	
Rows	40.439	14	2.888	12.1
Columns	10.136	4	2.533	10.6
Residual Variance	13.284	56	0.237	

(ii) Correlation of group status and trip generation per person.

	SUM OF SQUARES	o of F	MEAN SQUARES	F TEST
Total Variance	7.479	74	0.101	
Rows	0.424	14	0.030	6.0
Columns	6.757	4	1.689	33.7
Residual Variance	0.298	56	0.005	

This gives a possible 126 cells. The information is laid out in Table 3:3:5. Within each cell, the number of households, and the mean number of from-home trips is recorded. The relative trip generation rate for each status group is the ratio of the mean number of from-home trips per household for that occupational group, to the mean for all groups. Thus a relative trip generation rate of 1.15 means that families in that status group took 15% more trips than all other families of the same size and car ownership.

(7) Few families of eight and more were sampled, and these are excluded.

Table 3:3:5

Hsehld Size	Car Owner	Status Group 1		Status Group 2		Status Group 3		Status Group 4		Status Group 5		Status Group 7		
		From Home Trips	Relative F.H. Trips	From Home Trips	Relative F.H. Trips	From Home Trips	Relative F.H. Trips	From Home Trips	Relative F.H. Trips	From Home Trips	Relative F.H. Trips	From Home Trips	Relative F.H. Trips	All Mean
1	0	1.00	1.12	0.96	1.07	0.90	1.01	0.92	1.03	0.87	0.97	0.69	0.77	0.89
	1	1.70	1.25	1.55	1.14	1.53	1.12			1.13	0.82	0.91	0.66	1.36
2	0	1.60	1.03	1.60	1.03	1.57	1.01	1.57	1.01	1.40	0.90	1.50	0.97	1.54
	1	4.08	1.26	3.91	1.21	3.87	1.20	3.07	0.95	2.52	0.79	1.90	0.59	3.22
	2	5.40	1.03	5.12	0.98	5.12	0.98							5.21
3	0	2.43	1.08	2.32	1.03	2.37	1.05	2.32	1.03	1.96	0.87	2.10	0.93	2.25
	1	5.51	1.14	5.40	1.11	5.36	1.10	4.20	0.86	3.84	0.79			4.86
	2	7.64	1.02	7.43	0.99	7.40	0.98							7.49
4	0	3.00	0.97	2.91	0.94	3.31	1.07	3.28	1.06	2.94	0.95			3.08
	1	6.85	1.04	6.74	1.02	6.70	1.02	6.00	0.91					6.57
5	0	4.00	1.09	3.56	0.97	3.62	0.98	3.60	0.98	3.60	0.98			3.67
	1	8.79	1.03	8.31	0.98	8.29	0.97							8.46
6	0			4.13	1.01	4.10	1.00	4.09	1.00	4.06	0.99			4.09
7	0			4.60	0.92	5.10	1.02	5.13	1.02	5.07	1.01			5.00

An examination of the rates indicates that 'higher' status means higher trip generation rates, although some very small cell frequence can produce large sampling variation.

The test carried out on this data was the calculation of Kendall's 'W' coefficient, the 'coefficient of concordance'. This is a multiple rank correlation technique, whose coefficients can have a value from zero to one. A value of one denotes complete agreement in ranking terms, and a zero value maximum disagreement.(8) This technique was applied twice. First on the five rows taking into account the 6 status groups, and the coefficient of concordance was found to be 0.82, a value which is highly significant at the 0.01 significance level. Secondly 10 rows were tested for five status groups, dropping group 7 which does not go beyond three person households, and a coefficient of 0.62 was computed, again highly significant at the 0.01 level. On the basis of this test, which requires no assumptions about the linear or non linear relationship of the variables, the hypothesis that socio-economic status does affect mean trip generation rates, can be accepted.

3. An analysis of variance was performed on the relative trip generation rates of Table 3:3:6. The results are shown below. Again this test seems substantiate the hypothesis.

Table 3:3:6

Analysis of Variance

(i) Relative from house trips 1.

	SUM OF SQUARES	o of F	MEAN SQUARES	F TEST
Total Variance	0.730	29	0.025	
Rows	0.002	4	0.001	0.09
Columns	0.504	5	0.101	9.18
Residual Variance	0.226	20	0.011	

(8) A fuller explanation of the method of calculation and tests for significance can be found in Appendix 6e; and in M.G. Kendall 'Rank Correlation Methods'.
London. 1948 C. Griffin. pp. 80-89.

(ii) Relative from home trips 2.

	SUM OF SQUARES	o of F	MEAN SQUARES	F TEST
Total Variance	0.556	69	0.008	
Rows	0.064	13	0.005	1.00
Columns	0.210	4	0.053	10.60
Residual Variance	0.282	52	0.005	

4. Fairly obviously both family size and car ownership are varying concommitently in their effect on socio-economic status trip generation rates. A method by which this can be overcome is set out in Table 3:3:7. Here an adjusted trip generation rate is given in the final column. This adjustment is carried out by moving the values up or down the regression line $X_1 = 2.33\ X_2 + 1.24\ X_2 - 0.58$ ($R^2 = 95$). Two sets of calculations were used, one based on status Group 1, and the other on Group 2, the means of the two results being the final adjustment used. An alternate and more accurate method would be to calculate a regression equation for each socio-economic group. After this adjustment, the differences still remain, so that allowing both for variation in car ownership and family size, trip generation rates do appear to increase positively with status group.

Obviously 'socio-economic status' as defined here includes other variables, such as actual income, education or years of schooling, actual occupation, number of people actively employed and so on. A method commonly used to combine these factors, is an attempt to define 'social areas' according to the Shevky-Bell typology, explained in the next subsection.

Table 3:3:7

STATUS GROUP	AV. NO. OF PERSONS /D.U.	CAR OWNERSHIP	F.H. TRIPS D.U.	ADJ. TRIPS	ADJ. TRIPS	FINAL ADJ.
1	2.71	0.94	5.02	5.02	4.74	4.88
2	2.86	0.63	4.74	4.47	4.21	4.34
3	3.22	0.21	4.01	3.94	3.67	3.80
4.	3.56	0.14	4.14	4.20	3.93	4.06
5	3.98	0.04	3.91	3.39	4.32	3.85
7	1.31	0.09	1.03	1.30	1.03	1.16

3:4 SOCIAL AREA INDICES

Most of the factors considered so far have been economic - car ownership, land values, an index of occupational level, largely because these data are more readily available. An indication of social factors can be obtained by turning to Shevky and Bell who established three indices to distinguish 'social areas'.(1)

An attempt is made here, faced with a lack of social data, to apply the Shevky-Bell typology, or rather to utilize two of the three indices.

Index 1. Social Rank, consists of two elements:-

(a) the ratio of manual workers to all workers.

(b) educational level, measured as the proportion of adults with less than -- years education.

The social rank index has a maximum value where there are no manual workers and where all adults have had higher education.

Index 2. Urbanisation, consists of three elements:-

(a) fertility; the ratio of children under five to the female population of child bearing age.

(b) female labour force; calculated as the percentage of women in the total labour force.

and (c) housing type; in the original analysis, Shevky and Bell used the ratio of single dwelling units to all dwelling units. The single dwelling is not prominent or widespread enough in Britain to make similar use of this measure. D.T. Herbert ignores this factor altogether, but here the ratio of high rated houses to all houses is substituted, since this is roughly comparable to the American measure.

---

(1) E. Shevky and W. Bell 'Social Area Analysis' 1955: the only attempt to apply this typology in Britain that has been reported is by D.T. Herbert 'Social Area Analysis (Newcastle-U-Lyme)' paper delivered I.B.G. Bristol meeting. 1965; its application to traffic analysis was first tried by Schuldiner and Oi. (op. cit.) pp. 116-120.

Index 3. Segregation. This is omitted, since it refers to the presence or absence of minority groups, which in Perth are too small to be measured.

Shevky and Bell showed that the frequency distribution of each index is independent of the values assumed by the others. In fact if in Index 2 the proportion of high rated houses is omitted, this orthogonality is lost, and some correlation between the two indices is found. This is a disadvantage in increasing the influence of each index, since mutual interference or colinearity occurs.

For each zone in Perth, a Social Rank, and Urbanisation Index, was calculated, by using data collected in the Home Interview Survey,(2) and the 1961 Census Scale D enumeration district data. This latter was corrected for time lag, and where necessary for the differing boundaries of traffic zones and enumeration districts. These indices are shown in Table 3:4:1, and the correlation matrix in Table 3:4:2.

Social Rank shows significant positive correlations with car ownership and distance, and a significant negative correlation with density. There was no significant correlation with from-home trips per household. But if total trips are classified in greater detail then there are positive significant correlations with from-home car driver trips (0.88), car passenger trips (0.91), business trips (0.75), person trips/daily traveller (0.80), and so on, and a significant negative correlation with walking trips (-0.80).

The Urbanisation Index shows significant negative correlations with car ownership, family size, business trips (-0.508), car driver trips (-0.521), social trips (-0.534), and a marginal negative correlation with trips/household.

Thus low car ownership, nearness to the C.B.D., and high density are associated with a small proportion of high rated houses, and high fertility. There is a similar relationship to car and business trips, and a similar inverse relationship to walking trips.

---

(2) See Appendix 3.

Table 3:4:1

ZONE	1	2	6	8	10	11	12	15	16	17	20	21	22	23	24
SOCIAL RANK	12.34	9.69	17.64	17.85	13.12	28.75	72.31	30.58	99.05	54.17	65.71	49.09	40.34	2.38	38.34
URBANISA-TION (1)*	68.56	43.45	73.16	81.39	55.50	67.90	79.65	78.83	82.15	87.50	72.83	55.40	35.03	29.86	84.06
URBANISA-TION (2)	77.14	50.63	82.11	87.59	70.33	70.27	57.27	79.22	56.43	78.33	51.88	69.60	55.69	53.30	72.71

* Urbanisation (1) consists of the two factors, fertility and female labour force; (2) adds the ratio of high rated houses. Urbanisation (1) was dropped after this; the correlation coefficient between it and social rank was 0.35, with trips was -0.23, with car ownership, 0.06, and with family size, 0.13.

Table 3:4:2

	TRIPS/HSE	CAR OWNER.	FAM. SIZE	DENSITY	DISTANCE	SOCIAL RANK	URBAN INDEX
TRIPS/HSE	1.00	0.56	0.78	-0.14	0.81	-0.30	-0.42
CAR OWNER		1.00	-0.03	-0.73	0.68	0.91	-0.87
FAM. SIZE			1.00	0.43	0.49	-0.02	-0.53
DENSITY				1.00	-0.33	-0.70	0.14
DISTANCE					1.00	0.71	-0.36
SOCIAL RANK						1.00	-0.11
URBANIS. INDEX							1.00

In regression analysis, using from-home trips, neither index showed a significant correlation, despite the appearance of Graphs 3:4:1 and 3:4:2 (R^2 0.17 and 0.09 respectively). Entering car ownership and family size into the regression increased the coefficient of determination to 0.43, with just car ownership 0.31, and family size 0.39.(3) The two indices together in multiple regression with trips, had an R^2 of 0.30.(4) In multiple regression social rank was an important dependent variable only in car and car passenger trips, and urbanisation in 'other' trips (R^2 = 0.8235 and 0.4425 respectively).

Contrary to the earlier attempt, social area indices were not useful in analysing trip generation rates. Part of this may be due to differences between North American cities and Perth, and the omission of the third index, though certain faulty premises can also be detected.(5) It is maintained that you cannot analyse a 3-dimensional space, and that the hypotheses are not themselves related to any theory of urban social structure.

Despite the lack of success here, social area identification would seem on the inductive level to be correlated with trip generation. Partial evidence for this is presented elsewhere when considering car ownership and socio-economic status. Alternative measures do exist to identify social areas, although much more research needs to be carried out.(6)

---

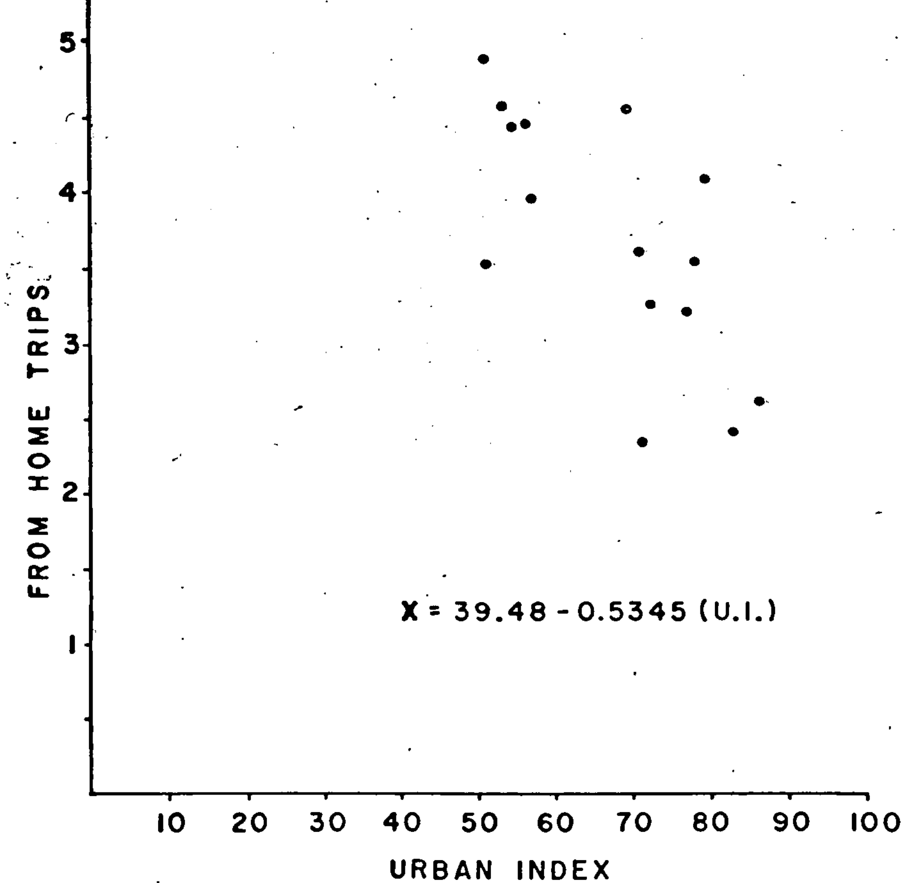
(3) X = 13.51 + -0.001 (S.R.) + -0.77 (U.I.) - 12.36 (F.S.) + 16.74 (C.O.)
X = 13.46 - 0.001 (S.R.) - 0.29 (U.I.) + 14.14 (F.S.)
X = 64.44 - 0.001 (S.R.) - 0.89 (U.I.) - 7.15 (C.O.)

(4) X = 42.85 - 0.001 (S.R.) - 0.59 (U.I.) - 7.15

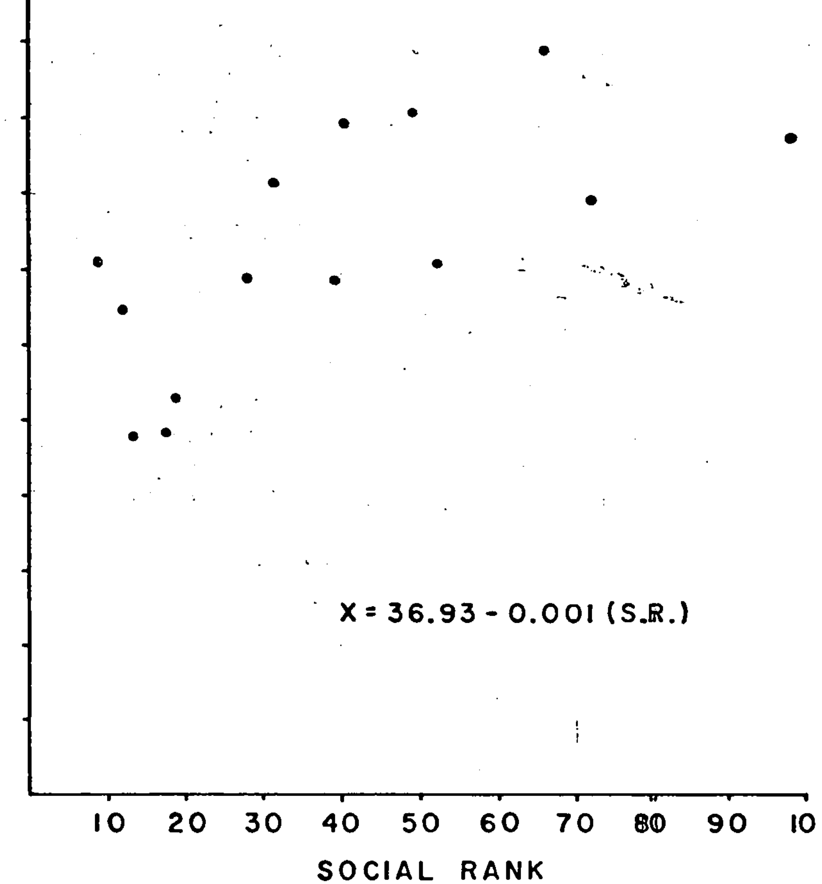
(5) A.H. Hawley and O.D. Duncan, "Social Area Analysis: A Critical Appraisal". Land Economics November 1957. pp. 337-345.

(6) O. Duncan, B. Duncan, and Cuzzorts, in "Statistical Geography" (Glencoe, The Free Press, 1959) mention an index of concentration and specialisation, the Lorenz Curve Model, and an index of social area. See also, N. Gross, "Social Class Identification in the Urban Community". American Sociological Review Vol. 18. 1953. pp. 398-404; C. Van Paassen, "Preliminary to Social-Geography Theory". Utrecht Geographical Institute (mimeo) 1965; and E.M. Gibson "Geography as an Index of Integration" unpublished research paper, Simon Fraser University, July 1966.

GRAPH 3:4:1



GRAPH 3:4:2



SECTION IV MODE OF JOURNEY

In the analysis so far, the assumption has been made that all journeys are alike, irrespective of mode, purpose, length, time, or destination. That is, the analysis has been concerned with overall frequency rather than qualititative differences. However many of these qualititative factors are important in determining patterns of trip generation, and they will be considered in this and subsequent sections.

First, mode of journey. Modal choice is probably the least understood phase of traffic analysis, and like many other aspects, has been largely investigated only in North America. (1) Each of the projects has taken a different approach, and has relied on competitive factors between the media, socio-economic criteria, and so on. Table 4:1 lists some of the variables which can influence modalcchoice.

Table 4:1

Principal Dependent Factors in Modal Choice

1. Factors affecting car ownership

Income

Occupation

(Housing type
(
(Residential density

Household size

---

(1) For example, S.L. Warner "Stochastic choice of Mode in Urban Travel: A Study in Binary Choice". Northwestern Univ. Press. 1962.
J.F. Kain "An Econometric Model of Urban Residential and Travel Behaviour" Rand Corp. P. 2667. 1962.
Traffic Research Corporation, unpublished work, including the model of W.T. Adams.
Schuldiner and Oi. op. cit. Chapter 5. pp. 125-149.

(Level of public transport
(
(Public transport convenience
(
(Distance of home or work from bus stop or terminal
(
(Length of wait
(
(Number of transfers
(
(Average journey speed
(
(Shelter at stop or terminal
(
(Fare structure
(
(Location of home in community relative to stops
(
(etc.

Employment density

Length of journey to work.

2. <u>Factors affecting car usage by owners</u>

Car usage required by employment

Effect of wives having driver's licence

Car/public transport convenience

Distance from stop or terminal

Average wait for public transport

Number of transfers

Travel time ratio between car and public transport

Cost ratio between car and public transport

Level of public service

Vehicle occupancy

Parking restrictions and costs

Availability of parking, time required to park

Fare as percentage of income

Car occupancy

Household size

Number of driving licences in household

Effects of weather

Car pool usage.

3. Sociological and psychological factors

Life style

Element of prestige in various travel modes

Vehicle characteristics

Effects of level of service

Available carrier space

Smoking on public vehicles.

4. Land Use factors

Residential density

Housing type

Size of labour force in area

Industrial density

Service location

C.B.D. or non C.B.D. location of traffic attractors.

5. Home purchasing factors, effect of housing costs on:

Home location

Choice of residential density

Car ownership.

6. Traffic engineering factors

Traffic engineering measures affecting travel speeds

Parking developments and/or restrictions

Capital investment in the transport networks for competing systems.

Now no model could hope to contain all these variables (which is not a complete list), and the less dominant ones must be eliminated.(2)

Most people in Perth walk (3) whether considering all-trips (34.0% of the total) or from-home trips (33.0%),(4) followed by bus (27.2% and 31.0% respectively), car (18.3% and 15.7%), and cycle (8.8% and 10.5%). There is an internal differentiation of mode used, dependent on the spatial variation of the variables noted in Table 4:1.

A matrix of correlation coefficients, illustrating some of these functions is shown in Table 4:2, and the spatial variations in Map 4:1 and Table 4:3. The relationships indicated are fairly straightforward. As would be expected, walking shows a negative relationship with distance, car ownership, and with tests of social standing; and a positive relationship with density. That is walking appears to be the dominant mode in densely populated areas near to the C.B.D., which have a fairly low social and economic status. Conversely, similar analysis seems to show that the car, as a modal choice, is most frequently used in low density high social and economic areas, at some distance from the C.B.D.; public transit use seems to be affected by distance from the C.B.D. and family size; cycle trips show a positive relationship only with family size.

---

(2) This problem is also to be found in J.F. Kain, op. cit. and J.B. Lansing and N. Barth, "Residential Location and Urban Mobility". University of Michigan, Institute for Social Research. 1964.

(3) The categories distinguished in the home interview and journey-to-work surveys were, walk; car driver; car passenger; motor cycle; cycle; bus; train and other (lorry driver, taxi, motor cycle passenger, etc.).

(4) Most traffic surveys in fact ignore this mode.

MAP 4:1

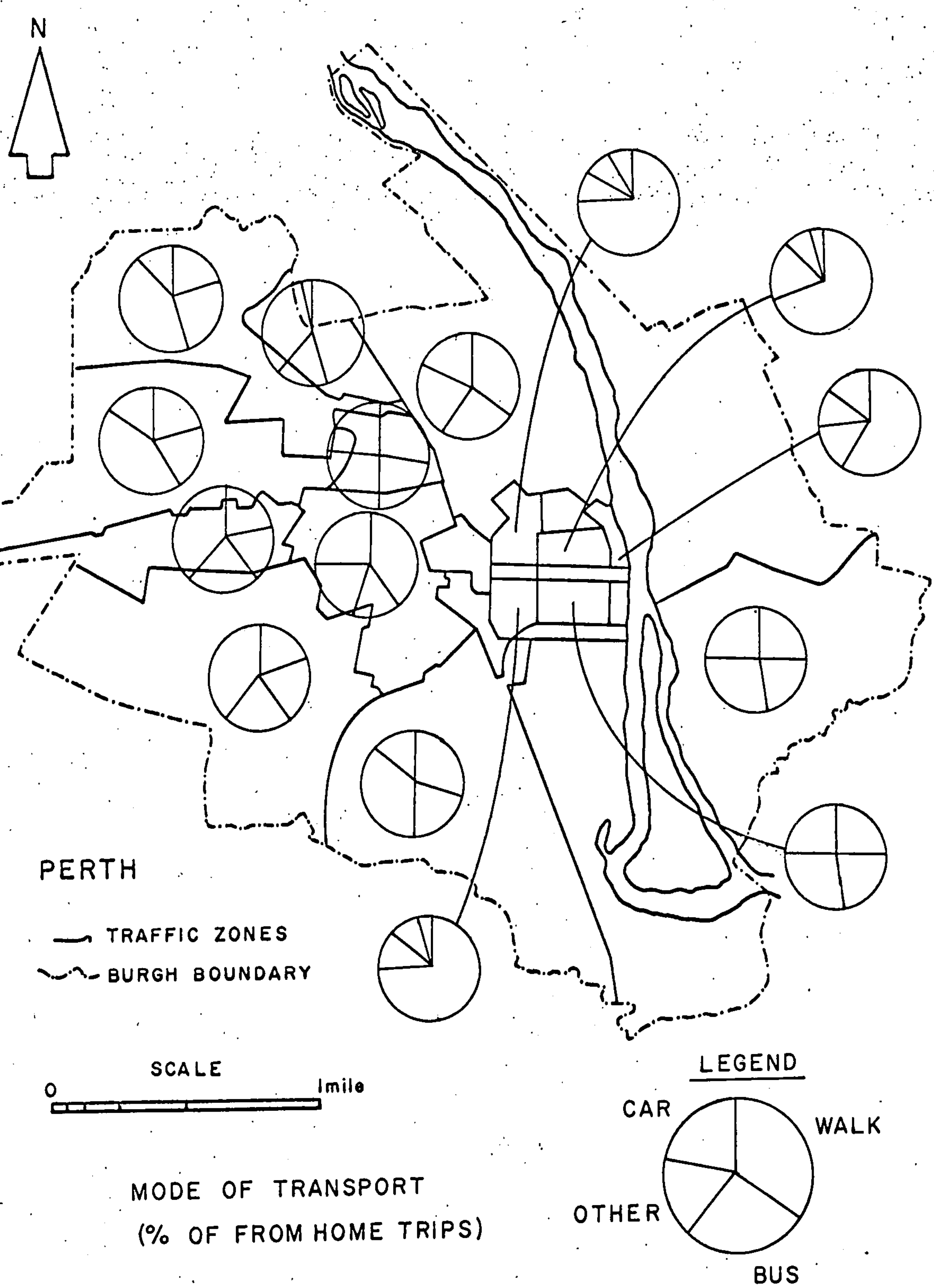

N
PERTH
TRAFFIC ZONES
BURGH BOUNDARY
SCALE
0
Imile
MODE OF TRANSPORT
(% OF FROM HOME TRIPS)
LEGEND
CAR
WALK
OTHER
BUS

Table 4:2

Mode :-	WALK	BUS	CAR	CYCLE
DISTANCE TO C.B.D.	-0.87	0.78	0.69	0.43
DENSITY	0.54	0.10	-0.69	0.31
CAR OWNERSHIP	-0.69	0.22	0.96	-0.16
SOCIO-ECONOMIC STATUS	-0.52	0.04	0.92	-0.26
FAMILY SIZE	-0.15	0.83	0.06	0.70
SOCIAL RANK	-0.80	0.31	0.88	-0.07
HOUSE TYPE	-0.53	-0.06	0.86	-0.26

Table 4:3

Modal Choices, by selected zone (ranked by distance from C.B.D.) and car ownership. Figures in %.

ZONES	C.O.	WALK	BUS	CAR	CYCLE	ALL OTHER MODES
1-10	0	86.1	4.0	0.2	8.4	2.3
	1	78.8	3.0	9.1	8.3	0.8
	Mean	81.2	3.6	5.5	8.3	1.4
23	0	46.6	36.5	0.1	13.9	3.0
	1	22.1	22.2	51.0	3.0	2.7 *
	Mean	45.5	35.0	3.1	13.7	2.8
11	0	38.1	30.2	0.0	17.1	12.7
	1	23.0	21.1	46.2	4.0	5.7
	Mean	35.0	28.3	12.0	15.3	9.4
12-13	0	26.2	40.3	1.3	15.1	17.1
	1	24.6	10.6	54.6	1.7	8.3
	Mean	25.0	28.0	24.5	10.0	12.5
15	0	35.6	43.2	0.7	18.0	4.4
	1	10.8	12.8	59.2	7.8	10.0
	Mean	29.5	36.0	12.5	15.0	7.0
21	0	32.2	47.1	1.0	8.7	12.0
	1	9.6	14.0	58.1	5.3	13.0
	Mean	22.0	44.0	14.0	7.5	12.5
16	0	36.4	42.1	1.2	7.3	14.0
	1	10.0	8.7	60.1	4.2	16.0
	Mean	20.0	21.0	39.0	5.0	15.0

* Only a small number of households interviewed had a car.

Walking, as a modal choice, is highest in the central area irrespective of car ownership, since of course most trip purposes can be satisfied by this mode within the area. The exceptions are work journeys to other parts of Perth, social trips, and so on. The proportion of walk trips remains high, falling to its lowest, 20.0% in Zone 16, which has the highest car ownership rate, the highest rank in socio-economic terms, and is the most distant from the central area. Walking is the first modal choice in 9 out of the 15 zones; of the six remaining zones, four have bus, first, and walk, second (Zones 12, 15, 21 and 22) far out in time - distance terms but of a lower socio-economic rank than Zone 16. In only two zones - 16 and 20 - does the automobile come first, with bus and walk approximately equal second.

Family size and mode are analysed in Table 4:4. Within each car ownership group the number of car trips increases with increasing family size, but at a slower rate than the increase in numbers of bus and walk trips, so that the proportion of car driver trips declines as family size increases. The higher proportion of non-car trips reflects of course a change in age composition, and an increase in the number of occupants of school age. This means that in any estimation of trip generation of a zone, which takes account of mode, must include not only the number of households, mean family size and car ownership, but also age structure and the dispersion of family size about the mean. The greater this dispersion at any car ownership level, the fewer the car driver trips.

Diagram 4:1 is a further illustration of the effects of car ownership on mode. Considering mean family size, as car ownership increases, car driver trips rise both numerically and proportionately. Walking and bus trips are high at all levels of car ownership, though they fall in relative terms. This maintenance of high levels, of non car trips is associated with the location of the car owning groups (distant from the C.B.D.) and the necessity to travel further for shopping and school trips.

DIAGRAM 4:1 ALL PERTH

A Absolute number of trips.

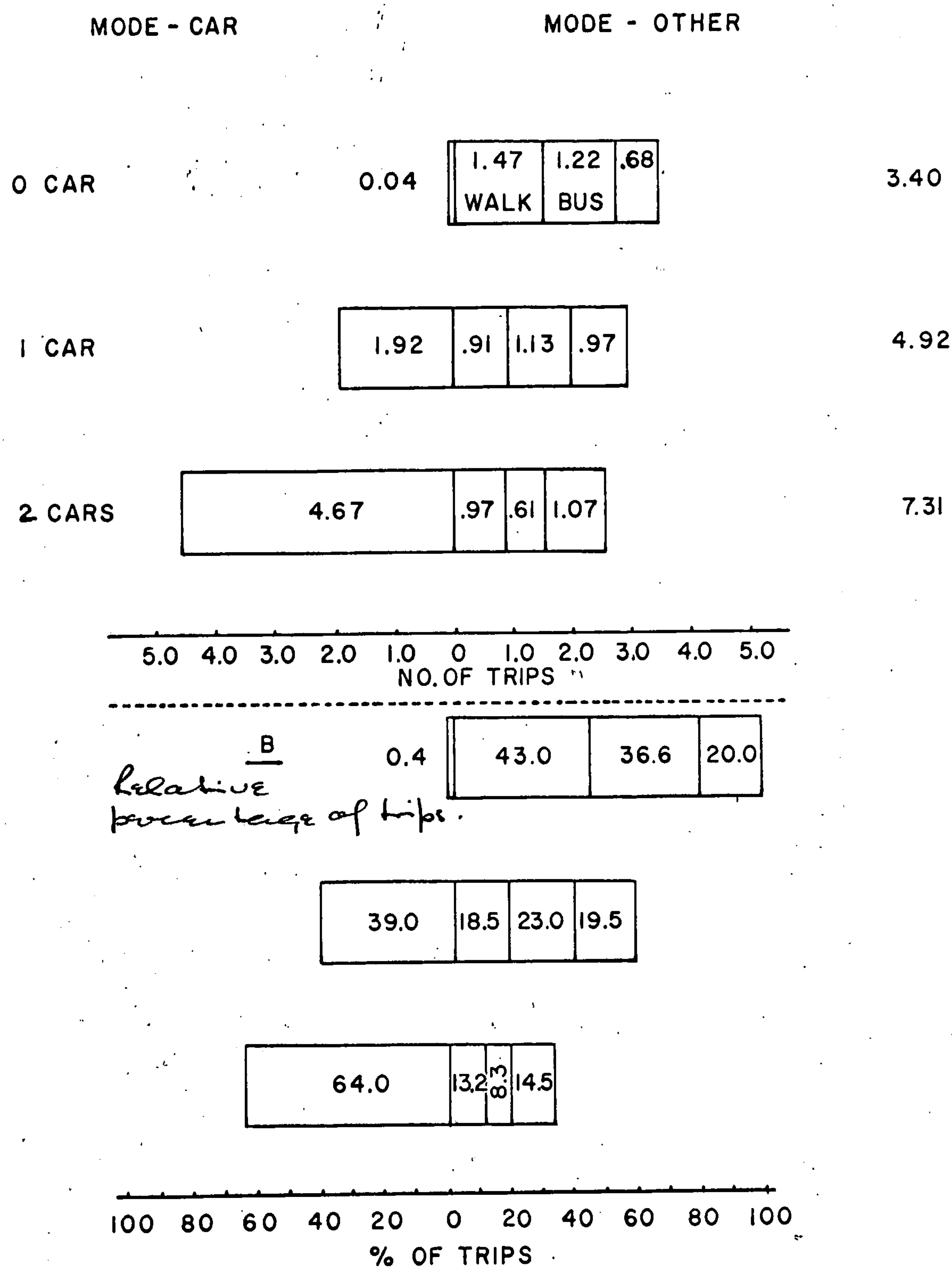


Table 4:4

FAMILY SIZE		TRIPS/HOUSEHOLD	MODE CAR	BUS	WALK
0 Car	1	0.84	0.02	0.33	0.49
	2	2.39	0.01	0.96	1.42
	3	3.41	0.00	1.41	2.00
	4	4.77	0.01	1.91	2.85
	5	5.59	0.00	2.43	3.15
	6+	7.60	0.03	3.09	4.47
1 Car	1	2.08	1.01	0.53	0.53
	2	3.40	1.80	0.79	0.81
	3	5.21	2.51	1.35	1.35
	4	6.83	3.10	1.60	2.17
	5	8.11	3.42	1.91	2.78
	6+	10.29	3.71	2.62	3.95
2 Cars	2	5.01	2.63	1.18	1.20
	3	7.34	3.71	1.45	2.18
	4	10.25	5.00	2.10	3.15
	5	12.17	5.14	2.80	4.13
Mean		3.86			

In order to test further the choice between modes, the factors set out in Table 4:1 were carefully examined, and simple regression models were set up. The models cannot hope to contain all these variables as components,(5) though they must all be examined and the noninfluencing or less dominant ones eliminated, whilst the models must remain reliable in order to approximate to the basic operation of the human modal choice mechanism.

MODELS

$$Cj = Oj + Rj + Ij + Hj + Wj + Lj$$

$$Bj = Oj + Rj + Ij + Hj + Wj + Lj$$

$$Oj = Hj + Rj + Ij + Wj + Fj$$

$$Tj = Rj + Wj + Hj + Lj + Bj + Dj$$

(5) A regression model must not be unwieldy, so the variables must be few in number both for simplicity of data collection and for economic reasons. However the residual (the unexplained part of the variables) must remain small.

Independent Variables

Cj = In zone j, modal choice, car

Bj = In zone j, modal choice, bus

Oj = In Zone j, mean car ownership

Tj = Mean time distance from zone j to destination

Dependent Variables

Rj = Percentage of zone j's inhabitants living in highly rated houses

Ij = Bus index, a measure of the level of bus service provided in zone j.[6]

Hj = Percentage of zone j's inhabitants who fall into socio-economic group 1.

Wj = Percentage of zone j's workers who are male

Lj = Labour force participation by j's workers, i.e. the percentage of workers belonging to families having single wage earner.

Fj = The familysize of j's workers: the percentage, belonging to families of more than two.

Dj = A measure of residential location (in actual distance terms).

The decision about modal choice is taken to be affected by car ownership, life style, sex, and level of public bus service, and the competitive demands on the use of the family car by other wage earners - measured by the family labour force participation variable. The matter of car ownership is obviously critical, and it is hypothesized here that it is affected by the life style chosen, income, bus service, and the preference for car ownership and operation (in turn influenced by sex, family size and so on).[7] An equation has also been added here about time distance, since it involves some of the previous factors about life style, transportation mode and income.

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(6) Measured as accessibility to a bus route, taking account of frequency, i.e. number of bus miles per zone multiplied by frequency and divided by the number of dwelling units.

(7) See discussion Part I, Section II, on the complex interrelationship which may in fact influence the purchase of a car.

Modal Choice[8]

The proportion of people in a zone who choose to drive by car (allowing for some variation according to journey prupose) could be directly related to the zone's mean car ownership, while the proportion of the zone's modal choice, bus, could be inversely related. Since car usage is commoner amongst those who live in superior quality housing, the percentage using the bus could be inversely related to the percentage residing in better housing. Car use would be expected to be inversely related to the level of bus service available, and bus use directly related to that level. Since higher income workers would be expected to place higher value on their time, higher income zones should have higher proportions of car drivers, even when car ownership and the level of bus service are held constant. It nearly always takes less time to travel a given distance by car than by bus. Further, since females less often know how to drive, usually have a lower income, and less frequently own cars, zones with large proportions of female workers should have lower proportions of car drivers and higher numbers who use public transport, even with income and car ownership held constant. Finally, zones with an above mean family size should have higher bus usage.

Car Ownership

Bearing in mind the discussion in Section II, an attempt is made here to explain the spatial variations in car ownership, as a function of bus usage and transit levels. Thus one could perhaps expect car ownership to be lower in areas well serviced by public transport, so a negative correlation would be looked for. A positive relationship would be expected between car ownership and the percentage of good quality housing. If say a worker wishes to live at a low density residential site, his journey-to-work will probably be quickest and cheapest if he drives his own car since, by and large, low density residential areas have poorer transit service. In these areas without a car, a person faces time consuming transit services.

(8) See Kain op. cit. pp. 18-22.

It is fairly obvious that zone income (or some comparable measure) should be positively related to car ownership, even if the effects of low density, level of public service and so on were held constant. Cars are valued not only because they provide transportation, but because they can be a reflection of life style, and can provide certain comforts and conveniences. So that probably ownership alone is no longer the predominant status symbol.

For a number of reasons one also expects car ownership to be greater in zones with a high proportion of males. There are cultural factors which make it less common for females to own and operate cars; two car families are rare, in Perth and Britain as a whole, even among those households with more than a single wage earner. Moreover since women earn less than men, single women are less likely to own cars.

Distance

Distance may be measured in a number of ways. Here reference is made to time-distance, i.e. to the mean time taken for all journeys made from a given one. Obviously this is a complex index, since it measures the spatial separation of residence from work place, school, shops and so on, as well as a decision by the resident about the relative value of location, time, money, etc. To some it is a substitution type relationship between, the private car with higher average costs but higher speed, public transportawith lower speed but lower cost, and in Perth to many, also the alternative of walking, with no cost except that of time. Obviously in fact because of location and differences in level of service available from zone to zone, different sets of transportation alternatives are available to the various residents. Another complexity involved here is the decision whether to live near or far from the central area, which in Perth contains most of the employment, shopping, etc. - it can be hypothesized that the worker makes marginal decision be tween higher site-rent expenditure and distance to work; one would expect that if other variables are held constant, the time distance spentby a zone's inhabitants between residence and destination would be positively correlated with higher income groups, larger proportions of good quality housing, and so on. In addition consideration must be given to the proportion of males in a zone (females tend to make fewer and shorter journeys, since they are not always involved in the journey to work), number of wage earners, the proportion using slower means of transport, since they will all have some effect on a zone's mean time distance function.

Regression Equations

(1) $Cj = 5.822 + 36.620\ Oj + 0.181\ Rj + 0.074\ Ij - 0.020\ Hj$

't' (3.12) (2.68) (0.18) (0.12)

$-0.016\ Wj - 0.129\ Lj$ R^2 0.9670

(0.12) (0.77)

Eliminated at the 10, 5 and 1.0% significance levels to:-

$Cj = 0.374 + 37.460\ Oj + 0.148\ Rj$ R^2 0.9574

't' (6.25) (3.52)

Eliminated at the 0.1% significance level to:-

$Cj = -1.113 + 54.82\ Oj$ R^2 0.9132

't' (11.70)

(2) $Bj = -5.188 + 57.630\ Oj + 0.062\ Rj + 2.140\ Ij - 0.542\ Hj$

't' (3.57) (0.66) (3.87) (2.25)

$+ 0.399\ Wj - 0.391\ Lj$

(2.13) (.168)

(3) $Oj = -0.001 + 0.002\ Rj + 0.007\ Hj - 0.001\ Wj - 0.023\ Ij$

't' (0.81) (.168) (0.18) (1.82)

$+ 0.006\ Fj$

(.165) $R^2 = 0.9176$

Eliminated at the 10% level to:-

$Oj = 0.152 - 0.001\ Ij + 0.012\ Hj$

(0.04) (7.60) $R^2 = 0.8570$

Eliminated at the 5, 1,0 and 0.1% levels to:

$$Oj = 0.151 + 0.012\ Hj$$
$$(8.82) \qquad R^2 = 0.8570$$

(4) $$Jj = 4.492 - 0.003\ Rj - 0.033\ Wj - 0.034\ Hj$$
$$(0.23) \quad (1.09) \quad (1.76)$$
$$+ 15.47\ Dj + 0.006Lj - 0.059\ Bj$$
$$(18.84) \quad (0.20) \quad (2.31) \qquad R^2 = 0.9974$$

Eliminated at the 10% level to:

$$Tj = 2.675 + 13.63\ Dj - 0.018\ Bj$$
$$(30.04) \quad (1.06) \qquad R^2 = 0.9949$$

Eliminated at the 5, 1.0 and 0.1 levels to:

$$Tj = 2.523 + 13.25\ Dj$$
$$(47.91) \qquad R^2 = 0.9944$$

Interpretation

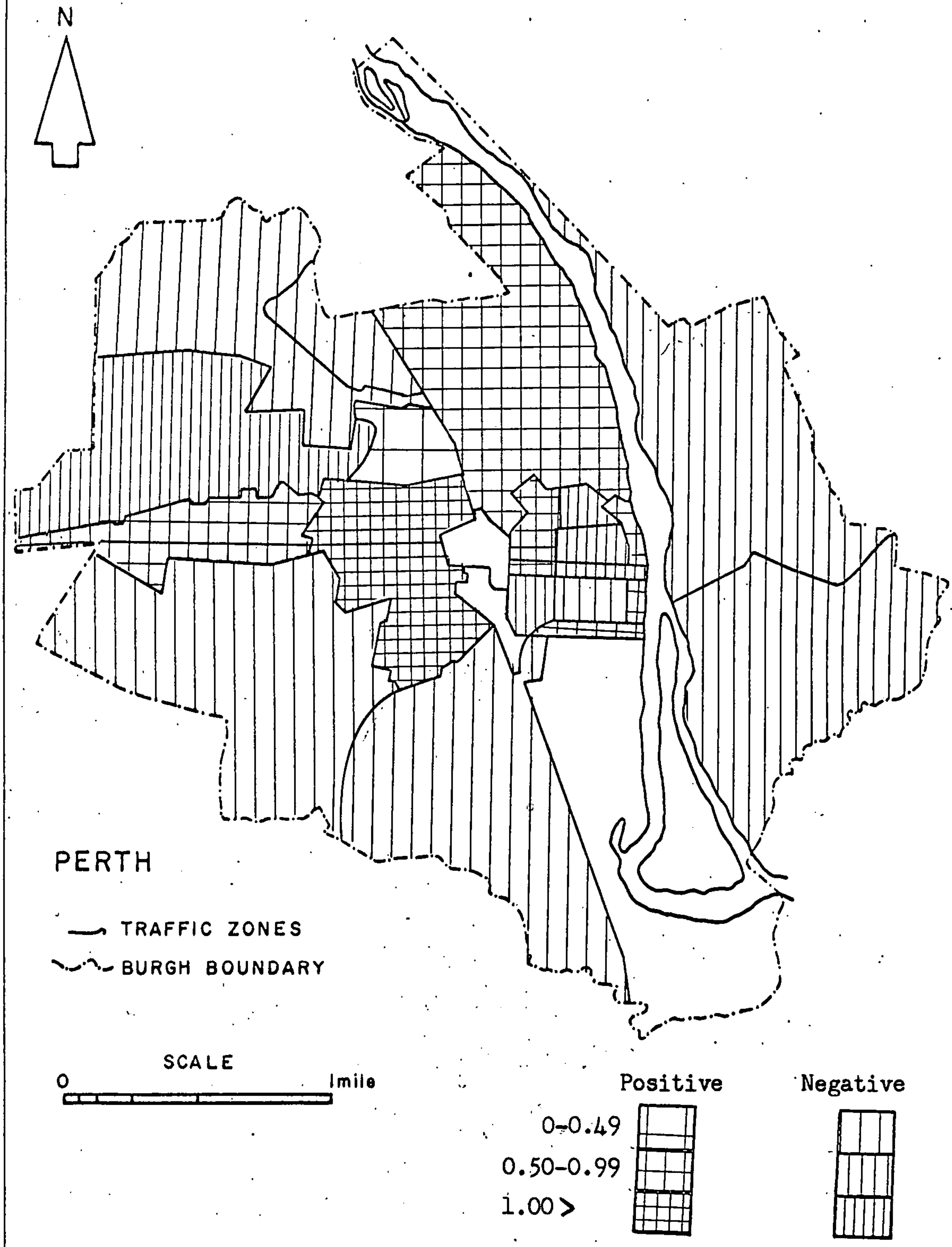
From the equations, the significant determinants of modal choice, car, appear to be the ownership of a car (significant at all levels), and the type of area in which a resident lives - the higher the quality of housing the more he is likely to use a car for a journey. The residuals from these are shown in Maps 4:2 and 4:3. The addition of measures of residential quality, improves the predictive ability of the equations, as is indicated by the smoothing of the surface between Maps 4:2 and 4:3.

The other postulates (inverse relationship to level of bus service, positive relationship to income (9) and the number of male workers) proved insignificant in these calculations. However, if you then ask what variables are most closely correlated with car ownership, which is itself so strongly tied to the modal choice "car", then one which shows an inverse relationship, is "level of bus service"; a positive correlation with high socio-economic status

(9) This may be a reflection of the method of measurement since in the 'Haystack' calculation (Appendix 6e), it proved to be significant at all levels in explaining car usage.

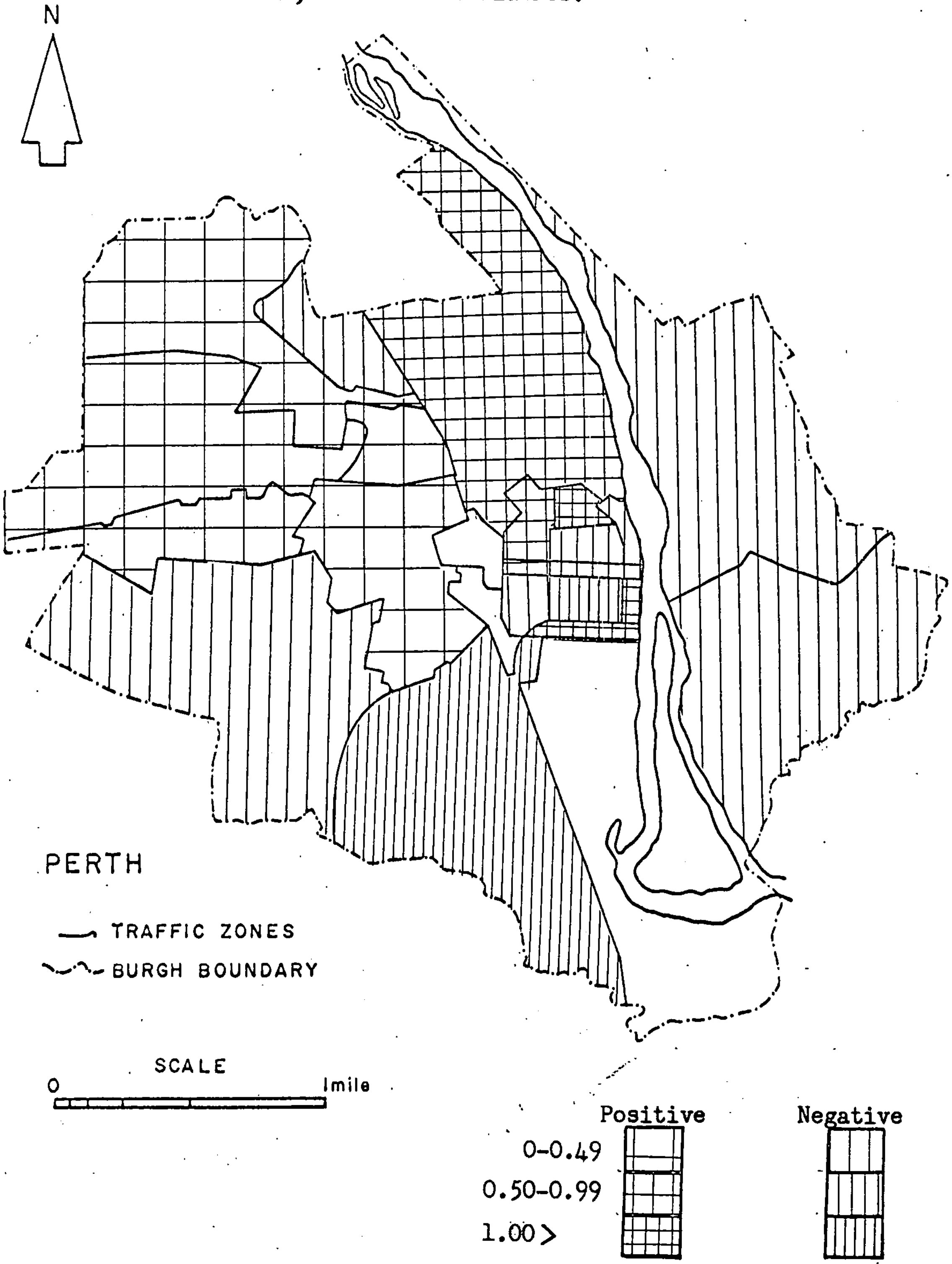
MAP 4:2

Residuals from regression. Modal choice 'car'; car ownership.



MAP 4:3

Residuals from regression. Modal choice 'car'; car ownership, bus index, and other variables.



also occurs. Again the other postulates did not prove significant in these calculations. Maps 4:4 and 4:5 show the spatial variations in the residuals from these regressions, exhibit similar surfaces and similar deviations.

Modal choice, bus, showed the postulated negative relationship with the percentage of high rated housing, the positive relationship with the level of transit service, but also showed a positive correlation with car ownership. This latter result may simply occur due to the nearness of most residential areas to the central area, and a fairly high level of transit service in most areas. Family size was non significant in this equation, but in another group of regression equations (labeled for convenience, 'Haystack', Appendix 6e), taking family size alongthere was a significant positive correlation. Map 4:6 indicates that the best prediction occurs in areas with a high level of transit service (zones 11, 15, 20 and 21) and in the central area.

Finally time-distances was considered, largely as a variable of the factors considered earlier. Of the five postulates, three proved signficant (bus index, high income, and good quality housing), and two non significant in these calculations (percentage of males, and number of wage earners). The three significant factors were all positive, indicating quite logically that the outer areas of high income were associated with greater length in time-distance terms, high car ownership, and high bus usage. Maps 4:7 and 4:8 show the residuals from these calculations. The central area was predicted poorly in Map 4:7 as were Zones 12, 13, 16 and 20 which have high proportions of households in the upper status groups. The addition of a variable to represent high status in Map 4:8 however worsened the overall rate of predictability, but improved the pattern in individual cases (e.g. Zone 16), Besides choice of car and bus as a mode of transport, other methods were examined in the 'Haystack' computation.[10]

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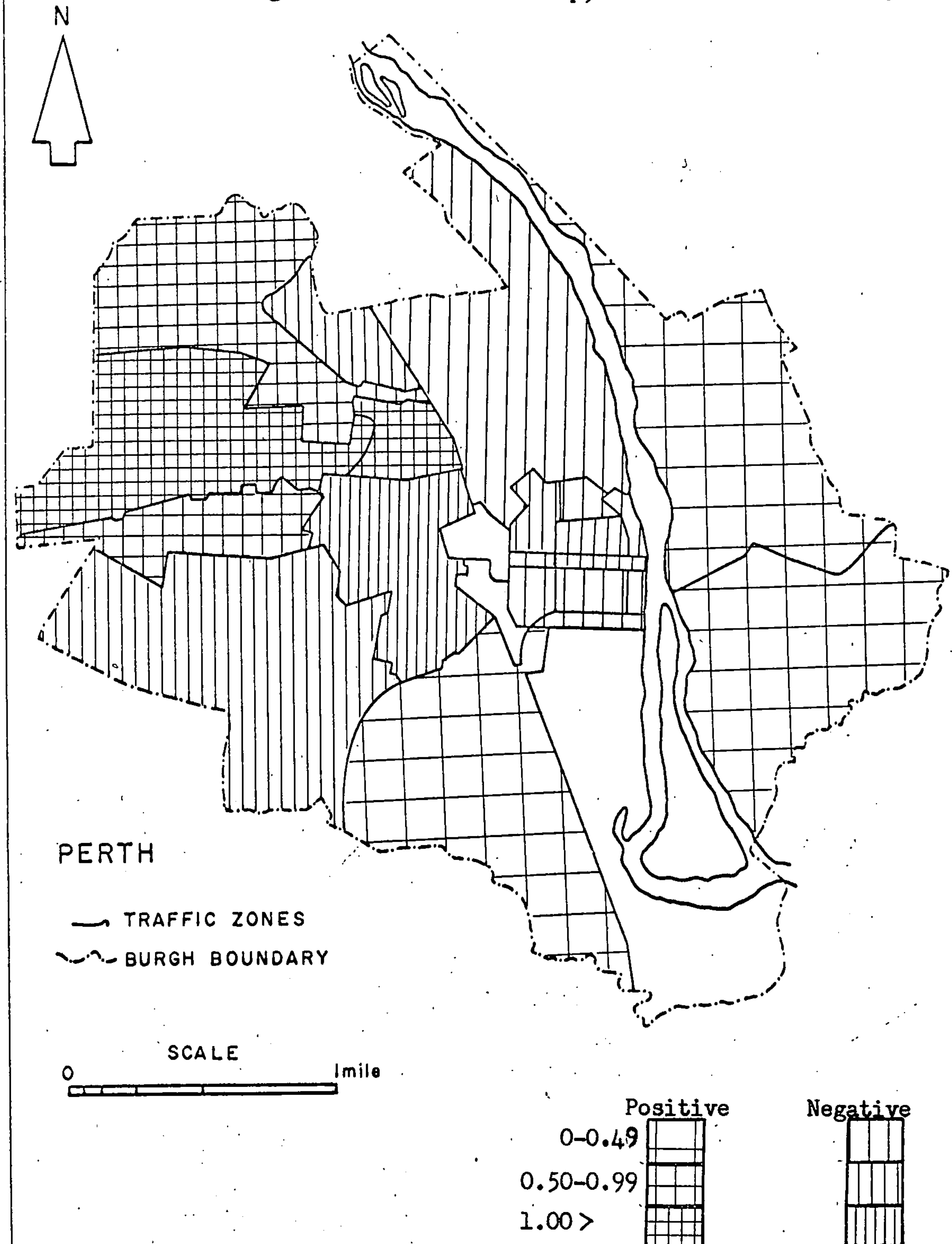
(10) 'Haystack' a convenient term for a group of regression equations. See Appendix 6e.

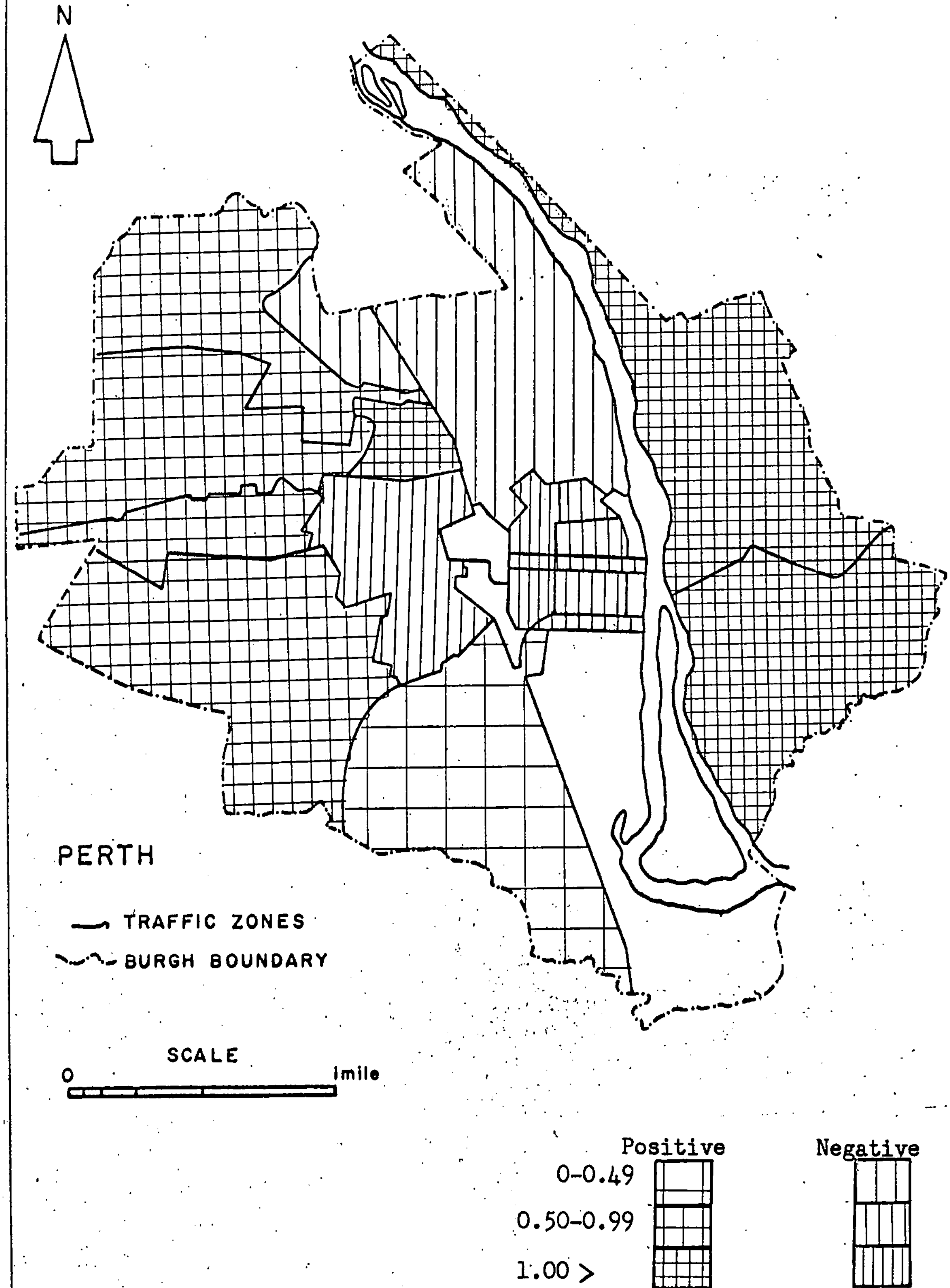
MAP 4:4

Residuals from regression. Car ownership; socio-economic status.



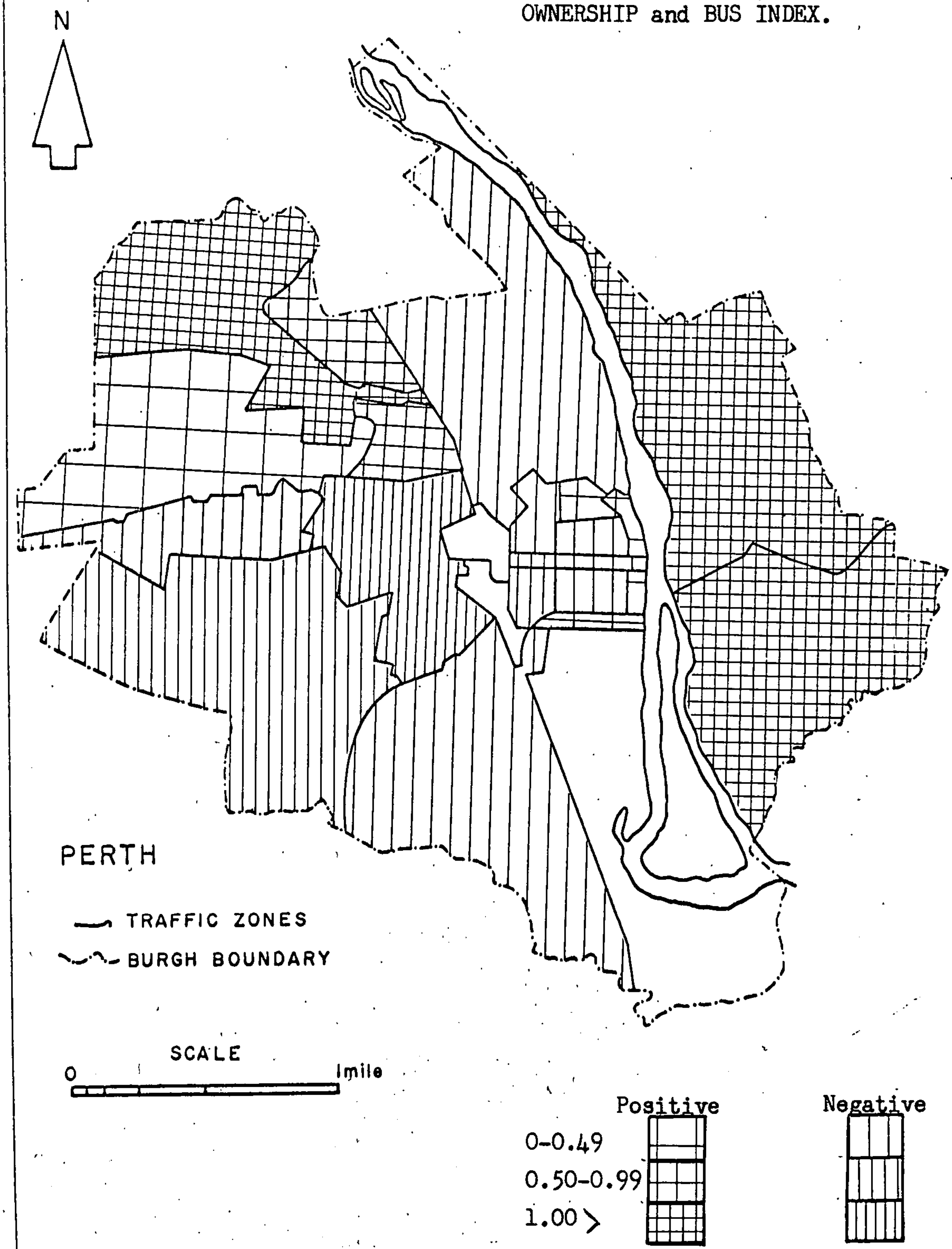
MAP 4:5

Residuals from regression. Car ownership; level of bus service.



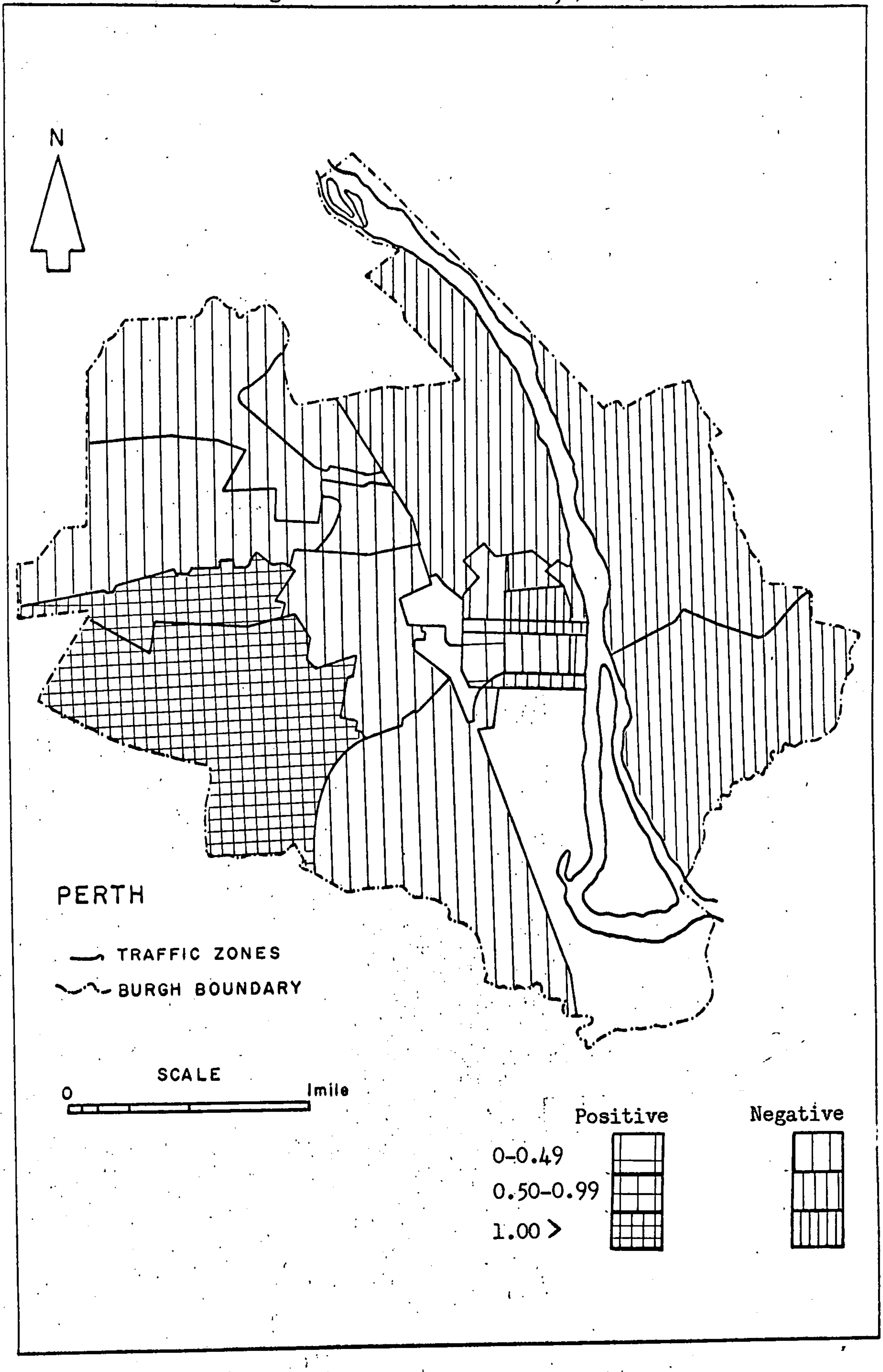
MAP 4:6

Residuals from regression. BUS USAGE; CAR OWNERSHIP and BUS INDEX.



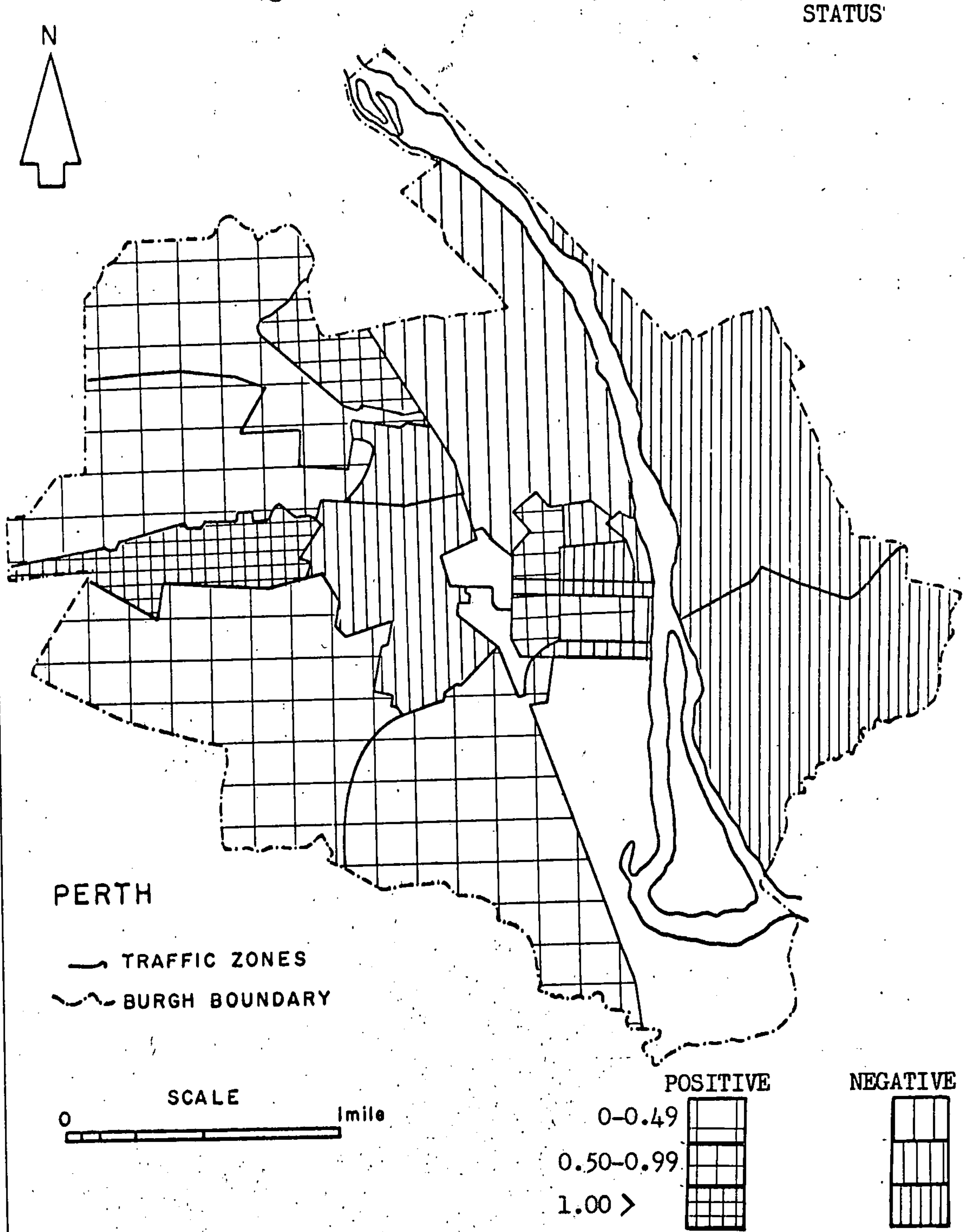
MAP 4:7

Residuals from regression. Time Distance; % Bus.



MAP 4:8

Residuals from regression. TIME DISTANCE; BUS USAGE, SOCIO ECONOMIC STATUS



"Walking" at the 10 and 5% significance levels was "explained"[11] (R^2 = 0.97) negatively by distance, social rank, and the number actively employed, and positively by density and the urbanisation index; and at the 1% level all but density and distance were eliminated, so that the mode "walk", so important in Perth appears as a direct function of density, and an inverse function of distance (R^2 = 0.8262).

Mode, "cycle", was at all significance levels directly "explainable" by cycle ownership (R^2 = 0.5582); "motor cycle" was negatively correlateable with social rank, and positively with the proportion of the population in the 16-21 age group (R^2 = 0.5934); "car passenger" was strongly correlated with car ownership in the family (R^2 = 0.9398), but also with a number of other variables - distance from the C.B.D. (R^2 = 0.5381), social rank (0.8235), income (0.8232); the remaining modes, labelled "other" because of their varied nature and small proportion of the total modes, showed too much randomness and variability to be "correlateable" at a significant level with any of the variables measured.

This analysis, although crude and elementary does seem to indicate that it is possible to isolate the predominant factors which motivate "modal choice" in an urban area. It suggests that further work could produce a model that would be capable of reproducing the existing conditions and perhaps capable of predicting future levels of the modal choice.

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(11) "Explain" is used in the statistical sense.

SECTION V JOURNEY PURPOSE

It is people who make trips, and their motivations can be expressed as trip purposes. Table 5:1 shows how the average number of journeys, per size of household, is divided amongst the various journey purposes. These variations are shown graphically in Graph 5:1; zonal variations are shown in Map 5:1; in both the predominance of the work and school trips is obvious.

The classification of a journey 'business' relates mainly to salesmen for whom travelling is an essential part of their occupation. It was felt that a differentiation should be made between this type of journey and those made to a fixed place of employment. The proportion of journeys on business proved to be under 5% of the whole.

Zonal variations are set out in the map, and Table 5:2.

Zonal variation can be partially explained as a complex of family size, socio-economic status, and other factors. Thus the smallest percentage of school trips coincide with high socio-economic status (though note it is high also in the central area, coincident with the largest number of single person household, mostly retired), and work trips with family size and socio-economic status. In fact the explanations are more complex than this, and the rest of this section will examine in more detail each journey purpose.

5:1 The Work Trip

The work trip has received special consideration in earlier traffic studies, and there is a fairly extensive literature,[1] for two reasons. First, except for the 'to-home' trips, work trips are the most prevalent journey purpose; in the category 'from-home' trips, work trips are the most important. (See Table 5:1:1). Second, work trips tend to be subject to or an assymmetric

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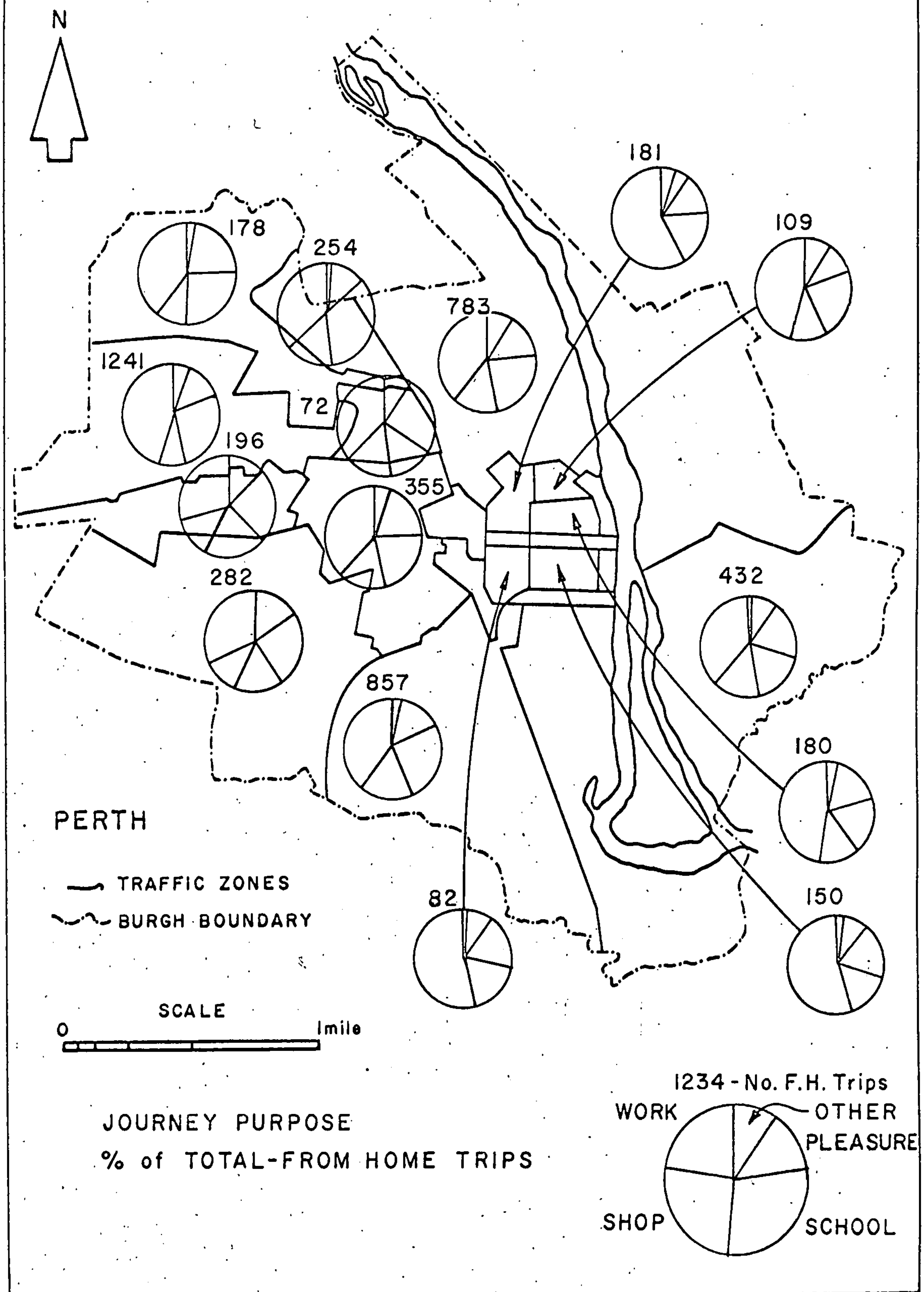
(1) See for example the bibliography in H.S. Lapin 'Structuring the Journey to Work'. Philadelphia. University of Philadelphia Press 1964.

MAP 5:1


N
181
109
178
254
783
1241
72
196
355
282
432
857
180
150
82
PERTH
TRAFFIC ZONES
BURGH BOUNDARY
SCALE
0
lmile
JOURNEY PURPOSE
% of TOTAL-FROM HOME TRIPS
1234 - No. F.H. Trips
WORK
OTHER
PLEASURE
SHOP
SCHOOL

GRAPH 5·1

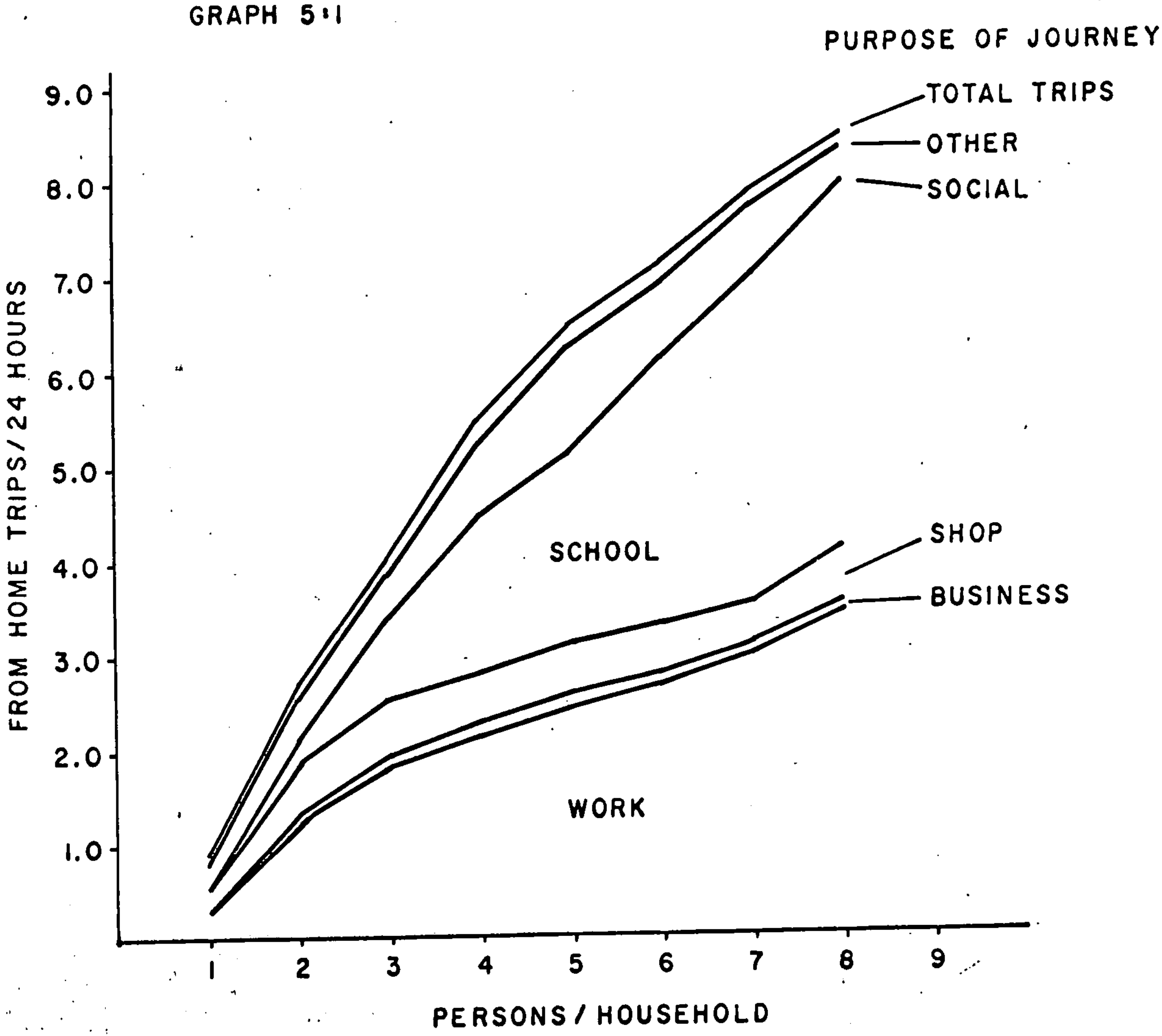

PURPOSE OF JOURNEY
TOTAL TRIPS
OTHER
SOCIAL
SCHOOL
SHOP
BUSINESS
WORK
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
FROM HOME TRIPS / 24 HOURS
1
2
3
4
5
6
7
8
9
PERSONS / HOUSEHOLD

Table 5:1

Journey Purpose: All Perth

Household Size	Work Trips /Household	%	Business Trips /Household	%	Shopping Trips /Household	%	School Trips /Household	%	Social Trips /Household	%	Other Trips /Household	%	Mean
1	0.29		0.01		0.30		0		0.32		0.07		0.98
2	1.32		0.07		0.57		0.18		0.49		0.11		2.75
3	1.84		0.10		0.57		0.81		0.61		0.15		4.07
4	2.20		0.17		0.52		1.63		0.77		0.17		5.46
5	2.45		0.18		0.51		2.08		1.08		0.16		6.47
6	2.68		0.16		0.50		2.80		0.84		0.12		7.10
7	3.00		0.13		0.46		3.46		0.75		0.16		7.92
8	3.47		0.13		0.47		4.00		0.27		0.13		8.47
Mean/ Household	1.62		0.10		0.51		0.90		0.61		0.13		3.86
Mean/ Person	0.54		0.03		0.17		0.30		0.20		0.04		1.28

Table 5:2

in %

Journey Purpose, by Zone

ZONES	WORK	BUSINESS	SHOP	SCHOOL	SOCIAL	OTHER
1-7	47.0	1.0	13.0	19.0	17.0	3.0
2-5	46.0	4.5	12.0	23.0	11.0	3.5
6	55.0	1.0	16.0	18.0	9.5	0.5
8	54.0	0	18.0	18.0	10.0	0
10	58.0	4.0	18.0	15.0	5.0	0
11	40.0	3.0	14.0	23.0	15.0	5.0
12-13	38.0	4.5	14.0	19.0	19.0	4.5
15	40.0	2.0	16.5	25.0	16.0	0.5
16	32.0	4.0	11.0	16.0	25.0	8.0
17	39.0	4.0	15.0	22.0	19.0	1.0
20	31.0	4.0	13.0	20.0	23.0	9.0
21	46.0	1.8	8.6	27.0	12.5	4.1
22	40.5	1.0	10.0	25.3	22.2	1.0
23	37.0	0	15.0	34.0	14.0	0
24	38.0	3.0	14.0	14.0	25.0	6.0
All Perth	41.0	2.5	13.1	23.4	15.9	3.3

time-distribution, most being concentrated into a few peak hours (see Secion I, Part 6). It has been suggested by several writers that the costs incurred in this work-travel are a major determinant of residential location, and that therefore most workers attempt to minimise the length of the journey to work.[(2)] More recent work indicates that this is in fact an over-simplified explanation, and that many factors, sociological as well as economic, enter into the work-journey decision.[(3)] In particular the behavioural aspect may have some

(2) Amongst others,
J. Douglas Carroll ' The relationship of home-to-work, and the spatial pattern of cities'. Social Forces. 30. March 1952 pp. 271-282.
L.F. Schnore 'The Separation of Home from Work; A Problem for Human ecology' Social Forces 32. May, 1954. pp. 336-343.

(3) Includes
J.H. Niedercorn and J.F. Kain 'An Econometric Model of Metropolitan Development' Rand. Publication P.2663. 1962.
M.E. Eliot Hurst 'Some Reflections on Future City Forms' Papers B.C. Meetings of C.A.G. Tantalus. Vancouver. 1966.

importance in residential site choice decision making.[4] Two types of 'work' trip were distinguished in the Perth survey:-

1. The home-to-work, work-to-home trip,hereafter simply called the journey to work or work trip. An additional special survey (the journey to work questionnaire) dealt specifically with this type of trip.[5]

2. Trips that are an essential part of work activity, but which do not constitute part of the regular ebb and flow of the former type. These are distinguished under the category 'BUSINESS' trips - journeys by delivery men, commercial travellers. The majority of these trips are generated from land uses other than residential and in fact form only 2.5% of from-home trips.[6]

Table 5:1:1

in percent

	ALL TRIPS	FROM HOME TRIPS
WORK	19.0	41.8
SHOP	8.1	13.1
SCHOOL	10.7	23.4
SOCIAL	9.2	15.9
'HOME'	34.0	0
OTHER	19.0	5.8

(4) Behavioural and decision making literature is vast, but of interest to the geographer are:
W. Kirk 'Historical Geography and the Concept of the Behavioural Environment'. Indian Geographical Journal (Silver Jubilee Souvenir Volume) pp. 152-160;
H. and M. Sprout 'The Ecological Perspective on Human Affairs'. Princeton, Princeton University Press. 1965;
H.A. Simon 'Models of Man', New York, Wiley, 1957. especially Chapters 14 and 15;
D.C. Russell 'Psychology and Environment'. Planning Outlook. Vol. 6, No.2 1964. pp.23-37; and
J. Wolpert 'The Decision Process in Spatial Context'. Annals of the Association of American Geographers. Vol. 54, Dec. 1954. pp. 537-558.

(5) See Appendix 4.

(6) A full analysis has been carried out by N.G. Sato, 'Estimating Trip Destinations by Purpose - Personal Business' C.A.T.S. Research News Vol. 8, No.2. July 1966. pp. 3-7, 16.

Tables 5:1:2 and 5:1:3 illustrate the frequency of work trips by family size, car ownership, and status. Work trips are positively related to family size, even when car ownership is held constant. However the number of work trips declines relatively, with increasing family size, as age composition changes and a larger number of school and/or younger children are found.(7) When, however, family size is defined by the number of wage earners, a linear relation is observed between mean work trip generation rates and wage earners (Graph 5:1:1). In fact this is but more evidence of the household size effect discussed earlier. Increasing family size is associated with a greater chance that there will be more than one wage earner. The resultant increase in work trips associated with increase in family size is thus a result of this. Graph 5:1:2 and Table 5:1:3 shows however that non-work trips increase at an even factor rate.

Table 5:1:2

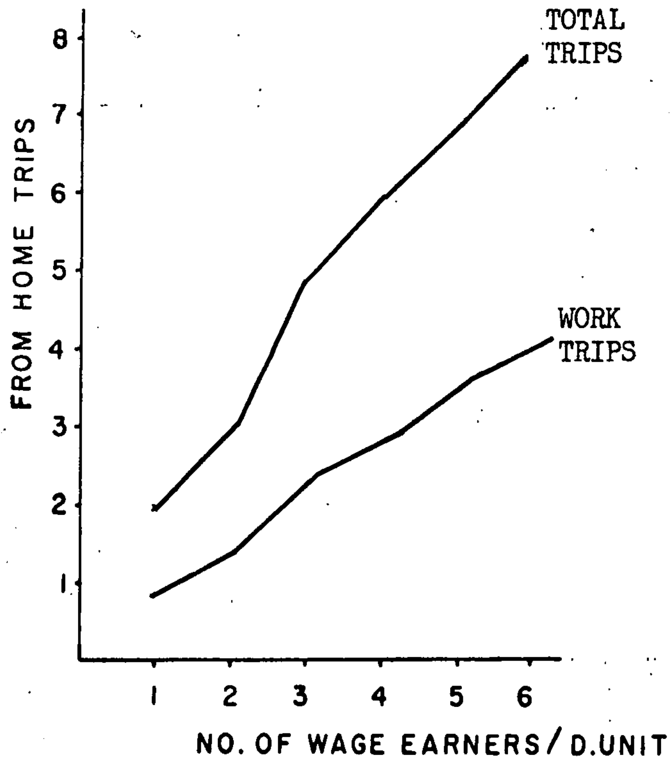
Work trips, related to household size and car ownership

Household Size	1	2	3	4	5	6+
0 Car	0.26	1.14	1.79	2.10	2.26	2.89
1 Car	0.28	1.31	1.82	2.20	2.41	3.02
2 Cars	0.31	1.42	1.86	2.24	2.61	3.27
All Perth	0.29	1.32	1.84	2.20	2.45	3.05

(7) One person households are excluded from this comparison since they contain a high proportion of retired persons.

GRAPH 5:1:1

RELATIONSHIP BETWEEN MEAN WORK TRIP GENERATION AND WAGE EARNERS.



GRAPH 5:1:2 RELATIONSHIP BETWEEN FAMILY SIZE, TOTAL, and WORK TRIPS

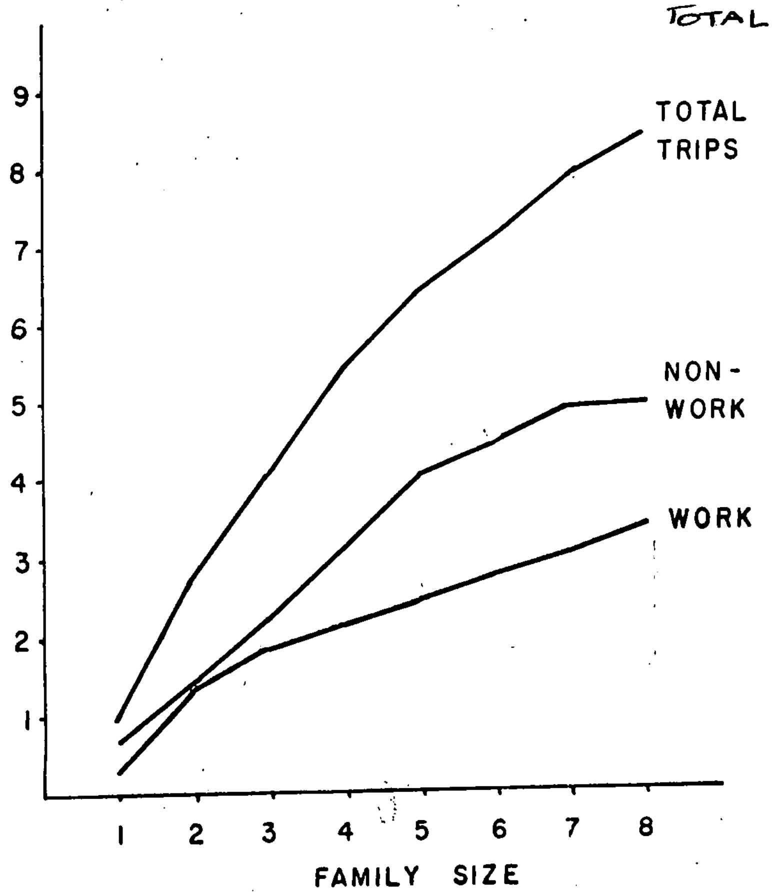


Table 5:1:3

Household Size	No. of F.H. Nonwork Trips	No. of F.H. Work Trips	Total F.H. Trips	Total All Trips	Work Trips % of all Trips	Work Trips as % of F.H.
1	0.70	0.29	0.98	2.51	11.0	29.2
2	1.43	1.32	2.75	6.82	19.4	48.1
3	2.25	1.84	4.07	10.15	18.1	45.0
4	3.36	2.20	5.46	13.08	16.3	40.0
5	4.02	2.45	6.47	15.52	15.7	37.8
6	4.42	2.68	7.10	17.04	15.7	37.6
7	4.92	3.00	7.92	18.99	15.8	37.8
8	5.00	3.47	8.47	20.29	17.1	41.0
Mean	2.24	1.62	3.86	9.38	17.3	42.0

A distinction can perhaps be made here, between primary and secondary employment. The head of the household would be the primary sector; the other employed members of the household, the secondary sector. This distinction could be important to the extent that secondary wage earners might select employment within easy access of the home, and the structuring relationship between workplace and residential area would then be attributable mainly to the characteristics of the work trip of the primary wage earner. This is a rather simple explanation however, and where a family knows there will be several wage earners, a residence might well be a compromise selection bearing in mind the several workplaces, assuming that of course there is a relationship between house selection and jobsite. This is really a consideration of real estate analysis. However, many travel surveys have shown that the average travel patterns of men and women do differ considerably. From the analysis of the home interview data, men had a daily average of 1.13 trips for work, but the equivalent average for women was only 0.38. On the other hand the daily average for trips for other purposes (shopping and social) was 2.13 for women and only 0.71 for men. Similarly

23.7 % of the males drove a car to work, and only 4.2% of women, whose main mode to work was by public transport (45.8), whilst only 18.2% of trips by men utilised this mode.

Any analysis of the journey to work must then make some compensation for primary or secondary wage earners, which allows not only for sex difference but also age.

The relationship between socio-economic status (an approximate measure of income and occupation) and from-home work trip generation is set out in Table 5:1:4. High status is associated with a decline in the proportion of work trips, though an absolute increase in number. This latter may result from the greater flexibility afforded by car ownership, job position, which would allow a person to return home for lunch, or even for mid-morning or mid-afternoon breaks. Group 7, retired persons, naturally record few work trips.

A similar kind of relationship between occupation and work trip has been recorded in many traffic surveys,[8] where the essential character of the work trip has been closely observed. The work trip makes up about 50%

Table 5:1:4

Purpose of Journey and Socio-economic Status, in %

STATUS	WORK	BUSINESS	SHOP	SOCIAL	SCHOOL	OTHER
1	30.3	5.2	17.1	24.8	17.0	5.6
2	35.2	8.5	16.3	18.7	19.3	2.0
3	40.8	10.1	15.0	16.1	17.1	0.9
4	42.1	3.2	14.0	16.7	22.0	2.0
5	46.7	1.7	12.3	10.0	26.0	3.3
6	48.4	0.4	12.0	8.0	29.2	2.0
7	10.2	0.1	24.2	51.0	4.5	10.0
All Perth	41.8	2.5	13.1	15.9	23.4	3.3

(8) e.g. Penn-Jersey Transportation Survey (Reports Vol. 1-3, 1965-4) Pittsburgh Area Transportation Survey (Reports Vols 1 and 2, 1961-3) as well as surveys from Baltimore, Puget Sound, Chattanooga, Fort Worth, Washington and in Chicago. For the latter see N.G. Sato 'Estimating Trip Destinations by Purpose - Work Trips'. C.A.T.S. Research News, Vol. 7, No.3 Oct. 1965 pp. 2-6.

of the trips taken by households in Perth that report small daily trip frequencies, with the exception of the retired category. To emphasize this relationship, the percentage of work trips to all from-home trips was computed, as in Graph 5:1:3. Thus for households reporting 4 from-home trips, about 40% were work trips. The addition of the accompanying 'to-home' trips would mean that a high proportion of the trips made by this group of households would be related to work activity.

For 10 complete trips daily about 18% would involve trips to and from work. As reported trip frequencies increase, the relative importance of work trips declines, being under 30% for 8 from-home-trip-households and under 15% for households, with 13 total trips daily.

Of course this proportion will vary with the factors noted earlier - age, sex, number actively employed, occupational status, car ownership. For individual families this proportion will vary with the factors noted earlier - age, sex, number actively employed, occupational status, car ownership.

Some of these factors were submitted to multiple regression analysis, virtually all were eliminated at the 10% level significance tests, only family size, proportion of the population between 15 and 65, and income survived. Table 5:1:5 sets out the results.

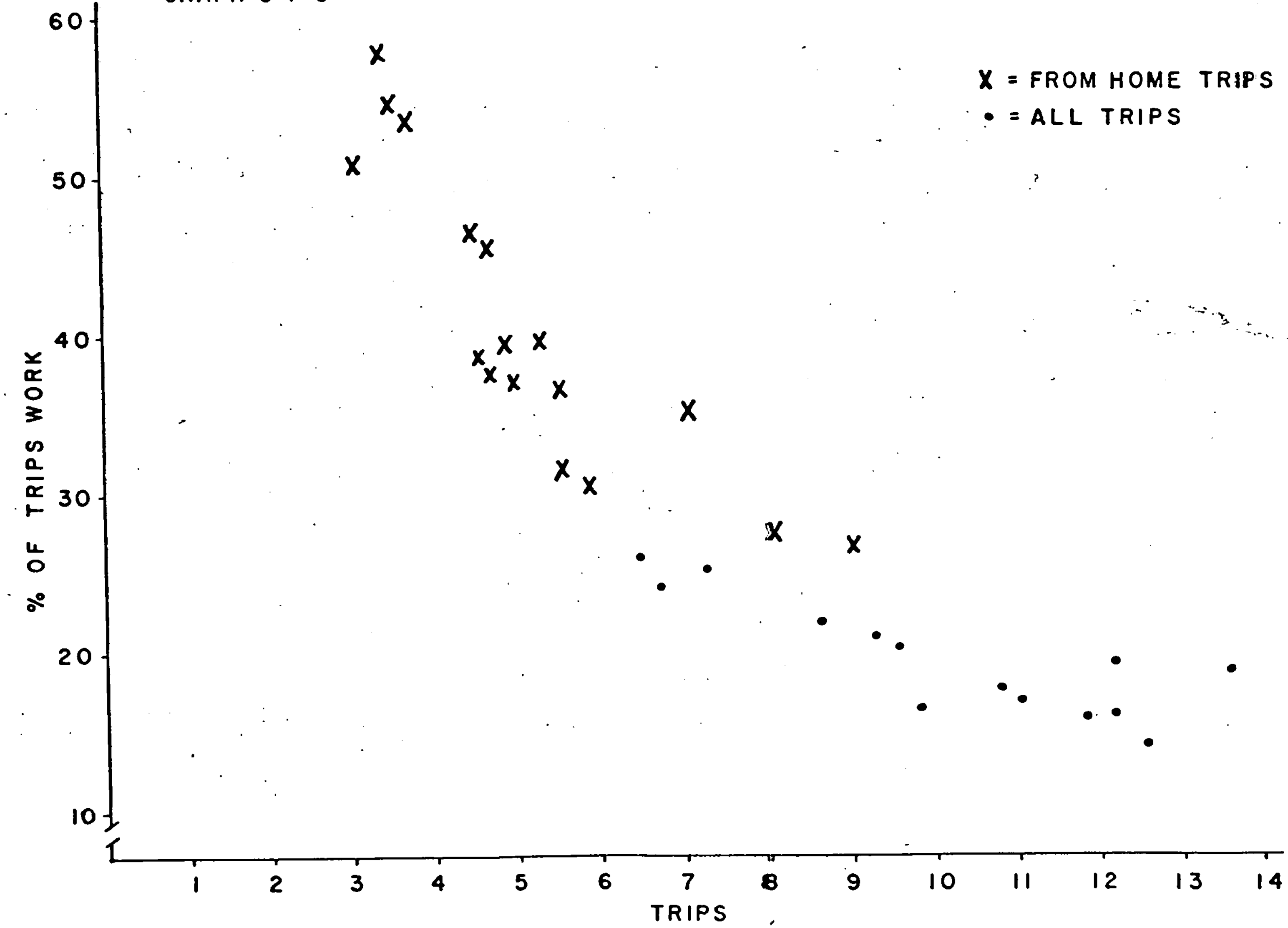
Table 5:1:5

Indep. Variable	Dependent Variables				
	FAMILY SIZE	15-65	S/E STATUS	CONSTANT	R^2/r^2
Work Trips	+0.2913	-	-	0.6975	0.5188
	-	0.0315	0.0069	3.6560	0.4271

Colinearity necessitated the separation of family size from 15-65 age group in the analysis. The correlations are self-explanatory and in part substantiate what has already been detailed.

Work trips are considered again in greater detail in Part II when the attraction of workplace sites is analysed, and more briefly in Part I, Section 7 when time-distance effects are noted.

GRAPH 5:1:3



X = FROM HOME TRIPS
• = ALL TRIPS
% OF TRIPS WORK
60
50
40
30
20
10
TRIPS
1
2
3
4
5
6
7
8
9
10
11
12
13
14

5:2 Shopping Trips

Shopping trips reflect consumption orientated travel behaviour.[1] They can be combined with travel for some other reason, and it may constitute an activity for a housewife's leisure time, especially in the higher socio-economic groups.

Perth is the County Town of a very large county, by far the largest shopping centre in the county, and it has a wider range of shops than might otherwise be considered to occur in a town of its size. This range is illustrated by the fact that some shops attract customers from larger shopping areas such as Dundee. But as well as a wide range, shops are owned mainly by independent firms, less than 20% of the shops belonging to multiple chains. Table 5:2:1 and Map 5:2:1 illustrate these points. The definition 'central shopping area' taken by the Board of Trade's Census of Distribution however, is much more restricted than the term used in this thesis.

Table 5:2:1 Retail Establishments, Perth.

	CENTRAL SHOPPING AREA	OTHER AREAS	TOTAL
Total Shops	190	289	479
Multiple Organizations	16	72	88
Turnover Organizations	£ 583,000	£2,694,000	£3,277,000
Turnover Other Shops	£4,180,000	£5,671,000	£9,851,000
Grocers	14	82	96
Other Food	38	61	99
News Agents, etc.	27	45	72
Clothing & Footwear	35	46	81
Household Goods	33	30	63
Other Non-Food	*	*	60
General	*	*	8
Service	*	*	35

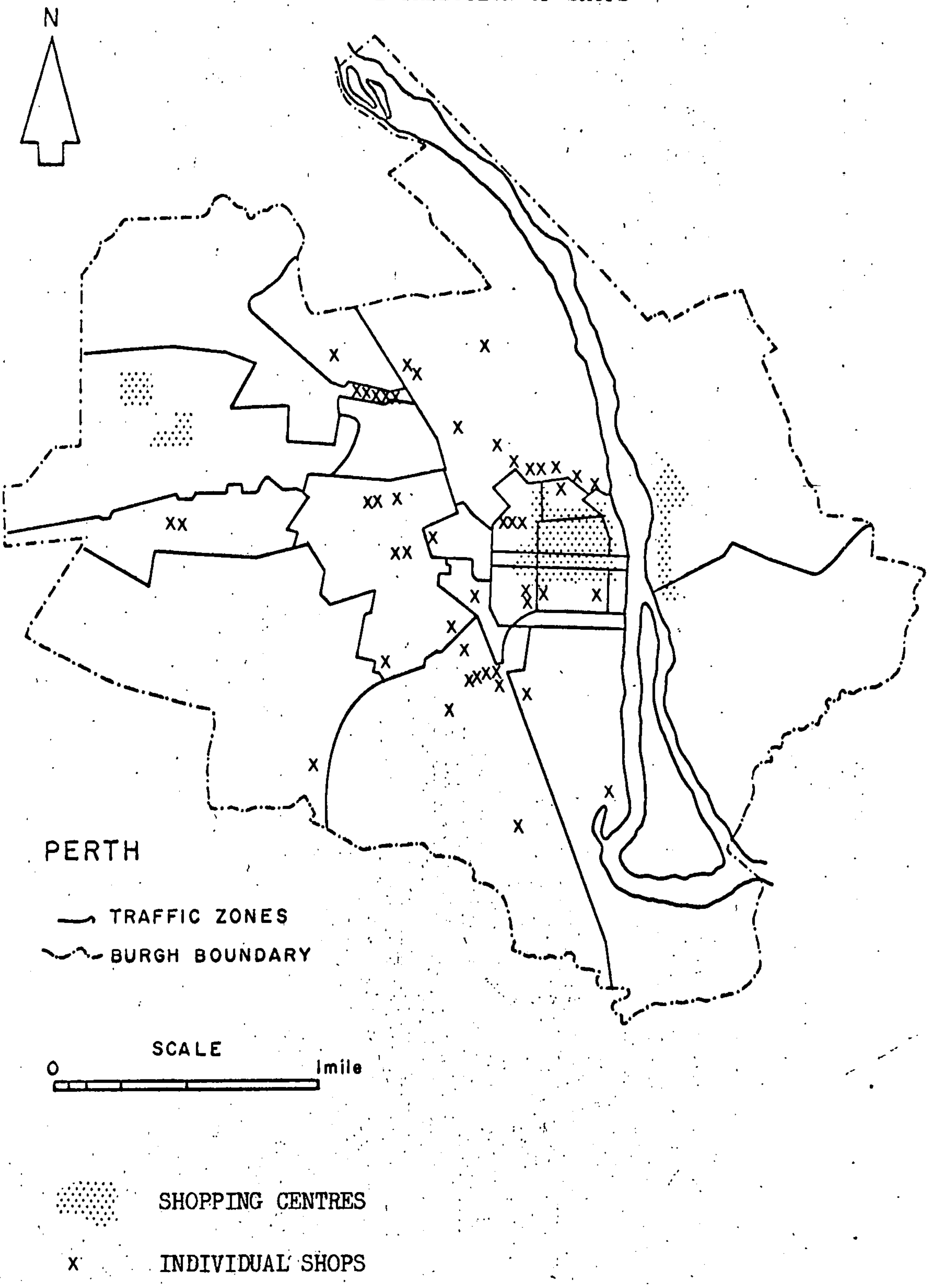
*Information not given.

Source: Census of Distribution 1961. H.M.S.O. London 1964.

(1) Two important studies of shopping trips are, Highway Research Board, Special Reports, 11.A. 'Shopper Attitudes' 1955; and 11.B 'Shopping Habits and Travel Patterns'. 1955.

MAP 5:2:1

DISTRIBUTION OF SHOPS



As with 'work' trips, the bulk of the analysis comes in Part II, which analyses the retail structure and travel patterns more thoroughly. It suffices here to make a preliminary analysis. The operative factor would seem at first, on a-priori grounds, to be population density, since the proximity of stores and shops could be directly related to the residential or population density of the zone where a household is located. Where densities are high there is a high probability that groceries, butchers, and so on, will be located within walking distance of the home. In thinly populated zones, the density of such retail establishments would also be quite low; hence households residing in such areas must substitute vehicular for pedestrian travel, to reach either the central area or the few more widely scattered local shops. Distance and density are commonly used variables in most traffic and marketing analyses.(2)

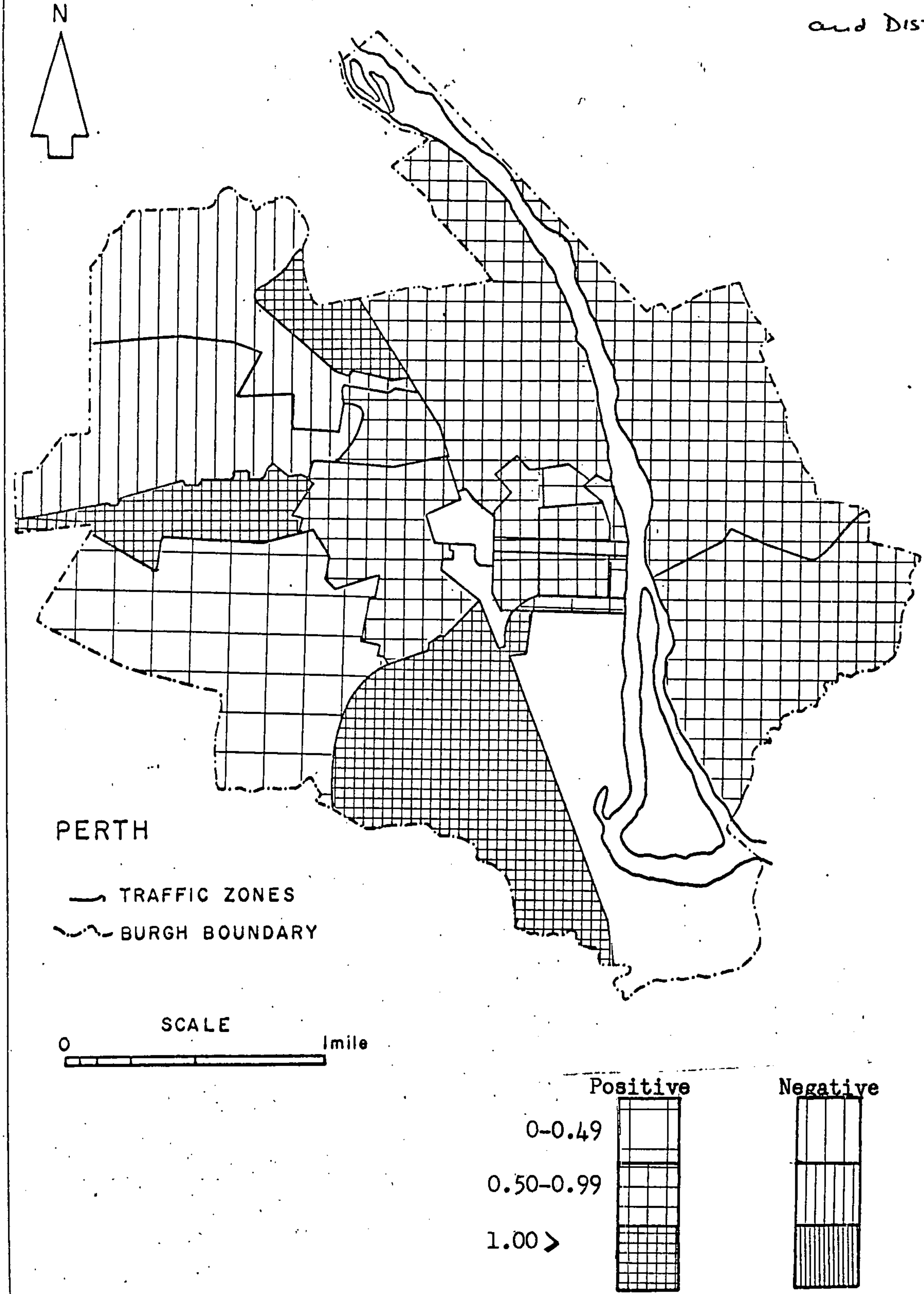
On a-priori grounds 9 variables were entered in a multiple regression analysis, taking total from-home shopping trips as the dependent variable. The independent variables were family size, density, distance, socio-economic status, car ownership, social rank, urbanisation index, house type, and the number over 65 years of age. The coefficient of determination was 0.93. However all but the urbanisation index, house type and distance were eliminated at the 10% significance level. The three remaining dependent variables were significant at the 0.1% level. The coefficient of determination was now reduced to 0.65. All three variables showed a negative relationship with shopping trips, indicating that the more densely populated urban area surrounding the C.B.D. was coterminous with higher numbers of shopping trips. Map 5:2:2 shows the trend surface of this regression, the relationship working least well for zones 15, 20 and 23. The nature of the data and the assumed relationships does not warrant further analysis.

---

(2) A consideration of the effect of spatial flexibility and inflexibility, and comparative shopping is to be found in R.G. Golledge, G. Rushton, and W.A.V. Clark 'Some Spatial Characteristics of Iowa's dispersed Farm Population and their Implications for the Grouping of Central Place Functions'. Economic Geography, Vol. 42, No.3, July 1966. pp. 261-272.

MAP 5:2:2

Residuals from regression. Shopping Trips; URBANISATION INDEX, HOUSE TYPE, and DISTANCE.



$$X = 0.0309 - 0.0315\ Y_1 - 0.0449\ Y_2 - 0.0129\ Y_3$$

$$t \qquad (4.23) \qquad (3.66) \qquad (2.43$$

$$R^2 = 0.65$$

Where Y_1 = urbanisation index

Y_2 = house type

Y_3 = distance from the central area.

It is fairly obvious that this is a crude way to treat shopping trips, since it takes no account of local shopping facilities, nor of the proportions of shopping carried out locally or in the central area. The zonal or spatial pattern of all shopping trips in fact is non-significant by Bartlett's test, and Graph 5:2:1 indicates that what differences do exist are largely the result of difference in family size. When however the distribution of shopping trips to local shops, and to the central area, are analysed separately, there do prove to be significant differences. In Part II an attempt is made to measure quantitative differences in shopping measuring distances to local shops, distance to the central area shops, local retail floor space, the proportion of local to central retail floor space, and convenience and shopping-goods trips.

5:3 Social Trips

Social trips include a wide range of activities - visits to friends, the theatre, cinema, sports activities, restaurants, pleasure driving, with pointers to both car ownership and socio-economic status affecting the volume of these trips. However, there is not so much guidance in determining variables a-priori here, since many psychological and behavioural stimuli could account for the generation of any one social trip. The spatial differences that do occur within Perth were significant by Bartlett's test, so that some general explanatory factors or variables, to explain particular differences are required. Table 5:3:1 sets out simple correlation coefficients between social trips and a wide range of variables chosen inductively. Measures of high status

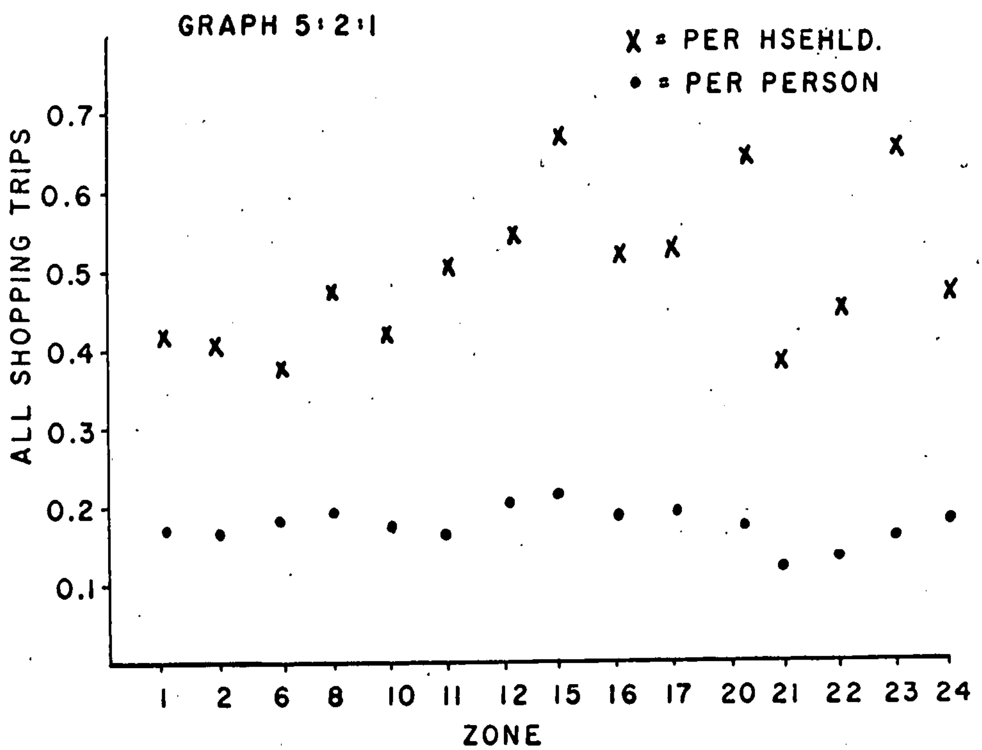

GRAPH 5:2:1
X = PER HSEHLD.
• = PER PERSON
ALL SHOPPING TRIPS
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
6
8
10
11
12
15
16
17
20
21
22
23
24
ZONE

Table 5:3:1

SOCIAL TRIPS, correlation coefficient with various factors.

Family Size	0.36	Social Rank	0.74
Density	-0.47	Urbanisation Index	-0.53
Distance	0.82	Cycle Ownership	0.36
Socio-Economic Status	0.73	% Skilled Workers	-0.64
Car Ownership	0.79	% Manual Workers	-0.62
House Type	0.67	No. of Persons Actively Employed	-0.79

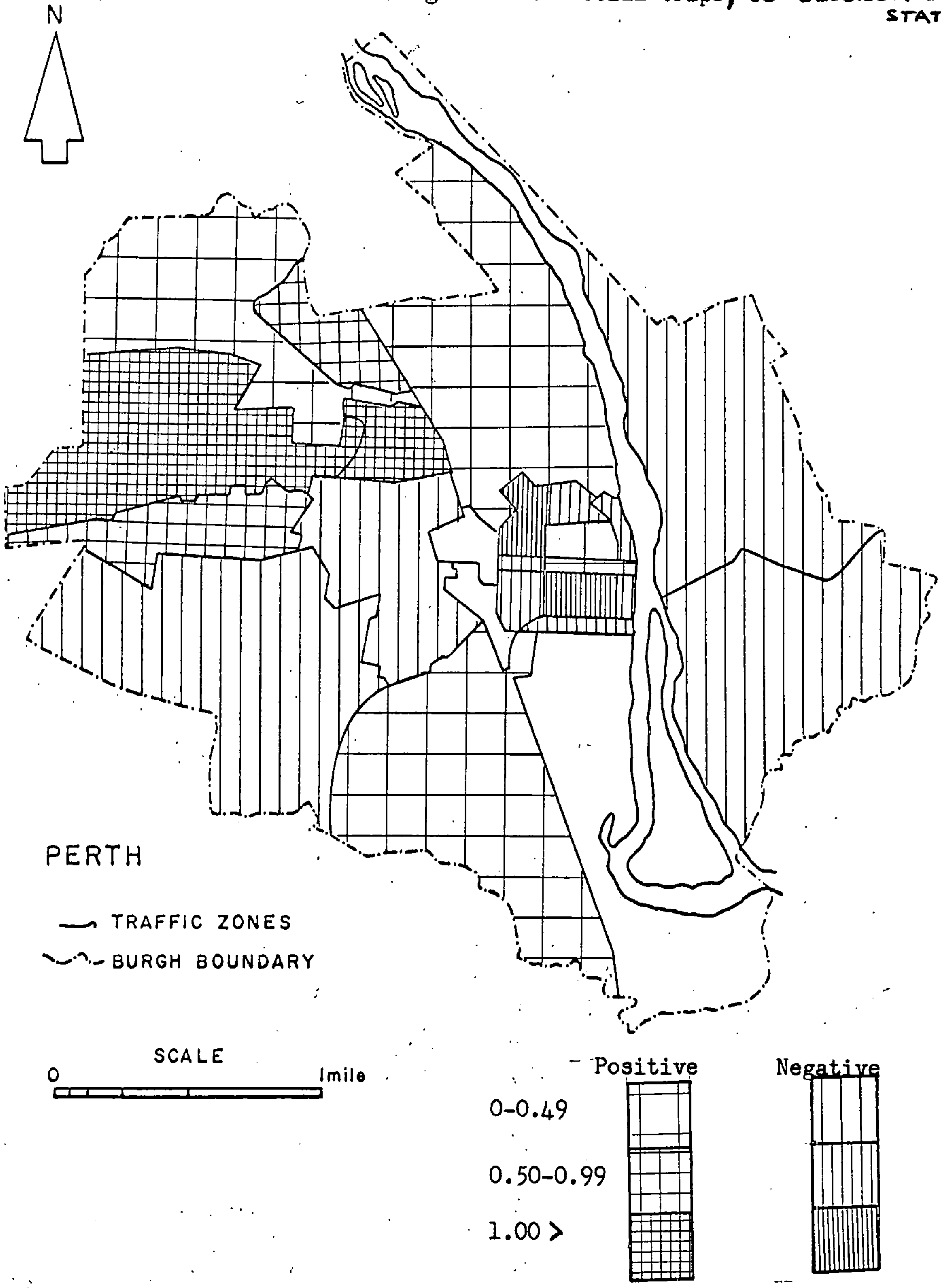
show positive correlations with the number of social trips - distance from the central area, social rank, economic standing, car ownership, and house type; measures of lower status, high density, high urbanisation index, a high percentage of manual and skilled works, show significant negative correlations. Family size is non-significant.

Because of the effects of colinearity it is not possible to carry out multiple regression on all the variables, however certain combinations can be used and some of the results are shown in Table 5:3:2. The highest coefficient of determination in simple regression occurs with distance from the C.B.D. Car ownership also has a fairly strong effect.

Social trips, since they contain an element of luxury, are influenced by income (measured here as socio-economic status). A significant correlation ($r^2 = 0.53$) was obtained between the number of social trips and socio-economic status. Zonal variations can be explained in income and distance terms (though they are to some extent colinear), and in Zones 12, 13, 16, 20 and 24, 19-25% of from-home trips are social trips, as against 5-10% in the other zones. Graph 5:3:1 underlines this relationship,and the residuals from the regressions are found on Maps 5:3:1-5. Poor prediction occurs in those areas with a lower proportion of social trips. At this lower level obviously other variables are more important.

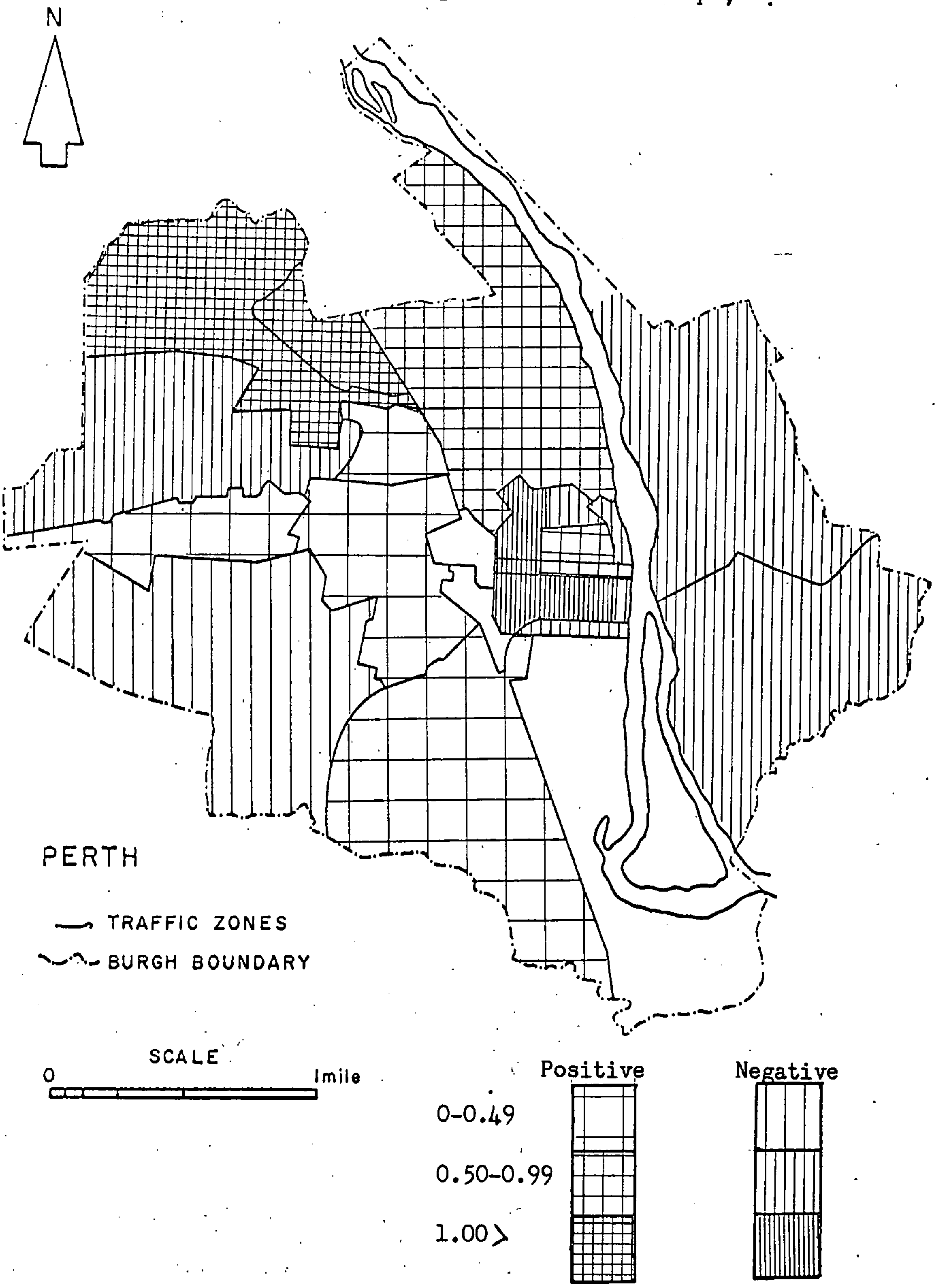
MAP 5:3:1

Residuals from regression. Social trips; SOCIOECONOMIC STATUS.



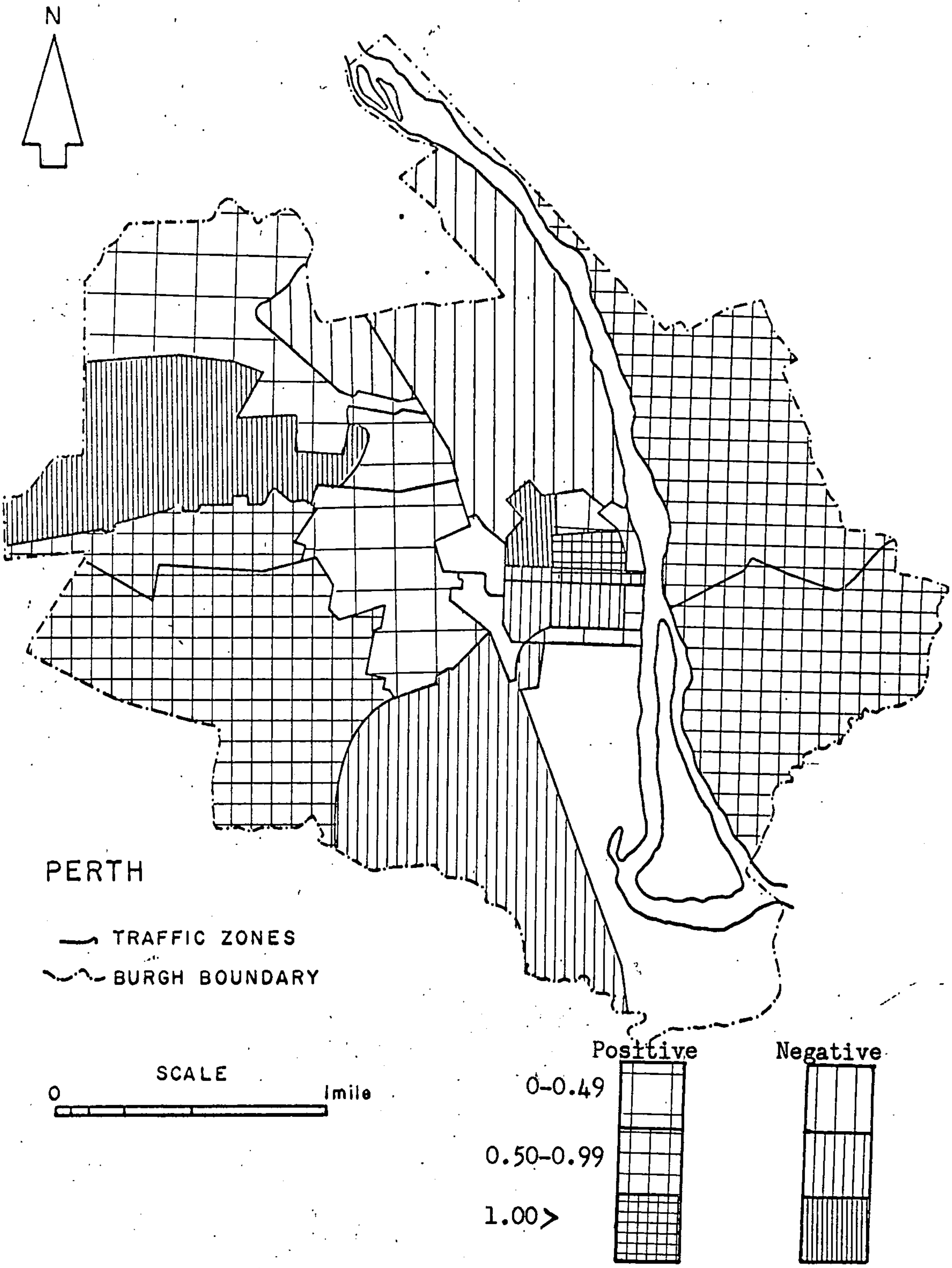
MAP 5:3:2

Residuals from regression Social trips; CAR OWNERSHIP.



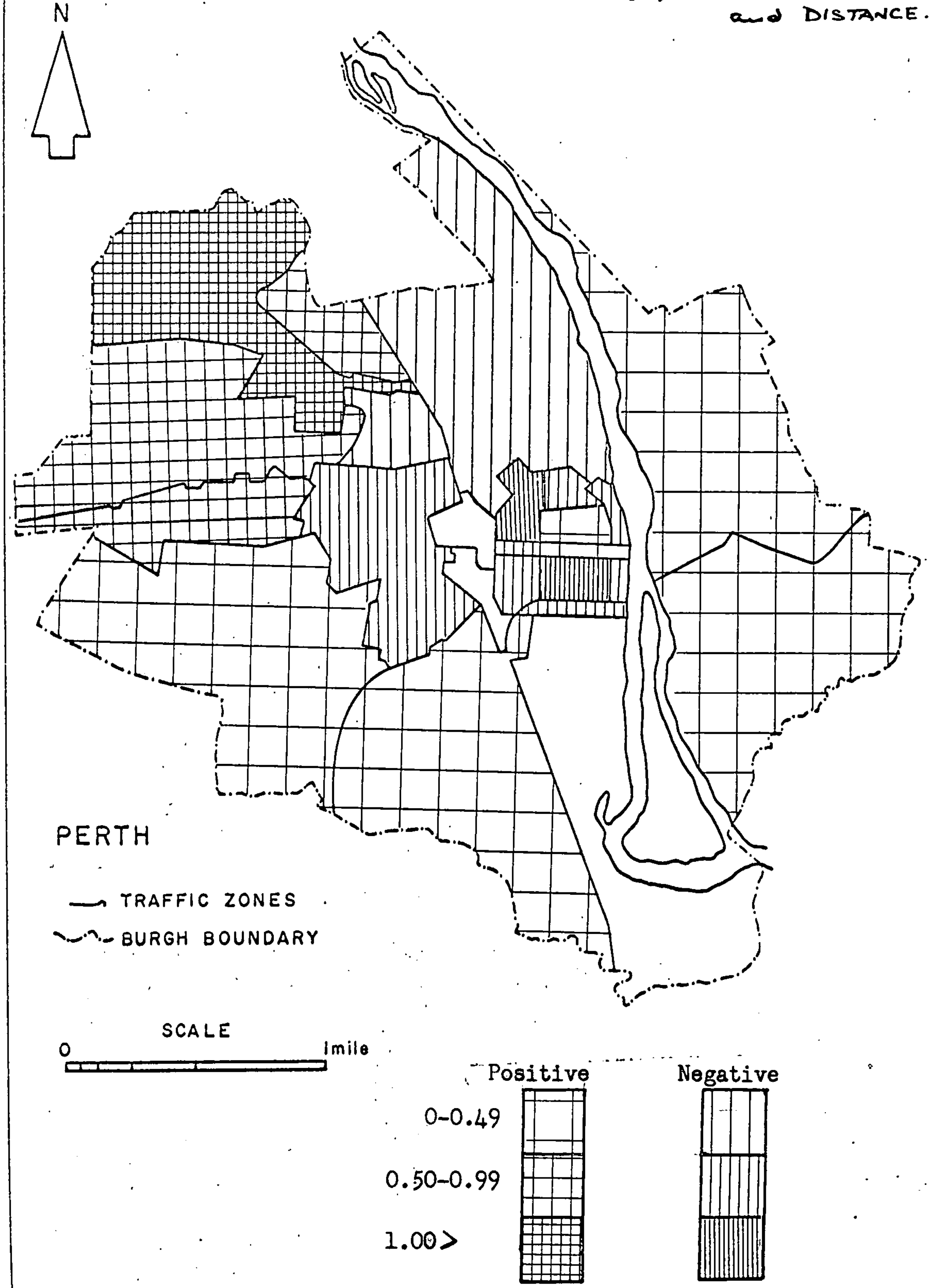
MAP 5:3:3

Residuals from regressions. Social trips; distance.



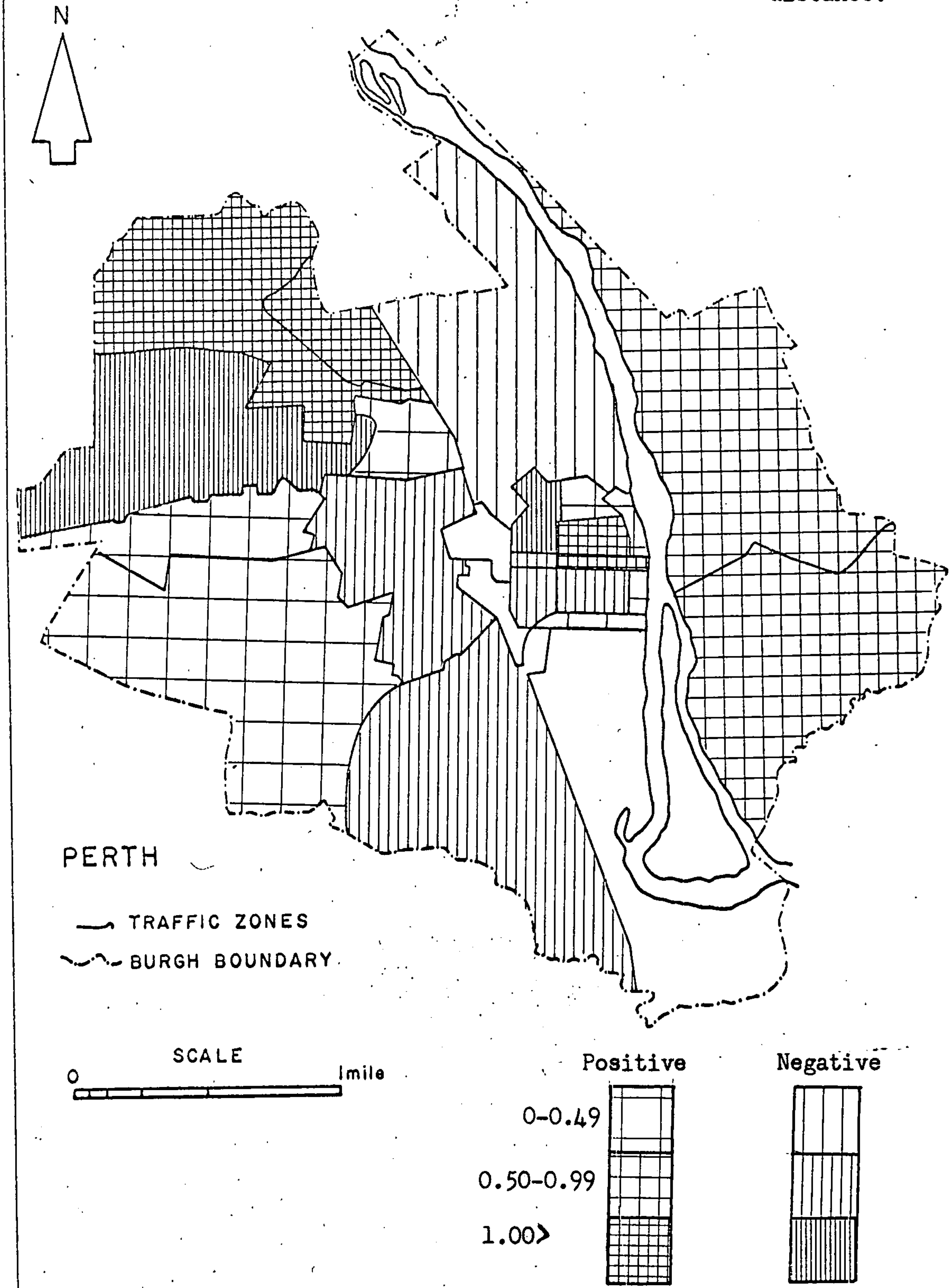
MAP 5:3:4

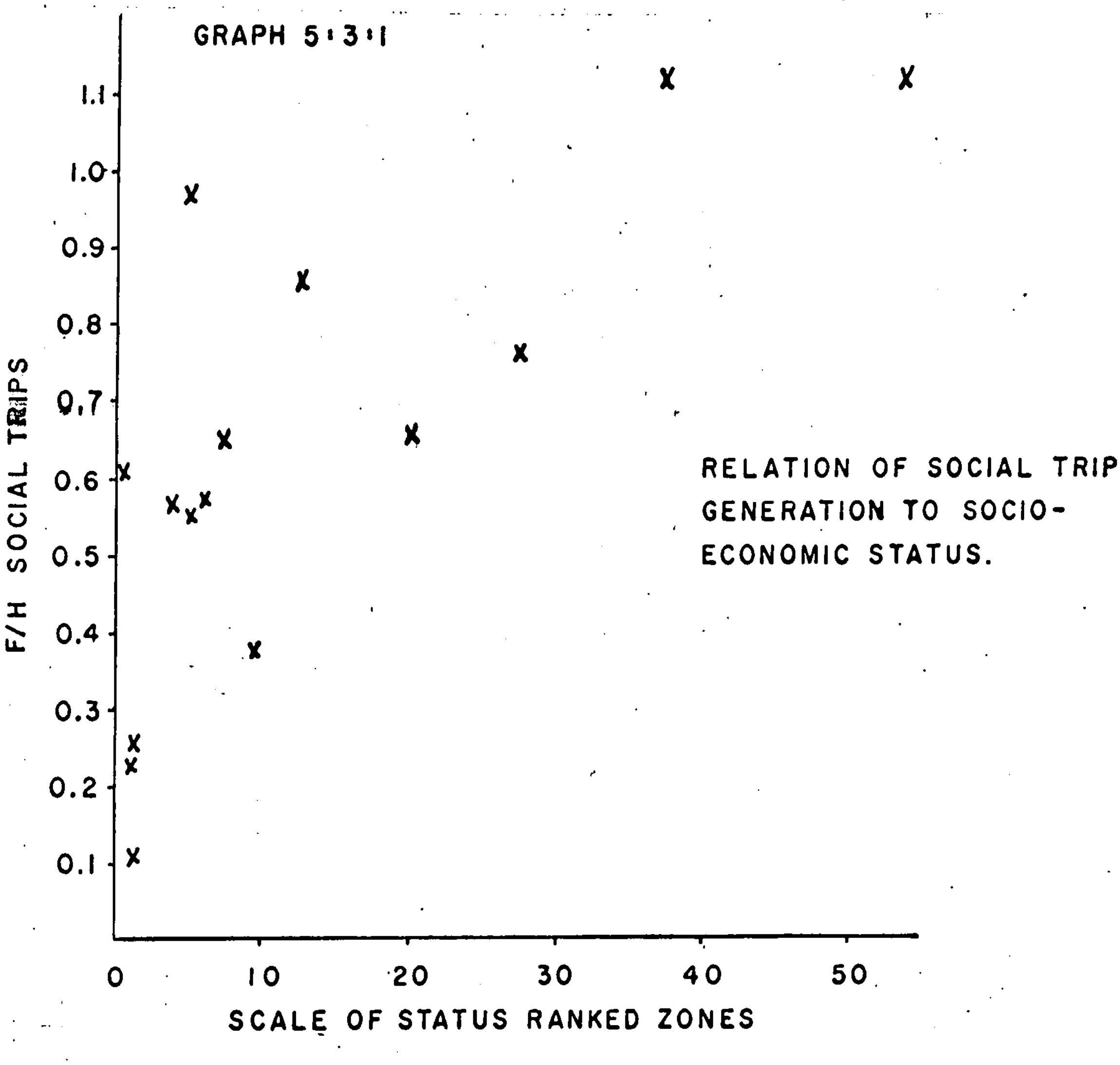
Residuals from regression. Social trips; SOCIOECONOMIC STATUS and DISTANCE.



MAP 5:3:5

Residuals from regressions. Social trips; housing type and distance.





GRAPH 5:3:1
F/H SOCIAL TRIPS
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
SCALE OF STATUS RANKED ZONES
RELATION OF SOCIAL TRIP GENERATION TO SOCIO-ECONOMIC STATUS.

Table 5:3:2

Social Trips. Regression Analysis

CONSTANT	DISTANCE	S/E STATUS	C. OWNER/P	H. TYPE	t	R^2
0.4427		0.0143			3.80	0.5259
0.2595			1.2100		4.66	0.6258
0.2322	0.5362				5.10	0.6757
0.4075				0.0072	3.26	0.4499
0.2051	0.4226			0.0036	3.89 2.02	0.7568
0.2299	0.3973	0.0081			3.98 2.68	0.7958

In summary, car ownership, income, and distance have modest effects on the frequency of social trips, so that the factors which influence total trip generation rates also appear to influence social trip generation rates.

5:4 School Trips

Trips to school can be a very important element in a household's trip 'budget' and can account for up to 50% of all from-home trips made by a family, although the mean is 23.4%. Obviously there is a great deal of dispersion about this mean accountable by a direct correlation with family size and the number in the family between 5 and 15 years of age.

Not only is it an important element in small unit terms, but forms an important element in the total circulation pattern. School trips form, on average, one quarter of a household's trips, and in total terms, account for 21% of bus passenger traffic, 18% of the car passengers, 33% of the cycle, journeys, and 35% of total pedestrian movement.(1) Thus school trips are an important element, though they have been omitted from many traffic studies.

(1) Of school trips, 29% are by bus, 5% car passengers, 15% cycle and 51% walk.

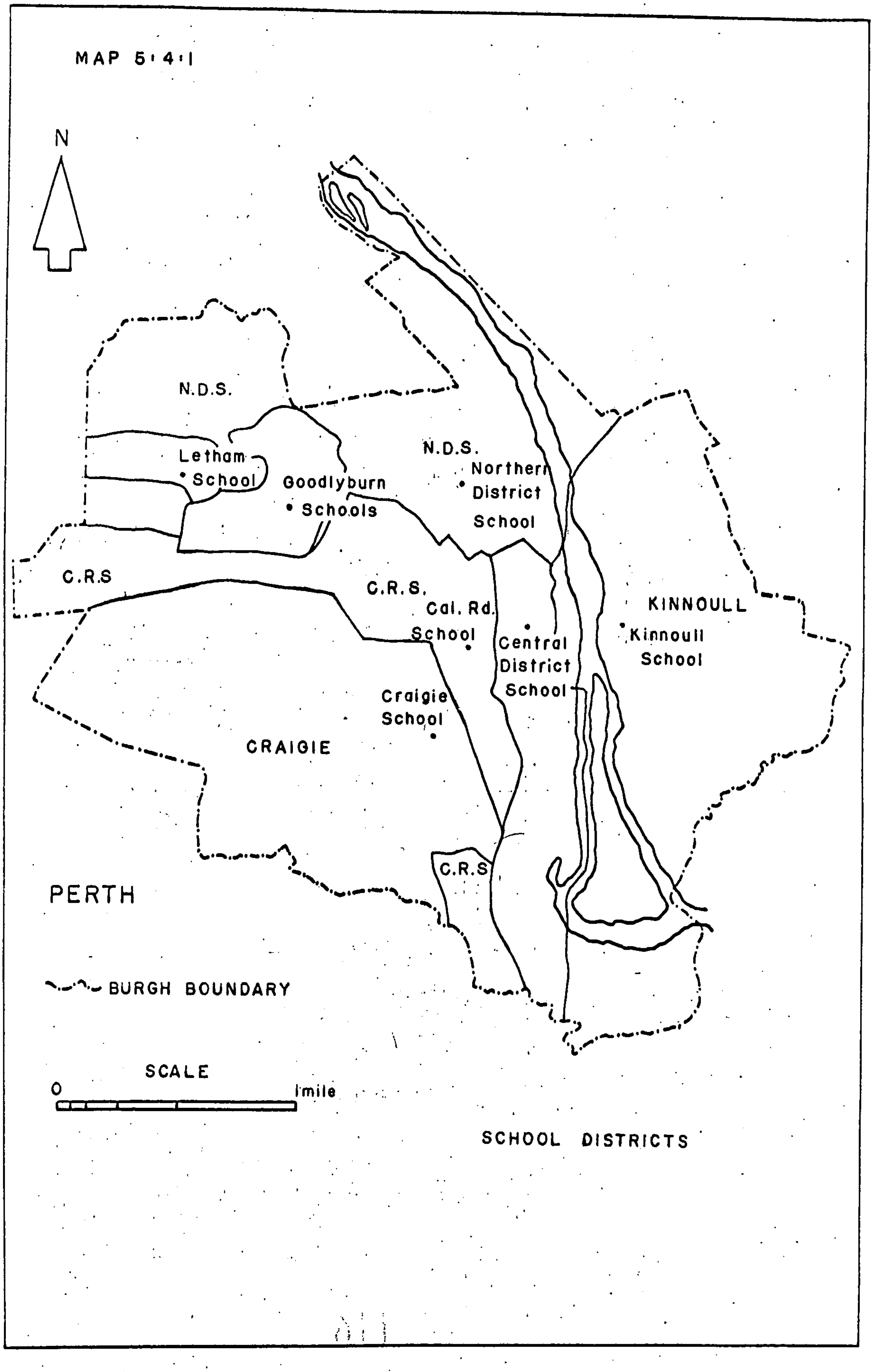
Zonal differences and household differences, are explainable in direct terms, but the total circulatory pattern is complicated by the existence of set school districts, and environmental difficulties like main roads. The territorial divisions for the primary schools are shown in Map 5:4:1, and the linkage pattern of Map 5:4:2. The secondary schools are not zoned in this way. The implication is that schools should be identified by type - specifically, primary, secondary, municipal zoned, private, and college.

The regression analysis, in Table 5:4:1 and the residuals in Maps 5:4:3 and 4, underline the simple and direct relationship noted above. Both family size and age group 5-15 years were significant to the 0.1% level. Density, to some extent a sub-function of those two previous factors, was significant to the 1.0% level. Problems of colinearity, however, did not allow persual of these interrelationships.

Table 5:4:1

Regression Analysis: School Trips

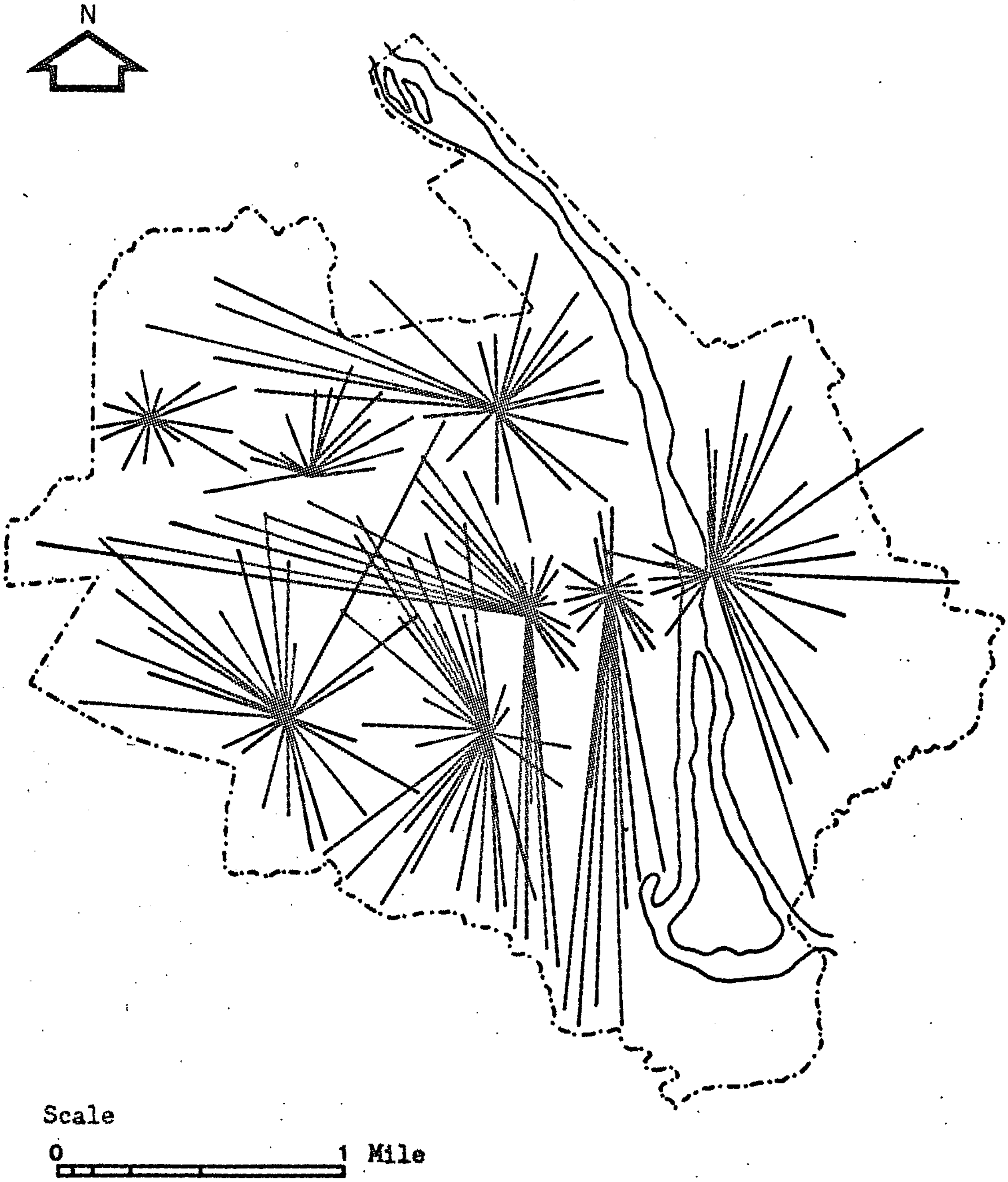
CONSTANT	FAMILY SIZE	DENSITY	5-15 AGE GROUP	t	R^2/r^2
-0.9383	0.6488	0.0946		20.19 2.05	0.9746
-0.9822	0.6207			19.13	0.9657
0.0404			0.0555	6.32	0.7542


MAP 5·4·1
N
N.D.S.
Letham School
Goodlyburn Schools
N.D.S.
Northern District School
C.R.S
C.R.S.
Cal. Rd. School
Central District School
KINNOULL
Kinnoull School
Craigie School
CRAIGIE
C.R.S
PERTH
BURGH BOUNDARY
SCALE
0
1mile
SCHOOL DISTRICTS

MAP 5:4:2

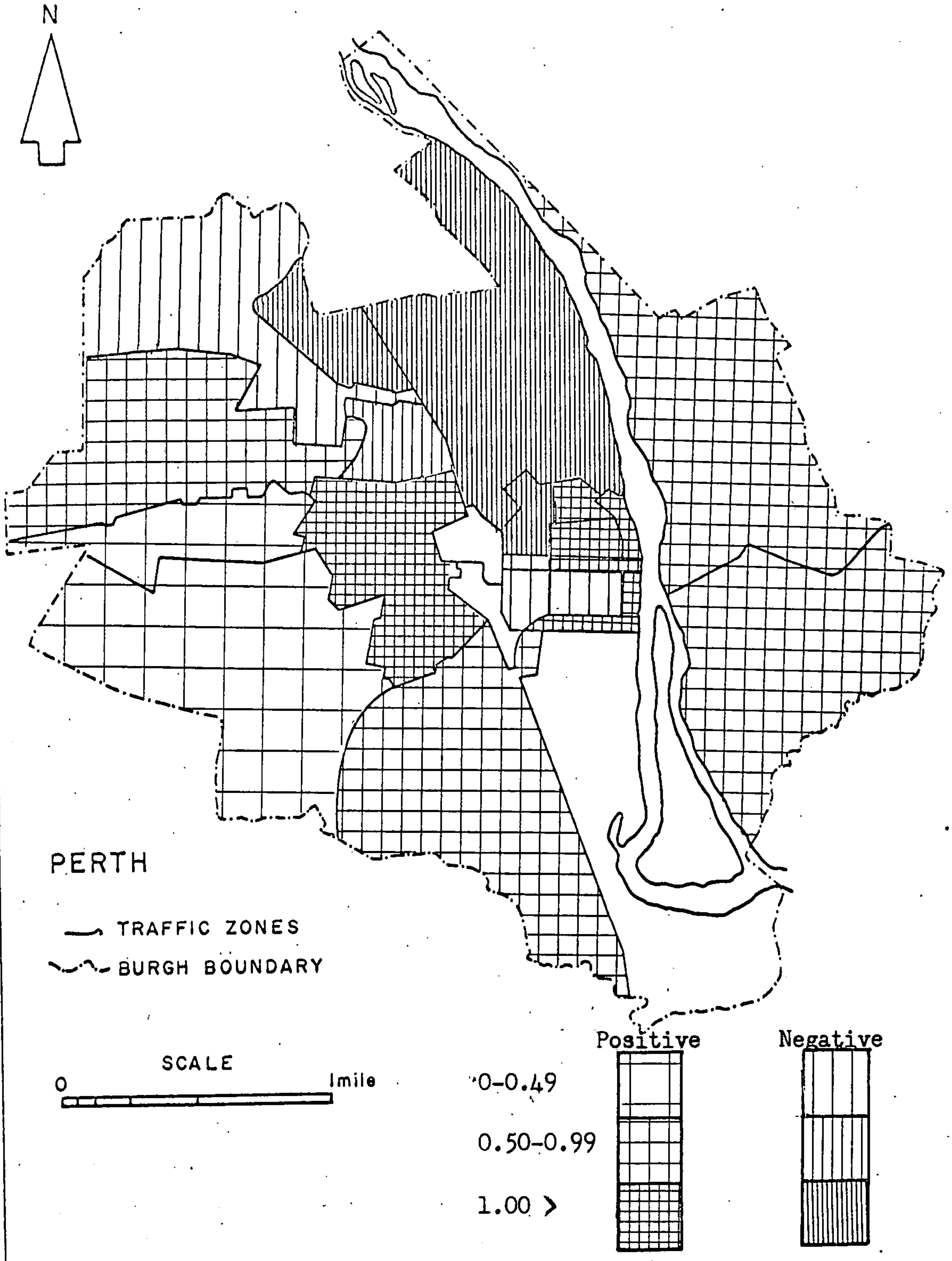
LINKAGE PATTERN - ZONED PRIMARY SCHOOLS.

DIAGRAMMATIC REPRESENTATION OF PRIMARY SCHOOL CATCHMENT AREAS.



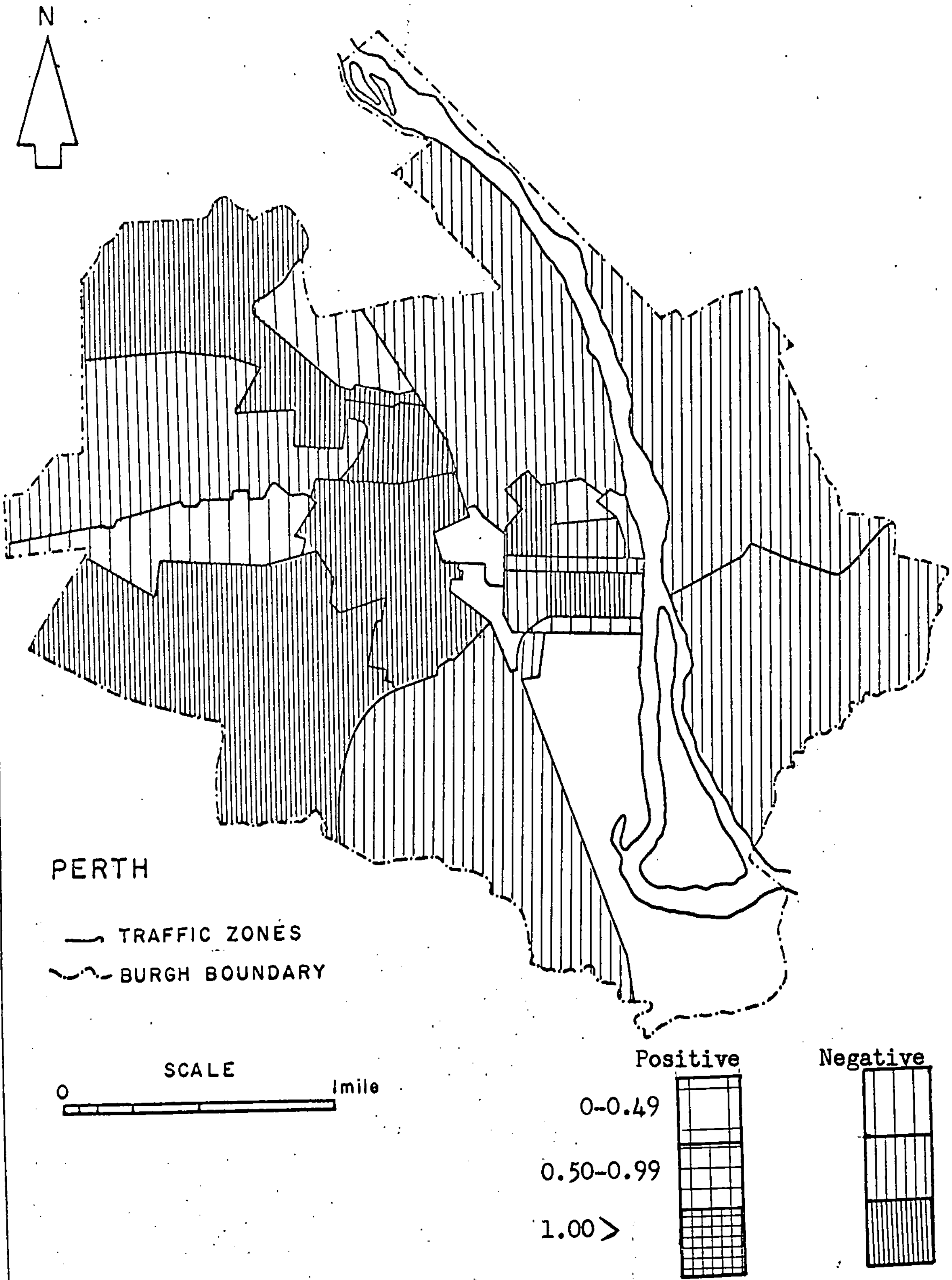
MAP 5:4:3

Residuals from regression. School trips; 5-15 AGE GROUP.



MAP 5:4:4

Residuals from regression. School trips; FAMILY SIZE.



SUMMARY

Perth shows very similar journey purpose characteristics to other urban areas. With some variations, a regularity is found amongst all families, though attributes such as car ownership, distance, and socio-economic status have some effect.

The analysis of the work trip supported the anticipated impacts of family size and socio-economic status on work trip generation rates. Car ownership was also positively correlated, even with family size held constant. Its essential character is evidenced by its relative importance for households who travel infrequently.

Shopping trip analysis involved distance from the central area, urbanisation index,and house type, all negatively correlated with trip frequency. These were found to be a crude measurement, and later analysis will involve actual distance and retail floor space. Car ownership appeared to have a weak relationship with shopping trip frequency. Social trips showed modest relationships with measures of high status. Finally school trips were found to have a direct and strong relationship with family size and the 5-15 age group.

SECTION VI PEAK HOUR FLOW

I has already been indicated that certain journey purposes exhibit an assymmetric distribution in time. This period, the 'rush' hour or 'peak' hour, contains in fact a large proportion of the total trips generated during a 24 hour period. There is usually a morning peak of journeys outward from the home, an evening return peak, and two lesser peaks at the lunch hour.

Since these four 'peaks' have basically the same characteristics, though perhaps on a lesser scale, or in reverse, only one of the periods will be analysed in detail. The period chosen is the peak of from-home trips between 6.30 and 10.00 a.m. For the purpose of this study, the period was divided into 15 minute intervals, and the material was drawn from the Home Interview and Journey-to-Work Surveys. (1)

During this morning peak period, 79.5% of the from-home work trips are generated, and the majority of the school trips. Their distribution is shown in Graph 6:1 for all Perth, and for three selected zones in Graphs 6:2 to 4. Considering the total trips there are two main periods in the peak hours, a lesser peak from 7.01 to 7.46, and the greater peak 8.16-8.46. (2) The various trip purposes, and the three zones, differ from this mean. Zone 16 (Graph 6:3) has only one pinnacle from 8.16 to 8.46; Zone 21 (Graph 6:2), two, though the second is of a shorter duration than that recorded for Perth as a whole; and Zone 1 (Graph 6:4) has a major and two minor summits during the peak flow.

Turning to particular trip purposes, during the morning peak period, school and work trips predominate, though the period of maximum flow varies. For all Perth there are two main peaks for work trips, a reflection of occupation structure, 7.16 to 7.46 and 8.16 to 8.31. Again there is zonal variation; in lower income/status areas, the example graphed is Zone 21, the

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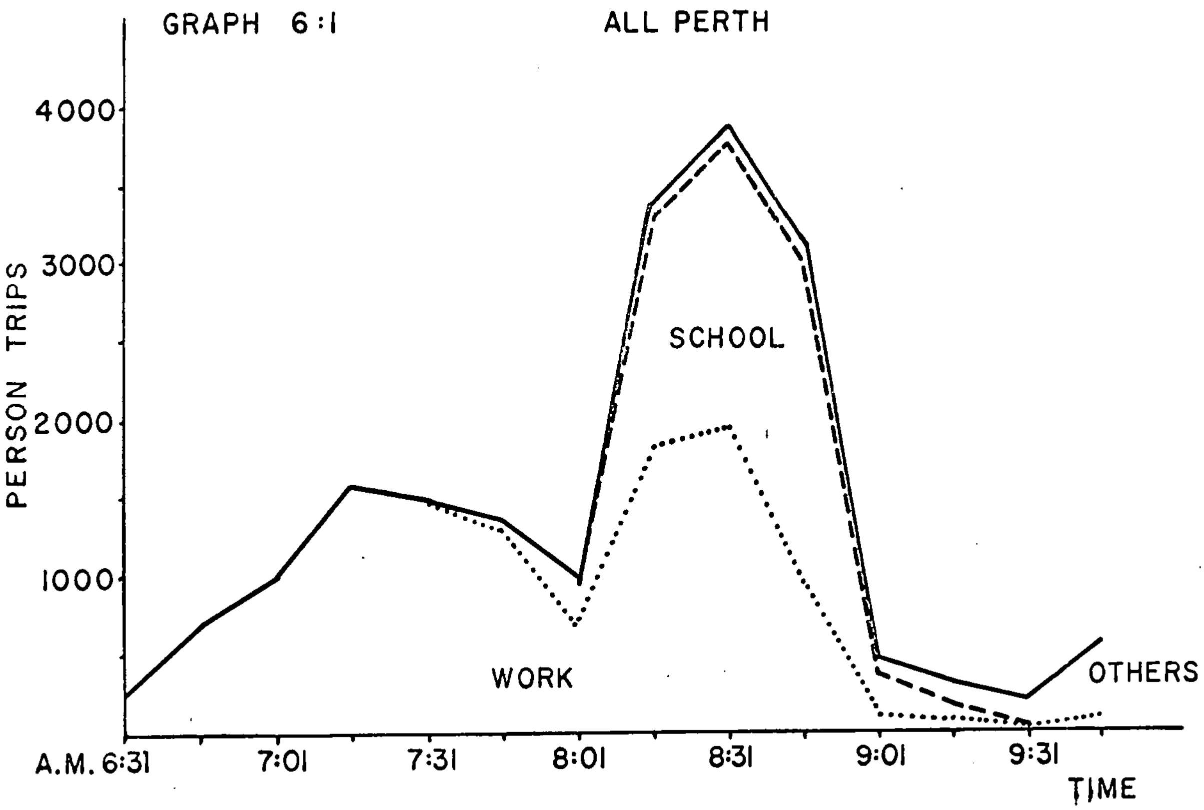
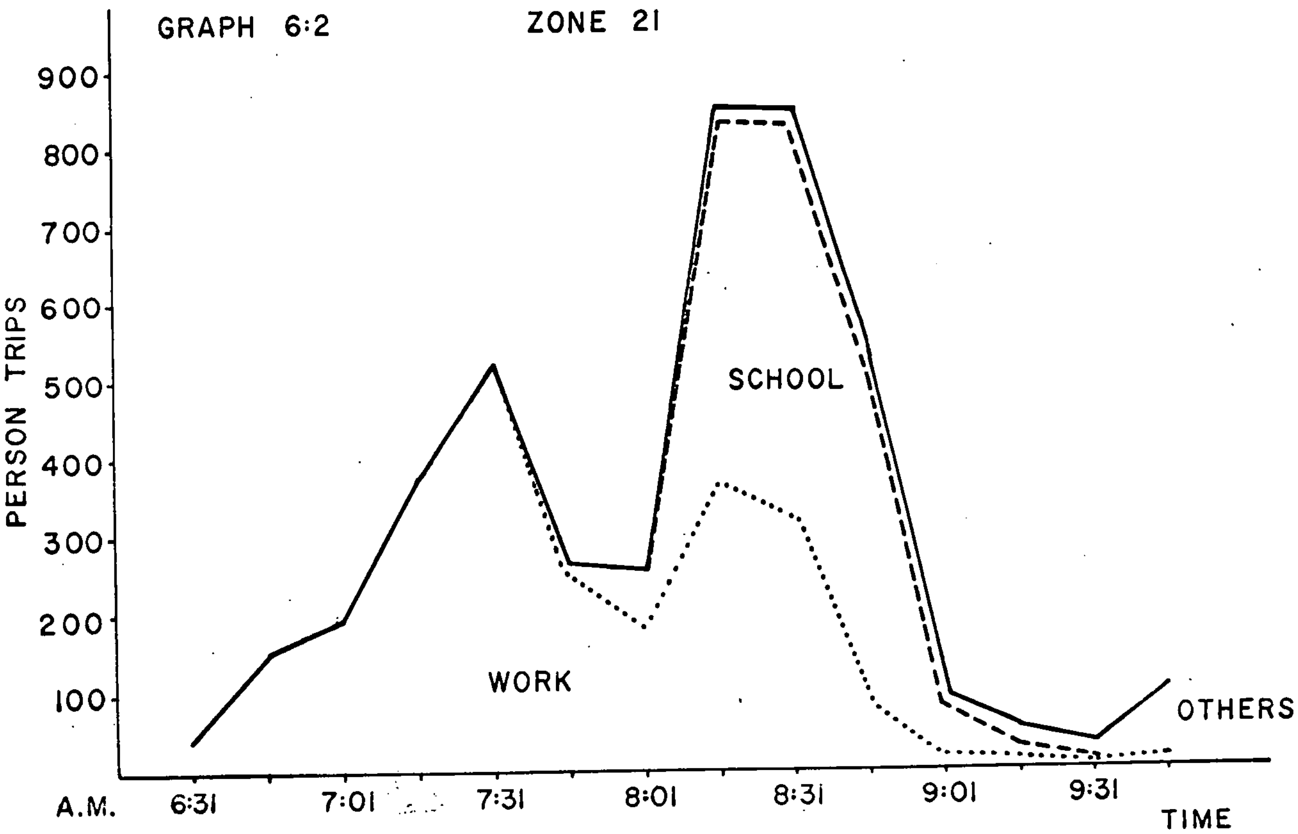
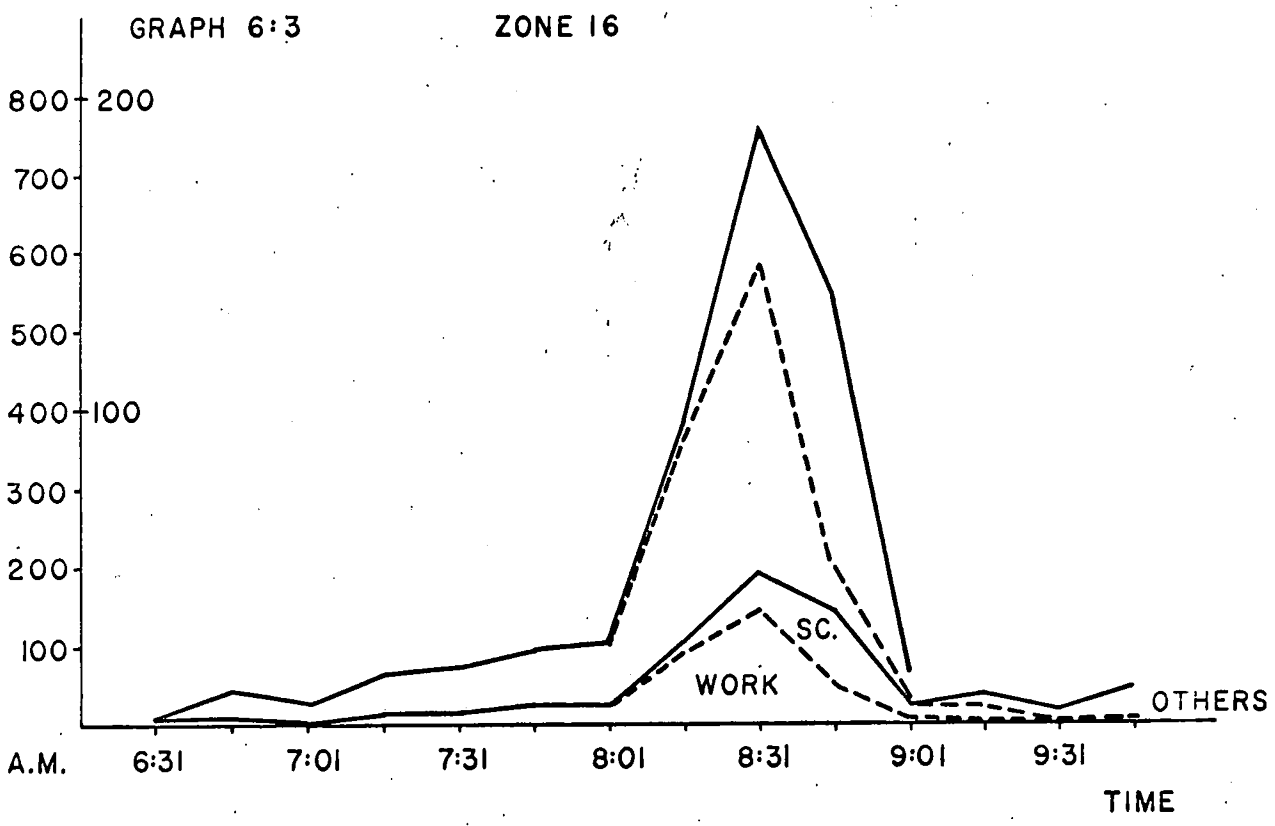
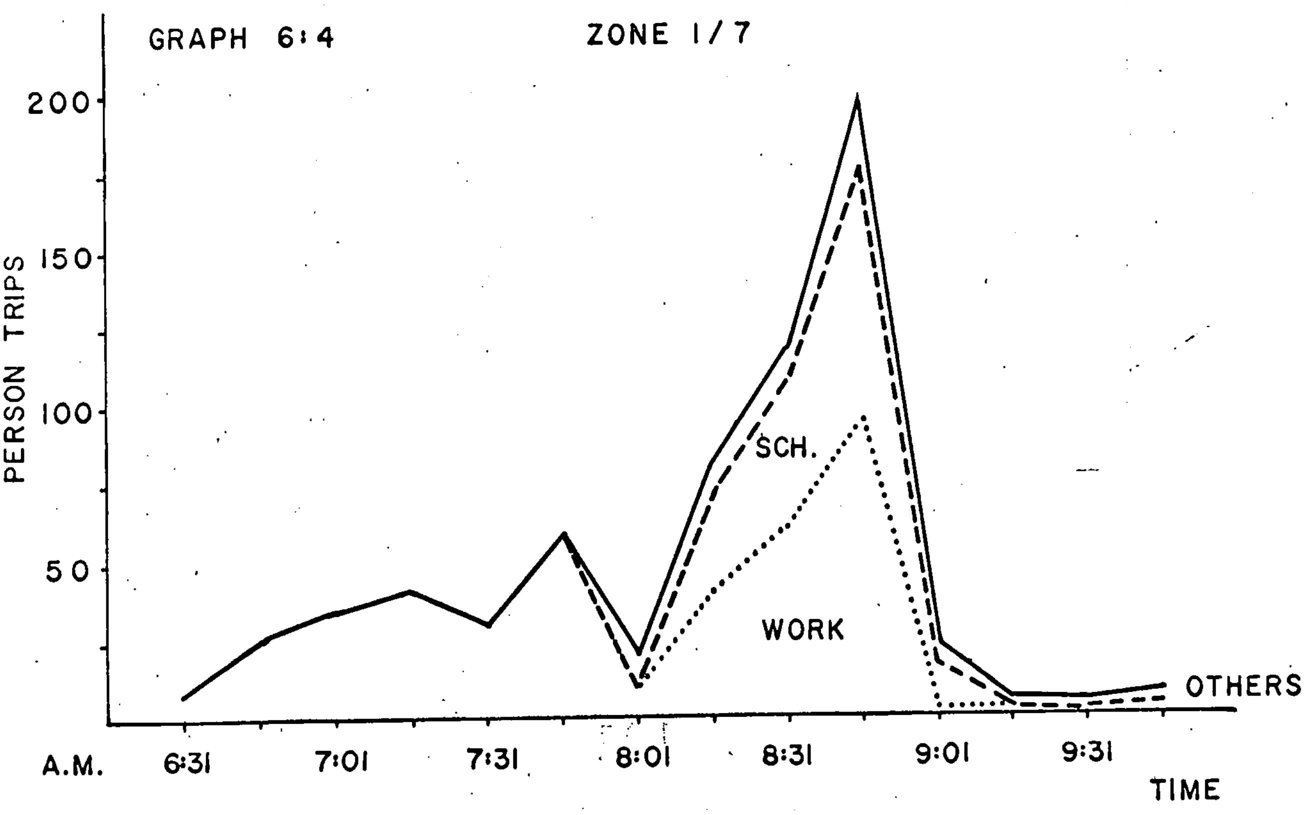
(1) See Appendices 3 and 4.
(2) Williams reports a peak from 8.0-9.0 a.m. for Ponteland. See T.E.H. Williams and D.M. Robertson 'Traffic Generated by Households: Peak Period' Traffic Engineering and Control Vol. 6, No.11, March 1965, pp. 668-671.


GRAPH 6:1
ALL PERTH
PERSON TRIPS
4000
3000
2000
1000
SCHOOL
WORK
OTHERS
A.M. 6:31
7:01
7:31
8:01
8:31
9:01
9:31
TIME


GRAPH 6:2
ZONE 21
PERSON TRIPS
900
800
700
600
500
400
300
200
100
SCHOOL
WORK
OTHERS
A.M.
6:31
7:01
7:31
8:01
8:31
9:01
9:31
TIME


GRAPH 6:3
ZONE 16
800
200
700
600
500
400
100
300
200
100
SC.
WORK
OTHERS
A.M.
6:31
7:01
7:31
8:01
8:31
9:01
9:31
TIME


GRAPH 6:4
ZONE 1/7
200
150
100
50
PERSON TRIPS
SCH.
WORK
OTHERS
A.M.
6:31
7:01
7:31
8:01
8:31
9:01
9:31
TIME

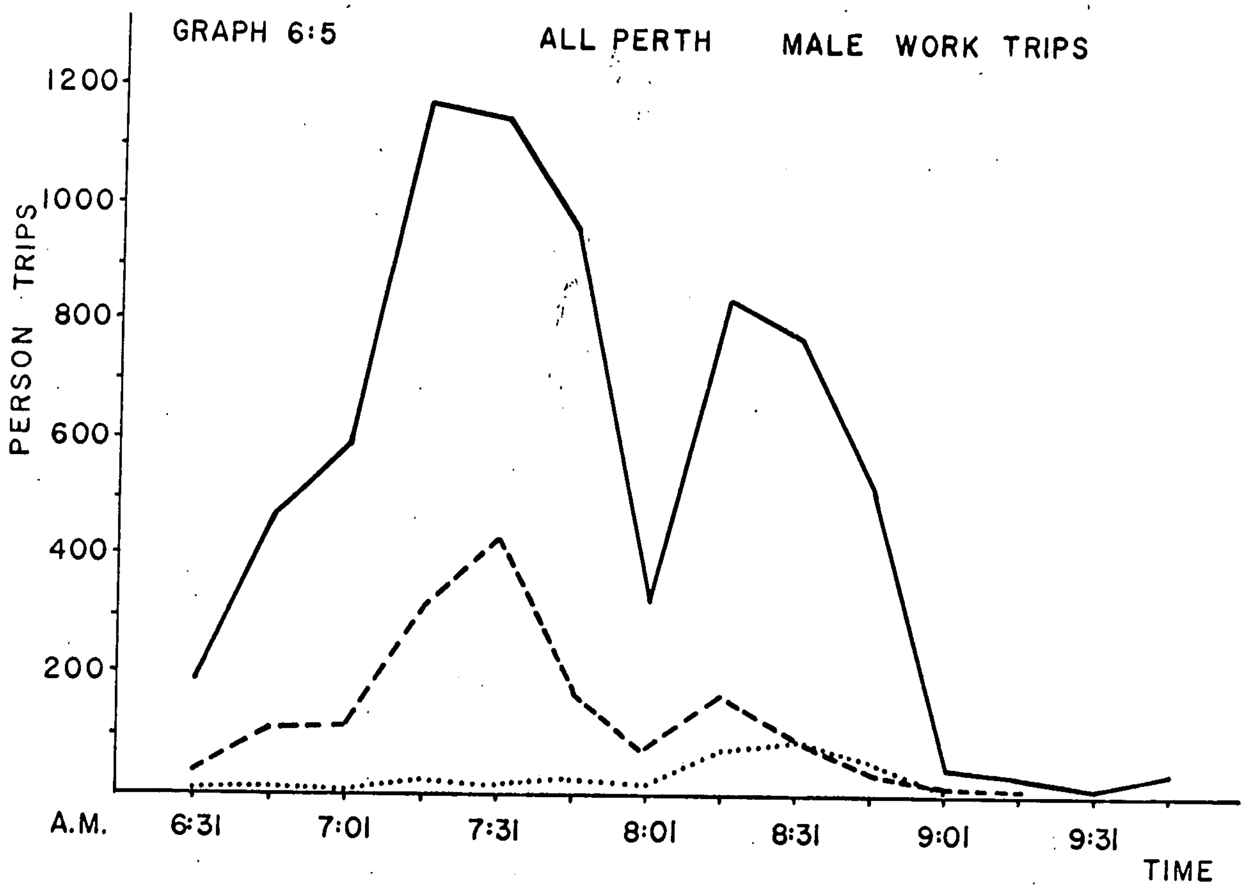
main flow to work is earlier, 7:01-7:31 and predominant. The second period being 8:16-8:31. Zone 16 a high socio-economic area, shows only one peak, 8:16-8:46; in this zone 71% of the peak period trips occur between 8:01 and 9:01, as against 39% during the same time period in Zone 21. The third zone illustrated, Zone 1, has two early minor peaks, and a main flow delayed until 8:46, illustrative of its nearness to the main work centre, especially for non-manual work locations.

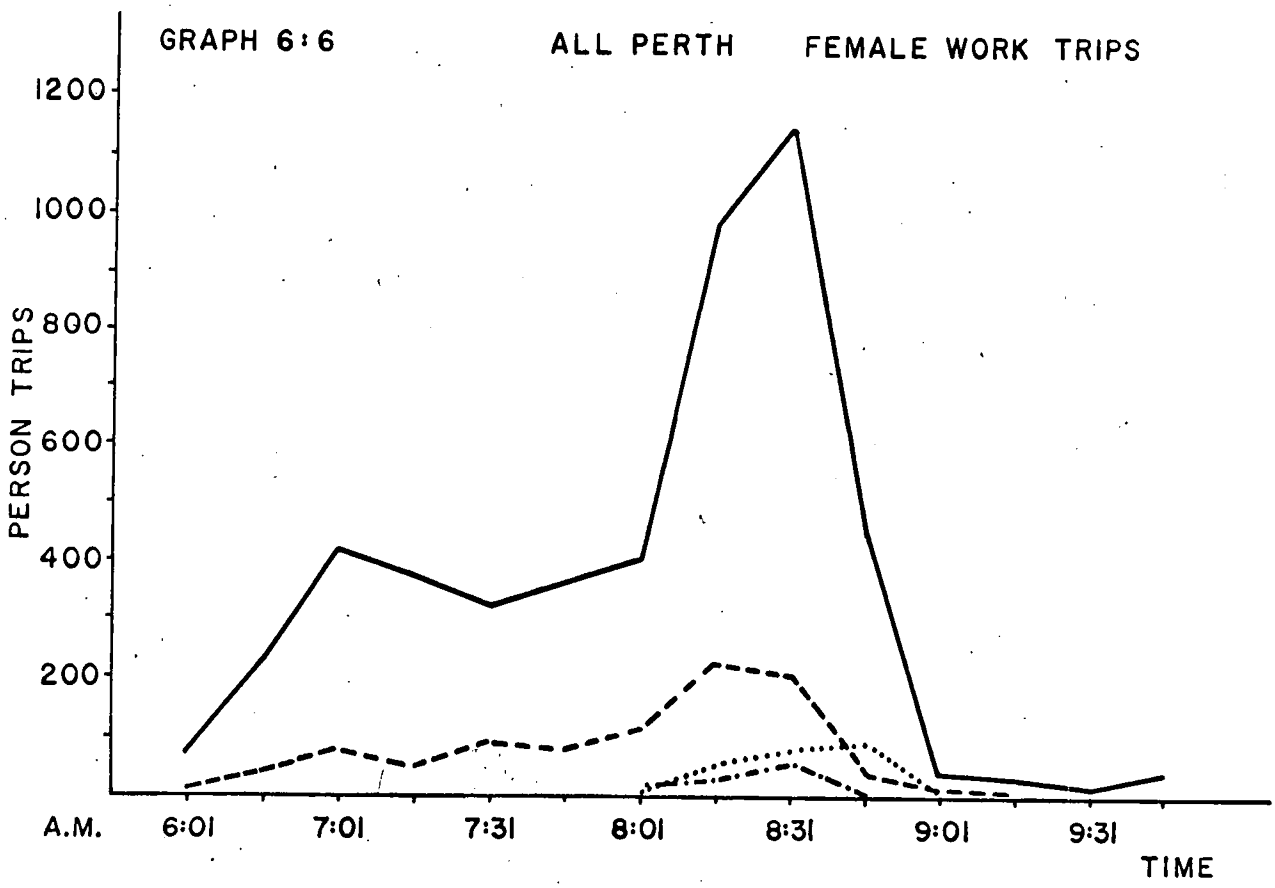
School trips exhibit one peak - 8:46 to 9:00 a.m. in the principal quarter hour period for all Perth, and for 9 of the zones (including Zones 1 and 16); for the remainder 8:31-8:45 is the principal period. This difference is due to school locations,(3) difficulty of access and availability of transport. Whilst of course work trips were distributed throughout this peak period, all school trips were concentrated into the period 7:45-9:00 a.m.

Other trips, mainly for shopping, are minimal throughout this period, and in all zones only become important after 9:30 a.m.

Not only can differences be detected according to purpose, location, and occupation, but for work purpose there is also a sex differential. Graphs 6:5 and 6:6 shows the male and female worker departure times for all Perth and sample zones. This sex difference is partially explicable in occupational terms. It has already been noted that non-manual workers have a main flow from 8:00 to 8:46, and manual workers 7:00 to 7:46. Since most of the female workers are non-manual, their time departure graph shows one summit from 8:16 to 8:46, with a smaller summit at 7:00 a.m. A large proportion of male workers in Perth are manual workers, though there is still a substantial proportion of males who are non-manual workers. Graph 6:5 shows the dual peaks, the earlier manual departure being the greater. These differences are feflected between the zones too, Zone 21 with predominantly manual workers has one early major period, and a smaller later one, and Zone 16 where the male workers are predominantly non-manual has one major late period.

(3) See for example Map 5:4:1.


GRAPH 6:5
ALL PERTH MALE WORK TRIPS
PERSON TRIPS
1200
1000
800
600
400
200
A.M.
6:31
7:01
7:31
8:01
8:31
9:01
9:31
TIME


GRAPH 6:6
ALL PERTH FEMALE WORK TRIPS
PERSON TRIPS
1200
1000
800
600
400
200
A.M.
6:01
7:01
7:31
8:01
8:31
9:01
9:31
TIME

The consideration of the journey purpose and modal choice shows the importance of the pedestrian and bus traffic, and the relative overshadowing of the car user. Diagram 6:1 shows the percentage of journeys to work, school and other places in relation to the proportion of car drivers, cyclists, bus passengers, pedestrians, and other modes. During this peak period, 93% of the car trips were accounted for by the journey to work, 62% of the bus trips and 53% of the pedestrian trips. The bulk of the remaining trips, except car trips, were due to the journey to school.

In terms of the total number of journeys made by residents during 24 hours, the journeys from home in the morning peak period were, on average, equivalent to 14.7% of all trips, or 36.0% of trips made from the home. The percentages vary with the size of the family, from 7.9% and 25.0% respectively for households of one person to 32.4 and 58.3% for eight person households (Table 6:1 and Graph 6:7). The increase with family size, of the proportion of travel taking place during the morning peak period reflects the age groups present within those households.

The number of journeys per household during the morning peak period is then, naturally, related to the size of family, age composition, as well as the number employed. Tables 6:1-3 reflect these differences. If the morning journeys are expressed as journeys per person the highest values are for the two person household (0.92 from-home trips/person) but when the period 8:15-9:00 a.m. is examined (the school 'peak'), the five person household records the highest value 0.55 from-home trips/person as against 0.42 for 2 person households during that period.

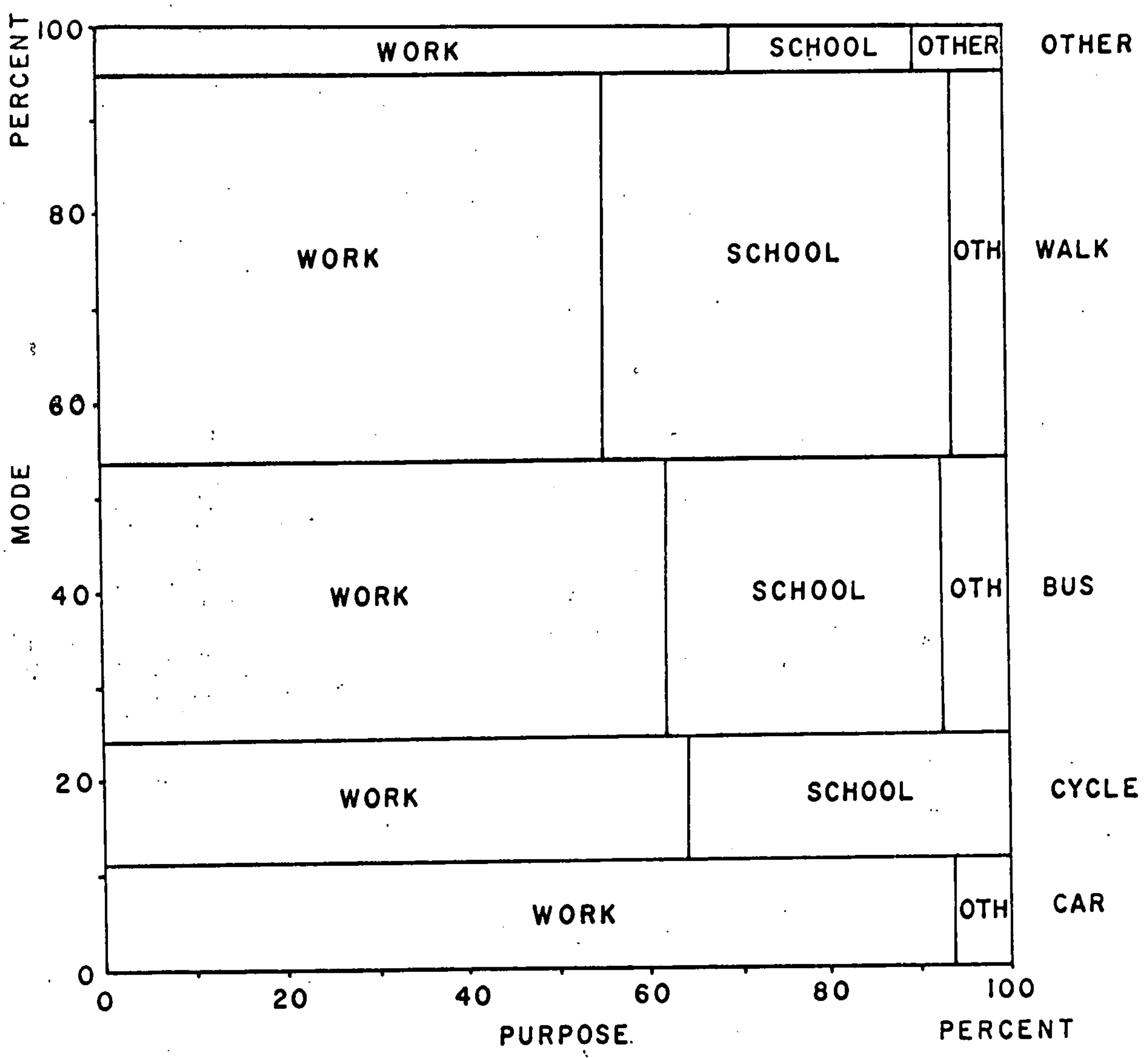


DIAGRAM 6·1 ALL PERTH TRAVEL MODES 6:30-10:00 A.M.

Table 6:1

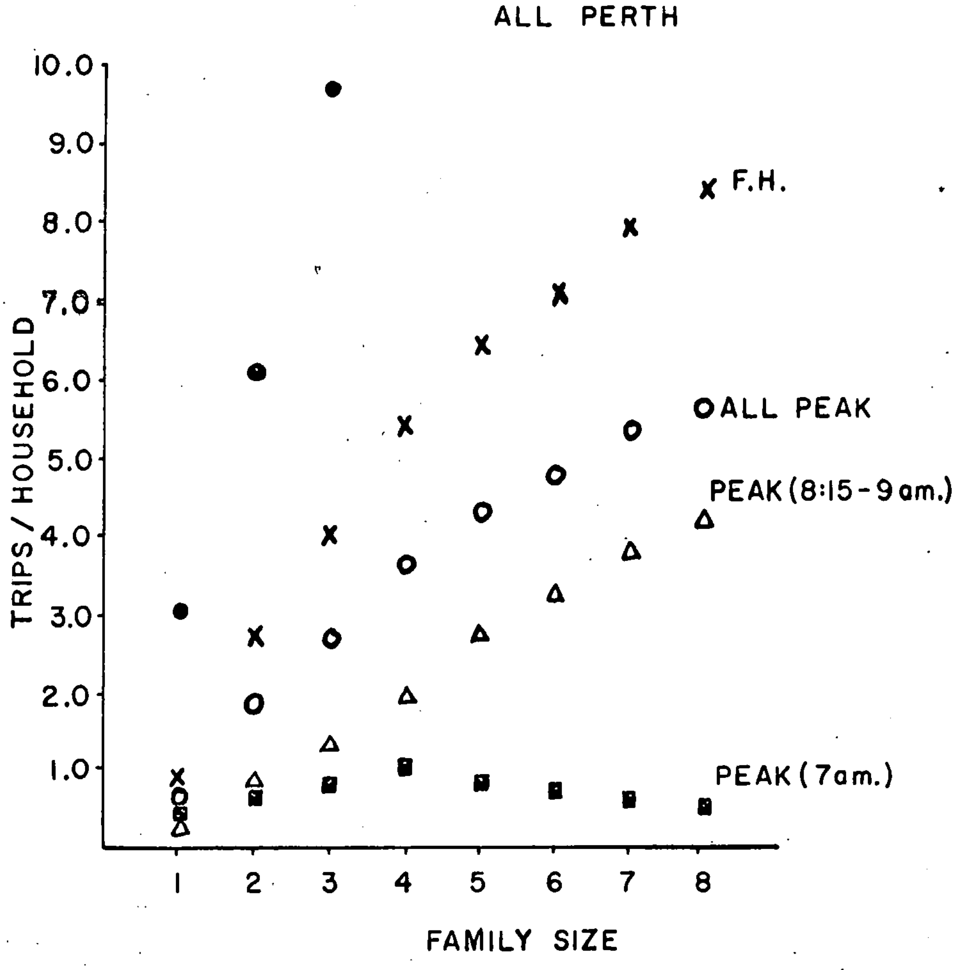
Effect of Family Size on the % of Travel from the Home during the Peak Period.

PERSONS/ HOUSEHOLD	FROM HOME TRIPS/DAY	ALL TRIPS /DAY	PART PEAK HOUR (8:15-9:00am)	PEAK HOUR AS % OF ALL TRIPS	PEAK HOUR AS % OF F.H. TRIPS
1	0.98	3.11	0.25	7.9	25.0
2	2.75	6.18	0.83	13.5	30.3
3	4.07	9.72	1.39	14.3	34.0
4	5.46	10.52	1.97	18.8	36.2
5	6.47	11.42	2.75	24.1	42.6
6	7.10	12.81	3.76	29.3	52.9
7	7.92	13.96	4.50	32.2	56.8
8	8.47	15.27	4.93	32.4	58.3
Mean	3.85	9.48	1.39	14.7	36.0

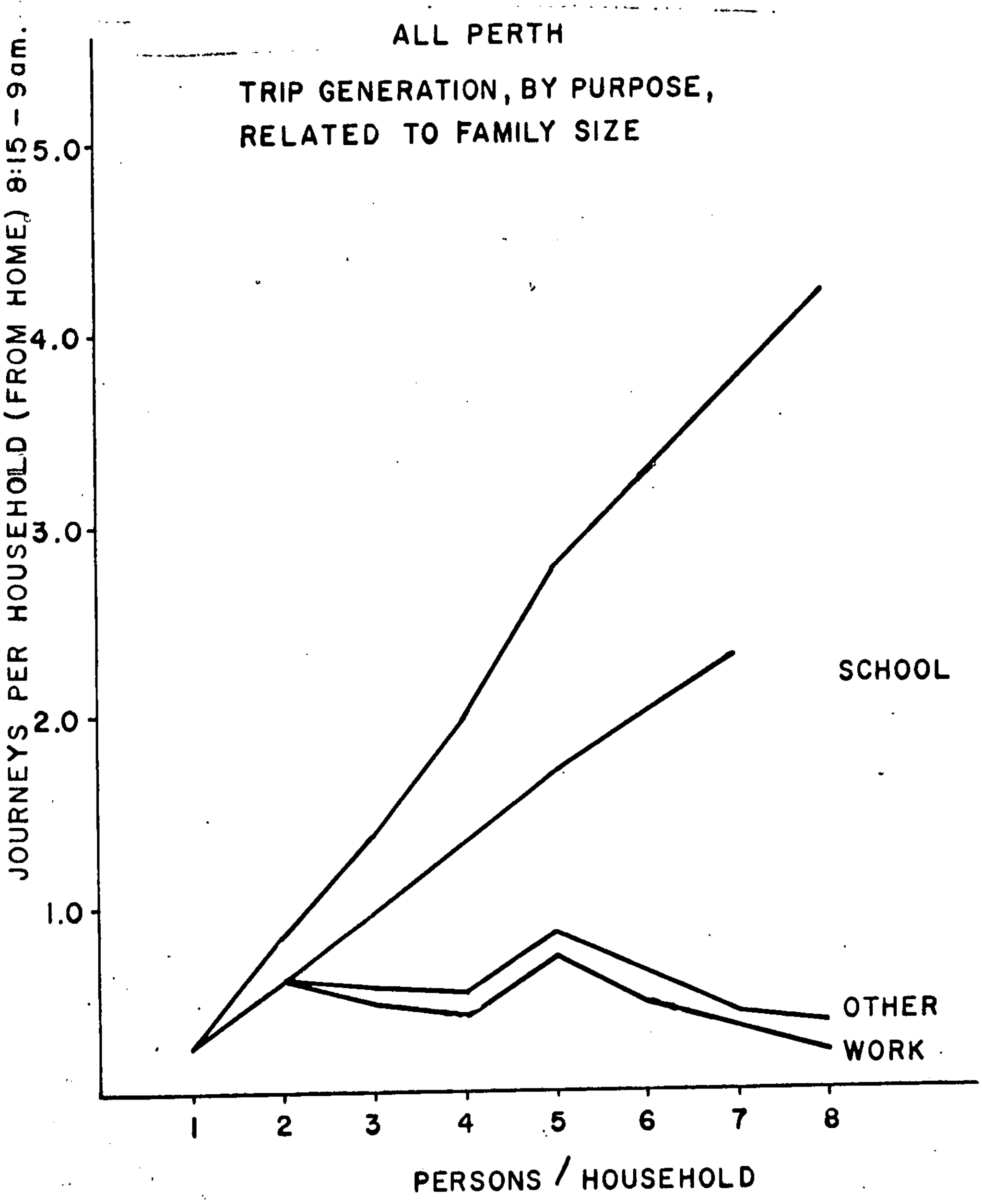
In terms of journeys per household, the trips rose from 0.66 for one person households to 5.69 trips for 8 person households. In families greater than two, the decline in trips per person during this peak period reflects the presence of very young children and the natural limitation in the number of employed persons. This was particularly noticeable in families of greater than five, and especially during the 7:00-8:00 a.m. peak.

The effects of the number of employed persons was confirmed when the purpose of journeys was considered. Graph 6:8 which shows the school peak period 8:15-9:00 a.m. indicates the predominance of school trips for families over two, and especially over five in number. Table 6:3 shows how the number of journeys per household, by purpose, is in fact related to the number of employed persons per household. As the number of employed persons increase, the number of journeys increase, but not just journeys to work, journeys to school too, though at a lower rate, indicating on average a corresponding increase in the number of school children.

GRAPH 6:7 EFFECT OF FAMILY SIZE ON THE TRIPS MADE DURING THE PEAK PERIOD.



GRAPH 6:8



ALL PERTH
TRIP GENERATION, BY PURPOSE, RELATED TO FAMILY SIZE
JOURNEYS PER HOUSEHOLD (FROM HOME) 8:15 – 9am.
5.0
4.0
3.0
2.0
1.0
SCHOOL
OTHER
WORK
1
2
3
4
5
6
7
8
PERSONS / HOUSEHOLD

Table 6:2

Effect of Family Size on Peak Period Trip Generation from the Home.

Persons /Hsehld	6:30-10:00 a.m.		7:00-8:00 a.m.		8:15-9:00 a.m.	
	Trips/ Household	Trips/ Person	Trips/ Household	Trips/ Person	Trips/ Household	Trips/ Person
1	0.66	0.66	0.29	0.29	0.25	0.25
2	1.85	0.92	0.67	0.34	0.83	0.42
33	2.74	0.91	0.83	0.28	1.39	0.46
4	3.67	0.92	1.02	0.26	1.97	0.49
5	4.34	0.87	0.88	0.18	2.75	0.55
6	4.77	0.80	0.79	0.13	3.28	0.55
7	5.33	0.76	0.64	0.09	3.79	0.54
8	5.69	0.71	0.51	0.06	4.22	0.53
Mean	2.61		0.73		1.39	

Table 6:3

Effect of Number of Employed Persons on 'Trip' Generation from the Home.

Employed Persons/ Hsehld.	Trips/ Work	Hsehld School	7:15 - Other	7:45 All	Trips/ Work	Hsehld School	8:15 - Other	9:00 All	All/hse 6:30-10:00am
0	-	-	-	-	-	-	0.14	0.14	0.14
1	0.62	0.01	-	0.62	0.57	0.61	0.03	1.21	2.23
2	0.86	0.01	0.01	0.88	0.70	0.80	0.19	1.68	3.15
3	1.05	0.01	0.02	1.08	0.99	0.88	0.21	2.08	3.88
4	1.25	0.01	0.01	1.26	0.46	0.90	0.07	2.42	4.53

Referring back to Graph 6:7, it can be seen that there is an overall increase in morning peak journeys, but that the increase with family size is at a decreasing rate. This in fact is a counterbalance between the two main flows - Graph 6:7 shows an overall decrease in the early morning peak, but an almost linear increase in the later peak. As the number of children increase, a decreaing proportion of a family's trips are work trips, hence the convex line.

Tables 6:4 and 5 show the variation in the number of peak hour journeys per household with varying size of household and car ownership. Trips increase with both these variables, as would be expected from the evidence of earlier sections, except with some of the trips in the early flow, which is associated with occupation structure.

Table 6:4

Combined Effects of Family Size and Car Ownership on Peak Hour Trip Generation from the Home.

Hsehld Size	CAR OWNERSHIP						Mean	
	0		1		2			
	7.00 am	8.15	7.00	8.15	7.00	8.15	7.00	8.15
1	0.27	0.22	0.42	0.41	-	-	0.29	0.25
2	0.63	0.78	0.85	1.06	0.92	1.13	0.67	0.83
3	0.80	0.95	0.88	1.61	1.20	1.97	0.83	1.39
4	1.04	1.77	0.97	2.31	1.31	2.71	1.02	1.97
5	0.82	2.63	1.03	3.00	1.40	3.52	0.88	2.75
6	0.79	3.26	0.87	3.40	-	-	0.79	3.28
7	0.61	3.52	0.78	3.82	-	-	0.64	3.79
8	0.51	4.22	-	-	-	-	0.51	4.22

The effect of school trips occurring within one brief period is also obvious, especially in Graph 6:9. This graph illustrates also the difference between the number of journeys made by households with and without cars.

The ownership of one or more cars greatly affects the choice of mode of travel during the morning peak hour, as would be expected. The ownership of a car or two cars leads to 60.0% and 82.6% respectively, of journeys being made by car to work in those households. With no car the emphasis is on walking and public transport. For school journeys the main effect of car ownership is on car passenger journeys, which increase from 1.1 to 13.1 and 22.0% with zero, one and two car ownership respectively. Travel by bus and by other modes decreased significantly with car ownership.

Table 6:5

Effect of Car Ownership on Mode of Travel from the Home. % of Trips 8:15-9:00 am.

Mode of Travel	Work				School				Other			
		Car Ownership				Car Ownership				Car Ownership		
	All	0	1	2	All	0	1	2	All	0	1	2
Car	16.2	-	60.0	82.6	-	-	-	-	10.9	-	41.7	48.5
Car Passenger	3.0	1.6	6.5	0.7	4.1	1.1	13.1	22.0	3.4	1.5	8.8	11.7
Bus	29.5	7.5	9.9	0.7	29.1	28.1	30.4	24.4	29.8	34.6	15.8	12.6
Walk	35.0	40.5	16.5	13.0	5.17	54.0	43.4	43.8	41.0	45.3	25.0	23.3
Cycle	13.2	16.0	6.5	-	15.1	16.8	13.1	9.8	13.0	14.8	7.9	3.9
Other	3.1	4.4	0.6	-	-	-	-	-	2.9	3.8	0.8	-

Morning peak trip generation is also influenced by socio-economic status, a measure ofooccupation and income.

GRAPH 6:9 ALL PERTH CAR OWNERSHIP and PEAK PERIOD TRIPS

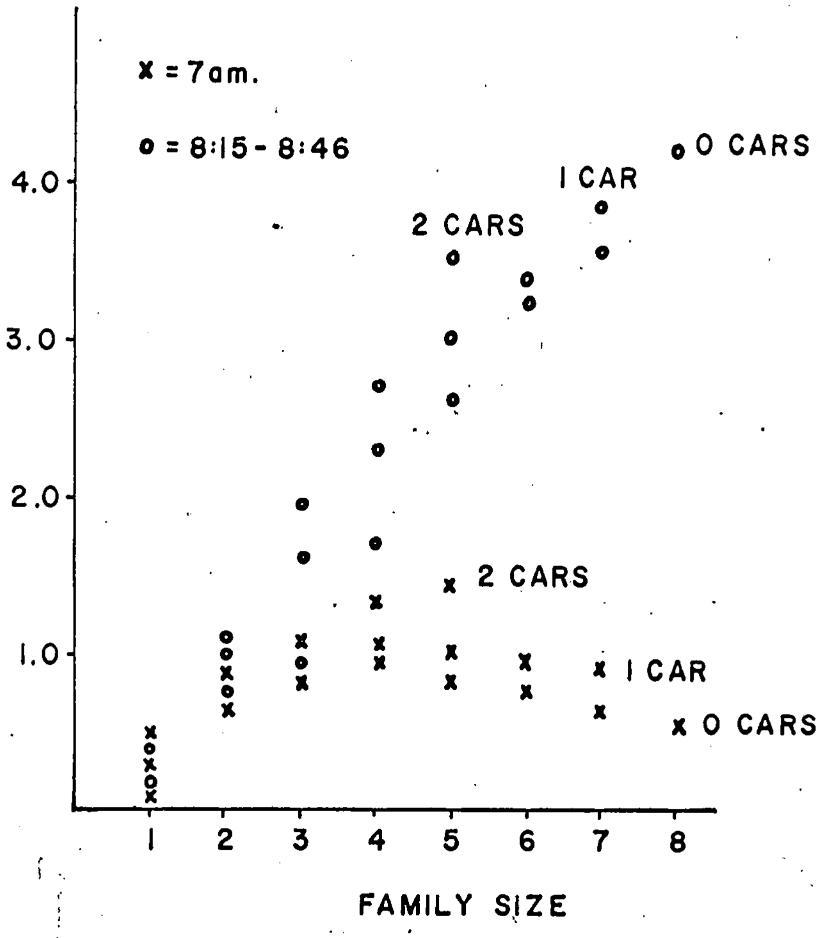


Table 6:6.

Effect of Socio-Economic Status on Peak Period Trip Generation from the Home.

Socio-Economic Status	Av. Fam. Size	7.15 - 7.45 a.m. Period Trips/ Hsehld.	Trips/ Person	8.15 - 8.46 a.m. Period Trips/ Hsehld	Trips/ Person	6.30 - 10.00 a.m. Period Trips/ Hsehld.	Trips/ Person
1	2.71	0.31	0.11	2.51	0.93	3.39	1.25
2	2.86	0.45	0.16	2.38	0.83	3.47	1.22
3	3.22	1.08	0.30	1.69	0.52	3.25	1.01
4	3.56	1.78	0.50	1.23	0.35	3.32	0.99
5	3.98	1.54	0.39	1.55	0.39	3.80	0.96
6	3.09	0.57	0.18	2.47	0.80	3.80	1.23
7	1.31	-	-	0.04	0.03	0.10	0.07

As would be expected from the earlier analysis, the times of the major peak varies. Only 8.9% of group 1's (Professional) and 12.9% of Group 2's (Intermediate) trips occur between 7.15 and 7.46 a.m., against 32.0% for Group 3 (Manual; skilled), 40% for Group 5 (unskilled), and 50.0% for Group 4 (semi-skilled); the mean is 27.9%. Conversely 73.5% and 68.5% of Group 1 and 2's trips, respectively, occur between 8.15 and 8.46 and 52, 40 and 34% for Groups 3, 5 and 4 respectively; the mean is 53.5%. Thus, in general, the number of trips decreases relative to socio-economic status, despite the reverse trend of family size. Households of socio-economic group 1, generate 25% more trips per person than households of group 5. During the late peak the corresponding difference in generation between the two groups was 130%, but the position was reversed in the early peak when group 5 generated over 200%, more trips per person.

These results have shown that the traffic generated from a residential area during the morning peak period can be related to the characteristics of the individual household in a manner similar to that used earlier for generation from the home in a 24 hour period. The size of a family, age structure, and occupation are the predominant factors in peak hour traffic.

SECTION VII DISTANCE

Probably one of the most important findings of traffic studies has been the detection of the relationship between traffic movement and generation on one hand, and distance or travel-time on the other. It has been shown for example that the number of people travelling to an industrial area from a residential area 1 mile away was greater than the number travelling from a similar residential area 5 miles away. Such observed relationships have served as the basis for traffic estimation procedure.(1) Of course the relationship is modified according to the type of trip. For shopping trips, for example, one would look for the competitive relationship amongst various shopping centres in terms of distance and selections. More recently, greater refinement has occurred, and the earlier hope that a single transformation of distance would be applicable to all or to many forms of social interaction has been abandoned.(2) Attempts are now made to take account of several variables, both continuous and discrete. In the concepts of gravity and potential models the interaction between zones is seen as varying directly with some function of their populations, and inversely with some function of the intervening distance, the latter acting as some kind of frictional effect.(3) There is full explanation given of why distance has this effect.

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(1) See for example F. Houston Wynn 'Intra-city Traffic Movement' Washington. Highway Research Board, Annual Meeting. 1955.

(2) G.W.G. Hansen 'How Accessibility Shapes Land Use'. Journal of the American Institute of Planners, Vol. 25. 1959. pp. 73-76.

(3) A full account is given in W. Isard, 'Methods of Regional Analysis' Cambridge. M.I.T. 1960, especially pp. 493-566.
A.M. Voorhees, 'A General Theory of Traffic Movement'. Proceedings Institute of Traffic Engineers. 1956. pp. 5-16.
M. Schneider, 'Gravity Models and Trip Distribution Theory'. Papers and Procs. of the Regional Science Association, Vol. 5, 1959, pp. 51-56; and I.C. Tanner, 'Factors Affecting the Amount of Travel'. Road Research Laboratory Technical Paper No.51, H.M.S.O. 1961, are also of interest.

Modifications of this view point have occurred, by Lowry who used a standardisation procedure,[4] and by Taafe, Garner, and Yeates.[5] They used a static version of the Monte Carlo simulation of diffusion put forward originally by T. Hagerstrand, and modified the initial P/d model by assigning a range of low or high probability factors to each relative location they considered. Besides some measure of distance, this method allows consideration of other variables, such as work place competition, occupation, income, etc. Another valuable view point is that of Lapin[6] who described systems of trips in terms of an original destination matrix, from which a single algebraic expression can be derived to describe the relationship between trip length and deviations from the average proportion of trips to the destination.

Distance data related to a number of journey purposes and journey modes were collected in Perth, and some of the data has already been analysed. Voorhees[7] postulated a number of distance relationships, which he believed held good irrespective of mode, for non central locations. Two of these were tested:-

Social trips = dwelling units + D^3

Business trips = floor space + D^2

The first variable is a unit to express the size of the attractor, and the second is the distance factor. Assuming linear relationships these were tested as multiple regressions. Social trips, using the independent variables noted had a coeffecient of determination of 0.65, significant to the 0.1% level. For interest other measures of distances were used - D, D^2, $\sqrt{D}$ and log D.

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(4) Ira S. Lawry 'A Model of Metropolis' Santa Monica. Rand Corporation Memorandum. RM.-4035 RC.1964, pp. 29-36, and Lawry 'Location Parameters in the the Pittsburgh Model' <u>Papers and Procs. of the Regional Science Association</u> Vol. 11. 1963. pp. 145-165.

(5) E.J. Taafe, B.J. Garner, and M.H. Yeates. 'The Peripheral Journey to Work'. Chicago. Northwestern University Press. 1963.

(6) H.S. Lapin 'Structuring the Journey to Work' Philadelphia, University of Pennsylvania Press. 1964, especially pp. 88-99 and pp. 100-141.

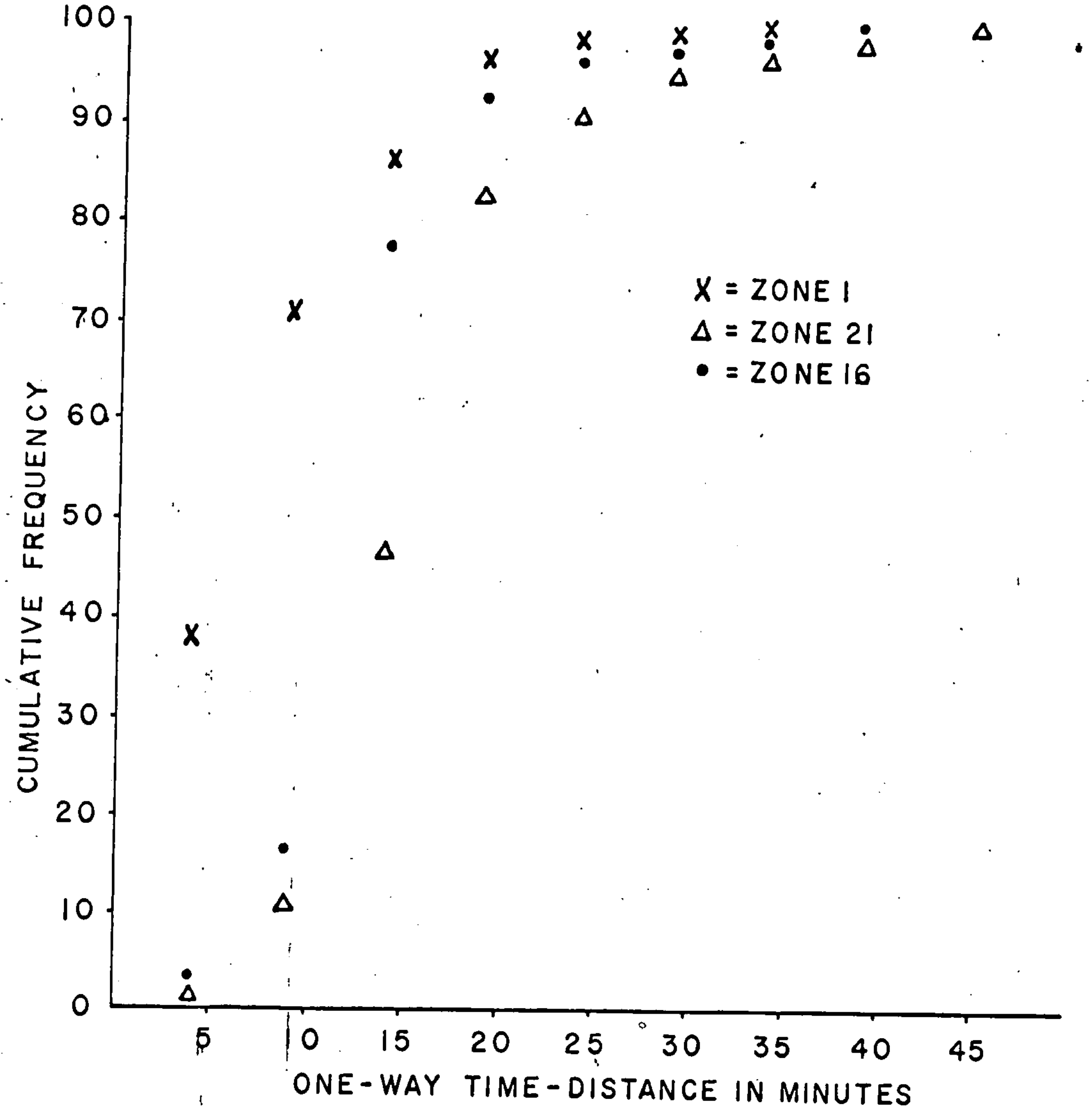
(7) Voorhees. op. cit. p. 13.

Coefficients (R^2) or 0.68, 0.67 and 0.64 were obtained, all significant at the 0.1% level. The analysis of business trips were less successful, a coefficient (R^2) of 0.26 was obtained with D^2, significant to the 1% level. Again, D, D^3, $\sqrt{D}$, and log.D were used (R^2 0.26, 0.21, 0.25 and 0.26), so in this case the result corresponded to Voorhees' use, though with less than modest significance.

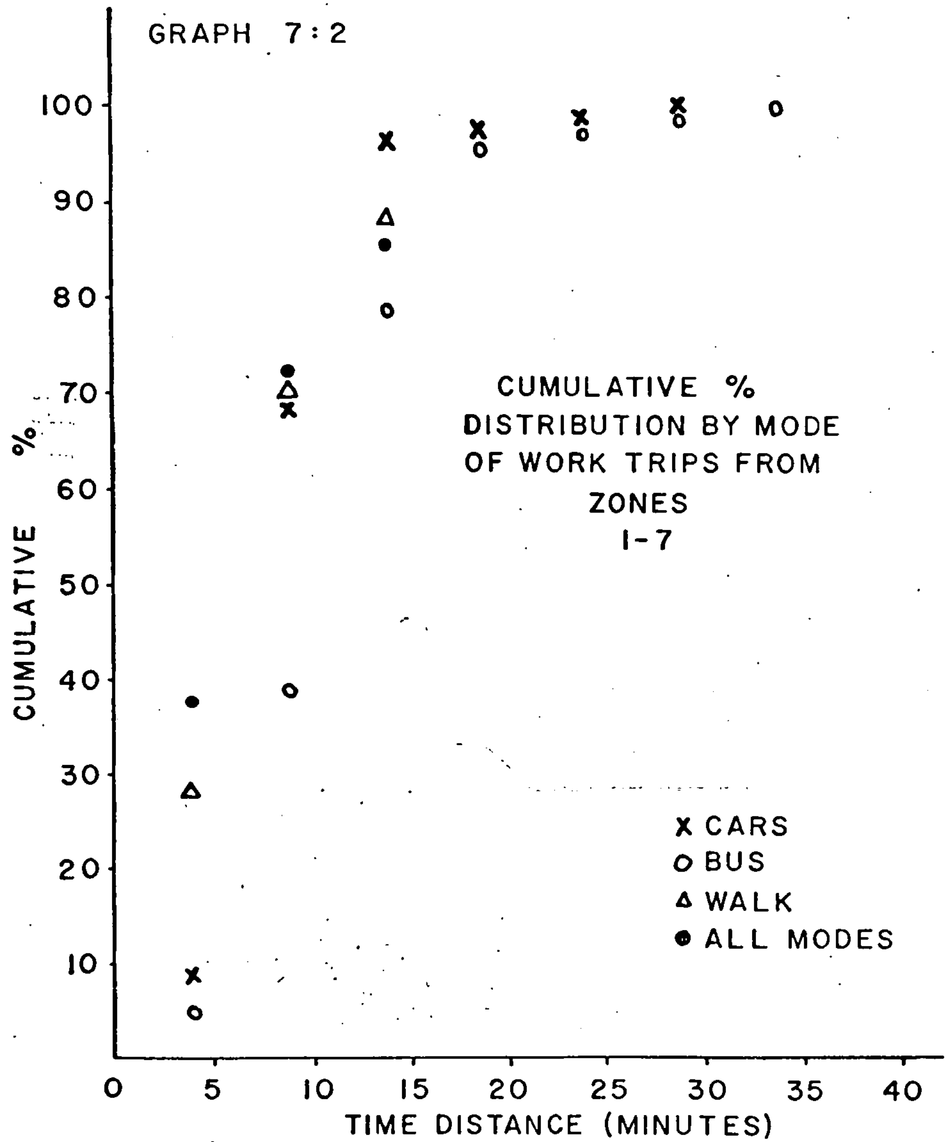
Another measure of distance is to compute the time taken to travel from the residence to the destination. Average time-length of work trips by all modes from a number of residential zones has been computed, and are shown in Graph 7:1 and Table 7:1. Graph 7:1 shows three curves, two zones which show extreme, and a third, average time-distances. Median travel time ranged from 6.0 minutes for Zone 1 to 15.1 minutes for Zone 21. The effect of distance and the proportion working in the central area obviously have an effect on the form of the curves. Zone 1, for example, whose curve rises most steeply has easy access to work place sites, whilst Zone 21, which has a more slowly rising curve, is the most distant area from the C.B.D. and other work places, and hence its residents have to spend more time in travelling to and from work. Naturally longer travelling times still are experienced by those who live without Perth, and here the median travel time is 29.2 minutes.

Mode and other factors should also affect the form of the curves, and the time spent in travelling. Table 7:2 and Graphs 7:2-4 isolate the mode used in three groups of zones. The effect of easy access to work for those who live in the central and centro-peripheral zones, is to shorten journey times and steepen the curve, irrespective of mode. Car trips in the other two cases remain the speediest method of transport, but flatter curves occur because of the effect of public transport and walking. This is particularly noticeable in Zone 21, which exhibits the least steep curves, and is most distant in terms of home-work separation.

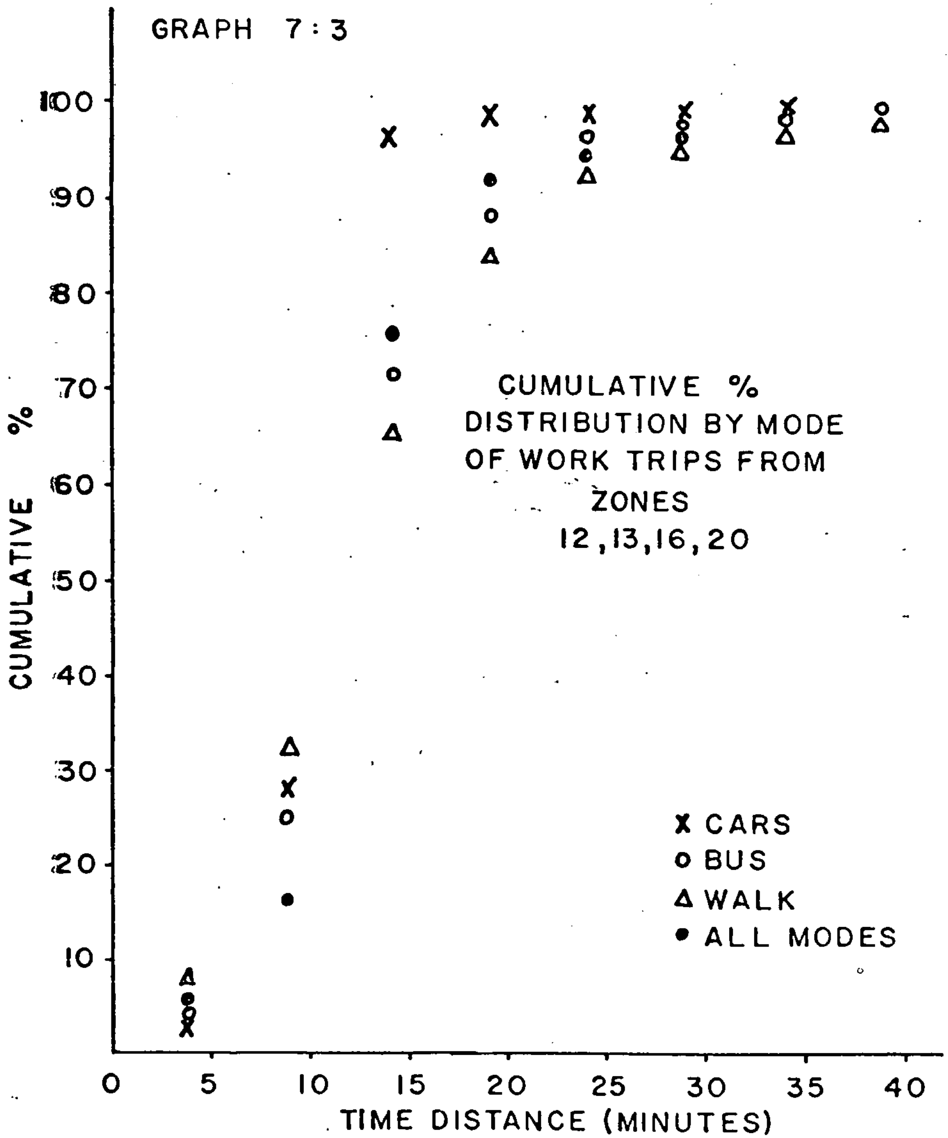
GRAPH 7:1



100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE FREQUENCY
X = ZONE 1
Δ = ZONE 21
• = ZONE 16
5
10
15
20
25
30
35
40
45
ONE-WAY TIME-DISTANCE IN MINUTES



GRAPH 7:2
CUMULATIVE % DISTRIBUTION BY MODE OF WORK TRIPS FROM ZONES 1-7
CUMULATIVE %
TIME DISTANCE (MINUTES)
X CARS
O BUS
Δ WALK
● ALL MODES



GRAPH 7:3
CUMULATIVE % DISTRIBUTION BY MODE OF WORK TRIPS FROM ZONES 12,13,16,20
CUMULATIVE %
TIME DISTANCE (MINUTES)
X CARS
O BUS
Δ WALK
● ALL MODES

Table 7:1

Percentage distribution and median time length of work trips from residence.

TIME DISTANCE (in minutes)	ZONES					All Perth	Ext. Zones
	1	11	15	16	21		
0-4	38.1	4.0	3.5	3.6	1.1	8.9	1.0
5-9	33.4	19.1	14.5	12.5	9.6	18.1	3.2
10-14	16.7	38.1	34.4	61.3	36.7	33.9	4.5
15-19	8.5	25.6	26.6	15.7	35.3	24.1	11.1
20-24	2.3	7.9	13.2	3.2	7.5	7.8	16.7
25-29	0.6	4.0	5.5	2.2	4.8	3.8	13.8
30-34	0.4	1.2	1.9	1.4	3.5	1.7	18.0
35-39		0.1	0.3	0.1	0.9	0.4	5.6
40-44			0.1		0.5	0.2	5.7
45+					0.1	0.1	20.4
Median Minutes	6.0	13.1	14.0	11.9	15.1	12.5	29.2

Table 7:2 Mode and Distance (in %)

TIME DISTANCE (in minutes)	ZONES 1 = 7			ZONES 12,13,16 & 20			ZONE 21		
	CAR	BUS	WALK	CAR	BUS	WALK	CAR	BUS	WALK
0-4	9.5	4.3	28.8	1.6	2.5	7.8	0.2	0.4	5.6
5-9	59.3	34.8	41.2	26.8	22.7	24.1	21.3	14.4	10.7
10-14	27.8	40.0	19.0	68.0	46.6	34.1	73.0	63.3	13.0
15-19	1.2	18.1	7.9	3.4	16.9	18.6	5.5	11.8	18.2
20-24	1.2	0.8	2.0	0.2	8.6	8.6		6.5	13.0
25-29	1.2	1.0	0.6		2.0	5.0		3.2	14.7
30-34		1.0	0.4		0.7	1.8		0.4	15.7
35-39			0.1						5.2
40-44									3.6
45-50									0.3

Further analysis by four occupational groups, set out in Table 7:3 and Graphs 7:5-7, confirms these curve patterns.

Table 7:3

Occupation and Distance (in%)

TIME DISTANCE (in minutes)	ZONES 1-7				ZONES 12,13,16 & 20				ZONE 21			
	1	2	3	4	1	2	3	4	1	2	3	4
0-4	41.3	26.2	22.4	17.0	16.4	12.4	0.6	1.3	2.2	0.7	-	-
5-9	33.4	29.6	36.7	40.5	17.6	4.5	14.2	18.6	8.0	14.4	4.8	11.7
10-14	15.5	22.7	24.0	19.1	43.2	25.1	46.0	40.8	31.5	35.6	35.1	41.7
15-19	6.8	15.4	12.2	19.1	15.2	43.0	28.9	32.4	38.8	27.5	41.1	32.1
20-24	1.4	5.0	4.1	4.3	4.7	10.2	6.4	5.6	8.1	6.8	8.8	5.3
25-29	0.4	1.1	0.6	-	2.9	2.8	3.3	1.3	3.6	7.6	5.4	4.6
30-34	0.7	-	-	-	-	2.0	0.4	-	6.0	5.9	2.9	2.2
35-39	0.4	-	-	-	-	1.0	0.2	-	0.8	0.8	1.5	2.0
40-44	-	-	-	-	-	-	-	-	1.0	0.7	0.4	0.4

Service Occupation = 1

Professional = 2

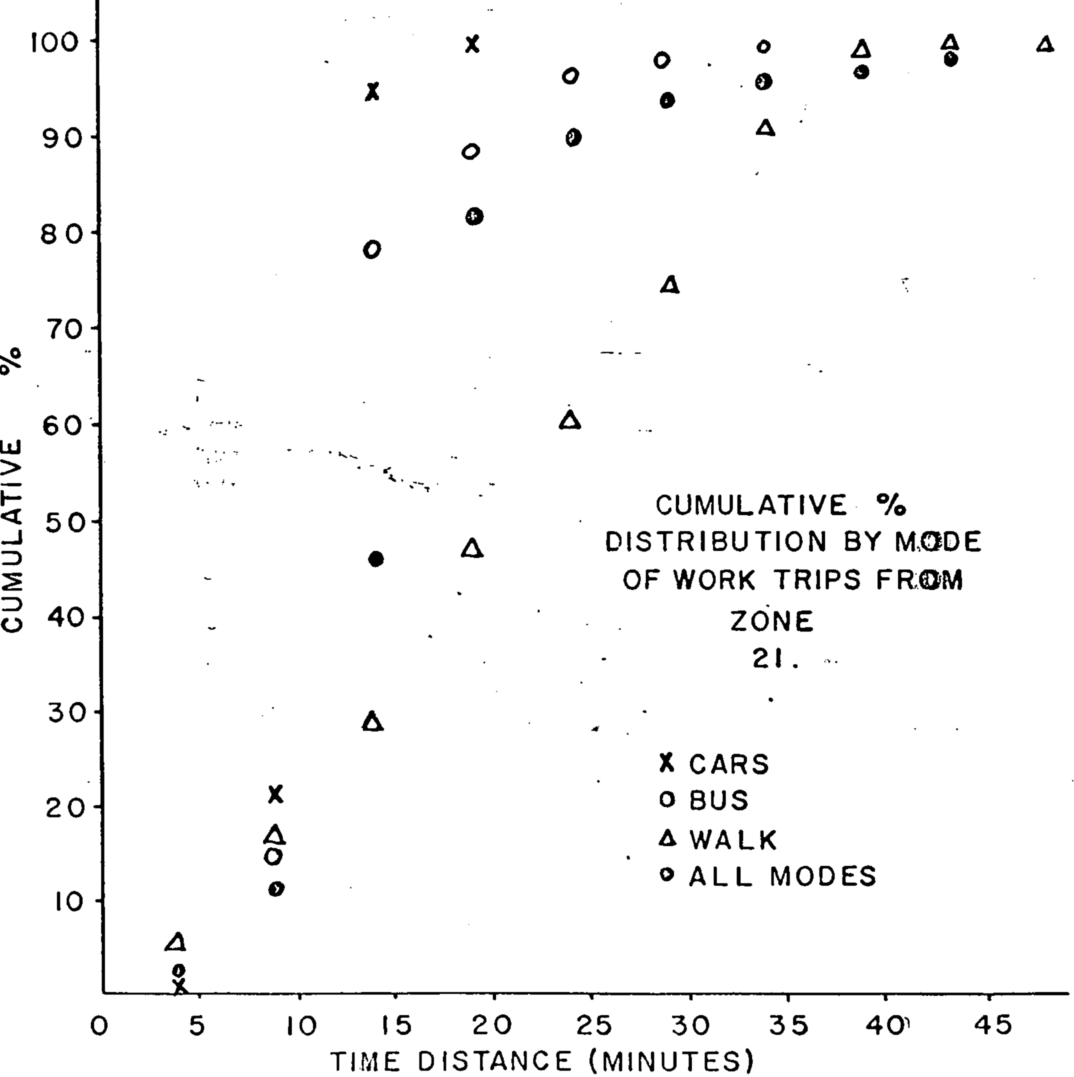
Clerical = 3

Engineering (manual)= 4

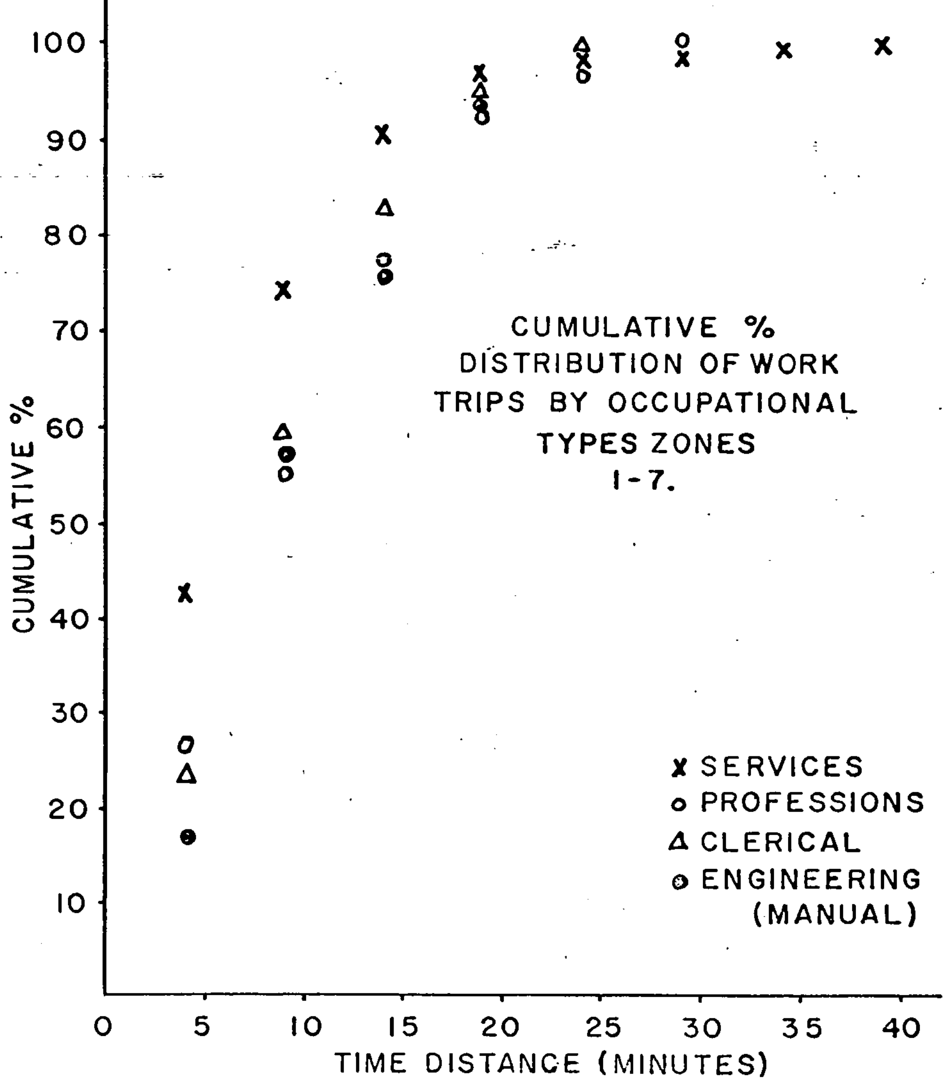
Considerable variation exists then in the mean length of journey to work.(8) Although some part of this variationcan be attributed to spatial differences in socio-economic status, as Graphs 7:5-7 show, the major part can be analysed in terms of the location of the various work place sites. That is, the mean length (in physical distance terms) of the journey varies spatially with the proximity to employment opportunities.

(8) See the surveys of H.S. Lapin op. cit.

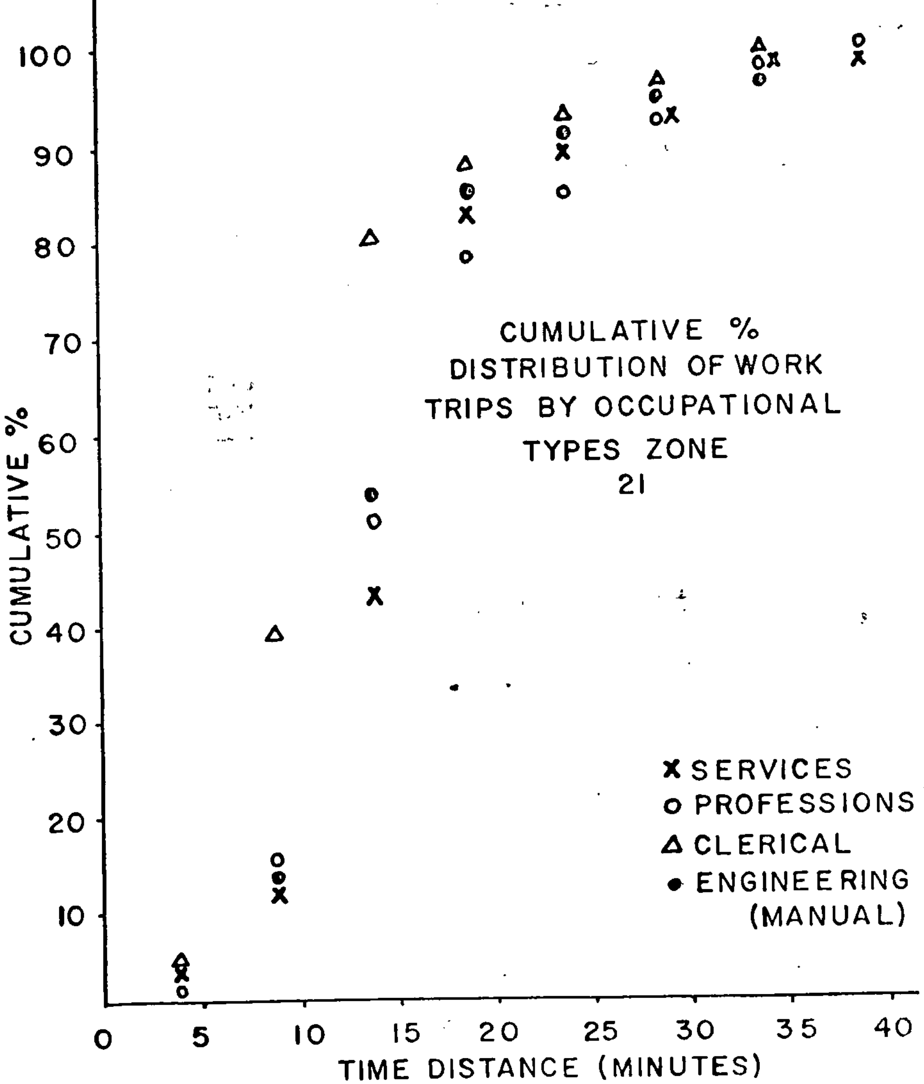
GRAPH 7 : 4



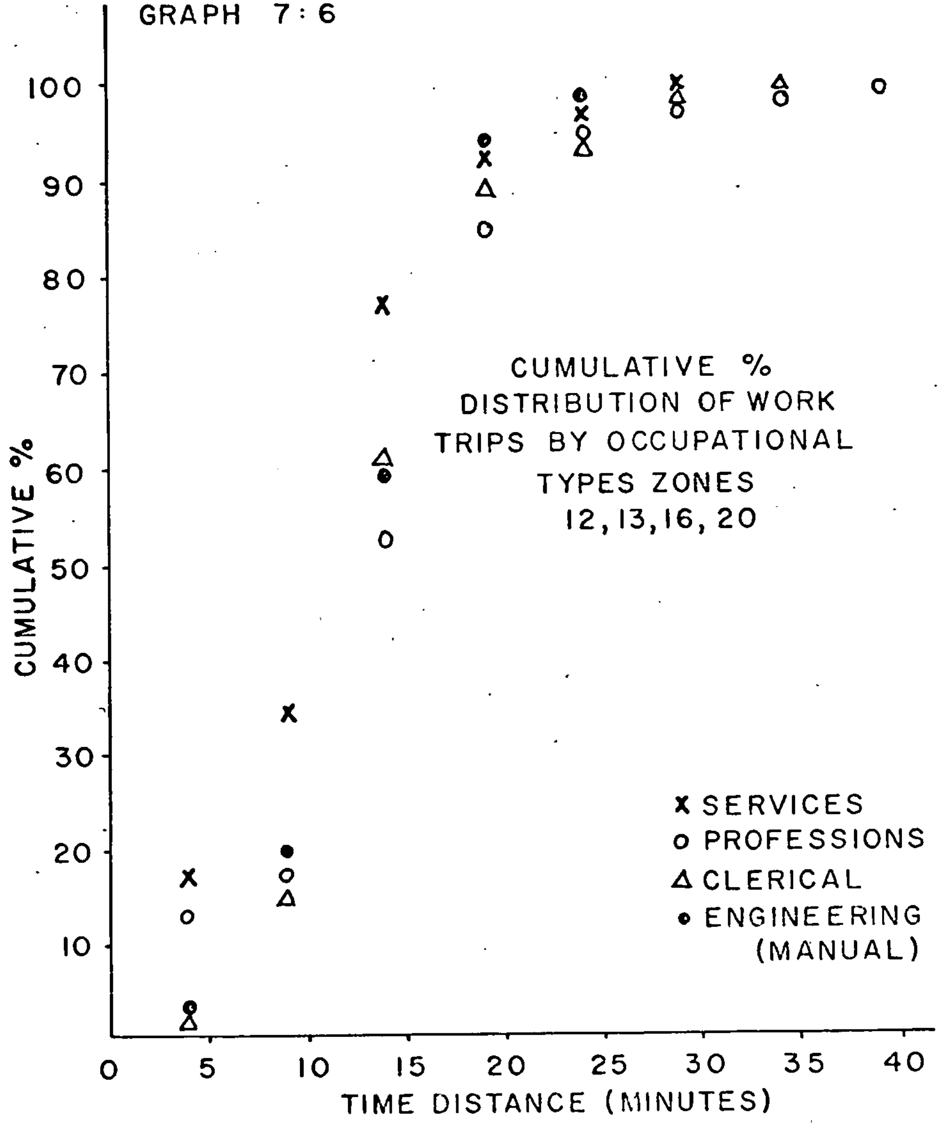
GRAPH 7 : 5



GRAPH 7:7



GRAPH 7:6



An index is required to express the proximity to jobs in gross terms. Although the central area draws a major part of this employment, a measure of distance from that one area fails to take into account the pull of other employment sites. In fact there are a number of indices available, which try to determine the accessibility characteristics of a site. They include the principle of 'least effort' (Zipf),[9] distance inputs (Isard),[10] social gravity hypotheses (Stewart),[11] principle of intervening opportunities (Stouffer),[12] and stochastic processes (Vining).[13] Most of these do not offer a convincing explanation,[14] and the most satisfactory, as far as closeness to a comprehensive concept goes, is Hansen's index of accessibility.[15] This is a measure of interaction opportunities (work site) and their pertinent distances. The measure is given as:-

$$A_1 = \frac{S_1}{T_{1-2}^{x}} + \frac{S_2}{T_{1-2}^{x}} \cdots\cdots \frac{S_n}{T_{1-n}^{x}}$$

where A_1 = index of accessibility to an activity (in this case, employment)

S_1 = the size of activity in the zone (all jobs)

T_{1-2} = travel time between zones

x = an empirically derived exponent describing the effect of travel time between zones.

Implicit in the Hansen model, by the term $T...^{x}$ is some specified mode of transport, whereas here the primary concern is with accessibility to work in general. In this case the similar potential model will be used. Now accessibility

(9) G.K. Zipf. 'Human Behaviour and the Principle of Least Effort' Cambridge, Addison - Wesley Press 1949.
(10) W. Isard, op. cit.
(11) J.Q. Stewart, numerous references including 'The Development of Social Physics' American Journal of Physics Vol.5, 1950 pp. 239-53.
(12) S.A.Stouffer 'Intervening Opportunities; A Theory Relating Mobility and Distance' American Sociological Review, Vol. 12, 1940 pp. 845-57.
(13) R. Vining 'A Description of Certain Spatial Aspects of an Economic System' Economic Development and Cultural Change, Vol. 1, 1955, pp. 147-95.
(14) A useful review is G.A.P. Carrothers 'An Historical Review of Gravity and Potential Concepts of Human Intra-action' Journal of the American Institute of Planners Vol.22, 1956, pp. 94-102.
(15) W.G.Hansen, op.cit. espec. p.74.

to employment of each zone is given by:-

$$A_1 = \frac{S_1}{i} + \frac{S_2}{D_{1-2}} + \frac{S_3}{D_{1-3}} \; \ldots\ldots \; + \frac{S_n}{D_{1-n}}$$

where A_1 = the accessibility of Zone 1 to employment.(16)

In this computation, direct distances between zones was used, except in the crossing of the Tay, when straight-line distances to and from the bridges were used. Isolines of equipotential accessibility gradient (Map 7:1) is steepest close to the central area, and is more shallow towards the periphery. The steepest gradient is towards the Tay, and less steep gradients occur where there are areas of alternative employment. It seems from this computation that the work-home distance varies inversely with the accessibility to employment, and this is confirmed by Graph 7:8 and a regression line of modest significance. Since the work force is residentially disposed the distance travelled to work appears to be a function of the concentration of employment opportunities, and as no zone is self sufficient, there is a proportion of the work force who find employment elsewhere. The mean distance travelled to work by these people, however, decreases toward employment concentration.

Accessibility, measured as straight-line distance, route distance, or time distance (17), plays an important part in trip generation and distribution, and as such cannot be neglected in any investigation of residential sites. Although this distance effect is well substantiated, the reasons for its occurrence are not. Distance seems to affect trip frequency for two reasons:-

(1) The greater the distance, the greater the time spent in travelling, and transport costs are much greater.

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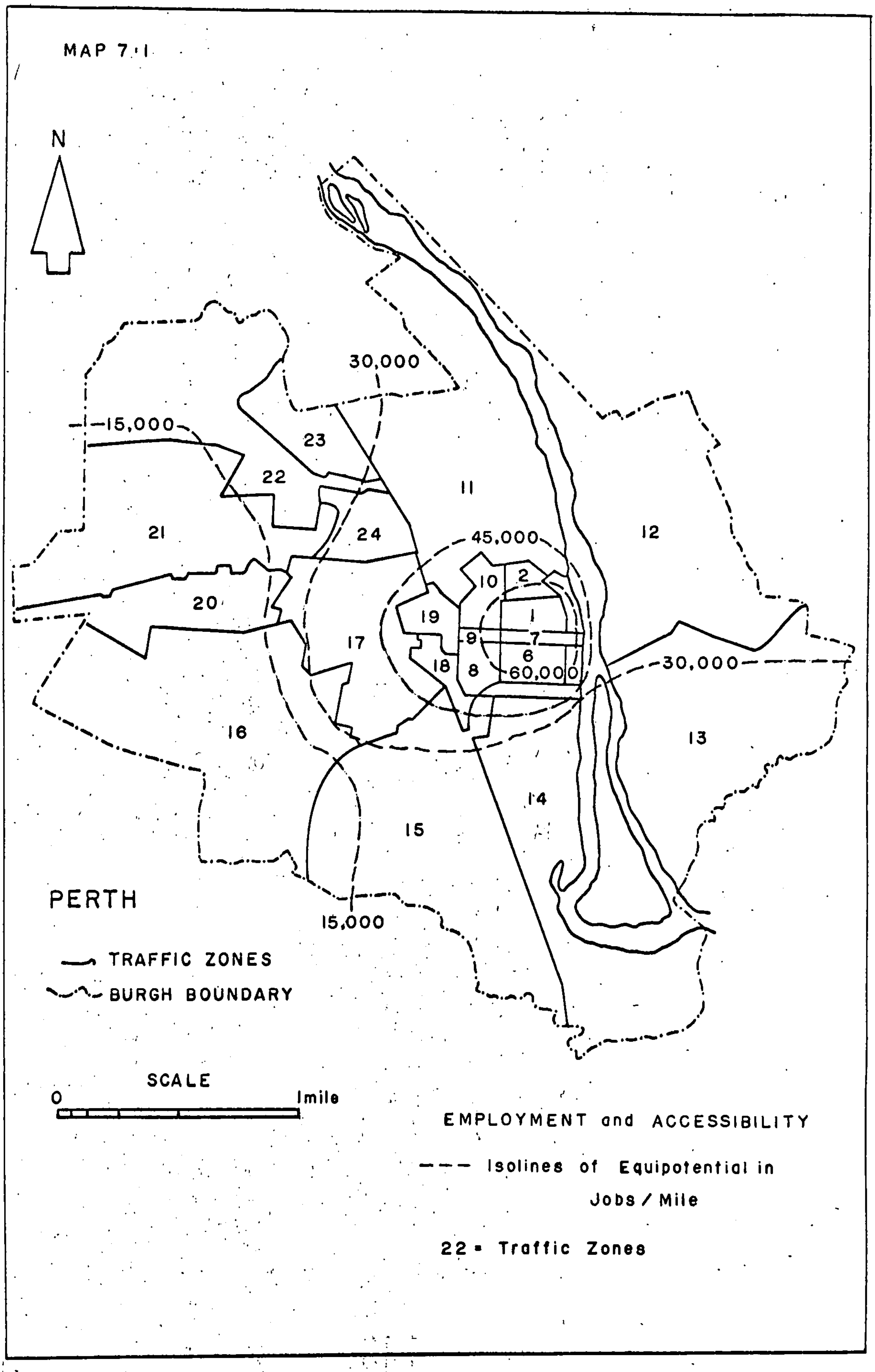
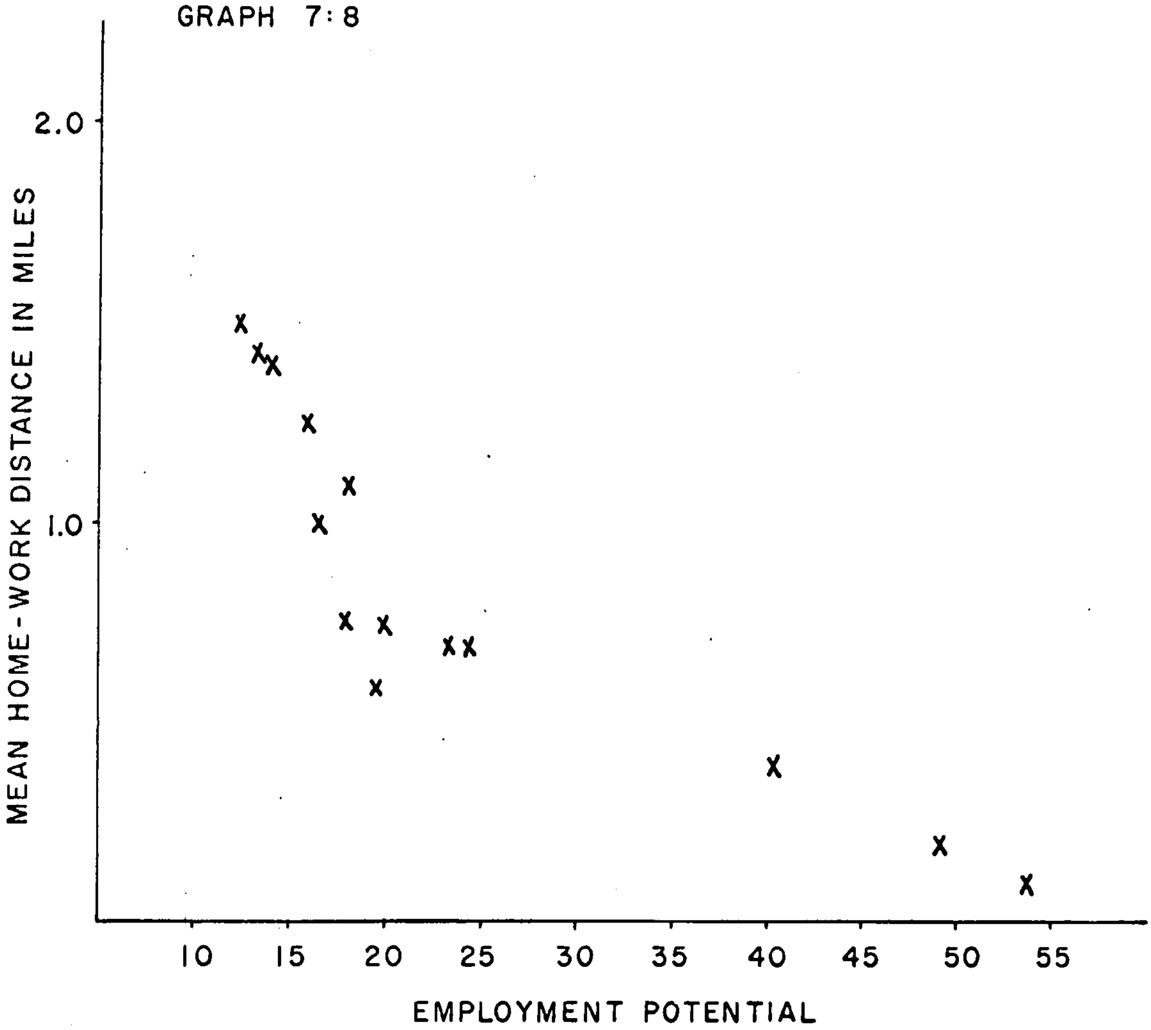
(16) See Isard op. cit. Chapter II.
(17) Another measurement might be cost-distance.


MAP 7·1
N
30,000
15,000
23
22
21
24
11
12
45,000
10
2
1
19
9
7
6
17
20
18
8
60,000
30,000
16
13
14
15
PERTH
15,000
TRAFFIC ZONES
BURGH BOUNDARY
SCALE
0
1mile
EMPLOYMENT and ACCESSIBILITY
Isolines of Equipotential in Jobs / Mile
22 = Traffic Zones

GRAPH 7:8


MEAN HOME-WORK DISTANCE IN MILES
2.0
1.0
10
15
20
25
30
35
40
45
50
55
EMPLOYMENT POTENTIAL

(2) The greater the distance, the less likely is an actual relationship between a potential pair of people leading to a trip. That is the farther apart people live, the less likely they are to know each other.[18]

Present investigation have not really gone beyond these elementary causal effects, but obviously until they do go further, any consideration of distance will be incomplete.

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(18) These propositions are more fully set out by F.C. Iklé 'Sociological Relationahip of Traffic to Population and Distance'. Traffic Quarterly April 1964. pp. 123-136.

SECTION VIII RESIDENTIAL LAND USE AND TRIP GENERATION

An attempt has been made to erect a number of relationships to express movement from the home, either in total, or in terms of mode and purpose. The general body of theory in transport indicates that relationships exist between the amount spent by a household on transport and other factors such as family size, car ownership, distance, and the value of the residential site. Although numerous empirical studies have been undertaken, no coordinating study has been made.[1]

In an attempt to delimit the factors which influence the level of transport expenditure, it is necessary to consider previous theoretical studies, and to compare the Perth results with other empirical studies.[2]

The theoretical studies concerned are mainly those of general location theory. In fact the works of Isard, Lefeber, and others give only scant attention to the spatial problems of the individual consumer, since they have been concerned with problems of the broader scale. Lefeber,[3] does not for example discuss the optimality conditions for consumers, and Isard[4] states that current concepts in location theory are unable to account for variations in transport inputs from household to household.

Isard gives some indication that apatial relationships may not be the only factor of importance when he introduces the idea of the consumer's space preference,[5] an idea noted earlier when considering choice of residence in relation to workplace.[6] Different individuals placed in the same spatial

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(1) Partial answers have been given by W.L. Garrison, B.J.L. Berry, D.F. Marble, J.D. Nystuen and R.L. Morris 'Study of Highway Development and Geographic Change'. Seattle University of Washington Press. W.Y. Oi and P.W. Schuldiner 'An Analysis of urban Travel Demands'. Evanston, Northwestern University Press 1962.

(2) Expenditure on transport is equated here with the number of transport 'inputs' consumed.

(3) L. Lefeber 'Allocation in Space'. Amsterdam. North-Holland Publishing Co. 1958.

(4) W. Isard 'Location and Space Economy' New York. Wiley. 1956.

(5) Defined as a measure of the individual's desired level of social contact. Isard op. cit. pp. 22-23, 84-85, 144-145, 286-287.

(6) See page 52 and footnote 2 . Reference must also be made to D.F. Huff 'A Topographical Model of Consumer Space Preferences' Papers and Procs. Regional Science Association. Vol. 6, 1960 pp. 159-173.

situation with identical information may exhibit differing patterns of spatial behaviour. The explanation may be differences due to social and psychological forces outside the general spatial system, and from these differences in behaviour result. Thus a resident might make 5 or 10 trips a day irrespective of the distance from his desired destination. The problem is left as to a satisfactory measurement of such 'desires'.

In addition to the general theorists, a number of other work are of importance. Troxel(7) analyses the demand for movement in terms of total elapsed time, and concludes that for each household or individual member of a household there is some total amount of time spent away from the house which will maximise the net travel expenditure or 'inputs'. This maximum level is related to the individual's own level of wants, his position in the spatial system, and the ease with which he is able to move within the system. Again no attempt is made to measure these factors satisfactorily.

A more explicit model is given by Baumol and Ide(8) who present a simple decision model for the individual consumer. For a given shopping trip the probability of a successful outcome at any given store is a function of the number of items stocked by the store, though in some cases price differentials between stores may also be important. This probability was denoted by 'p(N)'. Balanced against the probability of a successful outcome are the costs of the shopping trip - costs of moving from the residence to the shop, etc. The cost function was given by

$$C_d D + C_n \sqrt{N} + C_1$$

where D is the consumer's distance from the shop; N is the number of items stocked. Assumed costs are C_d (the unit cost of movement to the shop), C_n (the unit cost of actual shopping) and C_1 (the total opportunity cost).

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(7) E. Troxel, 'Economics of Transport' New York. Rinehart 1955.
(8) W.J. Baumol and E.A. Ide 'Variety in Retailing' Management Science , Vol. 3. October 1956 pp. 93-101.

The two elements were then combined into an equation:-

$$f\ (N,D) = wp\ (N) - V\ (C_dD + C_nN + C_1)$$

where 'w' and 'v' are subjective weights assigned by the consumer. A shopping trip will be undertaken only when 'f(N,D)' is positive. Berry and Garrison have shown that this decision model is entirely compatible with existing central place theory.(9)

Another useful decision model was that proposed by Marble.(10) Marble drew upon Game Theory, the game being one played against 'nature'. The problem which the individual faces is set out as taking place under conditions of uncertainty, 'with the movements of the individual in space as physical analogues of his movements among the branches of a Game tree'.(11) The individual chooses from among a set of trips whose relative desirability depends upon which 'state of nature' prevails. The individual has to select a trip which is in some way satisfying, though not optimal, considering his degree of knowledge about the possibilities within 'nature' or the Game.(12) The trip selection continues in this way until the residence becomes the next destination, and the game is terminated. A wealth of empirical data is presented which indicates that a significant relationship exists between the socio-economic status of a consumer, distance, and the number of trips made.

Finally Voorhees' paper must be mentioned.(13) His general theory was based on the premise that all trips emanating from a residential area are attracted to various land uses in accordance with certain empirical values, two of which were considered in Section 7. He took particular consideration of distance or some function of distance.

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(9) B.J.L. Berry and W.L. Garrison 'Recent Development of Central Place Theory' Papers and Proceedings of the Regional Science Association, Vol.4, 1958, pp. 107-120.

(10) D.F. Marble 'Transport Inputs and Urban Residential Sites' Papers and Proceedings of the Regional Science Association, Vol.5, 1959. pp.253-266, from which this preliminary discussion was drawn.

(11) Marble. op. cit. p. 264.

(12) Simon substitutes for the Optimum solution, that of the 'satisficer', in which the individual seeks only for a solution which is 'good enough'. Instead of omniscient rationality there is a 'bounded rationality'; see H.A. Simon 'Models of Man', New York, Wiley, 1957, especially Chapters 14 and 15; also H.A. Simon 'A Behavioural Model of Rational Choice' Quarterly Journal of Economics, Vol.69, 1952, pp.99-118.

(13) A.M. Voorhees 'A General Theory of Traffic Movement' Procs., Inst. of Traffic Engrs. 1956 pp. 46-56.

This is by no means a complete list of the theoretical structures proposed, but it gives some idea of the range of the hypotheses available.

Turning to empirical studies, there is a wide range of studies, particularly in the last few years, which have considered measures of transport 'inputs' consumed by individual households. The seventh International Study Week in Traffic Engineering took as its fifth theme 'Interaction of Traffic and Land Use in Urban Areas', and twelve reports were presented which are of importance here.(14) What follows is a comparative analysis of some of these studies and the findings in Perth.

Comparisons are sometimes difficult to make because of difference in data collection, analysis and definition. For example sometimes trips made on foot or by cycle have not been included.

The computation found in all studies, and thus perhaps the most stable quantity, is the number of journeys per household (Table 8:1). The comparison is only possible when approximate corrections are made to give a common denominator. For example, the study by Williams et al of Ponteland reports only trips made from the residence.(15) Inspite of the approximate nature of the corrections, the comparison does show a concentration of the values for trips made by all types of motor vehicle in the range 4 to 6 trips per family. This in fact accords with the range given by S.T. Hitchcock in a general report in the same Theme, on trips in American cities. Table 8:2 sets out results for those who reported on the number of trips per family by rate of car ownership. There is a measure of agreement between Chicago and London (vehicular trips only); but much higher reporting from the other two, particularly Perth. Both these latter included all types of trip, and the questionnaire in Perth demanded listing of all trips no matter how short.

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(14) Seventh International Study Week in Traffic Engineering, London. September 21st-25th, 1964. Theme V 'Interaction of Traffic and Land Use in Urban Areas.'

(15) S.T. Hitchcock's paper, same Theme, mentions from-home trips and the exact return journey represent c.80% of all trips. Therefore William's figures were multiplied by 2 x 1/0.8.

Table 8:1

Average Daily Number of Trips per Family (16)

Country and Town	Population of Survey Area in 000s	All Trips including those on Foot	All Trips by Motor Vehicle	Trips by Private Car
UNITED KINGDOM				
London	8826.0		3.8	1.65
London			6.8	4.1
Ponteland	5.2	7.2	5.9	5.0
Perth	41.0	9.4	4.4	2.1
U.S.A.				
Detroit	3000.0		6.5	
Chicago	5170.0		6.1	
FRANCE				
Nantes	303.0			4.5
Rennes	160.0		4.4	1.9
NETHERLANDS				
Delft			6.0	
SWITZERLAND				
Lausanne	170.0		5.7	
Geneva	225.0		)	
Bienne	80.0		) 5.4	
Aaron	42.0		)	

Table 8:2

Number of Trips per Family in Relation to Car Ownership

No. of Cars /Household	CHICAGO	LONDON	PONTELAND*	PERTH*
0	2.42	2.50	5.10	8.50
1	5.46	6.45	7.50	12.20
2)	)	9.46	9.20	)
)	) 9,02			) 18.20
more than 2)	)	12.00	9.80	)

* includes all trips, on foot, etc.

(16) J.L. Biermann and G. Junker; and S. Goldberg. The latter paper appeared in Traffic Engineering and Control, Vol. 6, No.7. November 1964. pp. 439-442. The Chicago data comes from the Chicago Area Transportation Study, Final Report, December, 1959. To make these figures comparable certain additional calculations were made.

Table 8:3

Journey Purpose (From Home) in %

	PONTELAND	PERTH	LONDON	RENNES	DELFT	CHICAGO
Work	36.0	41.8	47.5	39.3	49.0	38.3
Business	5.0	2.5	14.2	21.3		17.6
Shop	18.0	13.1	8.2	16.7	13.0	9.4
School	23.0	23.4	18.3	11.2	21.0	25.6
Socio-Recreational	12.0	15.9				
Other	5.0	3.3	11.8	11.5	17.0	9.1

The influence of distance is reported by Kerensky and Grosthwaite for London, and the number of trips per car owning family increased by 0.15 for each additional mile from the central area. This is much less marked than in Chicago and Detroit, where within the same limits, the increase per mile was 0.47, and for Perth was 1.38. In the latter of course the distance relationship is rather different and probably compressed.

Journey purposes (Table 8:3) suffer from ambiguous definitions, however 'work trip' can be relied on, and it forms in every case the largest part of from-home trips. If one considers that each work trip has an exacted opposite return trip, the importance of this daily ebb and flow is underlined. The variations to be found elsewhere in the table probably stem from a lack of comparability of the data. Where definitions are essentially similar (Ponteland and Perth) a close matching occurs.

Finally Table 8:4 sets out figures for journey mode. Modal choice seems to have been more fully studied, and there are more complete figures available. For home-to-work trips in the U.S.A. Hitchcock gives the figures of 12% by public transport and 64% by car. The differences are thus not dissimilar from the majority of towns in Europe, though even among these there are striking variations. The standard of living and the rate of car ownership as well as the structure of the town and the public transport service explain these variations. Behaviour seems much more varied there, in the use of the different modes of transport from the residence.

On the basis then of the study of residential trip generation in Perth, and of the studies mentioned here as well as other currently available theoretical and empirical work, it appears that four sets of factors operate so as to influence the level of trip generation of individual households. These are, (1) the availability of transportation, especially the level of car ownership; (2) the socio-economic structure of the household; (3) the location of the residential site relative to the other elements in the spatial system, which includes distance, land values, etc.; and (4) a behavioural element, which although it varies amongst households and individuals, could be conceptualised and quantified, as shown by Huff.[17]

(17) Huff. op. cit.

Table 8:4

Journey Mode in %

MODE	ALL TRIPS						HOME TO WORK					
	London	Perth	Ponte-Land	Rennes	Amsterdam	London to Centre	London	Milan	Paris	Rennes	Vienna	Perth
Rail	16.5				)	64.0	27.0	30.0	44.4		)	
Bus	34.2	27.2	27.9	9.1	) 23.6	22.9	31.7	25.0	25.7	9.2	) 75.8	28.5
Tram					)			10.0			)	
Car	43.0	18.3	65.1	29.3	38.2	10.5	25.9	)	11.8	15.1	) 24.2	18.1
Cycle	) 4.7	8.8	4.7	) 60.8	38.2	1.9	14.0	) 35.0	14.5	75.3	)	10.8
M. Cycle	)	3.4		)				)				3.8
Other	1.6	42.3*	2.3	0.8		1.6	1.4		3.6	0.4		38.8*
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Includes trips on foot, which constitute 34.0% and 30.6% respectively.

PART 2.

PART II

INDUSTRIAL/COMMERCIAL LAND USE TRIP GENERATION

INTRODUCTION

Land use plays an important though sometimes ambiguous role in trip generation analysis. It can never be ignored in such study, yet its uncritical use may lead to the obscuring rather than to the revelation of functional relationships between patterns of travel and urban activity. The problem has been one of definition and of data collection.

Generalised land use by itself is usually inadequate as a basis for estimating trip generation or induction. If however, the very broad categories of land use are subdivided on a basis more indentifiable with the nature of the activities performed, a more rational and useful basis for trip generation is created. It is not only that a broad term like 'non-residential' is too general and includes many unrelated uses, but it is also true that broad categorisations are too far removed from the activities which take place on them and which are the reasons for which trips to a given use are made. As finer groupings of land use are made, the move is made closer and closer to an identity with specific activity designations and farther away from the traditional concept of land use. Thus this is largely a problem of definition of terms.

Much of the data used in transportation studies is based upon detailed interviews conducted at a sample of households in the study area. This produces a wealth of data directly applicable to residential trip generation, as was seen in Part I of this thesis. But very little data are normally obtained through facility-user surveys, directly for non-residential land uses. As a result,to date, most of what is known about the trip generating characteristics of non-residential land has been derived indirectly from home interview surveys. Consequently techniques for analysing non-home based trips and the resulting estimates of travel demand are relatively unsophisticated and inaccurate compared with the understanding of home-based trip generation.[1]

Whilst estimates of household characteristics such as car ownership, location, or socio-economic status can be used as fairly reliable indicators of residential travel demands, no such fundamental and clear-cut relationships between non-residential characteristics and trip generation can be established.

An element which has a direct bearing on the problem of non-residential trip generation is the recognition of functional relationships between land-use activities and the volume and character of the traffic which these activities produce. This approach requires consideration of the generator, interrelationships and linkages, competing and complementary generators, and the characteristics of the hinterland from which its traffic is drawn.

Non-residential land use classification affords essentially then, a means for understanding travel characteristics. Urban travel is spatially as well as activity orientated, and the definition and physical location of activities is an essential part of the analysis. Mere measurement of traffic volumes produced by a given generator or set of generators without a consideration of function, links, competitors, and tributory areas will not provide the necessary understanding of urban travel.

In the following sections an attempt is made to analyse the relationship of land use and traffic generation or induction along these general lines.

Broadly land use can be summarised as:

Commercial Important components are volume of sales; floor space; distance. Goods are usually divided by economic and marketing geographers into convenience and shopping categories. A more satisfactory measure would probably be expenditure per trip or some measure of turnover.

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(1) These factors are confirmed by a 'trip generation analysis conference' held at Northwestern University in May 1965; the Conference proceedings are recorded in a research report edited by P. Schuldiner, 'Nonresidential Trip Generation Analysis', Northwestern University, November. 1965.

Commercial activities also include warehousing, offices, banks, and small workshops. These are considered in terms of the general business district or central area as measured by floor space, employment, and service offered.

Industrial Measurable factors here include number of employees, sex of the employee, occupational composition and floor space. Direct measures of labour intensity were non-significant. These employment measures can be related to the technological characteristics of the activity which allows the grouping together of industrial activities with similar employment functions.

Transportation Two terminal facilities were studied, in relation to total usage, taxi movements and goods vehicle trips.

Recreational Scant attention has been paid to this group by most transportation studies. Of the variables analysed employment was the most significant.

Each of these facilities was analysed whenever possible in relation to its location, nearness to the central area, availability of transportation, presence or absence of other facilities, travel-time characteristics, socio-economic level of the tributary area, and parking. Work, shopping, business, recreational, and goods trips were related to these and the broad categories set out above.

SECTION I STUDIES AT THE ATTACTION SITE

To date there have been only isolated studies of trip generation based upon observation at non-residential sites. Exceptions to this are the North American studies of traffic and parking characteristics at shopping centres.[1] Many of these are descriptive with inadequate attention paid to the critical variables which relate specific activities at non-residential sites to the volume and characteristics of the trips they produce. There are some exceptions to this statement, and the more pertinent of these will be compared with the results obtained in Perth.

1:1 Commercial Facilities; (a) Retail

Commercial establishments are considered under two categories: shops; and a consideration of the central business district. Trip generation analyses of individual commercial establishments have also been made.

Traffic engineers, market analysts, geographers and planners have all been concerned in North America to measure the traffic and parking requirements of shops and shopping areas. However there is still much uncertainty as to the amount of traffic which shopping areas generate. Differences in the characteristics of various centres, the nature of their trade areas, and competition from other shopping centres all affect traffic volumes, but many of the variations go unexplained.

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(1) Examples include D.E. Cleveland & E.A. Mueller 'Traffic Characteristics and Regional Shpping Centres'. New Haven. Yale Bureau of Highway Traffic 1961; T. Lakshmann & W.G. Hansen 'Analysis of Market Potential for a Set of Urban Retail Centres'. Paper presented at the 20th International Geographical Congress Symposium. Nottingham. July 1964; A.M. Voorhees, G.B. Sharpe, & J.T. Stegmier 'Shopping Habits and Travel Patterns' Highway Research Board Special Report 11B. 1955.

Shopping trips are usually divided into two general classes: (1) Trips primarily concerned with the purchase of 'convenience' goods (items usually found locally, and purchased frequently such as groceries, meat, etc.), and (2) Trips concerned with 'shopping' goods (clothing, furniture, appliances, etc. not usually found locally). Although this is a commonly used categorisation, many shoppers 'economise' on shopping effort, and combine both types of shopping on one trip. This is especially so in a small urban area like Perth, and a high percentage of those who go to the central area purchase food items.

The relationship of trip generation to retail areas can be thought of in terms of origin, trading area, destination, mode and time distance, frequency and environmental perception.(1) This latter aspect is difficult to measure, but it offers areas for future research.(2) Traditionally the explanatory variables have been floor space, frequency of trips, or sales volume.(3)

Table 1:1:1 sets out the basic details of Perth's retailing structure, as to floor area and employment. The dominance of the central area is obvious, since here is located 83% of the total retail floor space, 92% of the 'shopping goods' floor space, and 73% of the 'convenience goods' floor space, and 82.5% of the employment.

The next largest area, Zone 15, has only 3% of the total retail floor space, predominantly in the convenience goods sector. The ratio of employment to floor space shows a rather different bias, and there is a variation

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(1) This involves concepts of 'imagery', 'perception' and 'motivation'. See K. Lynch 'Image of the City' Cambridge, Mass. 1960; S.U. Rich and B.D. Portis "The 'Imageries' of Department Stores", Journal of Marketing Vol. 28. 1964, pp. 10-15; and D.L. Thompson 'New Concept: Subjective Distance' Journal of Retailing. Vol. 39, 1963. pp. 1-6.

(2) See D.L. Thompson 'Future Directions in Retail Area Research' Economic Geography Jan. 1966 Vol. 42, No.1, pp. 1-18.

(3) Even Huff who uses behavioural and probalistic terms in his analysis, still uses Floor Area and a Distance Factor. D. Huff 'Ecological Characteristics of Consumer Behaviour' Papers and Procs. Regional Science Association Vol. 7, 1961. pp. 19-28.

Table 1:1:1

Relationship between Floor Area and Employment

	Gross Floor Area (sq.ft.)			Employment*			Floor Area/Employee		
	Total	Shopping Goods	Conven.	Total	Shopping Goods	Conven.	Total	Shopping Goods	Conven.
Central Area	409,655	263,127	146,528	2,887	2,069	818	142	127	179
Zone 6	2,649	849	1,600	34	8	26	78	106	61
Zone 8	3,824	813	3,011	37	7	30	104	116	100
Zone 10	7,969	2,918	5,051	79	27	52	101	108	97
Zone 11	12,357	3,205	9,152	82	22	60	150	146	152
Zones 12 & 13	14,064	3,633	10,431	94	25	69	149	145	151
Zone 15	14,885	3,659	11,226	110	29	81	136	126	138
Zone 16	920	-	920	6	-	6	153	-	153
Zone 17	6,792	913	5,879	51	4	47	133	228	125
Zone 20	2,073	-	2,073	18	-	18	115	-	115
Zone 21	12,859	3,149	9,710	83	13	70	155	242	138
Zone 22	2,133	-	2,133	20	-	20	106	-	106
Zone 23	413	-	413	3	-	3	137	-	137
Zone 24	313	-	313	1	-	1	313	-	313
				Average			140	129	158

*Full Time Employees.

from 78 sq. feet to 155 sq. feet, discounting Zone 24 (which has only one shop of 313 sq. feet and one full time employee). The lowest ratio occurs in Zones 6, 8 and 10, which are part of the centroperipheral zone, dominated by small shops. The shopping/convenience goods ratio shows the reverse pattern to what might be expected. The shopping goods stores have a larger ratio of floor space to employment outside the central area, and the reverse for the convenience goods. It may be that the larger groceries and butchers in the central area, operating on a semi-self-service basis require fewer employees. The larger shopping goods areas probably result from the fact that many such outlets without the central area are also wholesalers.

Tables 1:1:2 and 3 carry the structural analysis further, drawing on the 1961 census of Distribution as well as personal surveys. The census definition of the central area is more restricted than that in Table 1:1:1 based on the traffic zones. Bearing in mind these differences, the basic pattern is similar. 31% of the convenience goods shops and 60% of the shopping goods are found in the central area, and 42.5% of all shops (73%, 92% and 83% of floor space respectively of the more loosely defined central area), with a higher percentage of the turnover in each case. As one would expect the central area lacks particularly groceries, and has a dominance of household goods particularly as regards turnover. Basically then the retail structure is dominated by the central area, whether defined as in the census or by traffic zones.

Since there is this dual division of location and of type, it is important to see how trips are distributed between them. In fact 75% of all shopping trips are made to the central area, though this varies zonally according to the supply of local shops. 92% of the shopping trips are made from Zone 16 which has only one or two shops. to the central area, as against 64% from Zone 21 where awwider range of services are available locally. Another consideration is the weekly distribution of such trips. Tables 1:1:4 and 5

Table 1:1:2

Perth: Central Area and Suburban Retail Structure *

Type of Retail Establishment	All Perth			Central Area			Suburban Areas		
	No. of Ests.	Turn-over 000's £	Employ-ment**	No. of Ests.	Turn-over 000's £	Employ-ment	No. of Ests.	Turn-over 000's £	Employ-ment
Grocers	96	1,986	490	14	374	90	82	1,612	400
Other Food Retailers	99	2,086	990	38	809	320	61	1,277	670
Confectioners, etc.	72	771	255	27	305	84	45	466	171
Chemists	21	352	114	12	196	63	9	156	51
Hair-dressers	26	92	151	12	51	76	14	41	75
Boot and Shoe Repairs	9	45	43						
Clothing, etc.	81	1,841	566	35	603	209	46	1,238	357
House-hold goods	63	1,689	540	33	1,257	385	30	432	155
Books, etc.	7	259	77						
Jewel-lers	25	328	127						
General	7	311	122						
Other non-food	8	1,523	604						
TOTAL	514	11,283	2,036						

* Restricted definition of central area.

** Full and part time employment
Source: Census of Distribution 1961. H.M.S.O. 1964. Table 3. p. 13/32. Some information is withheld by the census to avoid disclosure.

Table 1:1:3

Perth: Retail Structure; Shopping and Convenience Goods in %.(1)

	CENTRAL AREA			SUBURBAN AREAS		
	No. of Ests.	£ 000's Turn-over	Employ-ment	No. of Ests.	£ 000's Turn-over	Employ-ment
Grocers	14.5	18.9	18.4	85.5	81.1	81.6
Other Food	38.2	38.8	32.4	61.8	61.2	67.6
Confectioners	37.5	39.0	33.0	62.5	61.0	67.0
All Conven. Goods	31.0	33.0	31.0	69.0	67.0	69.0
Household Goods	52.3	74.3	71.0	47.7	25.7	29.0
Clothing	48.3	33.0	37.0	51.7	67.0	63.0
All Shopping Goods	60.2	72.6	74.0	39.8	27.4	26.0
All Establishments	42.5	53.4	52.0	57.5	46.6	48.0
% of Area in Convenience Goods	47.2	28.7	29.8	73.6	68.5	72.9
% of Area in Shopping Goods	52.8	71.3	70.2	26.4	31.5	27.1

(1) Source: Census of Distribution 1961. op. cit. and personal survey.

set out the results from the Home Interview Survey, which did not cover trips made on a Saturday. The amajority of the trips in Perth as a whole occur on a Monday, Thursday and Friday, coincident with the Perth Market Days. Wednesday is the normal half closing day. Again there is zonal variation, trips being almost equally distributed through the week in Zone 21, approximate to the average in Zone 16, and are concentrated on a Monday and Friday for those resident within the central area. This latter group of households have a wide range of retail facilities available to them within a few minutes walking distance, yet they do not seem to avail themselves of this. It may be partly due to the high number of employed women in these zones.

There is also a difference in pattern for shopping carried out locally and in the central area according to week day. On the average, central area shopping trips predominate on a Thursday and Friday, with local shopping trips fairly equally distributed throughout the week, though with a relative predominance of the earlier part of the week. There are few zonal variations from this pattern.

If the weekly pattern is studied including Satur day (Table 1:1:6), the overall predominance of Saturday is strong. This information was obtained fromsstudying records of turnover. They confirm the 5 day pattern picked out by the Home Interview Survey, although obviously there are variations and some shops do a predominantly weekend trade.(1)

Not only is there a spatial and daily pattern of shopping trips, but Graph 1:1:1 shows the hourly pattern of arrivals at a sample of shops in the central and local areas. Local areas show not only a fairly even distribution of trips throughout the week, but also a fairly even distribution throughout the day, without the morning and afternoon peaks of the central area. In the central area 35% of the arrivals were counted between 10.00 a.m. and 12 noon, and 35% between 2.00 and 4.00 p.m.

Table 1:1:4

Distribution of Shopping Trips, by Weekday in %.

	Monday		Tuesday		Wednesday		Thursday		Friday	
ORIGIN	C. Area	Local	C.Area	Local	C.Area	Local	C.Area	Local	C.Area	Local
Zone 21	17.0	26.0	21.6	19.9	13.9	14.1	21.7	18.2	25.8	21.8
Zone 16	19.1	25.2	13.9	23.2	18.2	25.4	27.0	16.2	21.8	10.0
Zones 1-7	38.6	-	13.4	-	4.2	-	4.8	-	39.0	-
All Perth	20.4	29.0	17.4	14.4	14.4	16.5	21.3	16.5	26.5	20.0

(1) Since these figures were obtained, one shop, 'Caird's', now closes all day Wednesday (Table 1:1:6).

Graph 1:1:1

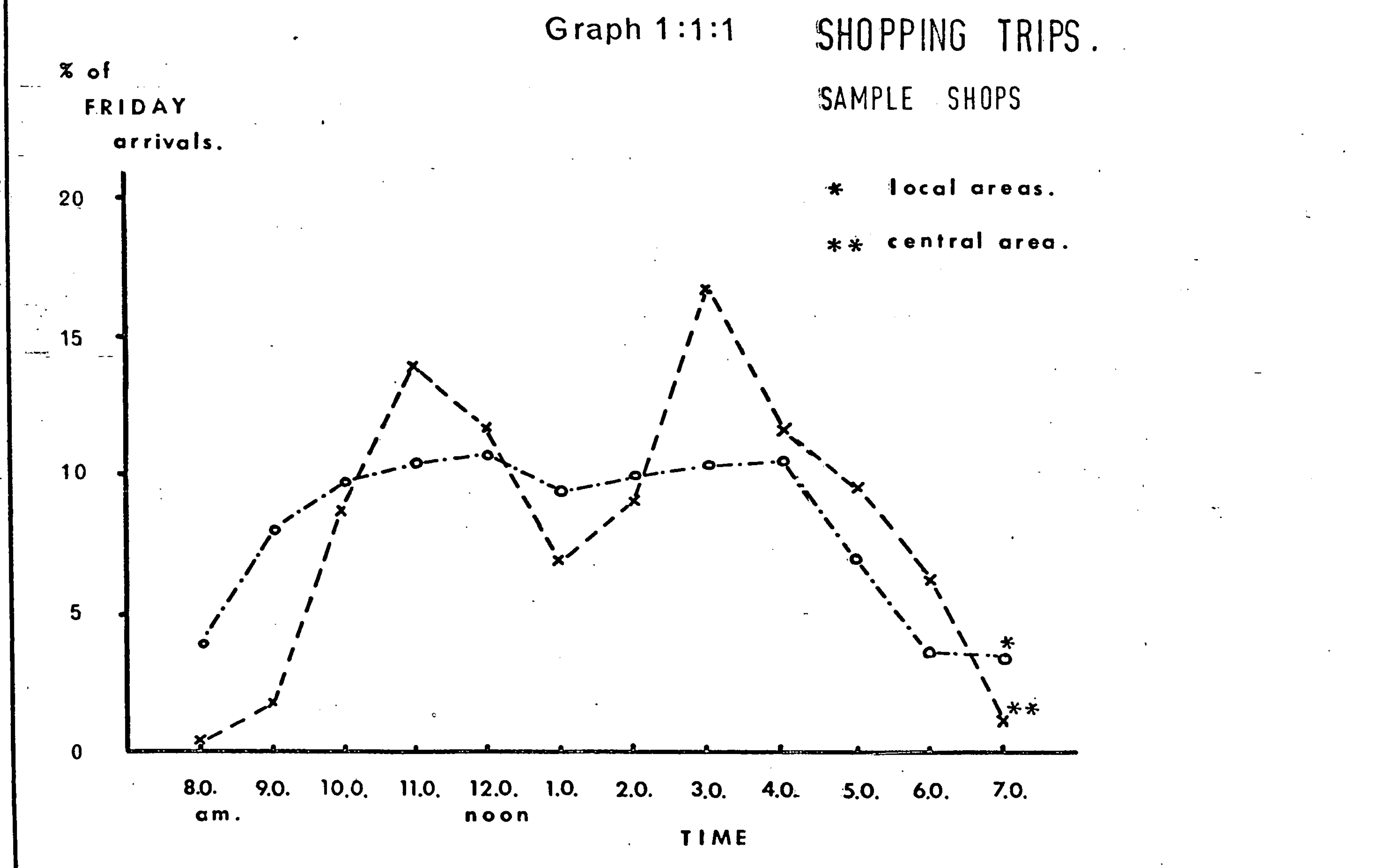

SHOPPING TRIPS.
SAMPLE SHOPS
% of FRIDAY arrivals.
* local areas.
** central area.
20
15
10
5
0
8.0. am.
9.0.
10.0.
11.0.
12.0. noon
1.0.
2.0.
3.0.
4.0.
5.0.
6.0.
7.0.
TIME

Table 1:1:5

All Shopping Trips (in %)

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Zone 21	20.6	20.3	13.9	20.3	24.9
Zone 16	21.0	15.9	19.0	24.0	20.1
Zones 1-7	38.6	13.4	4.2	4.8	39.0
All Perth	22.6	17.6	14.8	20.0	25.0

The facility-user survey not only collected data about time of arrival, but questioned a sample of customers (arriving and leaving) as to their previous subsequent destination. Shops were chosen within the central area and in three of the suburban zones. The results are set out in Tables 1:1:7 and 8. The home predominates as origin and subsequent destination in all cases of local shopping, and in only a few cases were multiple trips contemplated, and in the case of Zone 21, less than 10% of destinations other than the home were intended. The local shopping areas tend then to be the first, and in many cases the only, stopping point.

The travel pattern is different in the central area. In one third of the cases sampled shopping was not the dominant motive, but was combined with a work or social trip. In cases of multiple trips, shopping tended to be last call point. This use of multiple trips illustrates the range of service and opportunity that are available, compared to the local areas, and the fact that the central area is a funnel or focus for many interchange trips.

The final variable to be noted in this account of retail structure is distribution of trip lengths and trip origins. Graph 1:1:2 records the time-distance from which three areas draw their customers - the central area, Zone 21 and Zone 17. Two patterns stand out; the immediate area from which the suburban centres draw their customers, they rely on little interzonal travel, and the much wider tributary area which the central area relies on.

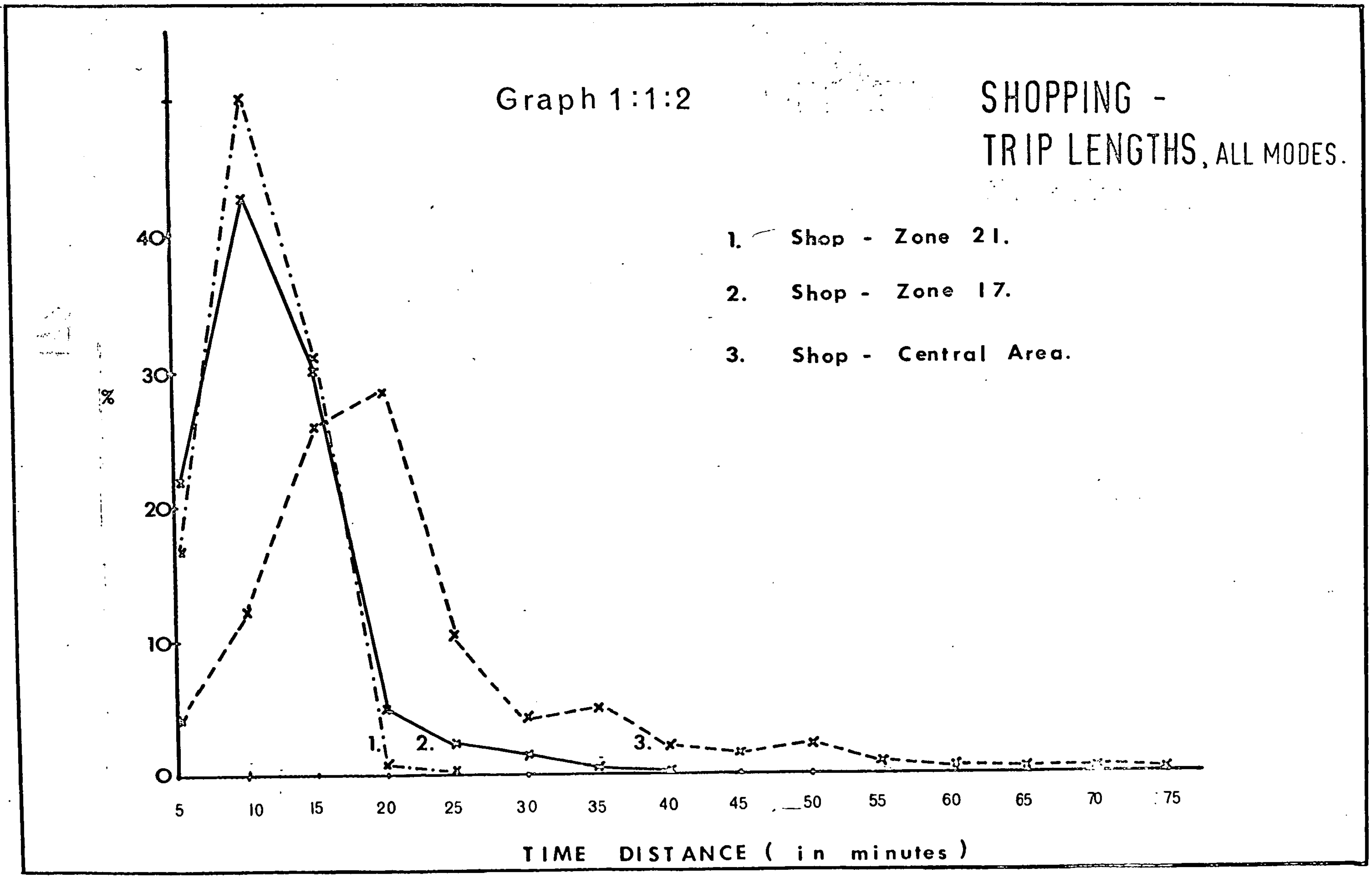

Graph 1:1:2
SHOPPING -
TRIP LENGTHS, ALL MODES.
1. Shop - Zone 21.
2. Shop - Zone 17.
3. Shop - Central Area.
%
40
30
20
10
0
1.
2.
3.
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
TIME DISTANCE (in minutes)

Table 1:1:6

Daily Turnover Expressed as % of Weekly Turnover.

Selected Central Area Shops.

BUSINESS	MONDAY	TUESDAY	WEDNESDAY*	THURSDAY	FRIDAY	SATURDAY	
F.W. Woolworth	16.07	13.41	6.07	13.10	16.74	34.61	(1)
	13.82	10.88	5.90	9.50	12.14	47.76	(2)
Marks & Spencer	11.22	9.18	2.04	16.33	22.45	38.78	(3)
Boots Chemists	15.40	14.21	7.51	17.21	19.86	25.81	(4)
Caird's (General Outfitters. Local Firm)	15.89	16.37	6.57	15.34	17.18	28.65	(5)
	14.62	15.51	6.00	17.43	19.12	27.32	(6)
	14.98	15.44	5.89	17.89	18.37	27.43	(7)
	14.50	14.91	6.58	16.52	18.04	29.45	(8)
Garvie and Syme (Ironmonger local. ½ day closing Saturday)	12.51	18.75	12.32	25.17	18.70	12.55	(9)

*Half day closing.

(1) average June 1964

(2) 8-13th May, 1965 (sale)

(3) Average May 1965

(4) Yearly average 1964

(5) Average June 1964

(6) Yearly average 1964

(7) Yearly average 1963

(8) Yearly average 1962

(9) Yearly average 1964

Table 1:1:7

Purpose at Origin of Trip to Shopping Area (in %)

From	To CENTRAL AREA	ZONE 11	ZONE 17	ZONE 21
Home	66.3	78.2	80.3	80.1
Shop	9.5	7.3	5.5	5.1
Work	10.1	5.2	6.3	12.6
Business	3.1	1.3	1.0	0.3
Social	3.3	1.7	0.9	0.2
Meal	2.1	-	-	-
School	5.6	6.3	6.0	1.7

Table 1:1:8

Next Purpose at Completion of Shopping (in %)

To	From CENTRAL	ZONE 11	ZONE 17	ZONE 21
Home	73.2	80.7	84.7	90.1
Shop	12.1	8.2	6.0	5.2
Work	11.2	5.0	6.3	4.0
Business	2.0	0.9	0.5	0.1
Social	1.2	4.0	0.5	0.1
Meal	1.1	-	0.2	0.1
School	0.2	1.2	1.8	0.4

The central area draws about 66% of its customers from within Perth, and the rest from greater time distances. The tributary areas of a number of shops are shown on Map 1:1:1, the local shops drawing customers from the immediate traffic zones (chosen basically as route catchment areas), whilst the central shops draw from the whole spectrum (note that customers from Zones 21, 22, 23, 24 and 11 are omitted for clarity).

Map 1:1:2 shows the catchment areas without Perth of three of the leading grocers in the city, and one department store. Perth is not only the county town of a very large county (strictly two, Perthshire and Kinross), but by far the largest shopping centre in the county, and has a wide range of specialty stores. Map 1:1:2 reveals three catchment zones, an inner area of more intensive drawing power, of approximately 10-15 mile radius, probably representing weekly visitors; a median area stretching 40 miles to the north, approximately 20 to 25 miles east and west, and about 15 miles to the south, an area of more occasional, perhaps monthly visits; finally an outer area of very occasional visitors. The areas are affected by the availability of shopping at competitive centres, including Glasgow, Edinburgh, Dundee, Inverness, and Aberdeen. Convenience goods customers are drawn from a more immediate area, than for shopping goods.

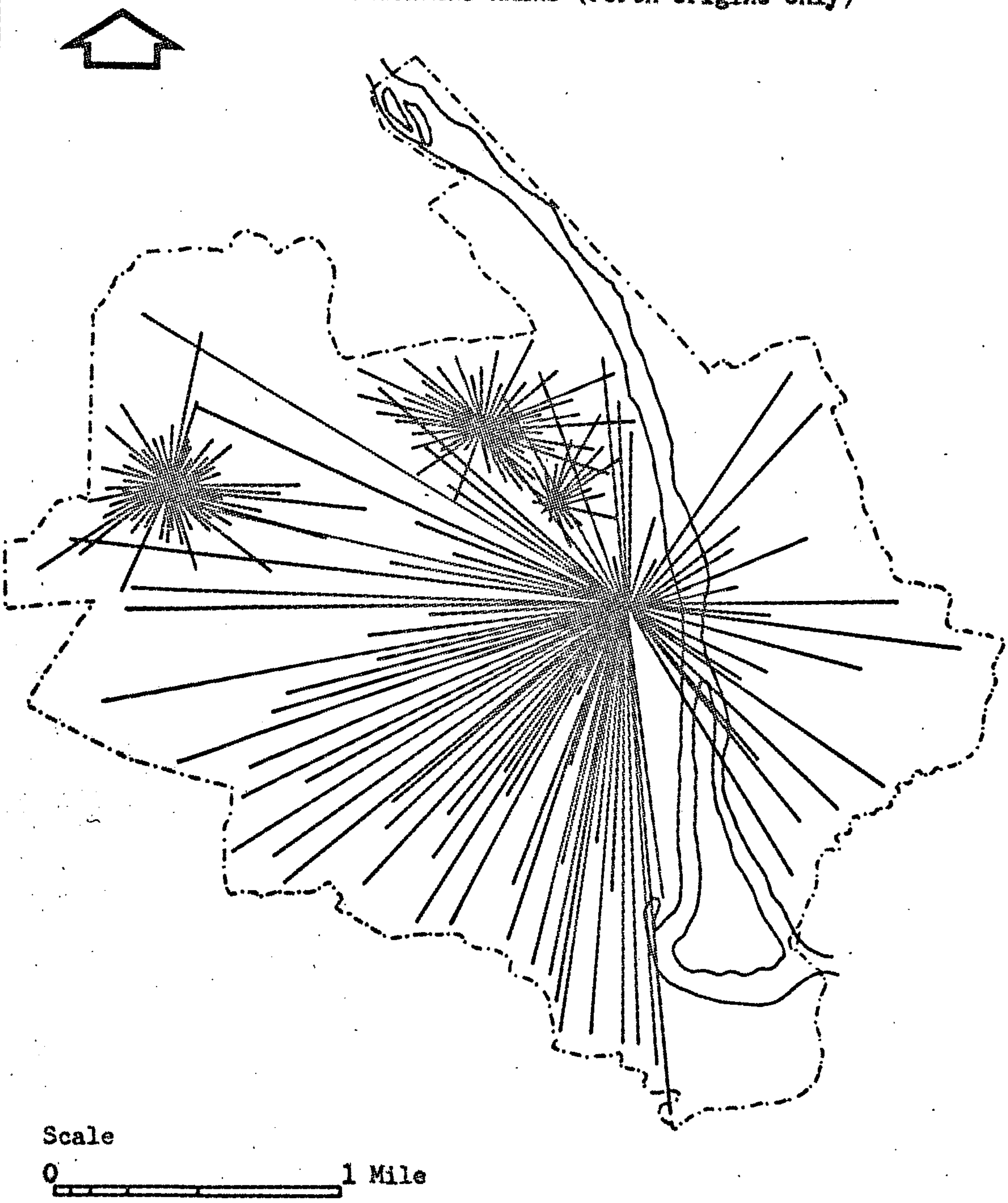
Table 1:1:9

Average Weekday Car and Person Trips (Purpose Shopping)

DESTINATION	CAR TRIPS	BUS TRIPS	PERSON TRIPS
Central Area	1,800	4,903	16,811
Zone 11	54	71	816
Zone 17	31	34	396
Zone 21	56	51	912
All Perth	2,321	6,008	24,543

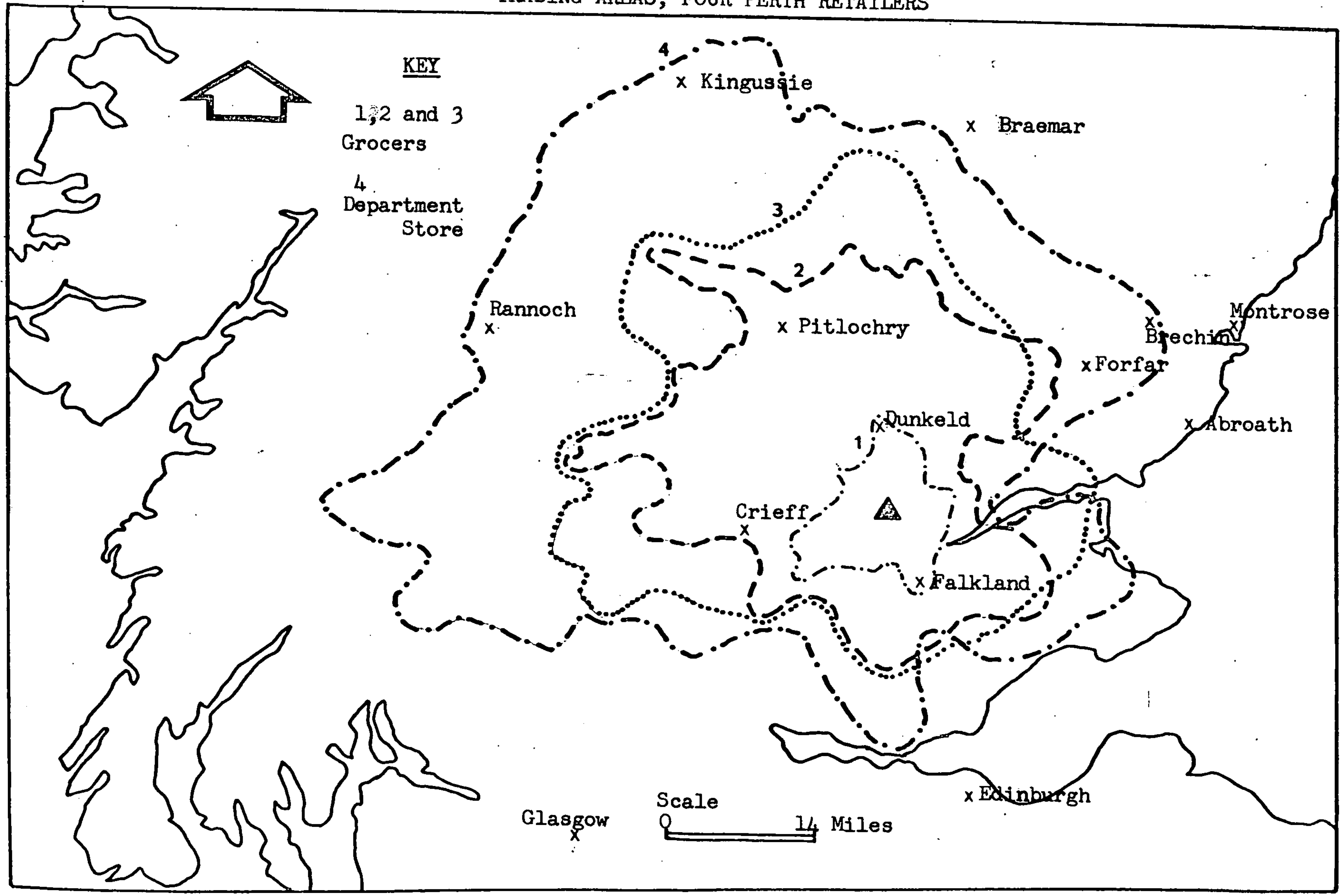
MAP 1:1:1

STORE CATCHMENT AREAS (Perth origins only)



MAP 1:1:2

TRADING AREAS, FOUR PERTH RETAILERS



Having analysed the functional structure of the Perth retail pattern, the trip generation pattern can be better understood. The average daily person trip (Table 1:1:9) reflects the dominance of the C.B.D., range of facilities available, floor space, and distance. 68.5% of the person trips for shopping are made to the central area, though comparison with the turnover figures would seem to indicate a lower number of actual 'purchase trips'. 30% of the trips to the central shopping area are made by bus, 11% by car, in comparison to 25% and 9% for all Perth respectively. The person trips made to a suburban shopping area are predominantly made on foot (9% bus, 6% by car).

Person trips per square foot of floor space, reinforces this pattern (Table 1:1:10). It takes more floor space in the suburban areas to induce one shopping trip than in the central area, though the amount inducing one car trip or one employee trip is fairly constant. A generalised equation relating total trips to a shopping area to floor area (in convenience or shopping goods), distance, etc. was tested. The equations are rather simple and represent only approximations at analysing trip generation,[4] since they do not take into account parameters for turnover or consumer behaviour, this information was not available.

An attempt was made to relate total shopping trips per household to convenience and shopping goods facilities, but it was entirely non-significant by the 'F' and 't' tests. The correlation matrix is set out in Table 1:1:11, and the regression analysis for the two separate trip types in Table 1:1:12. Distance to the shopping facilities has only a weak effect, and is shown by the 't' statistic to be non-significant; the other variables tested,

(4) Other more sophisticated attempts to apply regression analysis include V.K. Russell 'The Relationship Between Income and Retail Sales in Local Areas' Journal of Marketing, Vol. 21, 1957 pp. 329-332; R. Ferber, 'Variations in Retail Sales between Cities' Journal of Marketing Vol. 22. 1958. pp. 295-303; D.L. Thompson 'Analysis of Retailing Potential in Metropolitan Areaa' Berkeley 1964; and T. Borton 'Trip Generation Characteristics of Retail Commercial Land Use' C.A.T.S. Research News Vol. 5, No. 4, Sept. 1963, pp. 10-16.

Table 1:1:10

Trip Generation Rates

AREA	TOTAL TRIPS	TRIPS/SQ.FT.F.S.	CAR TRIPS/F.S.	EMPLOYEE TRIPS
C. Area	16,811	24.3	227.4	142.1
Zone 6	191	13.9	236.1	78.2
Zone 8	266	14.4	235.8	104.0
Zone 10	562	14.2	231.3	101.4
Zone 11	816	15.1	229.2	150.3
Zones 12 &13	941	14.9	220.6	148.9
Zone 15	917	16.2	239.7	136.7
Zone 17	396	17.1	218.9	133.6
Zone 21	912	14.1	251.0	155.2

family size, car ownership, and socio-economic effect had little bearing on shopping trip generation. On the other hand, the facilities available, the range of goods and services, as measured by the amount of floor space, have a strong effect in the regression analysis, particularly with convenience goods shopping. An increase in the availability of 1000 square feet of convenience goods stores increased by 0.02 the number of shopping trips per household. The comparable figure for an increase of 1000 square feet of shopping goods space is 0.01 trips/household/day.

An alternative measure is the analysis of the local and central area, which combine convenience and shopping goods trips, though in different proportions. The results are set out in Tables 1:1:13 and 14. Certain areal characteristics seem to influence the choice between local and central shopping - the higher status areas make more use of the central area, which is partly accounted for by the comparative lack of retail facilities from some of these areas.

Again floor space appears to be the predominant explanatory variable, and the other parameters, including distance, have no significance. The results seem to indicate that an increase of 100 sq. feet of local shopping area would increase local trips by 0.24 trips daily, and 100 sq. feet in the

Table 1:1:11

Zero Order Correlation Matric. Convenience and Shopping Goods Trips

All Shopping Trips	Conven. Shop. Trips	Shop-ping Goods S. Trips	Dist. to Conv. Shops	Floor Space Conv. Goods	Dist. to S.Goods Shops	Floor S.S. Goods	Socio Econ. Status	Family Size	Car Owner
1.00									
0.56	1.00								
0.64	-0.28	1.00							
0.40	0.51	-0.01	1.00						
0.29	0.95	-0.54	0.44	1.00					
0.43	0.38	0.14	0.68	0.35	1.00				
-0.29	-0.95	0.54	-0.44	0.42	-0.35	1.00			
0.30	-0.16	0.50	0.40	-0.27	0.52	0.27	1.00		
0.50	0.44	0.17	0.42	0.38	0.49	-0.38	-0.11	1.00	
0.25	-0.08	0.36	0.43	-0.13	0.68	0.12	0.92	-0.03	1.00

Level of significance r = 0.49 at 0.01% level.

Table 1:1:12

Regression Analysis. Conveniences and Shopping Goods Trips

Constant		Distance	Floor Space	Socio Economic Status	Family Size	Car Ownership	r^2R^2
* 0.00645	 S.E. t.	0.04592 0.03970 1.16	0.000020 0.000001 9.21				0.91
* 0.01201			0.000014 0.000001 10.68				0.90
* -0.02053		0.00876 0.05379 0.16	0.000014 0.000001 7.97	0.00206 0.00131 1.56	0.01457 0.01513 0.96	-0.13130 0.09260 1.42	0.93
** -3.97700		0.06532 0.04150 1.57	0.000011 0.000003 2.83				0.41
** -3.09500			0.000009 0.000003 2.30				0.29
** -3.28500		-0.00859 0.07836 0.11	0.000009 0.000003 2.04	0.00449 0.00314 1.43	0.07530 0.04504 1.67	-0.18130 0.28680 0.63	0.63

* Convenience goods trips, distance to convenience goods stores, and convenience goods floor space.

** Shopping goods trips, distance to shopping goods stores, and shopping goods floor space.

Table 1:1:13

Zero Order Correlation Matrix. Suburban and Central Area Shopping Trips

Central Area Trips	Local Shop Trips	Dist-ance C.Area	Dist-ance Local	Floor Space C.Area	Floor Space Local	Density	Family Size	Car Owner	Socio Econ. Status
1.00									
-0.70	1.00								
0.20	-0.51	1.00							
-0.07	-0.03	0.04	1.00						
0.70	-0.98	0.50	0.03	1.00					
-0.70	0.90	-0.51	-0.03	-0.90	1.00				
-0.60	0.30	-0.21	-0.00	-0.32	0.29	1.00			
0.11	0.16	-0.07	0.02	-0.18	0.16	0.95	1.00		
0.36	-0.59	0.61	0.11	0.60	-0.59	-0.72	-0.51	1.00	
0.52	-0.70	0.40	0.18	0.71	-0.69	-0.72	-0.52	0.91	1.00

Level of significance r = 0.49 at 0.01% level.

Table 1:1:14

Regression Analysis. Local and Central Area Shopping Trips

Constant	Distance	Floor Space	Density	Family Size	Car Ownership	Socio Economic Status	r^2R^2
*	-1.8070	0.002128	16.03	-6.007	32.190	-0.1346	
-789.6	6.9410	0.000397	19.00	11.590	19.710	0.2307	0.98
	0.26	5.36	0.84	0.52	1.63	0.58	
*		0.002295					
-847.2		0.000231					0.93
		9.94					
**	0.5232	0.002371	-1.4840	0.8871	-0.7914	-0.0095	
482.0	0.3093	0.000139	0.8122	0.4864	0.5232	0.0079	0.98
	1.69	16.97	1.83	1.82	1.51	1.19	
		0.002394					
522.3		0.000089					0.94
		26.66					

** Local shopping, distance to local shopping area, local shopping floor space.

* Central area shopping, central area floor space, and distance to central area.

C.B.D. by 0.23 trips daily. The addition of turnover 'data' would be helpful, as noted earlier.

This statement that the addition of turnover 'data' might be a better parameter, is taken from the widespread studies of the Yale Bureau of Highway Traffic,[(5)] and the Transportation Centre, NorthwesternUniversity.[(6)] Significant relationships were noted in these studies between trip volumes and sales, and Dickey's model used with success the parameter 'sales per unit gross leasible area'. The concept of a non-economic consumer behaviour has not been applied to traffic studies in detail to date.

Despite these drawbacks this study has indicated that there is, statistically, a significant relationship between the number of trips attracted to a shopping area, and the facilities available at that area measured as square feet of floor space. In a small town such as Perth, the competition between areas is measurable not so much in distance terms, but in terms of what an area can offer compared to a competitor, both in the range of goods available, and in the existence of any price differential.

Analysing Table 1:1:10 slightly differently, the relationship between retail land use and trips indicated, can be summarised like this:

In the central area, 1,000 square feet of retail floor space induces, on average, 41.1 shopping trips,

4.4 vehicle trips,

and 7.0 employee trips.

In the suburban areas, 1,000 square feet of retail floor space induces, on average, 67.7 shopping trips,

4.2 vehicle trips

6.9 employee trips.

This trend was to some extent substantiated in the results of the regression analysis, bearing in mind the assumptions made.

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(5) D. Cleveland and E. Mueller, op. cit.
(6) J. Dickey 'A Model of the Maximum Generation of Traffic to Planned Shopping Centres' M.S. Thesis. Northwestern University, 1965.

1:2 Commercial Facilities: (b) The Central Business District

As the historical centre of the urban area from the standpoint of commerce and service activities, the central business district is the focal point of street traffic. The approximately radial pattern of many cities emphasises this dominance. The central area of towns has been studied from the point of view of travel patterns, habits, and congestion for some time. Amongst the early studies was that conducted by Eberle,[1] who surveyed twenty land use groups in ten business districts which included San Francisco, Long Beach, Los Angeles and Honolulu. He found that 60% of the customers in these towns were generated by the central area and the rest by nine surrounding districts. The proportion of the total generation was calculated for each land use class (2.9% banks 2.38%, filling stations 4.42%, hotels 1.82%[2]) but actual generation rates were not presented.

Since this time a number of general studies have taken place, the most notable of which is that by Harper and Edwards.[3] They pointed to a high correlation between the square footage of certain land uses and total person trips. They studied retail, service-office, and manufacturing warehousing in seven North American cities. Additional work on a simpler basis has occurred in both North America and Britain, particularly by local planning departments, but much of it remains unpublished.[4]

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(1) G.J. Eberle, 'The Retail Merchant's Interests in the Traffic Problem'. Traffic Quarterly, April 1951 pp. 115-130.

(2) Eberle, op. cit. Table 1 p. 116.

(3) BCS Harper & H.M. Edwards, 'A Study of the Generation of Person Trips by Areas in the C.B.D.', Kingston, Ontario. Report No. 9 Queen's University, May 1960, also reported in Highway Research Board Bulletin 253. 1960 pp. 44-61.

(4) E.M. Horwood, 'Center City Goods Movement: An Aspect of Congestion'. Highway Research Board Bulletin 203. 1958, pp. 76-98.
C.T. Jonassen, L.E. Wagner, and W.I. Watkins have separate articles in Highway Research Board Special Report No. 11, 1953, on parking and central areas, pp. 1-50, 51-90 and 91-112 respectively.
In Britain most of the work of the Department of Planning, Manchester University; The London County Council (as was); and the Surrey County Council, along these lines can be obtained only in unpublished mimeographed form.

A number of techniques were applied inthe Perth study to analyse trip generation structure within the central area including a follow up of the Harper and Edwards' method. Many of the simple relationships erected were reached deductively from existing traffic studies, or inductively from observed conditions.

Trips inducted to the central area were examined, by correlation and regression analysis, as a function of total C.B.D. floor space, and as a function of inhabitants and work places. The trip ends (arrivals, departures and both) were correlated with all land usages, for the peak hour and the off peak hour, for four travel modes, and for total trips.

The regression of floor space on trip induction took the simple linear form:

$$T = c + aS,$$

where T = trips (arrivals, departures, or both)

S = floor space, in thousands of square feet.

a = regression coefficient

and c = constant.

In Table 1:2:1 the average number of trips/1,000 square feet is calculated by $\frac{ET}{EF}$. The column headed $c/\bar{T}$ indicates the percentage contribution of the constant (c) to the average number of trips per district ($\bar{T}$). It is desirable for this ratio to approach zero. When it is zero the regression line passes through the origin point. The poorest correspondence in both the off peak and peak is found with vehicle trips, and the best with all trips. For the off peak hour, the arrivals and departures, taken separately, are about equally correlated to the floor area, with the exception of cycle trips. This could be expected, because in an off peak hour the numbers of arrivals and departures are nearly equal. The correlation coefficients for arrivals and departures are slightly higher.

Table 1:2.1

Regression of trips on total floor area

Means of Transport	Arrival or Departure	OFF PEAK No. of Trips /000 sq.ft.	OFF PEAK a	OFF PEAK c/$\bar{T}$	AFTERNOON PEAK (5) No. of Trips /000 sq.ft.	AFTERNOON PEAK (5) a	AFTERNOON PEAK (5) c/$\bar{T}$
Vehicle	a	1.1	0.23	0.20	1.6	0.37	0.21
	d	1.0	0.22	0.20	1.9	0.37	0.20
	a + d	2.1	0.45	0.21	3.5	0.75	0.21
Bus	a	1.3	0.35	0.12	2.1	0.61	0.12
	d	1.2	0.33	0.12	2.5	0.60	0.14
	a + d	1.5	0.69	0.12	4.6	1.21	0.13
Walk	a	1.8	0.48	0.13	2.8	0.80	0.11
	d	1.7	0.47	0.12	3.3	0.78	0.14
	a + d	3.5	0.95	0.12	6.1	1.58	0.13
Cycle	a	0.6	0.17	0.11	0.9	0.26	0.11
	d	0.5	0.14	0.16	1.0	0.24	0.13
	a + d	1.1	0.30	0.13	1.9	0.50	0.12
All Modes	a	4.9	1.69	0.10	7.4	2.61	0.09
	d	4.5	1.52	0.11	8.7	2.61	0.11
	a + d	9.4	3.57	0.14	16.4	5.21	0.10

For the afternoon peak, the separate correlations of floor area to arrivals and departures show a greater disparity. This is understandable too, since the number of arrivals is high and departures low when the C.B.D. is viewed as a dwelling area, whilst as a working area the reverse is true. Both arrivals and departures were correlated with the same floor area, so as good a correlation cannot be expected.

The correlation coefficient gives only a general indication of the association of trip production and floor area. The variation coefficient (ratio of the standard error of estimate to the mean), is a better measure of the estimating ability of the regression equation and shows the expected

(5) In Part I, a section was devoted to the Morning Peak; this afternoon peak is the reverse in flow terms, lasting from 3.30 to 6.30 p.m. Its greater length is due to the staggering of school leaving, industry office closure, and shop closure.

deviation. As seen in Table 1:2:3, the variation generally is lower when floor area is correlated to arrivals plus departures for each means of transport, and is lowest when correlated with arrivals plus departures for all means of transport together.

The regression coefficient indicates how many trips are produced by a given amount of floor area. The figures in the column under (a) in Table 1:2:1 indicates this ratio. An instability is caused by the constant (c). This constant can only be used for areas of 1,000 square feet, since this was the basic unit used in the calculation of the regression equations.

Although all the calculations reported in Table 1:2:1 are significant to the 1% level by the 'F' ratio, the coefficients of determination range from only 0.19 to 0.35. This indicates that although there is significant correlation between this particular breakdown of trip induction, the relationship with floor area is far from strong.

An attempt was made to carry this analysis further, but to substitute inhabitants and workers for floor area. A twofold correlation of trip production to inhabitants and workers was calculated, using the equation

$$T = c + a\,I + bW$$

in which
- T = trips
- C = constant
- a, b = regression coefficients
- I = inhabitants
- W = workers

In most cases, the relationship with inhabitants and workers was significant, but for vehicle trips to the 0.1% level, the relationship was significant only with workers. The results of these correlations are shown in Table 1:2:2 and 1:2:3. The terms $c/\bar{T}$ again shows the percentage contribution of the constant to the average number of trips per district.

Table 1:2:2

Regression of trips on workers

Means of Transport	Arrival and Departure	Off Peak			Afternoon Peak		
		a	b	$c/\bar{T}$	a	b	$c/\bar{T}$
Vehicle	a	.0022*	.1920	.26	.0012*	.2814	.43
	d	.0020*	.1775	.18	.0079*	.3282	.37
	a + d	.0041*	.3695	.22	.0067*	.6097	.41
Bus	a	.0487	.1931	.01	.0946	.2993	.22
	d	.0462	.1804	.12	.0774	.3582	.19
	a + d	.0948	.3735	.06	.1720	.6577	.21
Walk	a	.0679	.2635	.03	.1337	.3917	.17
	d	.0670	.2521	.13	.0953	.4773	.09
	a + d	.1349	.5156	.08	.2290	.8690	.13
Cycle	a	.0231	.0897	.21	.0411	.1238	.06
	d	.0173	.0796	.14	.0290	.1508	.21
	a + d	.0404	.1694	.17	.0701	.2746	.13
All Modes	a	.1625	1.0670	.09	.3032	1.5220	.18
	d	.1412	.9588	.16	.2002	1.8130	.22
	a + d	.3120	2.0690	.13	.5109	3.3370	.20

* = non significant.

In all cases the correlation coefficients and variation coefficients show that inhabitants and workers, or workers, are more closely related to trip production than is floor area. The coefficient of determination ranges from 0.79 to 0.87.

The regression coefficients are now more meaningful than for floor area because they are split into 'a' for inhabitants and 'b' for workers. The number of inhabitants appear to have no influence on vehicle arrivals or departures at any time (car ownership/dwelling in the C.B.D. is fairly low), and their influence in the other categories is on the

Table 1:2:3

Correlation of floor area inhabitants and workers to trip production.

Means of Transport	Arrival Or Departure	Off Peak: Correlation Coefficient: Floor Area	Off Peak: Correlation Coefficient: Workers and Inhab.	Off Peak: Variation Coefficient: Floor Area	Off Peak: Variation Coefficient: Workers and Inhabs.	Afternoon Peak: Correlation Coefficient: Floor Area	Afternoon Peak: Correlation Coefficient: Workers and Inhabs.	Afternoon Peak: Variation coefficient: Floor Area	Afternoon Peak: Variation coefficient: Workers and Inhabs.
Vehicle	a	.46	.92	.45	.21	.51	.93	.43	.25
	d	.46	.92	.44	.21	.43	.91	.42.	.19
	a + d	.46	.92	.44	.20	.47	.92	.43	.19
Bus	a	.52	.91	.39	.35	.54	.92	.39	.24
	d	.53	.90	.39	.37	.50	.90	.38	.24
	a + d	.52	.91	.39	.36	.49	.92	.35	.23
Walk	a	.52	.90	.47	.34	.52	.92	.39	.22
	d	.53	.92	.42	.19	.50	.89	.39	.20
	a + d	.52	.91	.43	.20	.50	.91	.37	.19
Cycle	a	.52	.91	.40	.21	.54	.92	.42	.19
	d	.53	.90	.36	.20	.49	.88	.43	.25
	a + d	.52	.89	.38	.20	.52	.91	.43	.19
All Modes	a	.54	.93	.35	.19	.54	.92	.35	.18
	d	.56	.93	.34	.17	.50	.90	.36	.21
	a + d	.60	.94	.29	.16	.52	.91	.32	.18

arrivals, the time of greatest influence being on arrivals in the peak hour. On the other hand the number of workers influences off peak arrivals, and greatly influences the number of departures.

As can be seen from the coefficients for arrivals plus departures for all means of transport, one worker contributes more to the number of trips than one inhabitant, both in the peak and off peak hour.

In this first attempt land use, measured by the number of workers and inhabitants, was more successful in regression than total floor space. Obviously the latter is too gross a term, and floor space needs breaking down into its most important components.

A computation was therefore undertaken to relate particular trips to particular measures of land use, actual industrial and retail floor space, for instance, was related to the number of goods vehicle and business trip ends at those central area land use sites. Using zonal averages however produced less satisfactory results than later analyses using more detailed data. Tables 1:2:4, 5 and 6 set out the results, utilising some function or measure of land use activity. The equations take the general form:

$$BT = \sum p + (1.5 \times j)$$

where BT = business trip

p = population

and j = jobs

so that the analysis was in the simple regression form.

The basic data chosen was floor space, population and employment, as before, but more specifically related to traffic inducing activities. In order to be sure that the structural data chosen led to the most reliable results, further regression analyses were carried out with more elaborate functions. As the tables show these attempts were not successful.

Business trips were most closely related to employment, retail floor space, and a function of those two and a population function. Goods trips were related to similar expressions, and in multiple regression to population plus employment in a non-functional relationship. This pattern was repeated in the regression of both trips on that functional data.

Retail floor space is dominant in this set of calculations, reflecting its overwhelming importance in the central area. Industrial floor space is present too, but its effect is swamped by the consideration of all goods and business trips.

Table 1:2:4

Business trip ends, Central Area, related to various combinations of data.

DATA	a.	b.	s	r^2
Population	0.4075	270.9	0.2288	.2839
Jobs	0.5439	77.36	0.0625	.9044
Population + (1.5 x Jobs)	0.2895	35.13	0.0343	.8993
1.5 x Jobs	0.2176	77.36	0.0250	.9044
Industrial floor space	-0.0002	497.5	0.0014	.0017
Retail floor space	0.0055	249.9	0.0009	.8167
Jobs + Indust. f. space	-0.0003	496.3	0.0014	.0012
Jobs + Retail f. space	0.0056	236.4	0.0008	.8500
Population + (300 x R.F.S.)	0.00018	250.0	0.00003	.8166
Population + (100 x R.F.S.)	0.00006	249.9	0.00001	.8167
Population - (300 x R.F.S.)	0.00002	250.0	0.00001	.8166

a = regression coefficient

b = constant

s = standard deviation

r^2 = coefficient of determination

Table 1:2:7 persues the land use/floor space/traffic generation relationship further. This data is a straight-relationship between area and traffic recorded at various C.B.D. locations. They are general guides, since they represent only an untested sample of businesses, and hence only the broadest indications can be obtained. One striking relationship is the markedly higher rates of good vehicle trip generationamong the retail and office land uses in general compared with the lower figures for storage and industrial usage, which reflects a differing intensity of land use.

Table 1:2:5

Goods Trip Ends, Central Area, related to various combinations of data.

Data	a	b	s	r^2
Population	.3426	159.3	.1303	.4634
Population + (1.5 x jobs)	.1949	37.28	.0172	.9413
Jobs	.3562	73.24	.0429	.8959
1.5 X jobs	.1425	73.26	.0172	.8958
Industrial floor space	.00027	330.5	.00094	.0104
Retail floor space	.00354	189.9	.00068	.7716
Jobs + Retail floor space	.00358	182.1	.00064	.7953
Population + (300 x R.F.S.)	.000011	190.0	.000002	.7715
Population + (100 x R.F.S.)	.000035	189.9	.000006	.7716
Population - (300 x R.F.S.)	.000018	190.0	.000002	.7714
Population + jobs (multiple regression)	.1463 .3003	34.81	.0432 .0323	.9606

a = regression coefficient

b = constant

s = standard deviation

r^2 = coefficient of determination

Table 1:2:6

Business + Goods Trip ends, related to various combinations of data

Data	a	b	s	r^2
Population + (1.5 x jobs)	0.4845	72.41	0.0473	0.9290
Population + (300 x R.F.S.)	0.00003	440.0	0.00001	0.8100
Jobs	0.9002	150.6	0.0977	0.9139
1.5 x Jobs	0.3601	150.6	0.0391	0.9139
Retail floor space	0.0091	439.8	0.0004	0.8101
Jobs + Retail floor space	0.0092	418.5	0.0004	0.8400

Table 1:2:7

Goods trips in relation to land use (C.B.D.)

	Goods Trips/Week 1,000 sq.feet
Convenience Goods Shops	47.4
Restaurants, cafes	10.8
Public houses	1.8
Shopping Goods (draper, outfitters)	4.2
Shopping Goods (consumer durables)	53.5
Dry cleaners	70.8
Motor cycles, components, accessories	9.8
Insurance offices	20.0
Accountants' offices	9.7
Professional services	25.7
Company offices	11.2
Central and local government	13.6
Business services and agencies	11.5
Miscellaneous	17.1
Libraries	13.7
Hospitals	13.2
Clubs, assembly halls, etc.	9.1
Manufacturing industry	4.7
Service industry	12.2
Wholesale warehouse	7.1
Storage warehouse or space	8.7
Open air storage	1.1

There seems to be some correlation between goods trips and floor areas, and bearing in mind the restrictions on the data collected for this very detailed land use breakdown, simple regression analyses were undertaken with the following results:

Convenience Goods

Weekly Goods trips = -0.6472 + 0.006075F

$r^2 = 0.98$

$t = 29.01$

where, F = floor space

Restaurants, cafes, public houses

WGT = 41.06 + 0.000339F

$r^2 = 0.27$

$t = 2.71$

Professional offices

WGT = -1.823 + 0.002317F

$r^2 = 0.96$

$t = 30.73$

Central and Local Government Offices

WGT = 3.810 + 0.000447F

$r^2 = 0.87$

$t = 9.37$

Service Industry

WGT = 8.937 + 0.000616F

$r^2 = 61$

$t = 16.16$

Manufacturing Industry

WGT = 11.078 + 0.000511F

$r^2 = 42$

$t = 7.10$

Storage space

$WGT = 5.113 + 0.000203F$

$r^2 = 0.58$

$t = 4.43$

Wholesale, warehouse

$WGT = 13.13 + 0.001288F$

$r^2 = 0.61$

$t = 5.91$

All central area non residential land uses (sample)

$WGT = 137.5 + 0.00104F$

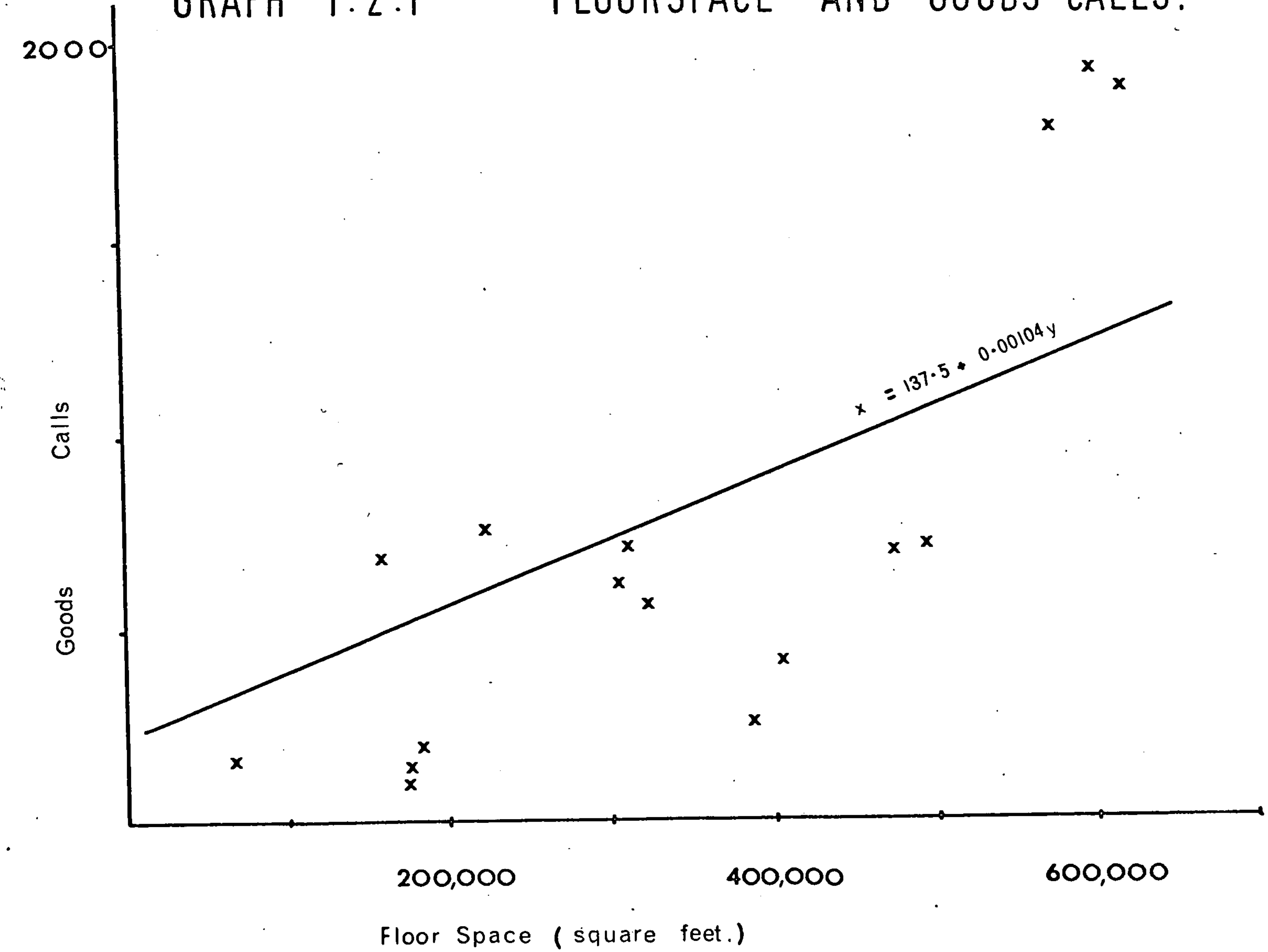
$r^2 = 0.36$

$t = 4.33$

Strong correlations between goods trips and floor area are found for retailing, professional offices, and government offices; weak relationships exist for restaurants, and all land uses (graph 1:2:1). With the exception of the latter two categories there is a moderate to strong positive correlation between goods vehicle calls and floor space, and that this correlation is significant to the 0.1% level in nearly all cases.

It seems then, that when specific land use activities are examined, a correlation between goods trips and floor areas occur, but that it is also evident that other factors also play a part. The evidence examined here is not entirely conclusive, but it may be that the users of large floor areas are necessarily more concerned about and skilled in, the organization not only of space within buildings, but also of vehicular movements between them, and that the smaller firms being relatively unconcerned about the use of large, expensive space or about the organization of goods transport would tend to be greater trip generators per unit of floor area.

GRAPH 1:2:1 FLOORSPACE AND GOODS CALLS.

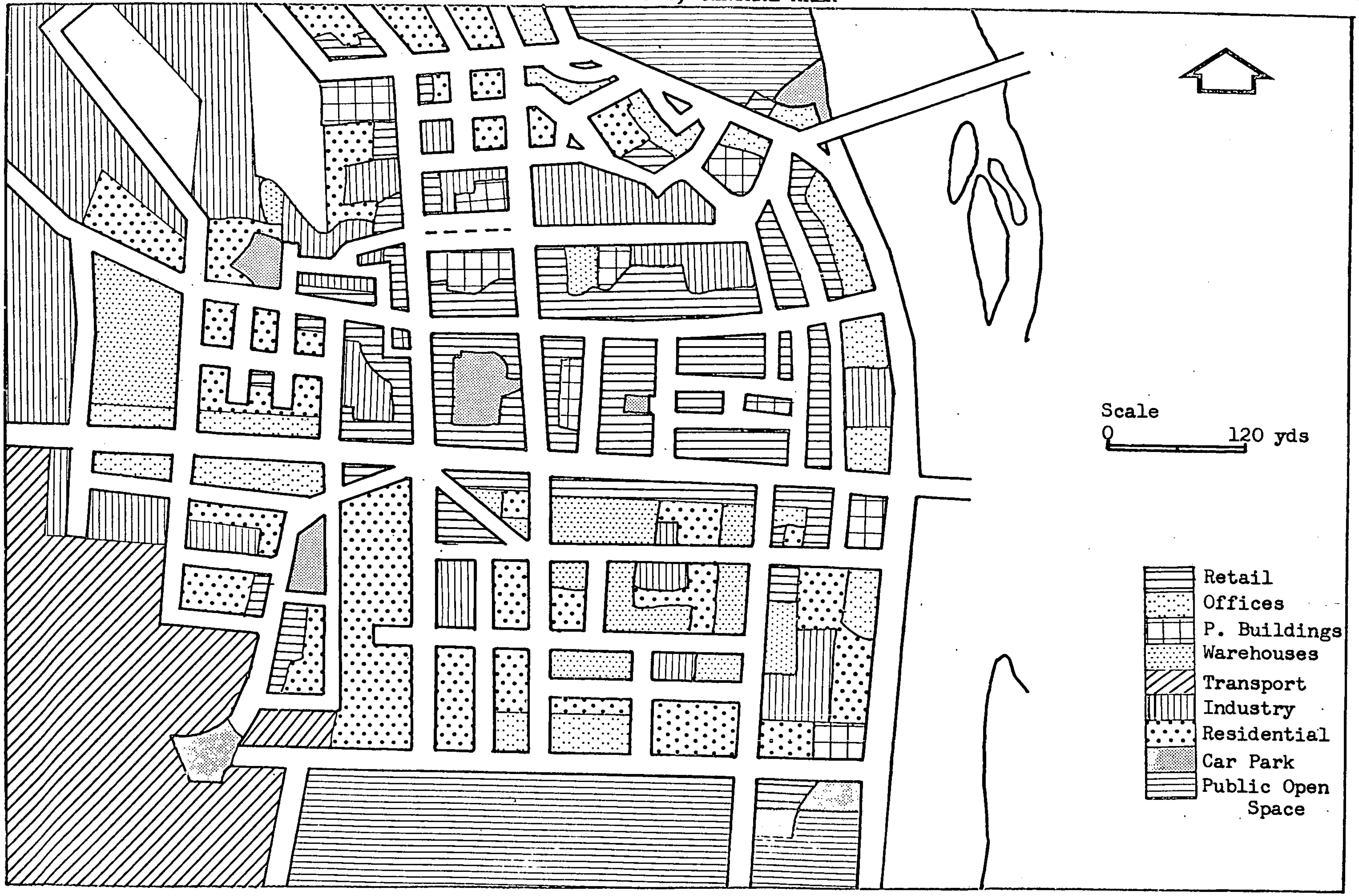


The smaller floor areas tend to be occupied by the quick-turnover retail trades which require more frequent trips for the replenishment of stocks and removal of empty boxes and crates, than do the wholesalers and storage firms occupying large spaces and often perhaps employing skilled transport managers and using their <u>own</u> transport more efficiently. Perhaps these reasons explain the underlying relationship analysed by the regression equations, whereby an addition of 1,000 square feet increases goods trips by 6.08 trips per week for retail land use, 2.31 for offices, 1.28 for wholesale, and 0.62 for industry.

The implications of this generation pattern are obvious from any land use map (Map 1:2:1) - the main thoroughfares are lined with premises whose activities are amongst the highest traffic generators whilst the "backland" is devoted to occupants who are relatively undemanding of loading and unloading time and space. High street preeminently, and the other main routes to a lesser extent, suffer considerably because their frontages are high trip generators, loading and unloading being done from the kerbside in the great majority of cases. A solution would be to service these buildings from a rear access and rear loading bays.

Additional calculations are set out in Graph 1:2:2, relating the average number of goods vehicle trip ends per 1,000 square feet of non residential space to the proportion of space in different land uses in the general business area, taken here at Zones 1-10. Six regression lines were calculated for the percentage of space in a given use against the average number of goods calls/1,000 sq.ft. of space. In each of the equations, the coefficient of 'y' indicates the increase or decrease in the average number of goods vehicles that could be attributed to an increase of 1% in a given land use. The constant term represents the average number of 'calls' that could be expected if a given use did not exist. Thus as zero percentage of floor space in each use is approached, the number of 'calls' in the one reflects the amalgamated influence of the remaining uses. The constants vary, so that

MAP 1:2:1 LAND USE, CENTRAL AREA

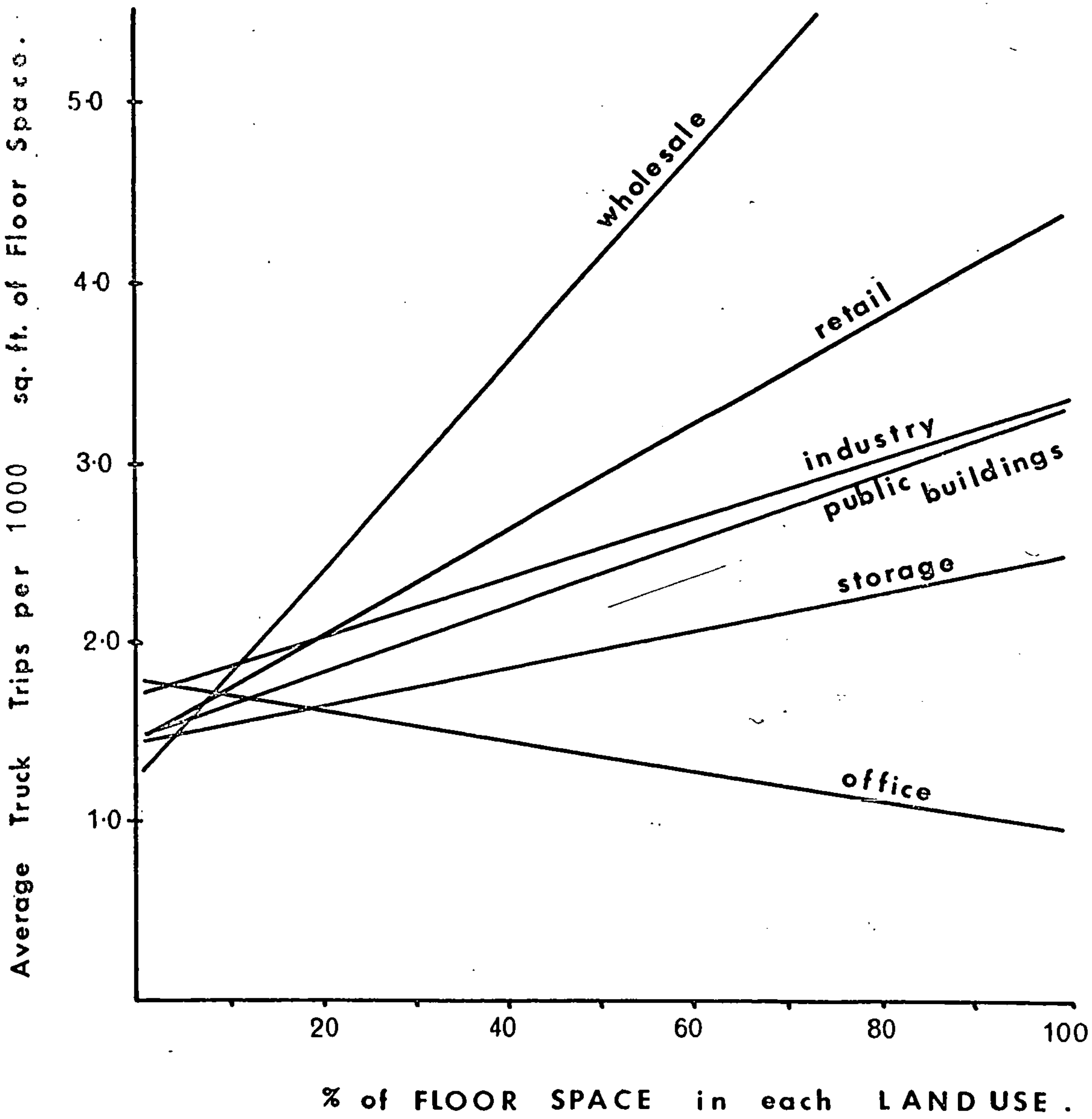


GRAPH 1:2:2

Regression equations.

Wholesale	$x = 1.214 + 0.061y$
Retail	$x = 1.509 + 0.026y$
Industry	$x = 1.746 + 0.014y$
Public Buildings	$x = 1.504 + 0.017y$
Storage	$x = 1.517 + 0.008y$
Office	$x = 1.806 - 0.009y$

GRAPH 1:2:2



Average Truck Trips per 1000 sq. ft. of Floor Space.
5·0
4·0
3·0
2·0
1·0
wholesale
retail
industry
public buildings
storage
office
20
40
60
80
100
% of FLOOR SPACE in each LAND USE.

not only do the different land uses exact differential influences, but also the land use mix of any five land uses can be influenced by the introduction of a sixth - industry, office and wholesaling in particular.

Parking

Involved in any consideration of a central area, and implicit in the study of induction or generation, whether of office, retail or industrial floor space, is the matter of parking. It is of course closely related to the intensity of trip generation.(6) Parking patterns like traffic flow, are dynamic and vary with the hour of day, day of the week, and month of the year, and are effected by the level and type of economy,business activity, size of city, capacity and location of parking facilities, convenience and cost of parking, etc.(7)

The data utilised was obtained in a Parking Survey carried out in conjunction with the burgh of Perth's Surveyors Department.(8) Graph 1:2:3 indicates the duration a vehicle remains parked, in the central area on a weekday. It reveals that 70% of the vehicles park for 20 minutes or less, and 90% for less than one hour. Thus 90% of the parked vehicles can be equated with shopping, business and goods trips, and the remainder with longer shopping, business, work, and residential parking. Graph 1:2:4 indicates the number of vehicles parked at a particular time of day; the 800 vehicles parked at 8.0 a.m. represent the 'core' vehicles, representing residential, industrial and wholesale parking. Parking patterns for Zone 7 shown in Graph 1:2:5 again indicate that 90% of the vehicles park for one hour or less, and a very similar distribution is found through the day. It is notable that at peak hours, even though this is October, that all available parking spaces are fully utilised, leaving no excess for summer visitors.

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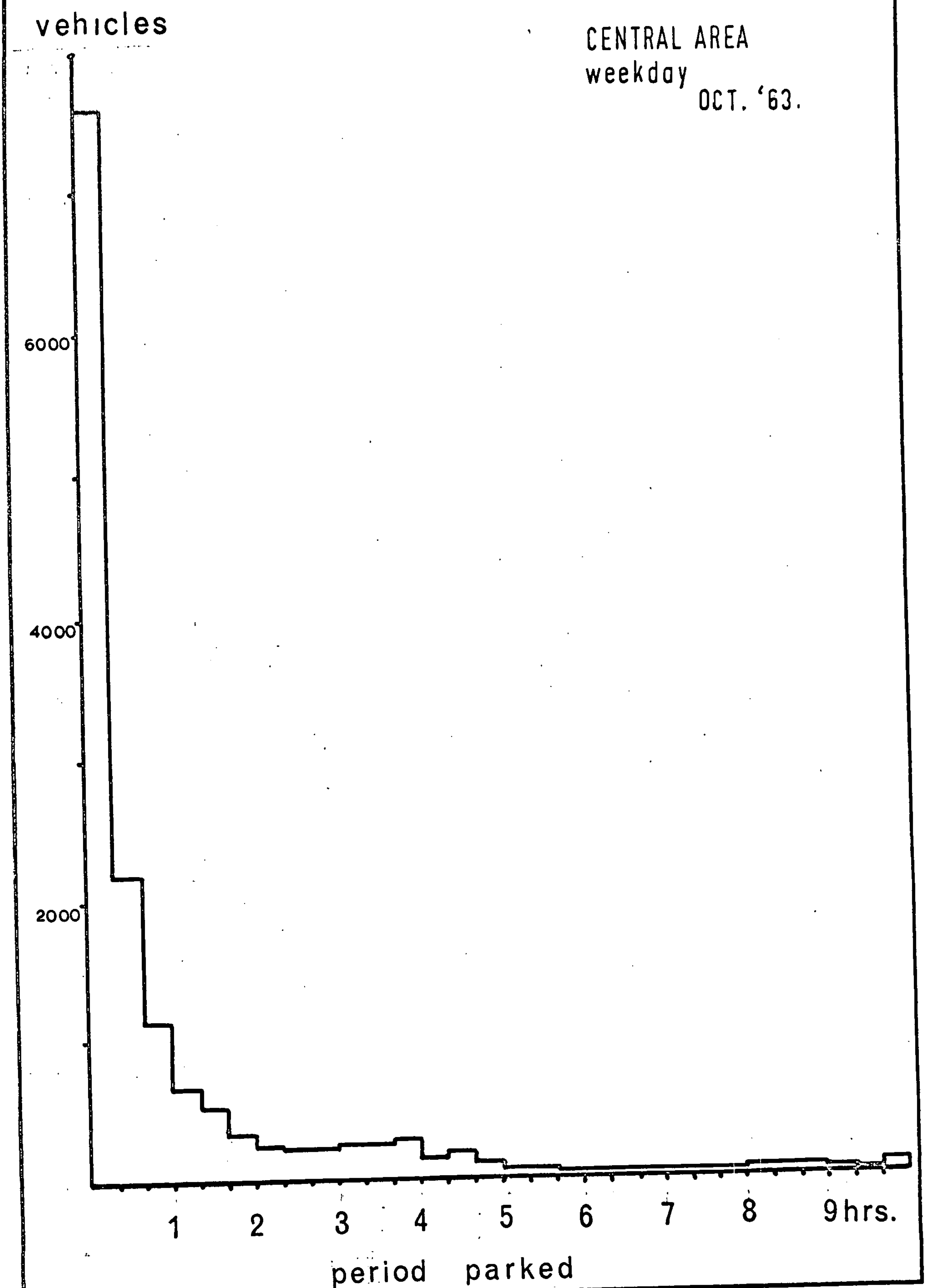
(6) A useful summary of parking in North American and European cities can be found in P.H. Bendtsen 'Town and Traffic in the Motor Age' Danish Technical Press. 1961. pp. 62-104; and R.H. Burrage and E.G. Mogren, 'Parking', Eno Foundation, Saugatuck, 1957.

(7) S.T. Hitchcock 'Influence of Population, Sales and Employment on Parking' Public Roads, Dec. 1953, pp. 248-258.

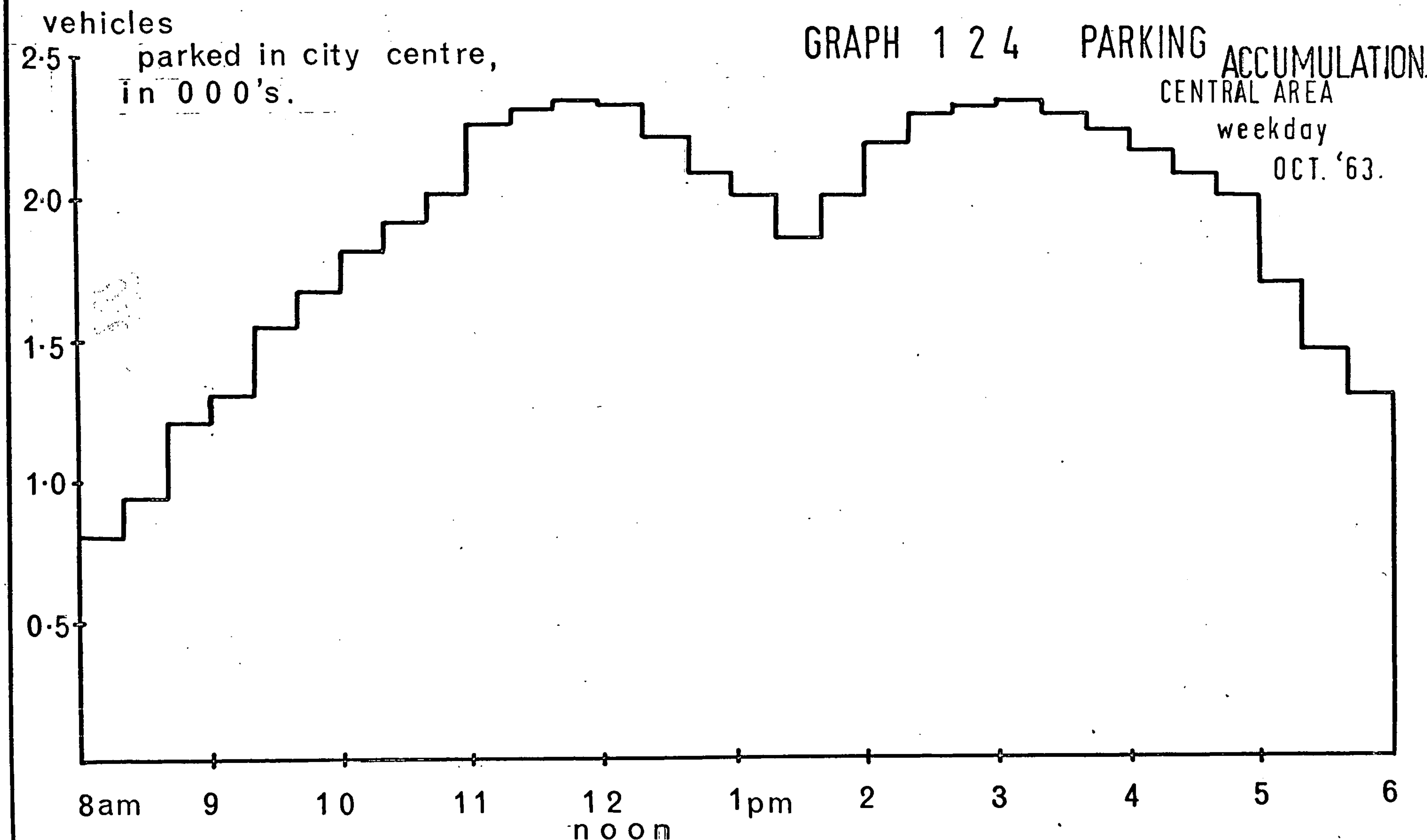
(8) The method utilised was that basically outlined by G. Charlesworth & H. Green 'Parking Surveys' Roads and Road Construction, May 1953.

GRAPH 1:2:3

PARKING DURATION

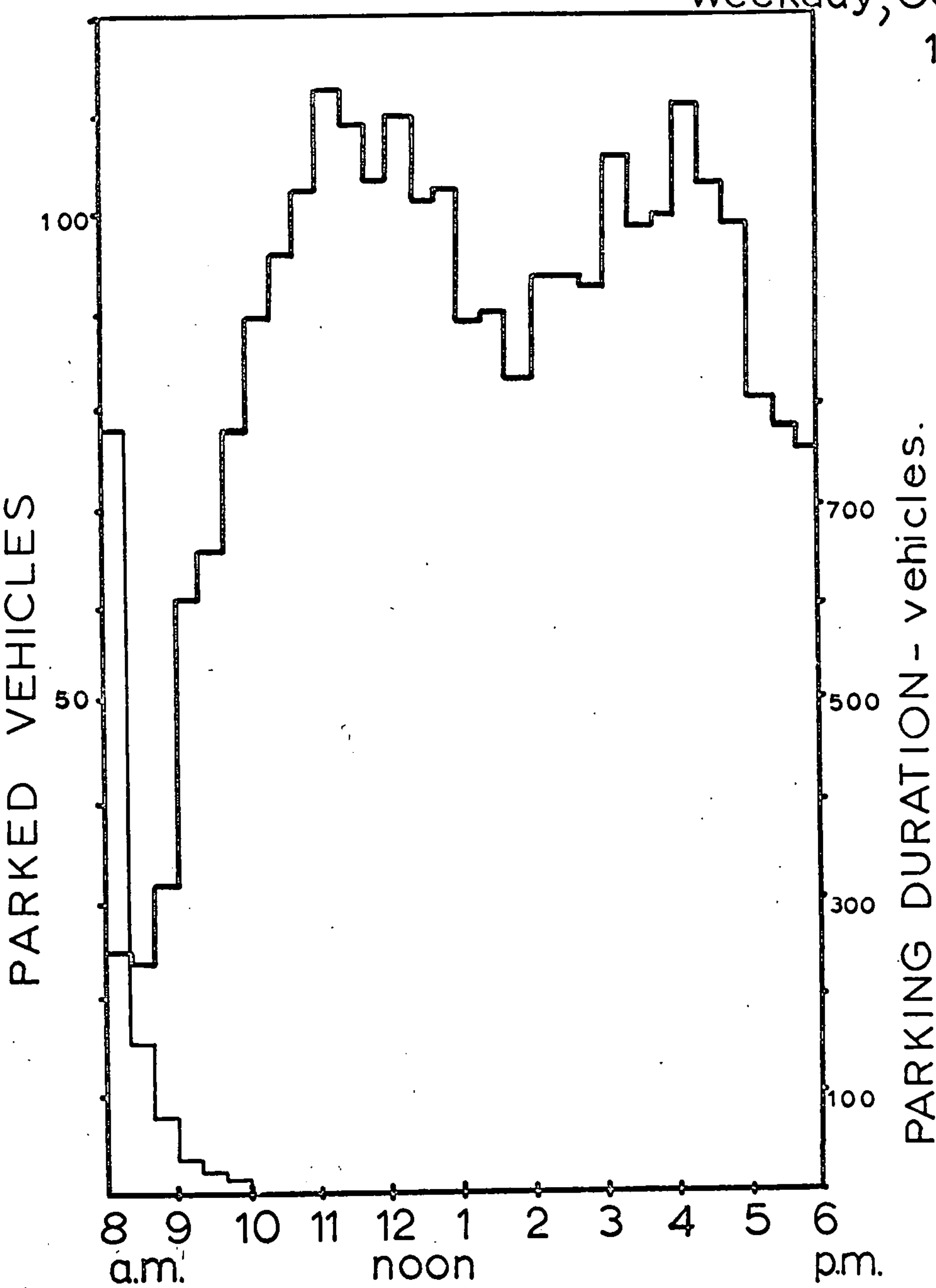


GRAPH 1 2 4 PARKING ACCUMULATION.



GRAPH 1:2:5

PARKING ACCUMULATION, zone 7, weekday, October 1963.



It was stated earlier that there was a relationship between parking accumulation[9] and land use, or some function of land use, and this was tested statistically, in a series of regression analyses, of the simple form

$$X = C + Ya + Zb$$

where X = parking accumulation

Y = parking spaces) or alternative measures

Z = floor space)

c = constant

a, b = regression coefficients

$$X = -19.39 + 0.5404\,\underline{Y} + 0.000307\underline{Z} \qquad r^2\ 0.9812$$

$$t\ 5.21 \text{ and } 3.13$$

This form was significant at the 10 and 5% levels by Snedecor's 'F' test. The eliminated form at the 1% and 0.1% levels was:

$$X = -6.194 + 0.000770\underline{Z} \qquad r^2\ .9084$$

$$t\ 8.91$$

For every 1,000 square feet of non residential floor space, there is a parking accumulation of 0.77 vehicles. Or put another way, 1,000 sq. ft. of non residential floor space generates 0.77 vehicle calls (Graph 1:2:6). To break this down further, parking accumulation was correlated with retail, office, and service floor space, with the following results:-

$$x = 116.6 + 0.00179\ Z \text{ retail} \qquad r^2\ 0.53$$

$$t\ 3.02$$

$$x = 155.6 + 0.00223\ Z \text{ office} \qquad r^2\ 0.33$$

$$t\ 1.92$$

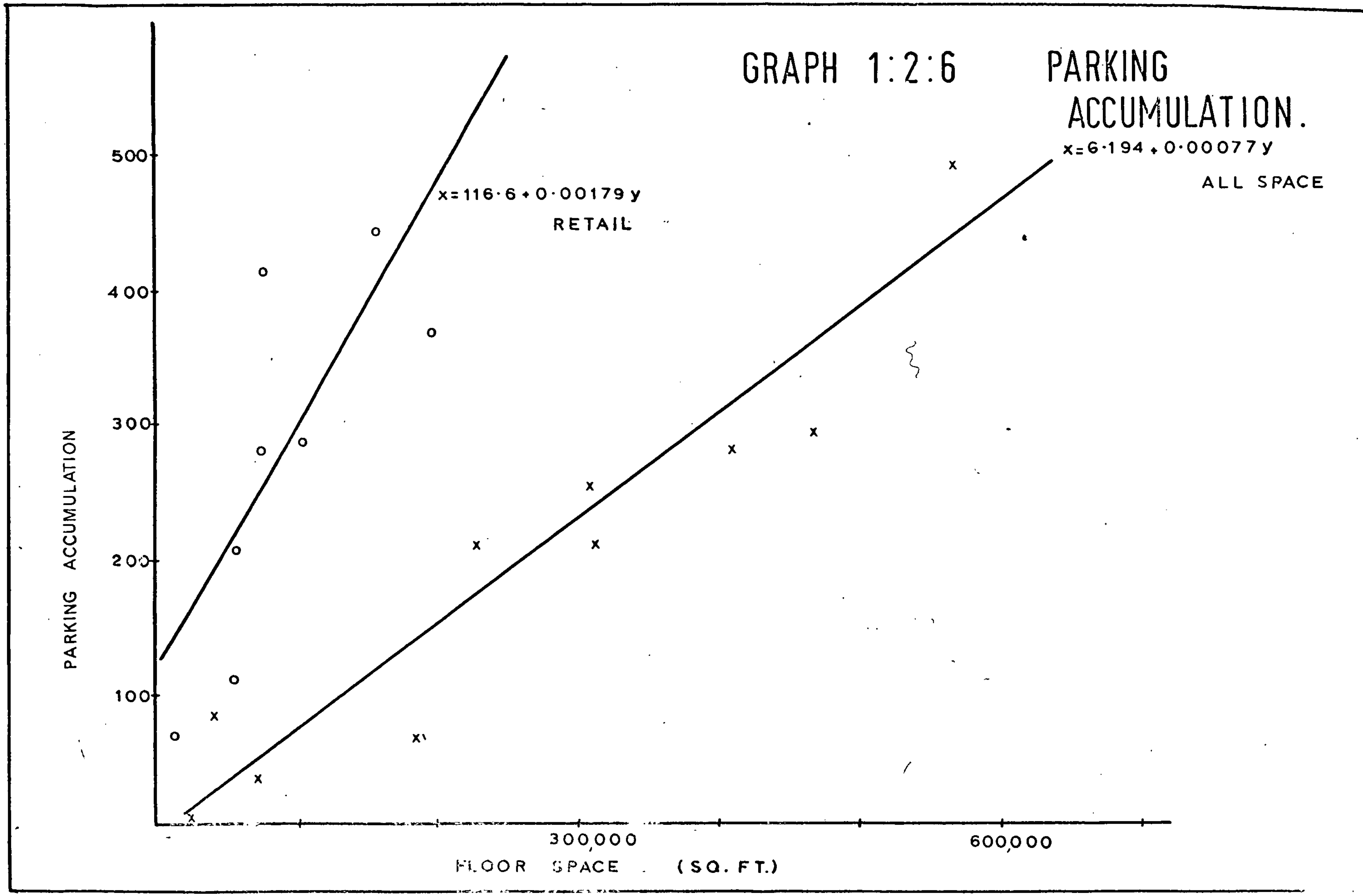
$$x = 157.2 + 0.00078\ Z \text{ service} \qquad r^2\ 0.05$$

$$t\ 0.66$$

---

(9) The number of vehicles parked at a particular time is the accumulation at that time. The average parking accumulation is the average of the volumes parked at 20 minute intervals from 8.0 a.m. to 6.0 p.m.

GRAPH 1:2:6 PARKING ACCUMULATION.



The last two are non significant but 1,000 square feet of retail floor space induces 1.79 parked vehicles (in parking accumulation terms), a correlation shown in Graph 1:2:6. Further tested relationships are set out in Table 1:2:8.

Table 1:2:8

Parking Accumulation

Constant	Parking Spaces	Inbound Cordon Count.	Employment	Total Floor Space	Population	r^2R^2
-10.65	0.7457 0.1426 5.23	-0.0092 0.0397 0.23	0.0434 0.0835 0.53			0.96
53.58	0.1037 0.0245 4.22					0.69
80.67			0.1537 0.0306 5.02		0.1294 0.0409 3.16	0.90
42.06			0.2005 0.0391 5.13			0.77
-19.10	0.5229 0.1238 4.22	0.00398 0.01241 0.32		0.00030 0.00010 2.84		0.98
-19.39	0.5404 0.1037 5.21			0.00031 0.00009 3.13		0.98
-3.418			0.0763 0.06535 1.17	0.00042 0.00031 1.32	0.0572 0.0670 0.85	0.93

Of these the most useful appears to be employment although when combined with total floor space, its 't' statistic falls and it is eliminated as non significant by the 'F' test. The findings here compare well with North Americal results, although in North America it is usual in planning new shopping facilities to allow between 7 and 15 car spaces/1,000 square feet of rentable retail floor area (sometimes £3,300 - £5,000 turnover/car space is used instead) as against just under 2 for Perth.[10]

Pedestrians

Another element in the total travel patterns with a central area are pedestrian trips.[11] In Perth these assume an importance both within and without the general business district, but the largest concentration is within the central area. Pedestrians were counted in two ways - at particular street junctions, and at individual sites. A combination of these gives an approximate measure of volume.

Diagram 1:2:1 and Map 1:2:2 show the general flow of pedestrian traffic. Diagram 1:2:1 gives some impression of the time variation at an important junction - the major flow down the High Street is in mid-afternoon, and flow up it is more evenly spread out. The most utilised routes are strongly correlated with those streets which have important shopping facilities - Kinnoull Street marks a boundary of less important shopping in Diagram 1:2:1 for instance. Total pedestrial movement was correlated with retail and office floor space, as the most important generators of bulk pedestrian movement, and a very strong significant correlation was obtained

$$PM = 349.9 + 0.0900R + 0.0276O \qquad r^2 \; 0.97$$

$$t \; 31.15 \text{ and } 6.55$$

where PM = total pedestrian movement

R = retail floor space

O = office floor space

significant to the 0.1% level.

(10) K.C. Welch 'Factors in Planning Regional Shopping Centres' Highway Research Board. 1953. Bulletin 79;
L.C. Pendley 'Comparative study of parking and buying habits of Department Store's Customers', Highway Research Board Special Report No. 11. C. 1956;
Hitchcock op. cit.
R.E. Schmidt and M.E. Campbell 'Highway Traffic Estimation' Eno Foundation, Saugatuck 1956. pp. 105-117.

(11) One of the few papers on pedestrial volumes is that by W.C. Hayhurst, 'A Survey of Pedestrian Trips in the Chicago Central Area'. C.A.T.S. Research News. Vol 6 No 4 1964. pp. 14-16.

MAP 1:2:2

PEDESTRIAN FLOW: CENTRAL AREA, WEEKDAY 8 a.m. - 6 p.m.

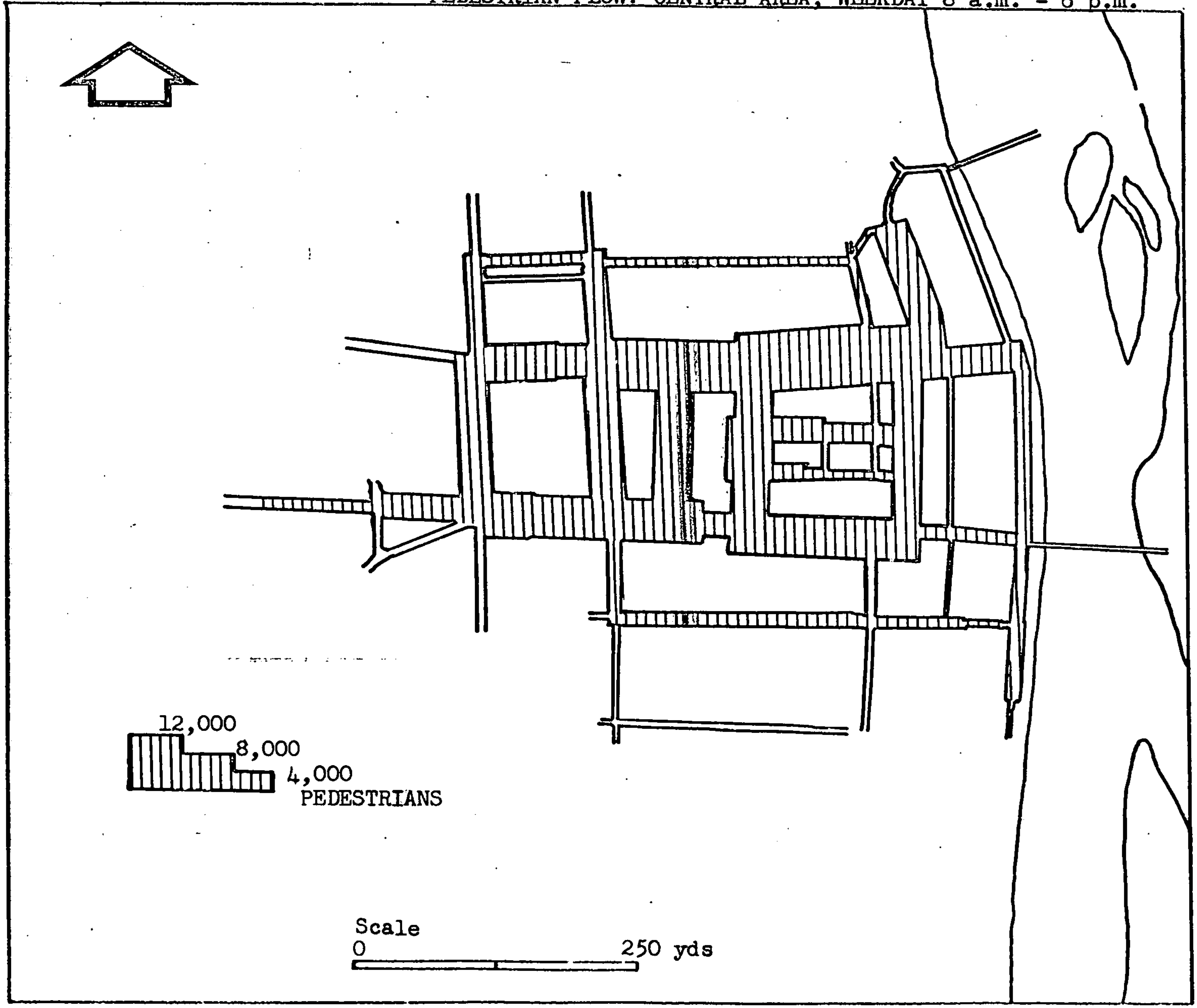
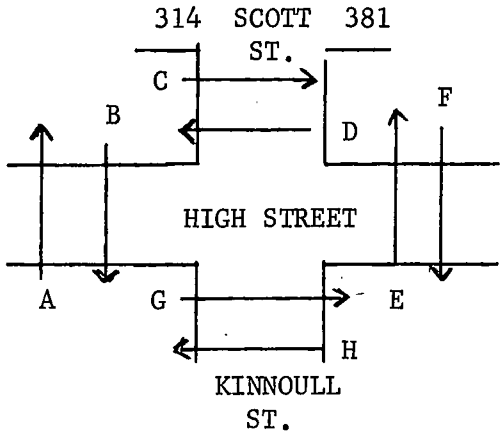


Diagram 1:2:1

Pedestrian Count. Weekday, May, 1964.

		C	D
8-9.0	a.m.	93	255
12-1	p.m.	295	343
1-2	p.m.	328	528
4-5	p.m.	444	447
5-6	p.m.	401	331
TOTAL		1571	1904
Average		314	381

A	B
288	180
378	419
452	487
411	457
431	577
1960	2120
392	424



E	F
101	125
149	138
162	211
190	195
237	231
839	900
168	180

	G	H
	150	291
	331	302
	386	440
	429	418
	417	358
	1713	1809
av.	343	362

Having analysed a number of factors in this general way - total trips, business trips, goods vehicle 'calls', parking accumulation and pedestrian movement[12] - a sample of locations was studied in detail to assess actual patterns of movement building by building, and use by use.

(12) Work trips are examined in detail in Section II of this Part.

Information was gathered by observation, traffic counts, examination of vehicle log sheets, and interview. Table 1:2:9 indicates the number and type of establishments used.

The total traffic inducted is made up of a number of components according to the source of generation:-

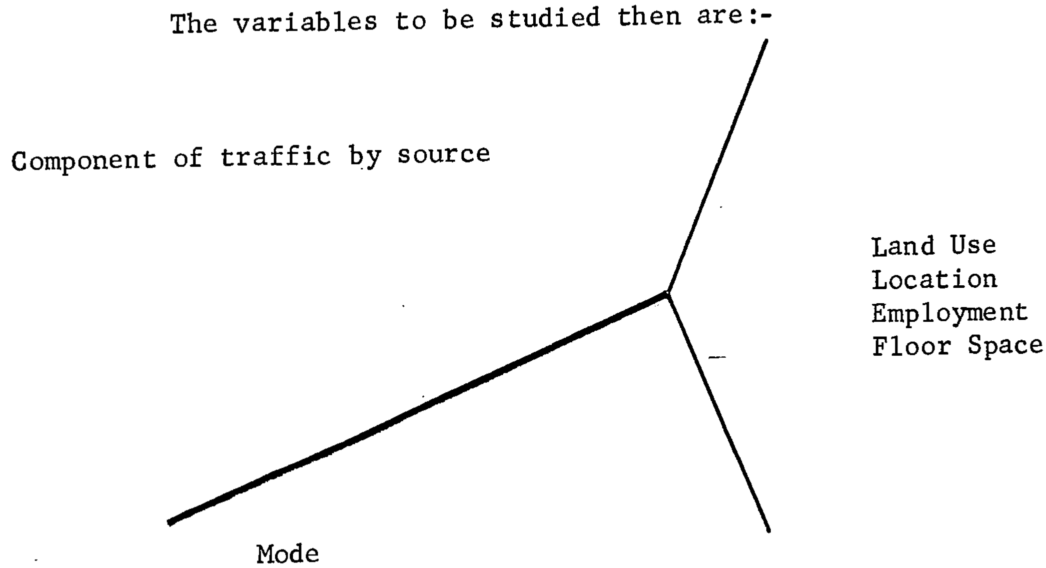
(i) Traffic attracted to the premises by the employees travelling to work by various modes of transport.

(ii) Traffic generated by the premises itself - the firm's own vehicles in the case of a warehouse.

(iii) Visitor calls - shoppers, etc.

(iv) Traffic inducted to service the building, delivered or collected goods, etc.

The variables to be studied then are:-



The proportion of total movement generated by the components, listed above, within the sample firms studied is shown in Table 1:2:9. Employees (component 1) account for the largest proportion of traffic in industry and offices, and component 3, visitors call, account for the greatest proportion of retail traffic. Commercial and wholesale land uses are sites for intensive goods vehicle movements.

Table 1:2:9 in %s

USE GROUP	COMPONENT (1) EMPLOYEES	(2) OWN VEH.	(3) VISITORS	(4) GOODS
Offices	34.0	20.1	29.2	15.7
Industry	29.2	19.3	16.2	35.2
Commerce	15.3	10.1	25.3	49.5
Wholesale	11.6	23.4	27.2	37.8
Shops	7.0	1.0	90.5	1.5

Table 1:2:10

Trips / 1,000 square feet

USE GROUP	MOTOR CAR	PEDESTRIAN	LIGHT GOODS	HEAVY GOODS	TOTAL TRIPS
Office	2.13	10.62	10.10	1.10	23.95
Industry	1.36	7.29	4.41	1.50	14.56
Commerce	1.27	x	3.20	0.92	5.39
Wholesale	1.45	x	4.10	1.34	6.81
Shops	4.40	39.80	6.91	1.01	52.12

x = insufficient information.

Table 1:2:9 shows the modal division of trip arrivals for each use group. Although industrial and commercial premises have a high number of goods visits in relative and actual terms, these sites are surpassed in actual terms by retail establishments which have a high goods turnover (compare with earlier paragraphs). In total trip terms/1,000 square feet of floor space, shops and offices surpass all other use categories, largely because of the frequency of pedestrial callers.

An alternative measure of comparison is trips/employee, which is set out in Table 1:2:11, which earlier analyses have shown to have an importance almost comparable to floor space. The order of importance and proportions of the different trip modes is similar to that noted above. Shops induce twice the number of calls that offices do, four times the number that industry does, and almost ten times the number of calls to wholesalers.

Table 1:2:11

Trips / 100 Employees

USE GROUPS	CAR	PEDESTRIAN	GOODS VEHICLE	TOTAL
Office	5.63	31.30	22.30	59.23
Industry	3.91	21.16	17.73	42.08
Commerce	2.72	x	8.10	10.82
Wholesale	2.91	x	8.71	11.62
Shops	17.61	141.85	31.68	191.14

x = insufficient information

This survey does emphasise the considerable variations of traffic generation between five major use groups, although in judging these results the size of the sample must be borne in mind. Total traffic generated seems then to bear a strong relationship to land use measured by floor space and the number oemployed.

Considering the components of movements, the greatest variation is found in the third category, visits or customer calls, the largest source of generation atretail sites (90.5%) and the second largest at office (29.2%). Shops show a high proportion of under five minute calls, offices have the longest duration of calls, and shops the lowest number of calls from privatecars. For calls from light goods vehicles, commercial and wholesale premises have the longest calls, and shops again the shortest.

Obviously length of stay is as important as total calls in any assessment of parking accumulation. Much more thorough investigation is needed at this level before any overall conclusions can be brought, but this brief indicates some of the useful results that can be obtained.

It is instructive to compare these results with those obtained in Manchester andChicago, the only cities for which there is data collected on anything like a comparable basis.(13) In fact there is a great divergence between the results. In the category of offices the induction of person trips/unit area of floor space is about twice that in Chicago and four times as much as it is in Manchester. In retail shopping Manchester attracts about 7 times the number of people per unit of floor space compared to Perth, and about five times compared to Chicago. Much of the discrepancy may well be differing definitions, way of collecting and calculating data, although superficially they seem similar. I would hesitate to draw any conclusions from these comparisons.

Table 1:2:12

Floor space which induces ONE trip

LAND USE		EMPLOYEE TRIPS	CALLER TRIPS	PERSON TRIPS	GOODS VEHICLE TRIPS
OFFICE	Perth			41.7	454
	Manchester	72	97	42	466
Industry				68.5	860
		51			367
Retail				19.3	729
		102	12	11	1176
Wholesale				146.5	410
		182			346

(13) Chicago Area Transportation Study. Final report 3. Vol. 1959-1962. F.D.Medhurst 'Traffic Induced by Central Area Functions' Town Planning Review. Vol. 34, No. 1, April 1963. pp. 50-60.

Table 1:2:13

Floor Space/Trip

		CHICAGO	MANCHESTER	PERTH
Person Trip	Retail	63	11	19
	Office	108	42	42
Employee Trip	Industry	78	51	
	Wholesale	453	182	

Table 1:2:14

Perth Central Area. Floor Space and Person Destinations

ZONE	FLOOR SPACE 000's sq. ft.				Person Destinations (24 hours) Y	Estimated Person Destinations		% Error
	Office X_1	Retail X_2	Wholesale X_3	Industry X_4				
1	65.6	207.7	57.9	7.6	12573.0	12574.5	-0.005	0.09
2	10.2	14.6	2.2	200.0	2573.0	2630.4	-0.214	2.25
3	115.1	29.9	4.1	39.7	6100.0	5842.2	0.961	4.42
4	1.3	0.2	6.4	0	490.0	246.4	0.908	49.71
5	6.4	0	0	0	364.0	475.6	-0.416	30.77
6	64.8	58.2	69.2	54.9	4770.0	4939.7	-0.632	3.54
7	9.1	53.9	1.9	0	3209.0	3329.7	-0.450	3.74
8	60.5	6.3	1.4	0	2294.0	2625.3	-1.235	1.44
9	4.8	16.5	0	0	1315.0	1275.2	0.148	3.14
10	13.3	44.8	40.1	64.8	3114.0	2862.5	0.938	8.04

Estimating equation $Y = X_1 + X_2 + X_3 + X_4$

$$Y = 256.5 + 0.03398X_1 + 0.05156X_2 - 0.01101X_3 + 0.004122X_4$$

t	13.68	25.17	2.37	4.40

Standard error of estimate 268.18 person destinations

R^2 0.9869

Significant to the 0.1% 'F' significance level.

Finally as a summary, all C.B.D. trip ends were entered into regression calculations similar to those carried out by Harper and Edwards[14]. Table 1:12:14 sets out the first of the results, following exactly the method shown by Harper and Edwards. The results here are comparable. It had been intended to add service, public building and workshop floor space to the regression, but it was unnecessary (R^2 0.9869). The estimates assume that the only factors causing differences betweenthe zones are the differences in the amounts of the floor space of the four land uses types in use in the zones - this is not completely true, and the errors between the estimated and the actual numbers inducted gives an indication of how well this relationship represents the actual conditions. In practice the equation estimates the person destinations extremely well, the largest divergences occurring in small zones and those with little or no retail floor space. This calculation does establish then, within the limits set by all analyses of this type, a definite and strong relationship between trip ends and certain land use/floor areas in the central area. If all trips ends are related to non residential floor space, irrespective of use, the multiple coefficient of determination (R^2) is reduced to 0.6105, and the errors of estimate drastically increased in many cases (standard error of estimate = 2382.53 person destinations) as is shown in Table 1:2:15. The error between observed and predicted results increases greatly where office and retail space are well represented, and the gap is greatly reduced where wholesale land use makes up a great proportion of the total.

(14) Harper and Edwards, op. cit.

Table 1:2:15

Zones	% in land use in 4 land use categories				Error of Estimate	
	Office	Retail	Wholesale	Industrial	4 selected floor spaces	All floor space
1	19.6	60.8	17.0	2.6	-0.005	1.800
2	3.1	4.4	0.7	91.8	-0.214	-1.759
3	61.0	15.0	2.0	21.0	0.961	0.687
4	16.4	2.6	81.0	0	0.908	0.061
5	100.0	0	0	0	-0.416	0.129
6	26.3	23.3	28.2	22.2	-0.632	-0.501
7	14.1	97.1	2.9	0	-0.450	0.290
8	88.5	9.2	2.3	0	-1.235	-0.885
9	22.4	87.6	0	0	0.148	0.217
10	8.1	27.4	24.6	39.9	0.938	-0.045

Three other measures of trip ends in the C.B.D. were subjected to a similar analysis:

(1) All vehicle trip ends (expressed as 'passenger-car units')

(2) Journeys to work, mode vehicle (p.c.u.)

(3) Pedestrian callers,

with the following results (X_1, X_2, X_3 and X_4 as before):-

$$(1) = 175.1 + 0.01313X_1 + 0.01735X_2 - 0.00662X_3 + 0.001930X_4$$

t	7.03	11.27	1.90	2.62

$$R^2 = 0.9846$$

Standard error of estimate 201.63 vehicle destinations significant at the 10% level, eliminated at the 5, 1 and 0.1% levels to

$$(1) = 157.7 + 0.01267X_1 + 0.01545X_2 + 0.001811X_4$$

t	5.71	11.03	2.51

$$R^2 = 0.9548$$

Standard error of estimates = 241.55

$$(1) = 267.4 + 0.01231X_1 + 0.01516X_2$$

t	4.60	9.00	R^2 = 0.9080

significant at all levels.

$$(2) = -8.290 + 0.009183X_1 + 0.009362X_2 - 0.004857X_3 + 0.002496X_4$$

t	12.95	17.25	3.95	9.60
			R^2 0.9842	

significant to the 1% level, eliminated to

$$(2) = 124.9 + 0.008372X_1 + 0.007578X_2$$

t	3.29	4.73	R^2 0.8765

at the 0.1% significance level.

$$(3) = 91.29 + 0.01102X_1 + 0.02519X_2$$

t	11.96	43.42	R^2 0.9774

significant at all levels. The addition of X_3 and X_4 makes no difference in this calculation, as one would have expected from earlier analyses. Wholesale floor space was also of only modest significance in the calculation of all vehicle trip ends. All of these measures show an improved relationship over earlier attempts. In each case, person trips, vehicle trips, journeys to work by car, or pedestrian trips, an improved relationship is found when trip ends are correlated to specific land uses, in particular retail and office floor space, although this varies from zone to zone.

Within the general business district or central area, traffic generation and induction has been tested against various measures of land use. The undoubted relationship between the two functions is underlined by the results obtained. The results indicate that models or equations can be erected to estimate very closely known travel patterns, without necessarily understanding the full implications of such relationships.

1:3 Industry

Many studies of industrial facilities have been conducted in the past 10 years.(1) However, in only one case were detailed characteristics of production techniques investigated as to their effects upon employment intensity,(2) and usually groups of plants rather than individual establishments were considered. Normally, primary sources were used to determine (a) site location, (b) sites size, (c) ground floor area, and (d) number of employees.

The 'factory' the basic industrial unit is defined as 'a place within which persons are employed in manual labour in processes concerned with making an article or part of an outside; altering, repairing... or adapting an article for sale'.(3) Most 'factories' in Britain, as definted above, are small (Table 1:3:1), and if those employing 10 or less are excluded, nearly 75% employ less than 100 people. Employment is concentrated much more into the larger units, and almost as many people are employed in 'factories' with 500 plus employees as those with 11 to 500. In Perth however the smaller units predominate both relatively and actually.

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(1) D. Muncy 'Land for Industry - A Neglected Problem' Harvard Business Review Vol. 32, 1954 pp. 51-63.
D. Munch, 'Space for Industry' Urban Land Institute, Technical Bulletin 23, Washington, 1954.
B. Harris 'Industrial Land Facilities for Philadelphia' University of Pennsylvania Institute for Urban Studies, 1956.
W. Garrison et al ' A Study of Land Development Problems at Freeway Interchanges' Seattle, University of Washington, 1960.
E.J. Burtt 'Changing Labour Supply Characteristics along Route 128' Boston, Federal Bank of Boston, 1961.
D.F. Pegrum ' Urban Transportation and the location of Industry in Metropolitan Los Angeles' Los Angeles University of California Bureau of Business Research 1963.
T.E.H. Williams and J.C.R. Latchford 'Prediction of Traffic in Industrial Areas' series of five articles in Traffic Engineering and Control, Vol. 7 No.8 December 1965, pp.498-501, Vol.7 No.9 January 1966 pp.566-568; Vol.7, No.10 February 1966 pp.628-630; Vol.7 No.11 March 1966 pp.679-680, 685, Vol.7 No.12 April 1966 pp.735-737.

(2) C.D. Rogers and E.M. Horwood 'Measurement of Industrial Land Use Consumption by Major Industry Groups' Seattle, University of Washington Transportation Research Group 1961.

(3) Factory Act. 1937, Part 14 Section 151.

Table 1:3:1

Size of Manufacturing Units. Perth and U.K.[4]

AVERAGE NO. EMPLOYED	% OF ESTABLISHMENTS U.K.	PERTH	% OF PERSONS EMPLOYED U.K.	PERTH
11-99	73.7	92.5	20.5	63.1
100-499	21.6	6.5	32.2	26.3
500-999	2.7	1.0	13.5	10.6
1000-1999	1.3	0	13.2	0
2000+	0.7	0	20.6	0

An investigation was undertaken in Perth to persue the characteristics of 'factories' and their travel patterns. The floor space per worker was one of the parameters used, in simple and multiple regression. The results (Table 1:3:2) show the general consistency of this ratio within an 'industry' and the variation between industries. The same data was then analysed to see if the sex of the employee affected this relationship (Table 1:3:3) and although no improvement was noted within industries, a very significant overall equation was obtained. This data was then subjected to analysis for a third time (Table 1:3:4) relating a simple breakdown of employment types (professional, etc; skilled; semi- and unskilled) to floor space, and again an apparently significant overall equation for all'factories' was obtained.

Industries engaged in different processes require different types of workers, both by occupation type and by sex. This information is summarised in Table 1:3:5. The percentage of females employed in the 6 industrial types

(4) D.S.I.R. '<u>Factory Building Studies No.12</u>' : ' The Economics of Factory Building' H.M.S.O. 1962 p.3.

Table 1:3:2

Relationship between total employment and floor space

INDUSTRY	CONSTANT	REG. COEFF.	t_2	r^2
Cleaners & Dyers	2.438	0.0261	6.74	0.71
Electrical Engineers	17.119	0.0311	2.71	0.60
Metal Working, etc.	3.112	0.041	4.29	0.78
Textiles	4.327	0.0271	5.51	0.87
Transport	13.192	0.003	10.82	0.80
Distillers, etc.	2.371	0.026	5.21	0.68

Table 1:3:3

Relationship between total floor space and employment (by sex)

		REGRESSION COEFFICIENTS			
INDUSTRY	CONSTANT	MALE	FEMALE	t	R^2
Cleaners & Dyers	-1.170	0.2404	0.9868	3.75 8.40	0.71
Electrical Engineers	-2.161	0.2428	0.1014	3.79 3.55	0.58
Metal Working, etc.	-1.868	0.2022	0.0939	10.88 4.10	0.62
Textiles	-1.659	0.3992	0.9971	4.77 8.39	0.61
Transport	-1.117	0.9868	0.1321	6.72 3.19	0.72
Distillers, etc.	-1.879	0.2131	0.1327	3.71 3.62	0.61
All Industries	-2.990	1.1930	0.6030	10.83 7.92	0.89

Table 1:3:4

Relationship between floor space and employment

(by composition)

INDUSTRY	CONSTANT	t statistic GROUP (1)	(2)	(3)*	R^2
Cleaners and Dyers	-2.132	2.31	4.79	6.21	0.61
Electrical Engineers	3.672	3.12	9.31	7.12	0.59
Metal Workers, etc.	11.921	2.91	10.12	8.19	0.67
Textiles	10.321	4.21	5.12	7.32	0.63
Transport	-1.622	8.29	8.67	6.27	0.72
Distillers, etc.	7.912	2.63	8.32	5.42	0.83
All Industries	1.739	6.21	9.19	7.36	0.91

* Employment group (1) Administrators, clerical and technical staff

(2) Skilled and foreman (manual)

(3) Semi-skilled and unskilled (manual)

varies widely, the contrast being in particular between the metal workers, and the cleaners and dyers. All had however approximately the same overall employment composition - 2.7% administrators, managers, and professional staff; 5.5% clerical and technical staff; 53.5% skilled manual staff and foreman; and 38.3% partly skilled and unskilled staff, although an industry like cleaning and dying has a high proportion of only partly trained operators. Floor space per worker averages between 500 and 600 square feet, with the notable exception of metal working, where drop forging and so on utilise greater space per worker.

Table 1:3:5

INDUSTRY	Total Empl.	% Females	Floor Space Workers	EMPLOYMENT %(1)	%(2)	%(3)*
Cleaners and Dyers	776	74.9	542	10.2	20.3	69.5
Electrical Engineers	574	17.1	478	8.1	79.4	12.5
Metal Working, etc.	105	16.2	816	9.3	58.7	32.0
Textiles	478	45.6	511	8.6	84.3	9.1
Transport	2562	10.7	573	10.5	62.6	21.9
Distillers, etc.	365	44.6	598	6.3	55.0	38.7

* Definition as Table 1:3:4.

This latter measure is an industrial land use variable that reflects, for a certain type of 'factory' within each industry, the number and type of workers employed. However, within a particular industry one unit might have a floor space ratio different from the average due to overcrowding, special requirements of their industrial processes, new buildings or old inefficient buildings. This latter is true of some of the distilleries and dry cleaning units. The total floor space figures quoted in Table 1:3:5 are a summation of individual units and so include in fact a wide range of floor space ratios. Despite this, floor space proved to be statistically significant in many of the computations, and is a readily accessible measure. The relationship of generated traffic to floor space of these industrial sites proved tobe statistically very significant.

This generated or induced traffic was measured in a number of ways - total person trips, total vehicle trips, and private car trips. Person trips were subdivided for later analysis by modal choice.

The composition of traffic calling at the sites of the six industrial categories studied reflects the importance of the daily ebb and flow of employees. Although there were variations, the daily work journey accounted for more than half of the total daily flow, and the peak hour traffic varied from 20 to 40% of the total daily flow. Shift systems, found in Perth mainly in the textile industry, played a part in determining the size of a particular peak hour, and the industrial activity of different industries contributed varying amounts of non-journey-to-work traffic. The average vehicular composition of the total daily flow of all industry was 35.7% lorries, 48.9% cars and light vans and 15.4% motor and pedal cycles.

Table 1:3:6

Relationship of peak hour to total daily flow, (all trips/ends), percentages

Industry	Work Journey in One direction/total traffic generated	Peak Hour flow in one direction/total daily flow
Cleaners & Dyers	61.2	39.8
Electrical Engineers	63.1	41.3
Metal Workers, etc.	70.8	40.6
Textiles	60.3	22.5
Transport	0	31.2
Distillers, etc.	52.4	43.7

The traffic generated by all industries indicated that the peak was about 35% of the total daily flow, the variation being accounted for by shift systems, amount of goods vehicle traffic, which arise from varying industrial processes.

The relationship between traffic generated and floor space is set out in Table 1:3:7. Because the total for all Perth is made up of a large number of small units, which are proportionally greater traffic generators than large units, the 'constant' is greater than that for selected individual industrial groups. The values of the constant varies amongst the industrial groups because of varying floor space ratios and employment composition. Graphs 1:3:1 and 1:3:2 show the relationship for one industry and all industries. Several of the industrial groups showed no significant relationship in this analysis, because of the variation in conditions amongst the units.

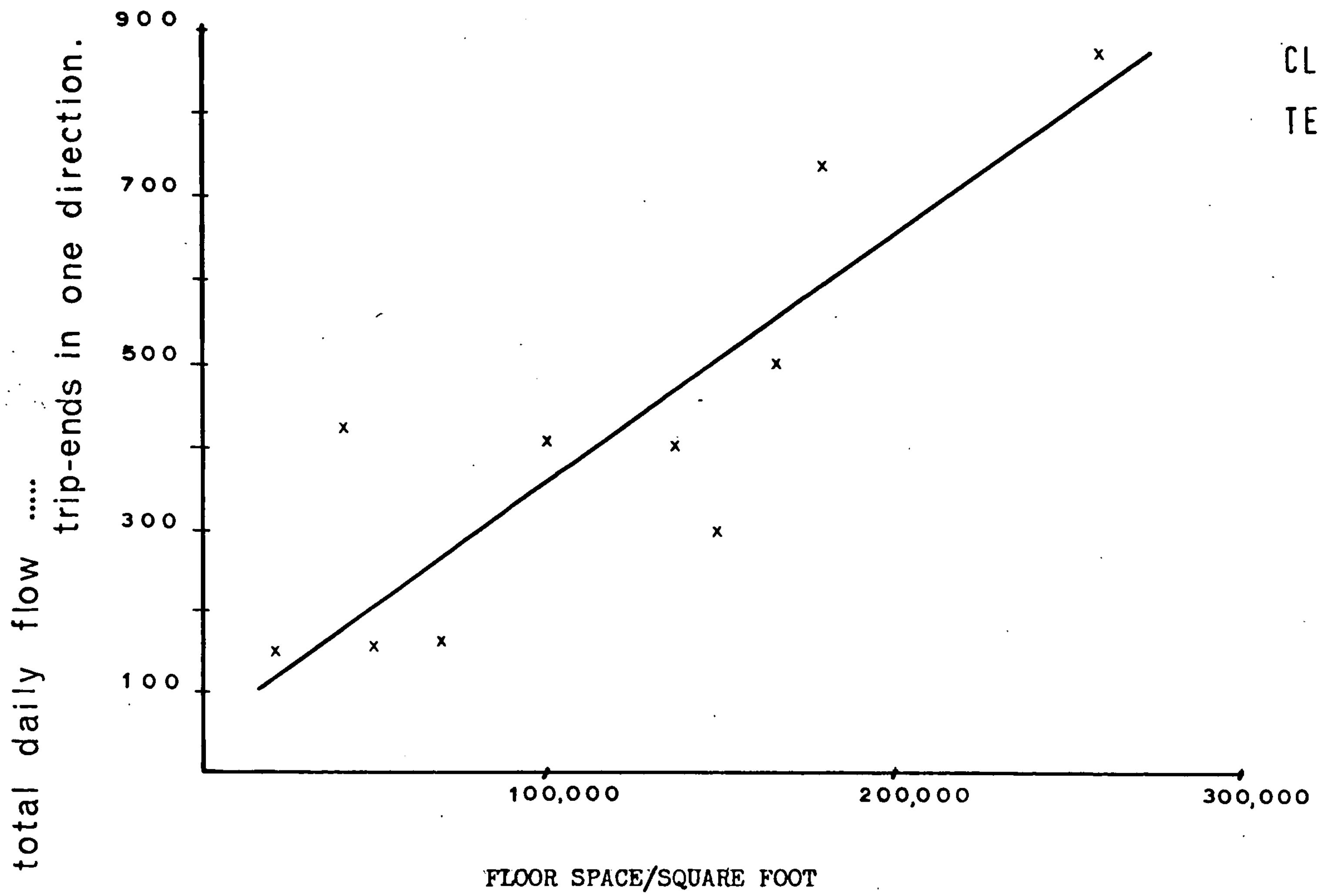
As has been shown in earlier sections, a very powerful alternative measure to floor space is total employment. The number of people employed obviously has a strong relationship to the site's ability toattract journeys to work, and is also related in part to its attraction for visitors and goods vehicles. It is a variable that can be cross classified by sex and occupational type, which improves the statistical significance of employment as a regression parameter.

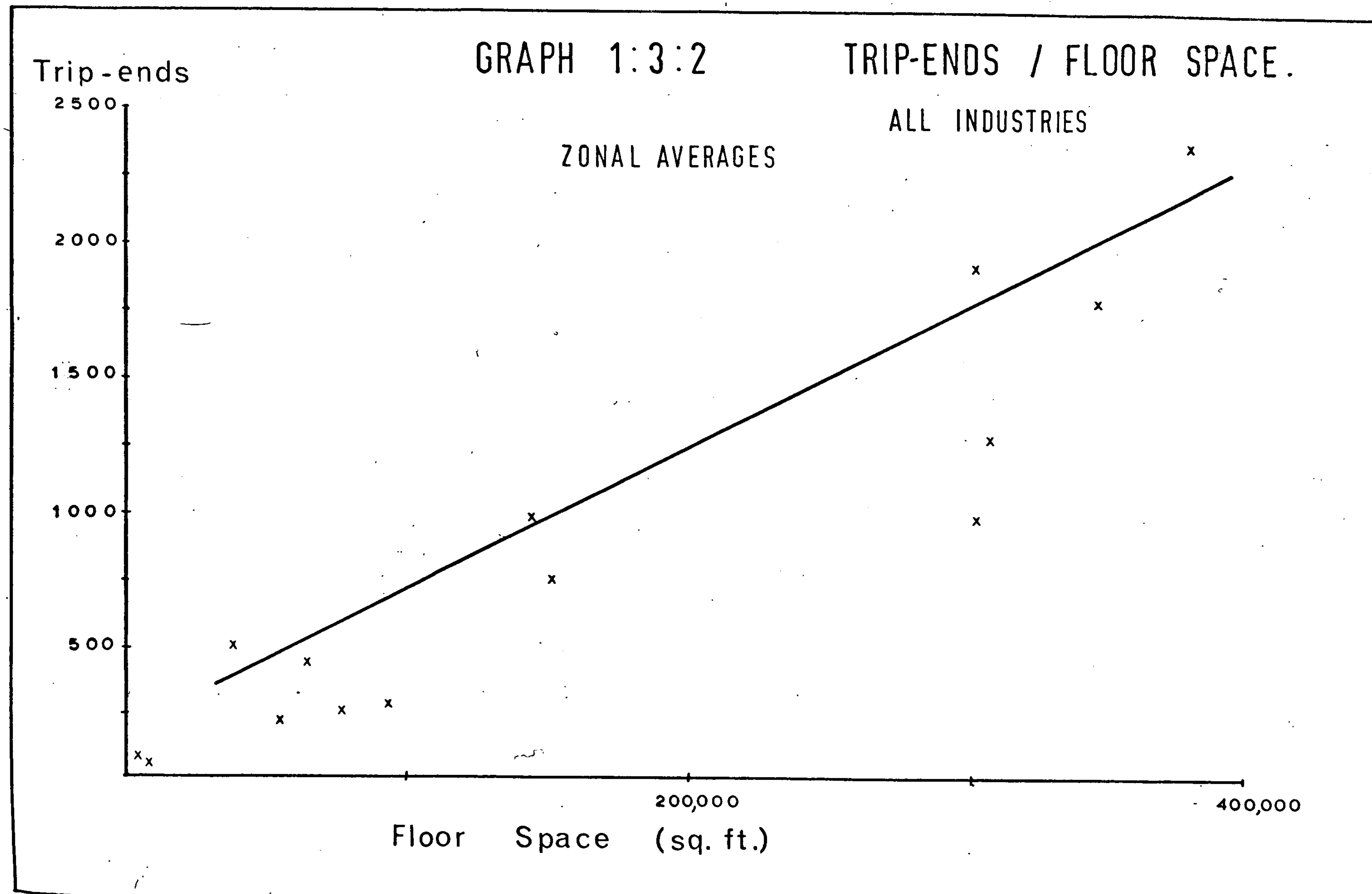
The relationship of total employment to daily trip ends is evaluated in Table 1:3:7 and in Graphs 1:3:3 and 1:3:4. The results obtained again show considerable variation, and illustrate the effect of small units, differing processes, etc.

GRAPH 1:3:1 TRIP-ENDS / FLOOR SPACE.

CLEANERS

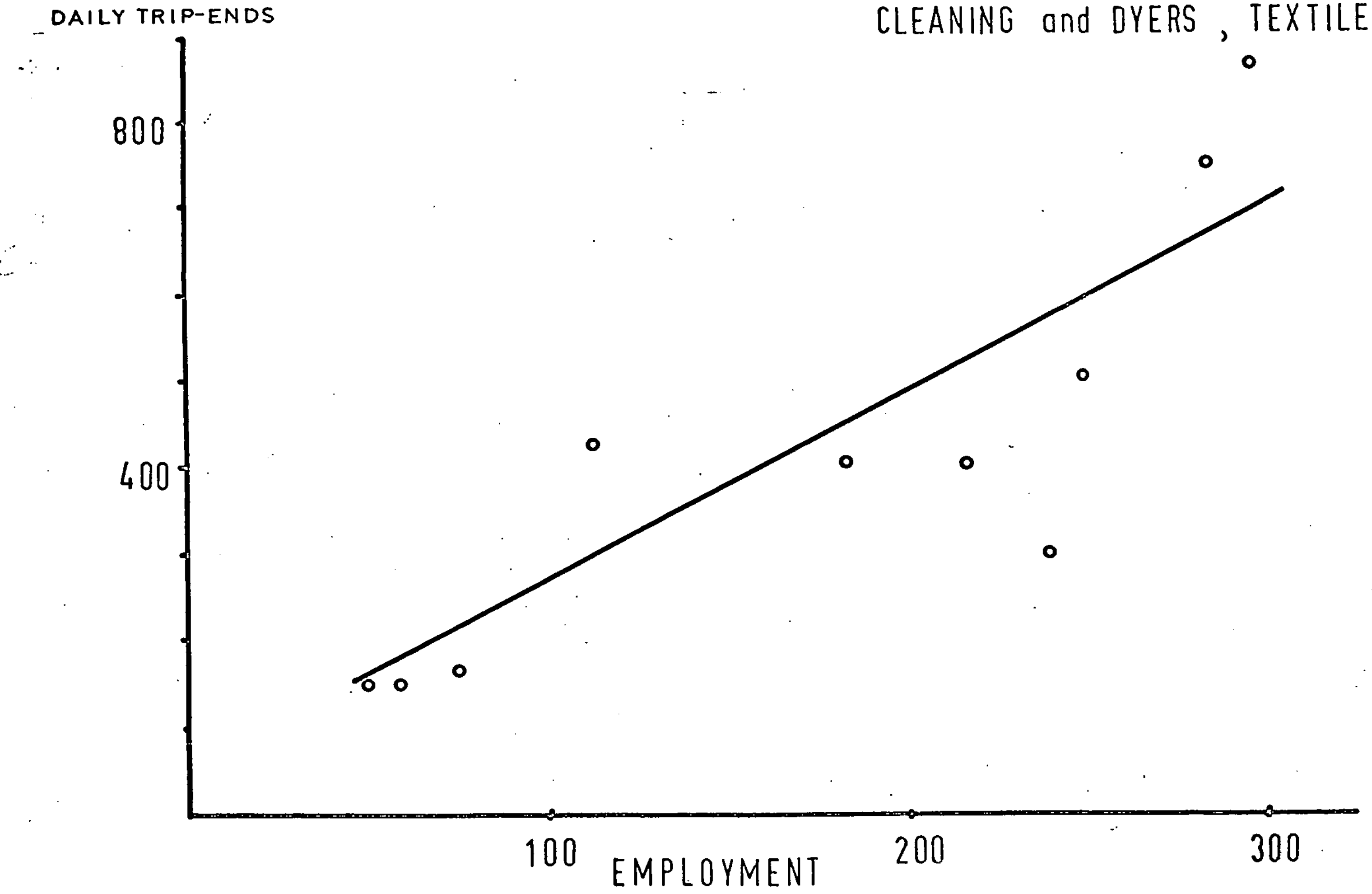
TEXTILES




GRAPH 1:3:2
TRIP-ENDS / FLOOR SPACE.
ALL INDUSTRIES
ZONAL AVERAGES
Trip-ends
2500
2000
1500
1000
500
200,000
400,000
Floor Space (sq. ft.)

GRAPH 1:3:3 trip-ends / employment.

CLEANING and DYERS , TEXTILES .



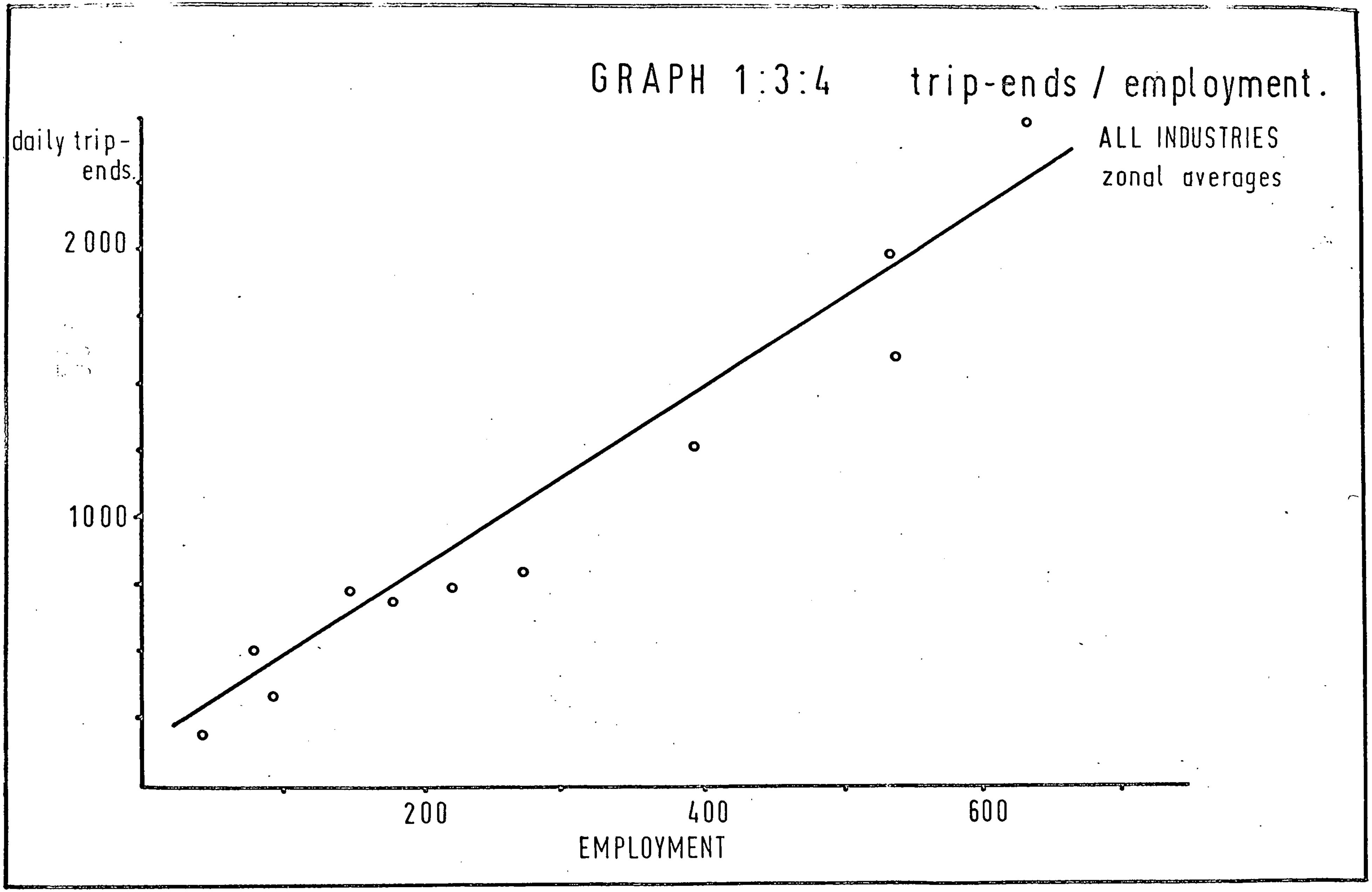

GRAPH 1:3:4 trip-ends / employment.
daily trip-ends.
2000
1000
ALL INDUSTRIES
zonal averages
200
400
600
EMPLOYMENT

Table 1:3:7

Relationship between daily trip ends, employment and floor space.

INDUSTRY	CONSTANT		't' Statistic		r^2
	Employment	Floor Space	Employment	Floor Space	
Cleaning & Dyers	16.291	30.160	2.92	3.01	0.63 0.61
Electrical Engineers	7.321	15.721	4.29	6.72	0.59 0.61
Metal Working, etc.	10.122	18.912	2.37	3.02	0.70 0.75
Textiles	6.132	13.632	4.62	2.91	0.65 0.64
Distillers, etc.	11.364	31.124	2.61	2.07	0.90 0.83
Transport	13.189	29.476	10.31	6.21	0.77 0.77
All Industries	32.321	69.324	6.72	4.29	0.89 0.96

Table 1:3:8

Relationship between daily trip ends and employment type.

Industry	Constant	't' Statistic Group (1)	(2)	(3)	R^2
Cleaning & Dyers	21.071	2.06	2.31	1.92	0.5132
Elec. Engineers	18.100	1.99	3.67	3.54	0.6037
Metal Working etc.	16.327	2.71	3.96	4.54	0.4192
Textiles	23.221	3.21	2.91	2.67	0.3392
Distillers, etc.	24.723	5.41	3.20	2.93	0.8123
Transport	31.217	3.67	7.21	6.54	0.7891
All Industries	91.106	4.72	10.81	9.62	0.9032

Employment composition was related to traffic attracted to the site and statistically significant equations were established, thoughthe small sample in some cases reduced the levels of significance.

The relationship between floor space, goods, person and car trips is set out in Table 1:3:9. Person trips during the peak hour are also subdivided by modal choice (Table 1:3:10). Obviously this latter aspect is more affected by an industry's location than its industrial type or floor space ratio, since it determines the distance that employees travel, availability of public transport, etc.

Table 1:3:9 reveals a fairly consistent pattern of employee induction, the major exception once more being metal working where the particular processes involved utilise more space per worker; this consistency is paralleled by the induction of private vehicle trips. The major variant is goods vehicle trips, some industries showing an intensive pattern/1,000 square feet, and other like Textiles showing a less intensive one. Consequently total trip-ends (which includes pedestrian callers)vary too, and the ratio of total to employee trips issmall in the case of transportation where the reliance is on large total area, and larger with textiles which inducts a larger number of other trips but to smaller total areas.

As stated earlier modal choice mainly reflects the location of the industries and the areas from which they draw traffic. Cleaning and Dying, and Transport are mainly located in centro-peripheral areas easily accessible to almost all the residential areas in Perth - hence over one third of the trips in the peak hour are on foot. Obviously other factors are important too - occupational type and sex. This is illustrated again by the Cleaning and Dying industries. Car ownership and use is sex linked, and associated with socio-economic status. This particular industrial groupemploys a high number of women, who are also semi-skilled and unskilled. From the earlier analysis this group is known to have the lowest car ownership/use rate, and the highest walk/bus rate, which the figures for the Cleaning and Dying industries reflect. Textiles have a somewhat similar pattern, though more male skilled workers are employed. Location is reflected in the Distillers' pattern; the largest employer has a location just outside the Burgh boundary, beyond walking distance for most zones, and hence lays on a private bus shuttle service. This explains the lower than average proportion of pedestrians and higher than average bus users.

Map 1:3:1 illustrates for one industrial site, the labour catchment area; work trips seem to be fairly evenly distributed, that is at random according to the number of households, residents or employees, about the site. The form of the catchment shows its influence on the modal choice of the employees. Work trip distribution is investigated more fully in Part II, Section 2.

Like the investigation of retail trip generation, industrial traffic flows seem to be related to certain parameters such as floor space, sex of the worker, total employment, employment composition, and location of the site. These parameters could well be used to predict future trends in traffic patterns, since they have been shown to be such important and significant explanatory variables.

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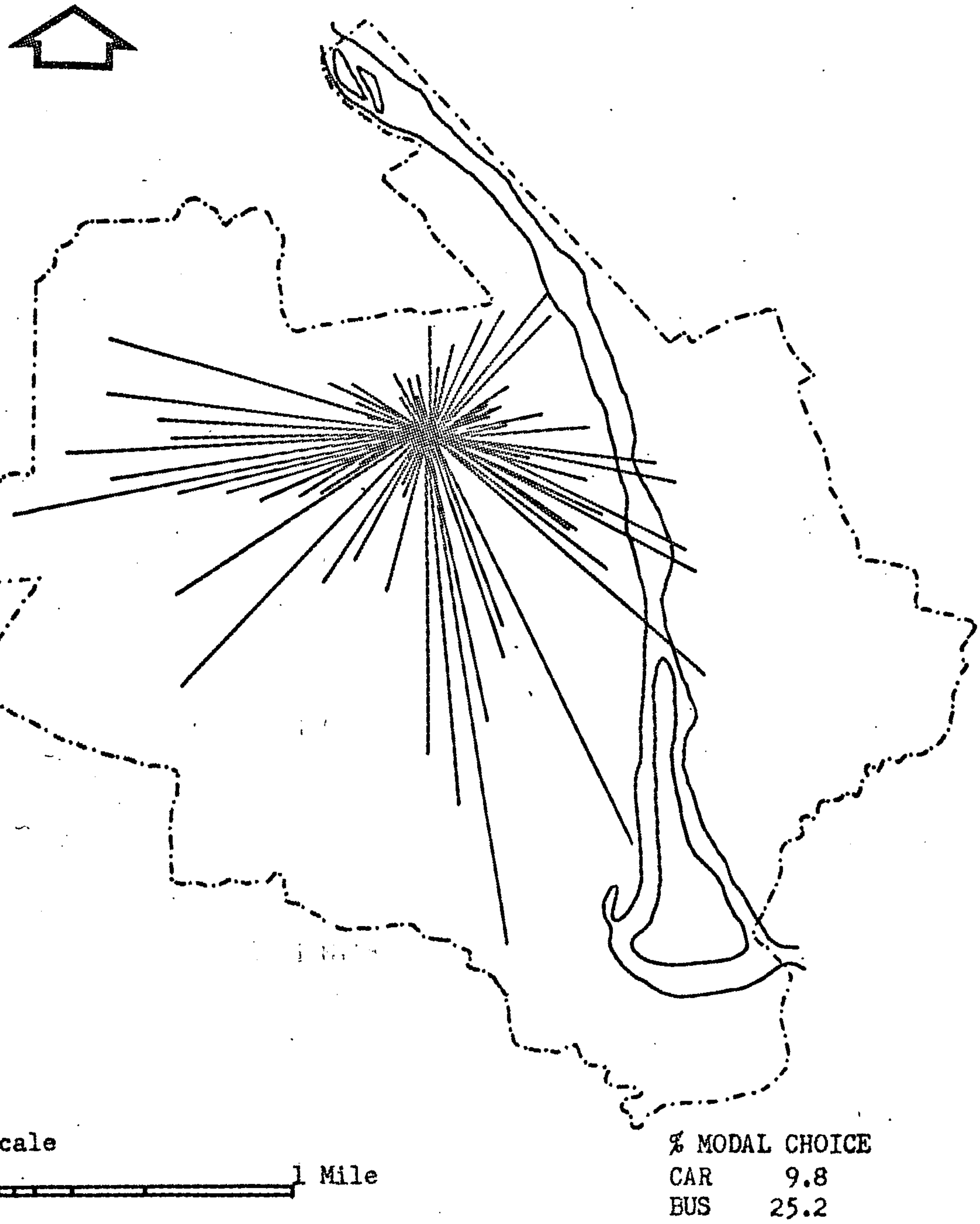
MAP 1:3:1

CATCHMENT AREA, ONE FIRM



% MODAL CHOICE	
CAR	9.8
BUS	25.2
WALK	52.0
OTHER	13.0

Table 1:3:9

Trips /1,000 Square Feet

Industry	Employees	Goods Vehs.	Person	Private Cars
Cleaning & Dying	1.8	1.1	3.5	0.4
Electrical Engineers	2.0	1.3	3.6	0.2
Metal Working	0.6	1.02	2.0	0.3
Textiles	1.9	0.7	3.7	0.3
Transport	1.7	0.7	2.1	0.2
Distillers	1.6	1.06	2.9	0.5

Table 1:3:10

Peak Hour trips ends: Modalchoice. in % (the balance, consists of other modes)

Industry	Car	Walkm	Cycle	Bus	Goods Vehicle
Cleaning and Dying	3.4	36.1	16.3	41.2	1.9
Elec. Engineers	16.2	21.0	13.9	39.2	4.3
Metal Working	13.1	24.2	15.1	36.3	4.9
Textiles	10.3	26.2	15.1	40.2	7.1
Transport	13.7	37.5	20.0	15.6	10.2
Distillers	15.3	10.2	12.0	45.5	6.7
All Industry	14.5	23.4	14.3	38.8	5.6

1:4 Warehouses and Storage Sites

Besides the detailed studies of retail and industrial land uses, and the analysis of the central business district, a number of other land use types were studied: warehouses, storage, transportation facilities, and recreation sites.

The first group of these, warehouse and storage sites, like industrial land uses, are an important traffic generator, since the distributive nature of their business activity leads to high trip attraction. They compose an important category in Perth, since being the distribution point for a large county and catchment area, these functions are well represented. There are 48 wholesale and 62 storage sites in Perth, despite its small size, occupying 687,000 and 756,000 square feet of covered space respectively. No individual studies ofthis land use type have been published in relation to traffic generation.

Table 1:4:1 sets out the basic relationships found in Perth. Since their distributive aspect is so important the first analysis takes into account goods vehicle trip-ends. This indicates that every 1,000 square feet of wholesale floor space can be related to the generation of 14.418 goods vehicle trips per day; the comparable figures for storage space is 5.316. The difference between the two figures reflects the differing intensities of activity since by its very nature, storage land use is extensive in its character. The addition of another measure, employment, non significant for storage by itself, improves the measure in both cases. The degree of variability from the figures first mentioned can be seen in Graph 1:4:1.

Unlike industry, there is only a small relationship between employment and floor space - barely significant for wholesale, and non significant for storage. This is due to the great variability within the categories warehouse and storage - the floor space/employee ratio will vary from a newspaper warehouse to a fish warehouse, to a general provision

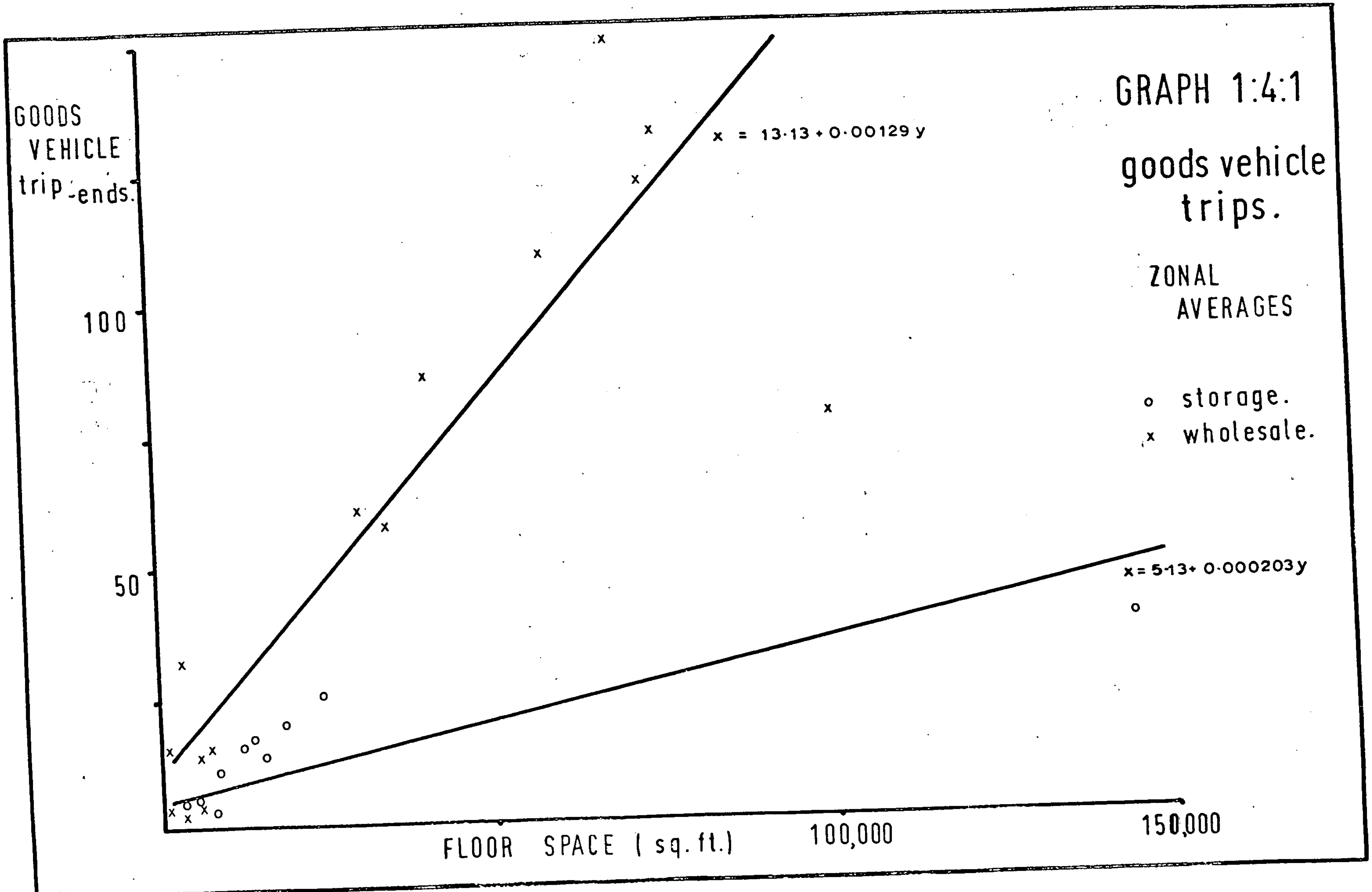

GRAPH 1:4:1
goods vehicle trips.
ZONAL AVERAGES
o storage.
x wholesale.
GOODS VEHICLE trip-ends.
100
50
x = 13·13 + 0·00129 y
x = 5·13 + 0·000203 y
FLOOR SPACE (sq. ft.)
100,000
150,000

Table 1:4:1

Goods Vehicle Trips, related to Floor Space and Employment.

Land Use	Constant	Reg. Coefficient Floor Sp.	Employ.	't' Statistic	r^2/R^2
Wholesale	13.13	0.001288		5.90	0.71
	20.82		0.9385	3.27	0.43
	4.461	0.001048	0.4496	4.68 2.14	0.79
Storage	5.113	0.000203		4.43	0.58
	5.260		0.05948	1.60	0.15
	2.541	0.000196	0.05201	4.87 2.26	0.70

Table 1:4:2

Total vehicle trip ends, related to floor space and employment.

Land Use	Constant	Reg. Coefficient Floor Sp.	Employ.	t	r^2/R^2
Wholesale	23.90	0.003228		9.00	0.85
	47.81		2.227	3.47	0.46
	5.407	0.002717	0.9593	8.45 3.19	0.92
Storage	17.42	0.0006577		4.25	0.56
	11.26		0.3227	3.15	0.42
	2.631	0.0006228	0.2990	8.92 7.50	0.92

warehouse. The number of establishments in most categories is too small to justify breaking the data down any further. The degree of variability is again evident in Graph 1:4:2.

Total vehicle trip ends (Table 1:4:2) shows a similar relationship to goods vehicle trips, though there is a stronger correlation. Comparable generation rates are 27.13 vehicle trips, and 18.08 vehicle trip ends/1,000 square feet for wholesale and storage land use per day, with the same reservations. Graph 1:4:3 once more shows the variation from the regression line.

Total person calls each day (employees journeys, goods vehicles, customer calls, all modes) were finally related to the two principal measures of land use activity. (Table 1:4:3). The results are similar to those earlier noted, with an improvement in significance.

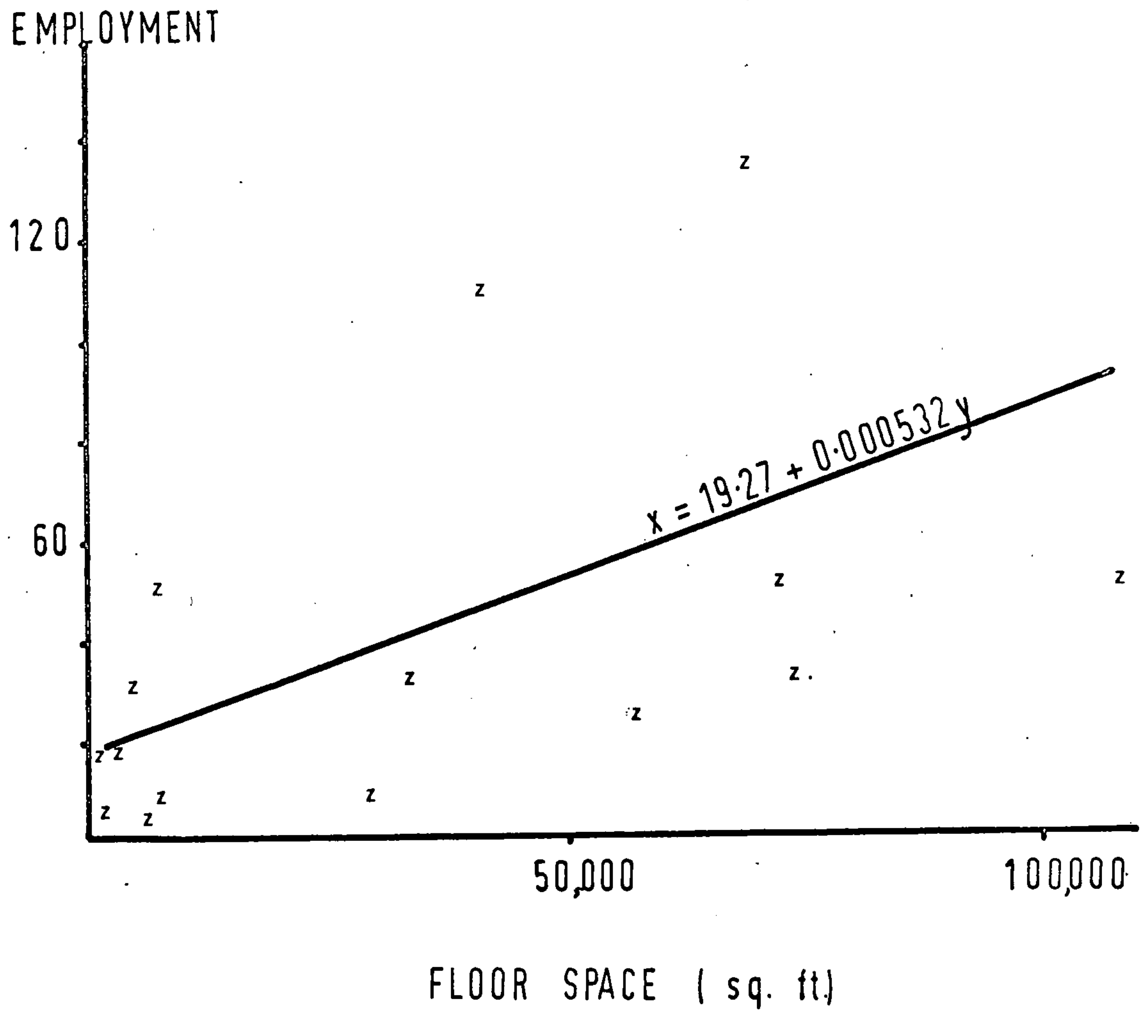
Table 1:4:3

Total person trips, related to employment and floor space

Land Use	Constant	Reg. Coefficient Floor Sp.	Reg. Coefficient Employ.	t	$r^2 R^2$
Wholesale	30.12	0.004613		10.21	0.90
	51.12		2.367	3.69	0.50
	6.512	0.003123	1.139	9.34 3.42	0.92
Storage	22.67	0.0008723		4.61	0.57
	14.39		0.4129	3.46	0.44
	2.839	0.0007938	0.3137	9.18 6.29	0.92

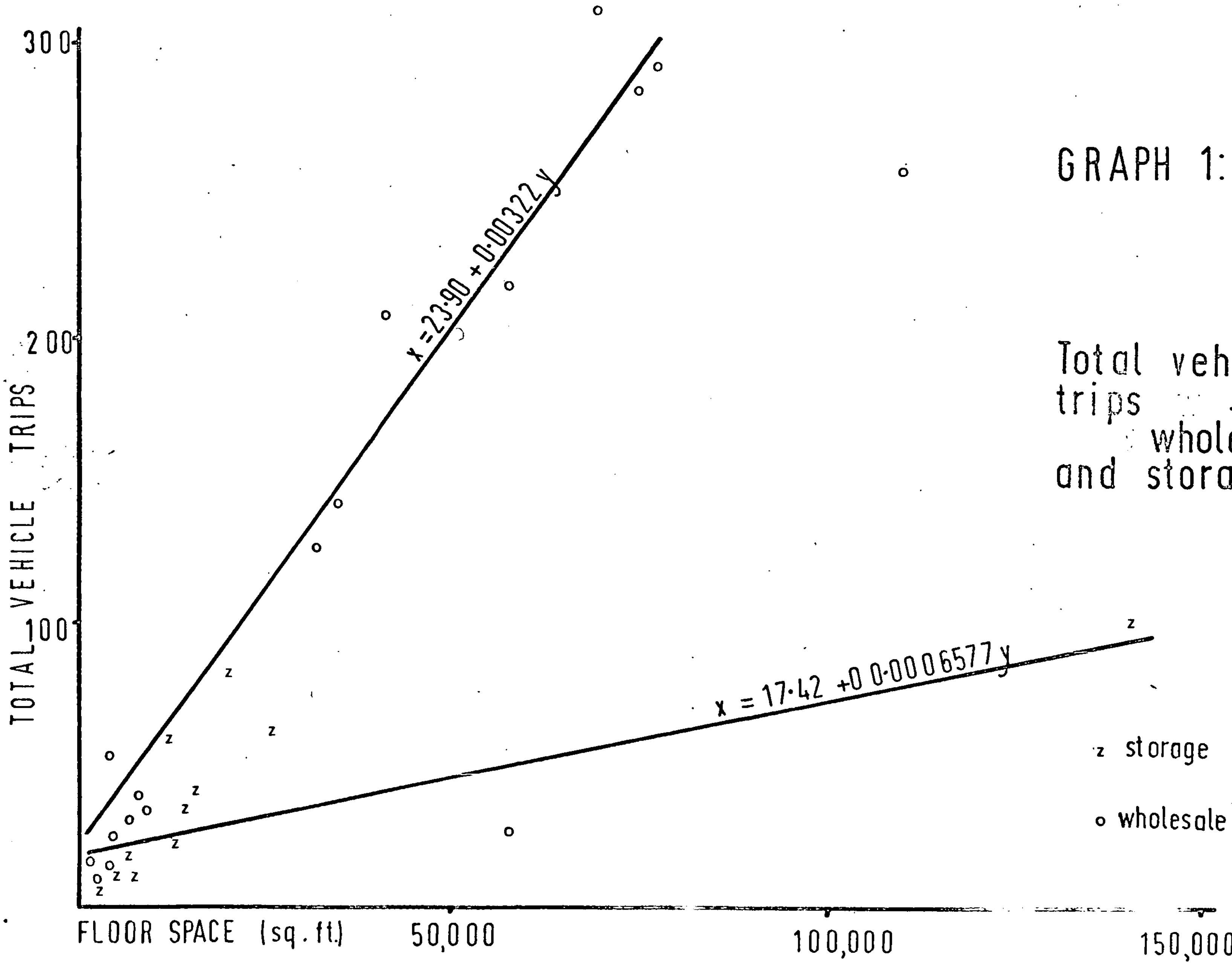
GRAPH 1:4:2 employment and floor space, wholesale land use.

ZONAL AVERAGES



GRAPH 1:4:3

Total vehicle trips – wholesale and storage.



These results show a marked similarity to those received earlier for retail, industrial, etc.land uses, and so they will not be persued, beyond the emphasis which they place on the relationship between land use and traffic generation, measured in terms of floor space and employment, goods vehicle, vehicle and total person trips.

The total goods flow generated by several of these sites is shown in Map 1:4:1. The site locations are dominantly centro-peripheral; or aligned along one of the main arteries leading out of Perth. One and two (Map 1:4:1) are wholesale grocers and they tend to supply a definite 'local'area, whilst three is a wholesale confectioner andtobacconist whose catchment area covers most of Perth. All three ofcourse supply a much wider area without the town, as part of Perth's central function.

The travel pattern is not as simple as the desire-lines of Map 1:4:1 suggest. E.M. Horwood[1] carried out a preliminary study of goods movements to and from central area establishments in Philadelphia, which showed the highly complex nature of commercial activity. Concerned mainly with the feasibility of consolidation of parcel movements, it is of interest to this study of wholesale floor space. Each of the desire lines on the map may well represent one of the three patterns shown in Diagram 1:4:1.[2] Of course there are many other combinations, but they are presented here to show how complex are the traffic generation or linkage patterns, which the simple studies at the attraction/generation sites tend to mask. Each of the patterns is really only one trip end or two 'total' trips, yet the implications for the whole travel pattern are more complex. This sort of linkage of course applies to all trips, not just goods vehicle trips from warehouse sites.

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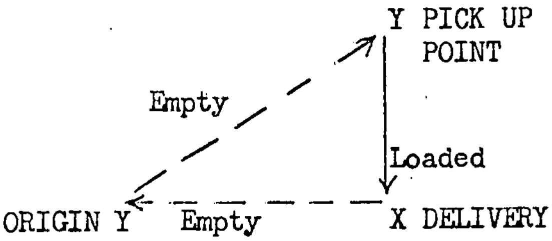
(1) E.M. Horwood 'Centre City Goods Movement; An Aspect of Congestion' Highway Research Board Bulletin 203, 1958 pp.76-98.

(2) Ibid p.86.

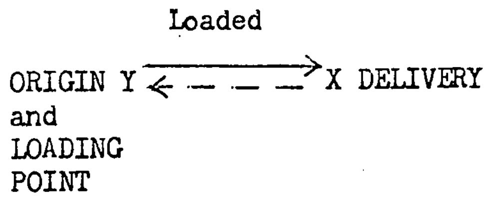
DIAGRAM. 1:4:1*

1. DELIVERY

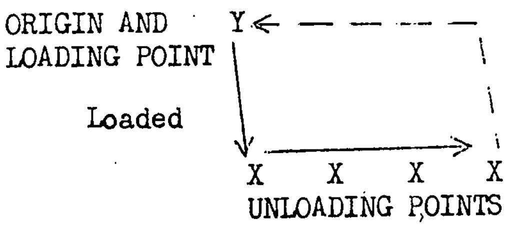
a)



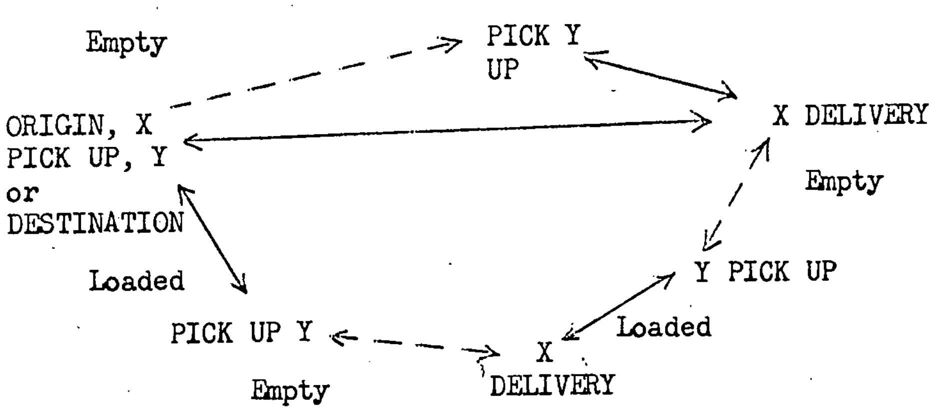
b)



2. SERIES DELIVERY



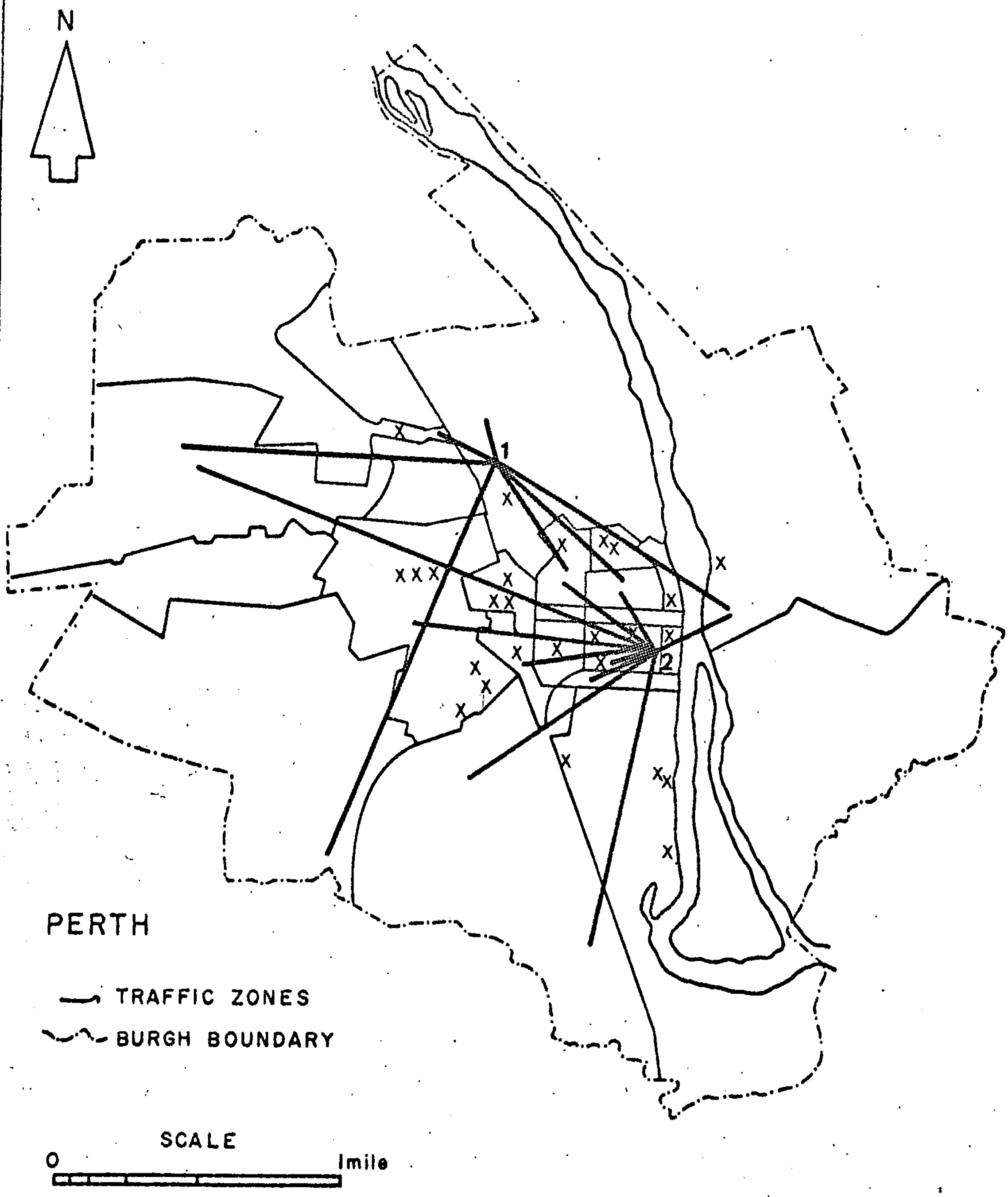
3. COLLECTION AND DELIVERY



* E. M. HORWOOD op cit. p. 86.

MAP 1:4:1

WHOLESALE ESTABLISHMENTS



1 WM. BROWN
2 STEWART and DICK
x OTHER WHOLESALERS

} REGULAR CUSTOMERS INDICATED DIAGRAMMATICALLY.

It is a very difficult pattern to plot since it needs detailed and accurate measurement and recording. Goodwin[3] has collected such data, but he could only do it by accompanying the lorry driver. Needless to say this method is not used widely. Other studies, then, like this one tend to be superficial in that they ignore the complexities of multiple trips, which all large scale studies must do until costs of data collection and analysis are reduced. It does not of course reduce the use of the warehouse attraction/generation data, but it does alter the 'confidence level' at which they can be applied.

1:5 Transportation and Other Attraction Sites

It has been usual in traffic studies to combine such diverse facilities as airports, railway stations, bus terminals, etc. into one combined category,[1] or quite frequently to combine data for these terminals with industry. Where transportation facilities have been studied in detail, for example, air terminals, generation rates have not usually been related to the characteristics of the generator as a producer of air travel, employment, or other trip purposes.[2]

In Perth, two transportation terminals were analysed - the General Railway Station and Perth North Goods Station. They were studied from the point of view of traffic generation in terms of the number of departing and/or arriving passengers/day; variations in time; auxiliary transportation (taxis); and goods vehicles.

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(3) C.A. Goodwin, 'Elements of Multipls-Stop Pickup andDelivery Operations in Urban Areas' Liberty Mutual Ins. Co. Boston and Yale Bureau of Highway Traffic 1950.

(1) Chicago Area Transportation Study. Final Report. Vol.11, p.43, Chicago, 1960. Pittsburgh Area Transportation Study, final Report. Vol.11, pp.32-33. Pittsburgh 1963.

(2) R.H. Harris and C.S. Michelski, 'Running and Design of Airport Terminal Facilities' Report of Technical Committee 6.D. Institute of Traffic Engineers. Chicago, 1956: Port of New York Authority, 'New York's Air Travellers', Saugatuck. Eno Foundation 1956; A more general study is that of J.R. Hamburg, 'A Comparison of Vehicle and Person Destination by Land Use'. C.A.T.S. Research News, Vol.2, No.13, September 1958 pp.12-16.

Tables 1:5:1 and 1:5:2 set out the monthly and daily flow of passengers in and out of the station. Their accuracy must be questioned since Perth is an 'open' station without barriers, and these figures are based on tickets issued, tickets collected on trains before reaching Perth, and spot counts taken from time to time. This may well account for the fluctuations, but the weather, economic conditions and local holidays must also be borne in mind. The total floor area at this site is 390,014 square feet, of which 3,000 square feet is retail space, 5,050 square feet restaurant and cafeteria, and 8,110 square feet of wholesale newspaper warehouse. The floor space relationships are set out in Table 1:5:3. On this basis, 1,000 square feet of terminal inducts and generates on average 6 passenger trip-ends/week, or about 0.85/day. In total trip terms the figures are higher, since they include visits for enquiries, to meet passengers, taxi trips, goods vehicle journeys, and journeys to work. The figure now rises to 7.0 trip-ends/1,000 square feet or 11.0 total trips.

Further investigation is needed here, and correlation with frequency and type of trains, volume of freight handled, as well as other measures may prove to be more meaningful than the simple floor space- trip relationship. Particular types of trips, such as goods vehicle and taxi trips were analysed further. Both trip types were studied as movement from the general station to all destinations. In the case of taxi trips, the destination was one of 24 zones cross classified by distance from the station, number of dwelling units in the zones, zonal population, and its socio-economic composition. Goods vehicle trips were traced to their exact destination which was then classified by land use type. The summation for each zone was then related to the amount of floor space utilised by that activity.

Table 1:5:1

Total Passengers/Perth General Station *

	1962	1963	1964
January	26,435	22,748	24,682
February	23,610	24,071	24,013
March	26,545	23,511	23,719
April	30,541	26,763	27,334
May	28,456	25,544	23,840
June	29,679	27,048	26,550
July	35,689	32,646	31,572
August	35,201	31,493	31,045
September	28,932	29,773	31,396
October	29,922	26,501	27,129
November	24,501	24,198	24,312
December	26,058	25,089	22,117

* Source - British Railways, Perth.

Table 1:5:2

Total Passenger, Perth General Station, weekly distribution *

	May, 1962	May, 1963	May, 1964
Monday	1,329	986	832
Tuesday	1,036	979	803
Wednesday	892	863	692
Thursday	669	782	683
Friday	1,163	1,213	1,103
Saturday	1,029	1,201	1,009
Sunday	431	192	216
Total	6,549	6,216	5,338

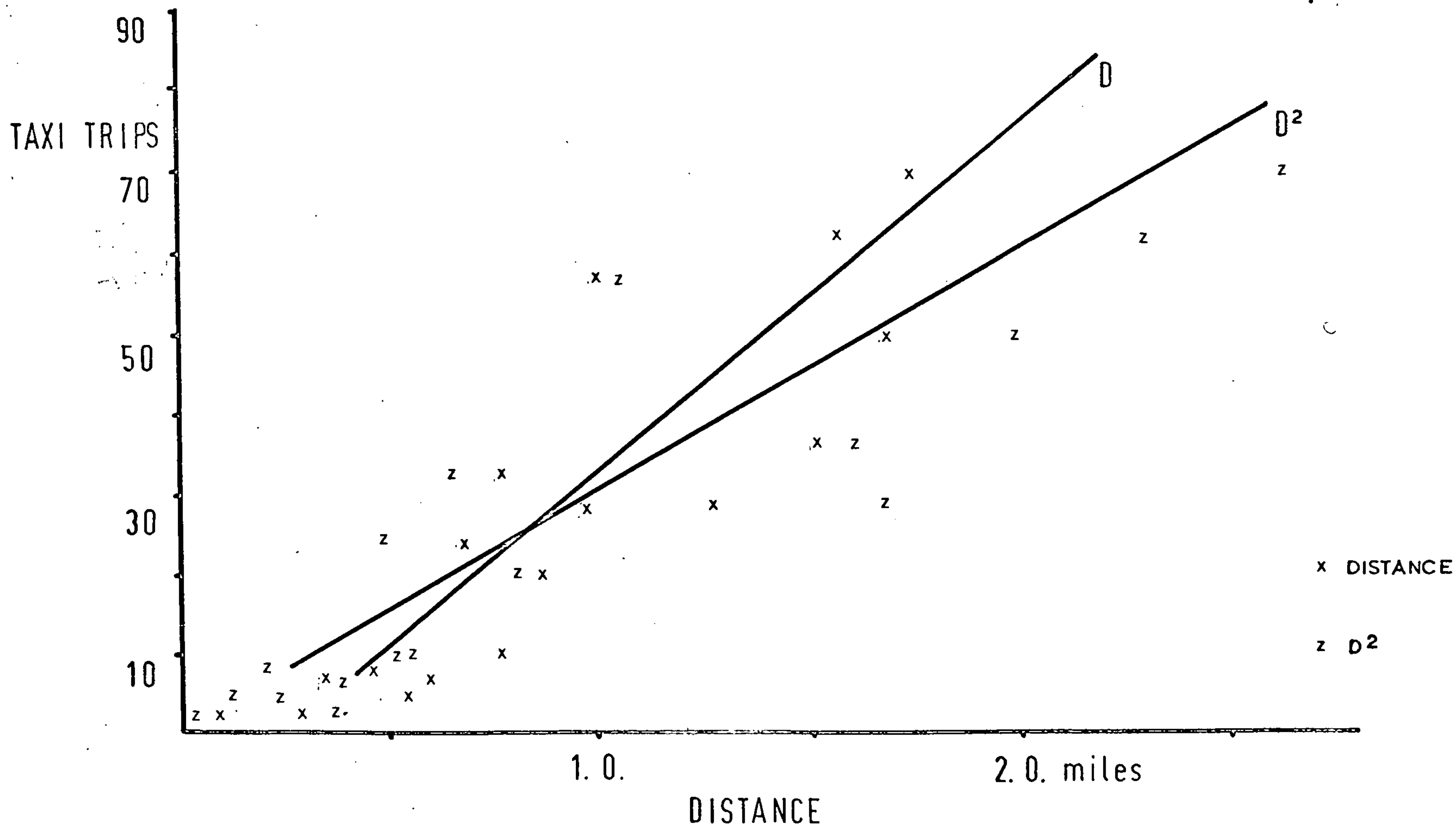
* Source - British Railways, Perth.

Two measures of distance were used for taxi trips generated per weekday from the station - distance, and the square of distance. The latter improved the correlation in all cases, though by small amounts. The most successful correlation (in terms of the coefficient of determination) was the regression utilising the variables, $distance^2$, zonal population and zonal dwelling units, closely followed by that substituting socio-economic status for population. By themselves however, neither dwelling units, population, nor socio-economic status, were powerful explanatory variables, with coefficients of determination about 0.30 to 0.35. The major part of the correlation was accounted for by distance or a function of distance, and the addition of one of these other variables improved the coefficient by only 10%, and a second variable by 13%.

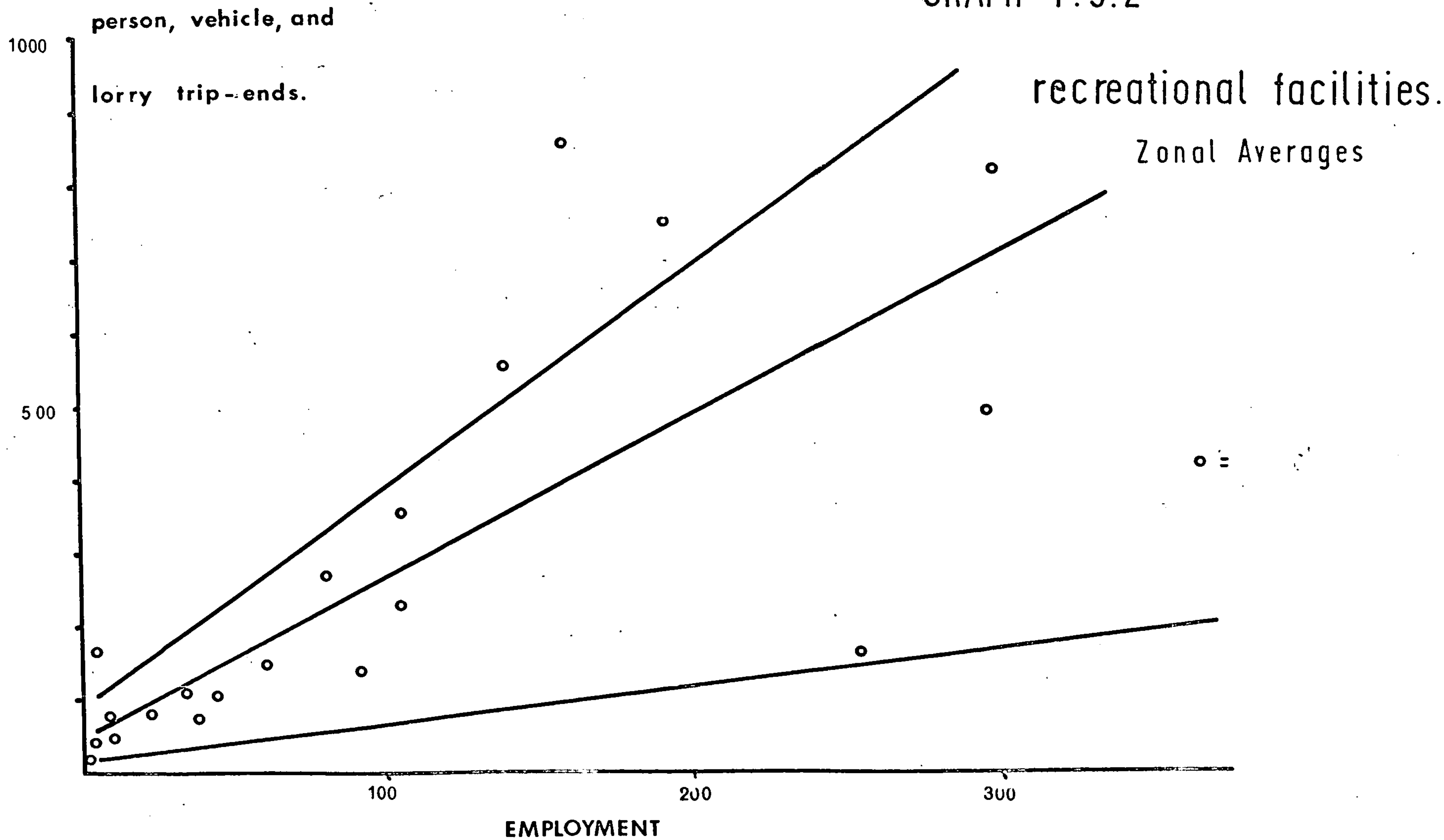
The generating power of the terminal facility itself is obviously its use for changing to another mode of travel. Accessibility from the rest of the urban area to that facility can be measured conveniently by taxi usage. Graph 1:5:1 indicates a direct relation between taxi usage and distance, and to some extent with socio-economic status at the residence (point of pick up).

Unlike taxi trips, the generation and induction of goods vehicle trips from the Railway Station is not significantly related to distance, and of the 9 land use types, only four have significant correlations. These are shown in Table 1:5:5 and graph 1:5:2. Where trips per floor space are correlated, in three of the four cases they are strongly correlated. For every 10,000 square feet of retail floor space, for instance, 7.118 goods vehicle trips are generated from the Station, 0.033 trips to storage areas, 24.21 trips to industry (per 100,000 square feet), and 1.45 to residential areas (per 100,000 square feet). Correlations with total floor space and total non residential floor space had coefficients of determination of 0.15 and 0.18 respectively, which were significant only to the 10% level of the 'F' test.

GRAPH 1:5:1 taxi trips.



GRAPH 1:5:2



person, vehicle, and
lorry trip-ends.
1000
500
100
200
300
EMPLOYMENT
recreational facilities.
Zonal Averages
o =

Table 1:5:3

Floor space and related data, Perth General Station

Location	Floor Space	EMPLOYEES M	F	T	Pedes-trian Callers	Private Vehicle Callers	Goods Vehicle Callers	Empl. Trip	Visit Trip	Vehicle Trip	Empl.	Goods
Retail	3,000	1	5	6	240	-	12	500	12	-	2.0	4.0
Wholesale	8,110	5	0	5	-	4	16	573		405	0.6	1.9
Station	378,904	562	99	661	1,515	138	239	1,622	242	1,596	1.7	0.6
Total	390,014	568	104	672	1,755	142	267	av. 580	224	1,460	1.7	0.6

Table 1:5:4

Taxi trips, regression analysis

Constant		Distance	$Distance^2$	Dwelling Units	Population	Socio-Economic Status	$r^2 R^2$
-5.311	(1) (2) (3)	42.84 4.742 9,06					0.79
0.4270			29.00 2.960 9.98				0.82
4.351				0.01369 0.00444 3.08			0.30
4.222					0.004538 0.00133 3.41		0.35
4.482						0.1230 0.00399 3.08	0.30
-1.026			26.08 2.22 11.69	0.007738 0.001735 4.46			0.91
-0.7360			26.02 2.46 10.56	0.00630 0.01735 3.65			0.89
-1.662			28.78 2.26 12.64	0.02672 0.00781 3.42	-0.00610 0.00240 2.48		0.93
-1.345			27.20 2.08 13.02	0.02684 0.00842 3.19		-0.01771 0.00767 2.31	0.93

(1) Regression Coefficient

(2) Standard Error

(3) t statistic.

In considering a single point of origin, one can identify traffic generation and attraction linkages - from the terminus in terms of trips/square foot and at the destination in terms of trips/square foot or some other measures such as socio-economic status. For taxi trips, every 1,000 ft. of terminal facilities generates 1.03 journeys, and every mile distance from the terminal facility increases the likelihood of taxi trips occurring by 42.84 - 5.31. For goods vehicle trips, every 1,000 ft. of terminal facility generates 0.68 goods trips, and retail floor space for example attracts or inducts 0.71 for the same measure.

Perth North Goods Station, deals with on the whole larger articles (in volume and weight) but the correlations tend to be similar to the General Station. Physically it consists of a smaller covered floor area, 20,000 square feet, but it has another 40,000-50,000 square feet of open storage space. Employee trip induction is 2.6 trips/1,000 square feet,and 12.8 goods vehicle trips/1,000 square feet of covered space daily. The regression analysis followed a similar form to the General Station,and is shown in Table 1:5:6. Again there was a strong relationship between retail floor space and the number of goods vehicle trips inducted. Storage land use was no longer significant, but offices, wholesale, and public buildings were entered. Table 1:5:7 compares the induction rates of the two stations. The differences between the two can be explained in terms of different types of goods carried - railway truck loads of provisions directly to a wholesaler, against individual consignments sent by passenger train. The relationship with residential areas onthe other hand is comparable.

Table 1:5:5

Railway Station, Goods Vehicle Trips to Four Land Uses

Land Use	Constant	Reg. Coeff.		t	r^2
Retail	-8.792	0.001591	0.000094	16.86	0.93
Storage	-0.0360	0.000007	0.0000003	18.24	0.94
Industry	-3.048	0.0002725	0.0000732	3.72	0.39
Residential	-5.652	0.0000421	0.0000045	9.46	0.80

Table 1:5:6

Perth North Goods Station, Goods Vehicle Trips to Six Land Uses

Land Use	Constant	Reg. Coeff.		t	r^2
Retail	-12.71	0.001764	0.000120	14.69	0.9075
Office	-0.4765	0.000128	0.000024	5.29	0.5595
Wholesale	3.937	0.000216	0.000107	2.02	0.1567
Industry	0.2761	0.000082	0.000008	10.13	0.8234
Public Bldgs.	-0.1263	0.000028	0.000005	6.08	0.6271
Residential	1.279	0.000003	0.0000007	4.57	0.4871

Table 1:5:7

Goods Trip: Induction rates per day

Land Use	General Station	Perth North
Retail	7.12	0.49
Storage	0.03	-
Office	-	0.08
Wholesale	-	6.10
Industry	2.42	0.85
Public Buildings	-	0.27
Residential	0.15	0.16

The investigation of recreational activities, the induction patterns of entertainment centres, and social trips in general, have received even more scant attention. Very little research has been completed concerning trip attraction by recreational facilities. One site in Perth, a hotel, was studied very tentatively, but no general conclusions could be hypothesised.

The hotel was situated in South Street, Perth, at a junction point important to tourists. Over the past few years the manager reported that the customers had changed from long term stays to one or two night stops, and had increasingly come whilst touring by car. It is interesting to note that comparing bedrooms and length of stay with Table 1:5:8 that only in one month of the year is the hotel fully utilised, and that only for 1/3rd of the year is it utilised over 85-90%. A more detailed study of one week in May, revealed the following pattern. 574 square feet attracted one employee trip (1.7/1,000 sq.ft.) per day, 861 square feet one guest trip (1.1/1,000 sq.ft.) per day, and 120 square feet one person trip (8.3/1,000 sq.ft.) per day.

Table 1:5:9 sets out the general attraction data for recreational sites. Recreational site was defined as cinemas, theatres, cafes, restaurants, clubs, etc., a group which are functionally similar, but differ in their floor space requirements. Any subgroup would be too small in Perth for significant analysis. This variability within the land use category accounts for the fairly low coefficients of determination, and for the predominance of employment not floor space in the regressions. Graphs 1:5:2 and 1:5:3 further illustrate this variability. Employment acts as the land use measure, and 100 employees induce 267 vehicle trips, 63 goods vehicle trips,and 389 person trips per day. The size of the facility in floor space terms makes little significant difference in the induction pattern, as measured here. These are simple relationships, but significant.

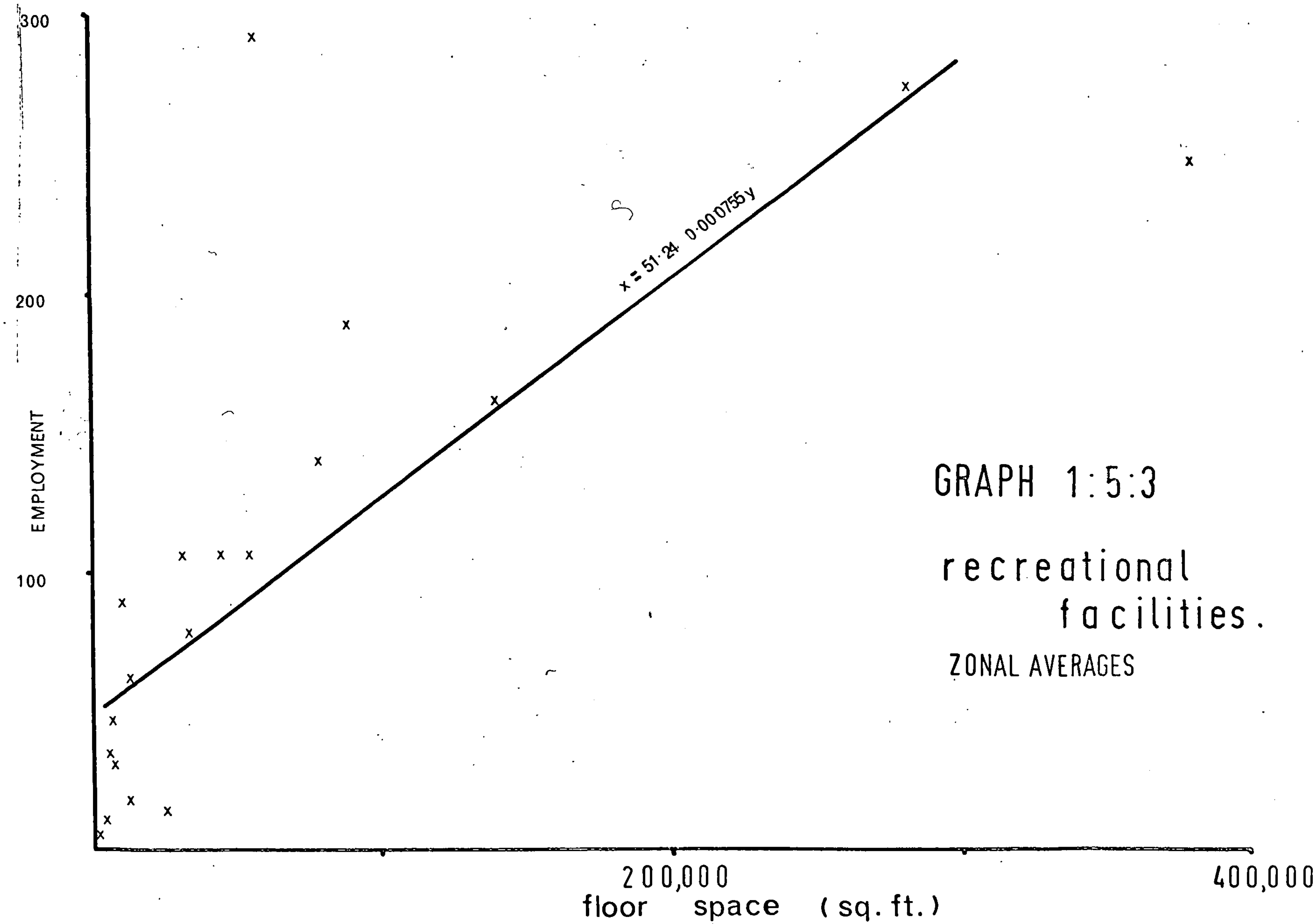

GRAPH 1:5:3
recreational facilities.
ZONAL AVERAGES
EMPLOYMENT
300
200
100
200,000
400,000
floor space (sq. ft.)
x = 51·24 0·000755y

Table 1:5:8

Number of sleepers, monthly return, Salutation Hotel.

	1961	1962	1963	1964
January	422	438	727	418
February	1,033	1,030	1,070	1,093
March	694	808	753	1,008
April	782	1,030	955	1,008
May	930	1,132	1,085	1,093
June	2,170	2,579	2,415	2,543
July	2,868	2,843	2,919	2,971
August	3,175	3,325	3,230	3,489
September	2,530	2,229	2,886	2,632
October	893	1,074	1,518	1,087
November	453	613	558	784
December	362	312	343	437

Two studies in North America have looked at recreational areas in general.(3) Crevo began with the idea that such characterists of summer weekend travel as travel-time, vehicle occupancy, and time of day, would differ according to the type of recreational facilities offered at any destination. However many of his findings did not substantiate this idea, and amongst others, he found that the facilities available at recreational areas apparently do not strongly influence travel considerations, especially for trips greater than twenty -five minutes in length. However the values he obtained for car occupancy did appear to differ according to the facilities available, and it was further found that the characteristics of family trips as related to population density and car ownership follow the pattern of other trip types.

(3) C. Crevo 'Characteristics of Summer Weekend Recreational Travel' New Haven. Yale University Bureau of Highway Research 1962; and L.L. Schulman 'Traffic Generation and Distribution of Weekend Recreational Trips' Lafayette. Purdue University Joint Highway Research Project. June 1964.

Table 1:5:9

Recreational Facilities: Relationship of Floor Space, Employment, Person Trips, Vehicle Trips, etc.

	Constant	Reg. Coefficients		t	r^2/R^2
EMPLOYMENT/ Floor Space	51.24	0.000755		5.36	0.59
TOTAL VEHICLE TRIPS/ Employment	55.42	2.124		5.17	0.57
TOTAL VEHICLE TRIPS/ Floor Space	178.3	0.001364		2.54	0.24
TOTAL VEHICLE TRIPS/ Employment/ Floor Space	46.19	2.579	-0.0005826	4.01 0.92	0.59
PERSON TRIPS/ Employment	71.20	3.179		5.30	0.62
GOODS VEHICLE TRIPS/ Employment	15.69	0.4736		4.55	0.51

In other words, as in Perth, as density increases fewer trips are made, due to the fact that decreasing car ownership accompanies increasing density. Finally Crevo noted that the time of day at which arrivals occur depend on the characteristics of the facility - if major events occur in the afternoon, then the peak of arrivals occurs shortly before that.

Schulman was mainly interested in the attraction of state parks in Indiana, and he found a strong relationship between available facilities and traffic inducted. He took into accountssuch variables as number of picnic tables, area of lake and park, availability of cooking facilities, etc. There is really no British equivalent to these kinds of park facilities.

Another type of miscellaneous facility which has received some attention in the United States is the attractive power of medical centres. Extremely detailed studies have been undertaken in one case, and significant variables include floor space, number of doctors by speciality, location of the facility, service available for treatment and diagnosis, and scheduling procedure.[(4)]

The research undertaken here was only able to pursue the broadest of lines. Such major generators of traffic as shops, industry and transportation terminals, as well as the central core, where offices, etc. were studied, have been analysed in some detail. The time available did not allow for the study of other facilities like restaurants, cinemas, etc. in such detail, since each demands a fairly complicated survey. Reliance must be placed on the home interview survey, and the analysis of social trips from the home, although as indicated in the introduction to Part II, this is far from satisfactory. It lays open an important avenue for further research.

1:6 Conclusion

On the basis of the material derived from the studies at the attraction sites, certain characteristics of the various types of land use can be identified as being relevant to the volume of traffic (in the broadest sense) which specific facilities induct. Since, of course, trip attraction is a manifestation of human activity, a high degree of variability occurs, particularly in activities like recreation, social interaction, and to some extent shopping, since here 'behavioural' rather than 'economic' man is operative. The underlying rationale remains the same however; the functional relationship between land use and urban travel.

(4) P.W. Schuldiner, B.J. Berry, et al 'Traffic and Parking Requirements of Off-centre Medical Office Buildings' Highway Research Board, Record No.49, 1964.

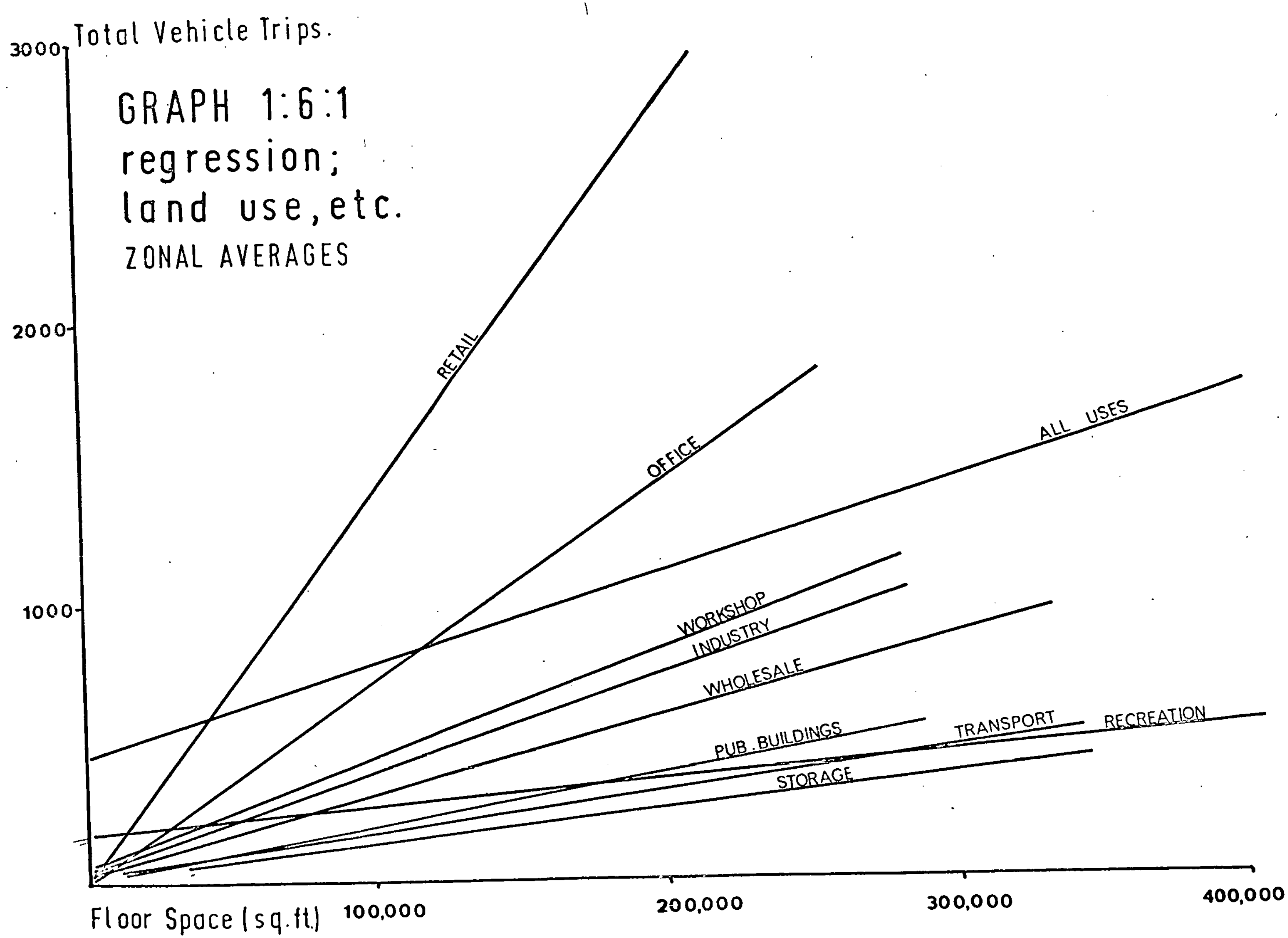
Table 1:6:1 sets out the most successful variables used in 'explaining' the trip induction pattern of the land use activities analysed. The common denominators are floor space and employment. Obviously there are variations, retail land use should be subdivided into convenience and shopping categories, and attraction based on some function of the range of goods available; industrial land usage can be measured by the sex of the worker and employment composition. Despite this the basic relationships appear to be common to all, and they point to a substantiation of the functional relationship hypothesised.

Graph 1:6:1 emphasises the difference between space-intensive and space-extensive land uses for traffic attraction or induction. 10,000 square feet of retail floor space inducts 152.0 vehicle trip ends, the same amount of wholesale floor space 56 trip ends, and storage space 26 trip ends. The relationship to land use measured by number employed is rather different (Graph 1:6:2) - thus though office land use is space intensive generation-wise, its much less intensive when measured by employment. Retail land use has intensive traffic generation measured either way; transport and storage land uses have low inductive abilities related to both employment and floor space, though not necessarily in total; and finally there are a group of land uses like 'wholesale' and 'recreation' which occupy a great deal of floor space, but induct a good deal of traffic when measured by employment. Graph 1:6:3 reflects the difference between retail and office space on the one hand, and on the other the less intensively inductive land uses.

The following comments can be made about the land use groups in general.

GRAPH 1:6:1

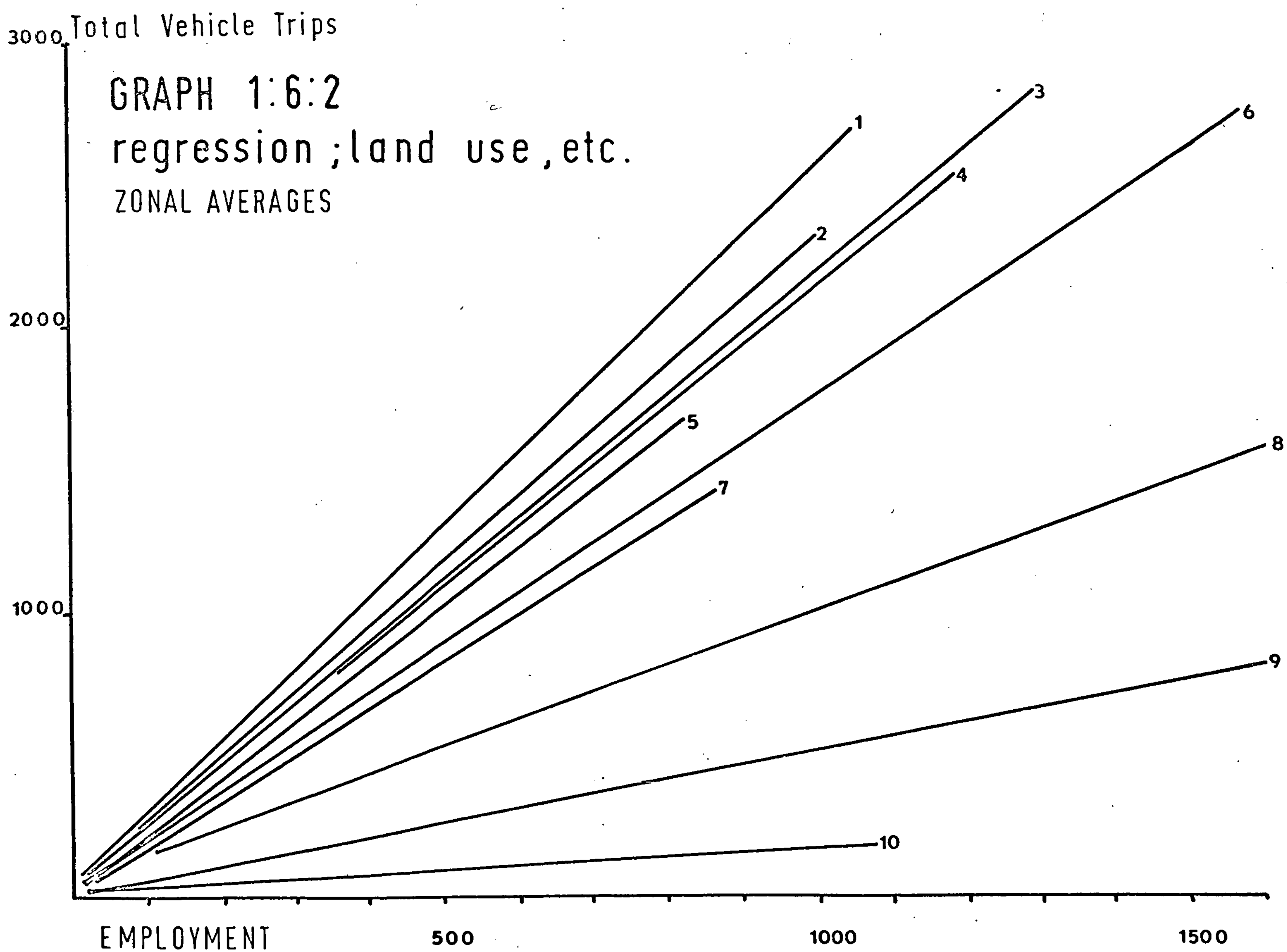
See Table 1:6:1 for regression equations.


Total Vehicle Trips.
GRAPH 1:6:1
regression;
land use, etc.
ZONAL AVERAGES
3000
2000
1000
RETAIL
OFFICE
ALL USES
WORKSHOP
INDUSTRY
WHOLESALE
PUB. BUILDINGS
TRANSPORT
RECREATION
STORAGE
Floor Space (sq.ft.)
100,000
200,000
300,000
400,000

GRAPH 1:6:2

1. Retail
2. Wholesale
3. Recreation
4. Industry
5. Workshops
6. All land uses
7. Public Buildings
8. Office
9. Transport
10. Storage

See Table 1:6:1 for regression equations.



GRAPH 1:6:2

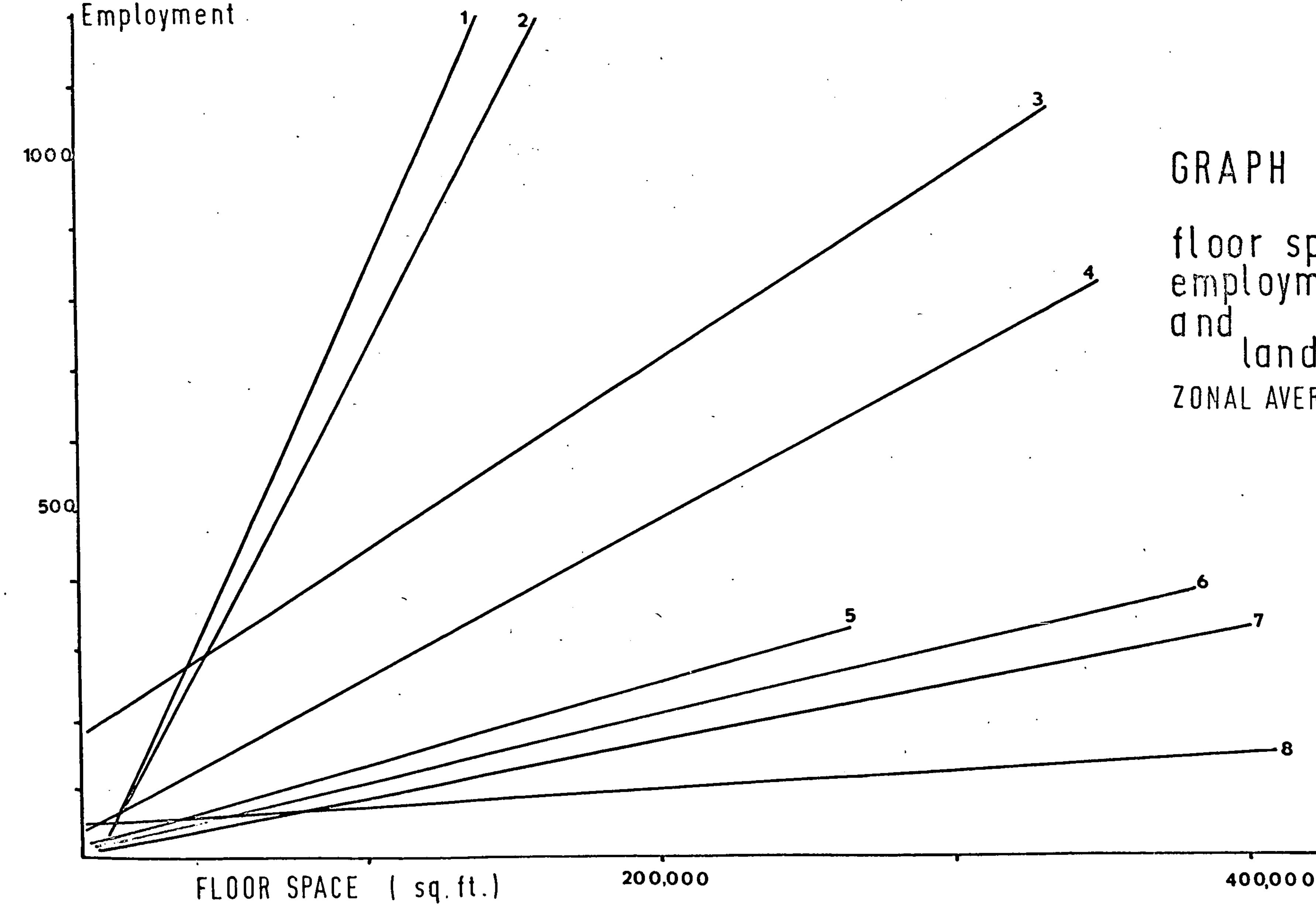
regression ; land use, etc.

ZONAL AVERAGES

GRAPH 1:6:3

Regression equations.

1.	Retail	$x = 36.85 + 0.008030y$
2.	Office	$x = 46.34 + 0.007714y$
3.	All land uses	$x = 184.0 + 0.001737y$
4.	Transport	$x = 50.81 + 0.001891y$
5.	Workshops	$x = 21.29 + 0.001421y$
6.	Wholesale	$x = 19.27 + 0.0005323y$
7.	Public Buildings	$x = 14.96 + 0.0005106y$
8.	Recreation	$x = 51.24 + 0.0007548y$



GRAPH 1:6:3

floor space, employment, and land use.

ZONAL AVERAGES

Table 1:6:1

Relationship between land usage and daily trip generation

Land Use	Measure	Constant	Regression Coeff. Floor Space (1)	Regression Coeff. Employment (2)	t	r^2/R^2
Office	Total vehicle Trips/ Floor Space/ Employment	-6.793	0.007012	0.1676	14.07 2.96	0.99
	Total Vehicle Trips/ Floor Space	-14.560	0.008304		28.19	0.98
	Total Vehicle Trips/ Employment	69.26		0.8631	8.64	0.82
Recreation	Total Vehicle Trips/Employ.	55.42		2.1240	5.17	0.57
Public Buildings	Total Vehicle Trips/Floor Space/Employ.	16.55	0.001017	0.4337	4.25 1.24	0.85
	Total Vehicle Trips/floor Sp.	23.04	0.001238		7.65	0.83
Industry	Total Vehicle Trips/Floor Sp./ Employment	13.055	0.001508	0.5464	16.57 4.36	0.98
Workshops	Total Vehicle Trips/Floor Sp./ Employment	16.750	0.003947	0.4014	16.99 3.30	0.98
	Total Vehicle Trips/Floor Sp.	25.29	0.004518		23.60	0.97
	Total Vehicle Trips/Employ.	15.82		1.938	5.94	0.65
Retail	Total Vehicle Trips/Floor Sp./ Employment	-9.779	0.01533	0.1944	5.11 0.53	0.98
	Total Vehicle Trips/Floor Sp.	-16.940	0.01689		33.01	0.98
	Total Vehicle Trips/Employ.	68.460		2.046	21.63	0.96
Wholesale	Total Vehicle Trips/Floor Sp./ Employment	5.407	0.002717	0.9593	8.45 3.19	0.92
Storage	Total Vehicle Trips/Floor Sp./ Employment	2.631	0.0006228	0.2990	8.92 7.50	0.92
Transport	Total Vehicle Trips/Floor Sp./ Employment	12.100	0.001196	0.1512	13.58 3.97	0.98
	Total Vehicle Trips/Floor Sp.	19.790	0.001482		20.41	0.97
	Total Vehicle Trips/Employ.	8.214		0.5743	6.98	0.78
All Land Use	Total Vehicle Trips/Floor Sp./ Employment	98.730	-0.0006462	1.927	1.86 13.36	0.94
	Total Vehicle Trips/Floor Sp.	455.000	0.002702		3.74	0.39
	Total Vehicle Trips/Employ.	39.62		1.734	16.46	0.93

Commercial Facilities

For the analysis of retail traffic attraction, goods should be initially separated into convenience and shopping goods categories. A finer differentiation based on expenditure/trip, or turnover, should be used where possible; if this information is unavailable then the number of square feet of sales devoted to the two categories can be used.

In this thesis the latter course was taken because of the non availability of turnover data, and 'significant' results were obtained (Table 1:6:1). It may be of some advantage in future investigations to separate goods on some basis which will reflect variations in their attractiveness to different socio-economic classes of shoppers at different distances from the facility. Similarly the behavioural element could be identified.(1) Total square footage of floor area may also affect the rate of trip attraction through the interaction of one type of goods upon another.

The location of one shopping area in relation to another, and particularly to the central business district, was important. In Perth shopping goods were almost entirely concentrated (in sales) in the central area, which was readily accessible from most residential areas. Where local facilities were available, these were used for the frequent purchase of convenience goods.

Additional factors which could be investigated are:-
Travel time characteristics; availability and level of public transport service; pressure or absence of other facilities in relation to the shopping area; the socio-economic levels of the catchment areas, and car ownership rates within them; the study of the overall geographic extent of the catchment area and its degree and density of development; and the behavioural impact.

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(1) D.L. Thompson suggests the use of 'imagery', transfunctional psychology, etc. in 'Future Directions in Retail Area Research' Economic Geography Vol.42, No.1, Jan. 1966. pp. 1-18.

These additional factors would provide a much clearer understanding of shopping trips than was ascertained here, and would aid the determination of traffic generation rates for commercial facilities.

<u>The Central Business District</u>

Every urban area develops relatively specialised services which operate from central locations. In a town of 40,000 the central core has such a variety of services that there is only a minimum provision of convenience goods stores in neighbourhood concentrations or in a dispersed manner, through the suburban areas. The central district distributes most of the clothing, furniture, and appliances, and located here too is most of the banking, business, and professional offices, and places of entertainment serving the immediate area.

Daily trips made to the central area depend on a variety of factors - the population of the town and its catchment area, distance, number of workers in the central area, level of car ownership, level of public transport service, the range of goods and services, and adequacy of local shopping. Other items could be added to this list.

Although a variety of variables were analysed, some function of land use as a measure of the range of attractiveness was the most significant statistically. In a series of regressions the most successful once more were employment and floor space. Improvement could have been achieved, but only on the basis of additional data on population, car ownership, income, and other social, geographic and economic facts.

<u>Industrial and Other Facilities</u>

Employment data, which reflected the technological characteristics of the facility, was the most important measure of industrial trip induction. If the number of industrial units had been greater, the units could have been grouped into facilities with similar employment functions, for more significant results. Other measures might reflect labour intensity, number of employees per unit area (largely non significant in this study), value of output, or capital investment.

Occupational composition, including the sex difference, was an important determinant of trip induction, particularly at the peak hour when the work journey predominates. Likewise location was a powerful determinant in the number of vehicular trips inducted.

Other facilities such as wholesalers, transportation terminals, and recreation sites had their own generation patterns, which reflected the range or type of business they offered. Wholesalers attract low volumes of traffic per unit area, although higher volumes per employee, and they tend to have locations away from the central core. The generation/induction pattern of transport terminals varied with the unit weight and volume of goods. The pattern associated with recreational uses was much more difficult to isolate, largely due to the poor quality of the data, but employment seemed a fairly significant measure.

This study is largely an exploratory one, and it has posed as many questions as it has answered. Much work remains to be done, especially in Britain where neither the residential nor the non-residential patterns have received adequate attention. These studies at the attraction site are only a beginning; the primary measures, like floor space and employment, have been isolated, but they are not necessarily the only ones.

SECTION II CONFLUENCE AT THE WORKPLACE

The work journey was considered in the first part of the thesis, and latterly in the general consideration of attraction sites. Since, however, the work journey forms such an important part of both from-home and total trips, and hence of total travel patterns, it must be considered in greater detail.

The extensive nature of the literature has already been mentioned, going back as far as 1896 in Europe, with a more intensive period of investigation occurring after 1945.(1) Liepmann, Westergard and Thompson, for instance, studied the social and economic costs of work journeys, and pointed to the need for planning to minimise journey lengths in an ever expanding industrial society.(2) Others, formulated theories of urban spatial structure in terms of the journey to work. Carroll,(3) and Schnore(4) studied the forces which minimise or maximise the work journey, whilst Vance(5) postulated a sequential model of the changing pattern of employment catchment areas through changes in transportation technology. The fault with many of these studies is that they take little or no account of the particular site characteristics of workplace location, which are of prime concern to the geographer.

The characteristics of workplace sites which are of interest include the volume and density of employment, the location of workplace, with special reference to its relation to the central area, and types of activity.

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(1) See for example H.S. Lapin's 'Structuring the Journey to Work' Philadelphia. University of Pennsylvania press 1964.

(2) K. Liepmann 'The Journey to Work' London, Routledge, 1944; J. Westergard ' Journeys to Work in the London Region', Town Planning Review 28, April 1957, pp. 37-62; J. Thompson 'The Journey to Work - Some Social Implications' Town and Country Planning, November 1950, pp. 441-446.

(3) J. Douglas Carroll 'The Relations of Homes to Work Places and the Spatial Patterns of Cities' Social Forces 30. March 1952, pp. 271-282.

(4) L. Schnore 'The Separation of Home from Work: A Problem for Human Ecology' Social Forces 32, May 1954, pp. 336-343.

(5) J.E. Vance 'Labour-shed, Employment Field and Dymanic Analysis in Urban Geography' Economic Geography 36, July 1960, pp.189-220.

Location of workplace is then of direct relevance to patterns of work travel and total travel. Patterns of trip origins about workplace destinations change with the location of such destinations and it has an influence upon the choice of mode. Carroll distinguished between the residential distribution of persons employed in the central area and those employed in intermediate or peripheral locations.(6) He stated that the residential distribution of the former approximates that of the population of the entire urban area, whilst the non-central workplace draws its employees from the immediate vicinity. This finding was substantiated in Perth in a more modest way, as would be expected when results are drawn from a small urban area.

Table 2:1 shows the number and percentage of workers who travel to part of the central area (Zone 1) and three factories just outside the boundary of Perth in Zone 37. The two patterns do seem to differ, but of course this may well be a result of employment density. To overcome this an 'expected' figure was calculated, based on the assumption that if there were no frictional factors operating, the numbers who travelled to work in Zone 1 and 37 would be directly related to the zonal proportions of total workers. The standard deviation of the differences between the actual and 'expected' number was calculated, and the variation about the deviation is shown. Zone 37 (Table 2:1 and Map 2:1) apparently draws most heavily from residential areas nearest to it, and least heavily from areas distant to it (over -0.50 Expected-Actual standard deviation); Zone 11 seems to be an anomoly, a result of a large zonal industrial employment.

The attraction pattern to the central area is rather different, only four of the twenty-two interval residential zones show a variation greater than ±0.25 from the standard deviation (Table 2:1, Map 2:2).

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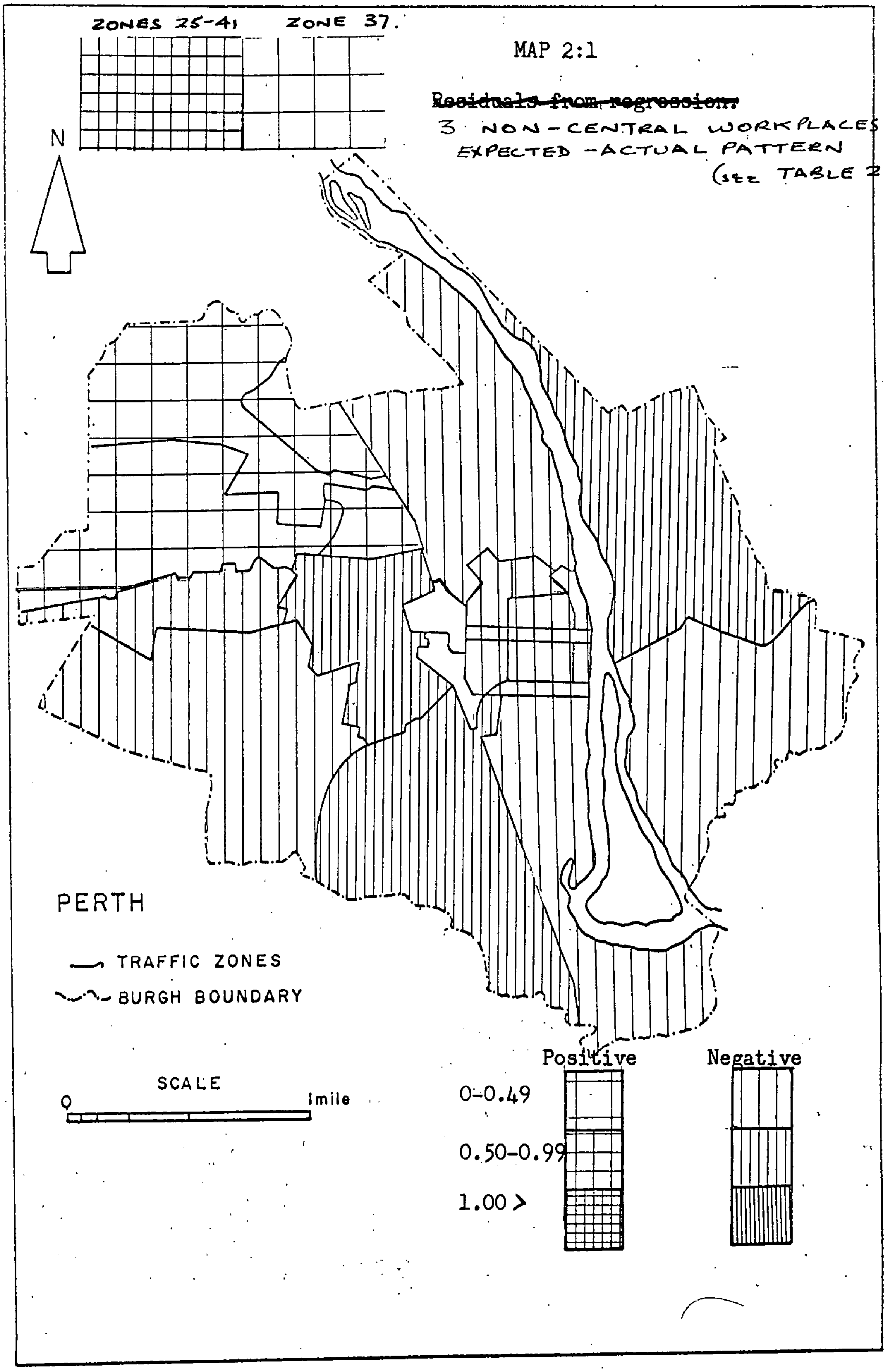
(6) J. Douglas Carroll, op. cit.


ZONES 25-41
ZONE 37.
MAP 2:1
~~Residuals from regression.~~
3 NON-CENTRAL WORKPLACES, EXPECTED - ACTUAL PATTERN (SEE TABLE 2:1)
N
PERTH
TRAFFIC ZONES
BURGH BOUNDARY
SCALE
0
1mile
Positive
Negative
0-0.49
0.50-0.99
1.00 >

MAP 2:2

~~Residuals from Regression.~~
CENTRAL WORKPLACES,
EXPECTED – ACTUAL PATTERN
(SEE TABLE 2:1)

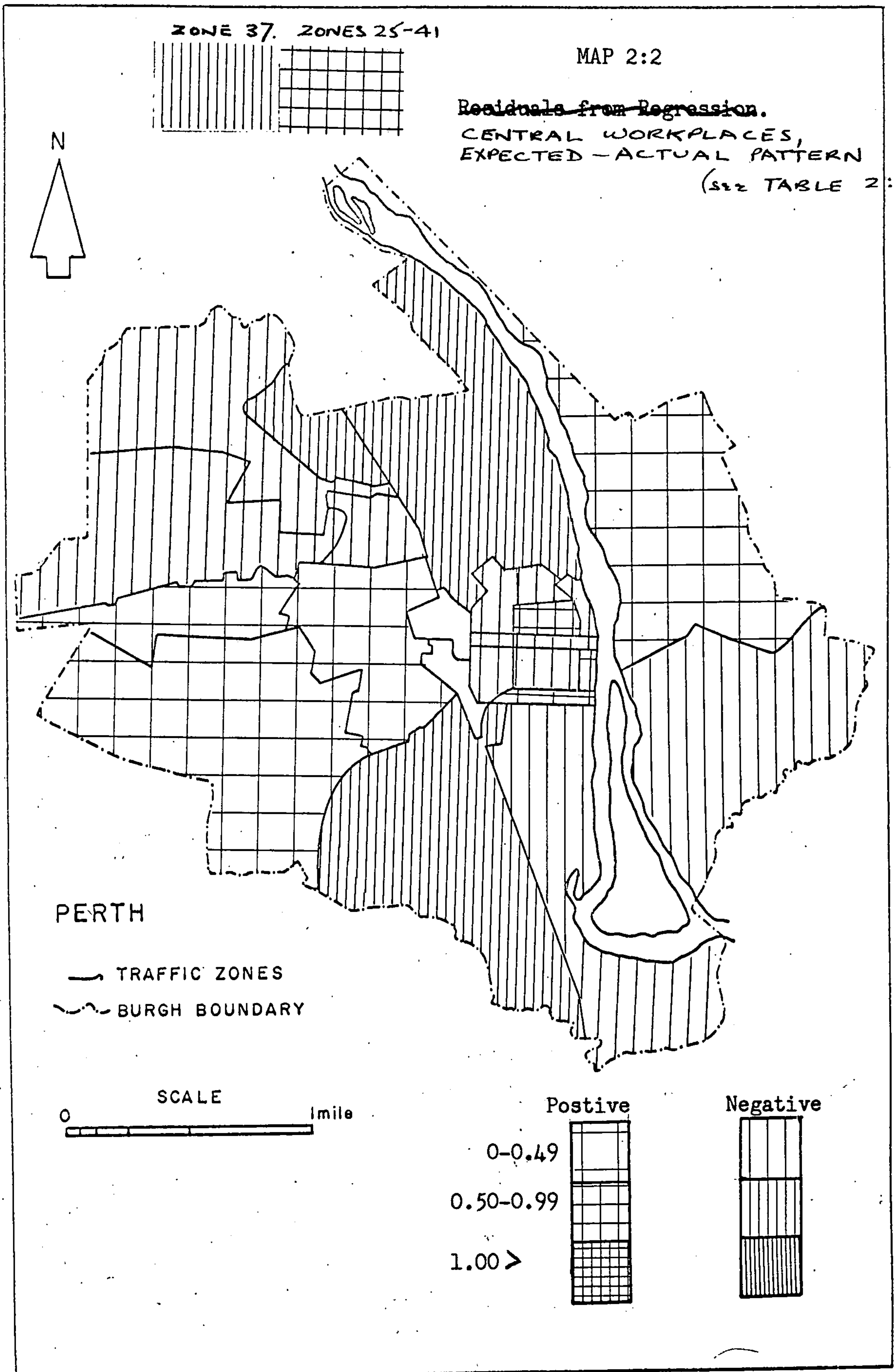


Table 2:1

ZONE	%Workers to Zone 37 from EACH ZONE	% Zone's Workers to Zone 37	Expected	Actual	Stnd. Dev. E-A ÷ S. Dev.	%Workers to Zone 1 from EACH ZONE	% Zone's Workers to ZONE 1	Expected	Actual	Stnd. Dev. E-A ÷ S. Dev.	Zone's % TOTAL WORKERS
1	1.6	8.3	42	32	-0.12	3.8	27.4	57	105	+0.77	2.1
2	0.4	4.0	26	9	-0.22	1.0	12.4	35	28	-0.11	1.3
3	0.8	8.2	22	16	-0.10	1.0	12.9	30	25	-0.08	1.1
4	0.2	9.5	2	3	+0.01	0.2	16.1	3	5	+0.03	0.1
5	0.2	10.0	2	4	+0.03	0.3	23.1	3	9	+0.09	0.1
6	1.8	6.2	62	37	-0.32	2.8	12.6	87	75	-0.19	3.2
7	0.3	4.5	16	6	-0.12	0.5	9.6	21	13	-0.13	0.8
8	1.2	6.5	42	25	-0.22	1.6	11.4	57	44	-0.21	2.1
9	0.1	0.2	8	1	-0.09	0.1	6.1	11	4	-0.11	0.4
10	2.3	7.4	66	46	-0.12	3.0	13.1	89	81	-0.13	3.3
11	10.0	9.0	236	202	-0.44	10.2	12.9	320	277	-0.69	11.8
12	2.1	4.5	94	42	-0.66	4.7	14.3	128	128	0.00	4.7
13	0.3	4.7	14	6	-0.10	0.4	7.9	19	10	-0.14	0.7
14	0.5	2.8	42	11	-0.40	1.0	8.1	57	31	-0.41	2.1
15	6.3	5.2	254	126	-1.64	11.4	12.9	344	310	-0.54	12.7
16	1.3	5.9	48	26	-0.28	2.4	14.8	65	65	0.00	2.4
17	2.6	5.2	106	52	-0.69	5.6	15.1	148	152	+0.06	5.3
20	1.0	6.6	30	20	-0.12	1.7	15.4	43	46	+0.05	1.6
21	18.5	11.2	350	374	+0.32	17.1	13.9	475	464	-0.18	17.5
22	3.0	11.8	56	61	+0.06	2.4	12.2	76	63	-0.21	2.8
23	4.2	14.1	64	86	+0.28	1.2	5.3	86	32	-0.86	3.2
24	1.0	9.5	21	21	0.00	0.9	11.8	32	26	-0.10	1.2
37	21.8	50.5	92	435	+4.39	3.3	10.4	125	89	-0.58	4.6
25-41	17.5	11.7	256	290	+0.44	23.2	17.5	346	633	+4.59	12.8

So far as the two attraction patterns are concerned then, location and accessibility seem to be more important for a non central work place site than a central site. Other factors contribute to the differences too, such as scale of activity, type of economic activity, and occupational composition. It does seem though, that location has an affect on the work journey and perhaps on the selection of the residential site.

The answer provided here is not explicit enough about the location of work journey origins and destinations and it is necessary to investigate this further. Workplaces can be thought of in comparison to some central datum or norm; thus the workplace site can be thought of as central, intermediate, peripheral, or exogenous. Table 2:1 examines central and exogenous locations. The location of workplaces in this classification is important, because if work-journey-origins really are conditioned by work place-locations, then an intermediate location might include a crossing of the central area, adding a further frictional effect. Therefore the distribution pattern of a work site which involves such frictional effects would be rather different. Thus relationship to a central datum of an urban area is important, since it mayaccount for certain assymetrical patterns of work journey origins.

Not only can work place-location be divided into simple components, but so can the residence-work place relationship. Both may theoretically show scattered or concentrated patterns, in the following kinds of ways:-

(1) Residence and employment scattered

(2) Residence and employment concentrated (central, intermediate, peripheral)

(3) Residence concentrated and employment scattered

(4) Residence scattered and employment concentrated (central, intermediate, peripheral, or exogenous).

An attempt to examine these simple patterns by erecting a simple matrix was made in the journey-to-work computations found in Appendix 4.b.(7)

The computer was used as a simple data plotter, and drawing from previously analysed material, it plotted origins and destinations by occupation, sex, and socio-economic status on a simple 10 x 9 matrix. In case (1) the results would be evenly scattered over the origin and destination matrixes, and in cases (2), (3) and (4) the appropriate concentrations would occur. The various combinations gave rise to 1,050 such matrixes. They were not entirely successful, but without the use of a computer so much material could not have been utilised. A descriptive analysis of these 'maps' can be found in Appendix 4.c.

The following conclusions could be drawn from this analysis. There is some residential segregation of the major occupational categories, a finding which was clearly substantiated in Part I. The length of the work journey seems to be more a function of the relative concentration of employment opportunities and of the residences than of any economic determinants. Again the earlier analysis of employment potential gave the same results. Finally movement to the central area is strongly marked in almost all categories of employment and from all parts of the city. However, strong currents cut across and run counter to the important centrifugal and centripetal movements, depending upon occupational categories.

Journey length was implicit in this analysis, and associated with this factor is modalchoice. Again some of the influences at work have been analysed, but here the hypothesis to be tested is, "that there is a relationship between the mode selected for a trip to work and the location of that workplace destination". Four workplace sites were chosen, with

(7) Appendix 4.b. bound separately. Table 25, pp. 58-91. A fuller description of the methods used is found in Appendix 4.c. this volume, and an analysis in Appendix 4.c.

varying mean work journey lengths, and the proportions travelling by various modes calculated. These are shown in Table 2:3. The major effect of increasing journey length is to reduce the number of trips made on foot, and to increase vehicle journeys including those by car, but in particular those made by public transport. Because a sex difference arises and the employment composition can thus be important, two locations are analysed for sex differences. The same, but more intensive, pattern is found for female employees. For them the decrease in pedestrian trips is almost entirely compensated by an increase in bus trips. The increase in car journeys is almost entirely a function of the number of male employees. The general hypothesis seems to be substantiated, but further and more sophisticated analyses are necessary where workplace sites are separated by greater distances.

Table 2:3

Workplace Destination: Mean Journey Length and Modal Choice (in %)

MODE	DISTILLERY Exogenous Location Male	Female	Total	RETAIL STORE Central Location Male	Female	Total	TRANSPORT INTER-MEDIATE locations Total	FOUNDRY Central Location Total
Car	21.4	3.3	15.5	12.9	4.0	7.2	17.6	6.9
Motor Cycle	4.3	0.6	3.1	6.0	0.4	3.0	3.4	3.1
Cycle	16.9	7.3	13.7	23.0	20.0	21.0	14.1	20.0
Bus	40.2	70.3	50.1	19.8	31.1	28.0	47.4	20.9
Car Passenger	8.3	5.9	7.5	1.6	0.9	1.0	4.6	1.5
Train	0.1	-	0.1	-	0.1	0.1	-	-
Walk	8.8	12.6	10.0	25.7	43.4	38.8	12.2	46.3
Other	-	-	-	1.0	0.1	0.9	0.7	1.2
MEAN JOURNEY LENGTH	3.16 miles			0.97 miles			2.0 miles	0.51 miles

When gross land use cat-egories are considered, clear differences can be noted amongst them in the proportions of work trips to all terminating trips (Table 2:4). Those land usages in which large numbers of customer trips are important, stand out - retail, service, public buildings and transport. At the other extreme are storage and workshop areas; the largest proportion of whose trip-ends are accountable for by work trips. The major attractors of work trip-ends are industry, retail and office land uses.

Table 2:4

Proportion of Work Trips to all Terminating Trips, by land use.

Land Use	All Perth	Central Area	% Total Work trips (All Perth)
Retail	23.2	15.9	16.4
Industry	37.2	35.2	22.9
Service	24.6	25.0	10.9
Public Buildings	26.2	22.3	3.7
Transport	10.2	-	11.3
Office	32.3	31.6	14.9
Wholesale	38.9	37.2	3.0
Storage	56.1	47.8	4.4
Workshop	64.3	60.9	8.8
Other	39.1	38.6	3.7

The varying attractiveness of destinations in the central area can be inferred from Table 2:5, and described in some cases to a dominant land use. There is in fact a range of attractiveness, and zones in the centro-peripheral area, that have a low attractiveness for total and work trip-ends. These zones are characterised by light industry, workshops and warehousing. On the other hand the core area, particularly Zone 1, with a higher proportion of retail and office space, has a much higher rate of trip attraction. Differing proportions of work to total trips result, as is obvious from both Tables 2:4 and 2:5, since of course retail and office land uses attract a large number of non-work trips. Thus only 18.6% of trip-ends in Zone 9, 21.2% in Zone 1, and 17.6 in Zone 7 (shopping areas) are work trips, whilst this proportion rises to 41.5% in Zone 2, an area of warehouses and industry.

Table 2:5

Trip-ends, Central Area, as a Function of non residential floor space

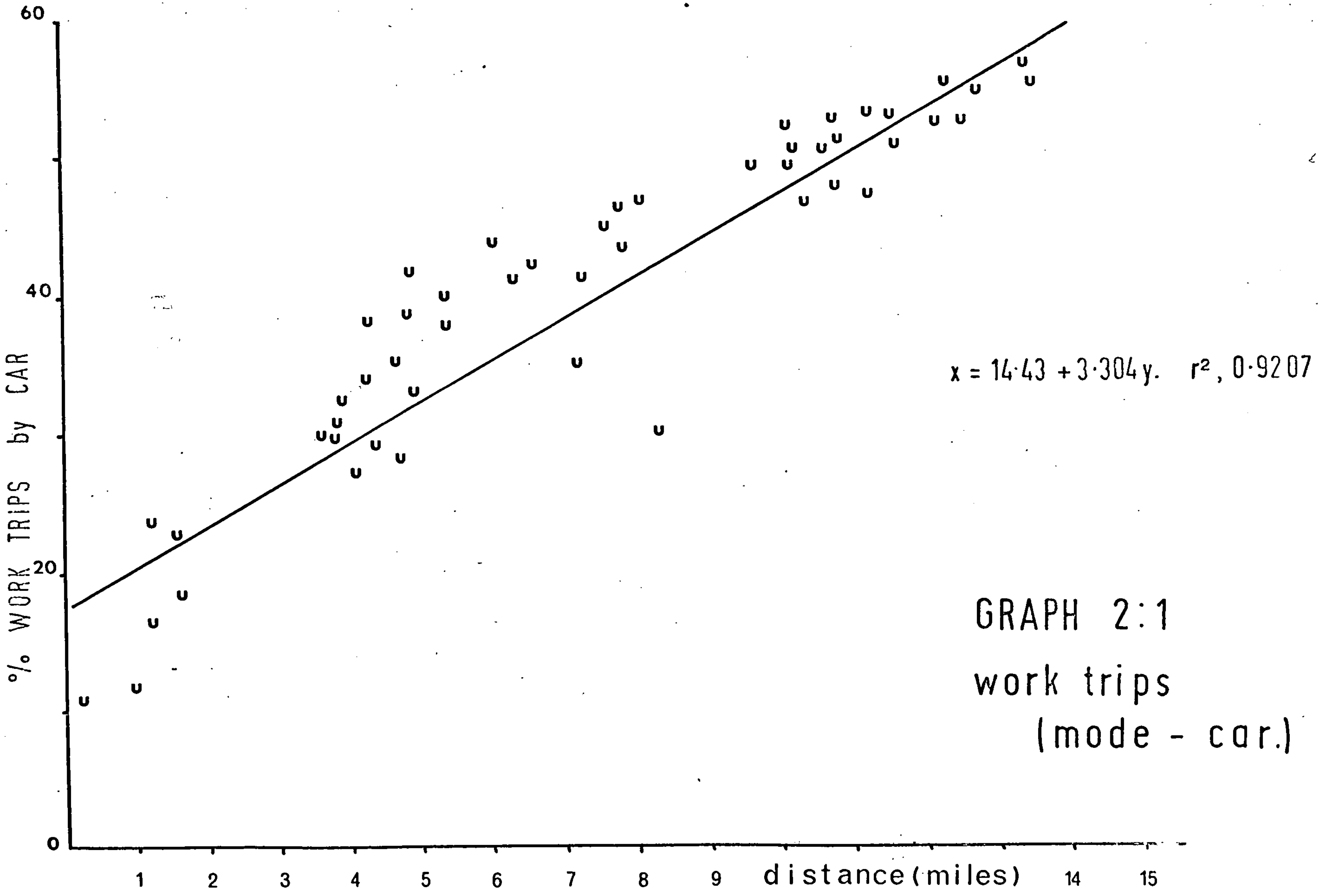
	TRIP-ENDS, ALL PURPOSES		WORK TRIP ENDS		
ZONE	Total	(1) /1,000 sq.ft.F.S.	Total	(2) /1,000 sq.ft.	RATIO (2) to (1)
1	12,573	22.2	2,715	4.7	0.212
2	2,573	5.8	1,107	2.4	0.415
3	6,100	19.6	1,884	6.0	0.360
4	490	14.2	56	1.5	0.164
5	364	19.3	79	4.2	0.218
6	4,770	11.6	1,124	2.7	0.232
7	3,209	17.6	566	3.1	0.176
8	2,294	7.1	692	2.2	0.310
9	1,315	19.3	247	3.6	0.186
10	3,114	13.6	710	3.1	0.228

The actual relationship between the spatial pattern of work trips and the type of economic activity of the worksite is not so much a direct causal one, as an amalgam of variables of travel characteristics. The earlier analyses, including the use of the 'computer-diagrams', have shown how important are the occupational composition and the sex ratio of the employees, to the worksite activity and associated work travel movements. In other words, the category of worksite destination does not of itself provide a direct indicator of work journey patterns, but it may include a number of characteristics - land use type, technological activity, employee composition, male/female proportion, central, intermediate, peripheral or exogenous location - that in a particular area will bear near-direct relationships to travel patterns. If land use type and location are held constant, the factors most strongly affecting trip characteristics are the composition of the employed force; occupational structure, and sex structure.

Having established and substantiated these particular relationships, it was then possible to submit the observed work trip patterns to more refined and sophisticated analytical techniques. As a preliminary, the earlier observed pattern of increased vehicle use at three or four sample sites according to greater mean work journey length was subjected to regression analysis, using material for the whole of Perth this time.

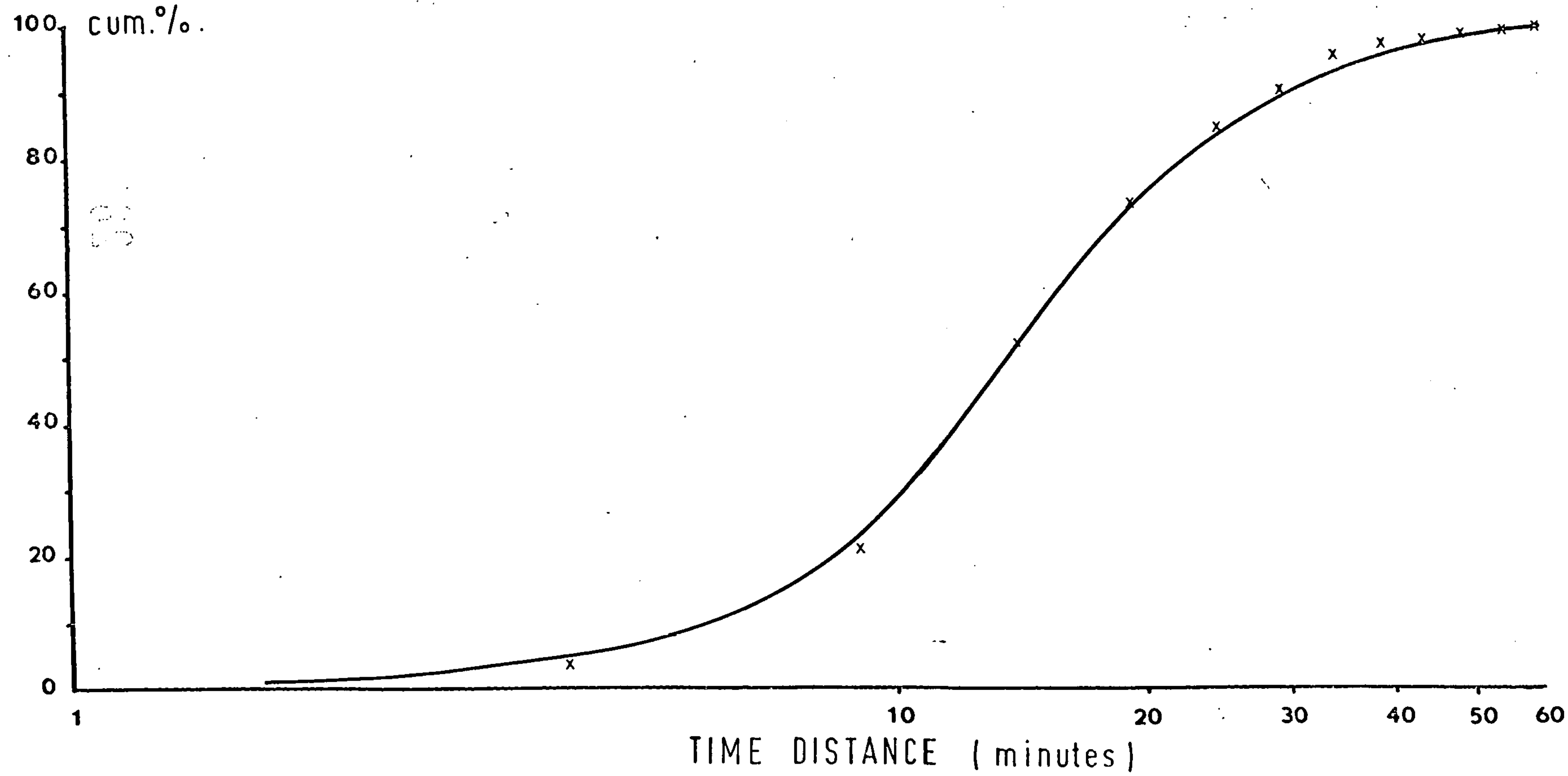
A clear relationship was indicated between modal choice 'car' and the distance of the workplace from the residence. Graph 2:1 indicates that at workplaces 2 miles from residence, from 16 to 22% of the trips are made by car; at 5 miles, 28 to 42%; at 10 miles, 45 to 53%; and at 15 miles, 53 to 60%. The regression of % trips by car on distance was $x = 14.43 + 3.304y$ with a 't' statistic of 18.98 and an $r^2 = 0.92$.

A fairly simple and easily prepared analytical method is to use a cumulative percentage distribution, and this is done in Graph 2:2, in which the distribution of residences about workplaces in Perth are correlated with time-distance. In studying confluence patterns at various workplaces in terms of distance between residences and the workplaces, no attempt has been made up to now to eliminate the effects of varying densities in the spatial



GRAPH 2:1
work trips
(mode - car.)

GRAPH 2:2 work trips / distance.



distribution of the labour force. However various methods are available to make allowances for these differences. Much of the remaining analysis involves consideration of these methods.

One method is to consider the proportions of all originating work trips from each traffic zone that have destinations at a particular worksite. These proportions can be then plotted against the distances of the individual origin districts from the respective worksite. Graph 2:3 illustrates this, representing 1563 work trip-ends of 27 average time distance (in minutes) about Zone 14. The data can be described by the regression equation:

$$\log x = 0.8363 - 1.397 \log y$$

The coefficient of determination was 0.84, the 't' statistic 10.14, significant by the 'F' ratio test to the 0.1% level. For the largest grouping of work trips to a single zone, the central area, the precision of measurement was quite poor ('t' 1.76, $r^2 = 0.13$, significant by the 'F' test at the 10% level only), as it was for one or two other zones. The results can be seen in Table 2:6 which also shows for some zones the relationship of equations:

$$\log x = c + a \log ya \text{ (Distance}^2\text{)}$$

and $$\log x = c + a \log y + b (\log y)^2$$

These other relationships are more complex than a simple power-function, and the last equation represents a parabolic curve. For instance the relationship of work trips and distance for Zone 11 was found to be described by the equation:

$$\log x = 0.57 - 14.230 \log y - 7.696 (\log y)^2$$

For this relationship, the coefficient of determination was found to be 0.8197 and statistically significant to the 1% level. This sort of curve indicates that though there is attraction from the immediate area, beyond this it is thinned out by some other factors, such as much of the local work force having skills other than those employed within the zone. One or two other zones also recorded such a relationship, but the simple power function

GRAPH 2:3 work trips / distance.

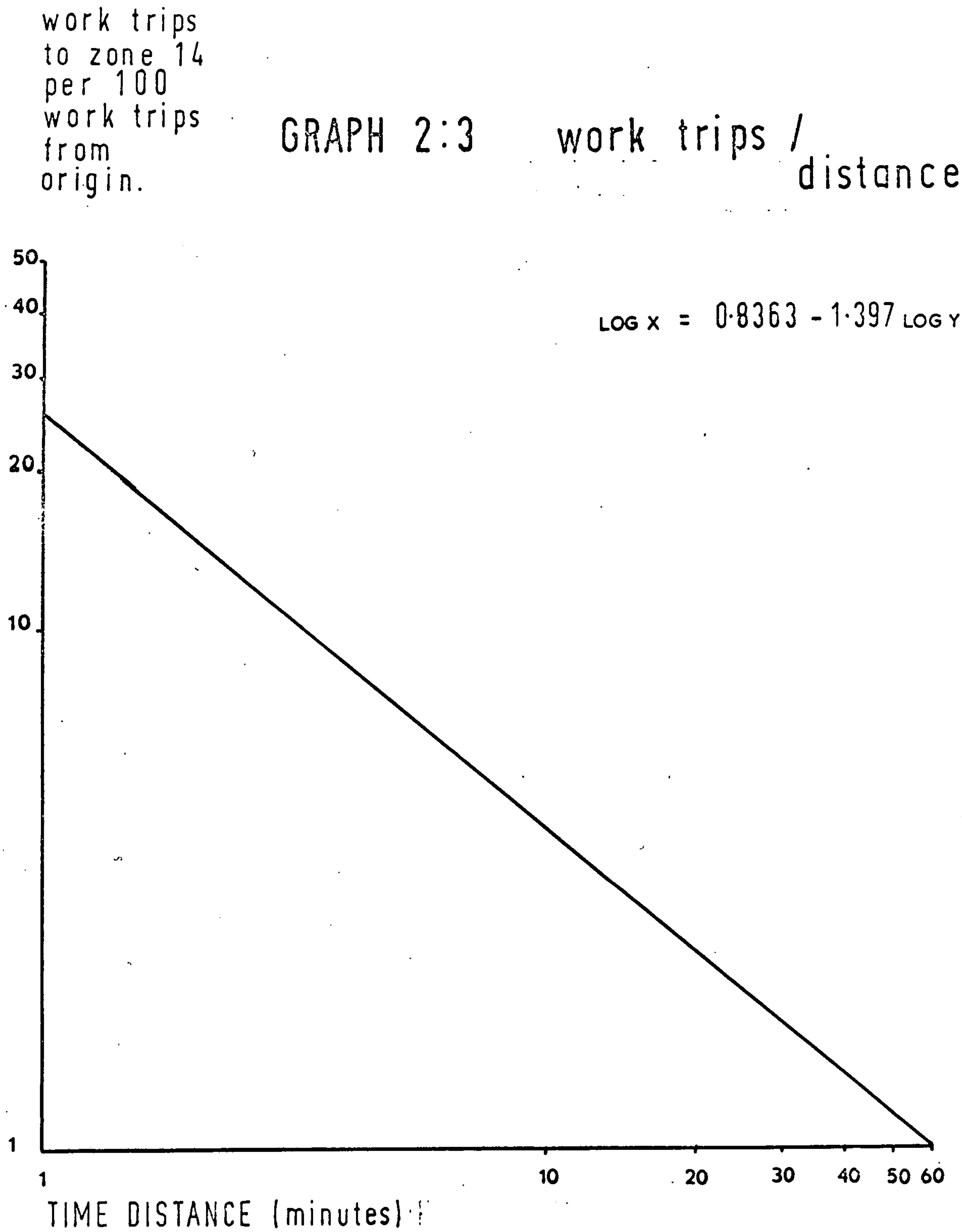


Table 2:6

Regression. Work Trips and Journey Distances

ZONE OF DESTN.		Constant	log y	log y (Dist.^{2})	(log y)^2	r^2R^2
14		0.8363	-1.397			
	SE		0.1378			0.8370
	t		10.14			
		0.8358		-0.6972		
				0.0690		0.8361
				10.10		
		0.8467	-38.390		18.480	
			20.430		10.700	0.8496
			1.88		1.72	
17		0.6104	-1.198			
			0.2224			0.6174
			5.39			
15		0.8113	-0.5129			
			0.0747			0.7238
			6.87			
12		0.5451	-0.7477			
			0.1700			0.5045
			4.40			
		0.5449		-0.3742		
				0.0846		0.5073
				4.42		
		0.5242	74.140		-37.380	
			28.020		13.980	0.6543
			2.65		2.67	
2		0.6398	-0.2921			
			0.1156			0.2514
			2.53			
1		1.0550	-0.1555			
			0.0885			0.1339
			1.76			
23			-1.098			
		0.1809	0.2351			0.6266
			4.67			
		0.1816		-0.5585		
				0.1186		0.6303
				4.71		
		0.1895	9.8370		-5.5460	
			2.4300		1.165	0.6458
			4.01		4.69	
11		0.5787	-1.3020			
			0.1453			0.8086
			8.96			
		0.5780		-0.6456		
				0.0716		0.8104
				9,01		
			-14.230		-7.6960	0.8197
		0.5725	5.589		2.7080	
			2.54		2.83	
10		0.5083	-0.3005			
			0.1123			0.3091
			2.68			

remained in force for most of them.

The relationship established from these results still contain an element of bias. Each worksite, and for that matter each area of origin, represents a varying proportion of Perth's employed force or inhabitants. To see the relationship without the bias of various sizes of area and work force, further refinements can be carried out by standardising in terms of some measure of central tendency, the proportions of work trips to a particular worksite. Table 2:7 shows one way of determining this. The proportions of all work trips which terminated in two sample zones, categorised by time-distance, were divided by the respective weighted proportions of all reported work trips to these destinations. This table should be compared with Map 2:3 which shows the more normal method of 'analysis', the 'dot' map. The dot map has a distinct visual impact of course for a particular point in time, but it is of little analytic worth in this context.[1] The distance relationships of the two zones are very similar.

Another ratio that can be developed is 'Actual to Probable Volumes'.[2] Basically it uses data assembled in a simple origin-destination matrix, and the aim is to derive a single equation or expression to indicate the relationship to trip distance of the deviations from the average proportion of trips to the destination. The basic concept is the same as the previous ratio, but this second method is more systematic, and is very similar to the approach taken at the opening of this section. Actual numbers of home-to-work trips are compared with the probable numbers which might be 'expected' if physical distances between origins and destination had no effect. Probable volumes of work trips between two zones are dependent only on the number of residents

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(1) H.S. Lapin 'Structuring the Journey to Work' Philadelphia, University of Pennsylvania Press, 1964. pp. 131-133 and pp. 162-164 pursues this 'distance-variable' ratio further.

(2) H.S. Lapin 'The Analysis of Work-trip Data: Relationships and Variances' Traffic Quarterly, April 1957, pp. 278-292.

MAP 2:3

Origin of Workers as worksites in Zone 1. cf. with TABLE 2:7

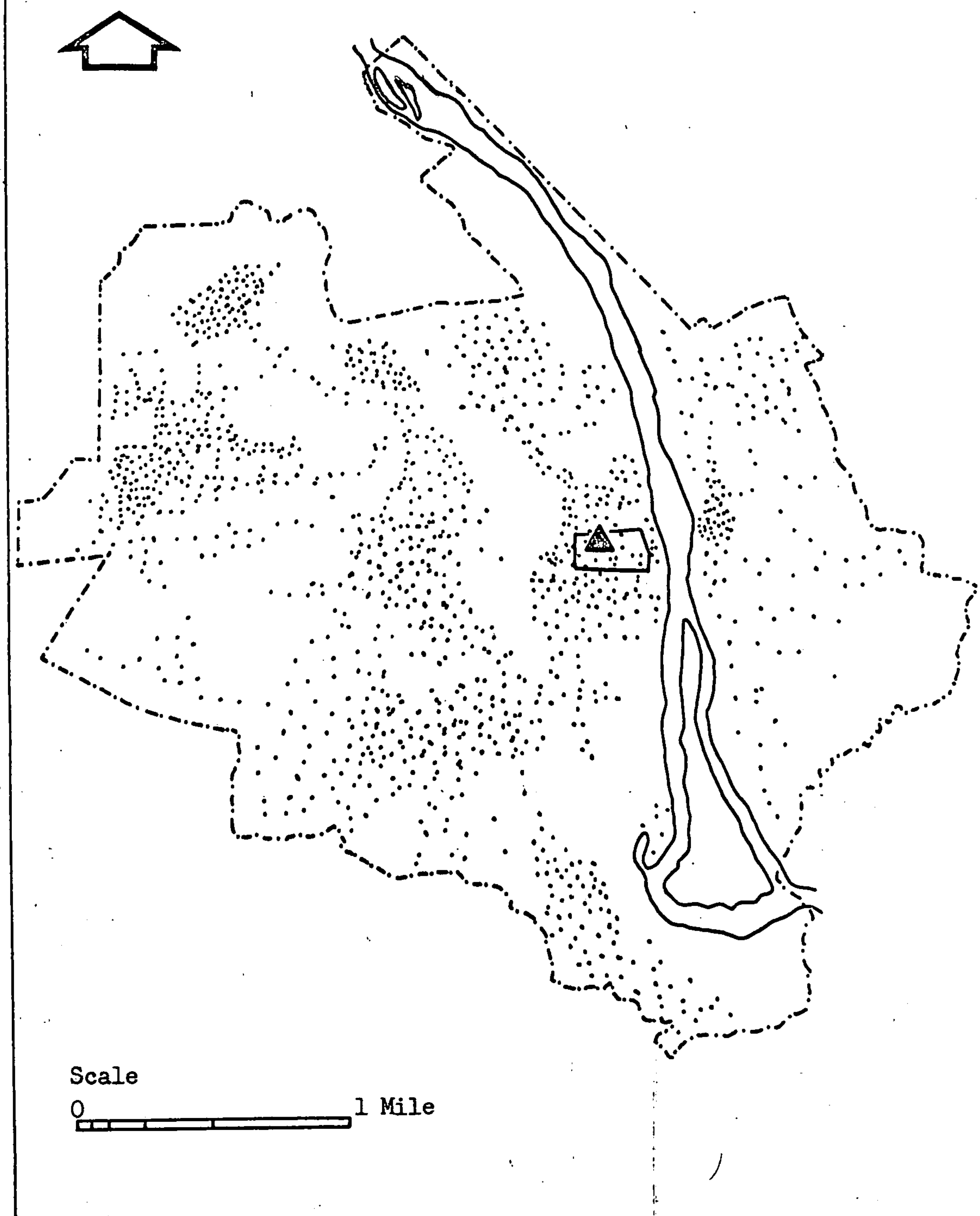


Table 2:7

Ratio, Distance to Work Trip Destinations

TIME-DISTANCE (in Minutes)	WORK TRIPS TO ZONES /100 Work Trips from Origins	Ratio *	WORK TRIPS TO ZONES /100 Work Trips from Origins	Ratio*
0-4	12.6	0.57	21.1	1.63
5-9	33.9	1.54	23.0	1.78
10-14	71.3	3.23	39.3	3.04
15-19	77.0	3.50	27.5	2.13
20-24	29.2	1.32	14.8	1.15
25-29	11.2	0.51	13.8	1.07
30-34	12.8	0.58	8.2	0.63
35-39	4.5	0.20	3.3	0.25
40-44	3.8	0.17	2.8	0.22
45-49	5.9	0.27	1.1	0.08
50-54	1.9	0.09	0.4	0.03
55-59	0.8	0.04	0.1	0.01
	22.0	1.00	12.9	1.00

* This ratio is derived by dividing the proportion arriving from each time-distance category by the weighted average proportion.

and numbers of employment opportunities, and not upon any frictional effect of movement between residence and work site. Ratios are then calculated between the actual and probable interchange volumes. Actual volumes are shown in Table 2:8, and the probability interchange matrix in Table 2:9. The average proportion of work trips to each worksite zone from all zones of origin calculated from Table 2:8 is applied to each worksite/particular origin zone cell in Table 2:9. The ratios of Table 2:10, are the calculated ratios between the values of the cells in the matrixes of Table 2:8 and 2:9. Distances are in this case air-line distances (with allowances for the bridging of the River Tay), set out in Appendix 7.b.

By regression analysis it is possible to erect a mathematical relationship which approximately describes this distance/trip ratio variation. 98% of the variation in the trip ratios was in fact 'explainable' statistically, in terms of the distance factor by this method. Using a log/log relationship the equation is:

$$\log x = 6.560 - 1.092 \log y.$$

S.E. 0.018

t 59.75 $\qquad r^2 = 0.98$

Graphs 2:4 and 2:5 show this relationship - Graph 2:3 plainly shows the curvilinear nature of the distribution, and the regression equation at this stage was:

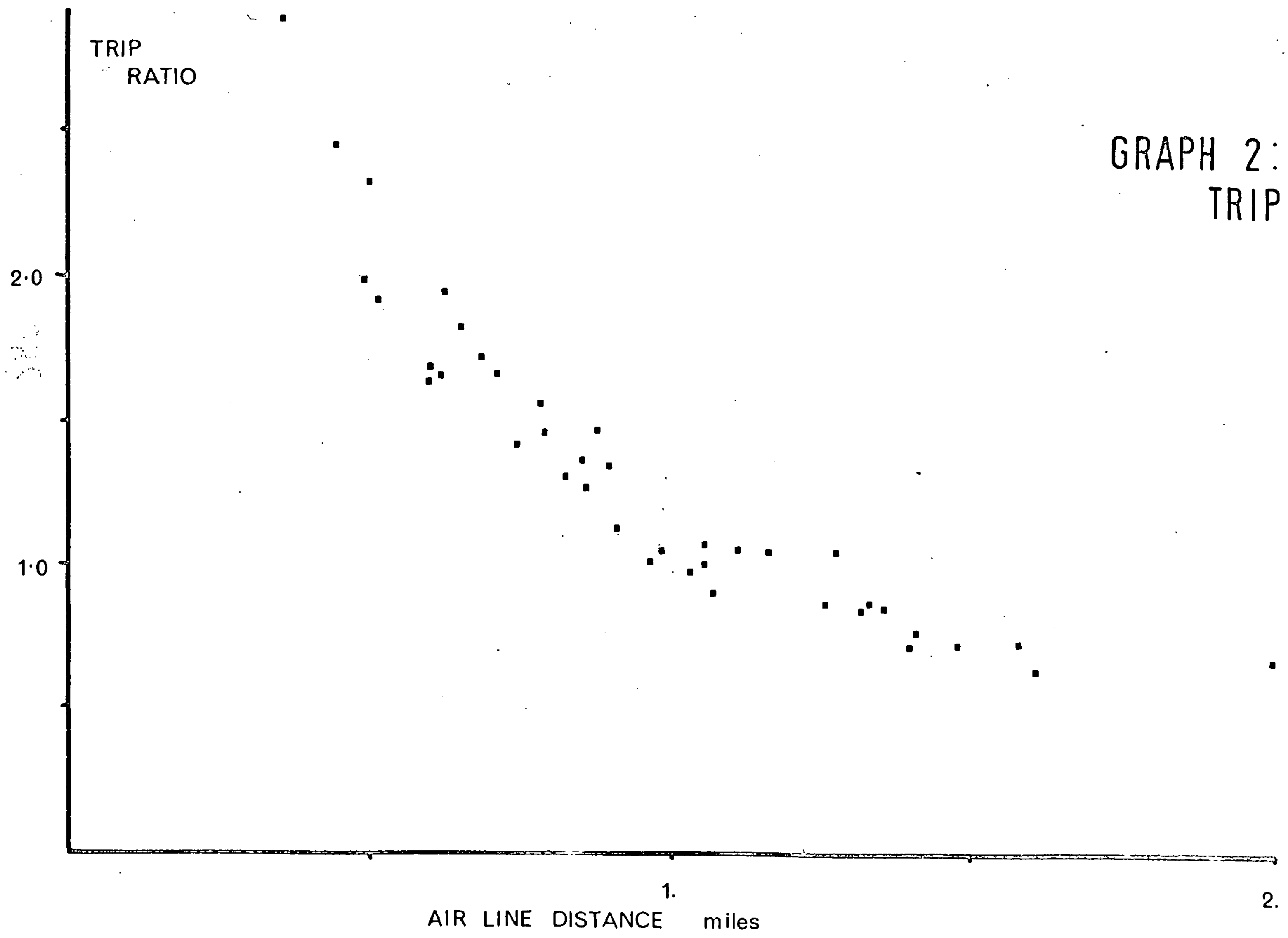
$$x = 5.471 - 3.099 y$$

S.E. 0.392

t 7.90 $\qquad r^2 = 0.47$

Graph 2:5 shows the log/log relationship and the close fit of the regression line and data.

GRAPH 2:4
TRIP RATIO



GRAPH 2 5 TRIP RATIO

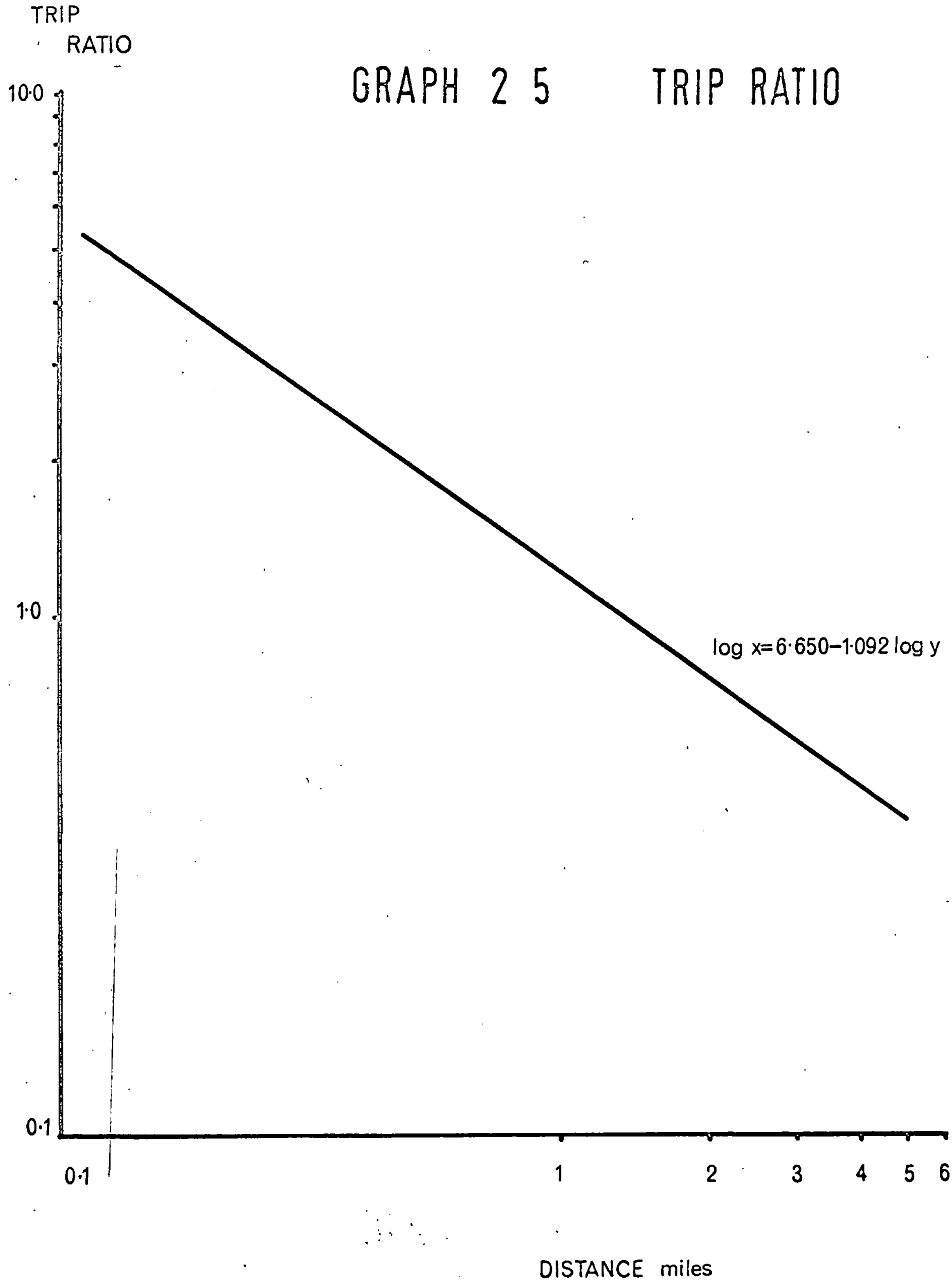


Table 2:8

Work Trip Origins   Actual Zonal Work Trip Interchange

Work Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	20	21	22	23	24	TOTAL	%
1	-	28	25	5	9	75	13	44	4	81	277	128	10	31	310	65	152	46	464	63	32	26	1,988	16.5
2	25	-	9	0	1	36	11	15	3	47	169	48	3	16	118	26	39	8	172	29	47	11	844	7.1
3	38	10	-	5	3	55	8	18	4	38	205	126	11	16	239	69	119	52	259	34	13	41	1,363	11.4
4	1	1	1	-	0	2	0	3	0	0	7	2	1	1	6	0	2	4	10	2	1	0	44	0.5
5	1	2	1	0	-	3	1	3	0	2	11	3	0	0	10	6	3	3	17	1	0	0	67	0.6
6	24	14	8	2	3	-	9	20	4	25	122	62	13	15	135	29	49	12	193	27	18	7	791	6.6
7	13	11	4	2	1	23	-	14	3	21	63	26	0	10	63	8	25	15	96	14	9	4	425	3.5
8	10	5	1	0	1	25	3	-	3	26	69	19	5	3	97	15	37	11	125	15	11	5	486	4.1
9	6	4	0	0	0	10	5	6	-	9	27	7	0	2	31	15	13	6	28	1	3	4	178	1.5
10	15	17	4	0	0	20	0	13	0	-	105	22	3	8	80	20	27	11	128	17	20	7	517	4.3
11	28	16	6	1	0	37	6	18	3	71	-	42	7	7	124	30	38	13	228	38	97	19	729	6.1
12	16	8	6	2	1	22	4	9	0	21	74	-	6	10	95	13	35	7	118	16	15	3	481	4.1
13	3	1	4	0	0	2	0	4	1	2	6	11	-	3	13	3	1	3	15	5	3	1	81	0.8
14	27	19	17	4	4	36	9	20	7	35	142	31	4	-	364	15	50	21	240	54	57	14	1,170	10.0
15	2	7	2	0	0	19	4	8	5	32	75	21	2	12	-	12	30	9	113	16	17	5	401	3.4
16	1	4	0	0	0	1	0	2	0	0	11	9	3	2	25	-	17	7	24	4	4	2	116	1.0
17	11	11	8	1	3	44	8	20	3	26	95	47	9	13	106	27	-	17	218	28	37	15	747	6.2
18	6	7	4	1	3	19	5	11	2	33	113	32	0	5	121	0	27	4	144	15	37	15	607	5.1
19	6	4	1	1	0	13	1	8	1	15	29	9	1	7	41	5	14	7	50	6	21	6	251	2.1
20	6	3	4	0	0	0	2	0	2	1	8	0	0	0	20	1	3	-	44	0	11	2	107	0.5
21	2	0	0	0	0	2	2	0	1	2	8	2	0	0	6	1	6	6	-	5	2	3	48	0.5
22	0	0	0	0	0	3	0	1	0	0	10	4	0	0	17	6	5	4	46	-	24	7	105	1.0
23	5	1	0	0	0	13	0	7	0	11	49	10	0	1	29	4	8	1	78	31	-	0	248	2.1
24	0	1	2	0	0	8	2	4	1	8	43	7	1	2	28	4	12	5	61	10	13	-	212	1.9
Total Trips	246	174	107	24	29	468	93	248	47	506	1718	768	79	64	2078	374	712	272	2871	421	475	192	11,986	100.0

Table 2:9

Work Trip Origins Probable Zonal Work Trip Interchange

Work Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	20	21	22	23	24	%
1	-	29	18	4	5	77	15	41	8	84	283	127	13	11	342	61	117	45	473	70	78	32	16.5
2	17	-	8	2	2	33	7	18	3	36	122	55	6	5	148	26	51	19	204	30	34	14	7.1
3	28	20	-	3	3	54	10	28	5	57	195	87	9	7	236	42	81	31	326	48	54	22	11.4
4	1	1	1	-	0	2	0	1	0	3	9	4	0	0	10	2	4	1	14	2	2	1	0.5
5	1	1	1	0	-	3	0	1	0	3	10	5	0	0	12	2	4	2	17	3	3	1	0.6
6	16	11	7	2	3	-	6	16	3	33	114	51	5	4	137	25	47	18	190	28	31	13	6.6
7	9	6	4	1	1	16	-	9	2	18	60	27	3	2	73	13	25	10	100	15	17	7	3.5
8	10	7	4	1	1	19	4	-	2	21	70	31	3	3	85	15	29	11	118	17	19	8	4.1
9	4	3	2	0	0	7	1	4	-	8	26	12	1	1	31	6	11	4	43	6	7	3	1.5
10	11	7	5	1	1	20	4	11	2	-	74	33	3	3	90	16	31	12	124	18	20	8	4.3
11	15	11	7	2	2	29	6	15	3	31	-	46	5	4	127	23	44	17	176	26	29	12	6.1
12	10	7	4	1	1	19	4	10	2	21	70	-	3	3	85	15	29	11	118	17	19	8	4.1
13	2	1	1	0	0	4	1	2	0	4	14	6	-	1	17	3	6	2	23	3	4	2	0.8
14	24	17	11	2	2	47	9	25	5	51	172	77	8	-	208	37	71	27	287	42	48	19	10.0
15	8	6	4	1	1	16	3	8	2	17	58	26	3	2	-	13	24	9	98	14	16	7	3.4
16	2	2	1	0	0	5	1	2	1	5	17	8	1	1	21	-	7	3	29	4	5	2	1.0
17	15	11	7	2	2	29	6	16	3	32	109	48	5	4	130	23	0	17	179	26	30	12	6.2
18	13	9	5	1	1	24	5	13	2	26	88	39	4	3	106	19	36	14	146	21	24	10	5.1
19	5	4	2	0	0	10	2	5	1	10	36	16	2	1	44	8	15	6	60	9	10	4	2.1
20	1	1	1	0	0	2	0	1	0	3	9	4	0	0	10	2	4	-	14	2	2	1	0.5
21	1	1	1	0	0	2	0	1	0	3	9	4	0	0	10	2	4	1	-	2	2	1	0.5
22	2	2	1	0	0	5	1	2	1	5	17	8	1	1	21	4	7	3	29	-	5	2	1.0
23	5	4	2	0	0	10	2	5	1	10	36	16	2	1	44	8	15	6	60	9	-	4	2.1
24	5	3	2	0	0	9	2	5	1	10	33	15	1	1	39	7	14	5	54	8	9	-	1.9
Total Trips	246	174	107	24	29	468	93	248	47	506	1718	768	79	64	2078	374	712	272	2871	421	475	192	100.0

Table 2:10

Probability Ratios, Interzonal Work Trips

ZONAL WORK TRIP MOVEMENT		Distance	Ratio Act/	ZONAL WORK TRIP MOVEMENT		Distance	Ratio Act/
From	To	(miles)	Prob.	From	To	(miles)	Prob.
1	7	0.09	1.44	12	2	0.77	1.22
10	9	0.11	1.13	21	24	0.77	1.13
1	3	0.17	1.35	11	6	0.82	1.07
10	19	0.17	1.50	11	5	0.91	1.10
1	6	0.18	1.51	10	12	1.03	1.00
10	2	0.20	1.31	12	18	1.03	0.82
21	20	0.20	3.14	12	8	1.05	0.61
1	10	0.26	1.36	12	9	1.07	0.58
1	9	0.27	1.48	21	16	1.10	0.83
10	7	0.28	1.17	11	20	1.14	0.89
10	18	0.29	1.27	21	19	1.20	0.83
11	24	0.35	1.30	12	11	1.23	0.91
1	19	0.38	1.20	12	17	1.27	0.98
15	14	0.44	1.76	10	21	1.28	0.66
1	18	0.45	2.10	21	9	1.32	0.65
21	22	0.50	1.58	21	2	1.42	0.84
10	11	0.54	2.29	10	22	1.44	0.20
1	12	0.58	1.61	12	14	1.49	0.40
21	23	0.60	1.30	12	15	1.54	0.81
1	13	0.63	1.50	12	23	1.65	0.63
11	23	0.65	1.31	1	22	1.68	0.10
15	16	0.65	1.19	21	4	1.75	0.71
15	18	0.66	1.14	12	21	2.01	0.50
15	8	0.72	1.14	12	22	2.08	0.50
11	3	0.76	1.05	21	13	2.18	0.52

The actual/probable volumes are closest together from about 0.90 to 1.10 miles. The actual volumes are much greater than the probable figures when accessibility is good (small distance), and the converse when accessibility is more difficult (larger distances), since the frictional effect is to some extent eliminated in the probability calculations. Also reflected in these figures are the fact that central area residents are largely employed within their zone of residence or adjacent zone, whereas those in intermediate and peripheral locations have more widely dispersed work trip patterns.

The relationship implicit in the actual/probable and distance-variable ratios can be refined still further by standardising for the uneven distribution of employment opportunities around the zone of origin. To do this, a trip distribution index was computed which standardised the distribution of employment opportunities around each area of residence, <u>and</u> standardised among residence areas for the number of work trips originating in each. The trip distribution measure can be represented by:

$$Pij = k \left[\frac{Wij}{\sum_j Wij} \div \frac{Eij}{\sum_j Eij} \right]$$

where 'W' is the number of work trips originating from the residential zone 'i', and 'E' is employment at a given work place zone 'j'. A scale-factor 'k', standardises the measure so that:

$$\sum_j Pij = 100$$

This measure really represents statistically the hypothesis that employment opportunities <u>are</u> evenly distributed about each residential zone. Implicit in the expressions obtained, is what percentage of all work trips originating

Table 2:11

Destination Land Use: AllOrigin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	10.4	5.7	5.3	4.1	2.7	5.4	5.6	3.3	6.1	5.1	4.9	4.8	4.9	3.9	0.7	1.3	2.2	2.0	4.8	10.5	3.0	0.0	3.4	0.0
2	3.8	12.8	1.9	5.6	7.3	4.2	6.4	2.2	5.5	7.8	3.8	3.2	2.2	3.7	3.2	6.9	3.0	3.1	4.3	7.1	0.0	0.0	0.9	1.2
3	4.8	4.0	19.1	8.0	5.3	3.5	3.3	0.6	0.0	2.6	2.0	3.5	12.6	4.8	1.3	0.0	3.1	2.6	1.6	13.7	0.0	0.0	0.0	3.5
4	2.3	0.0	3.2	76.1	0.0	2.1	4.0	0.0	0.0	0.0	0.8	2.7	0.0	2.7	0.0	0.0	0.9	1.5	3.7	0.0	0.0	0.0	0.0	0.0
5	4.1	1.0	1.9	0.0	75.0	3.1	2.0	1.5	0.0	0.0	0.0	1.4	0.0	2.6	0.0	0.0	2.8	4.5	0.0	0.0	0.0	0.0	0.0	0.0
6	4.3	4.7	4.4	4.8	4.7	11.7	5.7	4.8	5.9	3.9	3.7	3.8	1.9	3.0	3.7	0.7	5.1	3.6	6.0	0.0	1.7	2.7	5.1	4.2
7	2.7	5.1	2.3	0.0	5.6	4.2	32.0	2.1	10.5	0.0	2.2	2.5	0.0	2.7	2.8	0.0	3.3	3.4	1.7	7.2	6.2	0.0	0.0	3.7
8	3.3	2.5	1.9	9.3	6.1	3.4	4.5	27.8	4.6	3.3	2.4	2.0	4.9	2.2	2.0	1.9	3.0	2.7	4.8	0.0	0.0	1.2	3.5	2.7
9	1.1	1.9	1.5	0.0	0.0	2.5	3.6	2.8	50.9	0.0	1.5	0.0	4.5	2.8	4.7	0.0	1.7	1.8	2.2	9.8	4.2	0.0	0.0	2.5
10	4.7	6.3	3.1	0.0	3.2	3.3	5.3	5.1	5.4	13.4	7.3	3.7	1.9	3.0	6.3	0.0	3.1	6.4	7.1	1.0	1.8	0.0	4.4	4.3
11	4.4	6.1	4.5	4.0	4.7	4.3	4.3	3.6	4.3	5.6	18.5	3.5	1.5	3.2	4.0	2.2	3.0	5.9	3.7	2.2	1.9	2.4	5.2	6.2
12	5.0	4.2	6.3	3.2	3.2	5.4	4.4	2.5	2.8	2.9	2.9	21.4	7.0	1.7	2.8	4.5	3.7	4.1	2.8	0.0	1.2	2.4	2.6	2.5
13	1.0	0.7	1.7	4.5	0.0	3.2	0.0	1.8	0.0	1.1	1.3	2.0	73.1	0.6	0.7	4.2	2.0	0.0	0.9	0.0	0.0	0.0	0.0	1.0
14	3.7	4.3	2.6	4.9	0.0	4.0	5.1	1.2	2.4	3.2	1.4	3.5	5.8	135.4	4.8	3.0	3.1	1.9	6.7	0.0	0.0	0.0	0.8	2.1
15	4.3	3.7	4.6	3.4	3.3	4.2	3.8	4.5	4.4	3.8	3.0	3.9	2.9	7.3	19.2	4.4	3.0	5.5	4.6	4.9	1.2	3.6	2.7	3.5
16	3.7	3.4	5.5	0.0	9.4	3.8	2.0	2.9	8.8	3.9	3.0	2.2	2.8	1.2	2.3	28.8	2.1	1.0	2.3	1.0	0.9	5.3	1.6	2.1
17	5.5	3.2	5.9	3.0	2.9	4.0	3.9	4.4	4.8	3.3	3.4	3.8	0.6	2.6	3.6	7.83	17.3	13.2	4.1	1.9	3.3	2.8	1.9	3.9
20	3.6	1.4	5.7	13.1	6.4	2.1	5.1	2.9	4.8	3.0	1.8	1.7	3.9	2.4	2.4	7.1	2.7	1.0	4.5	8.3	7.1	4.9	0.5	3.6
21	4.1	3.5	3.2	3.7	4.1	3.9	3.7	3.7	2.5	3.9	3.5	3.1	2.2	3.1	3.4	2.7	3.9	4.2	3.6	6.9	11.2	6.3	4.7	4.9
22	3.5	3.7	2.6	4.6	1.5	3.4	3.3	2.8	0.6	3.2	3.7	2.7	4.5	4.3	3.0	2.0	3.1	2.7	2.7	0.0	4.2	20.5	11.6	5.0
23	1.6	5.4	0.9	2.1	0.0	2.0	1.9	1.8	1.5	3.4	8.5	3.2	2.5	4.1	2.9	2.6	3.7	6.1	8.5	9.7	1.5	5.4	15.6	5.9
24	4.0	3.9	8.8	0.0	0.0	2.4	2.7	2.6	6.3	3.7	5.1	1.4	2.5	3.1	2.6	4.0	4.7	7.6	7.5	5.4	7.0	4.8	0.0	9.87

in a particular origin zone would be destinated for each of the work site zones assuming the point-density of employment was constant.(3) Table 2:11 shows the results of this computation from all origin zones to all destination zones irrespective of the land use categories at the terminating point. In fact computations were also carried out in which work trips from a particular origin were sorted according to 10 land use types at the worksite. However despite its apparent sophistication, there are several ways in which errors may arise - the 'employment opportunities' surface which is used to standardise the distribution of work trip-ends for a particular residential area, may not for example, be entirely relevant to the labour force residing in that area.

The indicies set out in Table 2:11 and for the other specific land uses show the pattern expected from analyses earlier in this section. The relationships between the indicies and distance (airline) is shown in Graph 2:6 and 2:7.

A similar mathematical function to that developed for the actual/probable ratio was applied to the trip index/distance relationship, i.e.:

$$\log x = c - a \log y$$

which can be transformed to the inverted power function:

$$c = c\, y^{-a}$$

The results are shown in Table 2:12 for one particular zone of residence and the employment surfaces for the 10 land use types. In fact well over 150 equations were obtained from the data, and all were significant to the 0.1% level.

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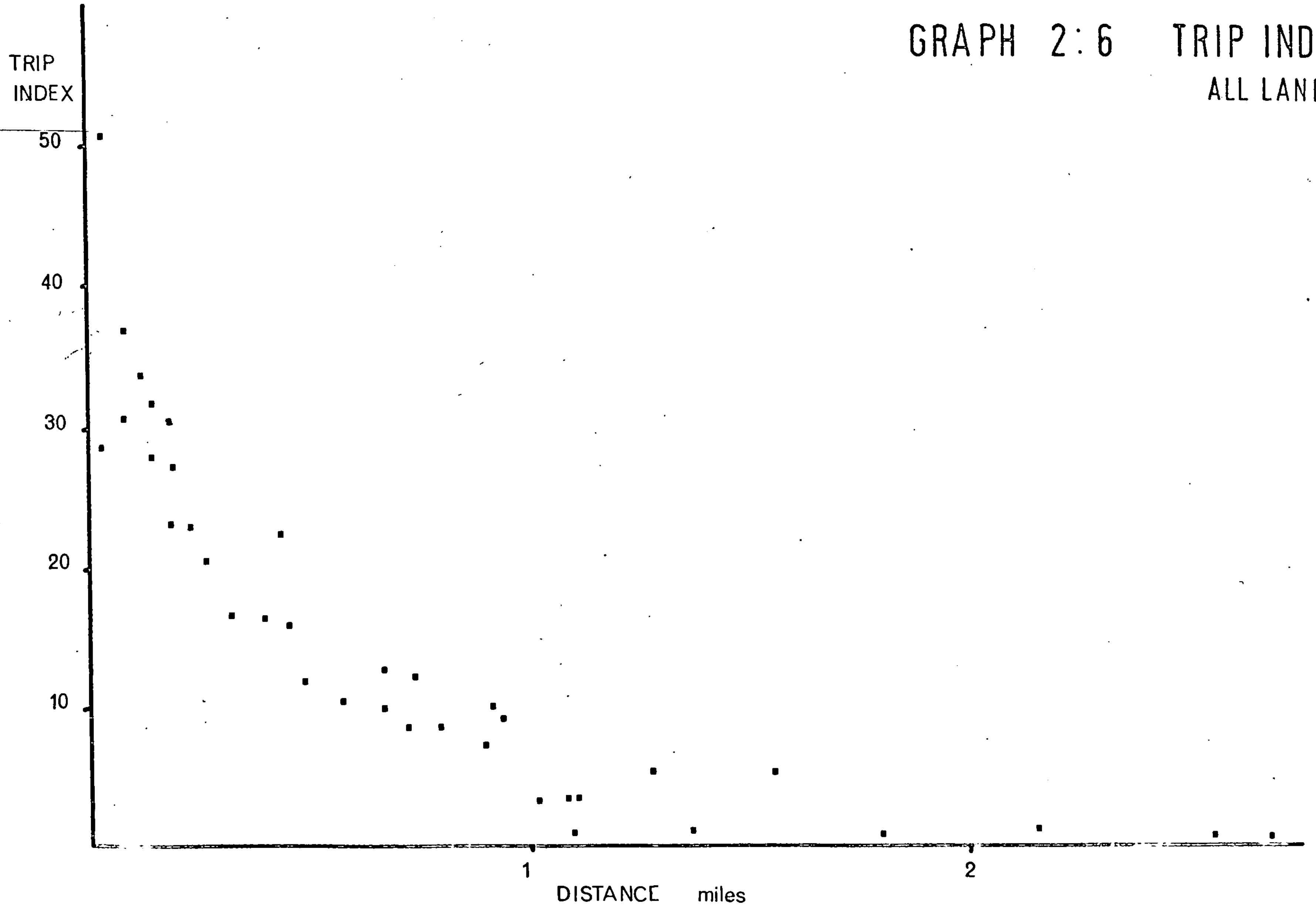
(3) The index applied here is an adaptation of that used in the Economic Study of the Pittsburgh Region, reported by I.S. Lowry in 'Location Parameters in the Pittsburgh Model' Regional Science Association Papers Procs. Vol. 11, 1963, pp. 145-165.

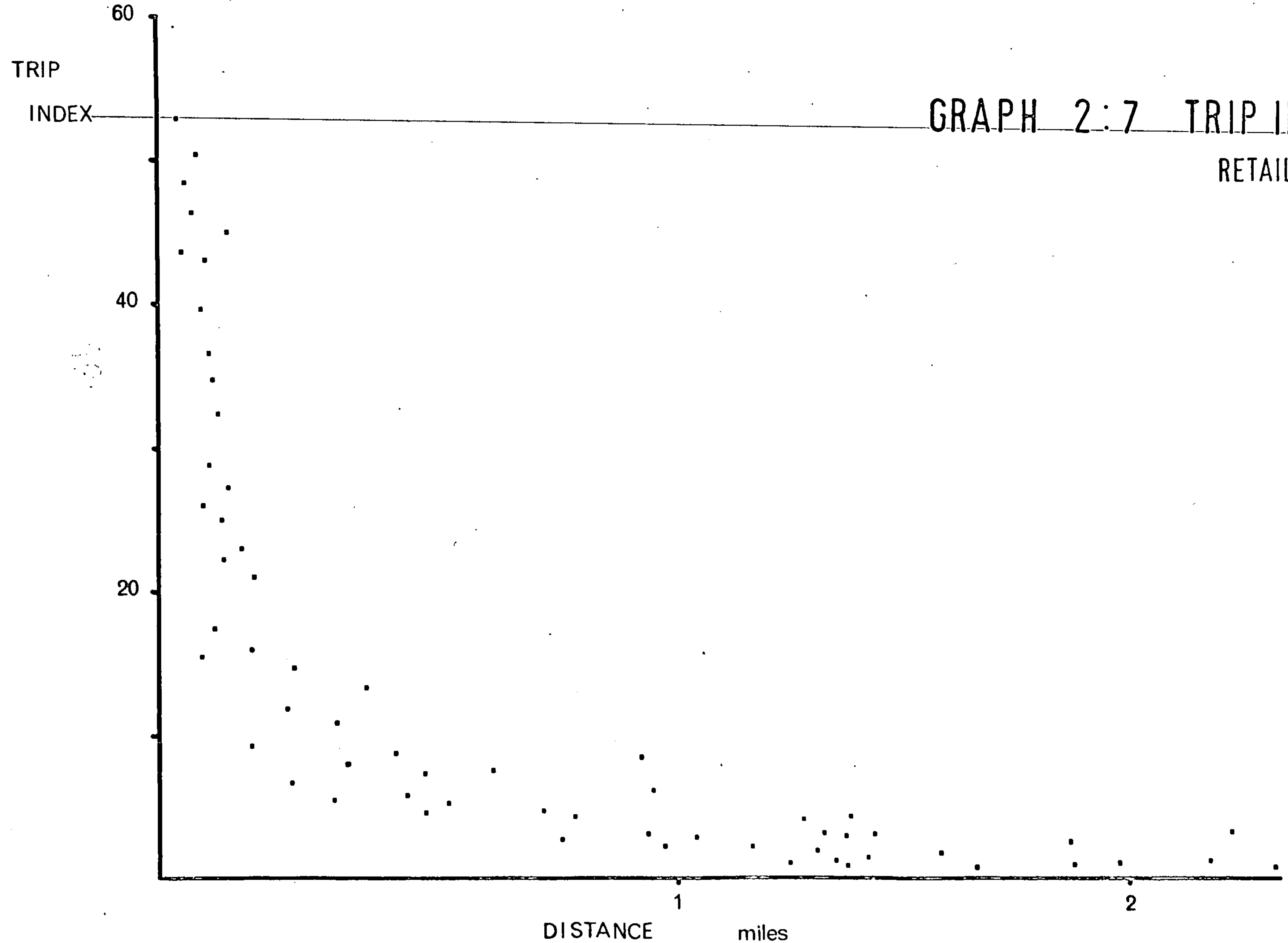
GRAPH 2:6 TRIP INDEX

ALL LAND USES



GRAPH 2:7 TRIP INDEX

RETAIL LAND USE.



The exponents of these power functions vary a great deal and indicate to some extent the nature of the work force. The lower the exponent the greater the residential dispersion indicated. Fairly high dispersion is shown in the total pattern as one would expect, but for Zone 15 a less dispersed pattern is found for the retail, office, service and wholesale work force, since in fact there are many local opportunities. Table 2:13 enlarges on this analysis for each land use type. The trip distribution indicies indicate from these regression results that a more dispersed residential pattern results from categories like offices, services, workshops and industry. Retail, storage, and transport uses show a concentration of residential origins around the worksite. Additional data could be fed in, in future concerning occupational composition, which would probably show an inverse relationship, with a more dispersed residential pattern the higher the occupational status. Even in a small urban area like Perth, then, there is some indication of a trade off between site-rents and transportation costs which indicates some kind of 'income effect' on locational choice of residence.(4)

The results obtained in this analysis conform to the earlier general formulation of the work trip/distance relationship. A diminishing interchange occurs between zones, with increasing physical distance. This was expressed in regression by a log/log equation. Other workers have also found a curvilinear expression is necessary, though since there is a variation in the data used, the mathematical format varies somewhat.(5)

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(4) See L. Wingo 'Transportation and Urban Land' Washington. Resource for the Future Inc., 1961; W. Alonso 'Location and Land Use' Cambridge, Harvard University Press, 1964; and J.F. Kain 'Commuting and the Residential Decisions of Chicago and Detroit C.B.D. Workers' Rand Men. P2735 April 1963.

(5) G.H.S. Lapin, op. cit.; Sven Godlund 'The Function and Growth of Bus Traffic Within the Sphere of Urban Influence' Land Service in Human Geography No.18, 1956, and S. Osofsky 'The Multiple Regression Method of Forecasting Traffic Volumes' Traffic Quarterly July 1959 pp. 423-445.

Table 2:12

Origin, Zone 15, Regression-Trip Value Index, and Distance

Land Use	Constant	Regression Coefficient	σ	t	r^2
9 Office	0.6626	-1.1540	0.07929	14.55	0.94
32 Retail	0.6390	-1.5680	0.1082	14.50	0.95
60 Service	0.5094	-1.7620	0.1882	9.36	0.84
77 Public Bldgs.	0.7125	-1.3400	0.1174	11.42	0.87
84 Wholesale	0.3960	-1.6030	0.1340	11.96	0.89
90 Storage	1.029	-0.7386	0.09243	7.99	0.75
96 Workshops	1.001	-1.1190	0.07538	14.85	0.93
99 Industry	0.7927	-0.9661	0.0843	11.46	0.89
105 Transport	0.9136	-1.015	0.1206	8.42	0.77
109 Other	1.1690	-0.4264	0.1062	4.02	0.42
49 All Land Uses	0.5371	-1.1431	0.1602	8.93	0.78
57 All Origins x All Land Uses	0.4504	-0.5403	0.0428	12.62	0.36

Table 2:13

Trip Value Index, and Distance. All Origins

Land Use	Constant	Regression Coefficient	σ	t	r^2
153 Office	0.8921	-0.6431	0.0382	16.85	0.95
146 Retail	0.6349	-1.694	0.1946	8.70	0.87
145 Service	0.5171	-0.7383	0.1000	7.38	0.76
150 Public Bldgs.	0.5607	-1.0460	0.1316	7.95	0.81
144 Wholesale	0.7563	-0.5811	0.0612	9.50	0.85
140 Storage	0.8151	-1.4850	0.1467	10.13	0.87
138 Workshops	0.5984	-0.6419	0.0525	12.22	0.90
131Industry	1.1850	-0.7673	0.1719	4.46	0.51
125 Transport	0.3714	-2.4010	0.2074	11.58	0.89
123 Others	0.4857	-0.8015	0.0792	10.12	0.84

Lapin and Godlund report the general relationship:

$$X = c + by^{a}$$

where 'a' is a negative exponent, and 'c' and 'b' are the values determined for a given system of trips. Osofsky reported a similar but more complex relationship:

$$x = Co + B\ (1 + y)^{a}$$

where 'B' is a multiplier calculated for a particular trip interchange between two specific zones. The form found in the Perth calculations was:

$$\log x = c + \log y^{a}$$

where again 'a' was a negative exponent. It is interesting to compare these regression forms with the general gravity method which can be represented algebraically as:

$$x = b\ y^{a}$$

The differences between this gravity formulation and the regression method are important and will be discussed in Part III of the thesis, where an attempt is made to formulate a model for totall trip zonal interchanges.

The following inferences can be made from this general consideration of work trip confluences. There was an apparent significant relationship between worksite and distance from residential origin; a fairly consistent decline in numbers of workers commuting to a worksite with increasing distance, whether the latter was measured as elapsed time or airline distance. Secondly, the number of employees at the worksite affects the number of workers drawn from each distance category; variation was also caused by location and occupational composition. Finally, there were similar probabilities of per capita attraction of workers from equal distance categories, although absolute numbers of workers drawn from external zones were high for large employment work sites.

The first two findings bear resemblance to the study of 'potential' made by macrogeographers and others - the relationship here being between a worksite trip confluence area and the 'field' from whichthe trips are drawn.(6) The field of employment can be considered as one of varying density of potential workers at an individual plant, with an equipotential surface about centres of employment. Map 2:4 shows an example of this; the surface shallowing to the periphery as the effect of accessibility and alternative sources of employment make themselves felt.

It is obvious from this study that the analysis of all travel movements is only just under way, there are many variables and associations barely investigated. This section has identified certain persistent patterns, although there may be many more, and has also tried to erect a synthetic model. But this is really the starting point for much more research.

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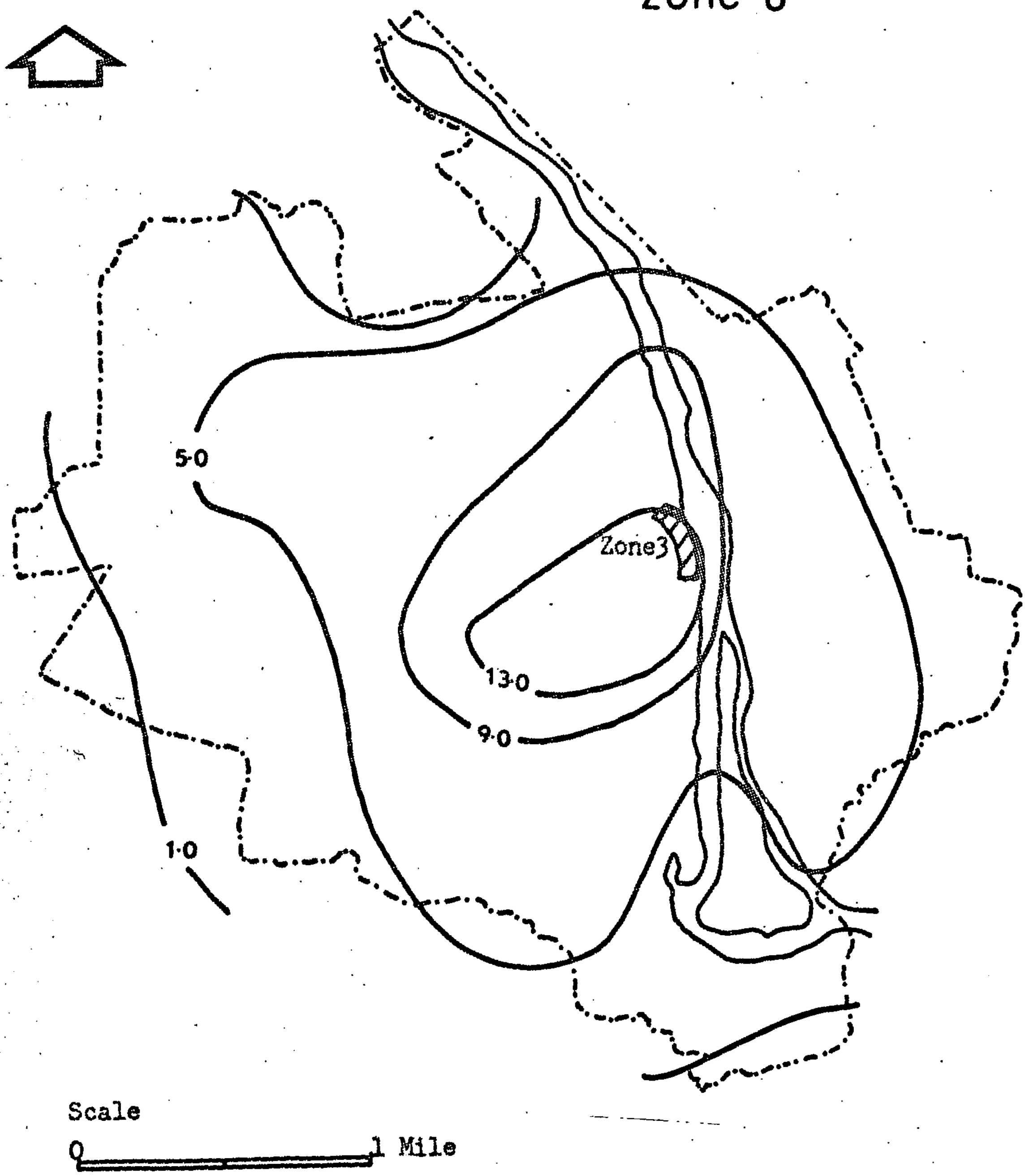
(6) J.Q. Stewart 'Demographic Gravitation: Evidence and Application' Sociometry - XI. Feb. 1948; and H.S. Lapin op. cit. pp. 162-165.

MAP 2:4 employment zone 3



EQUIPOTENTIAL FROM FORMULA:- $P_{ij} = k \left| \frac{W_{ij}}{\Sigma W_{ij}} \div \frac{E_{ij}}{\Sigma E_{ij}} \right|$

SECTION III CONCLUSION: NON-RESIDENTIAL TRIP GENERATION

To understand the geographic, economic, and engineering elements of travel movements, requires a careful analysis of the variables which affect such patterns. In recent years, especially in North America, a definite procedure for planning, designing, and evaluating urban travel patterns has evolved, a fundamental requirement of which is the estimation of the amount of traffic generated by the various uses of land in an area. Much of the data upon which such estimates are made are obtained from detailed interviews at the residence, and none or only a small part from the destination. Most land use generation data has thus in fact been obtained indirectly, with consequent errors.

This part of the thesis has tried to analyse actual landuuse generation or induction, though without revealing any clear cut relationships such as were found between residential trip generation and family size, car ownership, income, etc.

The underlying rationale is the functional relationship between land use and urban travel. Travel patterns are recognised to be a function of the locational distribution of various kinds of land use in an urban area. This functional relationship can be carried one step further by tying the rate at which trips are generated by various land uses to the intensity and type of land use activity. Trip induction was related to the kinds, amounts, intensities and locations of a set of land use classes. The latter were as specific as possible, in view of the dangers of using a very generalised classification.

One measure of land use activity used was floor area. It can be measured, either as gross or net totals, or in terms of the number of square feet of floor space devoted to a particular activity. The advantage of this latter measure is that it provides a measure of the intensity of use.

For example, an acre of single-storey office buildingsin a suburban area would be expected to generate far fewer trips than an acre of multi-storey office buildings in the central area. The number of trips per square foot of floor area would be much more comparable in the two instances.(1) Its disadvantage as a measure is the time and cost of collecting the data. It proved in Perth, however, to be a very significant measure, and is summarised in Table 3:1.

Besides intensity of use, measured by floor area, other land use activity measures utilised were employment, convenience and shopping goods availability, and distance. A summary of the factors used, and an indication of the range of variables used in North American studies is shown in Table 3:2.

Having established some basic relationship between intensity, employment, etc., though not the concrete terms of the relationships found in Part I, these factors were subjected to regression analysis, etc. Appendix 6.e. notes that the advent of computers has made feasible the application of a number of fairly sophisticated statistical techniques to the analysis of trip attraction. Particularly useful is stepwise multiple regression analysis used throughout this investigation. The computer is programmed to review automatically each dependent variable, determining the degree of correlation with the independent variable, and at the same time making allowance for the interrelated effects of all other variables which were reviewed previously. Variables can enter and remain only if they exceed a preselected level of significance, utilising boththe 'F' ratio and 't' tests.(2) A large number

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(1) M.A. Taylor working on a similar problem in Reading, used acreages and found them non significant. Personal correspondence.

(2) A similar usage can be found in M.C. Roberts and K.W. Rummage 'The Spatial Variations in Urban Left Wing Nottingham England and Waters 1951' Annals of the Association of American Geographers, Vol. 55, No. 1, March 1965, pp. 161-178 and especially p. 176.

Table 3:1

Summary: Trip Generation and Floor Space*

LAND USE	PERTH Person/Trips /1,000 sq.ft.	PERTH Square Feet /Trip	MANCHESTER** Square Feet/ Employee Trips	CHICAGO *** Square Feet/ Employee Trips
Office	23.95	41.7	42****	108****
Retail	52.12	19.3	11****	63****
Storage	4.39	227.8	) 182	) 453
Wholesale	6.81	146.5	)	)
Industry	14.56	68.5	) 51	) 78
Workshops	21.23	46.9	)	)
Public Bldgs.	5.91	168.9	183	182
Service	42.19	23.7	-	-
Transport	12.21	81.6	-	-
Others	13.67	73.2	-	-

* Compare also result of San Diego Transportation Study. Appendix 7.

** Source: 'Deansgate Analysis' Urban Studies Programme. Univ. of Manchester, 1962.

*** Chicago Area Transportation Survey.

**** Floor Space/person trip.

of variables can be handled, but greatest success was achieved with relatively few variables. The danger of a large number of variables is that they may be selected only on the basis of statistical association, with little or no theoretical underpinning or concern for the meaningfulness of the resulting equations. Table 3:3 summarises the regression findings but it is difficult in this case to compare Perth with North American examples.

Finally the last section devoted to work trips alone, utilised certain probability, regression, and potential techniques to analyse travel patterns.

Significant relationships were therefore identified between some measure of non residential land use and some measure of trip induction or attraction.

To further future attempts at any analysis some general principles can be elucidated.

Land use as frequently defined, is not in transportation terms, but rather in terms borrowed primarily from the field of town planning. Land use classes must relate directly to the purpose for which trips are made, and separate analysis should occur where activities produce significantly different proportions of work trips and non-work trips, so that work trips, goods vehicle trips, pedestrian trips, and so on, have been analysed separately in this thesis. To carry this further, activities which produce significantly different proportions by various modes should be kept distinct, in particular those uses which produce large proportions of goods trips should be studied separately from those that produce trips predominantly by other means. The land use classes used should be relatable to land use models and social and economic theory. The facility surveys should be tied in with the home interview survey as much as possible to act as a cross check, and respondents should be asked to identify the land use at their trip end. Land use classifications must then be understandable to the home interview respondent.

Finally, the linkages between land uses should be studied further, particularly those links that are connected by multi-purpose trips and daily trip circuits. The effect of working trips within the central area is obviously of importance here, as is the effect of the separation or of the juxtaposition of activities.

Table 3:2

Summary: Factors Used to Estimate Trip Attractions, in Perth and Certain North American Transportation Studies.

TRANSPORT STUDY	LAND USE CATEGORY						
	Office	Retail	Wholesale Storage	Industry	Service	Public Bldgs.	Transport
Perth	FcEc D	FcD E_R Ss/G	Fc Ec D	Fc E_M Ex E_z D	Fc D E_V	Fc E_V D	Fc D E
Washington DC	E	S_R	E	E	S_R H	H	
Kansas City	E D	SR D		E D	H		
New Orleans	E_O	SR H	E	H E A	S_RH	E	E
Fort Worth	E_O	EC	EC	E_M	E_O	E_O	E_O
Nashville	E	A D	E A	E $E_M E_W E_B$	H	A	A
Charleston	A	$E_R S_C S_P$	A	E E	$S_V E_V$H A		E_V A
Chatanooga	A	A	A	EA	H		A
Erie		E_R		E	H E_R E_O		
Fargo		$E_R E_O$H	E_O	E_M	E_O		
Appleton	E	E		D A		A	

Sources Transportation survey reports.

Explanation of symbols.

Employment

E	Total employment
ER	Retail
EM	Industrial
EC	Commercial
EO	Employment other than retail and manufacturing
EW	White collar
EB	Blue collar
EX	Employment composition (detailed breakdown)
EV	Various specialised employment
EZ	Male/female employment

Retail

SR	Retail Sales
SC	Retail Sales (convenience goods)
SP	Personal service sales
SV	Retail sales by various specialised categories
Ss/G	Relative provision of convenience and shopping goods

Area

FC	Square footage of appropriate land use
A	Acreage of appropriate land use.

Distance

D	Distance

Other

H	Household characteristics (income, etc.)

Table 3:3

Summary: Regression Analyses

Land Use	Constant	Regression Coefficients	t	r^2/R^2
Office (1)	-6.793	0.007012 0.1676	14.07 2.96	0.98
Retail (2)	522.3	0.002394	26.66	0.94
Industry (3)	13.055	0.001508 0.5464	16.57 4.36	0.98
Wholesale (4)	5.407	0.002717 0.9593	8.45 3.19	0.92
Transport (5)	12.100	0.001196 0.1512	13.58 3.97	0.98
Public Bldgs (6)	23.04	0.001238	7.65	0.83

Notes (1) Total vehicle trips/floor space/employment.

(2) Local shopping, distance to local shopping area.

(3) Total vehicle trips,floor space, and employment.

(4) Total vehicle trip ends, floor space, employment.

(5) Total trips, employment and floor space.

(6) Total vehicle trip ends, floor space.

PART 3.

PART III

TOTAL TRAVEL MOVEMENTS

Land use patterns - residential and non-residential uses - and the spatial structuring of those patterns cause movement. With activity specialisation, origins and destinations, desires and fulfillments, have become separated. Movement is the means of correcting any spatial imbalance.[1] Knowing some of these desires, and knowing some of the ways in which they can be fulfilled, can travel movements be deduced or predicted? Taken as a whole human activity is regular and orderly, though at the individual level it may appear irregular and random. It follows that travel, too, as a whole is regular and orderly. There are demonstrable time and space patterns of travel, subject to recognizable rules like repetitiveness, directional symmetry, and balance between origins and destinations. This thesis has demonstrated some of the relationships between land use and population distributions. Knowing these distributions then, the aggregate travel behaviour of an organised urban society can be measured, explained, and predicted.[2] The diagram below (3:1) sets out the predictable elements of urban structure, and their relationships.

The concept is simple. People function at different points in space, and in order to do so and to communicate with one another, they must move through a communications system. Actually the relationship is not so simple,

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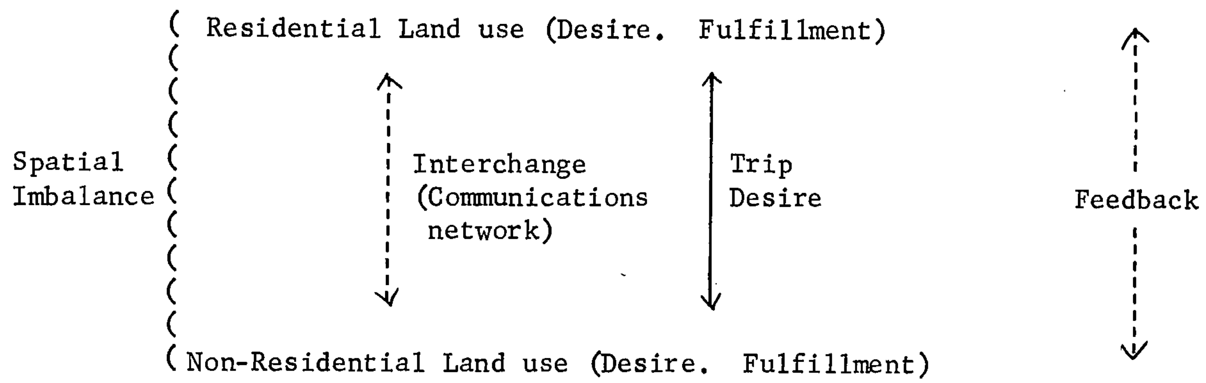
(1) Spatial imbalance is implicit in the concepts of 'complementarity', 'intervening opportunity' and 'transferability', see E.L. Ullman 'The Role of Transportation and the Bases for Interaction' in W.L. Thomas (editor), 'Man's Role in Changing the Face of the Earth', Chicago, 1956, pp. 862-877. It is also implicit in J.D. Carroll and H.W. Bevis, 'Predicting local travel in urban regions' Papers and Procs. of The Regional Science Association, Vol. 3, 1957, pp. 183-197; and in W.L. Garrison, 'Estimates of the Parameters of Spatial Interaction' Papers and Procs. of the Regional Science Association, Vol. 2, 1956, pp. 280-288.

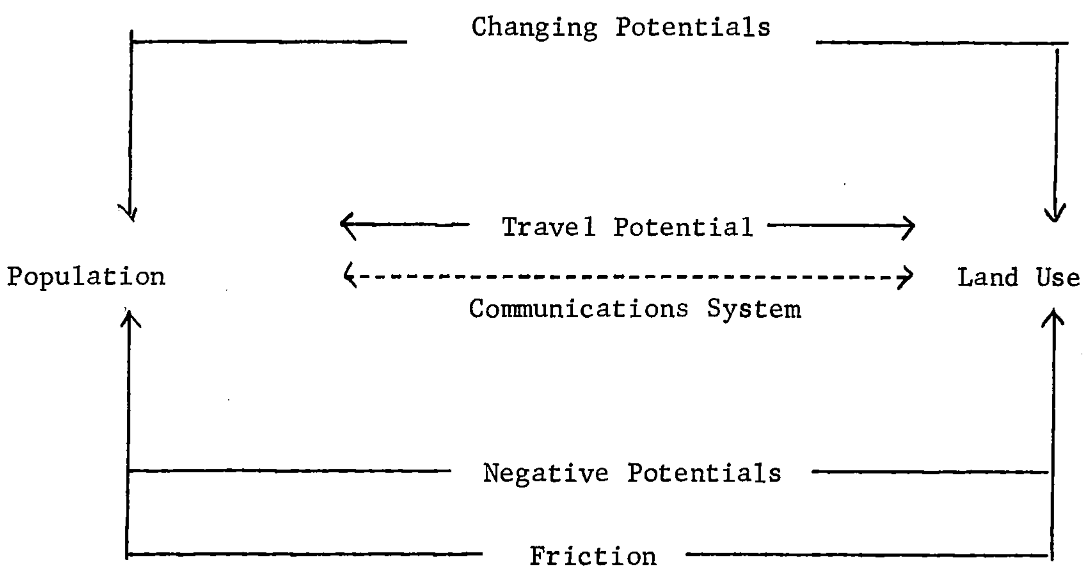
(2) Even though individuals may not choose a route on the basis of time-saving or cost-saving or any other assumption, but rather on the saving of mental and physical strain or entirely randomly, in total movements appear to be orderly. See however, R.M. Michaels 'Attitudes of Drivers Determine Choice Between Highways'. Public Roads 1965. Vol. 33.

Diagram 3:1



and feedback effects occur, as the transportation network for instance influence the development of land uses and population distribution, and is in turn itself influenced by such developments. So rather than considering a simple causal model, the model should represent a system varying between times of balance and imbalance. A more representative sketch is shown in Diagram 3:2

Diagram 3:2



People in a particular functional relationship have particular travel needs, and they pass through a network or system which in turn influences and is influenced by, those positive potentials. 'Changing potentials' is the dynamic aspect, which with advancing technology will alter the concept of accessibility, and vary the positive and negative potentials.

Identified here too were what can be called 'negative potentials', which operate against those basic travel needs or positive potentials. A number of these negative potentials were analysed in Parts I and II:-

(1) Household size, and the relative decrease in trip potential with increasing size through an 'economy of scale' effect, changing age composition, etc.

(2) Income or socio-economic status, which in part measures the ability to pay for travel, and in particular is related to the ability to own and operate a car. As car ownership rises the number of trips/person increases and vice versa.

(3) Location and distance (friction), with the corrolary of density. A location near to the central area, with a higher density of population, and the easier satisfaction of any spatial imbalance, leads to fewer person trips. A more sparsely developed area, distant from the central area where spatial imbalance is greater, generates more trips/person.

(4) The potential surface, induced by each land use type, varies. That is the degree of satisfaction varies amongst the land uses, and therefore the 'spatial imbalance' created is modified. Retail desires have to be satisfied more frequently than medical desires, for instance, although there is variation even amongst various retailing factors.

These four factors were borne out in Perth; the number of trips induced by a particular imbalance was greatest for a small car owning family, distant from the C.B.D. and finding satisfaction in many retail and recreational land uses.

What has been established is a system of movement, which describes the simple correlation of land use and population needs. It has been postulated in terms of individual elements as well as a functioning whole. It is the purpose of this final part to establish some kind of mathematical summary of total travel in Perth.

The development of total trip linkages is not easy to analyse. Basically when the decision is made to make a trip, a search is made for the land use destination(s) which can best satisfy the need, and then to choose amongst the alternatives, with the limitations imposed by imperfect knowledge, 'bounded rationality', and the particular behavioural environment. When the decision making processes of many individuals are amalgamated however, problems of 'capacity' arise. Each zone has a fairly fixed capacity for generating or inducting trips, usually because a fairly fixed number of trip opportunities exist, measured as jobs or retail floor space, etc. A principle of competition must thus be satisfied by a point opportunity.

The number of people travelling from a zone of origin to a zone of destination is a function of all the possible destinations to choose between, and at the point of choice is in competition with trips originating in all other zones desiring to travel to that particular point of destination. The zonal interchange volume then is a function of all other interchange volumes as well.

This relationship can be represented by:

$Tij = Ti.P(Tj)$

where

Tij = the number of trips from zone i to zone j.

Ti = total trips originating at zone i

and $P(Tj)$ = a measure of the number of trips attracted to zone j. taking account of the factors noted above.

The problem is then to find a satisfactory measure of zone j's attractiveness.

There are a number of ways of calculating zonal interchanges, mainly distinguished by the methods they use to identify the frictional effect of the distance between zones - the 'growth factor' or Frater method; the gravity method; and the opportunity, probability, or Chicago method.

Two fundamental concepts are assumed in most of these -

(i) that the likelihood of interchange between any two places is a function of the activity of each place. Given trips at zone i, the probability of them being attracted to j is related directly to the size of some attractive measure,

(ii) that trip interchange probability is a function of some measure of the distance between places: as distance increases trip interchange declines.

Briefly, the methods used are:-

(1) The Growth Factor Method This is the so-called iterative or Frater method[3] and was a method used by the Detroit study.[4] It is more or less an arbitrary logarithm, which uses the existing volumes of interzonal movement as a measure of the 'friction' and expands the volume between any pair of zones in proportion to a measure of interactance. It assumes trip attractions has the form:

$$Tij = Ti \frac{Tj}{T}$$

(3) T.J. Frater 'Vehicular Trip Distribution by Successive Approximations' Traffic Quarterly January 1954.
(4) Detroit Metropolitan Area Traffic Study. Vols. 1 & 2, Detroit 1955-6.

or that trips from zone i are attracted to zone j in the proportion that trips at j are of total trips in the area. This function is then converted into growth factors for future years:

$$Fi = \frac{Ti'}{Ti} \qquad Fj = \frac{Tj'}{Tj} \qquad F = \frac{T'}{T}$$

where Ti, Tj and T' are trip volumes at each zone, and in the total area, estimated in a future year. The existing interchange is thus expanded:

$$Ti'j = Tij \ \frac{FiFj}{F}$$

Obviously there are very severe reservations to be made about this method, which has virtually no theoretical underpinning and gives a very superficial explanation of trip behaviour.

(2) The Gravity Method Distance here is specifically made on inverse function of trip volumes. Usually, distance is stated in terms of travel time, and this measure of 'function' is raised to some exponential power to account for its restraining effect. The gravity formula was developed for practical use by Alan Voorhees[(5)] and used by traffic studies at Washington, Los Angeles, Baltimore, etc.[(6)] It has the form:

$$Tij = \frac{TiSj/Dij^{n}}{\sum Sx/Dix^{n}}$$

where

Sj = attraction factor at j

Sx = attraction factor at any zone x

Dij = distance (or travel time) from i to j

Dix = distance (or travel time) from any zone x

n = friction coefficient

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(5) A.M. Voorhees 'Forecasting Peak Hours of Travel', Highway Research Board, Bulletin 203, p. 37.

(6) U.S. National Capital Planning Commission 'Transportation Plan' Washington 1959; Los Angeles Regional Transportation Study, 'A Prospectus; LARTS', Los Angeles, 1960, etc.

This states that trips at zone i are attracted to zone j:-

(a) directly according to an attraction factor at j, which might be trips at j or something else, - this is the <u>interactance</u> principle,

(b) inversely according to the distance between i and j, raised by some power,

(c) inversely as attractions at all other zones ΣSx, draw zone i's trips away from j, and

(d) directly as distance between i and all other zones, Dix^n exerts a restraining influence upon the attractive force of Sx.

The attractive force for trips, Sj, can be expressed in several ways. It could be simply the number of trips terminating at zone j, which gives an index of travel at that place. However, gravity formulations are usually in terms of trip purpose, because different purposes are said to have different responses to the distance factor, and it is appropriate to use a measure of attraction which relates to each purpose. The logical measure for work purpose trips originating at the place of residence is employment in the destination zone. Another method, used in Toronto,(7) was to obtain in the course of trip generation analysis, the volume of trips <u>attracted</u> to each zone, as well as the volume <u>generated</u>, and to use the attraction volume as the Sj factor.

The main failure of this method is that it is not explanatory and does not try to be, it is really little more than a sophisticated approximation. Like the Frater method there is only a superficial explanation of trip behaviour, and the procedure for obtaining the intrazonal volumes and the relationship used to develop a distance factor are both subject to unduly high errors.(8)

(7) Metropolitan Toronto Planning Board, 'Metropolitan Toronto Transportation Research Programme', Report No.1, Toronto 1962.

(8) See S. Osofsky 'The Multiple Regression Method of Forecasting Traffic Volumes' <u>Traffic Quarterly</u> Vol. 13, 1959, pp. 423-445, especially pp. 425-428.

(3) The Opportunity Method The first postulation of this method came from Carroll and Bevis[9] who spoke of it as a 'probability' method. The mathematical justifications came later from Schneider,[10] and besides its original application to the Chicago study, it has been used in the Pittsburgh and Penn-Jersey projects.[11]

The principle used in this method, is that the probability of a trip finding its trip-ending in any zone is proportional to the number of terminal opportunities contained in the zone. To this, a rider is added that a trip tends to be as short as possible, lengthening only as it fails to find a terminal. This latter assumption may well prove to be false on many occasions. A trip with origin zone i, increases its opportunity tobe satisfied (i.e. find a destination), the farther it proceeds from that origin. Any destination can therefore be defined, in relation to an origin zone, (a) in terms of the number of opportunities a trip from the origin would have had to pass by to reach that zone, and (b), in terms of the number of opportunities available to satisfy the trip at that zone. This arrangement of opportunities, defined as trip-ends, plus a factor indicating the probability of a trip origin accepting any destination opportunity, yields an estimating formula.

The mathematical statement of the Chicago opportunity equation is fairly complex,[12] but the basic outline can be represented by:

$$Tij = Tj\,(e^{-Lt} - e^{-LT\,(T + Tj)})$$

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(9) J. Douglas Carroll and H.W. Bevis 'Predicting Local Travel in Urban Regions' Papers and Proceedings Regional Science Association, Vol. 3, 1957, pp. 183-197.

(10) M. Schneider 'Gravity Models and Trip Distribution Theory', Papers and Proceedings, Regional Science Association, Vol. 5, 1959 pp. 51-56.

(11) Chicago Area Transportation Study. Vols. 1, 2 & 3, Chicago 1959, 1962. Pittsburgh Area Transportation Study, Vol.1, Pittsburgh.

(12) Schneider, op. cit.

where

T = destination opportunities <u>closer</u> (in time of travel) to zone i than those in zone j.

Tj = opportunities in zone j

L = probability that any destination opportunity will be chosen.

It can be seen that the probability that trips fron zone i will stop at zone j is a function of the chance that they will get that far (e^{-Lt}) and the chance they will not go farther ($e^{-L(T+Tj)}$). The major critisicms of this method must be that the choice of a 'probability factor' is quite arbitrary, and that it accounts for only a <u>relative</u> change in the time-distance relationships between zones.

These three methods represent the major part of any effort made to date to predict total travel.(13) Their fault lies in that they try to minimise the number of variables considered, and yet no model predicting interzonal volumes can ever approach an acceptable standard of accuracy and explanation unless most variables are considered. One way in which this can be done with a slightly greater degree of acceptibility is to use a multivariate model, which can treat zonal interchanges individually and explicitly. Surprisingly, since the computers exist to undertake such large capacity calculations, very little work has been undertaken in this direction.(14)

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(13) Two methods not mentioned are Howe's 'Electrostatic field' theory of trip attraction, and J.G. Waldrop's method based primarily on the cost of travel. See R.T. Howe 'A. Theoretical Prediction of Work-trip Patterns' Highway Research Board <u>Bulletin</u> 253, 1960, pp. 155-165.

(14) Osofsky, op. cit. is an exception, but here again very little follow up work was completed.

Part II, Section II in conclusion, drew attention to the importance of a general equation. Insofar as a 'probability' analysis of confluence at the destination zone was concerned, the evidence obtained indicated that it could be represented by the power function:

$$X = c + b.y^{a} \qquad \text{Equation (1)}$$

where 'a' was a negative exponent and b, c, were values to be determined for a given system of trips. The expression is derived by considering the proportion of trips to a particular destination of all similar trips from origins, at each distance category from the destination. 'x' is a measure of such originating trips to the given destination, 'y' is the distance measure, 'b' is an ultimate but unattainable frequency of trips which may be measured at one unit of distance from the destination. This expression has the desirable characteristic that a line representing it becomes asymptotic to the distance axis with increasing values of 'y'. Thus this mathematical format has a major characteristic compatible with the real situation.(15) Having established in part an approximation to a 'real' situation, equation (1) can be included in a multiple regression model:

$$x = Co + Y \cdot (1 + y)^{a} \qquad \text{Equation (2)}$$

where 'Y' is a multiplier calculated for a particular trip interchange volume between two specific zones. This may be restated in the form:

$$x = Co + (c, b, + c_2b_2 + c_3b_3 + c_4b_4) \cdot (1 + y)^{a} \qquad \text{Equation (3)}$$

Or in a form comparable with the three earlier examples:

$$Tij = Co + (Pij + Eij + \ldots\ldots\ldots) \cdot (1 + Dij)^{a} \qquad \text{Equation (3a)}$$

where the multiplier 'Y' is represented by certain attraction indicies, say population and employment.

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(15) See also Part II, Section II, pp. 167-190 this thesis; S. Godland 'The Function and Growth of Bus Traffic Within the Sphere of Urban Influence' Lund Studies in Human Geography. No.18, 1956; and H.S. Lapin 'Structuring the Journey to Work' Philadelphia, Univ. of Pennsylvania Press 1964.

The justification for this regression model can be stated in this way:

(1) Earlier analyses[16] have shown that location is important, and that the trip volumes between one zone and each of the other zones will tend to decrease as distance increases, although the number of trips/person increases. This is essentially equation (1).

(2) Income, socio-economic status, car ownership and household size, which may be measured in various ways, affect positively or negatively the number of trips generated by a zone of origin.[17] So some parameter must be established in the model to represent them.

(3) The attractiveness of the destination may be represented by various parameters of land use, etc.[18] The selection of the factors best suited for use in regression depends primarily on two features - can the factor reasonably be measured, and secondly, will it logically and consistently contribute to a reduction of errors of estimation?

Table 3:1 sets out the experimental models used, of the general form of equation (3) above. The best of these models (Table 3:2) were then used to predict zonal interchanges as compared to the actual interchanges (Table 3:3). In fact the best model represented total movement quite well, drawing as it does from the evidence accumulated earlier, though in a summary form.

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(16) postulate three, p.201 this section.
(17) postulate one and two, p. 201 this section.
(18) postulate four, p. 201 this section.

Table 3:1

Models and Related Data.

Basic Model

$$X = C_0 \, (c_1 b_1 + c_2 b_2 + c_3 b_3 + c_4 b_4) \cdot (1+y)^a$$

Model 'a'

$$X = C_0 + \frac{P}{1 + D2} + \frac{E^2}{1 + D2} + \frac{V}{1 + D2} + \frac{L.UI}{1 + D2}$$

Model 'b'

$$X = C_0 \, \frac{P^2}{1 + D2} + \frac{E^2}{1 + D2} + \frac{V}{1 + D2} + \frac{L.U1}{1 + D2}$$

Model 'c'

$$X = C_0 \, \frac{P}{1 + D3} + \frac{E^2}{1 + D3} + \frac{V}{1 + D3} + \frac{L.U1}{1 + D3}$$

Model 'd'

$$X = C_0 \, \frac{\sqrt{P.V}}{1 + D2} + \frac{E2}{1 + D2} + \frac{CFS}{1 + D2} + \frac{IFS}{1 + D2}$$

Model 'e'

$$X = C_0 \, \frac{\sqrt{P.V}}{1 + D3} + \frac{E2}{1 + D3} + \frac{CFS}{1 + D3} + \frac{IFS}{1 + D3}$$

Model 'f'

$$X = C_0 + P + E2 + V + L.U1 + D2$$

Explanation of symbols, models 'a' to 'f':

X = trips between pairs of zones

D = distance between pairs of zones

P = population in each zone

E = employment in each zone

V = car ownership in each zone

LU1 = a land use index for each zone

CFS = commercial floor space in each zone

IFS = industrial floor space in each zone

Table 3:2

Model	Constant	Coef.(1)	Coef.(2)	Coef.(3)	Coef.(4)	R^2
'a'		-0.0000495	0.00000269	0.05810	-1.0750	
Origin	38.57	0.0000140	0.00000055	0.01875	0.4028	0.98
Zone 2		3.53	4.92	3.09	2.67	
All Destns						
'a'		0.02513	0.0002213	0.007375	-6.0060	
Origin	95.82	0.00285	0.0000212	0.001585	2.1781	0.93
Zone 15		8.77	10.45	4.10	2.84	
All Destns						
'b'		0.00000061	0.00000262	0.02980	-0.6090	
Origin Zone	32.16	0.00000024	0.00000045	0.00813	0.2035	0.89
2		2.47	5.83	2.83	2.93	
All destns						
'c'		-0.002555	0.00000026	0.06022	-0.1481	
Origin	38.97	0.000816	0.000000007	0.02363	0.0553	0.79
Zone 2		3.11	3.56	2.55	2.67	
All Destns						
'd'		0.0017890	0.00000779	-0.000106	-0.000014	
Origin	40.15	0.004536	0.00000181	0.000032	0.000005	0.87
Zone 2		3.94	4.31	3.37	3.13	
All Destns						
'd'		0.08556	0.0002188	0.0000274	-0.0000336	
Origin	84.20	0.01080	0.0000451	0.0000074	0.0000120	0.93
Zone 15		7.92	4.85	3.69	2.79	
All Destns						
'd'		0.03865	0.0004199	0.000112	-0.00519	
Origin	149.5	0.00596	0.0000872	0.000023	0.00137	0.81
Zone 21		6.48	4.81	4.80	3.76	
All Destns						
'e'		0.005495	0.00000087	-0.0000081	0.0000167	
Origin	51.30	0.001741	0.00000033	0.0000018	0.0000059	0.72
Zone 2		3.15	2.64	4.64	2.79	
All Destns						

Table 3:3

Model 'a' Zone 2

$X = 38.57 - 0.0000495 + 0.00000269\ b\ 2 \pm 0.05810\ b3 + 1.075\ b4$

Destination	Observed	Calculated	$(y_{cn} - y_n)/S_{yc}$ *
1	315.00	324.05	-0.24
2	343.00	328.43	0.39
3	50.00	47.94	0.06
4	5.00	31.83	-0.72
5	6.00	16.67	-0.28
6	41.00	80.96	-1.07
7	63.00	20.53	1.14
8	41.00	51.81	-0.29
9	29.00	3.39	0.87
10	57.00	110.68	-1.44
11	211.00	134.79	2.04
12	70.00	107.09	-0.99
13	18.00	44.58	-0.71
14	117.00	43.41	1.97
15	97.00	63.42	0.90
16	58.00	58.44	-0.01
17	59.00	76.49	-0.47
18	23.00	35.50	-0.33
19	30.00	24.97	0.14
20	35.00	44.89	-0.27
21	100.00	65.16	0.94
22	34.00	40.84	-0.18
23	8.00	39.61	-0.85
24	23.00	43.79	-0.55

Standard error of estimate 37.19

* $\bar{y}c$ = observed value

y_{cn} = computed value

S_{yc} = standard error of estimate

Despite the high overall precision of model 'a', it is evident from Table 3:3 that there are individual zonal prediction problems. In fact, model 'b' despite its lower coefficient of determination had a better standard error of estimate, 33.52. It is notable that similar zones caused prediction problems. These zones in fact are characterised by a large industrial employment and indistrial capacity, and were better predicted by model 'd', though at some expense to the other zones.

The resultant equations for models 'a', and 'b' despite the drawbacks mentioned were considered acceptable: the general fit of the equations was good with no excessive differences between the observed and calculated values (none were greater than 2.00 fromthe calculation $y_{cn} - y_c / Sy_c$) and the standard errors of estimate were no greater than 40.00. Of all the models these applied most reasonably to all 24 zones of origin.

Like the other methods, this multiple regression technique has its limitations, and some of the theoretical assumptions may be questioned. The net regression effect of the variables is not always completely understood; the variables may be highly correlated or not truly descriptive of an area. That is they may not be 'explanatory' but merely summaries of data.

On the whole the models put forward represent a reasonably efficient hypothesis, that is the variables were selected rationally and not merely on the grounds of 'best fit' alone. As was explained at the beginning each factor considered in the models was substantiated from the earlier findings. Numbers of employees, the product of the multiplication of value of population and car ownership, population and car ownership separately, distance, and land use indicies and floor space, represent proven factors influencing trip generation. Their inclusion is basic to the hypotheses behind these models. Of course it is not necessarily the only way of approaching the prediction of total movement, it seems however to have to some degree of theoretical substantiation as a holistic and descriptive model.(19)

There are ways of impfoving the precision of the models, particularly by selecting more appropriate zone boundaries. Those used in this survey were selected as road catchment areas. An improvement in precision might come from recasting those boundaries so that particular land uses are segregated.

Whilst these equations and models, both here and elsewhere in the thesis, are not necessarily transferrable exactly from urban area to urban area, since the constants and coefficients of the equation will vary between study areas, a start has been made, a general model form erected, and a technique provisionally elucidated, that can be the basis forfurther investigation. Future empirical and theoretical work will contribute to continuing refinements and improvement in this technique, and perhaps eventually to the creation of a new and more efficient model, through linear programming, or other methods which can more easily analyse and manipulate the myriad variables operating to produce travel patterns.

Land use and traffic have been thought of as separate but related fields of study, the province of the planner and engineer respectively. These two viewpoints have given rise to the current, 'chicken and egg' problem. Which comes first? Do traffic and transport facilities affect and shape land uses, or do land uses require transport facilities? In fact these are not really valid questions. The study of land use and traffic is

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(19) Other attempts not already noted include H.N. Knox, 'A Simplified Traffic Model for Small Cities' Traffic Quarterly, July 1962, pp. 336-360, who draws on the 'gravity method'; and F. Maki 'Movement Systems in the City' Graduate School of Design, Harvard University, 1965.

not a dual one, it is axiomatic that there is an interaction between the two activities, between the desire and the fulfilment. There is really no concern for which comes first. When proper identification is made of the relationship, both thechicken and the egg can beeffectively studied together. The travel/land use couplet is not completely understood if either aspect is considered dominant. They are mutually dependent, and it sufficess to say that land can be effectively utilised only when it is accessible.

This thesis in all its aspects has underlined thisddynamic holistic relationship, and has put this interrelationship into its spatial complex. Urban travel is exceedingly complicated. In deriving characteristics of this relationship, the pattern of individual behaviour has been sublimated to that of the group, and many disparate types of use activity have been broadly categorised. From this, models to represent the real-world system were built, duplicating those features of most importance and abstracting those of minor impact. Underlying this model building was the assumption that traffic is a function of land use. A study of an urban traffic system becomes a dynamic study of its land use system, and with it, the beginnings of an orderly theory of urban travel appears to be emerging.

APPENDICES.

APPENDICES

1. Origin and Destination Survey
   - (a) method
   - (b) results
2. Parking Survey
   - (a) method
   - (b) results
3. Home Interview Survey
   - (a) method
   - (b) results
4. Journey-to-Work Survey
   - (a) method
   - (b) results (bound in separate volume)
   - (c) 'computer diagrams', analysis
5. Other Surveys
6. Statistical Techniques; Analysis
   - (a) Kendalls 'W' coefficient
   - (b) Regression analysis
   - (c) Variance analysis
   - (d) Bartlett's test
   - (e) Multivariate analysis
7. Miscellaneous
   - (a) Land use definitions
   - (b) Distance matrix
   - (c) Floor space data
   - (d) Trip generation in 10 American cities
   - (e) San Diego, Traffic Generator Study
8. Basic data, 'Haystack' and Residentrip' analyses
9. Select bibliography.

APPENDIX 1

Origin - Destination Surveys

Appendix 1(a) Methods

There are five main methods of carrying out O.D. (origin - destination) surveys; by direct interview on the road; by noting registration numbers; by placing tags on vehicles; by giving postcards to drivers; and by home interviews.(1)

The surveys utilised were of the direct interview type. The first was an outer 'cordon' survey carried out in 1959 by the Perth and Kinross County Council and the Perth Burgh Council. The second was an 'inner' cordon survey designed jointly by the Burgh Surveyor's Department, Perth, and myself.

Although direct interview surveys are usually carried out simultaneously at all points, it is possible to deal with different survey points and different directions of travel on different days using a small number of interviews.(2) Since the method is less costly, it was intended to carry out in this way, but on the advice of the Road Research Laboratory, the idea was dropped and the full scale method was used.

A cordon was erected around the town centre and survey stations were erected on all roads leading to the town centre (Map A.1:1). All vehicles entering the town centre were stopped at these survey stations and the drivers interviewed. Vehicles leaving the town centre were not stopped, but were counted and classified according to type.

The survey was carried out for a period of 12 hours each day on three days in 1963; Thursday, 19th September; Friday, 20th September; and Saturday, 21st September. This period was chosen because it was the earliest possible following the period of exceptional tourist and holiday traffic of June-August and early September, and was probably reasonably representative of most of the rest of the year. The three days were chosen:

(i) the 'normal' weekday traffic (Thursday)
(ii) a busy market-day (Friday)
(iii) Weekend traffic (Saturday)

A total of 87 people were used as interviewers, or enumerators, during the three days, and four were retained for a period after the survey as coding clerks. The direct costs of hiring staff, printing forms, advertising in the local newspaper, etc. was £868.16.2, borne entirely by the Burgh of Perth.

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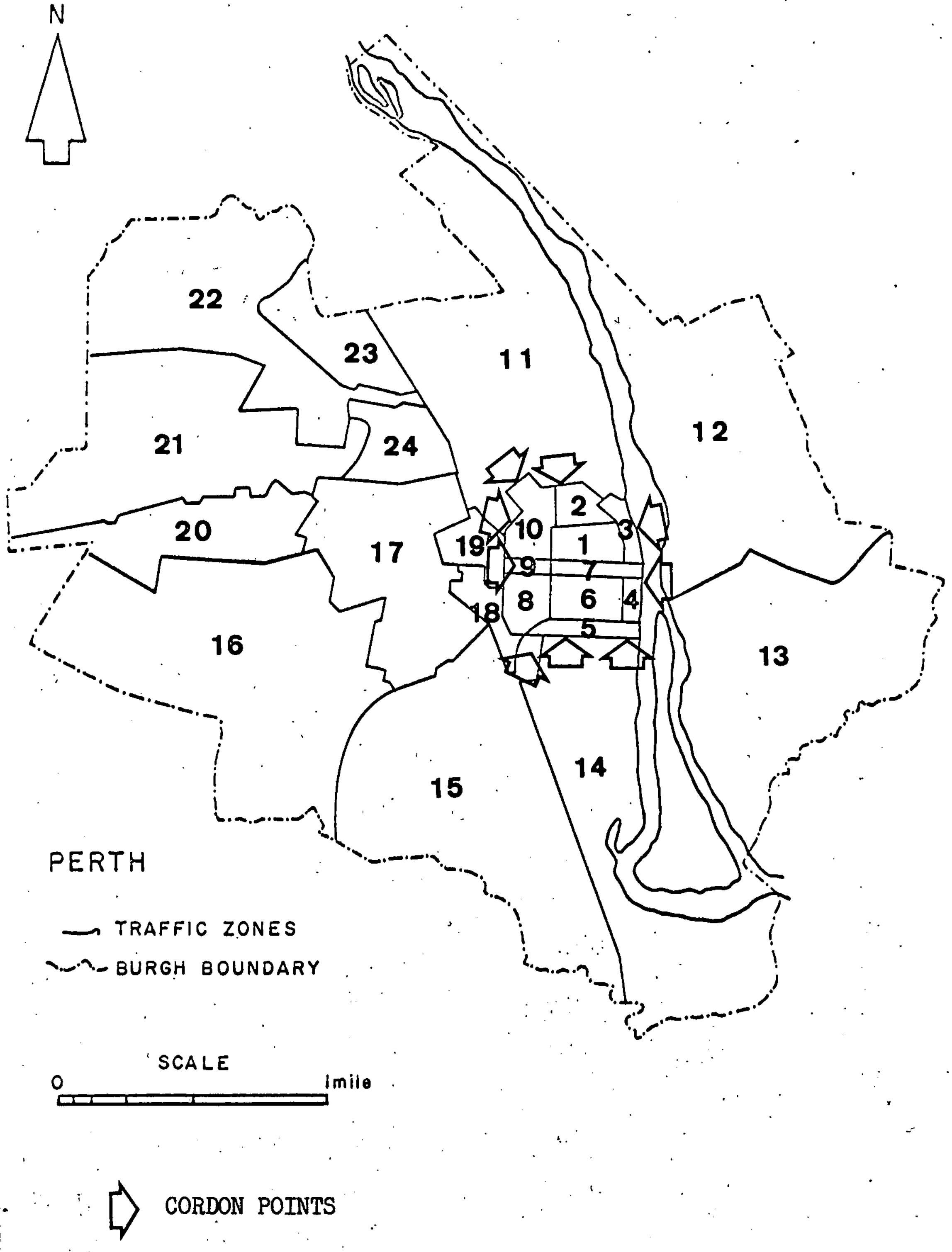
(1) A summary of these methods can be found in T.M. Coburn 'Origin - destination surveys' Chartered Municipal Engineer, Vol.89, No.5, 1962, pp.141-5; and T.J. Duff and D.A. Bellamy 'Surveys to determine the origin and destination of traffic' Road Research Laboratory. Research Note No. RN/2364. 1955.
(2) Coburn op. cit. p. 141.

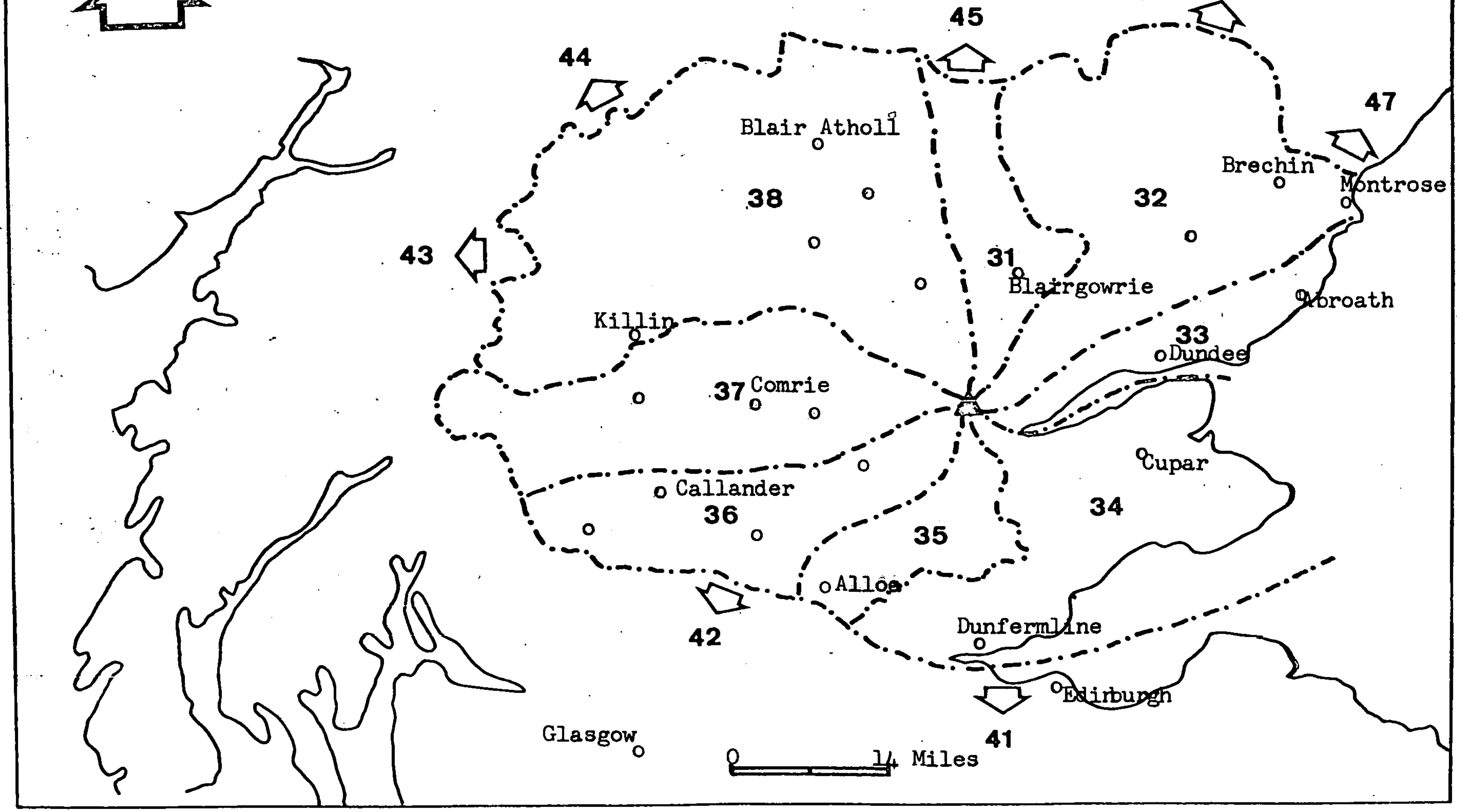
MAP A1:1

1963 TRAFFIC SURVEY INTERNAL TRAFFIC ZONES.



MAP A1:2

EXTERNAL ZONES



Because of the size of the task, the data, when coded, was processed by Messrs. International Computors and Tabulators Ltd. I.C.T. supplied, punched, and carried out a percentage check verification of, cards; calculated and applied an interview correction factor to four classes of vehicles for each half-hour period at the nine survey stations; and converted the results to one standard, 'passenger car units':

	Conversion factor
Private Cars	1.00
Motor Cycles	0.67
Light Commercial Vehicle	1.00
Heavy Commercial Vehicle	1.75

The cost of these calculations was £1,300.0.0, again paid for by the Burgh of Perth. A total of 375 (matrix 40 x 40) tables were produced of zone to zone movements in p.c.u.'s., for day, time, vehicle class, and trip purpose.

At all survey points a classified volumatric count was taken of all vehicles crossing the cordon line. The two directions of flow were kept separate. All incoming traffic, whenever possible, was interviewed. On one occasion on both Friday and Saturday, a sample were interviewed at the major survey points because of the build up of traffic.

Drivers were asked the following questions:-

1. Where did you begin this journey?

2. Where will the journey end?

3. If answer to 2 other than a destination in central Perth; do you intend to stop in central Perth, and if so, where?

4. What is the purpose of the journey?

   (i) work-to-home
   (ii) home-to-work
   (iii) shopping
   (iv) social
   (v) holiday
   (vi) business and goods.

The detailed siting of each interview station was agreed with the police, each laid out in accordance with the Road Research Laboratory recommendations, and manned by temporary staff and a Police Constable. Only vehicles on emergency journeys and public service vehicles were exempt from interview. Both the volumetric counts and the interviews were recorded on a half-hourly basis from 7.0 a.m. to 7.0 p.m.

The Burgh was divided into 24 traffic zones, 10 being inside the cordon area (Map A.1:1). There were also 16 external zones, eight for the immediate hinterland and another eight for the rest of Scotland (Map A 1:2). The Burgh zonal boundaries were drawn principally as route catchment areas, with allowance for major land use patterns, and where possible enumeration district boundaries. This was not entirely satisfactory, and in future a better result might be obtained by using enumeration district boundaries together with as many physical boundaries as possible. Two zones were however deliniated on a different basis - zone 18 consisted of the railway station only, and zone 19 the principal cattle markets.

Each trip origin, destination, central stop, and journey purpose were manually coded into zones, along with time periodaand vehicle type. The data in this form was then handed on to I.C.T. for further processing.

Traffic assignment, the assigning of traffic to an actual route rather than just interzonal data, was carried out manually, assuming that vehicles always took the shortest route (in time - distance terms).

The results are given in the following section in an abbreviated form, since in total the results would occupy several volumes.

DIAGRAM A:1:1

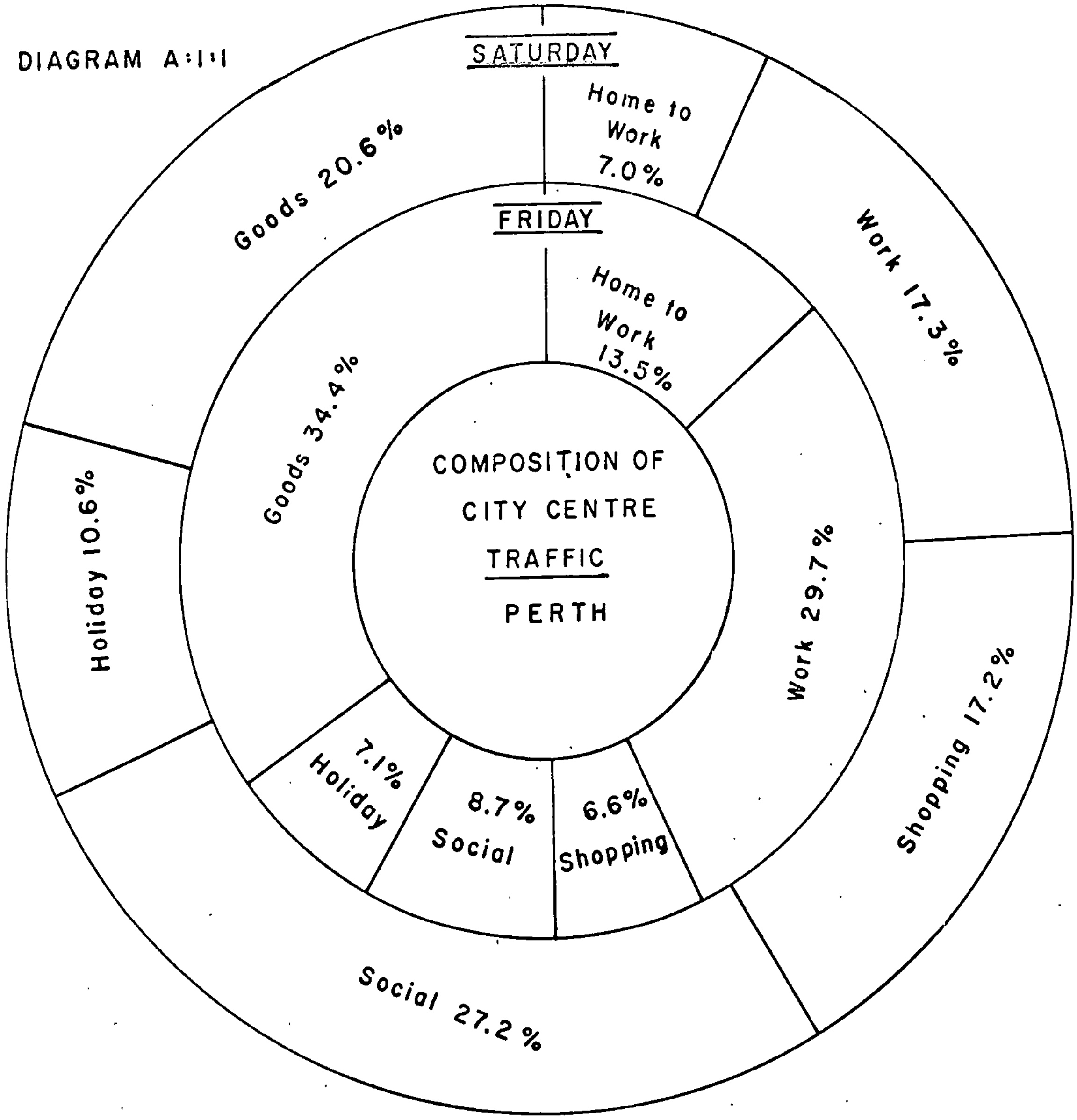
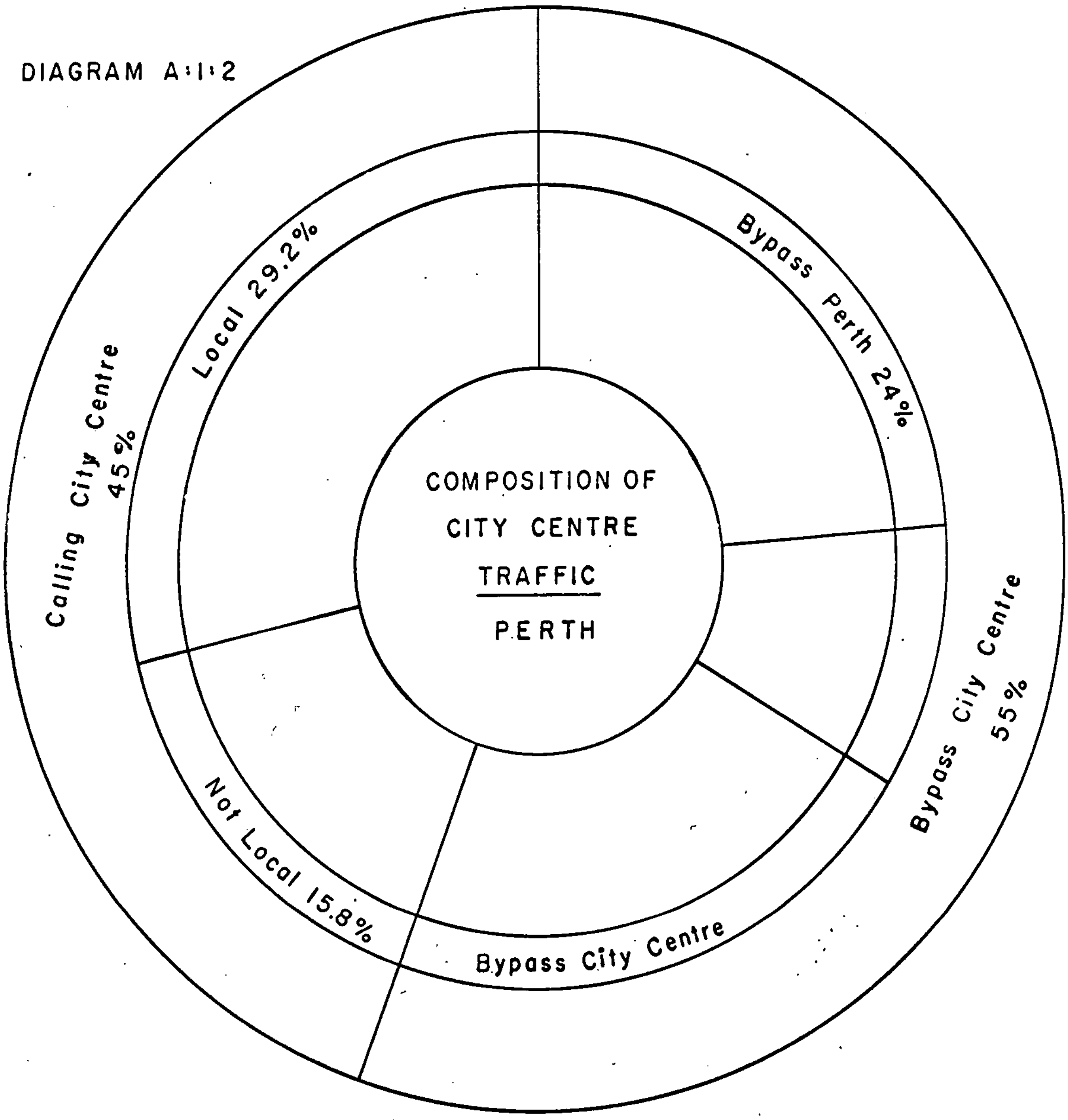
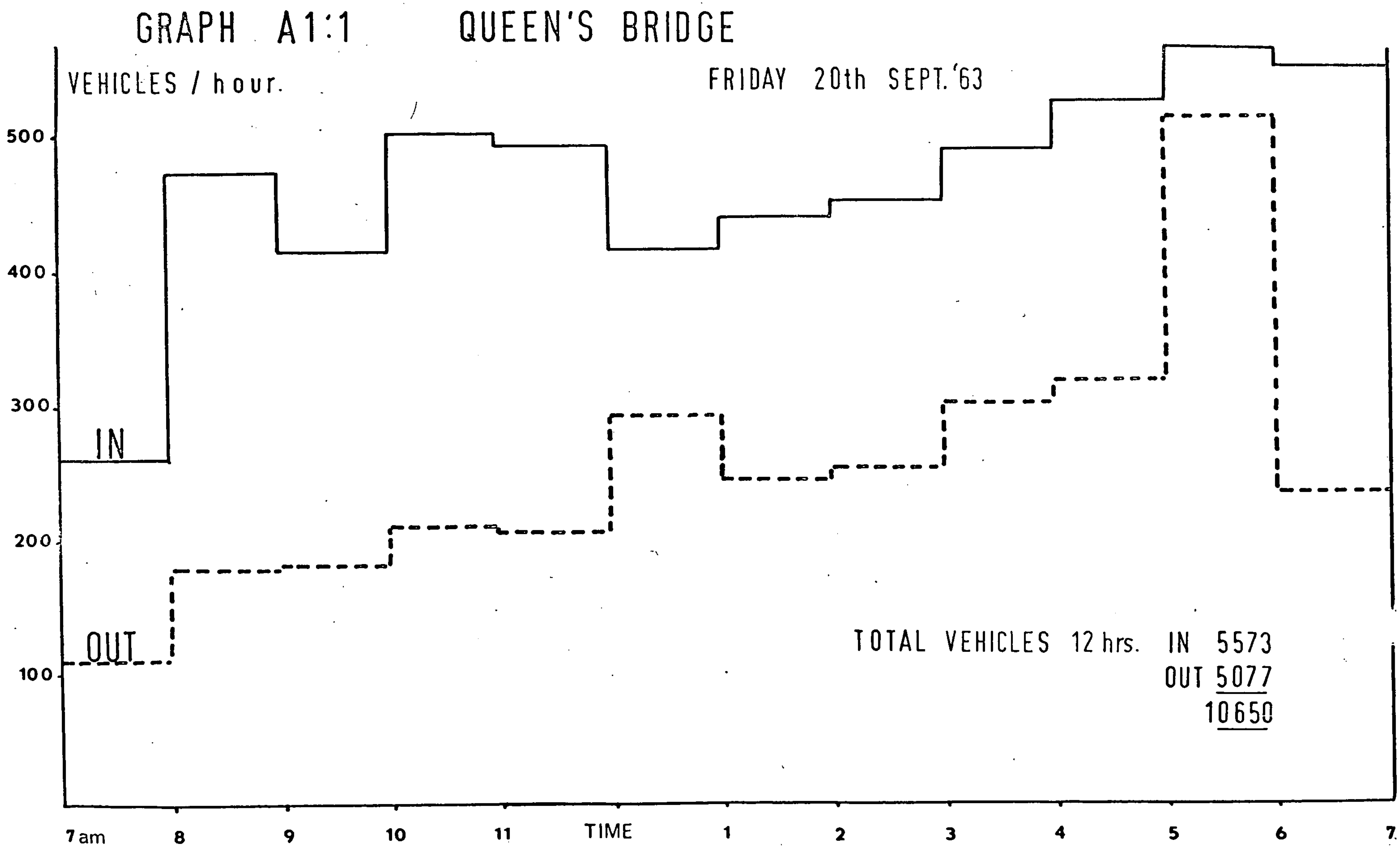
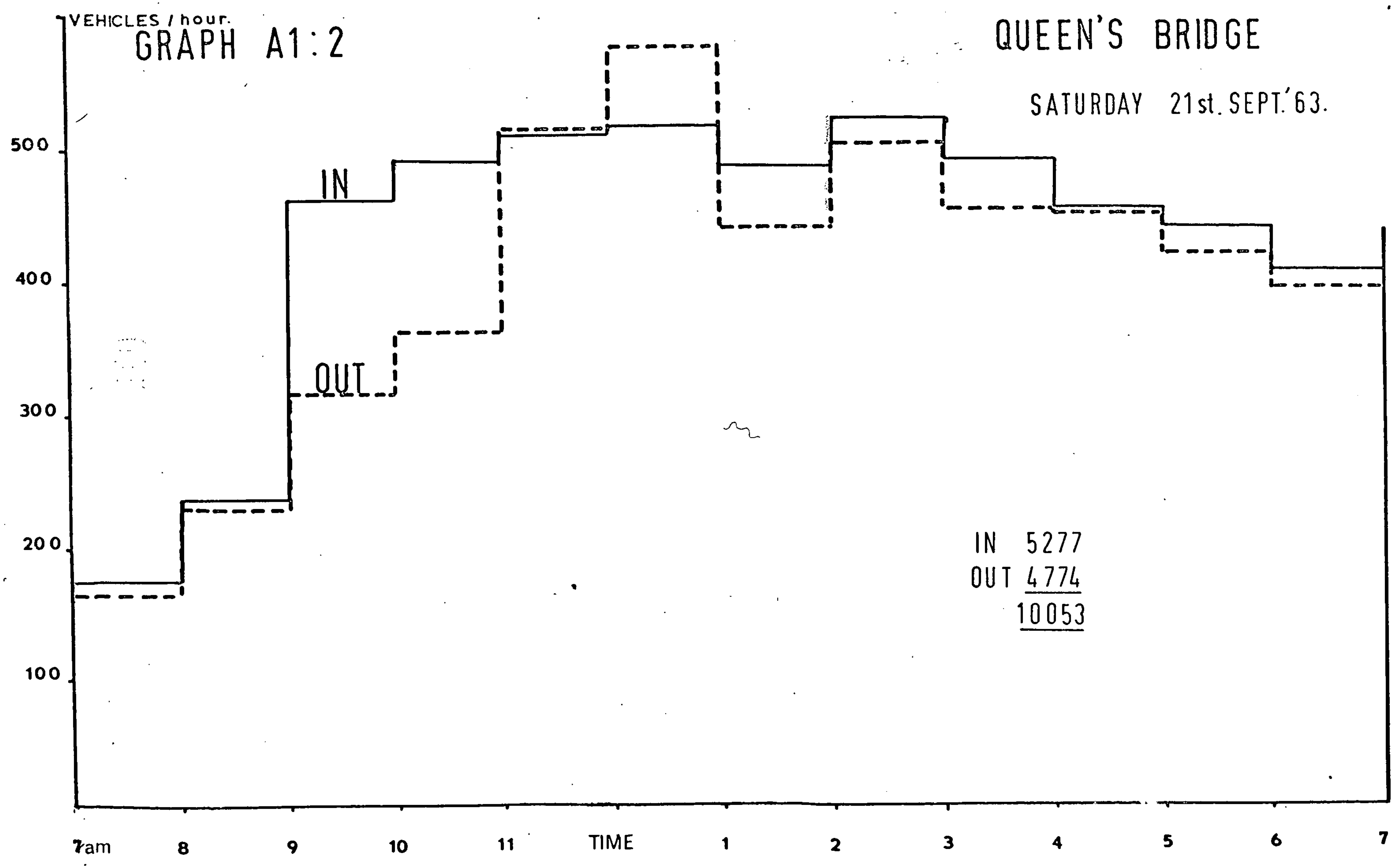
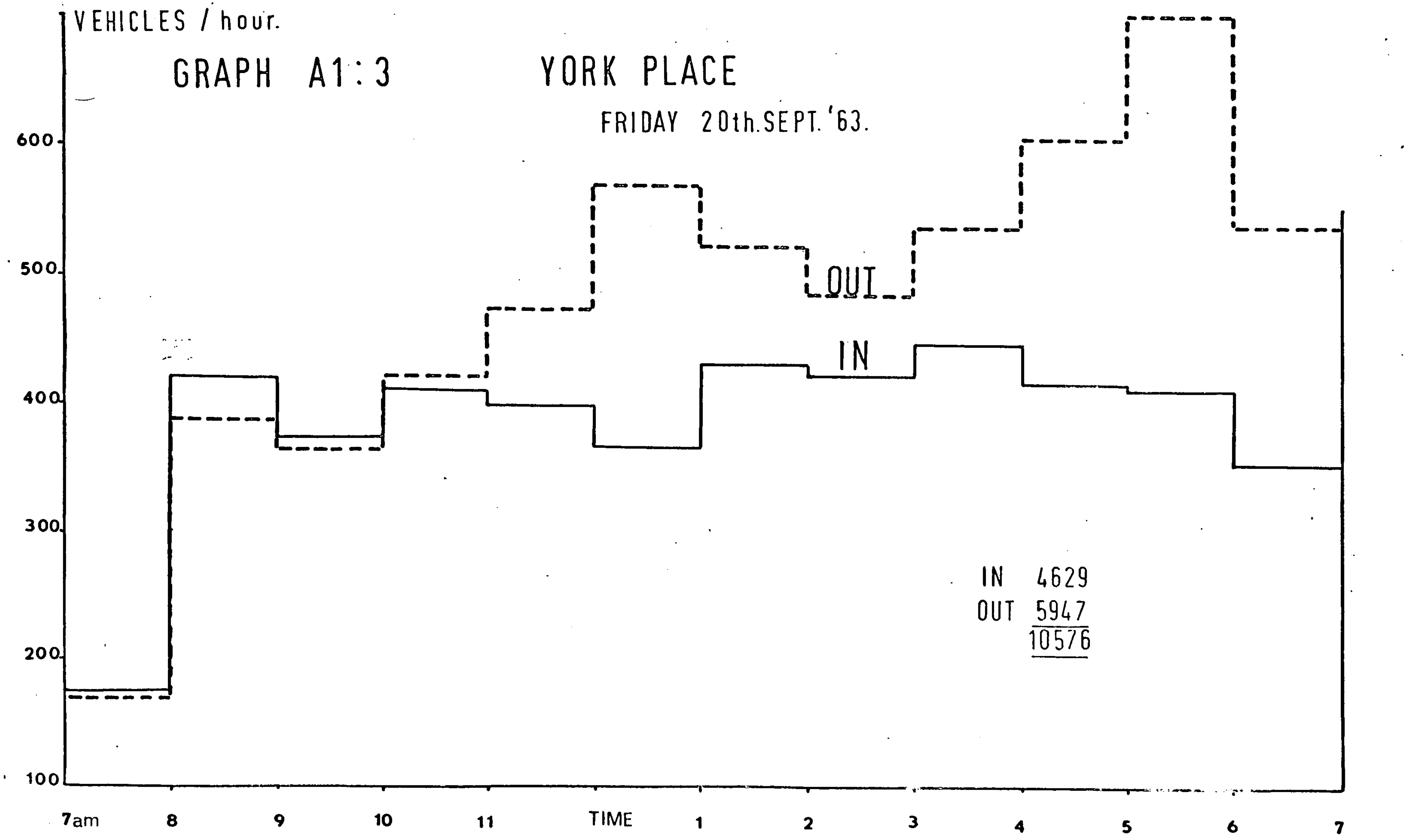

SATURDAY
Home to Work 7.0%
Work 17.3%
Shopping 17.2%
Social 27.2%
Holiday 10.6%
Goods 20.6%
FRIDAY
Home to Work 13.5%
Work 29.7%
6.6% Shopping
8.7% Social
7.1% Holiday
Goods 34.4%
COMPOSITION OF
CITY CENTRE
TRAFFIC
PERTH

DIAGRAM A:1:2

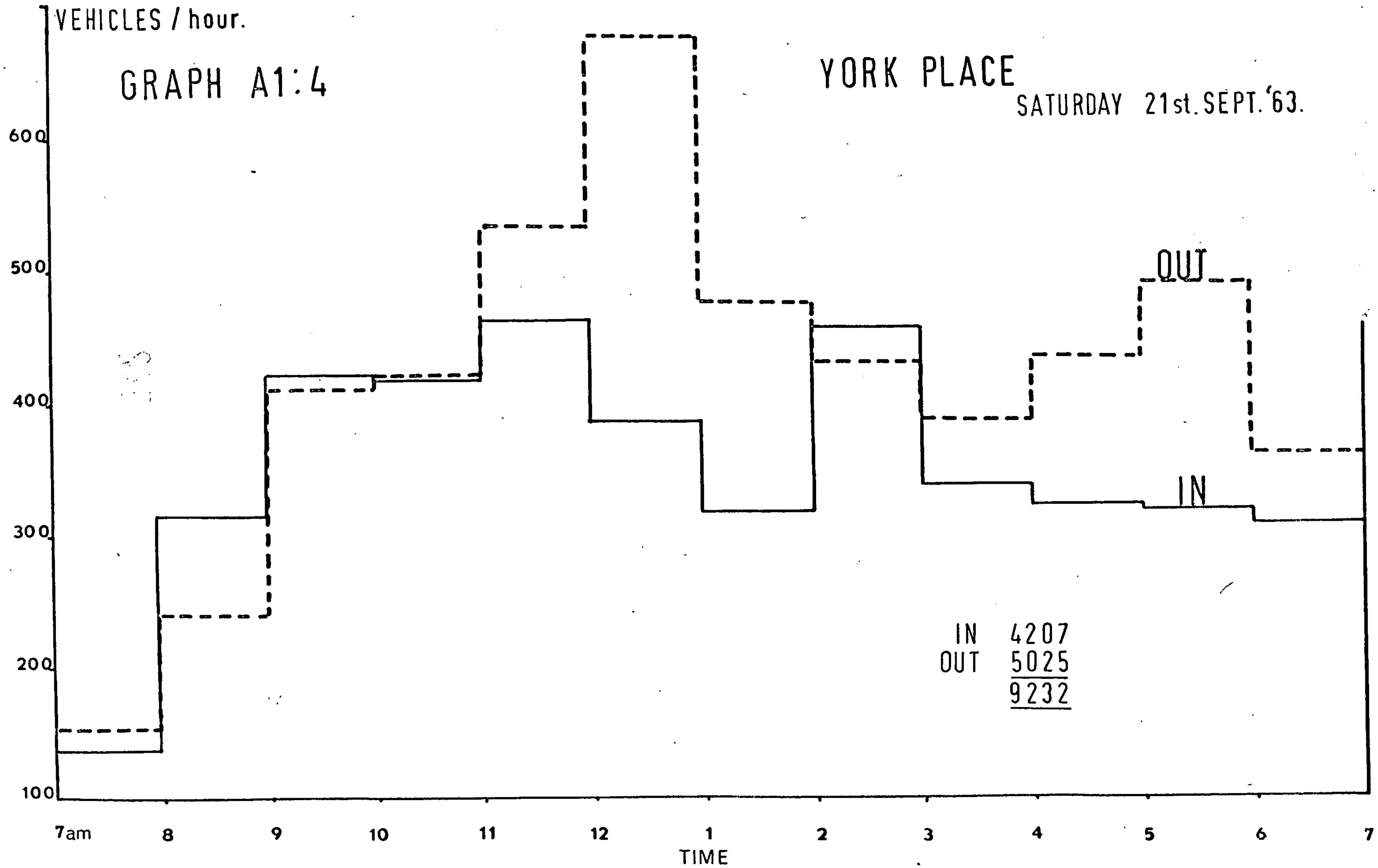

COMPOSITION OF
CITY CENTRE
TRAFFIC
PERTH
Calling City Centre
45 %
Local 29.2%
Not Local 15.8%
Bypass Perth 24%
Bypass City Centre
Bypass City Centre
55%


GRAPH A1:1 QUEEN'S BRIDGE
VEHICLES / hour.
FRIDAY 20th SEPT.'63
500
400
300
200
100
IN
OUT
TOTAL VEHICLES 12 hrs. IN 5573
OUT 5077
10650
7 am
8
9
10
11
TIME
1
2
3
4
5
6
7

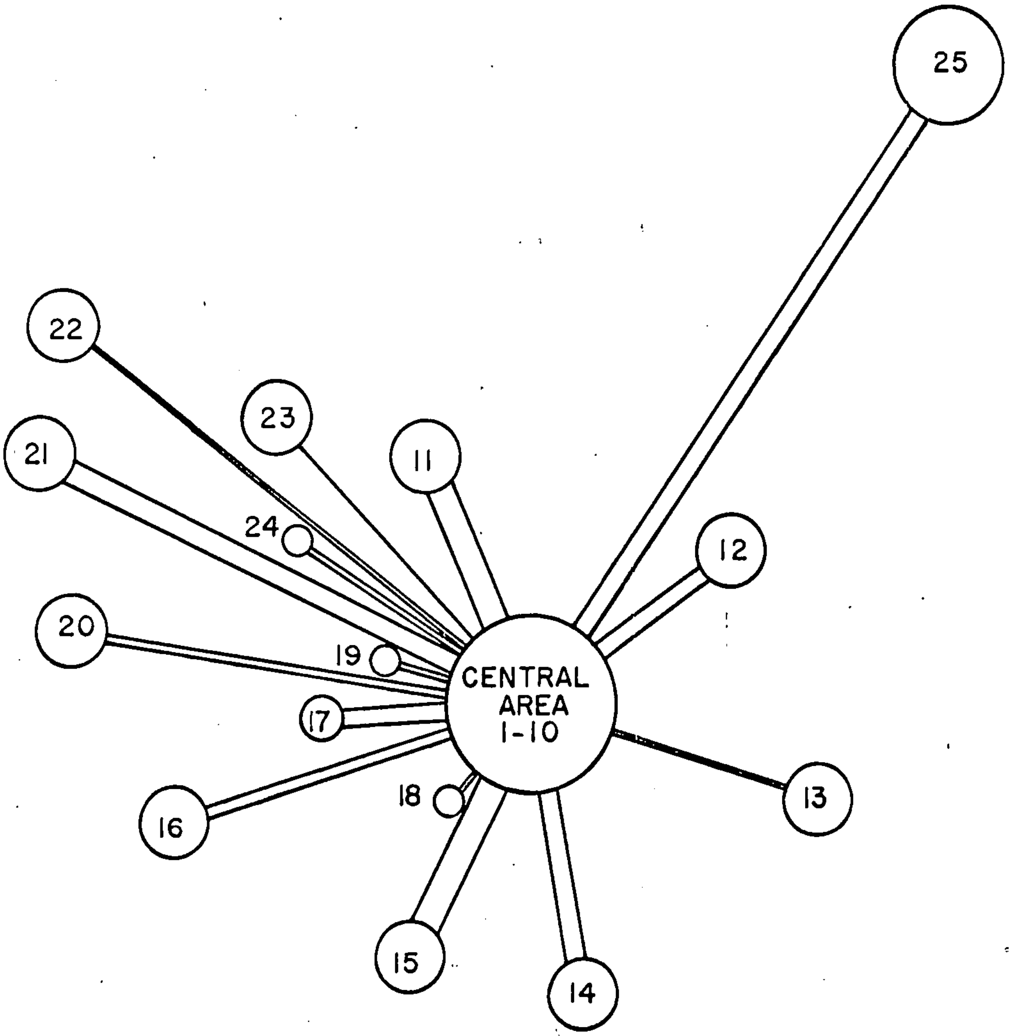

VEHICLES / hour.
GRAPH A1:2
QUEEN'S BRIDGE
SATURDAY 21st. SEPT.'63.
IN
OUT
IN 5277
OUT 4774
10053
500
400
300
200
100
7am
8
9
10
11
TIME
1
2
3
4
5
6
7



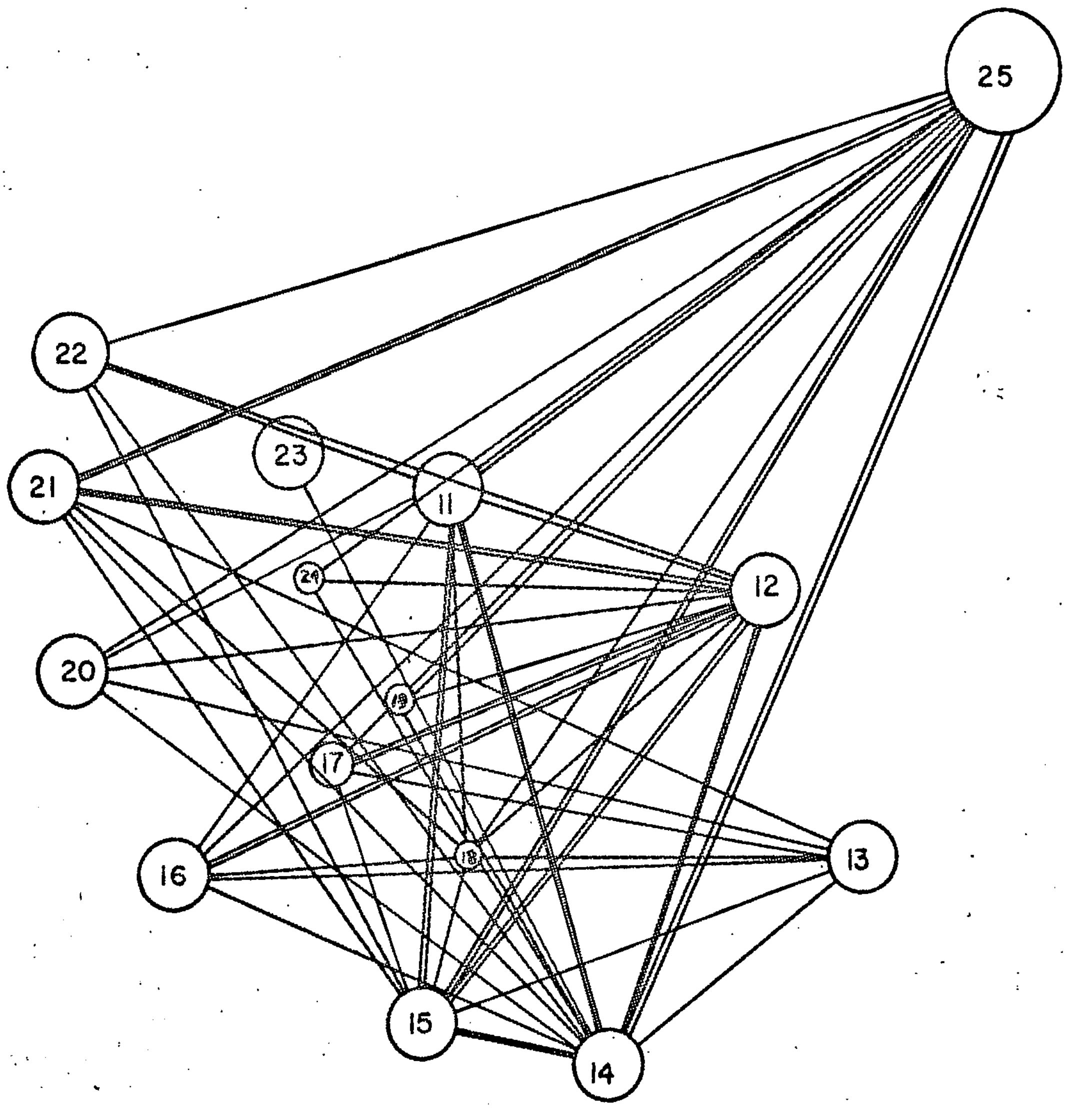
VEHICLES / hour.
GRAPH A1:3
YORK PLACE
FRIDAY 20th.SEPT.'63.
OUT
IN
IN 4629
OUT 5947
10576
600
500
400
300
200
100
7am
8
9
10
11
TIME
1
2
3
4
5
6
7


VEHICLES / hour.
GRAPH A1:4
YORK PLACE
SATURDAY 21st. SEPT. '63.
600
500
400
300
200
100
OUT
IN
IN 4207
OUT 5025
9232
7am
8
9
10
11
12
1
2
3
4
5
6
7
TIME

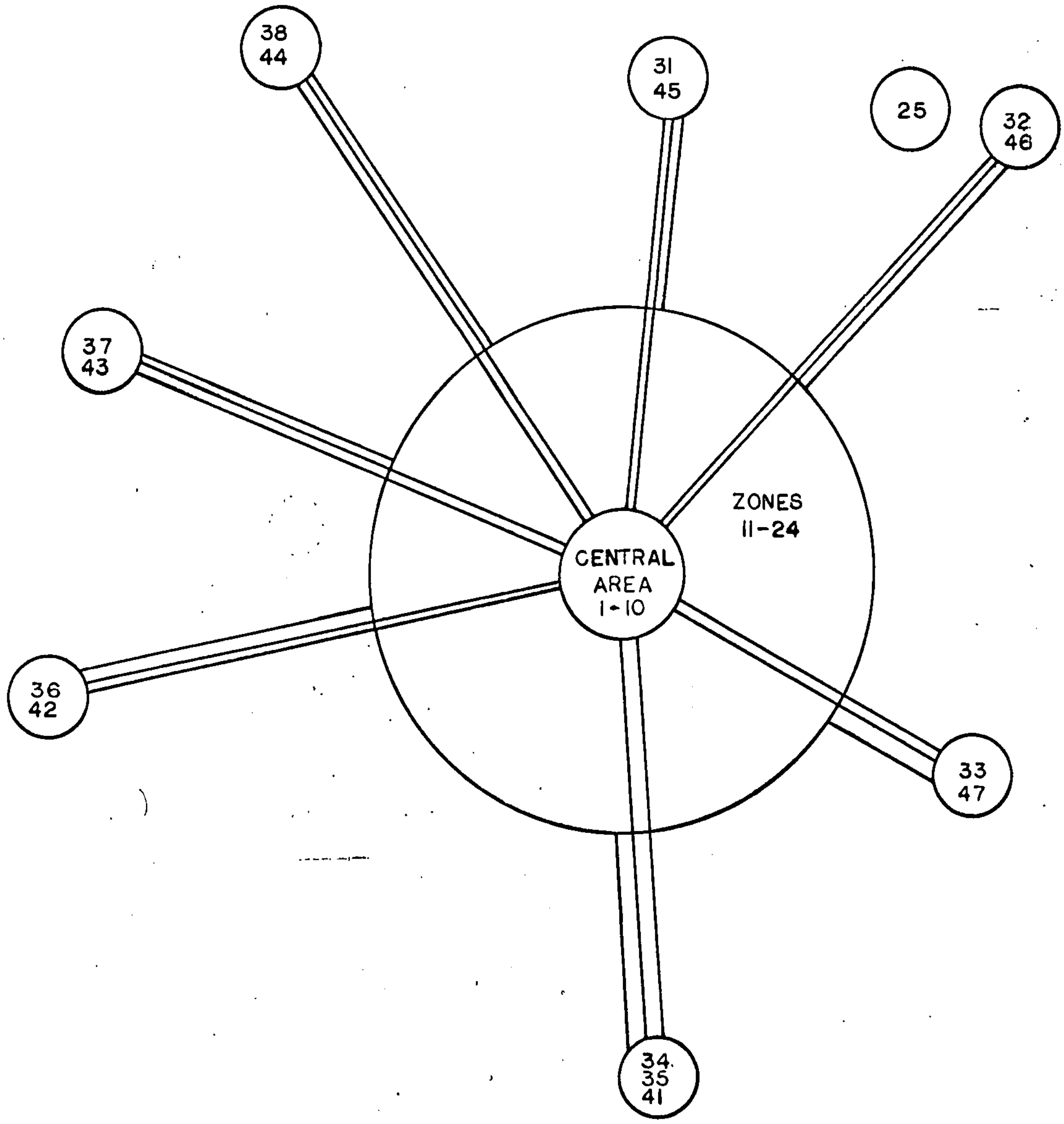
MAP AI:3 DESIRE LINES
ZONES 11-25 TO ZONES 1-10



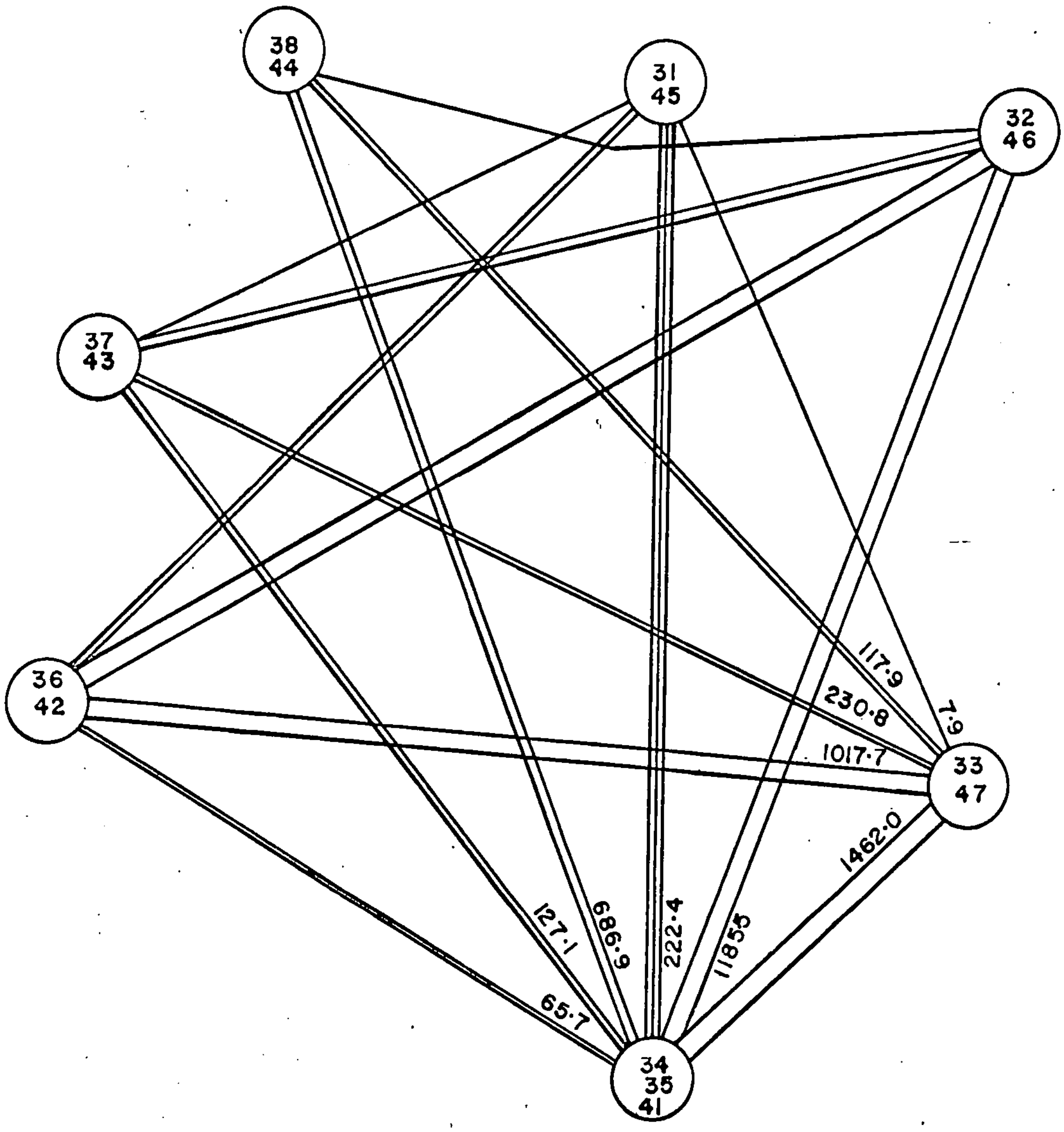
MAP AI:4 DESIRE LINES
ZONES 11-25 TO ZONES 11-25



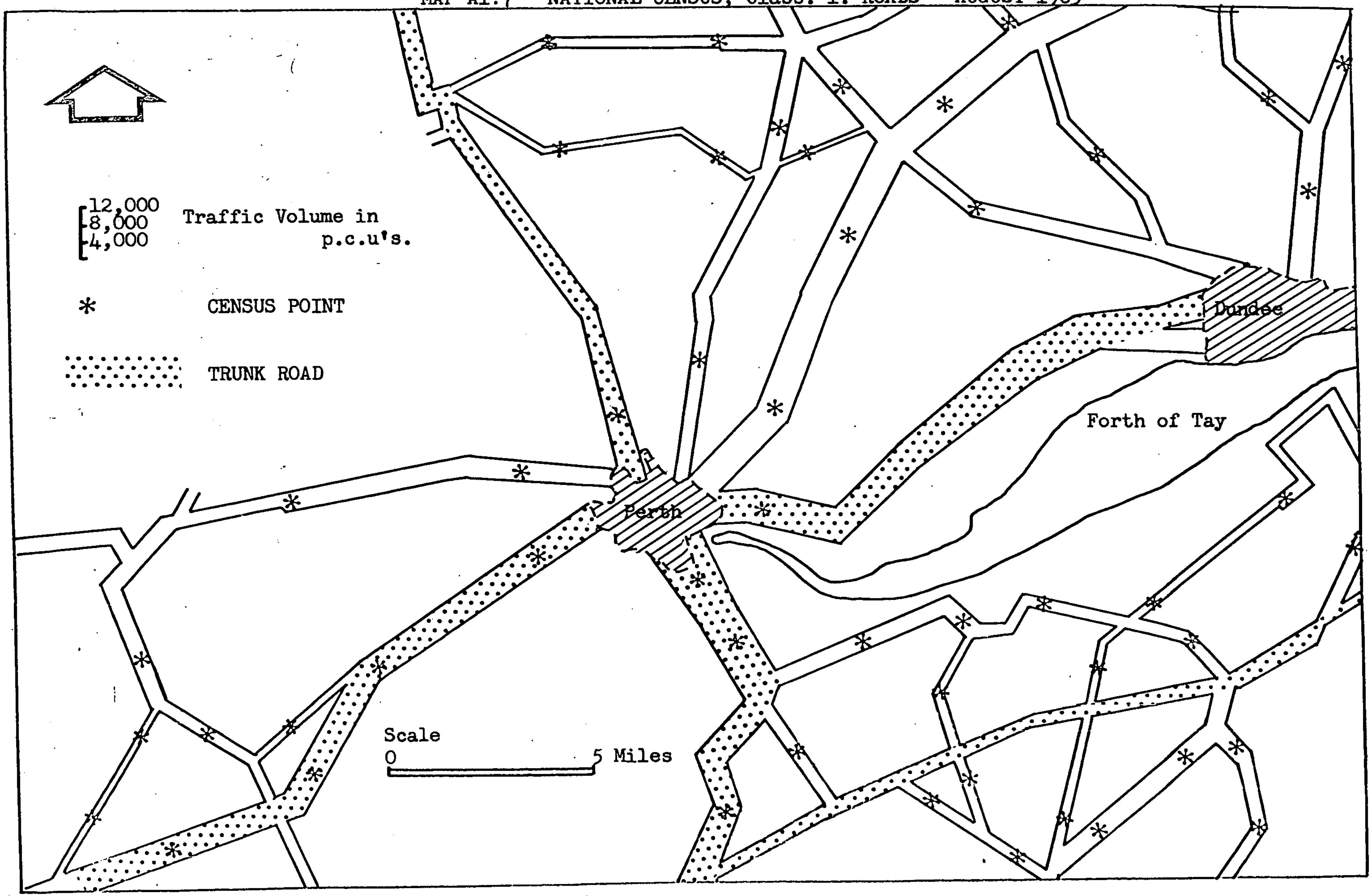
MAP A1:5 DESIRE LINES
EXTERNAL ZONES TO PERTH



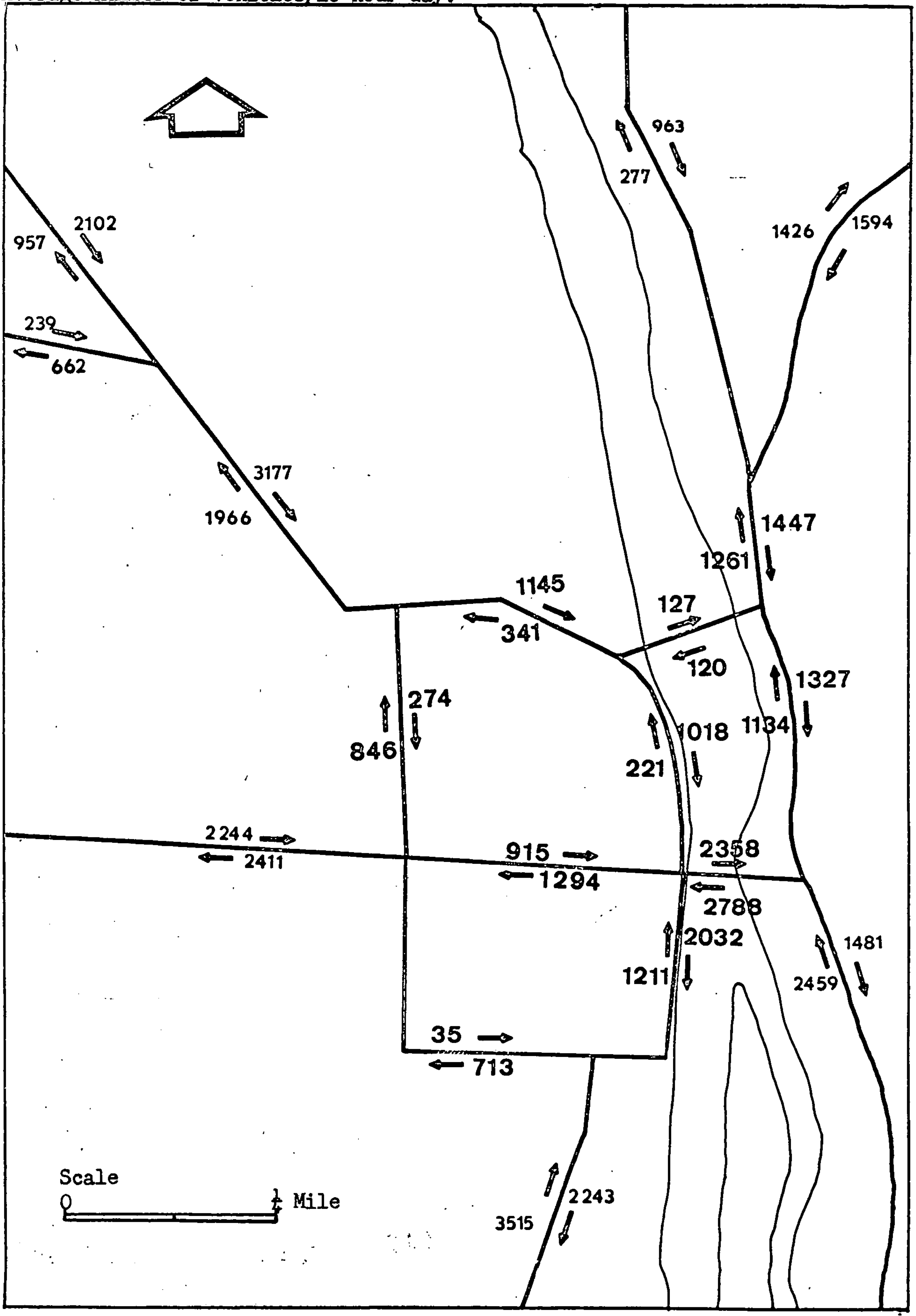
MAP A1:6 DESIRE LINES
EXTERNAL ZONES TO EXTERNAL ZONES



MAP A1:7 NATIONAL CENSUS, Class. 1. ROADS AUGUST 1963

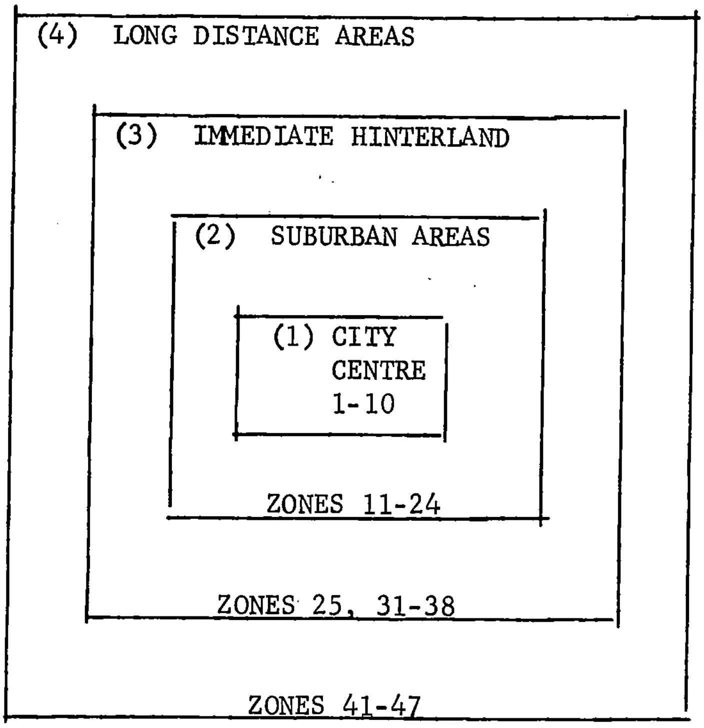


O-D Survey of Traffic 1959. Traffic entering and leaving the city.
Average number of vehicles/16 hour day.



Appendix 1(b) Burgh of Perth, Traffic Surveys, Basic statistics

Table 1. Basic travel pattern, one day.



(a) Total Flor 4 + 3 + 2 + 1 ⟶ 4 + 3 + 2 + 1

(b) Bypass Town (do not stop in Perth, could be bypassed)
4 + 3 ⟶ 4 + 3

(c) Non bypass 4 + 3 ⟶ 2 + 1

(d) Bypass central area (do not stop in central area, could be bypassed.)
4 + 3 + 2 ⟶ 2

(e) Bypass central area (local)
2 ⟶ 2

(f) Calling central area 4 + 3 + 2 ⟶ 1

(g) Calling central area (local)
2 ⟶ 1

Results, Thursday 19th September 1963 (in p.c.v.'s)

(a) 29,153.9
(b) 7014.3: 24.1%
(c) 6645.8; 23.7%
(d) 5631.6; 19.3%
(e) 3756.4; 12.9%
(f) 8729.5; 30.0%
(g) 7715.3; 26.5%
(h) Calling central area (internal) 1015.0; 3.5%.

N.B. (i) An outer ring road would reduce traffic in the central area by 24.1%.
(ii) A circulatory route round the city centre would reduce traffic by 70%.

TABLE. 2. Basic travel pattern, three days

	p.c.v's FRIDAY	%'s THURSDAY	FRIDAY	SATURDAY
Bypass Perth	7118.8	25.3	24.0	25.1
Bypass Central Area	16334.2	57.2	55.0	52.0
Bypass Central Area (local)	6861.7	22.1	23.1	19.8
Calling central Area (local)	8631.9	27.4	29.1	30.1
Calling central area	4699.6	15.3	15.8	17.9
Calling central area (total)	13331.5	42.7	44.9	48.0
Calling/Leaving central area (all)	1165.4			
All zones to all zones	31,055.0			
All incoming	29,665.7			
1 ----> 1 + 2 + 3 + 4 (as Table. 1.)	1389.3			

TABLE. 3.

Total traffic volumes, cordon points(three days.)

Inward flow	THURSDAY	FRIDAY	SATURDAY
Queen's Bridge	5147	5583	5288
Shore Road	1706	1845	1072
Dunkeld Road	3526	3861	4186
High Street	2730	3070	2546
St. Leonard's Bank	1531	1802	1416
Glasgow Road	4338	4629	4207
Edinburgh Road	3486	3642	4024
Perth Bridge	2881	3203	3119
Balhousie Street	1670	1741	2019
TOTAL (in)	27015	29376	27877
Overall total (in)			84268
Outward flow			
Queen's Bridge	4924	5088	4784
Shore Road	1551	1602	923
Dunkeld Road	4123	4789	5132
High Street	1798	2104	1684
St. Leonard's Bank	1326	1550	1235
Glasgow Road	5339	5857	5025
Edinburgh Road	4012	4360	4312
Perth Bridge	2865	3023	2811
Balhousie Street	1171	1296	1338
TOTAL (out)	27109	29669	27244
Overall total (out)			84022

TABLE. 4.

FRIDAY, 20th SEPT. 63. ALL VEHICLE CLASSES TRIP TYPE 1.

HOME TO WORK

PERIOD	SURVEY	INCOMING	CALLING CENTRAL AREA	NON-CALLING C. A.
1 0700-0730	165.9	161.7	53.5	108.2
2 0730-0800	432.3	418.6	227.8	190.8
3 0800-0830	324.9	319.1	196.2	122.9
4 0830-0900	611.2	599.1	430.3	168.8
5 0900-0930	146.3	144.3	107.1	37.2
6 0930-1000	34.1	32.1	26.4	5.7
7 1000-1030	19.7	18.7	13.4	5.3
8 1030-1100	12.6	11.6	7.3	4.3
9 1100-1130	5.4	5.4	3.5	1.9
10 1130-1200	29.8	29.8	17.9	11.9
11 1200-1230	139.6	135.0	64.3	70.7
12 1230-1300	187.8	183.5	102.8	80.7
13 1300-1330	233.9	231.1	137.4	93.7
14 1330-1400	261.8	259.8	196.8	63.0
15 1400-1430	137.8	135.4	99.9	35.5
16 1430-1500	43.5	42.3	24.8	17.5
17 1500-1530	35.4	35.4	11.8	23.6
18 1530-1600	58.4	55.4	25.4	30.0
19 1600-1630	125.5	117.1	31.8	85.3
20 1630-1700	213.8	208.8	69.0	139.8
21 1700-1730	486.7	467.1	151.4	315.7
22 1730-1800	277.9	268.9	86.0	182.9
23 1800-1830	140.4	136.7	34.7	102.0
24 1830-1900	77.4	76.7	11.9	64.8
T O T A L	4202.1	4093.6	2131.4	1962.2

TABLE. 5.

FRIDAY, 20th SEP. 63 ALL VEHICLE CLASSES TRIP TYPE 2.

PERIOD	SURVEY	INCOMING	CALLING C.A.	NON-CALLING C.A.
1 0700-0730	43.9	43.6	8.1	35.5
2 0730-0800	85.7	84.1	33.9	50.2
3 0800-0830	214.1	206.6	87.8	118.8
4 0830-0900	444.6	428.0	240.1	187.9
5 0900-0930	487.3	457.2	261.0	196.2
6 0930-1000	433.9	401.3	231.2	170.1
7 1000-1030	477.2	457.2	278.0	179.2
8 1030-1100	552.1	530.8	344.7	186.1
9 1100-1130	498.0	479.4	303.2	176.2
10 1130-1200	504.9	480.0	293.8	186.2
11 1200-1230	369.2	348.0	215.6	132.4
12 1230-1300	343.1	320.2	191.5	128.7
13 1300-1330	408.8	393.2	211.0	182.2
14 1330-1400	533.5	508.1	321.9	186.2
15 1400-1430	487.7	465.1	306.1	159.0
16 1430-1500	466.5	442.2	247.4	194.8
17 1500-1530	457.3	428.8	225.3	203.5
18 1530-1600	418.1	396.8	187.5	209.3
19 1600-1630	437.1	420.0	187.4	232.6
20 1630-1700	410.0	387.4	193.3	194.1
21 1700-1730	334.3	325.9	136.1	189.8
22 1730-1800	323.5	308.3	135.6	172.7
23 1800-1830	238.9	231.2	82.6	148.6
24 1830-1900	252.5	242.9	86.9	156.0
T O T A L	9222.2	8786.3	4810.0	3976.3

TABLE. 6.

FRIDAY 20 SEPT. 63 ALL VEHICLE CLASSES TRIP TYPE 3. SHOPPING

PERIOD	SURVEY	INCOMING	CALLING C. A.	NON-CALLING C.A.
1 0700-0730	1.3	1.3	1.3	0.0
2 0730-0800	1.2	1.2	1.2	0.0
3 0800-0830	7.4	7.4	7.4	0.0
4 0830-0900	25.7	25.7	24.7	1.0
5 0900-0930	62.9	60.6	59.5	1.1
6 0930-1000	109.9	105.5	99.7	5.8
7 1000-1030	128.7	124.8	118.4	6.4
8 1030-1100	147.9	142.2	132.9	9.3
9 1100-1130	130.0	126.1	117.4	8.7
10 1130-1200	108.6	100.1	95.2	4.9
11 1200-1230	87.5	80.4	76.0	4.4
12 1230-1300	57.3	55.4	51.3	4.1
13 1300-1330	81.6	72.2	64.2	8.0
14 1330-1400	109.1	104.0	96.1	7.9
15 1400-1430	172.2	161.8	152.2	9.6
16 1430-1500	171.3	163.7	147.9	15.8
17 1500-1530	138.9	130.4	123.9	6.5
18 1530-1600	128.5	118.8	116.0	2.8
19 1600-1630	106.6	101.0	87.5	13.5
20 1630-1700	100.7	94.7	88.8	5.9
21 1700-1730	95.7	90.1	84.1	6.0
22 1730-1800	39.2	34.7	31.1	3.6
23 1800-1830	16.2	16.2	15.2	1.0
24 1830-1900	12.0	12.0	8.1	3.9
T O T A L	2040.4	1930.3	1800.1	130.2

TABLE 7.

FRIDAY 20 SEP. 64 ALL VEHICLE CLASSES TRIP TYPE 4

PERIOD*	SURVEY	INCOMING	CALLING C. A.	NON-CALLING C. A.
1 0700-0730	8.9	8.9	3.2	5.7
2 0730-0800	7.2	7.2	0.8	6.4
3 0800-0830	14.8	13.7	3.1	10.6
4 0830-0900	38.2	35.9	13.9	22.0
5 0900-0930	52.0	50.7	17.7	33.0
6 0930-1000	55.2	52.0	15.3	36.7
7 1000-1030	71.2	65.9	23.3	42.6
8 1030-1100	87.8	80.0	23.3	56.7
9 1100-1130	77.6	73.9	25.2	48.7
10 1130-1200	81.4	77.6	17.9	59.7
11 1200-1230	79.9	73.7	23.3	50.4
12 1230-1300	91.6	82.1	36.0	46.1
13 1300-1330	58.7	54.4	18.2	36.2
14 1330-1400	79.6	76.3	25.2	51.1
15 1400-1430	83.5	79.8	23.4	56.4
16 1430-1500	135.8	126.7	41.9	84.8
17 1500-1530	112.7	108.4	35.5	72.9
18 1530-1600	157.7	152.0	46.3	105.7
19 1600-1630	133.0	129.6	42.1	87.5
20 1630-1700	154.4	150.3	39.4	110.9
21 1700-1730	165.3	158.9	58.4	100.5
22 1730-1800	209.8	202.7	77.0	125.7
23 1800-1830	316.4	308.8	101.4	207.4
24 1830-1900	426.1	418.1	171.4	246.7
T O T A L	2698.8	2587.6	883.2	1704.4

TABLE 8.

FRIDAY 20 SEP. 63   ALL VEHICLE CLASSES   TRIP TYPE 5

PERIOD		SURVEY	INCOMING	CALLING C. A.	NON CALLING C. A.
1	0700-0730	11.6	11.6	0.0	11.6
2	0730-0800	10.4	9.4	1.5	7.9
3	0800-0830	22.2	18.8	4.6	14.2
4	0830-0900	23.1	21.1	4.1	17.0
5	0900-0930	40.9	38.8	4.8	34.0
6	0930-1000	45.2	42.1	3.0	39.1
7	1000-1030	86.2	80.2	17.3	62.9
8	1030-1100	102.7	91.5	20.9	70.6
9	1100-1130	106.8	91.4	19.2	72.2
10	1130-1200	101.3	94.8	15.7	79.1
11	1200-1230	111.7	98.6	21.3	77.3
12	1230-1300	91.5	77.6	24.0	53.6
13	1300-1330	84.8	74.8	15.6	59.2
14	1330-1400	63.6	59.7	8.8	50.9
15	1400-1430	104.3	99.2	16.3	82.9
16	1430-1500	108.2	100.8	15.2	85.6
17	1500-1530	134.3	125.7	22.3	103.4
18	1530-1600	107.1	98.6	12.9	85.7
19	1600-1630	132.9	122.4	21.6	100.8
20	1630-1700	147.8	134.6	22.3	112.3
21	1700-1730	156.0	145.7	18.4	127.3
22	1730-1800	150.9	142.1	26.8	115.3
23	1800-1830	143.3	140.7	18.2	122.5
24	1830-1900	143.2	140.5	11.8	128.7
T O T A L		2230.0	2060.7	346.6	1714.1

TABLE 9.

FRIDAY 20 SEP. 64   ALL VEHICLE CLASSES   TRIP TYPE 6

PERIOD		SURVEY	INCOMING	CALLING C. A.	NON CALLING C. A.
1	0700-0730	284.3	272.5	57.9	214.6
2	0730-0800	408.6	386.4	89.3	297.1
3	0800-0830	469.6	456.6	175.9	280.7
4	0830-0900	472.0	457.9	165.5	292.4
5	0900-0930	521.3	489.3	168.8	320.5
6	0930-1000	499.0	468.4	161.9	306.5
7	1000-1030	478.6	458.1	177.2	280.9
8	1030-1100	553.5	519.5	216.2	303.3
9	1100-1130	529.3	512.6	183.1	329.5
10	1130-1200	559.9	541.6	203.7	337.9
11	1200-1230	489.7	462.9	183.4	279.5
12	1230-1300	475.9	451.7	133.0	318.7
13	1300-1330	459.2	438.2	135.4	302.8
14	1330-1400	468.1	449.9	170.2	279.7
15	1400-1430	457.2	441.7	149.6	292.1
16	1430-1500	434.5	406.1	137.2	268.9
17	1500-1530	397.0	378.3	111.6	266.7
18	1530-1600	535.3	517.0	141.5	375.5
19	1600-1630	488.2	476.1	152.8	323.3
20	1630-1700	482.2	466.9	152.1	314.8
21	1700-1730	434.9	421.0	129.9	291.1
22	1730-1800	350.7	342.7	84.8	257.9
23	1800-1830	244.5	229.4	45.7	183.7
24	1830-1900	168.0	162.4	33.5	128.9
TOTAL		10661.5	10207.2	3360.2	6847.0

TABLE. 10.

Classified Count (inward). Edinburgh Road,

Thursday, 19th September.

TIME	CAR	MOTOR CYCLE	LIGHT COMM. VEHICLE	HEAVY COMM. VEHICLE	COACH ~~BUS~~	BUS	TOTAL VEHICLES
0700	23	4	9	28		4	68
0730	60	10	18	25		8	121
0800	60	9	12	34		5	120
0830	81	9	12	28		17	147
0900	90	3	17	27		3	140
0930	80	1	12	30		3	126
1000	94	2	19	30		6	151
1030	72	1	27	34		2	136
1100	114	2	15	32	1	3	167
1130	125	4	19	48	1	2	199
1200	94	2	17	27		9	141
1230	95	10	13	28	1	3	150
1300	85	6	13	20	1	4	129
1330	76	5	15	27		5	128
1400	109	3	10	28		5	155
1430	92	3	12	30		3	140
1500	125	3	17	29		2	176
1530	80	1	13	35		6	135
1600	93	4	19	17		9	142
1630	149	9	16	36	1	8	219
1700	119	1	16	32	1	7	176
1730	104	3	12	20		6	145
1800	110	5	12	15		5	147
1830	82	1	8	22		6	119

TABLE. 11.

Zone. 21 (Letham) traffic flow (in p.c..u's) Thursday.

TO ZONE	PCU'S	%
1	51.2	9.4
2	127.7	13.0
3	179.4	17.2
4	141.1	8.7
5	47.2	3.5
6	36.6	3.2
7	54.8	4.5
8	39.9	3.3
9	48.8	3.9
10	30.7	2.5
11	30.3	2.5
12	69.6	5.9
13	80.8	6.8
14	120.5	9.4
15	55.3	3.9
16	40.8	3.3
17	48.7	3.8
18	39.1	3.2
19	49.9	3.9
20	53.3	3.6
21	50.7	3.4
22	51.8	4.5
23	63.4	6.2
24	72.3	7.0

TABLE. 12.

External cordon survey. 1959 (August 10th-16th)

(Total vehicles, in and out)

	A93	A94	A85 Dundee	A90 Edin-burgh	A9 Glasgow	A85 Crieff	A9 Dunkeld	TOTAL
CARS	9665	17729	23285	39169	21507	14314	23663	149332
MOTOR CYCLES	495	921	1399	2352	1042	1279	1511	8999
BUSES	354	440	1107	1688	885	987	1113	6574
COMM. VEHICLES	2642	2173	8669	11285	7537	4727	5807	47840
TOTAL	13156	26263	34460	54494	30971	21307	32094	212745

TABLE. 13

National Traffic Censuses. Perth. Average Daily figure

	1963	1959	1954	1938	1935	1931	1928	1925	1922
A93 Blairgowrie	2239	1869	1292	945	825	634	604	446	298
A94 Forfar	-	3746	2443	1711	1457	1100	1016	1017	654
A85 Dundee	7418	4909	3781	2429	2135	1611	1381	1010	575
A90 Kinross	9669	7782	4417	2932	2400	1628	1823	1415	837
A9 Auchterarder	11354	4413	3065	2383	2065	1651	1402	921	406
A85 Crieff	-	3040	1514	1237	1179	840	1017	891	587
A9 Dunkeld	11340	4578	2916	2209	1972	1557	1553	1255	965
TOTAL	-	30337	19428	13846	12023	9021	8796	6955	4322

APPENDIX 2

Parking Survey

Appendix 2(a) Method

Parking is one of the major problems facing those interested in urban transportation. It has a considerable effect on traffic flow. As the volume of traffic increases year byyear, traffic authorities are faced with the situation of finding increased parking accommodation and at the same time keeping the streets as clear as is feasible to prevent complete saturation of traffic in all streets. Because of this interest parking surveys have received much attention.

The purpose of thesurvey in Perth was to find out the number of vehicles parked within the central area at various times of the day, and the duration of parking.

The method employed was adapted from Charlesworth and Green (1). An enumerator patrols a given section of street at a set interval (20 minutes in this case), noting the registration figures of parked vehicles at each interval. The shorter the interval the greater the number of short term parkerscenumerated.

The central area was divided into 24 areas sufficiently small to be patrolled in the time interval. Each area consisted of one or more streets, and a circular patrol route was devised in each case.

A vehicle noted N times during a survey having a trip interval of T minutes is assumed to have parked N x T minutes. in actual fact as it cannot be determined exactly when it entered the section before it was noted and exactly when it left after it was last noted the actual time parked is more probably equal to N $\pm$ T, but for purposes of this survey, N x T minutes was taken as the parking duration.

A number of temporary workers were employed for the survey, and two were allotted to each area working on a shift system from 8.0 a.m. to 6.0 p.m. The shifts were so balanced that on average each spent 1 hour 40 minutes outside, whilst the other was doing the calculations.

The enumerator patrolled from the point of commencement along the prescribed route. The registration numbers of all stationery vehicles was entered in a column of the survey sheet. Buses, motor cycles and motor scooters were not enumerated. From the survey sheet the information was transferred to an analysis sheet, any particular registration is then traced through each patrol number until it disappears. An analysis sheet is complete when each registration number from the original records has been transferred and its 'occurrences' recorded.

This data is then transferred to a summary sheet, which is the final result of the survey work. Some of these results are shown in Appendix 2 (b).

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(1) G.K. Charlesworth and Hilary Green 'Parking Surveys' Roads and Road Construction May 1953.

Appendix 2(b) Perth Parking Survey, 17th, 19th October 1963

Parking	Duration	Total number of vehicles parked	Percentage
1	20 minutes	7594	49.97
2	40	2204	14.75
3	60	1128	7.48
4	80	686	4.55
6	100	525	3.43
6	120	354	2.33
7	140	269	1.76
8	160	254	1.67
9	180	241	1.58
10	200	274	1.79
11	220	282	1.85
12	240	288	1.89
13	260	186	1.22
14	280	191	1.25
15	300	105	0.69
16	320	52	0.34
17	340	58	0.38
18	360	28	0.18
19	380	27	0.18
20	400	19	0.12
21	420	19	0.12
22	440	27	0.18
23	460	17	0.11
24	480	19	0.12
25	500	49	0.32
26	520	44	0.29
27	540	58	0.38
28	560	43	0.28
29	580	24	0.16
30	600	96	0.63

Total vehicle trips = 58,989

Total number of different vehicles parked = 15,254

Average number of vehicles per trip = 1,936.3

Maximum number of vehicles parked = 2,935.

APPENDIX 3

Home Interview Survey

Appendix 3(a) Method

Most urban dwellers tend to have travel habits that are repetitive in time and place. In addition the travel habits of individuals tend to be representative of other persons in similar circumstances. These facts ensure that a survey of travel made by a small representative sample of indidivuals during a typical day can be used to represent the total travel of all residents in an area on all similar days.

The home is chosen as the site of the interview, since approximately 80% of all trips begin or end at the home. It is considered that a sample of homes will be representative if the homes included are distributed geographically throughout the survey area in the same way as the whole population.

The size of the sample needed depends primarily on the size of population or number of homes, and the degree of accuracy required. It also depends on the extent towhich the total population, or the trips made are to be subdivided into groups, and on the number of people or trips in each group. North American experience of home interview surveys show that the samplë sizes generally appropriate for American cities of various sizes are as in Table 1. No such experience is yet available for the United Kingdom,but certainly sample sizes should not be lower than the minimum rate recommended in Column A of Table 1.

Table 1

Recommended sample sizes for traffic surveys (1)

	% for each purpose						
Urban Population	A.	B.	C.	D.	E.	F.	G.
less than 50,000	10	20	12½	8	13	10	10
50-150,000	5	12½	3¼	4	$2\frac{2}{3}$	5	5
150,000-300,000	3	10	1	$1\frac{1}{3}$	2	2½	$3\frac{1}{3}$
300,000-500,000	2	$6\frac{1}{3}$	1	1	$1\frac{1}{3}$	$1\frac{1}{3}$	2
500,000 to 1 million	1½	5	1	1	1	1	1½
Over 1 million	1	4	1	1	1	1	1

A. Public Administration Service, minimum sample rate.

B. Bureau of Public Roads recommended sample rate.

C. P.A.S. rate for personal trips by car and transit ± 4% accuracy.

D. P.A.S. rate for personal trips by various purposes, ± 5% accuracy.

E. P.A.S. rate for personal trips to C.B.D. by various modes, ± 5% accuracy

F. P.A.S. rate for personal shopping trips to C.B.D. by car and transit, ± 5% accuracy.

G. P.A.S. rate for trips to a major traffic generator, + 10% accuracy.

(1) Source Procedure Manual 2.A. 'Origin - Destination and Land Use' Public Administration Service.

Because of limited financial support for this particular survey, the minimum rate of a 10% sample for a small urban area, with accuracy ± 5 to 8%.

The procedure for selecting the sample is basically that recommended by Yates (2). Revised ordinance survey sheets, at a scale of 1/2500 or 1/1250 used in conjunction with voters lists were found to be the best way of first identifying the dwelling units, since for the sampling method used each household must be identified. For institutions either bedrooms or persons must be sampled.

Once identification is complete, sampling begins. Each zone was broken down into its constituent enumeration districts, and each was considered separately. In this way a better geographical distribution was obtained and the data would be comparable with the 1961 census data at this level. For statistical reasons each district is sampled separately beginning in each case in the south east corner, andcounting begins at 6. The procedure is to count all the households, proceeding around each street block in a clockwise direction, considering the street blocks in the same systematic order in each zone, and selecting every 10th household for the sample. The number of households remaining in a block after the last sample is selected should be carried over into the next block. Even when the district has been completely sampled the carry over was noted since it was used in selecting samples from hotels, institutions, etc. The selected sample is then recorded on a field schedule.

Adequate publicity is essential for the success of the home interview, or indeed of any travel survey. Residents must be informed of the methods used, why it is necessary, and how their anonymity is protected. The text of the letter used is shown below.

Several weeks before the survey started statements were made in the local press on the nature and purpose of the survey, without however revealing too many of the details of the questions to be asked. Several days before a visit by an interviewer a letter was delivered.

The main purpose of the previsit letter is to 'break the ice' for interviewer, thus making it easier for him to carry out a successful interview, and saving considerable time when aggregated over the week's interviewing.

The actual questionnaire can take two forms - one is the type on which the interviewer records the answers he, or she, receives verbally from the interviewee; the second type is like the national census where the householder interprets and fills in most of the form on his own. Because detailed information was needed about <u>all</u> origins and destinations the personal contact achieved in the first type seemed to make it the best, and there was the probability of a higher response rate.

The questionnaire elicited two types of information - household information and personal trip information.

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(2) Yates 'Sampling Methods for Censuses and Surveys'. London. Griffin.

CITY AND ROYAL BURGH OF PERTH / UNIVERSITY OF DURHAM

Burgh Surveyor's Office,
Tay Street,
PERTH

Dear Sir/Madam,

HOME INTERVIEW TRAVEL SURVEY

The Burgh of Perth and the Department of Geography, University of Durham, have recently been carrying out a comprehensive investigation of all traffic movements in and about the town.

As you will be aware, the existing road situation is far from perfect, and with a probable 150% increase in vehicle numbers over the next fifteen to twenty years conditions may deteriorate rapidly. This survey represents a serious attempt to assess traffic needs, and will enable us to provide better facilities more in keeping with present and future requirements. Please will you help in providing the answers we require.

Your household has been selected (one in every ten houses is to be visited) for the Home Interview Survey, and you will be visited during the next few days, and asked to provide details of your daily journeys.

Your co-operation in furnishing this information will be greatly appreciated. All information received will be treated in the strictest confidence, and the system of recording has been so designed that all identity is destroyed in the analysis, i.e., it will not be possible to trace back any information to the original household.

Yours faithfully,

M. Eliot Hurst
University of Durham

TABLE. 2. Example Answer Sheet

Home Interview Survey

CITY AND ROYAL BURGH OF PERTH/UNIVERSITY OF DURHAM

HOME INTERVIEW RECORD

SAMPLE NUMBER | DATE
DWELLING UNIT TYPE
TOTAL NUMBER LIVING HERE
AGE CATEGORIES

< 3 | 3-14 | 15-20 | 21-65 | 65+

VEHICLES

	64	63	59
Pedal cycle			
Moped			
Scooter			

	64	63	59
Motor Cycle			
Car			
Van			

GARAGE

Single Garage
Single Space
No Space
Off house/open cite

Double Garage
Double Space
Lock-up from house

DRIVING LICENCES

JOURNEYS

NO.	STATUS	OCCUPATION	JOURNEY BEGIN	JOURNEY END	WHEN DEP.	WHEN ARR.	MODE	PURPOSE	PARKING LENGTH TIME
1									
2									
3									
4									
etc									

NON INTERVIEW

Vacant Dwelling.................No Answer...............

Answer Refused..................Other.................

Household Information Total number living at that address (not how many in the family); age groups, vehicle, scooter, cycle ownership; ownership last year and five years previously; company-owned vehicles, where the 'car, etc. was left overnight; number of driving licences. By observation the dwelling unit type was noted. In a pilot survey a question was asked about income, but a low response resulted, and the question was changed to one concerning occupation.

Personal Trip Information Information was required in detail on all trips made during the day previous to the interview, or the previous Friday in the case of a Monday visit. The days of the week were carefully balanced. All members of the household were included, over the age at which they could be expected to make unaccompanied journeys, i.e. about 5 years of age. A 'trip' is defined as the one-way journey from one point to another for a particular purpose.

Questions asked were: position in family? Where did journey begin ... end ... time of departure ... time of arrival ... mode of travel ... purpose of journey? A supplementary question was asked of those going by car or van to the central area, concerning parking.

The interviewing was carried out by my wife and myself, and by one helper loaned by the Scottish Development Department. In the course of six weeks about 1400 interviews were conducted, with a very high response rate. Refusals, empty houses, etc. accounted for less than 2% of the original sample. The interest of Perth people and the detailed publicity probably account for this response rate. Had a larger body of interviewers been used more careful instruction, questionnaires and questions would have had to have been undertaken.

The answer sheet was so designed that very little of the data had to be coded at the conclusion of the survey. An example of this sheet is set out at the end of this section.

The coded data were later transferred to magnetic tape and tabulated by the staff of the University of Durham computer unit, and an Elliott 803 computer. Some of the results are set out in the second section of this appendix.

Appendix 3.b.

TABLE. 1.

Households and persons interviewed.

TRAFFIC ZONE	DWELLINGS	POPULATION	MALES	FEMALES	CARS OWNED	TOTAL FROM HOME TRIPS	TOTAL TRIPS REPORTED
1 / 7	56	142	61	81	10	180	425
2 - 5	31	86	38	48	7	109	253
6	62	146	68	78	9	150	349
8	31	76	36	40	5	82	191
10	77	179	85	94	9	181	420
11	214	658	313	345	38	783	1823
12 / 13	109	298	134	164	55	432	1079
15	209	659	308	351	52	857	2089
16	64	178	80	98	48	282	735
17	101	267	132	135	26	355	889
20	40	127	56	71	27	196	501
21	274	947	464	483	98	1241	3018
22	40	138	67	71	10	178	434
23	56	235	113	122	5	254	619
24	21	54	25	29	9	72	180
TOTAL	1385	4190	1980	2210	408	5352	13005

TABLE. 2. Basic data. Home Interview Survey.

TRAFFIC ZONE	AV. FAMILY SIZE	CARS / PERSON	BYCYCLE / PERSON	M:C / PERSON	CARS / HSEHOLD.	DAILY FROM HOME TRIPS/ PERSON	DAILY FROM HOME TRIPS/ HSEHLD.	% OF WORKERS WITHOUT PERTH	PERSONS /1000 SQ.FT. RESID. FLOOR SPACE
1 + 7	2.54	0.07	0.12	0.035	0.18	1.27	3.21	7.0	4.7
2 - 5	2.75	0.08	0.07	0.034	0.23	1.27	3.51	6.5	2.9
6	2.32	0.06	0.10	0.027	0.15	1.03	2.41	9.8	4.1
8	2.39	0.06	0.09	0.039	0.16	1.08	2.64	10.0	5.4
10	2.32	0.05	0.12	0.028	0.12	1.01	2.35	12.5	5.2
11	3.06	0.06	0.13	0.029	0.18	1.19	3.65	12.0	4.1
12 + 13	2.73	0.18	0.10	0.009	0.51	1.45	3.96	6.0	2.5
15	3.15	0.08	0.15	0.039	0.25	1.30	4.10	9.0	3.6
16	2.75	0.27	0.10	0.011	0.75	1.58	4.40	13.0	2.2
17	2.65	0.09	0.14	0.015	0.25	1.33	3.51	5.0	2.7
20	3.14	0.21	0.11	0.007	0.67	1.54	4.90	10.0	3.1
21	3.46	0.10	0.13	0.042	0.36	1.31	4.52	12.0	4.3
22	3.42	0.07	0.16	0.029	0.25	1.29	4.45	11.9	5.2
23	4.19	0.02	0.09	0.029	0.09	1.08	4.53	14.0	7.7
24	2.45	0.16	0.13	0.018	0.43	1.34	3.42	16.0	2.3
	3.02	0.097	0.12	0.029	0.29	1.27	3.86	10.0	3.59

TABLE. 2. continued.

DAILY TRIPS (ALL)/ PERSON	DAILY TRIPS (ALL)/ HSEHLD.	HOUSEHOLD SIZE % OF HOUSEHOLDS 1.	2.	3.	4.	5.	6.	7/	SOCIO ECONOMIC GROUP % OF HOUSEHOLDS. 1	2	3	4	5	6	7	NON/HSE HOME BASED TRIPS
2.99	7.58	26	37	21	10	4.	2	0	6	3	50	14	9	1	17	4.37
2.94	8.16	30	35	19.5	9.5	3.5	3.5	0	9	3	52	13	6	0	16	4.65
2.39	5.62	31	36	18	9	3	1.5	1.5	2	7	52	15	4	1	19	3.21
2.51	6.16	22	39	22	6.5	3.5	3.5	3.5	2	2	60	14	10	0	13	2.52
2.34	5.45	31	36	18	9	3	1.5	1.5	2	3	52	16	7	3	17	3.10
2.77	8.51	17	30	22	14	8	4.5	4.5	5	5	51	17	9	1	12	4.86
3.62	9.89	19	37	20	14	6	3	1	27	11	35.5	7	4	3	12.5	5.93
3.16	9.99	14	27	22	18	9	6	4	7	8	58	11	6	0	10	5.89
4.12	11.48	17.5	33	22	17.5	9	2	0	54	16	12	1	1	1	15	7.08
3.32	8.80	21	33	21	15	7	2	1	20	8	43	9	5	0	15	5.29
3.94	12.52	10	28	26	20	12	2	2	37	17	30	5	0	0	11	7.62
3.18	11.01	6	21	27	27	14	4	1	4	7	61	17	6	0	5	6.49
3.14	10.85	7	20	24	28	15	3	3	5	5	56	18	10	0	6	6.40
2.63	11.05	6	22	20	19	12	14	7	0	4	44	28	19	1	4	6.52
3.33	8.57	19	43	24	9.5	4.5	0	0	13	18	49	8	2	0	10	5.15
9.38	3.10	16	30	22	17	9	9.5	2.5	10.9	7.3	50.1	13.7	6.5	0.7	11.0	

TABLE. 3.

From-home trips/mode of journey (in %)

TRAFFIC ZONE	CAR	MOTOR CYCLE	BY-CYCLE	BUS	CAR PASS-ENGER	WALK	OTHER
1 ≠ 7	5.0	3.5	10.0	8.5	1.0	69.0	3.0
2 - 5	14.0	1.8	4.4	12.0	4.4	59.0	4.4
6	4.0	1.4	8.0	11.4	0.8	73.0	1.4
8	3.7	2.5	7.7	8.5	2.5	74.0	1.3
10	9.0	1.3	5.0	7.7	1.3	74.4	1.3
11	12.0	2.7	15.3	28.3	5.7	35.0	1.0
12 ≠ 13	24.5	1.0	10.0	28.0	8.5	25.0	2.0
15	12.5	2.5	15.0	36.0	4.0	29.5	0.5
16	39.0	1.0	5.0	21.0	14.0	20.0	0-
17	20.0	1.4	7.4	25.0	6.0	39.2	1.0
20	38.3	1.0	5.1	22.0	11.2	22.4	0
21	14.0	5.3	7.5	44.0	6.2	22.0	1.0
22	11.8	4.0	15.7	43.0	3.3	20.2	2.0
23	3.1	2.3	13.7	35.0	0.4	45.5	0
24	33.5	1.5	11.0	26.3	8.4	27.8	1.5
TOTAL(av)	15.7	2.9	10.5	31.2	5.7	33.0	1.0
(numbers)	832	152	558	1642	291	1813	57
							5352

TABLE. 4.

From home trips / journey purpose (in %)

TRAFFIC ZONE	WORK	BUSI-NESS	SHOP	SCHOOL	SOCIAL	PICK UP PASSENGER	CHANGE MODE	OTHER
1 + 7	47.0	1.0	13.0	19.0	17.0	0	2.0	1.0
2 - 5	46.0	4.5	12.0	23.0	11.0	1.7	0.9	0.9
6	55.0	1.0	16.0	18.0	9.5	0	0.5	0
8	54.0	0	18.0	18.0	10.0	0	0	0
10	58.0	4.0	18.0	15.0	5.0	0	0	0
11	40.0	3.0	14.0	23.0	15.0	2.0	2.0	1.0
12 + 13	38.0	4.5	14.0	19.0	19.0	2.0	1.5	1.0
15	40.0	2.0	16.5	25.0	16.0	0.5	0	0
16	32.0	4.0	11.0	16.0	25.0	2.0	5.0	1.0
17	39.0	4.0	15.0	22.0	19.0	0.9	0	0.1
20	31.0	4.0	13.0	20.0	23.0	5.0	2.5	1.5
21	46.0	1.8	8.6	27.0	12.5	2.0	1.7	0.4
22	40.5	1.0	10.0	25.3	22.2	0	1.0	0
23	37.0	0	15.0	34.0	14.0	0	0	0
24	38.0	3.0	14.0	14.0	25.0	3.0	1.5	1.5
TOTAL(av)	41.8	2.5	13.1	23.4	15.9	1.5	1.3	0.5
(number)	2250	138	704	1245	839	79	71	26
								5352

TABLE. 5.

From-home trips / household size.

TRAFFIC ZONE	HOUSEHOLD SIZE 1	2	3	4	5	6	7	8	over 8
1 ≠ 7	0.25	2.70	4.00	5.30	6.00	6.60	-	-	-
2 - 5	0.60	2.40	3.80	5.10	6.10	6.85	-	-	-
6	0.51	2.22	3.20	4.43	5.20	5.70	6.20	6.55	-
8	0.91	2.30	3.38	5.10	6.12	6.81	7.01	7.74	7.91
10	1.06	2.60	3.16	4.09	5.82	6.50	7.20	7.65	8.20
11	0.75	2.44	3.62	4.96	5.25	5.95	6.27	6.70	7.02
12 ≠ 13	0.80	3.00	4.23	5.61	6.73	7.25	7.60	7.90	7.99
15	0.71	2.32	3.88	5.03	5.47	6.00	6.51	7.20	8.00
16	1.00	3.31	4.60	6.60	8.00	8.50	-	-	-
17	0.87	2.50	3.99	4.74	5.69	6.38	6.96	7.38	7.70
20	0.79	3.13	4.67	5.90	7.30	8.00	8.42	8.63	8.65
21	1.12	2.68	4.07	5.32	6.34	7.30	8.01	9.00	-
22	0.83	2.31	3.81	4.64	5.45	6.21	6.89	7.43	7.75
23	0.62	2.20	3.10	4.35	5.60	6.89	7.81	8.20	8.60
24	0.82	2.70	4.13	5.46	6.75	7.60	-	-	-
Av.	0.77	2.57	3.84	5.10	6.12	6.83	7.17	7.67	7.98

TABLE. 6.

Tenure (in %)

TRAFFIC ZONE	OWNER OCCUPIER	RENTED (local authority)	RENTED (private)
1 ≁ 7	11.0	6.0	83.0
2 - 5	14.9	9.1	76.0
6	19.1	12.6	69.3
8	10.0	41.2	48.8
10	15.0	19.0	66.0
11	19.8	47.2	33.0
12 ≁ 13	41.1	6.8	52.1
15	29.0	53.1	17.9
16	85.0	-	15.0
17	60.0	15.0	25.0
20	81.6	3.4	15.0
21	0.5	98.0	1.5
22	7.0	89.0	4.0
23	2.8	96.1	1.1
24	63.0	-	37.0
TOTAL (av)	24.5	44.0	31.5
(number)	325	585	420

TABLE. 7.

From home trips/mode and/journey purpose,/person

TRAFFIC ZONE	CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASS'R	WALK	OTHER	WORK	BUSI.	SHOP	SCHOOL	SOCIAL	OTHER
1 ≠ 7	0.060	0.040	0.130	0.110	0.010	0.880	0.040	0.060	0.010	0.170	0.240	0.230	0.020
2 - 5	0.173	0.023	0.058	0.162	0.058	0.742	0.058	0.581	0.058	0.162	0.291	0.139	0.046
6	0.041	0.013	0.082	0.126	0.006	0.753	0.013	0.561	0.013	0.171	0.184	0.096	0.006
8	0.039	0.025	0.078	0.092	0.025	0.802	0.012	0.578	-	0.197	0.197	0.105	-
10	0.093	0.011	0.050	0.083	0.011	0.759	0.011	0.586	0.039	0.184	0.150	0.050	-
11	0.143	0.031	0.182	0.337	0.068	0.414	0.010	0.474	0.003	0.165	0.275	0.179	0.062
12 ≠ 13	0.355	0.016	0.147	0.406	0.124	0.363	0.033	0.563	0.067	0.201	0.275	0.278	0.063
15	0.162	0.033	0.197	0.470	0.051	0.380	0.006	0.520	0.027	0.215	0.324	0.206	0.006
16	0.679	0.017	0.084	0.331	0.219	0.320	-	0.579	0.079	0.191	0.269	0.466	0.046
17	0.265	0.018	0.097	0.332	0.078	0.519	0.014	0.516	0.056	0.198	0.291	0.269	0.018
20	0.583	0.015	0.080	0.338	0.174	0.345	-	0.463	0.062	0.168	0.307	0.353	0.141
21	0.183	0.069	0.099	0.567	0.080	0.287	0.012	0.607	0.024	0.112	0.352	0.162	0.051
22	0.152	0.050	0.202	0.557	0.043	0.260	0.021	0.521	0.014	0.130	0.326	0.282	0.014
23	0.034	0.025	0.144	0.378	0.004	0.493	-	0.408	-	0.157	0.370	0.144	-
24	0.388	0.018	0.148	0.351	0.111	0.370	0.018	0.518	0.037	0.185	0.185	0.33	0.074

TABLE. 8.

All trips / mode (in %)

TRAFFIC ZONES	CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASS'R	TRAIN	WALK	GOODS VEHICLE	OTHER
1/7	5.5	5.0	6.6	11.6	1.8	0	66.0	3.6	0
2-5	13.0	2.0	4.0	15.0	6.5	1.0	57.5	0.5	0.5
6	5.4	4.3	7.0	9.3	4.3	0.5	65.0	3.7	0.5
8	4.0	4.0	7.5	9.0	4.0	0	68.0	3.0	1.0
10	10.0	4.1	4.1	8.6	1.8	0.4	69.0	2.2	0
11	14.0	4.0	14.1	25.9	5.0	1.1	33.0	1.5	1.4
12/13	28.0	1.6	6.5	28.0	6.0	0.5	26.9	1.8	0.7
15	15.0	3.0	12.4	31.5	3.0	1.5	31.2	2.0	0.7
16	42.7	0.5	3.0	19.8	12.2	0.5	20.6	0	0.5
17	28.0	1.3	7.4	21.0	4.7	0.2	35.0	2.1	0.2
20	42.8	1.4	5.6	21.0	13.4	1.4	14.4	0	0
21	15.5	5.4	6.8	37.4	5.9	1.3	25.0	2.0	0.7
22	13.9	3.7	12.9	35.4	2.8	0	29.2	1.6	0.5
23	3.4	2.9	1.7	30.2	0.6	0.3	46.9	4.0	0
24	27.8	1.1	8.9	28.3	6.1	1.1	25.0	1.1	0.5
TOTAL TRIPS	2383	445	1152	3573	680	114	4446	249	87
									13129

TABLE. 9.

All trips / journey purpose (in %)

TRAFFIC ZONE	WORK	BUSINESS	SHOP	SCHOOL	HAVE MEAL	SOCIAL	PICK UP PASS'R	CHANGE MODE	HOME	OTHER
1/7	22.0	6.0	9.0	10.0	7.0	11.0	0	1.8	33.2	0
2-5	21.0	9.0	8.5	12.0	8.0	6.3	2.2	0.6	32.0	0.4
6	24.0	6.0	9.0	7.8	8.5	10.0	0.5	0.8	33.0	0.5
8	25.2	3.0	11.4	9.7	8.0	6.8	0	3.0	33.0	0
10	26.0	5.3	10.7	8.6	7.1	7.3	0	0	34.9	0
11	20.8	6.2	8.2	11.0	9.0	7.3	1.0	1.0	34.8	0.5
12/13	18.0	8.0	11.0	8.5	8.5	10.9	1.1	0.8	32.8	0.4
15	17.5	8.0	9.5	11.0	7.2	10.0	0.9	0.3	34.9	0.3
16	14.7	9.0	7.9	7.4	8.7	14.2	2.1	3.0	31.4	1.4
17	16.6	9.1	10.0	9.6	8.0	11.0	0.9	0.9	33.6	0.2
20	19.1	9.4	6.3	7.8	8.8	10.8	1.7	2.1	32.0	2.1
21	19.5	10.5	4.2	13.0	9.5	7.0	1.1	1.4	33.7	0.1
22	16.9	9.0	8.0	12.2	8.5	11.3	0	0.4	33.6	0
23	16.4	4.8	10.0	14.4	5.8	10.3	0.3	1.3	36.0	0.6
24	16.7	7.9	11.0	6.1	8.4	12.2	1.1	1.1	35.0	0.5
total trips	2500	1066	1062	1413	1096	1215	126	148	4446	57

13129

TABLE. 10

TRAFFIC ZONE	TOTAL ALL TRIPS	TOTAL FROM-HOME TRIPS	TOTAL TRIPS TO HOME	TOTAL NON-HOME BASED TRIPS
1/7	455	180	184	91
2-5	275	109	110	56
6	374	150	155	69
8	206	82	85	39
10	452	181	190	81
11	1823	783	799	241
12/13	1079	432	446	201
15	2089	857	883	349
16	735	282	296	157
17	889	355	370	164
20	501	196	205	90
21	3018	1241	1300	477
22	434	178	183	73
23	619	254	258	107
24	180	72	78	30
TOTAL	13129	5352	5542	2235

TABLE. 11.

TOTAL SAMPLE

Number of Journeys, cars, households; journeys/household/size/mode.

SEHLD IZE	CAR & VAN	c	j	M/G	j	CYCLE	j	BUS	j	CAR & VAN	j	WALK	j	OTHER	j		j
1) 24	0.237	26	53	0.018	4	0.076	17	0.295	66	0.035	8	0.312	70	0.009	2	0.982	220
2) 08	0.716	143	292	0.056	23	0.326	133	0.579	236	0.135	55	0.912	372	0.026	11	2.750	1122
3) 10	0.742	113	230	0.142	44	0.474	147	1.142	354	0.287	89	1.248	387	0.039	12	4.074	1263
4) 38	0.660	77	157	0.180	43	0.529	126	1.904	453	0.352	84	1.777	423	0.055	13	5.457	1299
5) 20	0.679	40	82	0.191	23	0.575	69	2.401	288	0.345	41	2.184	262	0.091	11	6.466	776
6) 50	0.280	7	14	0.160	8	0.660	33	2.560	128	0.300	15	3.040	152	0.100	5	7.100	355
7) 24	0.127	2	4	0.208	5	0.833	20	2.916	70	0.166	4	3.583	85	0.083	2	7.916	190
8) 5	--	0	0	0.133	2	0.866	13	3.134	47	0.133	2	4.134	62	0.066	1	8.466	127
SEHLD	0.600	408	832	0.109	152	0.402	558	1.185	1642	0.215	298	1.309	1813	0.041	57	3.864	5352
ERSON	0.198			0.036		0.132		0.391		0.071		0.432		0.013		1.277	

TABLE 12.
TOTAL SAMPLE
Journeys/household size/purpose

HOUSEHOLD SIZE		WORK	j	BUSINESS	j	SHOP	j	SCHOOL	j	SOCIAL	j	OTHER	j		j
1.	224	0.286	64	0.012	3	0.295	66	-	-	0.322	72	0.067	15	0.982	220
2.	408	1.324	541	0.073	30	0.574	234	0.182	74	0.491	200	0.106	43	2.750	1122
3.	310	1.839	570	0.096	30	0.568	176	0.807	250	0.613	190	0.151	47	4.074	1263
4.	238	2.197	523	0.168	40	0.522	124	1.630	388	0.768	183	0.172	41	5.457	1299
5.	120	2.450	294	0.183	22	0.508	61	2.084	250	1.083	130	0.158	19	6.466	776
6.	50	2.680	134	0.160	8	0.500	25	2.800	140	0.840	42	0.120	67	7.100	355
7.	24	3.000	72	0.125	3	0.458	11	3.458	83	0.750	18	0.125	3	7.916	190
8.	15	3.467	52	0.133	2	0.466	7	4.000	60	0.267	4	0.133	2	8.466	127
/H		1.624		0.099		0.508		0.898		0.605		0.127		3.864	
/P		0.537		0.032		0.168		0.297		0.200		0.042		1.277	

TABLE. 13

Journeys/household/person, attracting to car ownership.

AR OWNERSHIP	CAR j/P	/H.	MOTORCYCLE j/P	/H	CYCLE j/P	/H	BUS j/P	/H	CAR PASSENGER j/P	/H	WALK j/P	/H	OTHER j/P	/H	
0	40	0.040	123.4	0.124	433.6	0.438	1200.8	1.215	75.1	0.075	1453.2	1.469	45.7	0.046	3.407
1	736	1.917	28.6	0.074	121.7	0.314	433.9	1.129	212.8	0.554	348.1	0.906	11.3	0.026	4.920
2	56.0	4.666	-	-	2.7	0.225	7.3	0.608	10.1	0.841	11.7	0.966	0	-	7.306
	832	.600	152	.109	558	.402	1642	1.185	298	.215	1813	1.309	57	.041	3.864

Av. journeys by car = 2.039

Av. occupancy / car = 1.358

TABLE. 14

Total Sample

HOUSEHOLD SIZE NUMBER	FROM-HOME JOURNEYS (ALL MODES) CAR OWNERSHIP 0	1	2	ALL	NUMBER OF JOURNEYS j	
1 (224)	0.838	2.076	-	0.982	220	
2 (408)	2.391	3.403	5.011	2.750	1122	
3 (310)	3.410	5.211	7.343	4.074	1263	
4 (238)	4.773	6.828	10.250	5.457	1299	
5 (120)	5.585	8.105	12.166	6.466	776	
6 (50)	6.697	9.571	-	7.100	355	
7 (24)	7.745	11.000	-	7.916	190	
8 (15)	8.344	-	-	8.466	127	
	3.407	4.920	7.306	3.864	5352	(Home5352)

TABLE. 15

ZONE:- 1 & 7 Journeys/household/mode

HOUSEHOLD SIZE	CAR & VAN j	%c	MOTOR CYCLE	%	CYCLE	%	BUS	%	CAR & VAN PASSENGER	%	WALK	%	OTHER	%	MEAN
1.	0.014	5.5	-	-	-	-	0.026	10.5	-	-	0.210	84.0	-	-	0.25
2.	0.133	4.9	-	-	0.283	10.5	0.241	8.9	0.022	0.8	1.941	71.0	0.087	3.2	2.7
3.	0.279	7.0	0.251	6.0	0.478	12.0	0.291	7.3	0.106	2.7	2.452	61.3	0.147	3.7	4.0
4.	0.324	6.1	0.430	8.1	0.521	9.8	0.441	8.7	0.244	4.6	3.133	59.0	0.207	3.7	5.3
5.	-	-	0.196	3.3	0.701	11.7	0.546	9.1	0.047	0.8	4.324	72.0	0.186	3.1	6.0
6.	-	-	0.198	3.0	0.852	12.9	0.644	9.6	0.033	0.5	4.693	71.0	0.180	3.0	6.6
/HSEHLD	0.152		0.101		0.330		0.279		0.025		2.235		0.101		3.225
/PERSON	0.06		0.04		0.13		0.11		0.01		0.88		0.04		1.27

TABLE 16

ZONES:- 1 & 7 **Journeys/household/purpose**

OUSEHOLD SIZE	WORK	%	BUSINESS		SHOP		SCHOOL		SOCIAL		OTHER		
1.	0.046	19.0	0.012	5.0	0.071	31.1	-	-	0.112	40.7	0.010	4.2	0.25
2.	1.288	49.3	0.018	0.76	0.448	16.0	0.353	13.0	0.564	21.0	0.029	1.0	2.7
3.	1.870	46.7	0.048	1.2	0.543	13.6	0.713	17.8	0.717	17.9	0.112	2.8	4.0
4.	2.128	40.2	0.082	1.5	0.715	13.5	1.284	24.2	0.820	15.5	0.271	5.1	5.3
5.	2.257	37.6	0.102	1.7	0.778	13.0	1.569	26.1	0.897	14.9	0.397	6.6	6.0
6.	2.321	35.5	0.111	1.7	0.795	12.1	2.011	30.6	0.949	14.7	0.413	6.3	6.6
/H	1.524		0.025		0.431		0.609		0.584		0.050		3.223
/P	0.60		0.01		0.17		0.24		0.23		0.02		1.27

Table 17

Zones 1 and 7 Daily Journeys made by a Household according to Car Ownership and Mode of Travel.

Car Ownership	Car	%	Motorcycle	%	Cycle	%	Bus	%	Car Passenger	%	Walk	%	Other	%	Total
0	0.010	0.3	0.110	3.5	0.336	10.9	0.374	12.1	0.001	0.03	2.258	73.0	-	-	3.089
1	0.804	19.5	0.056	1.3	0.300	7.3	0.126	3.1	0.134	3.3	2.126	51.5	0.561	13.5	4.107
Total per household	0.152		0.101		0.330		0.279		0.025		2.235		0.190		3.22
per person	0.06		0.04		0.13		0.11		0.01		0.88		0.04		1.27

TABLE 18

ZONE: - 1 & 7

HOUSEHOLD SIZE	FROM HOME JOURNEYS (MODE : CAR) CAR OWNERSHIP		
	0	1	
1	0	0.361	0.024
2	0.100	0.655	0.037
3	0.160	1.401	0.130
4	0	1.967	0.327
	0.010	0.804	0.152

TABLE 19

ZONE:- 1 & 7

HOUSEHOLD SIZE	FROM HOME JOURNEYS (ALL MODES) CAR OWNERSHIP		
	0	1	
1	0.17	0.90	0.25
2	2.48	3.66	2.70
3	3.50	5.50	4.00
4	4.85	6.00	5.30
5	6.00	-	6.00
6	6.60	-	6.60
	3.089	4.107	3.22

TABLE 20

ZONE:- 11 **Journeys/household/mode**

HOUSE-HOLD SIZE	CAR & VAN	%	MOTORCYCLE	%	CYCLE	%	BUS	%	CAR & VAN PASSENGER	%	WALK	%	OTHER	%	MEAN.
1.	0.205	27.3	0.055	7.2	0.200	26.6	0.100	13.4	0.015	2.0	0.180	23.8	-	-	0.75
2.	0.617	25.3	0.140	5.7	0.578	23.7	0.450	18.4	0.087	3.5	0.560	23.0	0.008	0.3	2.44
3.	0.525	14.4	0.110	3.4	0.712	19.6	0.931	25.7	0.182	5.0	1.152	31.8	0.008	0.2	3.62
4.	0.330	6.6	0.073	1.5	0.600	12.1	1.622	32.7	0.291	5.8	2.004	40.5	0.040	0.8	4.96
5.	0.435	8.4	0.100	1.9	0.705	13.5	1.592	30.4	0.315	5.8	1.927	36.7	0.176	3.4	5.25
6.	0.240	4.0	0.060	1.0	0.340	5.7	2.112	35.4	0.439	7.4	2.619	43.8	0.150	2.5	5.96
7.	0.240	3.8	0.060	0.9	0.820	13.0	2.120	34.2	0.280	4.5	2.650	42.2	0.100	1.6	6.27
8.	-	-	0.071	1.1	0.960	14.4	2.384	35.6	0.225	3.3	2.960	44.1	0.100	1.5	6.70
/HSEHLD	0.439		0.089		0.560		1.037		0.210		1.280		0.032		3.65
/PERSON	0.143		0.003		0.182		0.337		0.068		0.414		0.010		1.19

TABLE 21

ZONE:- 11 **Journeys/household/purpose.**

HSEHLD SIZE	WORK	%	BUSINESS		SHOP	%	SCHOOL	%	SOCIAL	%	OTHER		
1	0.188	25.0	0.015	2.0	0.187	25.0	-	-	0.285	38.0	0.075	10.0	0.75
2	1.212	49.7	0.156	6.4	0.562	23.0	0.142	6.1	0.355	14.4	0.013	0.4	2.44
3	1.559	43.0	0.127	3.6	0.551	15.2	0.703	19.4	0.610	16.8	0.070	2.0	3.62
4	1.866	37.6	0.103	2.3	0.538	10.7	1.476	29.8	0.777	15.7	0.200	3.9	4.96
5	2.135	40.6	0.100	1.9	0.519	9.9	2.278	43.3			0.228	4.3	5.25
6	2.435	40.7	0.040	0.7	0.497	8.3	2.611	43.8			0.281	4.7	5.96
7	2.664	42.5	0.040	0.6	0.481	7.7	3.000	47.8					6.27
8	2.903	43.2	0.040	0.5	0.467	7.0	3.150	47.0					6.70
/H	1.411		0.102		0.509		0.845		0.551		0.191		3.65
/P	0.474		0.003		0.165		0.275		0.179		0.062		

Table 22

Zone 11 Daily Journeys made by a household, according to car ownership, and mode of travel

Car Ownership	Car	%	Motorcycle	%	Cycle	%	Bus	%	Car Passenger	%	Walk	%	Other	%	Total
0	0.034	1.1	0.113	3.5	0.568	17.7	1.045	32.6	0.170	5.3	1.244	38.7	0.034	1.1	3.208
1	2.315	42.5	0.026	0.4	0.526	9.6	1.000	18.3	0.394	7.2	1.814	21.6	0.026	0.4	5.471
Total /Household	0.439		0.098		0.560		1.037		0.210		1.280		0.032		3.64
Per person	0.143		0.003		0.182		0.337		0.068		0.414		0.010		1.19

ZONE: - 11 TABLE 23

HOUSEHOLD SIZE	FROM-HOME JOURNEY (ALL MODES) CAR OWNERSHIP 0	1	
1.	0.515	3.327	0.75
2.	1.758	4.484	2.44
3.	3.072	5.641	3.62
4.	4.650	6.955	4.96
5.	5.101	8.169	5.25
6.	5.588	9.326	5.96
7.	6.000	10.383	6.27
8.	6.700		6.70
	3.208	5.471	3.64

ZONE: - 11 TABLE 24

HOUSEHOLD SIZE	FROM HOME JOURNEY (MODE : CAR) CAR OWNERSHIP 0	1	
1	-	2.466	0.205
2	1.000	2.343	0.617
3	0.700	2.400	0.525
4	0.900	2.250	0.330
5	0.400	2.333	0.435
6	0.400	2.000	0.240
7		2.400	0.240

TABLE 25

TOTAL SAMPLE

Numbers in sample, journeys, etc. / SOCIO-ECONOMIC STATUS

SOCIO ECONOMIC GROUP	% SAMPLE	NO. OF HOUSE HOLDS	PERSONS	CAR	JOURNEY	MEAN HOUSEHOLD SIZE	MEAN NO. CAR/ HOUSEHOLD	FROM-HOME /PERSON	JOURNEYS / HOUSEHOLD
1	10.8	150	407	142	754	2.71	0.94	1.85	5.02
2	7.3	101	289	64	479	2.86	0.63	1.65	4.74
3	50.0	692	2230	151	2781	3.22	0.21	1.24	4.01
4	13.6	188	670	27	779	3.56	0.14	1.16	4.14
5	6.5	91	360	4	356	3.98	0.04	0.98	3.91
6	0.8	11	34	5	45	3.09	0.45	1.32	4.09
7	11.0	152	200	15	158	1.31	0.09	0.79	1.03
		1385	4190	408	5352	3.02	0.29	1.27	3.85

N. B. SOCIO-ECONOMIC GROUP 1 = Professional
2 = Intermediate
3 = Manual (Skilled)
4 = Manual (Semi-skilled)
5 = Manual (unskilled)
6 = Others
7 = Retired

TABLE 26

ZONES: - 1-10

SOCIO ECONOMIC GROUP	% SAMPLE	NO. OF HOUSE HOLDS	PERSONS	CARS	JOURNEY	MEAN HOUSEHOLD SIZE	MEAN NO. CAR/ HOUSEHOLD	FROM-HOME JOURNEYS /PERSON	FROM-HOME JOURNEYS /HOUSEHOLD
1	4	10	24	10	41	2.4	1.0	1.70	4.08
2	4	10	22	4	35	2.2	0.4	1.59	3.50
3	53	136	361	21	422	2.63	0.16	1.16	3.08
4	14.4	37	100	3	106	2.70	0.07	1.07	2.62
5	7.0	18	59	0	55	3.27	0	0.93	3.05
6	1.6	4	11	2	13	2.75	0.5	1.16	3.25
7	16.0	42	52	0	30	1.23	0	0.[illegible]	0.71
		257	629	40	702	2.44	0.15	1.11	2.70

TABLE 27

ZONES:- 11, 15, 17, 21, 22, 23

SOCIO ECONOMIC GROUP	% SAMPLE	NO. OF HOUSE HOLDS	PERSONS	CARS	JOURNEY	MEAN HOUSEHOLD SIZE	MEAN NO. CAR/ HOUSEHOLD	FROM-HOME JOURNEYS /PERSON	FROM-HOME JOURNEYS /HOUSEHOLD
1	6.4	58	156	54	289	2.68	0.93	1.85	4.98
2	6.4	58	175	38	295	3.01	0.65	1.68	5.08
3	55.0	488	1652	106	2082	3.38	0.21	1.26	4.26
4	15.5	139	526	22	623	3.78	0.15	1.18	4.49
5	7.4	67	280	4	281	4.17	0.05	1.00	4.19
6	0.3	3	9	1	13	3.0	0.33	1.44	4.33
7	9.0	81	106	4	85	1.30	0.04	0.80	1.04
		894	2904	229	3668	3.24	0.24	1.26	4.11

TABLE 28

ZONES: - 12, 16, 20, 24

OCIO CONOMIC ROUP	% SAMPLE	NO. OF HOUSE HOLDS	PERSON	CARS	JOURNEY	MEAN HOUSEHOLD SIZE	MEAN NO. CAR/ HOUSEHOLD	FROM-HOME JOURNEYS /PERSON	FROM-HOME JOURNEYS /HOUSEHO
1	35.1	82	227	78	424	2.64	0.95	1.86	5.17
2	14.1	33	92	22	149	2.78	0.66	1.61	4.51
3	29.0	68	217	24	277	3.19	0.35	1.27	4.07
4	5.1	12	44	2	50	3.66	0.16	1.14	4.16
5	2.6	6	21	0	20	3.50	0	0.95	3.33
6	1.7	4	14	2	19	3.50	0.50	1.35	4.75
7	12.4	29	42	11	43	1.45	0.37	1.02	1.48
		234	657	139	982	2.80	0.59	1.49	4.19

TABLE 29.

TOTAL SAMPLE

FROM-HOME TRIPS

MODE

PURPOSE	CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASSGR	WALK	OTHER	TOTAL	%
WORK	392	81	264	693	81	694	45	2250	41.8
BUSINESS	125	5	0	5	0	1	2	138	2.5
SHOP	84	0	26	255	35	303	0	704	13.1
SCHOOL	0	0	188	361	52	636	7	1245	23.4
SOCIAL	161	52	75	267	126	156	2	839	15.9
PICK UP PASSR')								80	1.5
CHANGE MODE)	70	14	5	61	4	23	1	71	1.3
OTHER)								26	0.5
TOTAL	832	152	558	1642	298	1813	57	5352	
%	15.7	2.9	10.5	31.2	5.7	33.0	1.0		

ZONE 21. FROM HOME TRIPS TABLE 30

MODE PURPOSE	CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASSR	WALK	OTHER	TOTAL	%
WORK	119	49	56	273	34	39	5	575	46.0
BUSINESS	13	3	0	3	0	1	2	22	1.8
SHOP	6	0	2	61	6	32	0	107	8.6
SCHOOL	0	1	23	127	13	169	1	334	27.0
SOCIAL	25	10	10	63	21	23	2	154	12.5
PICKUP PASSR'	10	2	0	6	2	5	0	25	2
CHANGE MODE	0	1	3	12	0	3	1	20	1.7
OTHER	1	0	0	1	0	0	1	4	0.4
TOTAL	174	66	94	547	76	272	12	1241	
%	14	53	75	44	6.1	22	1.0		

ALL TRIPS　　TOTAL SAMPLE　　TABLE 31.

MODE	CAR	M/C	CYCLE	BUS	CAR PASSR	TRAIN	WALK	OTHER	TOTAL	%
PURPOSE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		
WORK 0	451	96	270	712	94	29	736	84	2500	19.0
BUSINESS 1	584	61	15	74	30	35	160	107	1066	8.1
SHOP 2	121	5	33	304	32	1	565	0	1062	8.1
SCHOOL 3	0	9	193	378	56	0	777	0	1413	10.7
MEAL 4	198	19	105	302	41	0	429	2	1096	8.3
SOCIAL 5	262	102	98	315	146	1	269	21	1215	9.2
PICKUP PASSR 6)	) 107	13	7	94	12	4	73	21	331-(126	0.9
CHANGE MODE 7)									(148	1.1
HOME 8	658	139	431	1394	268	44	1410	101	4446	34.0
OTHER 9									57	0.4
TOTAL	2383	445	1152	3573	680	114	4446	336	13129	
%	18.3	3.4	8.8	27.2	5.2	0.9	34.0	2.5		

ZONE:- 21 ALL TRIPS TABLE 32

MODE / PURPOSE	CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASSR	TRAIN	WALK	OTHER	TOTAL	%
WORK	119	49	56	273	34	6	46	5	588	19.5
BUSINESS	125	30	14	35	16	27	12	58	317	10.5
SHOP	8	0	2	66	6	0	45	0	127	4.2
SCHOOL	0	1	25	127	13	0	226	1	393	13.0
MEAL	37	11	19	114	4	0	101	1	287	9.5
SOCIAL	33	19	12	68	27	0	50	3	212	7.0
PICKUP PASSR	12	4	0	6	3	0	8	0	33	1.1
CHANGE MODE	0	1	4	20	0	0	16	2	43	1.4
HOME	133	49	73	415	76	6	249	12	1013	33.7
OTHER	1	0	0	1	0	0	1	2	5	0.1
TOTAL	468	164	205	1125	179	39	754	84	3018	-
%	15.5	5.4	6.8	37.4	5.9	1.3	25.0	2.7		

APPENDIX 4

Journey-to-Work Survey

Appendix 4(a) Method

The main purpose of this survey was to collect information on the movements of all workers within the Burgh, wherever their origin.

Discussions were held with the Chamber of Commerce and the local Trades Council (representing the Unions) to seek their cooperation and advice. A small census card was designed for distribution to all members of the work force. The card did not ask the name of the worker in order to preserve anonymity, but asked seven simple questions - sex, address, occupation, car ownership, time of departure, journey length, and mode.

A survey of numbers alone had been undertaken a year previously by the Burgh Surveyor's Department, which had counted 20362 employees (1). The list obtained was used as a base for the distribution of survey cards to the 662 shops, 198 offices, and 255 factories or workshops.

One of the difficulties in a survey of this scope, and it had only been attempted on such a scale before at Coventry (2), is the distribution and collection of the questionnaires. It is very difficult to dictate methods to employers, though it was suggested it be done through foreman or supervisors. Many in fact chose to follow this advice, but a few included the questionnaire in pay packets or attached them to the workers' clock card. These latter methods produced slightly lower rates of response, though the overall rate was very high indeed. Publicity in the press, works magazines, posters in the town generally and in shops and factories, together with radio broadcasts desiminated general information about the survey, and seemed to be the basis of the survey's success.

Of even more significance than distribution is the collection of the cards, and the advice was to do this via the distribution network rather than in ballot boxes, etc. The response rate tended to decline as the number of employees increased and as direct contact decreased, but even so 98% returned cards, a phenomenal return, compared with any similar survey, and with Coventry's 60%. In almost every case of the non-respondents addresses and additional information was obtained from the employer, so that the final tables (Appendix 4 b) represent something like a 99.5% result.

The advantages of this survey method was that they could be carried out by myself only, help being given by employer and employee alike, and since the cost had to be borne personally, it was inexpensive. For the survey, itself the only cost was £20 for the printing of 21000 survey cards; publicity, etc. was free. A second advantage was speed, it took only three weeks to complete the whole survey. Thirdly only ten code groups were necessary.

---

(1) The total count of the Journey to Work survey was 19228, of which close on 19000 responded. The difference between this total and the earlier survey is due to the exclusion of workers nominally employed within Perth, but permanently working without the Burgh.

(2) City of Coventry. 'The Coventry Road System' Report No. DPR 31 April 1963.

Before the coding was begun and before any analysis, a check was made on bias. The larger firms whose response was lower were asked to supply the addresses of all employees. The distribution of these employees in distance terms was checked against the survey addresses (Graph A1:1). The results showed a slight bias, in that people living close to the worksite seemed less inclined to complete and return the card, presumably having little to gain from an improved transportation network. Subsequent to this the weighting for non-respondents noted above was taken.

The easiest method of coding would have been to use mark sense card, or at least to have utilised a card sorter. Unfortunately the Elliott 803 at the University of Durham accepted only punch-tape. The coding was slightly more cumbersome than had originally been anticipated. Each card was coded and entered onto a summary sheet, which was then punched onto tape, and in turn stored on magnetic tape. The coding schedule is presented at the conclusion of this section.

The programme, supplied by the computer unit of the University of Durham, was fairly straightforward producing a basic matrix of 25 x 25 origins and destinations. Data was sorted as to sex, journey mode, time of departure and so on, and for land use. Some of the data was plotted by the computer on a 10 x 9 matrix, as avery simple 'computer map'. A much more sophisticated means would have been to use a data plotter, but this was not available at the time. These 'computer maps', or 'diagrams' are found at the conclusion of Appendix 4 b. Because of the nature and size of the result, all those abstracted are bound separately. Appendix 4 c contains an analysis of some of the 'computor diagrams'.

Coding Schedule

Column 1 Sex

Male: 0 Female: 1

Column 2 Origin

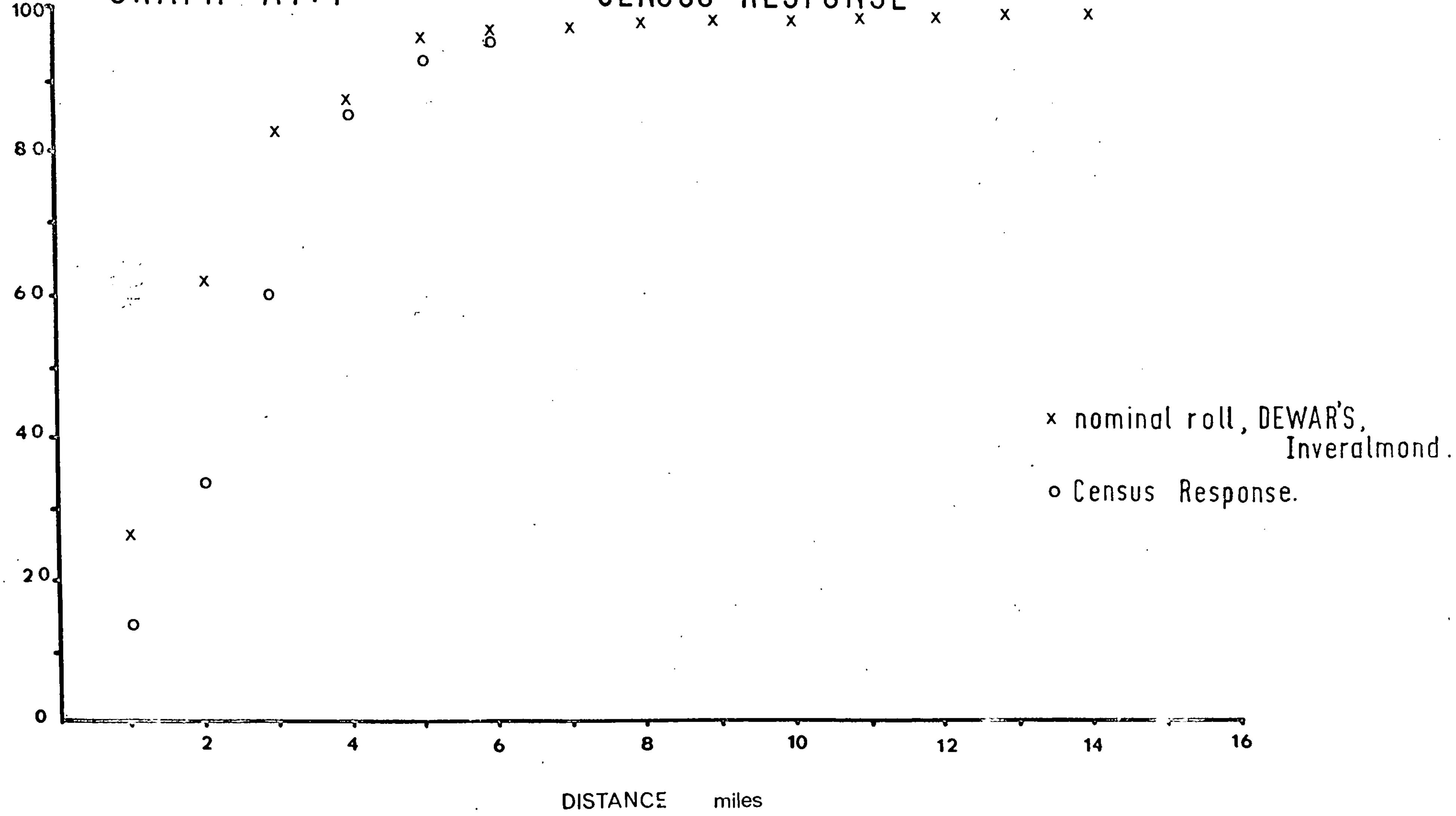
City centre 1-10
City suburbs 11-24
Scone 25
Perthshire, etc. 31-38
Scotland, etc. 41-47

(These were set out in detail in a coding manual. The zones were the same as those used in the other surveys.)

Column 3 Destination

City centre 1-10
City suburbs 11-24
Inveralmond, etc. 25

GRAPH A1:1 CENSUS RESPONSE



Column 4 Occupation

			Code
(1)	I	Agriculture	1
	II	Mining and quarrying	2
	III	Gas, coke, and chemicals	3
	IV	Glass and ceramics	4
	V	Furnace, forge, foundry, rolling mill workers	5
	VI	Electrical and electronic workers	6
	VII	Engineering and allied workers	7
	VIII	Woodworkers	8
	IX	Leather workers	9
	X	Textiles	10
	XI	Clothing	11
	XII	Food, drink and tobacco	12
	XIII	Paper and printing workers	13
XV	XIV	Construction workers	14
	XVI	Painters and decorators	15
	XVIII	Labourers	16
	XIX	Transport	17
	XX	Warehousemen, storekeepers, etc.	18
	XXI	Clerical workers	19
	XXII	Sales workers	20
	XXIII	Services, sports and recreation	21
	XXIV	Administrators and managers	22
	XXV	Professional workers, etc.	23
	XXVI	Armed forces	24
XXVII, XIV, XVII		Others (workers in rubber, plastics; process workers; poorly reported, etc.)	25

Column 5 Socio Economic Status

S.E.G. (2)

1 and 2	Employers and managers	1
3	Professional (self employed)	2
4	Professional (employees)	3
5	Intermediate (non-manual)	4
6	Junior (non-manual)	5
7	Personal service workers	6
8	Foreman, etc. (manual)	7
9	Manual (skilled)	8
10.	Manual (semi-skilled)	9
11.	Manual (unskilled)	10
12.	Workers on own account (non professional)	11
13, 14 and 15	Agriculture	12
16	Armed forces	13

(1) The Roman numerals refer to the Registrar General's 'Occupation Orders'. These were largely adhered to as shown, and his manual was used for 'difficult' occupations. 'Classification of Occupation'. H.M.S.O. 1960.
(2) Registrar General 'Classification of Occupation' H.M.S.O. 1960. Socio-economic groups pp. xi - xii.

Column 7 Car Ownership

Car: 1 No car: 2

Column 8 Departure time

12.01 a.m. - 4.00 a.m.	0
4.01 - 5.00	1
5.01 - 5.30	2
5.31 - 6.00	3
6.01 - 6.30	4
6.31 - 6.45	5
6.46 - 7.00	6
7.01 - 7.15	7
7.16 - 7.30	8
7.31 - 7.45	9
7.46 - 8.00	10
8,01 - 8.15	11
8.16 - 8.30	12
8.31 - 8.45	13
8.46 - 9.00	14
9.01 - 9.15	15
9.16 - 9.30	16
9.31 - 9.45	17
9.46 - 10.00	18
10.01 - 10.30	19
10.31 - 11.00	20
11.01 - 12.00 a.m.	21
12.01 p.m. - 1.00 p.m.	22
1.01 - 1.30	23
1.31 - 2.00	24
2.01 - 3.00	25
3.01 - 4.00	26
4.01 - 5.00	27
5.01 - 7.00	28
7.01 - 9.00	29
9.01 - 12.00 p.m.	30

Column 9 Time-Distance

On premises	0	35-39 minutes	8
5 minutes	1	40-44	9
5-9	2	45-49	10
10-14	3	50-54	11
15-20	4	55-59	12
21-24	5	60-74	13
25-29	6	75-89	14
30-34	7	90-104	15
		105-120	16
		more than 120 minutes	17

Column 10 Mode of Travel

Car	1	Car passenger	5
Motorised cycle	2	Train	6
cycle	3	Walk	7
bus	4	Other	8

On premises 9

(In addition for each batch of cards from one establishment a code for land uses 1 to 10 was entered - as set out in Appendix 7a.)

CITY AND ROYAL BURGH OF PERTH/DURHAM UNIVERSITY

Journey-to-work Census

Your journey to work should be as speedy and direct as possible. You can help the Town Council to review the road system by recording your journey on this card. The answers are confidential and your co-operation will be appreciated.

A. State male or female ....

B. Home address (street name) ....

(town) ....

C. Occupation (state as fully as possible) ....

....

D. Do you personally own a car? ....

E. What time do you leave for work? ....

and how long does it take you? ....

F. How do you usually travel to work?

CAR	MOTOR CYCLE	CYCLE	BUS	CAR PASS'R	TRAIN	WALK

Appendix 4(b) Results (bound in separate volume)

Appendix 4(c) Analysis, 'Computer Diagrams'

The computer was used as a simple data plotter. Drawing from the data stored on magnetic tape, the computer was used to plot origins and destinations by occupation, sex, and socio-economic status on a simple 10 x 9 matrix.

Each matrix represents the following zonal pattern, which approximates their position in reality. The matrix shown is the origin matrix; the destination matrix omits zones 31-37 and 41-47, exogenous work places being represented by zone '25'.

Diagram 1

Origin matrix, computer diagrams (appendix 4 b)

		38			31		32		
			23		11				25
37		22	24	19	10	2	3		
		21	17	9	8	1	7	12	
		20		18	5	6	4	13	
		16		15		14			
36			41-47		35		34		33

If both residences and employment have an even distribution, for any particular occupational category, then a similar pattern would result in the two matrixes, and an even proportion of workers would travel within their own zone. In fact this theoretical 'norm' is not found, though there are several cases which approximate the pattern. These involve Retail Workers (Appendix 4 b. p. 77) though its truer for males than females (1); services (p. 79); and administration (p. 79). In other words the employment opportunities and the workers available are both fairly ubiquitous.

(1) The letter code found in the diagrams represents total workers at origin and destination; a - j, and A-J, Z, simply represent an increase from a smaller to a larger number.

The second case cited in Part II, Section II of the main thesis, was of workers and work places both being concentrated. This assumes that there is a system of labour catchment areas of fairly limited dimensions which do not overlap. In these particular diagrams this pattern is difficult to detect. Again approximations occur with foundry workers (p. 63), all locations types; construction workers (p. 71); labourers (p. 73); transport workers (p. 75) and storekeepers (p. 75).

The third construct of the simple hypothesis cited in Part II, Section II, residence concentrated and employment scattered, does not seem to be well represented in general terms, though it is at the socio-economic level. Where professional classes are residentially concentrated for instance, their work places are fairly scattered. A much more frequent occurrence is the fourth construct, residential scatter, and concentration of employment. The extreme case is quarrying which has a peripheral worksite location in one zone only - Zone 15 (p. 59); Gas, coke and chemicals, which have minor centroperipheral locations, and major peripheral locations in Zone 14, draw from a wide residential scatter (p. 61); Glass, a peripheral location (p. 61); leather (p. 67); textiles (p. 67), which also have an important exogenous location; printing (p. 71) a much less distinct pattern; and the armed forces (p. 81). To use Liepmann's (2) terminology it could be said that these represent a strong conflux at a zone of work place, from a regionwide zone of distribution.

There are of course also implications about the length of the work journey in this simple hypothesis. Mean work-residence separation will be least when residence and employment are both evenly distributed with workers seeking employment at the place of work closest to home. On the other hand the mean length of the journey to work is at a maximum when employment is concentrated and residence of workers dispersed; of course it would also be at a maximum if the reverse pattern were found. When employment and residences are both dispersed, and where there is no preference for the work place closest to home, the journey will fall between the maximum and minimum values. Where residences and employment are both concentrated, mean journey length varies between the maximum and minimum theoretical values, depending upon the distance between the areas of concentration for each.

Agriculture

This category includes less than 100 workers, mainly horticultural, of whom 80% live in Perth, and are mostly males. Both employment and residences tend to be scattered, with an obvious marked absence of employment in the central area!

Quarrying

As mentioned earlier there is a marked concentration of employment. Total numbers are small, and are drawn from four zones with a high proportion of manual workers. The peripheral location leads to long work-residence journeys.

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(2) K. Liepmann 'The Journey to Work' Kegan Paul, London, 1944.

Foundry, Gas, Glass, etc.

These are specialised industries in Perth, and tend to occur in one major location with perhaps two or three industrial units, with smaller scattered 'workshops'. The peripheral location leads to lengthen work-journeys. Residences are fairly evenly scattered, with the largest numbers in the zones with the highest proportion of manual workers. There is a marked difference in occupational composition - foundries drawing upon semi-skilled labour.

Electrical, Engineering, Woodworkers, etc.

These are grouped together because of their similar work place patterns - dispersed, there being central, intermediate, peripheral and exogenous units. Residences are also dispersed, and some long work journeys result. The dispersed pattern is by no means even and zones 11, 15 and 21 are heavily drawn on.

Leather, Clothing, and Textiles

The industrial units for leather working are of workshop scale and essentially have a centroperipheral location. Workers are mainly drawn on from within Perth, and are randomly scattered. Unlike the other two groups, employment is dominantly male and skilled.

Textile units are peripheral, exogenous and concentrated, explicable through factors of geographical inertia. On examination the pattern of residences is not in fact so dispersed as might first appear, and major concentrations occur in the northwest near the factories, work journeys are thus short. The male/female residence patterns are similar, though the semi-skilled and unskilled workers of both sexes have a more peripheral residence pattern. Clothing industries show a more dispersed workplace pattern, but a similar residential pattern.

Labourers

Dispersed employment and residences; intermediate locations for workplaces, and peripheral for residences. Work journeys short to medium length.

Clerical

A conflux at central and intermediate workplace locations. Some exogenous locations too. Residential patterns peripheral, and a heavy flow from without Perth, particularly of females. A marked and distinctive pattern, long work journeys.

Sales Workers

Marked central workplace sites, particularly few female workers. Residences dispersed fairly evenly, so someshorter work journeys, but the labour catchment areas go beyond the Burgh boundaries particularly for female workers.

Service Workers

A continuation of the two previous patterns, but workplaces orientated to major traffic arteries, so that examples of all four locations can be found. Residence pattern scattered, work journeys of all lengths.

Administrative and Professional

Finally for managers, officials, and professional workers, although there is a conflux at the central area, there is a fairly even distribution of work places. The reverse is true for residential origins, residences are fairly scattered, but there are concentrations in zones with a higher overall socio-economic status.

APPENDIX 5

Other Surveys

In addition to the four major surveys described, a number of other surveys were undertaken to supply information on goods vehicles, taxis, facility usage, and detailed travel patterns. These will be described briefly.

Goods Vehicles

A selected number of retail stores, wholesalers, factories, etc. were approached either in person or by letter to ascertain the number and kinds of commercial vehicles they operated, and for a period of 14 days they were asked to list for each vehicle the number of trips it made. Included in this latter category were origin destination, and purpose of the journey.

In addition a number of individual sites were studied in greater detail - for one or two days vehicle counts were made of commercial vehicles entering or leaving a site, and details of unloading, etc. were recorded. In total over 100 establishments were contacted, and supplied either details about their own vehicles or about the frequency of commercial vehicle calls.

Taxi Records

Similar contact was made with a number of taxi firms - some supplied past records, and others supplied their drivers with detailed log sheets to record journeys made over a period of one week.

Facility Usage

Customers were interviewed on leaving a number of central area shops; in addition straightforward counts were made of customers entering or leaving a store in conjunction with the pedestrian count.

To qualify for interview, a customer had to walk through the doorway out of the store and cross an arbitrary line. Once an interview was finished, the next person to come out of the store was interviewed. To determine the sampling rate a total count was made. Because of the shortage of help and because two people were involved at each point, this surveying method was tried only several hours a day at each store.

A much higher refusal rate was obtained in this survey. A sampling rate of 20-25% was achieved at most locations, of whom one third refused to answer. The refusals were due to a number of factors - the study was carried out without any of the publicity which proved to be so important to the other surveys; although the interviews were identified by badges as to the purpose of the study and why shoppers were being queried, many people professed to be in a rush and therefore not able to stop and answer questions; many people also simply did not want to be bothered.

Customers were asked:

1. Where did your journey start?
2. How did you travel?
3. If by car, where is it parked?
4. Where is your next call?

Questioning of this type at the actual traffic induction point is well worth while, and to date very little of it has been undertaken in Britain. It is a useful cross check on data obtained through the Home Interview Survey, and can give much more detailed information about a particular land use/traffic relationship.

Travel Diary

Finally in this brief summary of additional surveys, a more unusual survey type was utilised. This was the travel diary. The travel diary method is simply a plan whereby each person included inthe survey keep an exact daily record, showing all trips made, the route travelled, mode of travel, time of departure and arrival. Because of its stress on exact routes rather than airline distances later assigned to the most likely route (the normal traffic survey procedure) its use to date has largely been by advertising agencies.(1) Their main aim is to know how many people pass a given advertising **hoarding** and how frequently one set of people will pass it.

Although it gives records in great detail, the disadvantage of this method is to get the sampled family to keep accurate records. In its commercial usage, families are paid to keep the records, but even here there is a fairly highfailure rate. It is also important for a person to keep records absolutely up to date.

Since this was experimental, there was no attempt to select a sample. Whilst interviewing in people's homes for an earlier survey, a number were asked whether they would be willing to keep more detailed records. 35 families agreed to keep records, of which 29 completed satisfactory and usable diaries. No financial incentive was offered to them.

The results themselves were complex and difficult to analyse, representing over 1000 trips. The difficulties of inducing a person to keep a diary will probably be more easily solved than the data analysis. It is easy to talk in terms of total trips, or trips by purpose, but much more difficult to rationalise the numerous route choices.

This experiment proved no more than it was possible to use this form of survey in traffic analysis, and that the results could be useful. What is needed is a much more careful arrangement ofquestions and answers to ensure that only analysable data is collected. Trip patterns from a number of families are shown on maps A 1:1 to A 1 :3.

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(1) Traffic Audit Bureau. 'Coverage, repetition, and impact provided by poster showings in Cedar Rapids and Linn County, Iowa'. Traffic Audit Bureau, Inc. 1950. A slight variant is reported in B. Copland, 'Advertising and Traffic' New Society, No. 46, 15th August, 1963.

A1:1 Sheet distributed to each family member.

UNIVERSITY OF DURHAM

TRAVEL DIARY

Name..........................

Address.........................

Family status.................. Age..................

Occupation.....................

NOTES

1. FAMILY STATUS: head of household, wife, daughter, son, spinster, bachelor.

2. JOURNEY DIRECTION: from house; from work; from town centre; from Perth; from Dundee, etc.

3. MODE: Car, motor cycle, bus, car passenger, train, on foot, other means. If more than one means is used, please note all modes, and indicate order in which used.

4. ROUTE: as fully as possible, preferably by street names when within Perth, road class and number elsewhere. If travelling part by bus, bus company and route number will suffice; if by train, the train part of the journey may be indicated by the names of stations used.

5. DESTINATION: as exact as possible if within the burgh.

6. PURPOSE: work, business, shopping, school, social, pleasure, etc.

7. INTERMEDIATE STOPS - please list all breaks in the main TRIP (see defn. below), i.e. breaks which are subordinate to the main purpose. For shopping, a route description, or shops visited (in order) could be given.

To avoid repetition a similar journey may refer in section 'ROUTE' to an earlier trip, which is numbered for this purpose. But all other details for that trip must be completed. Non-similar trips must be recorded in full.

TRIP: A trip is a journey between any two points where the person concerned makes a call and involves one direction only - the return journey would be a second and separate trip.

A1:2 Record of every journey is kept on a sheet like this.

UNIVERSITY OF DURHAM

TRAVEL DIARY

DAY........................... DATE........................

TRIP NO.....................

JOURNEY DIRECTION

MODE(S) OF TRAVEL

ROUTE (by street or streets)

DESTINATION

TRIP PURPOSE

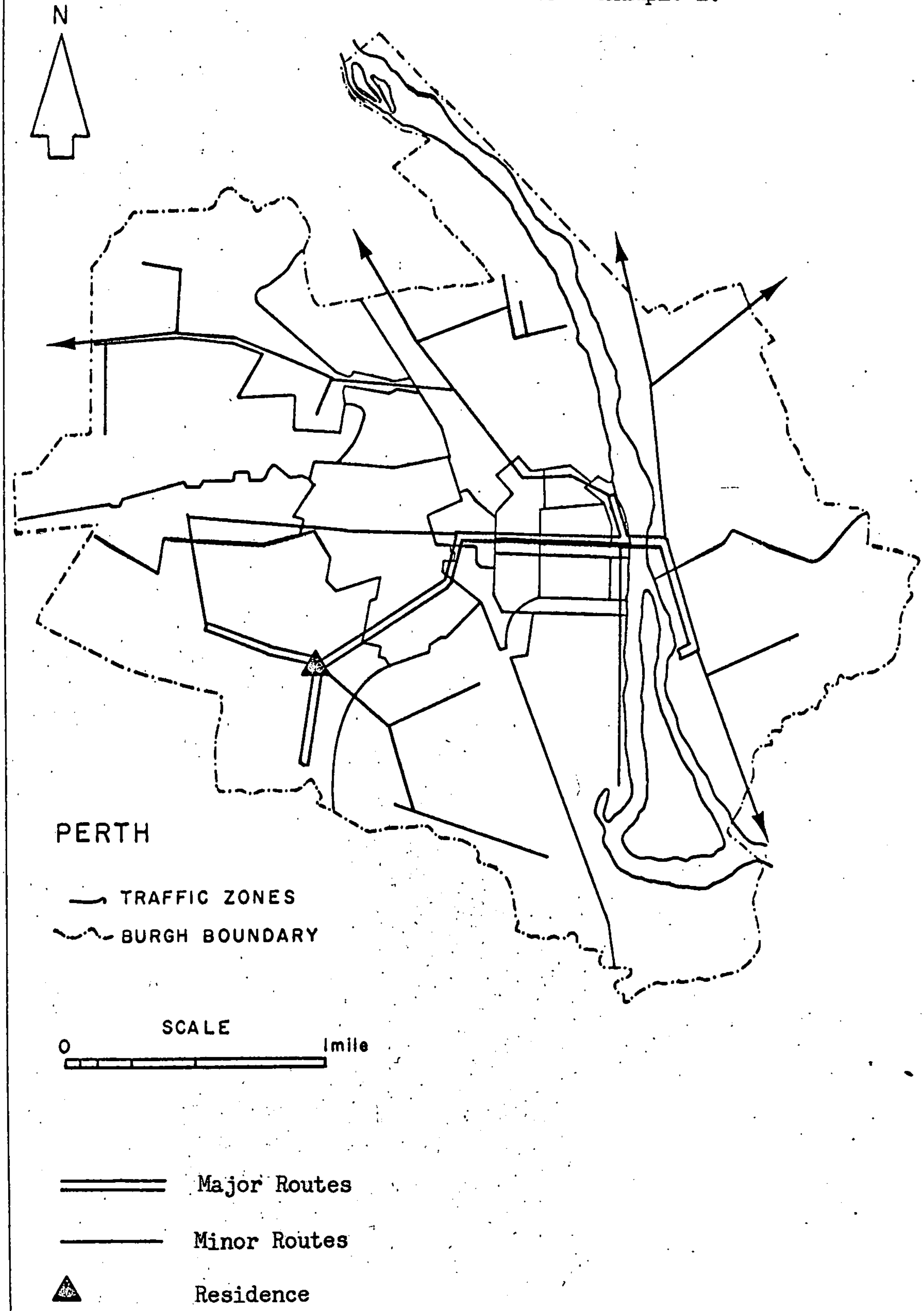
INTERMEDIATE STOPS

Time began................ Time arrived................

Comments

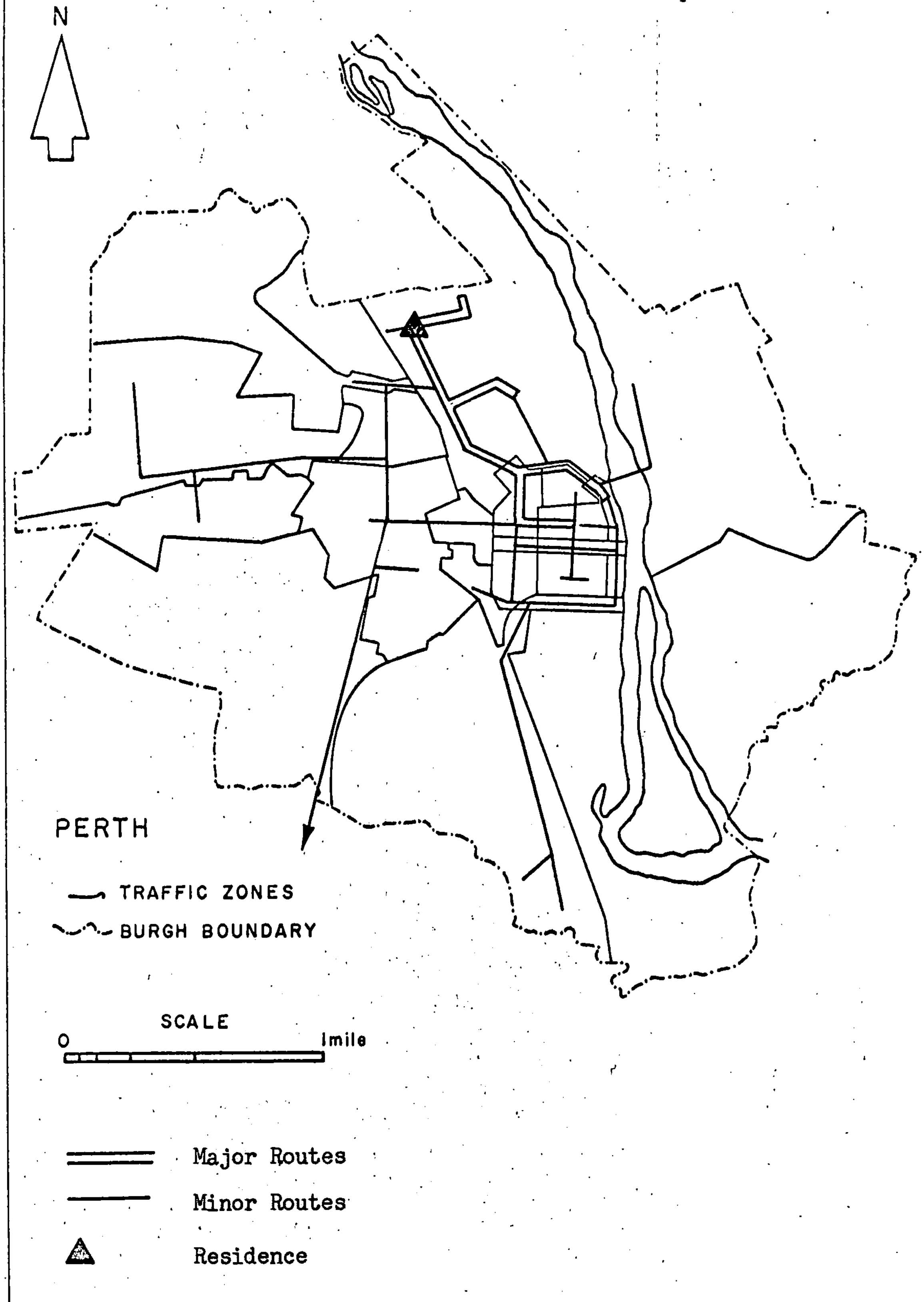
MAP A1:9

RESULTS OF TRAVEL DIARY. Example 1.



MAP A1:10

RESULTS OF TRAVEL DIARY. Example 2.



MAP A1:11

RESULTS OF TRAVEL DIARY. Example 3.

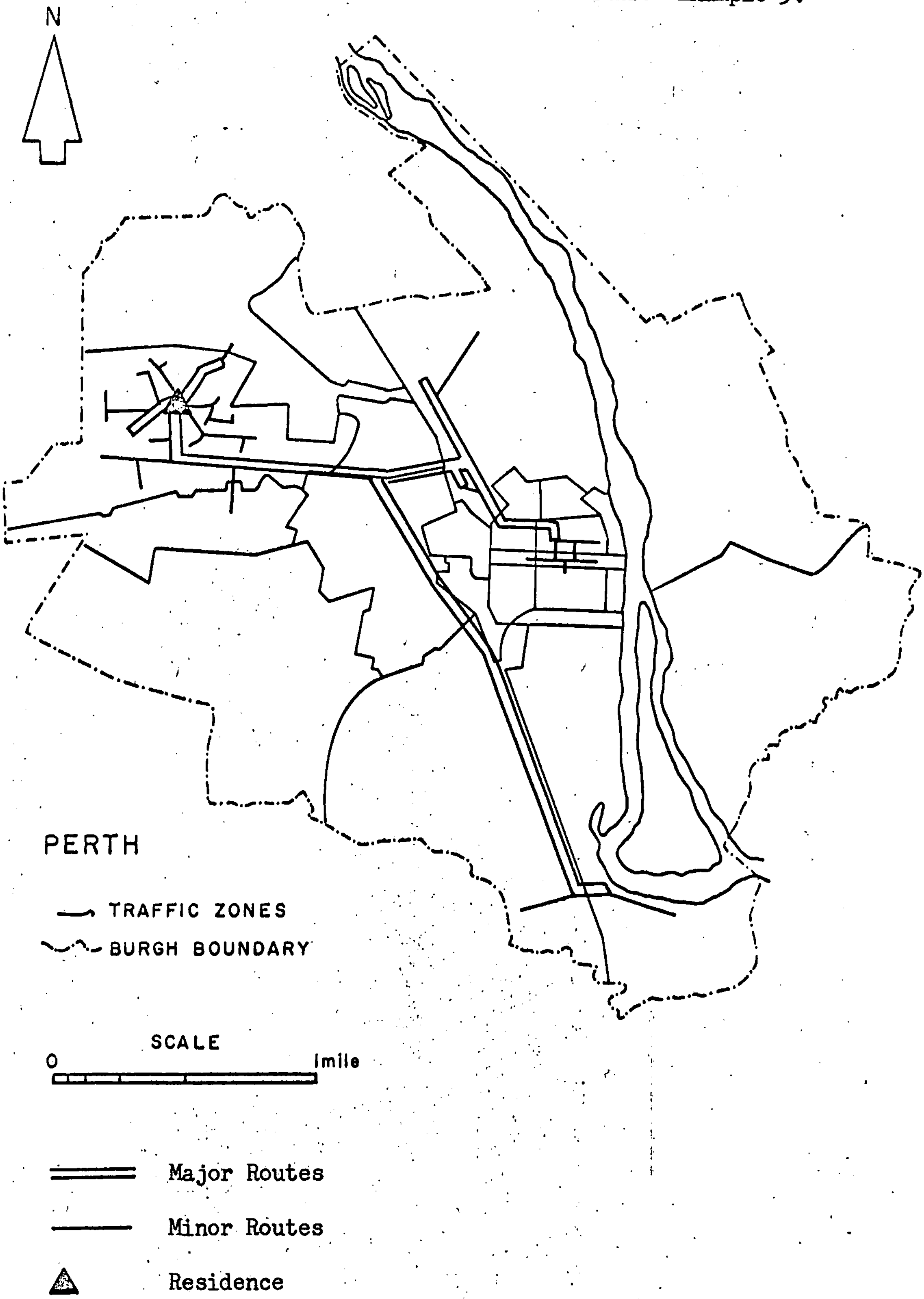


TABLE. 1. Origin Destination. Internal goods vehicle movements (one day)

DESTINATION ORIGIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	72	51	7	3	2	21	7	31	3	18	32	6	1	39	11	6	41	62	52	7	17	6	3	2
2	54	23	3	1	1	17	6	9	7	6	19	5	0	21	10	5	31	57	43	37	12	16	0	0
3	22	10	3	2	0	16	4	27	8	21	17	21	0	17	10	9	7	11	0	2	0	0	1	0
4	1	0	1	1	0	0	1	8	9	3	10	4	1	6	9	8	6	3	2	0	0	0	0	0
5	0	21	14	0	1	7	2	7	2	2	9	7	0	3	8	3	10	9	8	16	13	10	0	1
6	12	12	2	0	0	13	2	6	1	8	28	9	1	41	7	2	29	33	31	6	11	0	3	1
7	17	21	3	0	0	27	1	3	21	7	6	8	0	12	9	10	3	12	16	7	8	0	0	0
8	10	16	1	0	0	11	1	10	17	9	17	3	0	31	7	7	31	64	32	10	2	3	4	7
9	1	10	2	1	0	10	0	0	13	21	3	18	0	7	6	9	1	2	7	3	1	0	0	0
10	5	11	2	0	0	3	1	11	2	11	12	3	0	10	12	2	22	7	9	5	7	2	0	0
11	72	35	31	4	0	26	16	2	4	22	18	11	3	37	15	1	4	7	1	2	4	0	1	1
12	36	13	28	3	3	14	11	7	1	11	21	1	25	5	6	7	9	6	4	1	14	4	1	7
13	7	1	3	1	0	5	2	4	0	6	8	0	21	6	4	2	2	4	0	2	2	2	0	0
14	35	35	62	6	9	48	38	17	4	16	48	19	9	15	15	7	21	9	2	9	19	15	3	9
15	82	18	21	7	4	41	18	34	4	15	19	17	7	21	3	10	7	21	9	2	9	4	0	0
16	18	4	9	0	2	2	7	2	8	14	3	2	2	4	0	2	0	10	7	3	2	1	1	1
17	29	8	16	0	8	17	10	8	2	22	22	16	4	16	3	6	39	2	2	0	1	1	2	0
18	9	2	9	0	1	3	1	15	3	1	7	0	0	3	1	5	17	37	2	1	0	0	3	1
19	20	9	3	0	0	10	4	3	2	16	8	2	0	3	1	0	21	3	2	1	1	1	0	0
20	15	4	2	0	2	2	4	3	1	2	7	2	1	14	2	0	3	1	2	2	3	2	6	1
21	71	15	11	6	2	29	11	7	2	14	15	14	3	26	4	1	6	2	1	0	0	0	0	0
22	18	7	8	0	0	3	3	0	0	4	1	2	1	14	3	1	7	0	2	1	2	1	0	1
23	3	1	1	1	0	2	1	0	0	1	0	0	0	1	0	1	1	0	2	3	4	0	0	1
24	18	3	2	1	3	35	1	1	3	2	2	5	0	8	1	0	2	3	1	0	1	1	0	0

TABLE 2.

Commercial Vehicle Trips. Individual establishments or groups (for one day)

SELECTED DESTNS.	B.R.S.	PULLARS	STEWART & DICK	WM. BROWN	BAKERS	SLAUGHTER	CLEANERS	WHOLESALE CONFEC.	COAL
1	16	13	8	15	18	24	12	4	7
2	11	1	3	3	2	0	0	1	8
6	4	0	0	9	1	11	2	1	10
8	2	3	1	7	9	16	3	1	4
10	2	0	6	3	2	19	5	2	7
11	7	0	5	5	3	4	0	1	8
12	2	0	3	2	0	7	2	1	8
15	4	0	0	4	15	10	9	1	17
16	1	1	1	1	1	0	0	0	3
17	3	2	1	1	0	0	0	1	8
20	1	0	0	0	0	0	0	0	2
21	6	2	3	3	1	12	2	0	10
22	1	0	0	2	0	0	0	0	3
23	1	0	0	0	0	0	0	1	3
24	1	0	0	0	0	0	1	0	2

TABLE. 3. Goods Vehicle trips from Perth North

Goods Station (weekly calls)

DESTN.	LAND USE at DESTINATION RETAIL	OFFICE	WHOLESALE	STORES	WORKSHOPS	INDUSTRY	PUBLIC BLDGS.	SERVICE	RESIDENTIAL	TOTAL
1	396	4	17	0	5	0	2	17	2	443
2	7	5	22	0	12	16	0	5	5	72
3	21	25	19	0	9	5	0	6	0	85
4	3	2	5	0	0	0	2	0	0	12
5	0	2	0	0	0	0	0	0	0	2
6	7	3	82	1	11	10	1	2	2	119
7	52	0	0	0	3	0	0	8	2	65
8	2	1	0	0	9	0	0	5	5	22
9	15	2	0	0	3	0	0	2	0	22
10	24	0	21	0	7	2	1	3	1	59
11	4	0	20	0	15	26	8	3	6	82
12	16	0	7	0	3	0	3	1	5	35
13	0	0	0	0	0	0	0	0	1	1
14	2	0	0	1	9	37	14	4	4	71
15	8	1	2	3	13	8	1	1	7	44
16	1	1	0	0	0	0	2	0	5	9
17	8	3	9	1	17	12	1	0	10	61
18	0	0	1	0	4	0	0	2	0	7
19	0	1	0	2	14	2	0	1	0	20
20	0	0	0	0	2	0	0	0	1	3
21	6	0	0	0	0	0	0	2	7	15
22	5	0	0	0	1	0	2	2	7	17
23	0	0	0	0	1	2	0	0	1	4
24	0	0	3	0	4	7	0	0	0	14

APPENDIX 6

Statistical Techniques

Appendix 6(a) Kendall's 'W' Coefficient (1)

This is a simple method for dealing quickly with several rankings, or 'm' number and 'n' individuals.

The mean trip generation rates for families of identical size and car ownership were arranged in descending order, and assigned a rank from 1-6, or 1-5 in the second case. The same ranking procedure is carried out on each row, excluding those rows with incomplete information or very small call frequencies. If one group of calls always exhibits the highest trip generation rates, then it would always be ranked '1'.

The ranks in each column are then added, and the column totals when ÷ by the no. of totals gives the mean. The deviations from this mean are then calculated, and summed. Substitution then occurs in the formula:

$$W = \frac{12S}{m^2(n^3-n)}$$

W is measuring the communality of the ranking. If all sums of the ranks will be more or less equal, and the sums of squares becomes small with the maximum possible values, so that W = 0, As W increases from 0 + .1 the deviations become 'more different' and there is a greater measure of agreement.

	n					
	1	2	4	3	5	
	1	2	3	5	4	
	1	2	3	4	5	
	1	2	3	4	5	
m	1	4	2	3	5	
	1	2	3	4	5	
	3	5	1	2	4	
	1	5	2	3	4	
	1	2	3	4	5	
	1	5	2	3	4	
Σ	12	31	26	35	46	Σ 150 $\bar{x} = 30$
d	-18	1	-4	5	16	
d^2	324	1	16	25	256	$\Sigma d^2 = 622$

(1) M.G. Kendall 'Rank Correlation Methods' 1948, espec. Chapter 6, pp. 80-89.

Substituting the formula

$$W = \frac{622 \times 12}{10^2 \ (5^3 - 5)}$$

$$W = \frac{7464}{12000}$$

$$W = 0.622$$

Testing for significance - if all the results are independent then any set of ranks is just as probable as another. Kendall calculated some tables for use with small number of 'm' and 'n' (2) for larger numbers reference is made to significant points of S (d^2) (3).

For the first case of n = 6 and m = 5, S was 357 and W = 0.816.

The significant figures are 182.4 at the 0.05 level and 229.4 at the 0.01 level.

In the second case n = 5 and m = 10 S was 622 and W = 0.622.

The significant figures are 231.2 at the 0.05 level and 309.1 at the 0.01 level.

Thus both the coefficients calculated are significant at the 1% level.

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(2) Ibid pp. 146 - 149.
(3) Ibid p. 150

Appendix 6(b) Regression Analysis

This analytical tool is used extensively in this thesis, and so is described in some detail (1).

To begin with, assume a set of observations for a series of traffic zones. For each zone there are a number of say, shopping trips attracted to a zone, A, and at that terminal zone A number of square feet devoted to retail floor space, X. If the assumption is made that trip frequency (Y) is related to the amount of floor space (X), there are 3 important questions which can be answered by statistical analysis:-

1. What is the mathematical equation which best describes the relationship betweenY, the <u>dependent</u> variable, and X, the <u>independent</u> variable?

2. How closely can values of the dependent variable be estimated from observed values of the independent variable, under the relationship described by the selected mathematical equation?

3. How important is the relation of the dependent variable to the independent variable?

Regression analysis in fact specifies the unique equation relating X and Y which assures that the line so described will provide the 'best fit' to the set of observed points. The exact form of the 'curve' - a parabola, straight line, etc. must be specified in advance. The analysis merely provides the values of the coefficients of the selected equation which will best fit the data.

Assuming the simple case outlined above, a straight line Y = a + bX will be the 'best fit', and regression will select the particular value of the two coefficients, a and b, such that the sum of the squares of the differences between the observed values of Y and the Y values given by the equation will be at a minimum (2). All that can be said for the equation so developed is that it 'fits' the observed data better than any other equation of the same mathematical form.

Sy.x. The sketch below shows a line $Y_i = a + bX$; drawn through observed data. Y_ib identifies the value of Y (in this case, trips) which would be estimated by a regression equation for a given zone (i) if the value X_i (number of square feet of retail space in zone i) were known.

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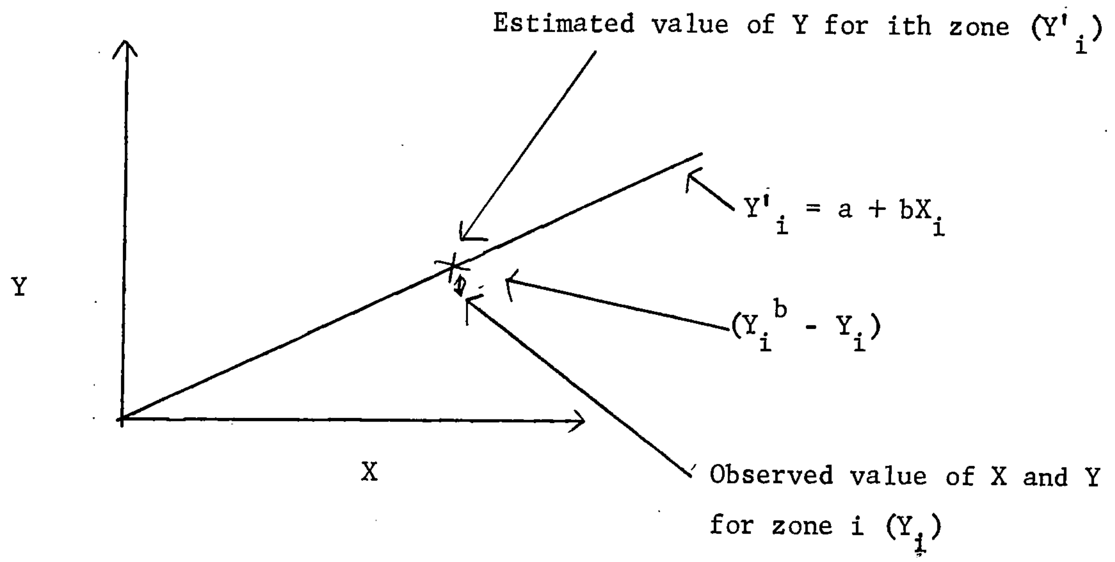
(1) This description is drawn freely from:
M. Ezekiel and K. Fox 'Methods of Correlation and Regression Analysis'. Linear and Curvilinear' 3rd edition, NewYork, Wiley, 1959.
and P. Schuldiner (ed.) 'Non-Residential Trip Generation Analysis' Research Report. Evanston,Northwestern University, pp. 67-92, Nov. 1965.

(2) Reference for the mathematical and computational procedure should be made to Ezekiel and Fox, op. cit. Other useful texts include P.G. Hoes 'Introduction to Mathematical Statistics' New York, Wiley, 1949; W.J. Dixon and F.J. Massey; Introduction to statistical analysis, 2nd ed. New York, McGraw Hill, 1957; and S.J. Gregory.



Sy.x., of Y given X, can be computed by taking the square root of the sum of the squares of the differences between the observed and estimated values of Yi for each zone, and dividing by the total number of traffic zones.

Thus

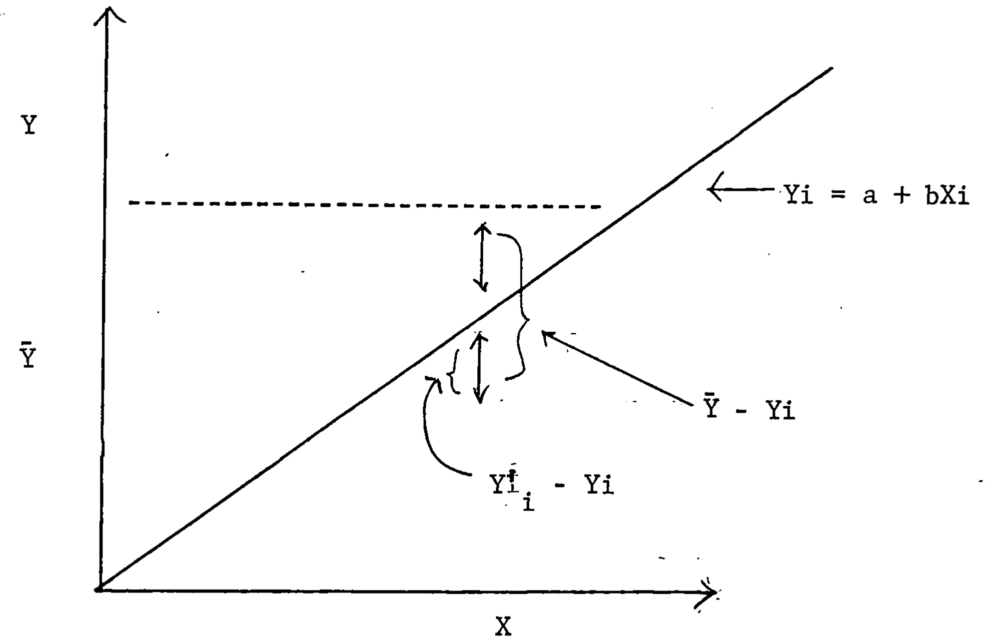
$$Sy.x. = \sqrt{\frac{\sum_{i=1}^{n} (Y'_i - Y_i)^2}{n}}$$

Where n is the total number of traffic zones. It is often expressed as a percentage of the mean of Y_i i.e. Sy.x. $/\bar{Y}$ x 100%. Sy.x. is also, analogous to the standard deviation of a set of data about their mean. With proper allowance for the size of sample used, about 2/3rds of the values of Y will fall within ± Sy.x. of the values estimated by the regression line, c.95% will fall within ± 2 Sy.x. etc. Confidence limits are often used in fact, but Sy.x refers only to the data used, and does not provide an estimate of the probable error in predicting a value of Y for a given value of X not used in the original computation Yi = a + bXi. A separate measure the 'standard error of forecast' can be used for this (2).

Apart from knowing the predictive ability of an equation, if a large number of variables are being tested, some method of selecting their relative importance is wanted. It is also of value to be able to determine the relative proportion of the observed variation in the independent variable which is accounted for by the regressionbetween the independent variable and either one or more of the dependent variables. The coefficient of determination (r^2 y.x), can be used here.

(2) Ezekiel & Fox op. cit. pp. 318 - 322 discusses the nature of forecasting errors.

Simply it is to proportion of the variance in Y, accounted for by the regression between Y and X.



The sketch above shows a set of points (X_1 Y_1)... (Xn_1 Yn)$_i$ the regression line $Y_i = a + bX_i$ i the distance between the observed value of Yi and the estimated value, Y'_i; and the distance between Yi and the mean of all the Y observations, $\bar{Y}$. The scatter in the original values of Y are defined by Sy, the standard deviation of Y about the mean, where

$$Sy = \sqrt{\frac{\sum_{i=1}^{n} (Yi - \bar{y})^2}{n}}$$

The variance of Y is Sy^2.

As was shown earlier the scatter of the observed values of Y about the regression line (the standard error of estimate) is defined by

$$Sy.x. = \sqrt{\frac{\sum_{i=1}^{n} (Y'_i - Y_i)^2}{n}}$$

the amount of variance of Y which is accounted for by the regression between X and Y is $S^2_y - S^2_{y.x}$. The proportion of the variation of Y which is accounted for by the regression is, then,

$$r^2 = \frac{S^2_y - S^2_{y.x}}{S^2_y}$$

The square root of r^2 (coefficient of determinatinn), is r, the coefficient correlation.

Finally, it is often necessary to select a multiple relationship, between a set of variables. For this multiple regression analysis is used.

The basic difference between the simple and multiple regression derives not from the fact that more than one independent variable is used in the regression equation to estimate Y, but that the additional variables are, in most cases, related not only to Y but also to each other. Assuming three independent variables, the regression equation then takes the form

$$Y = a + b_1 X_1 + b_2X_2 + b_3X_3$$

where b_1, b_2, b_3 are partial regression coefficients. That is, b_1 indicates the change in Y, for a unit change in X_1, when X_2 and X_3 are held constant.

As with simple regression, a coefficient of determination R^2y.1.2.3. and a standard error of estimate Sy 1.2.3. can be calculated. The subscripts y.1.2.3. indicate that these two measure include the sum of the net effects of all three variables, X1, X2, and X3. R^2y 1.2.3. indicates the proportion of the observed variation in Y accounted for by the combined regression on X1, X2, and X3. Sy 1.2.3. is the probable spreadaabout the regression line within which 2/3rds of the observed values of Y will fall.

Another commonly used factor in conjunction with the regression results in this thesis, is the 't' statistic. A sample may have a high multiple correlation, yet the computed value of the regression coefficients for some of the independent variables may be due solely to change. The statistical significance of both simple and multiple regression coefficients can be evaluated by means of this 't-test'.. A 'confidence interval' about B_1 the regression coefficient, can be specified which will cover the true regression coefficient within any desired level of probability. The width of the band is determined by the 't' statistic and is a function of the size of the sample and the desired level of precision. For example, let

b_1 the regression coefficient = 0.5

Sb, the standard deviation of b = $\pm$ 0.3

n, the size of sample = 60

(Actually the number of degrees of freedom n-j, where n is the sample size, and j is the number of simultaneously determined constants in the regression equation.)

Assume that 95% certainty that the confidence interval includes the true regression coefficient is desired, then:

t, the factor by which Sb must be multiplied in order to determine the confidence interval for b is equal to

$$\begin{aligned} b \pm (Sb) &= 0.5 \pm 2\ (0.3) \\ &= 0.5 \pm 0.6 \\ &= -0.1 \text{ to } + 1.1 \end{aligned}$$

That is, the chances are 95 in 100 that the observed value of b = 0.5 could have come from a population in which the true value of b is anywhere between -0.1 and 1.1, including zero. Other, lesser more precise, confidence limits can be chosen in the same way.

It is also possible to state the probability that the observed regression coefficient is something greater than zero. To do this, t is solved in this way:

$$t = \frac{0.5}{0.3} = 1.67$$

From a table of values of the 't' statistic it is found that there is one chance in twenty that the true value of b is equal to zero or less.

This brief statement on regression covers the most commonly used terms in this thesis.

Appendix 6(c) Analysis of Variance

Some statistical testing along these lines is found in Part I of the thesis. Essentially analysis of variance is a statistical procedure for testing for differences among the means of two or more populations (1). The analysis of differences in means is based on the fact that if means of subgroups are greatly different, the variance or scatter in the observations of the combined groups is much larger than are the variances of the separate groups (1). The analysis proceeds by separating the variance of all the observations into parts, each part measuring the variability attributable to some specific source. Depending on the conclusions desired, either the hypothesis that all populations have equal means may be tested, or individual populations may be compared to determine if they have significantly different means.

As an illustration of the way in which variance analysis can be used, here isaan hypothetical example. It is desired to know whether or not the availability of facility K affects the rate of trip generation.

	Without facility K	With facility K	All
Number of facilities	18	10	28
Average trips/acre	26	6.1	3.9
Sum of squared deviations about the mean	20.1	71.9	166.3

The analysis of variance may be organised in this way:-

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square
Between types of facilities	74.3	1	74.3
Within a type of facility	92.0	26	3.5
Total for all facilities	166.3	27	

The sum of squares is computed by abstracting the total within type sum of squared deviations, (20.1 + 71.9 = 92.0) from the sum of squares of all observations about the mean of all observations, (166.3 - 92.0 = 74.3). To test significance the 'F' ratio is computed:

$$F = \frac{74.3}{3.5} = 21.2$$

Since $F_{1, 26, .05} = 4.2 < 21.2$, there is 95% confidence that the observed differences between the average trip rates at facilities with factor K and without factor K are not due to chance.

(1) This description is freely drawn from: Schuldiner. op. cit. pp. 92-97.

The analysis of variance is similar to the regression equation in that it relies on the assumption that the samples are randomly chosenffrom populations having approximately equal variance. The F test of significance is valiid if the observations are from normally distributed populations with equal variances, but the results of the analysis of variance are changed very little by moderate violations of the assumptions of normal distribution and equal variance. The major advantages of this type of analysis includes, the ability to handle non quantifiable variables; and the linearity assumption are far less restrictive than for the linear regression equation. The analysis of variance design merely tests for differences in the mean values of Y. No constraints are imposed on thefunctional relationship between Y and the calssificatory variables. However, unliike regression, analysis of variance is primarily intended to isolate differences in means, and it cannot specify the magnitude of those differences.

Appendix 6(d) Bartlett's Test

It was decided to conduct tests for significance on the general data collected from the Home Interview Survey. With any such data, the procedure of testing usually follows several steps (1):-

1. State the Null hypothesis (H_o - a hypothesis of no difference).

2. Choose a statistical test to test H_o.

3. Specify significance level and sample size.

4. Find or assume the sampling distribution of the test under H_o.

5. On the basis of 2, 3 and 4, define the region of rejection, and

6. Compute the value of the statistical test, using the data obtained from the sample(s). If that value is the region of rejection, the decision is to reject H_o; if that value is outside the region of rejection, the decision is that H_o cannot be rejected, and at the chosen level of significance no differences exist amongst the data.

Because of the nature of the data (the fact that it is a sample from an unknown total universe), the normal methods could not be used. The method chosen was Bartlett's test of significance (2), which tests the variances of <u>more</u> than two sets of data. Here there were 16 sets, equivalent to the 16 traffic zones sample.

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(1) S. Siegal 'Non Parametric Statistics for the Behavioural Sciences' New York, McGraw Hill 1956, pp. 6-7.

(2) I must thank Dr. E. Sunderland, Department of Geography, University of Durham, for his advice as to the method to use. The method is stated moreffully in K.A. Brownlee, 'Industrial Experimentation' London 4th ed. H.M.S.O. 1960, pp. 38-39.

Assuming then, no difference (Ho), and having chosen the test, the first stage is to calculate the variances for the 16 zones. What in fact is hypothesised is that these 16 variances are drawn from a homogenous population, that is they are of the same variability.

The variance is calculated by knowing:

1. the degree of freedom
2. sum of squares
3. sum of observations
4. sum of observations squared, divided by the number of observations
5. sum of square, minus (4)
6. the result of 5 divided by the degrees of freedom

The natural logarithm ($\log_e$) of each variance is then obtained and summed ($\log_e$ variance). The mean of variances, S^z, is also obtained, and converted to its natural log - $\log_e S^z$. Two terms 'B' and 'C' are then calculated:-

$$B = kn \log_e S^z - n \sum (\log_e \text{variance})$$

and $C = 1 + \dfrac{k + 1}{3\,n\,k}$

where k = the number of variance compared

n = degree of freedom of the individual variances.

In fact, because of the unequal number of degrees of freedom from zone to zone, a slightly different formula is used:

$$B = (\sum ni) \log_e S^z - \sum (ni \log_e \text{variance})$$

$$C = 1 + \frac{1}{3\,(k-1)} \left[\sum \frac{1}{ni} - \frac{1}{\sum ni} \right]$$

Or put in the terms of the stages set out above:-

$$B = (\sum (1)) \log_e (\sum (2) \div \sum (1)) - \Big[\sum n \times \log_e \text{variance zone. } 1 + n \times \log_e \text{variance zone } 2 \ldots + n \times \log_e \text{variance zone } n \Big]$$

and $C = 1 + \dfrac{1}{3\,(k-1)} \left[\sum \left(\dfrac{1}{\text{o of F Zone 1}} + \dfrac{1}{\text{o of F Zone 2}} \ldots + \dfrac{1}{\text{o of F Zone N}} \right) - \dfrac{1}{\sum (1)} \right]$

If B/C is greater than χ^2 at the chosen level of significance (5% in this case) for (k-1) degrees of freedom then the hypothesis is rejected, and there is an indication of that level of significance that the variances are not drawn from a homogenous population, and vice versa.

As indicated in the main text virtually all the data tested did show significant variation at the 5% level, and therefore the differences between zones were significant.

Appendix 6(e) Multivariate Analysis

Although most geographers have a working knowledge of simple statistical methods, the increasing use of computers has made available some complex and sophisticated techniques, some of which are beyond the range of experience of many researchers in this field. (1) The ease with which large masses of data may now be handled, complex questions invoked, and the apparent precision of the final estimates, suggest a degree of reliability not always warranted by either the source data or the current understanding of the functional relationships underlying the observed associations. Nevertheless used with caution these analytical methods can be a boon to the geographer.

Regression analysis was used frequently, and it involves a number of assumptions, which some data cannot uphold. The basic assumption is a linear relationship of the data. Curvilinear regression methods do exist, but to avoid these, some transformation of the data is used, such as logarithms (2), and tests are available to ascertain the linearity or otherwise of the data (3). Other errors which might arise come through the collection of the data (4), and its processing. The result of such errors is that the computed regression coefficients tend to be smaller than those which would be obtained if correct values of the independent variables had been used in the analysis. This bias persists even for large sample sizes. The best way to deal with these problems, though again statistical techniques do exist to cope with some of them, is to be aware of them, and to use caution in interpreting results from their use.

Other problems include colinearity or multi-colinearity, and heteroscedasticity. Multi-colinearity is a serious difficulty. It occurs, 'when some or all of the explanatory variables in a relation are so highly correlated, one with another, that it becomes very difficult, if not impossible, to disentangle their separate influences and obtain a reasonably precise estimate of their relative effects' (5). If a perfect correlation exists among the independent variables it is then impossible to estimate the separate influences of the variables, and the regression method breaks down. Examples of explanatory variables which exhibited high colinearity are, car ownership and distance from the central area; socio-economic status and car ownership; and 'number of manual workers' and housing type.

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(1) Recent geographic literature shows an increasing tendency to utilise these techniques, a few examples are, G. Olsson 'Distance and Human Migration, a Migration Study', Geografiska Annaler, 47, B. No.1 January 1965, pp. 3-43; S. Nordbeck 'Location of Areal Data for Computer Processing' Lund Studies in Geography Series C No.2, 1962; and Y. Boye 'Routing Methods, principles for handling multiple travelling salesman problems' Lund Studies Georgraphy series C No.5, 1965.

(2) J. Aitchison and J.A.C. Brown 'The Log Normal Distribution' Cambridge University Press. 1957.

(3) For instance, Fractile Diagrams, see A.Hald 'Statistical Theory with Engineering Applications' New York, Wiley 1952, pp. 119-158.

(4) The accuracy of one of the survey methods used is set out in G.G. Dobson 'Accuracy of Home Questionnaire Surveys' Traffic Engineering and Control Vol. 16, No.12, April 1965, pp. 723-726.

(5) J. Johnston 'Econometric Methods' New York, McGraw Hill 1963, p. 201.

Violation of the homoscedasticity assumption, a constant variance for all values of the independent variable, is known as heteroscedasticity. The application of a regression technique to data without constant variance may result in estimates with vary wide confidence limits. The regression of trips per dwelling unit or persons per dwelling unit did show marked heteroscedasticity - that is, trips made by larger families showed a larger variance about the mean than trips made by smaller families.

Finally, in an empirical study like this, it is impossible to specify all of the pertinent variables. The almost inevitable omission of related variables produces a bias in the regression coefficients, the extent of which depends upon the degree of correlation between the excluded and the included variables. The best way to avoid this bias is to ensure a logical relationship between variables. That leads on to the statement that regression analysis can help determine only the nature and degree of statistical association between sets of observations, so that each equation must be looked at in terms of theory, logic, experienced judgment, or some other non-statistical bases.

The regression and variance techniques have already been discussed in Appendices 6(b) & (c) (6). These methods rest upon more or less restrictive assumptions regarding the nature of the statistical distributions of the populations from which the samples are drawn. Other methods, known as non-parametric techniques, do not rely so heavily upon the assumed nature of the underlying distributions. They rely on data which is simultaneously cross classified into sets of homogenous groups - for example the illustration of the effect of household size and car ownership on trip generation utilised this simple method (7).

Despite all these serious drawbacks, the predominant method utilised is the regression technique. The regression method has its merits; simplicity, ease in interpretation of results, and ease in handling simultaneously several variables. Basic linearity was upheld with most variables, with the notable exception of density, which was transformed by the use of hyperbole logarithms ($\log_e$). Most difficulty was experienced with multicolinearity, which seriously reduced in some cases the number of variables which could be tested.

In the consideration of residential trip generation, two major sets of data were tested. For convenience of programming these two sets were titled 'RESIDENTRIPS' and 'HAYSTACK'. Some of the results are set out at the end of this section.

'RESIDENTRIPS' was concerned with trips per household and per person (for from-home and total trips in 24 hours), trips made by car drivers, and trips made by those who travelled regularly. Six basic sets of regressions were tried, using five independent variables. The matrices of correlation coefficients are set out in Appendix Tables 7 and 8. Among the five explanatory variables considered, car ownership exhibits the highest simple correlations with from-home and all trips/person, car driver trips, and trips/daily traveller. Distance and socio-economic status show the next highest correlations.

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(6) Also M. Ezekiel and K.A. Fox 'Methods of Correlation and Regression Analysis: Linear and Curvilinear'. New York, Wiley 3rd Ed. 1959.
(7) This method is used extensively in the Puget Sound Regional Transportation Study. Seattle. 1964, various reports. In contrast Schuldiner and Oi op. cit. pp. 72-124, 231-243 use both regression and non-parametric methods in analysing data for Modesto.

The correlation matrix (Appendix Table 7) also reveals a number of interrelations among the five explanatory variables. First the correlations among these variables are generally quite high. In particular the correlation between car ownership and socio-economic status is very high, between density and socio-economic status, and density and car ownership, is high and negative. As pointed out colinearity makes it difficult to isolate the partial effect of any particular explanatory variable. For this reason those particular relationships were omitted from the regressions. Second, family size tends to show very little correlation with any of the other explanatory variables (and with 4 of the 6 dependent variables). These low correlations may be due in part to the small variance of this variable.

The dependent variables were then expressed, via regression techniques, as linear functions of various combinations of the five explanatory variables. The particular combination of explanatory variables included in any given regression equation can be read off Appendix Tables 1 to 6. If some explanatory variable was omitted no entry appears under its appropriate columns.

The least-square estimates for the parameters of each regression equation are also found in these tables. The first line pertaining to each equation gives the regression coefficient (the bi's or slope coefficients); the second, the standard error of each regression coefficient; the third, the 't' statistic (the ratio of the first to the second line). The simple or multiple coefficient of determination in the last column gives a measure of the fit, i.e. the proportion of the variance of the dependent variable explained by the linear relation to the included explanatory variable(s).

Appendix Tables 1 and 2 set out the results for two dependent variables, from-home, and all trips, per household. These tables reveal that car ownership, family size, and distance are the dominant explanatory variables. Inclusion of the two additional explanatory variables does not appreciably improve the goodness of fit. This is confirmed by the 't' statistic; each explanatory variable is tested by the 't' statistic. If an explanatory variable has no effect on trip generation, the expected value of its regression coefficient is zero. Chance factors will normally lead to a non-zero estimate even when no relation exists. The greater the value of the 't' statistic, the smaller is the likelihood that chance factors alone are responsible, and for a value of 't' greater than 2.15, there is only a 5% probability that chance factors are responsible.

If this criterion is adopted then two of the explanatory variables have on the whole no measurable effect on trip generation per household. These are density and socio-economic status. Contrary to expectations density has a positive coefficient in one equation.

Because of its colinearity car ownership appears alone and with family size. By itself car ownership 'explains' 30-40% of the variance, and the regression coefficients imply that an addition of one car/household would increase trips by 2.24 from home, and 6.98 total trips, daily. The addition of family size, improves the 'explanation' to 95%. Distance has a coefficient of determination of 0.6553 and 0.7109, so that its effect cannot be ignored. Combined with family size it does not produce as good an explanation as car ownership and family size.

In summary, Appendix Tables 1 and 2, indicate that car ownership and family size are the dominant explanatory variables, though distance is also significant. If density and socio-economic status are significant variables, then their impacts are swamped by the other variables, and no partial effects can be identified.

Appendix Tables 5-6 use trips/person as the dependent variable. Eliminating the effect of family size, which is therefore now non-significant, all the other four variables are revealed as significant. Much of this effect must have been masked by family size variance. Dominant now is car ownership, in simple regression, the coefficient of determination is 0.8324 and 0.8888, and the regression coefficient reveals that the addition of one car increases from home trips by 0.78 trips, and total trips by 2.46 trips daily. Although there is little change in the effect of distance, density and socio-economic status are brought into significance. An increase of 10% in the proportion of a zone's population in socio-economic group 1, for instance, increases total daily trips/person by 0.30 trips. In summary car ownership is far and away the dominant explanatory variable. Socio-economic status, density, and distance, in that order, have a secondary effect.

Table 3 sets out the regression for the dependent variable, car driver trips, which can be interpreted as the daily utilisation rate per car, it omits, of course, all person-trips via other travel modes. The dominant factors influencing car utilisation rates (besides obviously ownership of a car) are distance from the central area and socio-economic status. Using the 't' statistic family size, appears to have no effect on this measure of trip generation. Socio-economic status now appears to have the dominant effect, and increasing status or income is associated with higher car utilisation rates. Associated with this also, is the fact that an increase of one car per dwelling unit is accompanied by 2.63 additional car driver trips in those households, implying that zones with higher car ownership rates not only show more trips/household, due to more cars, but also utilise each car more intensively.

The final part of the RESIDENTRIP analysis involves the number of trips/regular daily traveller. The 't' statistic reveals that now both family size and distance are non-significant, and that the factors which best explain the variation in trips/daily traveller are car ownership, density (negatively), and socio-economic status. An additional car/household leads to an increment of 0.81 trips in the daily intensity of travel by each regular trip maker, and a 10% increase in a zone's proportion of socio-economic group 1 to 1.0 extra trip.

In these analyses of the residential unit, the dominance, in all but the first instance, of car ownership is the most striking. Higher average car ownership increases trips per household. This increase is evident not only in a higher utilisation of each car, but also in a heightened frequency of travel by each regular trip-maker.

These relationships were further pursued in the second analysis, HAYSTACK, breaking down trip generation further by mode and purpose. The matrix of correlation coefficients is shown in Appendix Table 9; there are 14 dependent variables and 16 independent variables, although one of the latter, car ownership is also used as a dependent variable. Some high correlations occur amongst the dependent variables themselves, for example car driver trips are correlated with car passenger trips, walking trips (negatively), business trips, social, other home and non-home based trips; bus trips with walk trips (negative); car ownership with car driver trips, car passenger, walk (negative), and business trips, etc. Amongst the explanatory variables family size exhibits high simple correlation with school trips and bus trips; socio-economic status and social rank with business trips, car passenger trips, and car driver trips, the number of skilled and manual workers have high negative correlations with car driver trips, car passenger trips, business trips, social trips and other home trips; and so on for the other variables.

As with RESIDENTRIP there are a number of striking correlations amongst the explanatory variables themselves, which because of multi-colinearity problems reduces the number of variables which can be entered in any one regression equation. A few examples are family size and the number 5-14 years of age, density and house type (negative), car ownership and social rank, socio-economic status and the proportion skilled or manual workers, etc.

Because of the number of regressions involved, and because a number of the equations have already been analysed in some detail in earlier sections, Appendix Tables 10-13 show only a selection. The format of the tables is the same as that of Appendix Tables 1 to 8.

In Table 10 (dependent variable, car passenger trips), car ownership is the dominant explanatory variable as revealed by its 't' statistic. Inclusion of an additional variable does not improve the goodness of fit appreciably. The point estimate for the regression coefficient of car ownership, indicates that the addition of one car per dwelling unit increases car passenger trips by c.0090 trips daily.

One variable, family size, can be dismissed as non-significant. Taken separately a number of other variables have some effect on trip generation, but to a smaller extent. It may be that these other effects are reflections of car ownership.

Walking trips (Table 11) appear to be negatively correlated with distance. The further the distance from the central area the fewer the walking trips made; for each mile of distance, walking trips decrease by 0.90 trips daily. The problem of multi-colinearity is eveident here too. Apparently significant results occur with the correlation of density and distance, yet these two are colinear, low density being highly correlated with great distance; similarly socio-economic status, social rank, and the number actively employed. Despite the outward results then, these must be rejected.

In order to identify the explanatory variables of social trips, and to avoid colinearity, simple and two factor correlations were established (Table 12). Again car ownership or one of the alternative measures (socio-economic status, house type) was dominant. Ownership of a car and the flexibility and convenience which it brings increases by 1.21 trips a day, the number of trips generated for social purposes.

Finally Table 13 indicates the parameters for other-house-based trips, non-house-based trips, and car ownership. These are self-explanatory. Car ownership and the number actively employed (negative relationship) are the dominant explanatory variables for other-home and non-home based trips respectively. For car ownership although the 7 variables entered offered a 93% 'explanation' of the dependent variable, an 'F' ratio test rejected all but socio-economic status despite apparently significant 't' statistics. By itself, at the 10%, 5%, 1% and 0.1% 'F' significance levels, socio-economic status was re-entered, with a significant 't' statistic. As far as Perth is concerned, and indeed in the United Kingdom as a whole, car ownership is highly correlated with income level. In North America car ownership is virtually universal, with the exception of only the very lowest income levels and the unemployed.

These regression analyses show the particular dominance of car ownership. The higher the average car ownership, the greater the increase of trips per dwelling unit. Again this increase shows itself not only in higher utilisation rates for each car, but in the heightened frequency of travel by 'daily travellers' and now also by increased social trip and other-home based trip generation rates. Other factors were significant, and in some cases displaced car ownership, but many variables are so interrelated with car ownership that it is difficult to isolate them.

As long as the assumptions behind regression techniques are accepted, in particular the linear and additive relations, the advantages for this analysis and other traffic studies are obvious. The introduction to this section set out many of the advantages and disadvantages of regression analysis, and the analyses which followed substantiated both sides, but showed the invaluable nature of the technique. It allowed in particular the identification of some of the more important explanatory variables in residential trip generation.

RESIDENTRIPS

Dependent Variables:

From-home trips per household
All trips per household
From home car driver trips per household
Trips per daily traveller
From-home trips per person
All trips per person

Independent Variables (within the limits stated, Table 1)

Car ownership
Family Size
Distance
Density
Socio-economic status

The results are set out in the following tables:

APPENDIX TABLE. 1.

Dependent Variables FROM HOME TRIPS / HOUSEHOLD

CONSTANT	CAR OWNERSHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 r^2
-0.5790	2.332 0.2554 9.13	1.236 0.09844 12.56				0.9515
3.0170	2.249 0.9228 2.44					0.3135
0.7227		0.7868 0.1983 3.97	0.9582 0.2197 4.36			0.8509
0.2004		1.213 0.2665 4.55				0.6145
2.6770			1.388 0.2792 4.97			0.6553
0.7925		1.592 0.1682 9.47		-1.276 0.2416 5.28		0.8841
-0.4133		1.301 0.1401 9.23			0.0281 0.0048 5.91	0.9015
0.8630		1.255 0.2245 5.59	0.4820 0.2384 2.02	-0.8619 0.2973 2.90		0.9155
0.0156		1.071 0.1599 6.69	0.4611 0.2065 2.23		0.0199 0.0055 3.63	0.9322
2.173			1.473 0.2990 4.93	0.3336 0.3876 0.86		0.6753
2.677			1.353 0.3401 3.98		0.0020 0.0103 0.20	0.6564
4.101				-0.3002 0.6109 0.49		0.0182
3.402					0.02349 0.01291 1.82	0.2031

Limits

Car Ownership	0-2
Family size	1-8
Distance	0-2
Density	0.5 to 2.5
Socio-Economic Status	% in Status Group 1.0-75.

APPENDIX TABLE. 2.

Dependent Variable ALL TRIPS / HOUSEHOLD

CONSTANT		CAR OWNERSHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 / r^2
-2.179		7.196	3.125				0.9594
	S.t	0.6354	0.2449				
	t	11.33	12.76				
6.910		6.986					0.4090
		2.329					
		3.00					
1.858			1.721	2.993			0.8373
			0.5634	0.6242			
			3.05	4.79			
6.132				3.933			0.7109
				0.6956			
				5.65			
0.2266			3.053				0.5258
			0.8041				
			3.80				
2.009			4.194		-3.841		0.8557
			0.5104		0.7331		
			8.22		5.24		
-1.707			3.328			0.08846	0.9107
			0.3652			0.01230	
			9.11			7.19	
2.251			3.033	1.658	-2.416		0.9059
			0.6442	0.6842	0.8533		
			4.71	2.42	2.83		
-0.3987			2.625	1.406		0.06369	0.9493
			0.3763	0.4860		0.01292	
			6.98	2.89		4.93	
5.417				4.054	0.4733		0.7163
				0.7603	0.9856		
				5.33	0.48		
6.129				3.594		0.01973	0.7250
				0.8277		0.02516	
				4.34		0.78	
8.056						0.07672	0.2927
						0.03307	
						2.32	
10.72					-0.1271		0.0442
					1.640		
					0.77		

APPENDIX TABLE. 3.

Dependent Variable - From - House, Car - Driver Trips

CONSTANT	CAR OWNER-SHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 / r^2
-0.1776	2.631 0.2037 12.91					0.9276
-0.1497	2.636 0.2002 13.17	0.09357 0.07714 1.21				0.9355
1.003		-0.3998 0.2159 1.85	1.050 0.2392 4.39			0.6175
0.4312		0.06720 0.2912 0.23				0.0041
0.01031			0.8311 0.2267 3.67			0.5082
1.044		0.4593 0.2049 2.24		-1.320 0.2943 4.48		0.6277
-0.3105		0.1746 0.1063 1.64			0.03319 0.003562 9.32	0.8790
1.133		0.03212 0.2694 0.12	0.6099 0.2862 2.13	-0.7955 0.3569 2.23		0.7365
0.05516		-0.02108 0.1135 0.19	0.3900 0.1463 2.67		0.02634 0.003873 6.80	0.9265
1.1[illegible]6			0.6353 0.1832 3.47	-0.7649 0.2375 3.22		0.7362
0.002703			0.3724 0.1070 3.48		0.02669 0.003236 8.25	0.9623
1.998				-1.038 0.3046 3.41		0.4719
0.2022					0.03255 0.003766 8.64	0.8518

APPENDIX TABLE. 4.

Dependent Variable - Trips/Daily Traveller

CONSTANT	CAR OWNER SHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 r^2
1.238	0.8107 0.09558 8.48					0.8470
1.363	0.8078 0.09417 8.50	-0.04297 0.03629 1.18				0.8630
1.778		-0.1688 0.08746 1.93	0.2646 0.09690 2.73			0.3972
1.633		-0.05105 0.09309 0.55				0.0226
1.358			0.1724 0.09272 1.86			0.2101
1.839		0.08061 0.05953 1.35		-0.4432 0.08550 5.18		0.6982
1.403		-0.01769 0.04032 0.44			0.01030 0.001352 7.62	0.8327
1.845		0.05430 0.09242 0.59	0.03757 0.09817 0.38	-0.4109 0.1224 3.36		0.7022
1.414		-0.02365 0.05516 0.43	0.01188 0.07112 0.17		0.01009 0.001883 5.36	0.8331
1.901			0.08048 0.06379 1.26	-0.3591 0.08270 4.34		0.6928
1.355			-0.007849 0.05235 0.15		0.01049 0.001584 6.62	0.8303
2.007				-0.3938 0.07977 4.94		0.6521
1.351					0.01037 0.001301 7.97	0.8300

APPENDIX TABLE. 5.

Dependent Variable - FROM HOME TRIPS / PERSON

CONSTANT	CAR OWNER-SHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 r^2
	0.7870	0.0371				
0.9240	0.0978	0.0378				0.8449
	8.05	0.98				
	0.7845					
1.032	0.0976					0.8324
	8.04					
		-0.1077	0.3076			
1.355		0.07467	0.08273			0.5389
		1.44	3.72			
		0.02920				
1.187		0.09156				0.0078
		0.32				
			0.2488			
1.087			0.07491			0.4590
			3.32			
		0.1637		-0.4527		
1.397		0.05313		0.07632		0.7477
		3.08		5.93		
		0.05967			0.009821	
0.9724		0.04579			0.001542	0.7734
		1.31			6.37	
		0.08715	0.1093	-0.3588		
1.113		0.07703	0.08182	0.1020		0.7829
		1.13	1.34	3.52		
		0.003713	0.1121		0.007845	
1.077		0.05688	0.07346		0.001953	0.8130
		0.07	1.53		4.02	
			0.1782	-0.2758		
[illegible]04			0.05531	0.07171		0.7576
			3.22	3.85		
			0.1152		0.007783	
1.086			0.05373		0.001633	0.8129
			2.14		4.77	
				-0.3524		
1.737				0.08874		0.5481
				3.97		
					0.009610	
1.148					0.001575	0.7413
					6.10	

APPENDIX TABLE. 6.

Dependent Variable - ALL TRIPS / PERSON

CONSTANT	CAR OWNER-SHIP	FAMILY SIZE	DISTANCE	DENSITY	SOCIO ECONOMIC STATUS	R^2 r^2
2.340	2.462 0.2642 9.32					0.8698
1.932	2.471 0.2542 9.72	0.1404 0.0979 1.43				0.8888
3.298		-0.3249 0.2143 1.52	0.9901 0.2374 4.17			0.5970
2.758		0.1157 0.2803 0.41				0.0129
2.491			0.8126 0.2166 3.75			0.5198
3.397		0.5250 0.1656 3.17		-1.378 0.2378 5.79		0.7400
2.073		0.2132 0.1184 1.80			0.03132 0.003988 7.85	0.8392
3.461		0.2198 0.2273 0.97	0.4358 0.2414 1.81	-1.003 0.3011 3.33		0.7994
2.421		0.02617 0.1364 0.19	0.3741 0.1761 2.12		0.02473 0.004683 5.28	0.8860
3.690			0.6095 0.1609 3.79	-0.7938 0.2086 3.81		0.7824
2.486			0.3959 0.1290 3.07		0.02429 0.003921 6.19	0.8856
4.488				-1.056 0.2801 3.77		0.5222
2.699					0.03057 0.004295 7.12	0.7958

APPENDIX TABLE. 7

Correlation coefficients (independent variables)

CAR OWNERSHIP				
-.026	FAMILY SIZE			
.676	.493	DISTANCE		
-.725	.427	-.332	DENSITY	
.923	-.105	.522	-.726	SOCIO ECONOMIC STATUS

APPENDIX TABLE. 8.

Correlation coefficients (both sets of variables)

CAR OWNERSHIP	0.560	0.912	0.639	0.933	0.963	0.920
FAMILY SIZE	0.784	0.088	0.725	0.114	0.063	-0.150
DISTANCE	0.809	0.677	0.843	0.721	0.713	0.458
DENSITY	-0.135	-0.740	-0.210	-0.723	-0.687	-0.808
SOCIO ECONOMIC STATUS	0.451	0.861	0.541	0.892	0.923	0.911

'HAYSTACK'

Dependent variables:

Modal Choice

Motor cycle trips
Cycle trips
Bus trips
Car passenger trips
Car driver trips (overlap with RESIDENTRIP)
Walking trips
Other mode.

Purpose

Work trips
Business
Shop
School
Social
Other home based trips
Non home based trips.

Independent Variables:

Family size
Density
Distance
Socio-economic status
Car ownership (also used as a dependent variable)
Social Rank Index (Shevky/Bell)

Urbanisation Index (Shevky/Bell)

Cycle ownership
Motor-cycle ownership
Percentage skilled workers
Percentage manual workers
House type
Number of persons actively employed
Number 5-14 years old
Number 15-65 years old
Number over 65 years

Limits as for RESIDENTRIP. In addition,

Social Rank Index, 9 to 100
Urbanisation Index, 50 to 88
Number actively employed, 0 to 5
House type index, 0 to 85
Number 5-14 years, 0 to 6
Number 15-65 years, 0 to 8.

APPENDIX TABLE. 9. Correlation Coefficient Matrix

	1. CAR DRIVER TRIPS	2. M. CYCLE	3. CYCLE	4. BUS	5. CAR PASS'R	6. WALK	7. OTHER MODE	8. WORKS	9. BUSI'S	10. SHOP	11 SCHOOL	12. SOCIAL	13. OTHER HOME	14. NON HOME	15. FAMILY SIZE
1	-0.165														
2	-0.126	0.541													
3	0.249	0.746	0.749												
4	0.977	0.092	0̄.110	0.279											
5	0̄.677	0̄.220	0̄.308	0̄.612	0̄.725										
6	0̄.253	0.083	0̄.102	0̄.211	0̄.236	0.275									
7	0̄.034	0.909	0.440	0.762	0.005	0̄.184	0.156								
8	0.840	0̄.331	0̄.285	0.039	0.828	0̄.533	0.072	0̄.152							
9	0.364	0̄.138	0.446	0.363	0.292	0̄.174	0̄.487	0̄.005	0.202						
10	0.111	0.660	0.665	0.842	0.104	0̄.166	0̄.154	0.762	0̄.062	0.499					
11	0.817	0.130	0.363	0.544	0.792	0̄.695	0̄.193	0.161	0.524	0.450	0.386				
12	0.927	0̄.098	0̄.171	0.172	0.943	0̄.574	0̄.194	0̄.021	0.762	0.211	0.078	0.721			
13	0.727	0.361	0.443	0.770	0.703	0̄.623	0̄.224	0.492	0.500	0.535	0.721	0.865	0.641		
14	0̄.063	0.641	0.700	0.827	0.056	0̄.147	0̄.233	0.720	0̄.141	0̄.500	0.983	0̄.355	0.057	0.680	
15	0̄.687	0.401	0.307	0.101	0̄.716	0̄.539	0̄.170	0.330	0̄.822	0̄.019	0.334	0̄.468	0̄.614	0̄.280	0.427
16	0.713	0.367	0̄.427	0.778	0.734	0̄.869	0̄.464	0.364	0.410	0.428	0̄.507	0.821	0.616	0.839	0.493
17	0.923	0̄.355	0̄.256	0.035	0.907	0̄.524	0̄.215	0̄.222	0.826	0.304	0̄.049	0.725	0.818	0.576	0̄.109
18	0.963	0̄.140	0̄.162	0.216	0.969	0̄.691	0̄.190	0̄.010	0.780	0.248	0.021	0.791	0.906	0.664	0̄.026
19	0̄.877	0̄.058	0̄.066	0̄.314	0.907	0̄.798	0̄.251	0̄.005	0.752	0̄.200	0̄.040	0̄.744	0̄.755	0̄.630	0̄.023
20	0̄.521	0̄.083	0̄.172	0̄.388	0̄.474	0.231	0̄.173	0̄.338	0̄.508	0̄.254	0̄.519	0̄.534	0̄.518	0̄.679	0.521
21	0̄.036	0.782	0.742	0.858	0.056	0̄.533	0̄.254	0.631	0̄.146	0.200	0.637	0.364	0̄.017	0̄.520	0.643
22	0̄.583	0.768	0.412	0.395	0̄.523	0.283	0.046	0.691	0̄.649	0̄.099	0̄.516	0̄.349	0̄.481	0̄.061	0.529
23	0̄.793	0.452	0.215	0.033	0̄.760	0.324	0.287	0.303	0̄.691	0̄.347	0̄.004	0̄.640	0̄.723	0̄.532	0.010
24	0̄.877	0.509	0.379	0.139	0̄.853	0.473	0.190	0̄.389	0̄.826	0̄.210	0.251	0̄.619	0̄.791	0̄.428	0.298
25	0̄.861	0̄.523	0̄.259	0̄.061	0.821	0̄.532	0̄.329	0̄.464	0.758	0.368	0̄.205	0.671	0̄.745	0̄.448	0̄.244
26	0̄.687	0̄.201	0̄.276	0̄.624	0̄.680	0.537	0.093	0̄.345	0̄.544	0̄.457	0̄.615	0̄.794	0̄.541	0̄.849	0̄.537
27	0.117	0.740	0.724	0.936	0.112	0̄.429	0̄.249	0.748	0̄.090	0.361	0̄.868	0̄.453	0̄.014	0̄.695	0.848
28	0̄.520	0̄.289	0̄.450	0̄.765	0̄.479	0̄.620	0.212	0̄.460	0̄.388	0̄.399	0̄.644	0̄.660	0̄.342	0̄.830	0̄.627
29	0.450	0̄.856	0̄.569	0̄.603	0.373	0̄.046	0.121	0̄.745	0.621	0.026	0̄.636	0.073	0.352	0̄.150	0̄.675
30	0.885	0̄.268	0̄.203	0.031	0.873	0̄.496	0.075	0̄.118	0.819	0.233	0̄.075	0.746	0.819	0.575	0̄.150

APPENDIX TABLE. 9. continued.

16. DENSITY	17. DISTANCE	18. SOCIO EC. STATUS	19. CAR OWNER SHIP	20. SOCIAL RANK	21. URBAN INDEX	22. CYCLE O.SHIP	23. M/CY. O.SHIP	24. % SKILLED	25. % MANUAL	26. HOUSE TYPE	27. ACTIVE EMPL.	28. AGE 5-14	29. 15-65	30. 65 +
$\bar{0}$.332														
$\bar{0}$.731	0.520													
$\bar{0}$.725	0.676	0.916												
$\bar{0}$.696	0.706	0.892	0.906											
0.140	$\bar{0}$.363	$\bar{0}$.420	$\bar{0}$.449	$\bar{0}$.307										
0.246	0.642	$\bar{0}$.185	$\bar{0}$.031	0.130	$\bar{0}$.058									
0.667	$\bar{0}$.056	$\bar{0}$.706	$\bar{0}$.578	$\bar{0}$.571	0.167	0.492								
0.541	$\bar{0}$.374	$\bar{0}$.921	$\bar{0}$.776	$\bar{0}$.733	0.511	0.285	0.704							
0.792	$\bar{0}$.398	$\bar{0}$.968	$\bar{0}$.885	$\bar{0}$.830	0.324	0.315	0.801	0.902						
$\bar{0}$.793	0.517	0.889	0.821	0.763	$\bar{0}$.208	$\bar{0}$.182	$\bar{0}$.775	$\bar{0}$.794	$\bar{0}$.919					
0.389	$\bar{0}$.731	$\bar{0}$.634	$\bar{0}$.620	$\bar{0}$.657	0.635	$\bar{0}$.304	0.188	0.556	0.456	$\bar{0}$.503				
0.277	0.657	$\bar{0}$.029	0.049	0.206	$\bar{0}$.324	0.860	0.461	0.057	0.223	$\bar{0}$.152	$\bar{0}$.594			
0.135	$\bar{0}$.699	$\bar{0}$.428	$\bar{0}$.477	$\bar{0}$.573	0.670	$\bar{0}$.499	0.143	0.452	0.298	$\bar{0}$.272	0.747	$\bar{0}$.742		
$\bar{0}$.720	$\bar{0}$.210	0.578	0.429	0.384	$\bar{0}$.007	$\bar{0}$.706	$\bar{0}$.897	$\bar{0}$.575	$\bar{0}$.717	0.661	0.013	$\bar{0}$.688	0.127	
$\bar{0}$.808	0.458	0.911	0.920	0.797	$\bar{0}$.451	$\bar{0}$.194	$\bar{0}$.631	$\bar{0}$.784	$\bar{0}$.901	0.812	$\bar{0}$.565	$\bar{0}$.122	0.$\bar{3}$38	0.571

APPENDIX TABLE. 10. Car Passenger Trips

CONSTANT	CAR OWNERSHIP	DENSITY	DISTANCE	FAMILY SIZE	SOCIO ECONOMIC STATUS	SOCIAL RANK	$\bar{R}^2$ r^2
-0.1501	0.8914 0.0613 14.55			0.0290 0.0236 1.23			0.9465
-0.0657	0.8895 0.0624 14.25						0.9398
0.3470			0.3652 0.0757 4.82	-0.1424 0.0683 2.08			0.6609
-0.0068			0.2874 0.0738 3.89				0.5381
-0.0093			0.1460 0.0381 3.69		0.0085 0.0012 7.41		0.9172
-0.0607					0.0108 0.0014 7.78		0.8232
0.4006		-0.2695 0.0714 3.77	0.2184 0.0551 3.96				0.7887
-0.0200						0.0062 0.0007 7.79	0.8235

APPENDIX TABLE. 11. WALKING TRIPS

CONSTANT	DENSITY	DISTANCE	SOCIO ECONOMIC STATUS	SOCIAL RANK	URBAN INDEX	NO. ACTIVELY EMPLOYED	r^2 R^2
2.2330	0.4407 0.1198 3.68	-0.6842 0.1123 6.09	0.0249 0.0051 4.93	-0.0174 0.0032 5.44	0.0074 0.0032 2.30	-0.0227 0.0078 2.92	0.9736
1.5880	0.4094 0.1554 2.63	-0.5557 0.1218 4.56	0.0248 0.0058 4.27	-0.0164 0.0040 4.11			0.9424
2.1070		-0.9042 0.01427 6.34					0.7554
1.8340	0.3834 0.1749 2.19	-0.8450 0.1433 5.89			-0.0041 0.0052 0.79		0.8354
1.5320	0.3804 0.1720 2.21	-0.8068 0.1327 6.08					0.8262

APPENDIX TABLE 12. SOCIAL TRIPS.

CONSTANT	FAMILY SIZE	DISTANCE	SOCIO EC. STATUS	CAR OWNER SHIP	HOUSE TYPE	NO. ACTIVELY EMPLOYED	NO. 5-14 YRS.	NO. 15-65 YRS.	r^2 R^2
-0.3169	0.2588 0.0912 2.84		0.0153 0.0031 5.00						0.7163
0.4427			0.0143 0.0037 3.80						0.5259
-0.3851	0.2216 0.0822 2.70			1.2250 0.2132 5.75					0.7671
0.2595				1.2100 0.2595 4.66					0.6258
0.2322		0.5362 0.1035 5.18							0.6737
0.2299		0.3973 0.0997 3.98	0.0080 0.0030 2.68						0.7958
-0.5755	0.3250 0.0902 3.60				0.0087 0.0016 5.20				0.7357
0.4075					0.0072 0.0022 3.26				0.4499
0.2051		0.4226 0.1086 2.02			0.0036 0.0017 3.89				0.7568
0.0461			0.0146 0.0028 5.13				0.0284 0.0086 3.30		0.7512
2.3490			0.0107 0.0036 2.98					-0.0289 0.0123 2.35	0.6754
-0.0742				1.1790 0.1989 5.92					0.7976
1.9300				0.9434 0.2615 3.61				-0.0247 0.0012 2.14	0.7292
2.2710						0.0353 0.0075 4.70			0.6299

APPENDIX TABLE. 13.

A. Other home based trips

B. Non home-based trips

C. Car Ownership

CONSTANT	FAMILY SIZE	DENSITY	DISTANCE	SOCIO ECON. STATUS	CAR OWNER SHIP	SOCIAL RANK	NO. ACTIVELY EMPLOYED	HOUSE TYPE	r^2 R^2
A. -0.4948	0.0761 0.0971 0.78	-0.0485 0.1169 0.41	0.0213 0.1009 0.21	0.0029 0.0045 0.67	0.7064 0.3371 2.10	-0.0021 0.0022 0.91	0.0058 0.0073 0.80		0.8665
A. -0.0682					0.6349 0.0823 7.72				0.8208
B. 13.9000							-0.1854 0.0320 5.79		0.7209
C. 0.6895	-0.1264 0.0971 1.30	-0.0500 0.1166 0.43	0.2375 0.1440 1.65	0.0107 0.0075 1.43		-0.0009 0.0035 0.25	-0.0025 0.0028 0.80	-0.0021 0.0029 0.72	0.9289
C. 0.1515				0.0118 0.0014 8.25					0.8396

Appendix 7(a) Detailed Classification Used in Land Use Analysis

1. OFFICES

Offices
Offices (central government)
Offices (local authority)
Offices (professions)
    Finance
    Insurance
    Real Estate
    Solicitors, etc.
Banks

2. PUBLIC BUILDINGS

Places of assembly, schools
Art gallery
Museum
Schools
Colleges
Law courts
Library
Labour exchange
Theatres, cinemas, public halls

3. RETAIL

Food
General merchandise
Clothes and accessories
Furniture, house furnishing and household appliances
Pharmacists
Miscellaneous retail stores
Dry cleaners (receiving)
Petrol stations (where no repairs)
Betting shops

4. SERVICE

Clinics
Doctors
Dentists
Opticians
Hospitals
Fire Brigade
Police
Cafes and restaurants
Hotels
Public houses
Window cleaners
Hairdressers
Pet salons

5. WHOLESALE

Wholesale food dealers and jobbers
Wholesale distributors with limited storage

6. STORAGE

Builders and contractors yards
Furniture depository
Grain silos
Local authority depots
Storage warehouse
Bonds
Storage yard
Transit warehouse

7. LIGHT INDUSTRY AND WORKSHOPS

includes repair garages

8. INDUSTRY

9. TRANSPORT

Railway
Bus
Haulage contractors

10. OTHERS

Agriculture
Armed forces
Cemeteries, parks, crematorium
Prison
Refuse destructor
Other utilities (water)
Quarry
G.P.O. (sorting office and exchange)

APPENDIX 7 (b) Distance Matric

Distance (from Zone Controid to Zone Centroid) in Miles

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0.11	0.20	0.17	0.25	0.31	0.18	0.09	0.33	0.27	0.26	0.68	0.58	0.63	1.01	0.96	1.14	0.78	0.45	0.38	1.47	1.54	1.68	1.27	0.85
2	0.20	0.09	0.28	0.42	0.44	0.33	0.26	0.36	0.28	0.20	0.50	0.60	0.80	1.17	1.07	1.15	0.67	0.48	0.35	1.36	1.42	1.53	1.08	0.68
3	0.17	0.28	0.09	0.22	0.40	0.31	0.21	0.47	0.43	0.42	0.76	0.48	0.55	1.04	1.07	1.29	0.89	0.62	0.55	1.63	1.69	1.80	1.38	0.97
4	0.25	0.42	0.22	0.04	0.25	0.22	0.19	0.43	0.44	0.47	0.93	0.67	0.50	0.83	0.88	1.21	0.90	0.57	0.56	1.67	1.75	1.92	1.49	1.07
5	0.31	0.44	0.40	0.25	0.12	0.11	0.21	0.24	0.29	0.37	0.91	0.91	0.74	0.72	0.66	0.95	0.69	0.34	0.38	1.48	1.58	1.80	1.41	0.97
6	0.18	0.33	0.31	0.22	0.11	0.11	0.10	0.22	0.23	0.29	0.92	0.77	0.67	0.83	0.77	1.01	0.68	0.35	0.35	1.46	1.55	1.74	1.33	0.92
7	0.09	0.26	0.21	0.19	0.21	0.10	0.09	0.28	0.26	0.28	0.76	0.68	0.62	0.91	0.88	1.09	0.73	0.42	0.38	1.48	1.56	1.73	1.32	0.89
8	0.33	0.36	0.47	0.43	0.24	0.22	0.38	0.10	0.09	0.20	0.73	1.05	0.88	0.89	0.72	0.82	0.46	0.14	0.15	1.23	1.34	1.56	1.17	0.75
9	0.27	0.28	0.43	0.44	0.29	0.23	0.26	0.09	0.03	0.11	0.64	1.07	0.87	0.97	0.82	0.88	0.47	0.20	0.12	1.23	1.32	1.50	1.12	0.69
10	0.26	0.20	0.42	0.47	0.37	0.29	0.28	0.20	0.11	0.12	0.54	1.03	0.88	1.08	0.92	0.95	0.48	0.29	0.17	1.22	1.28	1.44	1.03	0.62
11	0.68	0.50	0.76	0.93	0.91	0.82	0.76	0.73	0.64	0.54	0.29	1.23	1.30	1.62	1.43	1.29	0.70	0.77	0.62	1.14	1.12	1.09	0.65	0.35
12	0.58	0.60	0.48	0.67	0.91	0.77	0.68	1.05	1.07	1.03	1.23	0.35	0.86	1.49	1.54	1.85	1.21	1.03	0.94	1.97	2.01	2.08	0.65	1.27
13	0.63	0.80	0.55	0.50	0.74	0.67	0.62	0.88	0.87	0.88	1.30	0.86	0.22	1.32	1.38	1.68	1.34	1.02	0.99	2.09	2.18	2.47	1.97	1.58
14	1.01	1.17	1.04	0.83	0.72	0.83	0.91	0.89	0.97	1.08	1.62	1.49	1.32	0.36	0.44	1.09	1.21	0.90	1.02	1.91	2.06	2.37	2.03	1.62
15	0.96	1.07	1.07	0.88	0.66	0.77	0.88	0.72	0.82	0.92	1.43	1.54	1.38	0.44	0.41	0.65	0.88	0.66	0.82	1.50	1.67	2.04	1.73	1.35
16	1.14	1.15	1.29	1.21	0.95	1.01	1.09	0.82	0.88	0.95	1.29	1.85	1.68	1.09	0.65	0.25	0.58	0.68	0.79	0.91	1.10	1.53	1.34	1.05
17	0.78	0.67	0.89	0.90	0.69	0.68	0.73	0.46	0.47	0.48	0.70	1.21	1.34	1.21	0.88	0.58	0.30	0.35	0.34	0.77	0.89	1.18	0.86	0.50
18	0.45	0.48	0.62	0.57	0.34	0.35	0.42	0.14	0.20	0.29	0.77	1.03	1.02	0.90	0.66	0.68	0.35	0.12	0.15	0.13	1.24	1.49	1.13	0.72
19	0.38	0.35	0.55	0.56	0.38	0.35	0.38	0.15	0.12	0.17	0.62	0.94	0.99	1.02	0.82	0.79	0.34	0.15	0.11	1.11	1.20	1.41	1.02	0.61
20	1.47	1.36	1.63	1.67	1.48	1.46	1.48	1.23	1.23	1.22	1.14	1.97	2.09	1.91	1.50	1.91	0.77	1.13	1.11	0.24	0.20	0.70	0.72	0.78
21	1.54	1.42	1.69	1.75	1.58	1.55	1.56	1.34	1.32	1.28	1.12	2.01	2.18	2.06	1.67	1.10	0.89	1.24	1.20	0.20	0.38	0.50	0.60	0.77
22	1.68	1.53	1.80	1.92	1.80	1.74	1.73	1.56	1.50	1.44	1.09	2.08	2.47	2.37	2.03	1.53	1.18	1.49	1.41	0.70	0.50	0.35	0.44	0.84
23	1.27	1.08	1.38	1.49	1.41	1.33	1.32	1.17	1.12	1.03	0.65	1.65	1.97	2.03	1.73	1.34	0.86	1.13	1.02	0.72	0.60	0.44	0.19	0.43
24	0.85	0.68	0.97	1.07	0.97	0.92	0.89	0.75	0.69	0.62	0.35	1.27	1.58	1.62	1.35	1.05	0.50	0.72	0.61	0.78	0.77	0.84	0.43	0.12

Appendix 7(c) Floor Space Data

LAND USE	Traffic Zones 1	2	3	4	5	6	7	8	9	10	11	12
Residential	244797	100397	122558	8396	65729	348415	54230	141001	32459	342443	1589246	1071624
Retail	207376	15244	32454	290	-	58649	55291	6824	16538	47969	12357	13772
Office	365631	12933	119113	1940	9730	68272	9151	6758	4884	14838	25411	6421
Wholesale	60861	22892	4101	6433	-	69260	1937	1475	-	40128	72997	7631
Stores	133418	52229	35788	13448	1736	115698	43438	11559	5765	60776	36063	25830
Workships & Garages	40401	28535	3503	13958	1122	73880	36341	54256	3969	25932	139838	54812
Industry	7651	300098	39769	4158	7821	54969	-	5267	-	64840	312396	-
Public Buildings	105882	19221	50957	30506	13161	57197	7255	43634	7108	42083	127045	245832
Hotels, Cafes, etc.	20256	24247	76521	3145	1708	21813	66572	134638	41008	10779	11045	43046
Public Houses	8507	3523	1600	-	-	1671	11915	5302	1820	2850	-	2226
Cinemas, etc.	23785	32300	-	-	-	13760	-	-	-	-	109020	-
Derelict	34092	3428	6801	4722	-	5761	76731	12171	[illegible]	175772	10697	12389
Total	952657	615047	493165	86996	101007	889395	293803	422885	113551	828410	2641948*	1527583

LAND USE	13	14	15	16	17	18	19	20	21	22	23	24
Residential	241658	200440	1746504	797747	989751	740	56341	397734	2162950	336445	333821	2276077
Retail	292	979	14885	920	6792	3000	3723	2073	12859	2470	-	-
Office	-	8694	10856	5615	36121	21023	16133	1246	1608	74	-	4094
Wholesale	-	30302	75735	-	169319	8110	109535	-	-	-	-	6911
Stores	-	102236	34103	-	52161	15316	28898	5388	578	1191	17586	7815
Workships & Garages	-	58723	28310	404	139569	2000	42884	2203	7188	23467	10750	8784
Industry	-	333124	135896	-	95429	43825	-	-	-	-	147004	57183
Public Buildings	54562	379428	59544	167920	2009	292000	-	24500	19315	140796	-	11489
Hotels, Cafes, etc.	-	8914	11137	-	15166	4000	11064	-	-	7980	-	-
Public Houses	-	-	1120	1235	405095	-	-	-	6050	4461	-	-
Cinemas, etc.	-	-	-	-	-	-	-	-	-	-	-	-
Derelict	22193	1436	27200	108800	148559	-	550	200	-	-	-	-
Total	298705	1124386	2120810	984721	205997	290014	269128	433334	221054	56884	509161	323883

* this total also includes 195,833 square feet of War Office property.

Appendix 7 (d)

Summary of trip generation for 10 North American cities

	Residential		Commercial		Industry		Public		Transport	
	p.t.*	V.t.**	p.t.	v.t.	p.t.	v.t.	p.t.	v.t.	p.t.	v.t.
Tucson	18.2	13.0	134.3	112.6	3.9	4.3	14.3	8.8	-	-
The Twin Cities	26.5	15.2	187.9	118.7	12.6	9.3	17.4	7.5	-	-
Corpus Christi	30.5	19.7	174.4	127.7	10.6	8.6	35.3	22.0	-	-
Pittsburgh	23.9	14.6	157.8	110.6	24.6	21.7	15.9	6.8	21.3	35.0
Chicago	48.5	26.1	181.4	144.6	22.0	16.0	12.4	6.0	8.6	10.2
Detroit	29.1	-	271.2	-	37.2	-	16.5	-	-	-
Hutchinson (Kansas)	-	13.3	-	63.3	-	2.5	-	9.8	-	0.9
Ann Arbor	-	12.1	-	75.6	-	5.9	-	28.1	-	-
Flint	-	11.8	-	16.1	-	20.1	-	1.6	-	-
Baltimore	18.7	-	121.4	-	8.2	-	9.4	-	-	-
Range	18.2/ 48.5	11.8/ 26.1	121.4/ 271.2	16.1/ 144.6	3.9/ 37.2	2.5/ 21.7	9.4/ 35.3	1.6/ 28.1	8.6/ 21.3	0.9/ 35.0

* Person trip per acre
** Vehicle trips per acre.

Sources:

Ann Arbor Metropolitan Area Traffic Study, 1963
Baltimore Metropolitan Area Transportation Study, 1964
Chicago Area Transportation Study 1959-1962
Corpus Christi Transportation Study 1961
Detroit Metropolitan Area Traffic Study 1955
The Flint Metropolitan Area Traffic Study 1959
Hutchinson Transportation Study 1962
Pittsburgh Area Transportation Study 1961
Tucson Area Transportation Study 1960
Twin Cities Area Transportation Study 1962

Appendix 7 (e) Traffic Generator Study, San Diego Metropolitan Area Transportation Study

Factors used in San Diego to develop weekday trip origins.

LAND USE	TYPE OF AREA	FACTOR
Residential	Areas with less than 1.0 vehicle/household	2.7 origins/household
	Areas with 1.0 to 1.5 vehicles	3.2 origins/household
	Areas with over 1.5 vehicles	3.7 origins/household
Commercial	Strip development	215 origins/net acre
	Community and regional shopping centres	275 origins/net acre
Central Business District	Central core	700 origins/NA *
	Professional district	550 " "
	Mixed commercial	250 " "
	Industrial areas	180 " "
		105 " "
	Bay front district	150 " "
	Apartment district	200 " "
	Schools	60 " "
Industrial	Aircraft: without parking	180 " "
	some parking	110 " "
	parking	60 " "
	Modern industrial estates	65 " "
	Research estates	35 " "
	Distributional industrial area	85 " "
	Bay front and ship building	25 " "
	Large warehousing	50 " "
	Open storage and material plants	10 " "
Major Institutions	College without dormitories	0.7 origins/student
	High school	0.3 " "
	Civic Centres	140 origins/NA
	Hospitals: without parking	(2-3 origins/bed (175 origins/NA
	With parking	(4 origins/bed (70 origins/NA
Recreational	Ocean beaches	(175 origins/NA (0.33 origins/person
	Lake beaches	(650 origins/NA (0.33 origins/person
	Formal parks	10 origins/NA
	Undeveloped parks	2.5 " "
	Motels	5 origins/unit

* NA = per net acre

Appendix 8

Basic data used in the 'Haystack' and 'Residentrip' Computer Analyses

Traffic Zones	From Home car driver trips	From home cycle trips	From home bus trips	From home car passen-ger trips	From home walking trips	From home (other means)	Work	Business	Shop	School	Social	Other home based trips	Non-home based trips	Social Rank Index	Urban-isation index	Cycle Owner-ship	% Skilled Workers	% Manual Workers	% own occup. houses	No. actively employed	No. 5-14 years old	No. 15-65 years old	No. 65+ years old
1+7	0.152	0.330	0.279	0.025	2.235	0.101	1.524	0.025	0.431	0.609	0.584	0.050	4.37	12.34	77.14	0.303	50.0	73.0	11.0	54.9	10.0	70.1	14.2
2-5	0.483	0.161	0.419	0.161	2.064	0.161	1.611	0.161	0.419	0.806	0.386	0.128	4.65	9.69	50.63	0.193	52.0	71.0	15.0	44.8	8.8	68.0	16.5
6	0.096	0.193	0.274	0.016	1.774	0.032	1.322	0.032	0.387	0.435	0.225	0.016	3.21	17.64	82.11	0.241	52.0	71.0	19.0	57.0	8.7	67.8	17.4
8	0.096	0.193	0.225	0.064	1.967	0.032	1.419	0	0.483	0.483	0.258	0	2.52	17.85	87.59	0.225	60.0	84.0	10.0	52.1	8.3	72.9	12.5
10	0.207	0.116	0.181	0.025	1.765	0.025	1.363	0.090	0.428	0.350	0.116	0	3.10	13.12	70.33	0.291	52.0	73.0	15.0	59.2	8.8	66.4	15.8
11	0.439	0.560	1.037	0.210	1.280	0.032	1.411	0.102	0.509	0.845	0.551	0.191	4.86	28.75	70.27	0.429	51.0	77.0	20.0	50.6	12.7	67.7	13.0
12 + 13	0.990	0.403	1.110	0.339	1.000	0.091	1.541	0.183	0.550	0.752	0.761	0.174	5.93	72.21	57.27	0.275	35.5	47.5	41.0	42.8	12.6	58.3	23.7
15	0.511	0.622	1.483	0.157	1.200	0.019	1.641	0.086	0.679	1.023	0.650	0.019	5.89	30.58	79.22	0.471	38.0	75.0	29.0	48.0	18.5	64.4	10.4
16	1.718	0.218	0.921	0.609	0.890	0	1.437	0.203	0.515	0.734	1.125	0.390	7.08	99.05	56.43	0.281	12.0	14.0	85.0	37.1	13.8	60.5	19.0
17	0.702	0.257	0.881	0.207	1.376	0.039	1.366	0.148	0.524	0.772	0.653	0.049	5.29	54.17	78.33	0.376	43.0	57.0	60.0	39.1	16.2	63.0	18.9
20	1.875	0.250	1.075	0.550	1.100	0	1.500	0.200	0.650	0.975	1.125	0.450	7.62	65.71	51.88	0.350	30.0	35.0	82.0	39.4	13.9	61.2	17.8
21	0.635	0.343	1.996	0.273	0.992	0.043	2.098	0.080	0.390	1.218	0.562	0.178	6.49	49.09	69.60	0.521	61.0	84.0	0.5	44.4	21.2	61.5	4.3
22	0.525	0.700	1.925	0.150	0.990	0.975	1.800	0.050	0.450	1.125	0.975	0.050	6.40	40.34	55.69	0.550	56.0	84.0	7.0	40.7	23.6	57.9	4.4
23	0.142	0.607	1.589	0.017	2.071	0	1.714	0	0.660	1.553	0.607	0	6.52	2.38	53.30	0.375	44.0	91.0	3.0	41.3	21.0	59.2	6.9
24	0.809	0.380	0.904	0.285	0.952	0.047	1.333	0.095	0.476	0.476	0.857	0.190	5.15	38.34	72.71	0.333	49.0	59.0	63.0	47.1	9.8	66.0	17.9

Table 2 Basic data for 'Residentrip' (Zonal Average)
(Some of this data was also used in 'Haystack')

Traffic Zone	From Home Trips/ D.Unit	From Home Trips/ person	All Trips/ D.Unit	All Trips/ person	Person Trips /daily Traveller	Car Ownership	Household size	Distance	Density	% highest S.E.G.
1 + 7	3.21	1.27	7.58	2.99	1.53	0.18	2.54	0.03	1.54	6.0
2 - 5	3.51	1.27	8.16	2.94	1.55	0.23	2.75	0.15	1.06	9.0
6	2.41	1.03	5.62	2.39	1.30	0.15	2.32	0.22	1.41	2.0
8	2.64	1.08	6.16	2.51	1.32	0.16	2.39	0.28	1.68	2.0
10	2.35	1.01	5.45	2.34	1.31	0.12	2.32	0.18	1.64	2.0
11	3.65	1.19	8.51	2.77	1.36	0.18	3.06	0.75	1.41	5.0
12 + 13	3.96	1.45	9.89	3.62	1.69	0.51	2.73	0.69	0.92	27.0
15	4.10	1.30	9.99	3.16	1.47	0.25	3.15	1.06	1.28	7.0
16	4.40	1.58	11.48	4.12	1.86	0.75	2.75	1.34	0.79	54.0
17	3.51	1.33	8.80	3.32	1.48	0.25	2.65	0.78	0.99	20.0
20	4.90	1.54	12.52	3.94	1.75	0.67	3.14	1.35	1.13	37.0
21	4.52	1.31	11.01	3.18	1.41	0.36	3.46	1.24	1.46	4.0
22	4.45	1.29	10.85	3.14	1.40	0.25	3.42	1.22	1.65	5.0
23	4.53	1.08	11.05	2.63	1.27	0.09	4.19	0.72	2.04	0
24	3.42	1.34	8.57	3.33	1.59	0.43	2.45	1.09	0.83	13.0

APPENDIX 9

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