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TRIP GENERATION OF
SELECTED INDUSTRIAL GROUPS

by

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ABSTRACT

LEAKE, G.R. and GRAY, J.E. (1979) Trip generation of selected industrial groups. Leeds: University of Leeds, Inst. Transp. Stud., WP 113 (unpublished)

This paper determines the factors influencing commercial vehicle trip generation for selected industrial groups, and quantifies their effects using multiple regression analysis. Two methods of selecting the groups were adopted: one using eight of the Standard Industrial Classes; and one which attempted to put industries having similar vehicle generation characteristics into the same group, by subdividing SIC groups or by grouping together industries with similar manufacturing or trading processes. The survey combined an initial interview of firm's management about the operations of the firm with a recording by the firm of their travel data, using a sample of firms in the West Yorkshire metropolitan area. Of 22 relationships developed, 15 were considered acceptable descriptors of the variations in trip making, but only in 3 cases did a single variable (such as total floor area or total employees) account for more than 70 percent of the variation, and no single variable type gave the best fit for the various groups investigated.

TRIP GENERATION OF SELECTED INDUSTRIAL GROUPS

by G.R. Leake and J.E. Gray

1. Introduction

The analytical procedures constituting the transport planning process can be broken down into trip generation, trip distribution, modal split, and trip assignment. Although the four stages are clearly inter-related, the traditional approach has been to treat each stage more or less as a separate entity. This has been particularly true of trip generation, which is the subject of this paper.

Trip generation is important in that it establishes the scale of movement and hence has an important bearing on the level and cost of transport infrastructure which needs to be provided in order to cater for the anticipated demand. To date most of the studies on trip generation have been concentrated on person trip generation, primarily at the home end of the trip, using either regression analysis or category analysis as the mathematical technique.

Considerably less detailed research endeavour has been devoted to commercial vehicle trip generation to/from industrial premises. The reasons for this are:-

a) that it is difficult and costly to obtain sufficiently detailed data;
b) that since there is a wide range of type of industry, it is important to study a number of sub-groups (with industry within each sub-group having similar characteristics) if a sufficiently detailed analysis is to be carried out.

However, separating industry into a number of sub-groups creates another problem - that of accurately predicting the values of the influencing variables for each sub-group. Consequently most commercial vehicle trip generation studies, carried out as part of a Land Use/Transport Study, have adopted the macro approach, with various industry types 'mixed' together at the zonal level. Yet a little thought will be sufficient to show the importance of commercial vehicle movement in transport planning.

To take just two points. Firstly commercial vehicles are larger and slower than private cars. Consequently they exert a greater influence on road capacity than the latter. To allow for this it is normal practice to assume that one heavy commercial vehicle is equivalent, on average, to three passenger cars (i.e., 1 heavy commercial vehicle = 3 P.C.U.'s). Secondly, although commercial vehicles (including light vans) constituted only 10.3% of the total vehicle population in 1970, they consumed 29.2% of the total P.C.U. kilometres in Great Britain[1]. Hence it will be seen that commercial vehicles consume road capacity well in excess of their absolute numbers. Furthermore, because of their operating characteristics and their size, they contribute considerably to road traffic congestion, the costs of which run into hundreds of millions of pounds.

On the whole, past research work into industrial trip generation has treated the subject very generally. With only a few exceptions, most work (which has formed part of the major Land Use/Transport Studies), has been at an aggregated zonal level, and has considered different types of industrial unit together. This latter assumption is clearly a weakness. Vehicle generation characteristics of industrial premises depend on the type of process being conducted at the plant. For example, a car body manufacturing plant, which requires deliveries of steel and then distributes bulky car bodies to assembly plants, will generate more vehicle trips, per unit area, than a business concerned with the production of small machine tools.

The principal objective of the work set out in this paper is to attempt to fill in some of the gaps in our knowledge of industrial trip generation by looking at the characteristics of different types of firm. It is hoped that this will not only lead to a better understanding of the factors affecting industrial trip generation, but will also present the practising planner with a more useful mathematical prediction tool, and provide him with much useful data at a local planning level.

The paper is split into a number of sections. After setting out the main objective of the work outlined in the paper, a very brief, and to some extent superficial, review of some work carried out in this field will be attempted. This will be followed by a description of the study area from which the information was obtained, and the main problems encountered. Finally, some of the results obtained will be outlined and discussed for the industrial groupings considered.

2. Objectives

The main objective of the work set out in this paper was to determine and quantify the factors influencing vehicle trip generation for the industrial groups selected for study and which are defined in section 7.

The remainder of the paper is concerned with briefly outlining some previous work on industrial trip generation undertaken in this country, and then with describing the method of study and some of the results obtained.

3. Previous Work

Because of the limited space available, it is proposed to restrict discussion to:-

a) *Work carried out in Great Britain;*
b) Work carried out at the individual premise level.

For a more exhaustive treatment, reference should be made to two previous papers[2,3].

3.1 Some previous studies in Great Britain

3.1.1 W. Skellern[4]. Skellern, in his study of the Trafford Park Industrial Estate, Manchester, in 1961, examined a wide range of manufacturing and distributive trades. Firms were categorised into three classes of generator (high, medium, low). Because of the low sample size, the established regression models were not very accurate.

3.1.2 T.E.H. Williams and J.C.R. Latchford[5]. In this study, carried out in North East England in 1962, an attempt was made to relate traffic generation (which included the journey to work) of various types of industrial land uses with parameters such as employment. Four major industries, covering 34 factories, were considered: mechanical engineering, electrical engineering, plastics, textiles and clothing. Both simple and multiple regression models were established.

3.1.3 D.N.M. Starkie. This work was carried out in the Medway towns area in 1964. The 77 firms included in the survey embraced a wide range of manufacturing industries. Interviews were carried out at management level in order to obtain information on employment, floor space, etc., and vehicle movements were obtained by observation for one day. Trip generation equations were obtained using both linear and non-linear regression analysis. Starkie concluded that the type of manufacturing activity was an important determinant of trip generation, but that these activities could be grouped into a limited number of classes having similar trip generation characteristics.

3.1.4 G.R. Leake and R.C.H. Gan[7]. This study was carried out in Leeds, Bradford and Sheffield in 1969. Five distributive trades (totalling 116 firms) were studied and data was obtained for one day by means of a postal return questionnaire. Simple regression equations were established with vehicle trip generation as the dependent variable, and employment, total floor area, storage space, or site area being tried as the independent variable. Four different types of mathematical relationship were investigated - linear, parabolic, exponential, and power functions. No single parameter gave the 'best fit' for all five trades, although one of the 'area' measures was found to be consistently better than employment. Trip generation varied considerably between the groups studied.

3.1.5 I. Wallace[8]. Wallace, in his 1969 North Midlands study, investigated four industrial groups (engineering, textiles, pottery, food and chemicals) covering 76 firms. Vehicle movements were obtained from a one-day survey at the factories. Linear regression analysis was carried out relating trip generation with employment. Good correlations were obtained except for the 'potteries' group. Comparison of his results with those obtained by Starkie[6] showed reasonably close agreement, suggesting that changes over time may not be too rapid.

3.1.6 D. Maltby[9,10]. Two studies have been carried out by Maltby. The first study[9] involved a detailed examination of the Sheffield steel industry in 1967 and covered two groups: metal manufacture and production of metal goods. Linear regression analysis was used with total employment and total floor space as the independent variables. The second study[10] was carried out in 1970 in Manchester and Sheffield. Firms were studied at the Standard Industrial Classification (S.I.C.) level. A questionnaire technique was used to collect the data. This study recognised the importance of daily variations in vehicle flow and collected data for a complete week. Simple regression analysis gave the best results.

3.1.7 B.G. Redding[11]. This work was carried out in North-West London and investigated two types of industrial land use: clothing manufacture and electrical engineering. Vehicle movement data were obtained over a week. Direct interviews were carried out with the management of each firm in order to gain co-operation and items of data relating to the firm. Simple regression analysis was adopted, with total floor area or total employment usually being the 'best fit' independent variable.

3.2 Variables found to be important

Since relationships developed in trip generation studies are normally intended for prediction purposes, the independent variables should satisfy a number of requirements:-

1) They should be easily measurable;
2) They must be capable of accurate prediction.

Variables which have been found to be important in past studies are:-

1) Total employment
2) Employees by type (e.g. office workers)
3) Total floor space
4) Floor space by type (e.g. production floor space)

Other variables which have been tested include rateable value, number of company-owned vehicles, distance from the Central Area, number of parking spaces within the site and site area.

Of the four main variables listed above, total floor space and total employment have usually been found to exhibit high collinearity.

3.3 Analysis method

In virtually all cases simple linear regression analysis has been the mathematical technique adopted. In a few instances multi-variable linear regression analysis has been tested, but has not been found to add significantly to the 'explanatory' power of the relationship. Starkie[6] and Wallace[8] found that logarithmic relationships gave good results, whilst Leake and Gan[7] found that a parabolic relationship gave the 'best fit' for certain types of movement.

3.4 Conclusion

This brief outline of work on industrial trip generation in Great Britain enables certain general conclusions to be drawn. These are:-

1) Data should be collected preferably over a week;
2) The variables set out in section 3.2 should be included in the initial analyses;
3) No single parameter has been found to be the 'best' explanatory variable;
4) Simple regression analysis has usually been used;
5) Different industrial groupings have significantly different trip generation characteristics.

4. Description of the Study Area

The geographical area chosen for investigation was the Metropolitan County of West Yorkshire (see Figure 1). This was adopted for the following reasons:-

a) An up-to-date sample frame of industrial premises was available for nearly all of the area;
b) The area contained a sufficient number of firms within each of the groups selected for study;
c) Since personal contact with management was to form part of the data collection method (see section 5), there were considerable time and cost advantages in having a study area based on Leeds.

The Metropolitan County of West Yorkshire is a major centre for both commerce and industry, and is heavily dependent on wool textiles, clothing, and certain sectors of the engineering industry. Over 75% of the working population are employed in four main industries - engineering, textiles, clothing, and food production.

The economy of the area is very dependent on the textile industry which employs about 15% of the total workforce (about five times the national average). Engineering has been traditionally linked with the textile trades, thus creating an emphasis on the 'heavier' types of engineering product. A national demand for 'lighter' engineering products has been growing in recent years, and this trend is being reflected in the County, thus providing a better balanced engineering industry.

The clothing industry has undergone considerable change during the last decade. In the main clothing trade centre - Leeds - the industry employed 12% of all workers in 1971.

Despite the concentration on the above-named four industries, the remaining workforce is employed in a wide variety of industries; many being geographically localised such as printing, steel foundries, and non-ferrous metal manufacture in Leeds; sweets and biscuit manufacture in Batley and Halifax; tractors and associated components in Bradford and Huddersfield; and chemicals in Leeds and Huddersfield.

5. Survey Methodology

5.1 Introduction

In this paper it is not possible to outline, in detail, the survey methodology adopted in the study; this is covered fully elsewhere[12]. All that is proposed, therefore, is to set out, in general terms, the basic information obtained, the method of data collection, and the determination of the sample.

5.2 Information collected

The data required fell into two categories:-

(i) Details of the firm;
(ii) Trip movements to and from the firm's premises.

In this study the data obtained relating to the firm included floor area (broken down into different uses such as manufacturing, storage, etc.), number of employees (broken down by sex and job type), site area, designated parking areas, number and type of vehicle based on the premises, rateable value, type of goods being produced, and location. Where possible, the variation in business activity throughout the year was discussed with the firm, but not quantified.

Trip information was obtained for all vehicle movements made to/from the premises. Vehicle movements were categorised by type, and the time of arrival and departure of each vehicle was determined as well as the trip purpose (specified as goods in, goods out, service visit, visitor trip, etc.).

5.3 Method of data collection

At the outset of the study the most practical methods of collecting the required data were carefully examined[3], of which the following were considered to be the most suitable:-

1) Postal questionnaire;
2) Interview and travel data collected by the survey team;
3) Initial interview by the survey team, travel data recorded by the firm.

After due consideration, it was decided that the last alternative was the most satisfactory in terms of the amount and reliability of the data collected, and in maintaining a reasonable level of survey response.

In broad outline the survey method was as follows. The sampled firms were first sent an introductory letter which briefly set out the objectives of the study. Telephone contact was then made with each firm and a more detailed explanation of the purpose of the survey given. At the same time arrangements were made for the interviewers to see senior management within the firm. As will be seen from Table 1, about one third of the suitable firms declined to participate further in the study at the telephone contact stage.

At the interview, the firm's management were questioned on the operations of the firm and asked to give the required basic information concerning the firm (e.g. employment levels) together with any other background information which might be useful in interpreting the results. The requisite number of questionnaires were left with the firm for distribution and completion covering an agreed weekly period. Three basic types of questionnaire were used, namely:-

1) Personal business movements (covering the firm's own employees);
2) Visitor movements;
3) Goods vehicle movements.

As will be seen from Table 1, a further 20% of firms declined to participate further in the study at the interview stage, the main reason being that it was beyond their organisational capabilities. However, 54.9% of firms interviewed completed the survey.

5.4 Sample selection

As noted earlier, one of the main reasons for selecting the West Yorkshire Metropolitan Area for study was that a sample frame of industrial premises was in existence for almost all the area. This was brought up to date, and provided data on:-

1) The firm's address;
2) The type of activity carried out;
3) The employee size band.

The up-to-date sample frame was stratified into the groups selected for study and firms chosen randomly from within each stratum until a minimum sample, within each stratum, of 70 firms had been chosen. However, this was not possible for all groups because of inadequate numbers within the original sample frame.

6. Survey Response

6.1 Introduction

In this section the response rates obtained in the survey are outlined and the tests adopted for detecting response bias set out. The section ends with a brief discussion on the manual check surveys carried out.

6.2 Response rates

6.2.1 Overall response rate. From the pilot survey which had been carried out, it was anticipated that the response rate would be about 45% of the initial sample, as against the 40% achieved in the pilot, due to subsequent up-dating of the sample frame. However, as will be seen from Table 1, this proved to be extremely optimistic. A total of 1123 firms were selected initially for study, of which 325 (29%) were found to be either non-existent or unsuitable. A detailed breakdown of the reasons for losing the 325 firms from the initial sample is set out in Table 2.

As shown in Table 1, the final response rate achieved in the survey was only 25.6% of the initial contacts (or 36.2% of the acceptable sample after allowing for the loss of the 325 firms). Table 2 indicates that about 50% of the 'lost' firms had ceased trading. This was over 14% of the initial sample and compared with a figure of 8% in the pilot. Furthermore, 165 firms were incorrectly classified, either in terms of employee size (the study was only looking at firms employing between 5 and 300 employees) or in terms of the MLH (Minimum List Heading). In passing, it should be noted that the employee size of 300 was considered to be the maximum which could be satisfactorily covered by the chosen study method.

6.2.2 Response rate by industrial group. In a survey of this nature, where a wide range of industrial groups were studied, some variation in the response rate can be expected. This is set out in Table 3, and clearly shows the wide range of response obtained, with the lowest response being in the Drink industry (20.5%), the highest in the Wooden Products industry (55.0%).

6.3 Response bias

Before commencing the analysis, it was essential to check the responses in order to see if they were representative of the sampled population. Tests for bias were carried out using the χ^2 (chi-squared) test for 'goodness of fit', i.e. comparing the distribution of the initial sample with that obtained from the returns.

Tests for bias were carried out using two criteria:-

a) Size of firm;
b) Location of firm.

The results of these tests are set out below.

6.3.1 Size of firm. This test was carried out for each of the 14 groups listed in Table 3. For each group the firms comprising the original acceptable sample and those completing returns were broken down into a number of employee size ranges, and the resulting distributions compared. In 12 out of the 14 groups there was no significant difference between the distributions at the 95% level of confidence. In the other two cases, there was no significant difference at the 90% confidence level. Thus it is concluded that the completed returns were representative of the original acceptable sample based on employment size.

6.3.2 Location of firm. In order to investigate possible response bias by location, the study area was divided into five sub-areas. Four were centred upon the major urban areas of Leeds, Bradford, Huddersfield and Wakefield. The fifth was a composite of the smaller mill towns in the south of the study area such as Dewsbury, Batley, etc. As can be seen from the results shown in Table 4, there is no evidence of bias in the returns by location of the firm.

6.4 Check surveys

Because of time and cost limitations, it was only possible to organise manual check surveys on vehicle trip rates at the premises of 27 firms; the firms being split among the engineering and clothing industries. In the event, however, it was only possible to use the results for 16 firms, since four of the selected firms carried out the survey for a different week to that agreed, and seven did not complete the survey after agreeing to do it. Of the 16 useful firms, 8 were from the engineering industry, and 8 from the clothing industry. The total number of trips recorded by firms were 95% and 90% of those actually observed for the engineering and clothing trades respectively.

It is not possible to draw any firm conclusions from the results obtained because of the low sample size. However, the indications are that the recording of trips was generally of a high standard, with under-reporting being in the range 5%-10%. This is considered to be as good a result as is likely to be achieved, and compares favourably with the 15% level of trip under-reporting found in Household Home Interview Surveys.

7. Results

7.1 Relationships established

In common with most work on industrial trip generation, regression analysis was selected as the analytical method - in this case multiple regression analysis. The results considered are limited to those relationships linking total weekly vehicle trips (the dependent variable) with measurable parameters of the firm. It should be noted that the total weekly vehicle trips were aggregated over Monday-Friday (inclusive) and included all vehicular trips (both visitor and firm's business) to and from the firm's premises but excluded journey to work trips and other trips not concerned with the business of the firm. A trip was defined as a one-way movement either to or from the premises.

In order to determine the 'best' regression model, multiple stepwise regression analysis was used in which variables were entered into the regression analysis in the order in which they provided the greatest explanation. Twenty explanatory variables were used and these (together with the units in which they were measured) are set out in Table 5.

7.2 Groups investigated

Earlier in the paper the importance of separating industries into groups having similar commercial vehicle trip generation characteristics was stressed. In this work two basic grouping systems have been used, namely:-

a) Standard Industrial Classification (S.I.C.) system;
b) Intuitive groupings of industries having similar characteristics.

The S.I.C. grouping system provides a nationally recognised grouping system but one which is relatively coarse. In this work eight S.I.C. groupings were adopted, and these are shown in Table 6.

The intuitive grouping system was an attempt to put industries having similar vehicle generation characteristics into the same group. This was done by either sub-dividing S.I.C. groups (using Minimum List Headings (M.L.H.)) or by grouping together industries from different S.I.C. groups which had similar manufacturing or trading processes. Because of the small number of firms appearing in some of the initial groupings, it was necessary to combine some groups together in order to achieve a reasonable sample size, even though the industries were considered to have somewhat dissimilar characteristics. In the final analysis, 14 groups were identified. These are set out in Table 7.

It is not intended, as part of this paper, to compare the results obtained for the two grouping systems. This aspect will be covered in a later publication.

7.3 Criteria for testing the vehicle generation equations obtained

When looking at the validity of multiple regression equations, there are a number of tests which need to be applied if meaningful interpretation of the results is to be obtained. In this work five criteria were adopted:

a) What is the value of R^2?
b) Do the individual regression coefficients have the correct sign and reasonable magnitude?
c) Is the value for the constant term reasonable?
d) Are the regression coefficients statistically significant?
e) Do the independent variables, found to be significant, make sense?

7.4 Results for the S.I.C. groupings

The results obtained for the eight selected S.I.C. groups, together with the number of observations falling within each group, is shown in Table 6. In this section it is proposed to comment briefly on the result obtained for each group, and then to draw some overall conclusions.

7.4.1. Food and drink (S.I.C.3). Despite having a high R^2 value of 0.74, the established relationship has two weaknesses which restrict its usefulness. The first is the very high value of the constant term (70% the mean value of the dependent variable) and the second is the negative sign associated with the variable X_8 (% site area built upon). The latter indicates that the greater the area of the site which is built upon, the lower the number of trips generated. It is difficult to see the logic of this. The main significant variable was found to be total office employment (X_{14}).

7.4.2 Mechanical engineering (S.I.C.7). This group includes both heavy and precision mechanical engineering. Both the R^2 value (0.67) and the value of the constant term are acceptable, and the three significant explanatory variables (female office employment (X_{13}), total business vehicles operated by the firm (X_{20}), and area built upon (X_7)) are of the correct sign. What is, perhaps, surprising is the apparent significance of the number of female office employees for this group.

7.4.3 Instrument engineering (S.I.C.8). Although the sample size was low, the simple regression equation obtained was highly significant ($R^2 = 0.88$). Furthermore the value of the constant term was low and the coefficient of the explanatory variable (total office employment) was of the correct sign. It is, however, difficult to explain, for this group, why total office employment should be more significant than total non-office employment.

7.4.4 Electrical engineering (S.I.C.9). The relationship obtained accounts for 76% of the observed variation. The magnitude and sign of the regression coefficients is acceptable, with the two most significant explanatory variables being X_{20} (the total business vehicles operated by the firm) and X_9 (the number of male non-office employees). Intuitively both these variables could be expected to influence total vehicle generation. It is to be noted that X_{20} (total business vehicles operated by the firm) is a significant variable in the Mechanical Engineering group and in the following General Mechanical Engineering, Textile Industry, and Timber and Furniture groups.

7.4.5 General mechanical engineering (S.I.C. 12). With an R^2 value of 0.70 and the three significant variables (total business vehicles (X_{20}), number of male office employees (X_{12}), and number of female non-office employment (X_{10})) having the correct sign, the relationship is basically acceptable. The constant term is a little high when compared with the dependent variable mean value, and the intuitive validity of female non-office employment could be questioned.

7.4.6 Textile industry (S.I.C.13). This relationship has a constant term close to zero and an R^2 value of 0.70. The three significant variables (office floor area (X_4), total business vehicles (X_{20}), and male office employment (X_{12})) have the correct sign, but the influence of office activity (particularly office male employment) is somewhat difficult to explain. It should be noted that the variable (male office employees) is only significant at the 90% confidence level.

7.4.7 Clothing industry (S.I.C.15). This relationship does not appear to be particularly reliable. Firstly it has a low R^2 value (0.49). Secondly it has a high constant term (about half the mean value of the dependent variable).

7.4.8 Timber and furniture (S.I.C.17). As will be seen, four variables were found to be significant, with one of the variables (other floor area (X_5)) having a negative coefficient. However, since this relates to 'unproductive' floor area, this may not be illogical. The relationship is considered to be acceptable and has an R^2 of 0.68.

7.4.9. The principal conclusions to be drawn from the results set out in Table 6 can be summarised as follows:-

1) As can be seen from col. 5, the average number of weekly vehicle trips varies considerably between groups, with the lowest value of 32.25 being for the Instrument Engineering group, and the highest (83.3) for Food and Drink.
2) Generally, the relationships established have been found to be acceptable in terms of R^2, the size of the constant term, the sign attached to the explanatory variables, the significance of the explanatory variables, and the type of explanatory variable found to be significant. The two main exceptions were the Food and Drink, and Clothing Industry groups.

3) Only in one instance (Instrument Engineering) was the R^2 value greater than 0.80. In this instance, however, the sample size of 12 was very low.
4) The variables found to be significant varied between the groups, and were not necessarily the most intuitively obvious ones in some cases. The variable occurring most frequently was X_{20} (total business vehicles operated by the firm) and this was found to be significant in five of the groupings. The next most frequently appearing variables occurred only twice. The employment variables (X_9 - X_{17}) also featured in many of the relationships, occuring 8 times. However, there was no consistency in the actual employment variable between groups.
5) Variables relating to floor or site area (X_1 - X_8) did not figure quite so prominently as the employment variables in the established relationships - appearing six times. Again, there was no consistency in the type of area variable found to be significant.

7.5 Results for the 14 intuitive groupings

The results obtained for the 14 intuitive groups selected, together with the number of observations falling within each group, is shown in Table 7. The arrangement of the section is identical with that adopted for section 7.4.

7.5.1 Bread, flour and confectionery. This relationship has been established from 10 observations only, and despite a high R^2 value of 0.84, suffers from the same problems as the relationship established for the Food and Drink group in section 7.4.1 - namely an extremely high constant term and a negative coefficient associated with variable X_8 (% site area built on). The main significant variable X_3 (storage floor area) seems intuitively satisfactory.

7.5.2 Other food products. The result obtained for this group (which excludes bread, flour and confectionery) cannot be considered satisfactory for three reasons:-

a) the high value of the constant term (approximately 70% of the dependent variable mean value);
b) the negative coefficient associated with X_1 (total floor area), although this is mitigated by the extremely low value for the coefficient;
c) the low R^2 value of 0.44.

It will be noted that the variable found to have the greatest significance was the number of business vehicles operated by the firm (X_{20}).

7.5.3 Drink industry (including brewing). This is the smallest group for which a regression relationship was established, and the low number of observations (8) is clearly unsatisfactory. However, examination of the result obtained leads to greater optimism. From Table 7 it will be seen that a simple linear regression relationship was established with an R^2 of 0.98, and with an acceptably low value for the constant term. The significant independent variable was found to be total office employment (X_{14}) - perhaps a reflection of the automation involved in the drink manufacturing industry.

7.5.4 Heavy mechanical engineering. The group size is considerably higher than the three already considered in this section. The R^2 value of 0.75 is satisfactory, and the values and sign of the coefficients is acceptable. It will be noted that the variable found to be most significant was X_{13} (total number of female office staff). It must be admitted that the logicality of this is not readily apparent unless there is a direct relationship between the amount of goods produced and the clerical staff needed to process those goods. The other variables found to be significant were X_{20} (total business vehicles operated by the firm) and X_7 (total area built on).

7.5.5 Precision mechanical engineering. For this group only one significant variable was obtained, namely the number of business cars operated by the firm (X_{18}), giving an R^2 value of 0.56. The nature of the explanatory variable, and the difficulty of its prediction, makes the relationship of limited value for planning purposes.

7.5.6 Light electrical engineering. This particular relationship again provides an example of non-logically signed variables. Manufacturing floor area (X_2), which one would expect to be positively associated with vehicle trip generation, is found to be negatively related, even though its value is low and only significant at the 90% level. Furthermore, the constant term is very high. The R^2 value obtained was 0.66 and the most significant explanatory variable was X_{14} (total office employment). It would be difficult to use the relationship with confidence.

7.5.7 Heavy electrical engineering. In view of the importance of car ownership levels on trip generation at the household level, it is not surprising to observe similar variables having a significant effect at the industrial premise level. In this case the number of goods vehicles (X_{19}) and the number of business cars (X_{18}) operated by the firm explain 88% of the observed variability. The relationship appears strong even though it is based on only 10 observations.

7.5.8 Instrument engineering. Once again the number of vehicles (in this case the total number of business vehicles (X_{20})) operated by the firm is the most significant variable; the other being total non-office employment (X_{11}). The constant term has a value close to zero and the R^2 value (0.92) is high.

7.5.9 Metal products. This relationship provides one of the three instances in the total 22 groups where total employment (X_{17}) was found to be the most significant explanatory variable. The constant term obtained is a little high, but the R^2 value of 0.76 is satisfactory.

7.5.10 Textiles. Not a particularly satisfactory relationship, having a high constant term relative to the dependent variable mean value, and a low R^2 of 0.59. The two variables found to have greatest significance, namely total floor area (X_1) and total office employment (X_{14}), seem intuitively correct, especially the former. It will be noted that the trip generation capability of this group is low, being only 38 one-way trips per 5 day week, i.e. less than four 2-way trips per day. It will be noted that the coefficient for variable X_1 has a very low value.

7.5.11 Heavy outerwear clothing. A complex relationship involving four variables was derived for this group - the four variables being office floor area (X_4), total non-office employment (X_{11}), female office employment (X_{13}), and total goods vehicles operated by the firm (X_{19}). It will be noted that X_{13} has a negative coefficient. The value of the constant term is fairly high and the R^2 value (0.64) is just about acceptable.

7.5.12 Light clothing. Here the main significant variables were found to be those relating to the number of employees. Total employment (X_{17}) was the most significant variable. Furthermore, the constant term is low and the R^2 value (0.65) acceptable.

7.5.13 Timber products. One variable - male office employment (X_{12}) - was found to explain nearly 90% of the variation in the dependent variable. The significance of this variable is, at first glance, somewhat surprising. However, it will be realised that many firms falling within this group operate 'do-it-yourself' activities, with corresponding high levels of office-type employment. The value of the constant term is low.

7.5.14 Furniture production. The best regression relationship developed for this group contained two variables - total office employment (X_{12}) and the total number of business vehicles operated by the firm (X_{20}). It will be observed that the constant term is high relative to the dependent variable mean value, and the R^2 value is 0.74. The relationship can be considered to be acceptable.

7.5.15. The principal conclusions to be drawn from the results set out in Table 7 can be summarised as follows:-

1) Out of the 14 groups investigated, satisfactory relationships were established in 9 cases. The groups where it proved difficult to establish acceptable relationships were Bread and Confectionery, Other Food Products, Precision Mechanical Engineering, Light Electrical Engineering, and Textiles.

2) Of the nine acceptable relationships, three had R^2 values greater than 0.80. However, in all three instances the sample size was low (8-13).

3) Again, the variables found to be significant varied between the groups. The three variables occurring most frequently were total office employment (X_{14}) - 4 times, total goods vehicles operated by the firm (X_{19}) - 3 times, and total business vehicles operated by the firm (X_{20}) - 4 times. With this grouping arrangement there was less emphasis on the X_{20} variable than with the S.I.C. grouping arrangement.

4) The employment variables (X_9-X_{17}) were prominent- featuring more frequently than the variables related to the number of vehicles operated by the firm. However, there was a little more consistency in the type of employment variable found to be significant.

8. Validity of the Results for Planning Purposes

One of the aims of a research project of this nature is to provide mathematical relationships which can be used for predictive purposes in the short and medium term (5-15 years). In looking at this aspect, two questions need to be answered:-

i) How accurately can the variables, which have been found to be significant, be predicted for different future time horizons?

ii) Will the developed relationships be stable over time? From the results set out in Tables 6 and 7, the significant explanatory variables fall essentially into three groups:-

a) Floor/site area variables (X_1-X_8)
b) Employee variables (X_9- X_{17})
c) Variables relating to the number of vehicles operated by the firm (X_{18}-X_{20})

Considering the three variable groupings above, how do they react on the two questions posed at the beginning of this section?

a) Area variables. With the possible exception of site area measures, these variables can be difficult to predict, even though the planner has control over some of the measures of area used in this analysis (e.g. total floor area). The main problem, however, is that area variables cannot respond to changes in production methods and which result in higher output (and presumably higher vehicle trip generation rates) per unit area. This is clearly a problem, and analysis of suitable time-series data could help to overcome this.

b) Employment variables. Future levels of total employment are easier to predict than areas, although greater difficulties will occur when breaking down employment into finer sub-divisions such as office employment, non-office employment, etc. Unlike measures of area, employment levels are a more sensitive measure of a firm's economic activity and method of production. With regard to stability over time, the employment variables suffer from the same problem as the area variables. More automation, for example, can lead to lower employment levels but higher trip generation rates, and thus nullify any developed relationship. This is an area which needs to be further researched.

c) Vehicles operated variables. These have been found to be very significant variables for many of the industrial groups studied and may prove to be more stable measures of a firm's vehicle generation activity, since a firm (both now and in the future) will wish to maximise the use of its own vehicles. Hence an increase in production activity will lead to an increase in trips generated and a possible increase in the number of vehicles operated by the firm. However, predicting the future number of vehicles operated by the firm could prove to be difficult with our current knowledge of the factors influencing a firm's decision to operate its own vehicles rather than go to hire.

In summary, therefore, it cannot be argued that the relationships set out in Tables 6 and 7 will remain stable in the long term. However, in the short term, and particularly where no major changes have occurred in production technique, most of the developed relationships can be used with confidence by planners. In common with all trip generation relationships developed from cross-sectional data at a particular point in time, the predictability of the variables, and the stability of the developed relationship over time, are problems which cannot be overcome without further studies into these particular aspects. What is hoped is that by investigating industrial classes at a fairly fine level, planners will obtain:-

a) A more accurate planning tool for the short term and when devising local plans;
b) A fuller understanding of the factors influencing industrial vehicle trip generation.

In the analysis reported in this paper, the 'best' relationships have been set out using all the variables outlined in Table 5.

9. Conclusions

The main conclusions of this paper can be summarised as follows:-

i) In common with most work on industrial trip generation, the method of analysis adopted was regression analysis (in this case stepwise multiple regression analysis) linking total weekly one-way vehicle trips (Y) with measurable parameters of the firm (X's).

ii) Two industrial grouping systems were used in the analysis:-

a) A coarse system of 8 groups based on the Standard Industrial Classification (S.I.C.)
b) A finer system of 14 groups based on M.L.H. headings (and sub-headings) which attempted to have industries of similar vehicle generation characteristics within a particular group. For some groupings this finer division produced small sample sizes.

iii) Of the 22 relationships developed, 15 were considered to be acceptable on the basis of the 5 tests set out in section 7.3. These are indicated in Tables 6 and 7.

iv) In 3 cases only did a single variable explain more than 70% of the variation in trip making.

v) It was found that no single variable type gave the 'best' fit for the various groups investigated. This is not unexpected since the industries studied covered a wide range of activity. The frequency of occurrence of each variable is shown below:-

Variable	S.I.C. groups (8)	Subtotal	Intuitive groups (14)	Subtotal
Total floor area (X_1)	-		2	
Manufacturing floor area (X_2)	1		1	
Storage floor area (X_3)	-		1	
Office floor area (X_4)	2	6	1	7
Other floor area (X_5)	1		-	
Area built on (X_7)	1		1	
% site area built on (X_8)	1		1	
Male non-office employment (X_9)	1		-	
Female non-office employment (X_{10})	1		-	
Total non-office employment (X_{11})	-		2	
Male office employment (X_{12})	2	8	2	12
Female office employment (X_{13})	1		2	
Total office employment (X_{14})	2		4	
Total employees (X_{17})	1		2	
Total business cars (X_{18})	-		2	
Total goods vehicles (X_{19})	-	5	3	9
Total business vehicles (X_{20})	5		4	
	19		28	

vi) The two single variables found to occur most frequently for the S.I.C. Grouping and the intuitive grouping were X_{20} (total business vehicles) and X_{14} (total office employment).

vii) The 'single' type of variable, such as total floor area (X_1) and total employees (X_{17}), was not often found to be one of the significant explanatory variables in the 'best fit' relationships developed. This has implications regarding predictability of the explanatory variables, since it is easier to predict values for 'gross' variables (such as number of employees) than to predict values for 'breakdown' variables such as number of male employees, number of female employees, etc.

viii) Many of the developed regression relationships have a relatively high value for the constant term. Two possible explanations can be put forward:-

a) That there is a non-linear relationship between the variables for very small firms (i.e. below the firm size of 5 included in this study).
b) That there is a basic minimum level of vehicle activity required for servicing small firms.

ix) Most of the relationships developed (see Tables 6 and 7) are considered to be suitable for local planning purposes and short term projections. However, as in all studies of this nature which rely on cross-sectional data, there are problems with the stability of the relationships over the medium and long term, and with predicting the values of the explanatory variables at some future date. These problems can only be overcome by further detailed study into these particular aspects.

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	Total Number	Initial % of (a)	Acceptable % of (b)	Interviewed % of (c)	Surveyed % of (d)
No. of firms approached by letter (a)	1123	100.0			
No. of firms suitable (b)	798	71.0	100.0		
No. of firms interviewed (c)	526	46.7	65.9	100.0	
No. of firms agreeing to the survey (d)	430	38.3	53.9	81.9	100.0
No. of firms carrying out the survey	288	25.6	36.2	54.9	67.1

Table 1 - Overall response rate

	Total Number	%
No. of firms unsuitable	325	
No. of firms ceased trading	160	49.2
No. of firms employing more than 300	33	10.2
No. of firms employing less than 5	92	28.3
No. of firms wrongly classified	40	12.3

Table 2 - Breakdown of the unsuitable sample

	Initial Sample	Acceptable Sample(b)	Completed Returns(a)	Response Rate(a/b)
1. Bread, flour and confectionery	65	34	10	29.5%
2. Other food products	98	63	15	23.7%
3. Drink industry (including brewing)	60	39	8	20.5%
4. Heavy mechanical engineering	144	115	53	46.1%
5. Precision mechanical engineering	70	56	19	34.0%
6. Light electrical engineering	62	40	14	35.0%
7. Heavy electrical engineering	35	30	10	33.3%
8. Instrument engineering	48	30	13	43.4%
9. Metal products	54	42	15	35.7%
10. Textiles	118	82	31	37.9%
11. Heavy outerwear clothing	153	106	33	31.1%
12. Light clothing	110	81	29	35.9%
13. Wooden products	39	31	17	55.0%
14. Furniture production	67	49	21	42.9%
Total	1123	798	288	36.2%

Table 3 - Response rates by industrial group

	Area					
	1	2	3	4	5	Total
No. of firms sampled	432	258	170	107	156	1123
No. of firms suitable	303	175	126	80	114	798
No. of firms responding (O)	116	64	42	28	38	288
No. of firms expected to respond (E)	110	63	46	29	40	288

$\chi^2 = 0.845$ Degrees of freedom = 4

Tabulated value of χ^2 at the 95% level (4 d.f.) = 7.81

KEY: Area 1: Based on Leeds; Area 2: Based on Bradford;
Area 3: Based on Dewsbury and Batley;
Area 4: Based on Wakefield; Area 5: Based on Huddersfield

Table 4 - Result of bias test by location for all industrial groups

X_1	Total floor area (100's ft^2)	X_{11}	Total - non office employment (number)
X_2	Manufacturing floor area (100's ft^2)	X_{12}	Male - office employment (number)
X_3	Storage floor area (100's ft^2)	X_{13}	Female - office employment (number)
X_4	Office floor area (100's ft^2)	X_{14}	Total - office employment (number)
X_5	Other floor area (100's ft^2)	X_{15}	Total - male employment (number)
X_6	Site area (100's ft^2)	X_{16}	Total - female employment (number)
X_7	Area built on (1,000's ft^2)	X_{17}	Total employees (number)
X_8	% Site area built on (percentage)	X_{18}	Total business cars (number)
X_9	Male - non office employment (number)	X_{19}	Total goods vehicles (number)
X_{10}	Female - non office employment (number)	X_{20}	Total business vehicles (number)

Table 5 - Independent variables included in the regression analysis (together with their units)

Group number and Description	No. in Sample	Regression Equation	R^2	$\bar{Y}$	Root Resid. Mean Square	Sig. level of Eqtn.
*Food and Drink (S.I.C.3)	33	$Y=58.68+2.13X_{14}\underset{(b)}{-0.70X_8}$	0.74	83.3	33.65	0.001
Mechanical Engineering (S.I.C.7)	68	$Y=24.93+4.72X_{13}+1.32X_{20}+0.33X_7$	0.67	61.3	30.06	0.001
Instrument Engineering (S.I.C.8)	12	$Y=11.16+4.22X_{14}$	0.88	32.3	9.39	0.001
Electrical Engineering (S.I.C.9)	24	$Y=17.10+4.78X_{20}\underset{(a)}{+0.92X_9}$	0.76	82.3	25.33	0.001
General Mechanical Engineering (S.I.C.12)	20	$Y=20.11\underset{(a)}{+2.83X_{20}}\underset{(a)}{+3.36X_{12}}\underset{(b)}{+0.15X_{10}}$	0.70	45.0	12.13	0.001
Textile Industry (S.I.C.13)	43	$Y=-4.12\underset{(b)}{+0.49X_4}\underset{(a)}{+6.53X_{20}}\underset{(c)}{+1.93X_{12}}$	0.70	46.8	32.33	0.001
*Clothing Industry (S.I.C.15)	48	$Y=20.95+0.91X_4\underset{(b)}{+0.12X_{17}}$	0.49	43.7	23.31	0.001
Timber and Furniture Industry (S.I.C.17)	40	$Y=18.37+2.18X_{20}+0.07X_2\underset{(b)}{-0.23X_5}$	0.68	43.3	16.47	0.001

Notes: i) Y = total weekly one-way vehicle trips, X's are as defined in Table 5
ii) All regression coefficients are significant at the 99.9% level unless indicated as follows:-
(a) significant at 99% level, (b) significant at 95% level, (c) significant at 90% level
iii) The relationships developed for the groups shown with an asterisk (*) are not considered to be reliable

Table 6 - Regression relationships established for the eight groupings based on the Standard Industrial Classification (S.I.C.)

Group Number and Description	No. in Sample	Regression Equation	R^2	$\bar{Y}$	Root Resid. Mean Square	Sig. Level of Eqtn.
*1. Bread, Flour and Confectionery	10	$Y=107.26+\underset{(a)}{0.45}X_3-\underset{(a)}{0.79}X_8$	0.84	93.1	17.85	0.01
*2. Other Food Products	15	$Y=51.53+\underset{(a)}{2.82}X_{20}-\underset{(c)}{0.01}X_1$	0.44	71.6	36.10	0.01
3. Drink Industry (including Brewing)	8	$Y=29.90+2.62X_{14}$	0.98	93.0	14.46	0.001
4. Heavy Mechanical Eng.	53	$Y=22.61+5.04X_{13}+1.21X_{20}+0.37X_7$	0.75	61.4	28.13	0.001
*5. Precision Mechanical Eng.	19	$Y=19.17+10.20X_{18}$	0.56	53.0	21.80	0.001
*6. Light Electrical Eng.	14	$Y=56.21+2.43X_{14}-\underset{(c)}{0.12}X_2$	0.66	81.1	28.93	0.001
7. Heavy Electrical Eng.	10	$Y=13.93+\underset{(a)}{15.56}X_{19}+\underset{(c)}{4.22}X_{18}$	0.88	78.1	23.68	0.001
8. Instrument Eng.	13	$Y=1.46+5.10X_{20}+\underset{(b)}{0.70}X_{11}$	0.92	45.0	12.53	0.001

9. Metal Products	15	$Y=20.03+0.45X_{17}+\underset{(a)}{6.27X_{19}}$	0.76	43.6	10.74	0.001
*10. Textiles	31	$Y=21.74+0.03X_{1}+\underset{(c)}{0.32X_{14}}$	0.59	37.8	13.09	0.001
11. Heavy Outerwear Clothing	33	$Y=19.40+1.11X_{4}+\underset{(a)}{0.13X_{11}}-\underset{(b)}{2.57X_{13}}+\underset{(b)}{10.07X_{19}}$	0.64	47.6	19.92	0.001
12. Light Clothing	29	$Y=8.14+\underset{(a)}{0.35X_{17}}+\underset{(a)}{6.13X_{12}}$	0.65	37.6	17.66	0.001
13. Timber Products	17	$Y=19.01+11.53X_{12}$	0.89	59.7	27.43	0.001
14. Furniture Production	21	$Y=24.96+\underset{(a)}{0.94X_{14}}+\underset{(b)}{1.23X_{20}}$	0.74	49.5	14.00	0.001

Notes: i) Y = total weekly one-way vehicle trips, X's are as defined in Table 5
ii) All regression coefficients are significant at the 99.9% level unless indicated as follows:-
(a) Significant at 99% level, (b) significant at 95% level, (c) significant at 90% level
iii) The relationships developed for the groups shown with an asterisk (*) are not considered to be reliable

Table 7 - Regression relationships established for the fourteen intuitive groupings

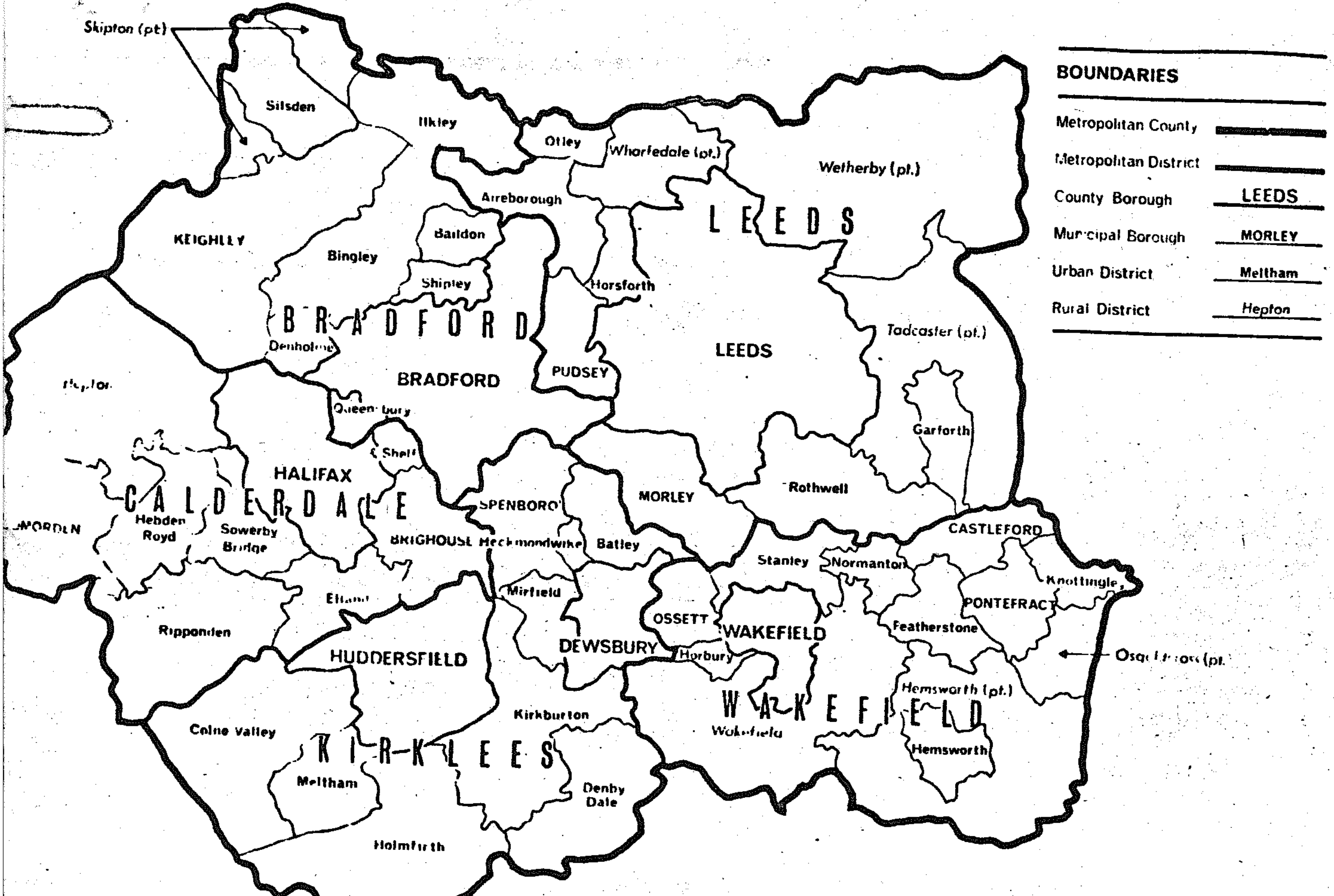

Fig.1. WEST YORKSHIRE METROPOLITAN COUNTY and DISTRICTS