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PARKING AND VEHICLE ACTIVITY SURVEYS AT LARGE CONVENIENCE FOODSTORES IN WEST YORKSHIRE: RESULTS AND GUIDELINES FOR DESIGN

S P Spinks

and

G R Leake

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G L O S S A R Y

Accumulation : As referred to herein this pertains to the number of parked vehicles within the boundary of a store's car park at a particular point in time. Also referred to as "Parking Accumulation"; however, the number of vehicles includes only stationary vehicles ie. it excludes circulating vehicles.

Flow Rate : (or "Vehicle Flow" or "Flow") refers to the number of vehicles either entering or leaving ("one-way" flows), or both entering and leaving in the same space of time ("two-way flow). In this report 15 minute flows are given.

Corrected Flow Index (CRFI) :
This is the "Flow Index" (see below) adjusted for the variation in the level of trading by being multiplied by the "Level of Trading Indicator" (see below).

Corrected Parking Index (CRPI) :
The "Parking Index" (see below) adjusted for the variation in the level of trading by being multiplied by the "Level of Trading Indicator" (see below).

Duration : (or Parking Duration) Is the time elapsed between a vehicle entering and subsequently leaving a store's car park. By this definition, duration includes the time vehicles are both parked and circulating within a store's car park.

Flow Index : This is the maximum observed two-way vehicle flow at a store during a given time period, divided by the retail floor area (RFA) of the store (square metres) and multiplied by 100. This gives the number of vehicles (per given time period) per $100m^2$ RFA.

Gross Leasable Area (GLA) :
Is the total enclosed area of the store.

Parking Index : Relating to either observed or design values. When observed, the Parking Index is the maximum parking accumulation (see above) divided by the retail floor area (RFA) of the store and multiplied by 100 to give vehicles per 100m^2 RFA. When specified as design values Parking Indices relate to the number of vehicle spaces per eg. 100m^2 RFA to be provided at the proposed new store.

Peak Time : Is the "time ending" (see below) at which either the peak parking accumulation or vehicle flow occurred. Mean peak time is the average of the peak times obtained at a set of stores on a particular day of the week (ie. Thursday, Friday or Saturday).

Retail Floor Area (RFA) : Is the internal floor area of the store used for selling and displaying goods.

Supermarket : A single level, self service store, supported by car parking, offering a smaller range of merchandise than a "superstore" (see below) and having a retail floor area (RFA) of less than 2500m^2.

Superstore : A single level, self service store offering a wide range of food and non-food merchandise with at least 2500m^2 of retail floorspace and supported by car parking. Stores with 5000m^2 or more RFA are commonly referred to as hypermarkets.

Time Ending : A term applied to a time period to denote the clock time at which that period ended. Thus, a 15 minute vehicle entry flow at "time ending" 1730 hours means that 50 vehicles entered a store's car park in the fifteen minute period ending at 1730.

Trading Indicator :

(or Level of Trading Indicator) A correction factor applied to the observed parking and flow indices to simulate "average" values likely to be encountered during a typical week-day; the resultant values are the "Corrected" Parking (CRPI) and Flow Indices (CRFI), (see above). Mathematically, the Trading Indicator is the total number of customer transactions for the survey week divided by the average weekly number of transactions for the year preceding the survey week.

1. INTRODUCTION

This report sets out the main results and conclusions of a series of vehicular activity and parking surveys at thirteen convenience food stores in West Yorkshire. The surveys, carried out in the period February - June 1982, were undertaken at stores ranging from a typical high street supermarket to large superstores. Data on vehicular flows and parking indices were obtained at twelve stores; in addition registration number surveys were completed at three stores to allow customer parking durations to be determined.

1.1 Background to the surveys

The work described herein forms part of a wider study into shopper travel characteristics, one of the aims of which is to provide guidelines and recommendations for inclusion in car parking design standards for retail facilities. The research is co-funded by the Science and Engineering Research Council (SERC) and West Yorkshire Metropolitan County Council (WYMCC).

1.2 Objectives

The initial objectives of the surveys at the convenience foodstores were:-

(1) To obtain peak period vehicular and shopper flow and parking accumulation rates.

(2) To obtain, information on parking duration.

(3) To use the results obtained from (1) and (2) above to assist in the formulation of design standards and planning policy recommendations for large supermarkets and superstores.

2. THE SURVEYS

2.1 Data Collected

The data collected comprised two groups which reflected objectives (1) and (2).

Two approaches to the collection of data were adopted after the Pilot Survey in February. The first approach (used at ten of the main survey stores) involved a simple count of vehicle flows in and out of, and vehicle accumulations within, the store's car parks. A variation of this first approach, undertaken at two stores, was to collect accumulation data only, since their car parks had too many entry/exit points to be covered by the available man-power. The second approach (undertaken at the pilot survey store and two of the main survey stores) consisted of recording vehicle registration numbers to permit the determination of parking duration. The second approach also enabled vehicle flows and accumulations to be obtained.

The two survey method approaches will henceforward be described as Type 1 for the first approach, and Type 2 for the second.

2.2 Survey Period

The surveys were executed in the period February to June 1982. A Pilot Survey was carried out in February to test the various data gathering approaches. The Main Surveys were undertaken continuously from the beginning of March - one store per week being surveyed except for a break of four weeks around the Easter period.

Every Main Survey store was surveyed on a Friday and Saturday and ten were also surveyed on a Thursday. The surveys began at 1600 hours on weekdays and 1000 hours on Saturdays. Where only simple flow and accumulation data was collected (Type 1), the surveys finished after the accumulation had reached its peak and was diminishing - the survey finishing usually not before 1930 on weekdays (the closing time for all the stores on weekdays was 2000), and 1230 on Saturdays. The registration number surveys (Type 2) began at 1600 hours and finished at 2000 hours (closing time) on Thursdays and Fridays); the corresponding times for Saturdays were 1000 and 1400 hours.

2.3 The Stores

Store choice criteria were evolved with regard to both the objectives and the financial and manpower constraints on the study.

The stores were located in a variety of situations :- three of the stores acted as the anchor trader in district centre complexes; as anchor trader they fulfil the predominant trading role, sharing the complex with other, smaller, retail and non-retail outlets. Of the other stores, three were in 'town-centre locations', adjacent to a main shopping street or high street; one other store was also in a 'high street' location but was in a suburban area; the remaining six stores were in 'freestanding' suburban locations (ie. they were not located within easy walking distance of any other retail outlets which might constitute an appreciable shopping attractor).

The characteristics of the store's catchment populations reflect a range of car ownership rates and socio-economic status. Two stores were in or near Wards of particularly high car ownership with respect to the County average, three stores were in or near Wards of low car ownership, whilst the remainder were located close to populations of average car ownership.

There is a comparable picture when the socio-economic status of the store's catchment populations is considered. Two stores were in Wards having a much higher proportion of professional/managerial people than the County average. Three stores were in Wards having an above average percentage of semi-skilled and unskilled workers. The rest of the store catchment populations conformed more closely to the County average.

In relation to the road network eight of the stores were located on or near to local distributors, four were on primary distributors (one of these a ring road), and one store was close to both a local distributor and a primary radial route.

Table 2.1 gives the physical attributes and year of opening of each of the stores.

Table 2.1 Physical Characteristics of the Stores Surveyed and their Years of Opening.

Store No.	RFA (m^2)	GLA (m^2)	Car park capacity	No. of Entry/Exits to car park	Year of opening
1	3010	4915	283	2	1976
2	2490	4357	189	1	1976
3	2982	4692	452	3	1976
4	4181	5110	400	2	1972*
5	1542	2731	90	2	1967
6	4929	8278	461	3	1969
7	2713	4394	395	3	1970
8	2155	3809	350	3	1969
9	2453	4156	250	1	1981
10	2108	4041	491	2	1981
11	1096	1400	107	1	1973
12	3066	4599	534	3	1972
13	2481	4673	195	1	1976

*This store was extended to its present dimensions in 1974.

Note: RFA = Retail Floor Area; GLA = Gross Leasable Area

2.4 Pilot Survey

The Pilot Survey was carried out at Store 1 over two consecutive days in February 1982 in order to test various data collection approaches. Both manual and non-manual methods were evaluated to determine which ones should be adopted given the man-power and financial constraints on the study.

Automatic vehicle detection apparatus was tried during the pilot survey but was found to be unresponsive to the low incident speeds of vehicles as they crossed the apparatus' tubes. It was therefore decided that the use of this apparatus was not practicable for the Main Surveys and that manual methods only would have to be employed. However, the limited manpower resources available meant that data pertaining to shopper flows and accumulations could not be obtained without loss of data on vehicular flows and accumulations (unless fewer stores were to be surveyed). Consequently, it was decided that if a reasonably large sample of stores was to be sampled, only vehicular activity data could be obtained; hence, Objective 1 (See Section 1.2) was amended to encompass vehicle flows and accumulations only.

A further consequence of adopting manual methods was that long time periods for recording were not practicable since:-

(i) manpower limitations, combined with the number of stores to be surveyed, mitigated against any form of "shift" system being operated; and

(ii) logistic problems associated with getting observers to and from the sites precluded any attempt at "full day" coverage.

A principal objective of the Pilot Survey was to test the Registration Number (Type 2) method of data collection. Generally no major problems were encountered although sometimes, when vehicle flows became large, it was often difficult for the observers to record all vehicle registration numbers. (This problem was somewhat ameliorated due to the propensity for queues to form at times of heavy flow so permitting a virtually static line of vehicles from which registration numbers could be more easily obtained).

2.5 Main Surveys

The Main Surveys were undertaken during the period March - June 1982. These surveys were carried out without major difficulty; although some sites presented problems where there were too many entry/exit points to the car park to be covered by the manpower available; in these cases only accumulation data was obtained.

The Type 2 surveys were more labour intensive, necessitating one observer per vehicle flow direction at each car park access point. Stores 1 and 6 required two observers whilst Store 10 needed four. The Type 1 surveys generally required only one observer, although two observers were needed at two of the stores.

The methods for the data collection have been mentioned in Section 2.4 (Pilot Survey). Essentially the Type 1 surveys entailed first obtaining an initial value of accumulation (by a simple count of parked vehicles) immediately before the start of

the survey period proper. The vehicle flow data (both inflow and outflow) were obtained using hand tally counters and aggregated over five minute periods. At half-hourly intervals the vehicle flow recording was halted and a "beat" survey carried out to check the parking accumulation within the next five minute period. This procedure was repeated until the accumulation had passed the peak value. The session was completed after a final "beat" survey was undertaken - again to check parking accumulation. Only cars and light goods vehicles were recorded during these surveys.

The Type 2 surveys were also commenced by obtaining the "initial" value of parking accumulation. For these surveys however, the major part of the work involved recording of registration numbers (the number and registration year letter part only) of vehicles, as well as the vehicle type and occupancy. As with the Type 1 surveys, subsequent check values of accumulation were obtained by "beats" at half-hourly intervals. At the end of the survey periods a "final" value of accumulation was obtained from a "beat" survey.

2.6 Level of Trading Indicator.

Because of the variability in the level of trading of the stores from week to week, a "Level of Trading Indicator" was obtained for each store. This Indicator was based on the ratio of the number of customer transactions for the survey week relative to the weekly average for the preceding year.

In most cases an actual figure for this ratio was obtained from the respective store operators or managements. For two stores, however, it was necessary to infer a figure for the Indicator from a qualitative (non-numeric) assessment of the level of trading given by the store operators concerned.

The parking and flow indices in this report have been adjusted according to these Level of Trading Indicators so as to give values corresponding to an average or "typical" week. Hence, the parking figures given herein are the "Corrected Parking Index" (CRPI), whilst for flows the figures represent a

"Corrected Flow Index" (CRFI).

3. SURVEY RESULTS

The following three subsections summarise the main results obtained:-

(1) Sub-section 3.1 deals with vehicle accumulation and parking indices;

(2) Sub-section 3.2 considers vehicle flow and flow indices;

(3) Sub-section 3.3 describes the main findings associated with vehicle parking durations at the three stores where registration number surveys were carried out.

It should be noted also that where averages are given for parking or flow indices, these have been derived from every store at which an Index was obtained except one. (One of the stores has been excluded from the data set due to it displaying markedly dissimilar vehicular activity characteristics although it has been included in the peak time distributions and peak mean time calculations). Thus, for the presentation of parking indices, eleven main survey stores (results from the pilot survey have been excluded) make up the data set although for Thursdays this is reduced to nine ; for flow indices the data set consists of nine stores, except for Thursdays where there are only seven stores (again, not counting the deleted store). For the discussions on peak times, all the surveyed stores have been included.

3.1 Parking Index

3.1.1 Parking Index (CRPI) by Day of Week

Table 3.1 gives the mean value of CRPI and its range for each of the survey days of the week.

3.1.2 Peak Parking Accumulation Times

The data collection and processing was designed to permit parking accumulation at five minute intervals to be obtained; therefore it was possible to identify the precise time at which the peak occurred.

Table A2.1 (see Appendix 2) shows the distribution of the number of stores whose peak parking accumulation and two-way vehicle flow occurred within the time periods given (the two-way flow distributions are discussed in 3.2.2). The mean times of the peaks are given in parentheses.

The tendency, as exhibited by the distributions in Table A2.1, for parking accumulation and two-way flow to peak closely in time, suggests that these variables were correlated. A regression analysis (the results of which are given in Appendix 1.3) between parking accumulation and two-way flow also showed that a statistically good relationship existed between these variables.

The mean time for peak accumulation on Saturday's was a little before noon; the range of times for this day was the smallest of the survey days: 1 hour compared with 2.5 and 3.0 hours for Friday and Thursday respectively. This smaller range possibly reflects the propensity of many Saturday shoppers to do their food and grocery shopping around these times - an aspect of shopper behaviour which, it is thought, contributes toward the higher parking demand of many of the stores on this day.

3.1.3 Comparison with Results from other Research

Published values, for Parking Index and peak time, obtained in previous studies are presented in Table 3.2, together with the values obtained in this study. All the stores are in the supermarket/superstore size range and values for Friday and Saturday are shown.

Table 3.2 shows that the range of Parking Index (CRPI) values obtained in this research is comparable with that obtained from previous work elsewhere. However, whilst results for this

research showed that Saturday tended to predominate as peak day, (two-thirds of the stores experienced their peak parking accumulation on this day), the previous studies are more evenly split with Saturday being the peak day for four cases and Friday for three. In addition, the numerical difference in Parking Index between days for individual stores in the previous studies, was, in most cases, smaller than in this study.

Table 3.2 Published Values of Parking Index and Peak Times for Supermarkets and Superstores in the U.K.

Day of Week and Store Location	RFA (m^2)	Date of Survey	Parking Index	Peak Time
FRIDAY				
Co-op, Cambridge	1550	July'71	8.9	1900
Tesco, Finchley	4250	May'79	7.9	1730
Cartiers, Sidcup	2320	Nov'78	5.4	1900
Fine Fare, Stirling	3160	Apr'75	5.2	1900
Gem, Crossgates	3530	June'73	4.6	1900
Asda, Gwent	3720	July'77	13.9	--
Leo's, Pyle	2790	Sept'76	9.2	--
Asda, Pudsey	4929	Jan'80	6.7	1730-1800
Co-op, Knaresborough	1116	Oct'79	8.9	1800-1830
This Research	1096-4929	Feb-June'82	4.3-10.0	1748*
			Mean = 7.2	
SATURDAY				
Co-op, Cambridge	1550	July'71	4.8	1100
Fine Fare, Stirling	3160	Apr'75	5.4	1530
Gem, Crossgates	3530	June'73	4.7	1100
Asda, Gwent	3720	July'77	14.0	--
Leo's, Pyle	2790	Sept'76	8.9	--
Asda, Pudsey	4929	Jul'80	7.0	1100-1130
Co-op, Knaresborough	1116	Jun'80	7.6	1100-1130
This Research	1096-4929	Feb-June'82	3.5-11.4	1143*
			Mean = 7.7	

*Mean Value

3.2 Vehicle Flows

3.2.1 Flow Index (CRFI) by Day of Week

Table 3.3 shows the mean value of CRFI and its range for each survey day. From this Table it can be seen that although Saturday gave the highest mean value for CRFI, Friday provided the widest range. It is also of interest to note that on Thursday and Saturday 44%, and on Saturday 62% of the stores are within twenty-five percent of the mean.

Table 3.3 Mean and Range of CRFI by Day of the Week.

Day of the week	No. stores in sample	Mean CRFI	Range of CRFI	No.stores in the range Mean CRFI±25%
Thursday	9	5.17	2.68 - 8.67	4
Friday	8	5.90	3.25 - 11.59	5
Saturday	9	6.19	2.87 - 10.22	4

Saturday was the peak day for five stores with Friday being a peak day for three others. One store had exactly the same maximum 15 minute two-way flow on both Friday and Saturday.

For the time periods in which the peak 15 minute two-way flows occurred at each of the stores, the ratios :

Inflow / peak two-way flow; and

Outflow / peak two-way flow;

were derived to determine whether Inflow was larger than Outflow (or vice versa), over the time period in which the peak two-way flow occurred. When averaged over all the stores the ratios were very close to 0.5; indicating that at the time of peak 15 minute two-way flow, Inflow and Outflow rates were almost identical.

3.2.2 Peak Vehicle Flow Times

Table A2.1 (see Appendix 2) shows the number of stores whose peak 15 minute two-way flow ended in the time periods given. The distribution for parking accumulation is also shown for comparison. (The distributions for peak two-way flow in Table A2.1 are also discussed in 3.1.2).

Table A2.2 shows, for 15 minute inflow and outflow, the number of stores whose peaks ended in the time periods given. It is apparent, on comparison with Table A2.1, that the patterns for peak inflow and outflow are similar to those of peak parking accumulation and two-way flow, in that the mean time for Friday was, again, earlier than for Thursday. The tendency for the

Table 3.4 Peak Hourly Flow Indices (Two-way vehicles per 100 m^2) from Previous Work and This Research

Store Name and Location	RFA (m^2)	Date of Survey	Flow Index
STORES WITHOUT PETROL OR ADDITIONAL FACILITIES			
Carrefour, Caerphilly	5115		16.74
Gem, Leeds	3534	June'73	22.28
Fine Fare, Stirling	3162	Apr'75	13.48
Leo's, Pyle	2790	Sept'76	23.52
Co-op, Knaresborough	1116	Oct'79?	32.62
STORES WITH PETROL AND ADDITIONAL FACILITIES			
Carrefour, Caerphilly	5115		26.44
Carrefour, Bristol	8370		19.80
Carrefour, Minworth	6510	Dec'77	27.90
Carrefour, Eastleigh	4650		29.24
Tesco, Irlam	8370		14.32
Asda, Gwent	3720	July'77	23.12
Asda, Llandudno	2790	Aug'78	33.86
Asda, Pudsey	4929	July'80?	21.92
THIS RESEARCH(8 stores*)	1096-4929	Feb-June'82	12.01-38.32 Mean=20.64 5 stores in range Mean±25% 7 stores in range Mean±50%

* Values are for Friday and includes one store with petrol facilities. Mean = 21.43 if store with petrol facilities excluded.

Table 3.5 Mean Parking Duration by Store and by Day of Week

Store No. & Location Type	Store RFA (m^2)	Day of week	Mean Parking Duration (minutes)
1 District Centre	3010	Thursday	31
		Friday	32
6 Freestanding	4929	Thursday	40
		Friday	43
		Saturday	37
10 District Centre	2108	Thursday	36
		Friday	43
		Saturday	41

Table 3.6 Mean Parking Durations at Other Stores in the UK

Store and Location	RFA (m^2)	DURATION IN MINUTES Midweek	Friday	Saturday
Gem, Crossgates	3530	--	34	32
Fine Fare, Stirling	3160	41	49	49
Cartiers, Sidcup	2320	--	41	--
Tesco, Finchley	4250	44	54	--
Asda, Pudsey	4929	45	--	41
Co-op, Knaresborough	1116	30	--	24

comparative size (again, a reflection of the high vehicular activity rates per unit area of floorspace associated with smaller stores).

3.3 Parking Duration

Data from the registration number surveys (carried out at stores 1, 6 and 10) were analysed using a number plate matching program supplied by the Transport and Road Research Laboratory (TRRL). The program outputs information on mean parking duration and also gives frequency distributions of vehicles parked for selected time intervals.

It should be noted that "parking duration" is defined as the total time elapsing between a vehicle entering the car park and its departure, and therefore includes circulation time.

3.3.1 Mean Parking Duration and Frequency Distributions by Day of Week at the Surveyed Stores and Others in the UK

Table 3.5 shows the mean parking time at each of the stores by day of week. Figures 3.1, 3.3 and 3.5 show the percentage frequency distributions of parking times at each of the stores on Thursday, Friday and Saturday respectively. (The corresponding cumulative frequency distributions are shown in Figures 3.2, 3.4 and 3.6).

Table 3.6 gives parking duration figures from previous studies at six UK stores. A comparison between Tables 3.5 and 3.6 shows that values obtained by this research are broadly in accord with findings elsewhere. The longest durations are for Friday but there is no apparent relationship with store size, although the durations at the larger stores are appreciably longer than at the smallest store in Table 3.6.

The frequency distributions shown in Figures 3.1, 3.3 and 3.5 reflect certain characteristics of the surveyed sites. The distributions are positively skewed and, in most cases, bimodal. Bimodality is most apparent in the distribution for Store 6 where petrol facilities were available on site. It is clear that the high proportion of vehicles having durations less than ten

minutes (up to more than 21% on Saturday) at Store 6 is a reflection of the large numbers calling for petrol only. As a result of the many short stay visitors the mean durations on each day for Store 6 are lower than they would otherwise have been.

Bimodality is also apparent in the parking duration distributions for Stores 1 and 10, although it is less marked and virtually absent for the latter store on Thursday. The differences in the distributions between these stores may also be attributed to site characteristics. The distribution for Store 1, located as it was in a district centre with many other, smaller, units (retail and non-retail) and a public house, shows again a high proportion of short stayers; a consequence, presumably, of visitors to the other outlets. Conversely, the distinctly more unimodal distributions obtained at store 10, are possibly due to its location in a centre having a smaller number of units, where the overwhelming predominance of the store as the major attractor has meant that the parking durations of visitors to it have subsumed those of visitors to the other outlets in the centre.

3.4 Summary

The foregoing discussion on the survey results in Section 3 may be summarised under the following headings:-

(1) Observed variability in Parking and Flow Index between stores.
(2) Times of Peak Vehicular Activity.
(3) Day of the week on which Peak Activity occurred.
(4) Parking Duration Times.
(5) Comparison with Previous Studies.

(1) Variability in Parking and Flow Indices Between Stores

The results displayed a measure of variability in both Parking (CRPI) and Flow Index (CRFI) between stores which was not explicable on the basis of store size (RFA) alone (see Appendix

A1.1 and A1.2). It was conjectured that other factors such as store accessibility in terms of location and perceived ease of access (including ease of finding a parking space) affect the degree to which a store is patronised. Catchment population characteristics must also play a part where the level of car ownership is thought to be particularly important in this respect.

However, the results showed that there was a tendency for the parking demand at larger stores to be less per unit area of retail floorspace than at smaller stores; ie. the CRPI at larger stores was less than at smaller ones.

As with CRPI, there was considerable variation in CRFI between stores. However, store size (in terms of RFA) was found to explain more of the variation in CRFI than it did in CRPI.

Given that considerable variation in both Parking and Flow Index occurred the following points may be made:-

(a) Up to 57% of the stores, and not less than 36% of them, had CRPI within 25% of the mean for a given survey day.

(b) Between 44% and 63% of stores (dependent on survey day) had CRFI within 25% of the mean.

(2) Times of Peak Vehicular Activity

Again, variation was present between the stores in their times of peak parking accumulation and vehicle flow. However, some general points can be made:-

(a) Peak Parking Accumulation Times:

(i) Results for Thursdays tend to show that stores experience peak times later than on Fridays. Some 70% of the surveyed stores had peaks after 6.15 pm whereas this was true of only 33% of the stores on Friday.

(ii) Accumulation peak times were more concentrated on Saturdays with 92% of stores having peaks in the hour ending 12.15 pm.

(b) Peak Vehicle Flow Times

(i) Thursday showed a wider range of peak activity times than Friday, with 40% of the stores having their peak

activity time after 6.30 pm. This is to be compared with none on Friday.

(ii) Some 40% of the stores on Thursday, and 45% on Friday had their peak early in the evening; ie. between 4.30 pm and 5.30 pm - the normal evening peak period.

(iii) On Saturday virtually all the stores had their peak activity in the morning: 30% between 10.30 am and 11.30 am, and 60% between 11.30 am and 12.30 pm.

(3) Peak Activity Day

The peak day for parking accumulation was predominantly Saturday (73% of surveyed stores). Of the six freestanding stores surveyed, Friday was the peak day for three with Saturday the peak day for the remaining three.

The peak days for 15 minute two-way vehicle flow also tended to be Saturday although this was true of only 56% of the stores.

(4) Parking Duration

The average durations obtained at the three stores surveyed ranged from 31 to 43 minutes. These figures are broadly in accord with expectation when compared with previous studies. No correlation with store size was apparent. The frequency distributions clearly exhibited store site characteristics; in particular the petrol station facility at store 6 produced markedly bimodal distributions. The presence of other outlets was also seen to affect the distribution of parking times.

(5) Comparison with Previous Studies

The results obtained in this research have been shown to be comparable with those obtained from studies elsewhere. However, the results of this work have shown greater variability between stores than might have been expected on the basis of previous studies. Such variation may be largely attributed to the greater variety of store in this study - a mix of freestanding, district centre and high street locational types.

4. GUIDELINES FOR DESIGN

4.1 General Proviso's

The lack of a strong relationship between Parking Index (Corrected or Uncorrected) and Retail Floor Area should induce caution when specificying Indices based on store size alone. However, it is common for planning practitioners to specify parking provision for new developments on the basis of "flat rate" design standards based on store size. Hence, it is considered worthwhile to propose tentative standards based simply on retail floor area alone, with the proviso that until further analysis on the data is carried out, "judgement" will need to be exercised in their application.

Further analysis to determine the effect of factors external to the store such as car ownership, public transport services and socio-economic characteristics of the catchment population have not been dealt with herein and consequently their influence on design standards remains indeterminate until further analysis incorporating them has been carried out. In addition, the influence of store accessibility and location, especially the proximity to residential areas and neighbourhoods with high car ownership, together with inter-store competition, range, variety, and cheapness of goods, and the way in which these factors are perceived by customers, must affect parking demand and vehicular activity at such retail facilities.

With the foregoing caveats in mind, Parking Indices are proposed in Section 4.2 which are "sliding scale" values for convenience food-stores in the size range 1000 m^2 to 5000 m^2 Retail Floor Area (RFA). The Indices have been derived from an expression relating Parking Index (PI) to RFA, which has in turn been derived from two highly significant relationships given in this report: one between entry flow and RFA obtained by Turner (see Appendix A1.2); the other between Two-way flow and Accumulation obtained by this research (see Appendix A1.3). The resultant expression predicts Parking Indices based on RFA alone and consequently does not allow for the effect of factors mentioned

in the foregoing paragraphs of this section. Therefore, the design PI values in Section 4.2 are meant as an indication only.

In Section 4.3 Peak Hourly Two-way Flows are given for store's in the same size range. Again, no allowance has been made for the foregoing factors and hence are for overall guidance only.

In Section 4.4 some guidance as to the likely peak days and times is given and in Section 4.5 the effect on evening peak traffic is discussed.

4.2 Parking Indices

An equation derived from Turner's relationship for peak entry flow index versus retail floor area (RFA), and the correlation between two-way flow and accumulation obtained in this study (see Appendix 1), was derived to give an expression for Parking Index in terms of RFA; Table 4.1 gives values for Parking Index predicted by this equation for RFA's in the range 1000 to 5000 m^2.

Table 4.1 Predicted Parking Indices (PI) for Stores from 1000 to 5000 m^2 Retail Floor Area (RFA)

RFA (m2)	1000	2000	3000	4000	5000
PI (Vehs per 100m^2 RFA)	8.00	8.42	8.08	7.70	7.37

Interestingly, the derived equation gives a maximum value of PI of 8.47 for a RFA of 1660.5 m^2; above this store size the PI's become less - a characteristic which reflects the proportionately lower parking demand for larger stores. For store's in this research, the aforementioned derived equation predicts a mean PI value of 8.11; this may be compared with the means given in Table 3.1 where this predicted value can be seen to slightly exceed the highest mean of 7.71 obtained from the surveys on Saturday's. Thus, the figures for PI in Table 4.1 are reflective of "average" observed peak parking demand.

To translate the PI values in Table 4.1 into design standards the following factors should be allowed for:-

(1) Vehicle circulation

(2) Future increase in car ownership to a design year (say 1990)

(3) Change over time in the number of foodstore outlets, linked also to possible future variation in the pattern of shopping behaviour

If factors of 1.11 and 1.19 (as suggested by Leake and Turner[2]) are applied to the Parking Indices in Table 4.1 to incorporate effects due to circulation and increasing car ownership respectively, then the design PI values, when modified, fall into the range: 9.7 to 11.1. It is probable that Planning Practitioners will prefer to specify Parking Indices in terms of an overall figure, hence for stores of the type studied in this research a basic Design Parking Index in the range 10.0 - 11.0 would seem appropriate.

It should be emphasised however, that possible disbenefits due to under-provision of parking space as a result of uncertainty in factors (2) and (3) above can be ameliorated if "staged" construction of parking provision is allowed for in the design of new facilities. Thus, areas could be incorporated into the proposal for a new facility which would be unpaved (and in the interim, landscaped) and would permit extra hard-standing at some future date should this become necessary.

4.3 Traffic Flows

Peak Two-way Vehicle Flows for stores without petrol facilities may also be obtained from the "derived" equation referred to above. Table 4.2 gives values predicted by the equation and shows, for a range of stores up to 5000 m^2, the Peak Hourly Flows likely to obtain.

Table 4.2 Peak Hour Two-way Flows for Stores from 1000 to 5000 m^2 Retail Floor Area (RFA)

RFA (m^2)	1000	2000	3000	4000	5000
Peak Hour Two Way Flow	336	531	694	839	972
Flow Index (Vehs/hr per 100 m^2 RFA)	33.6	26.6	23.1	21.0	19.4

Again, the caveats given in Section 4.1 apply here also. As with the values for Parking Index given in Table 4.1, the Hourly Flows predicted by the "derived" equation and given in Table 4.2, can be seen to be proportionately less, per unit area of floorspace, at larger stores than at smaller ones.

4.4 Times and Days of Peak Activity

Saturday predominates as the peak day for both parking accumulation and vehicle flow although Friday is more likely to be the peak day for freestanding stores.

Actual times of day at which peak activity occurs is likely to be quite variable. Evidence from this study suggests that there are two peak periods on Thursdays, (4.30 pm - 5.30 pm and 6.30 pm - 7.30 pm), two on Fridays (covering the two hours 4.30 - 6.30 pm) and a two hour period between 10.30 am and 12.30 pm on Saturdays.

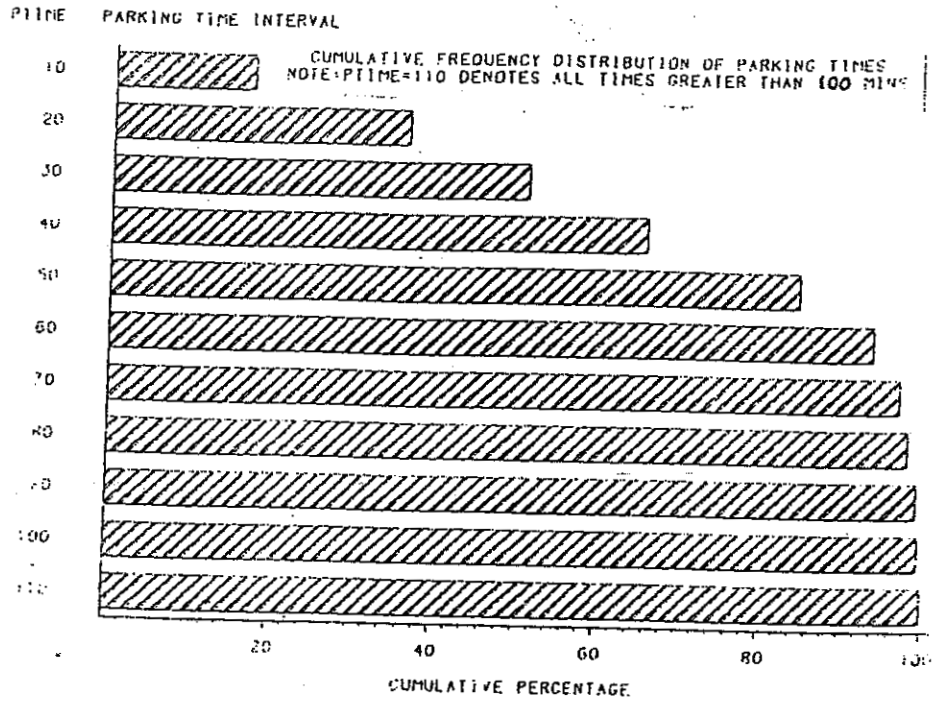
4.5 Effect on Evening Peak Traffic

An important design factor is the amount of traffic entering and leaving a store during the evening rush hour. An analysis of two-way flow at each store during the 15 minute time period ending at 5 pm, when compared with the maximum observed two-way 15 minute flow, (see Appendix 3) showed that for both Thursday and Friday, the average flow rate embracing all the stores was about 80% of the maximum observed value with the widest spread of values occurring on the Thursdays.

Because of the variability in the results obtained, it would appear prudent to design on the basis that traffic activity levels during the evening traffic peak from a store is 90% of the maximum Flow Index value on both Thursdays and Fridays.

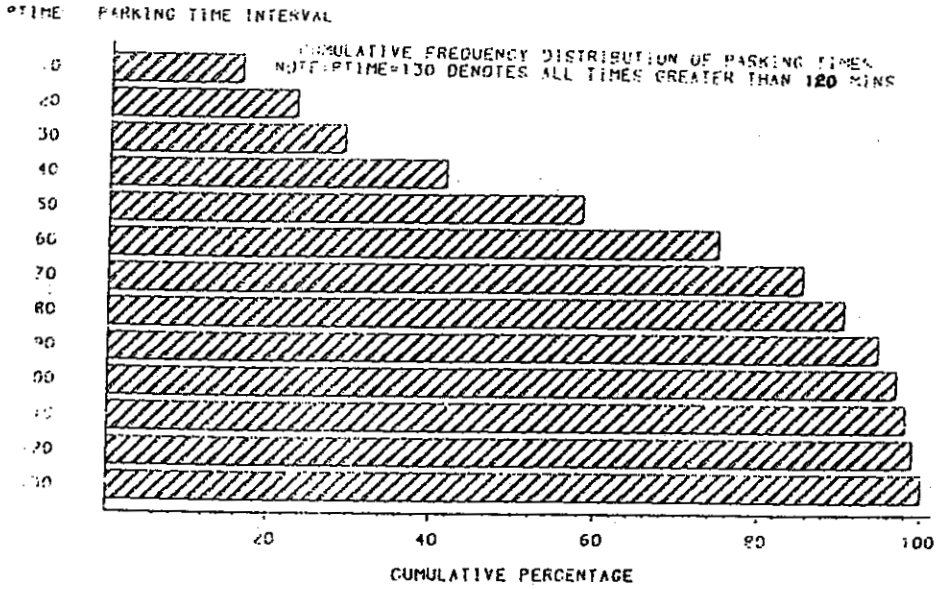
PARKING DURATION – THURSDAYS

STORE=1



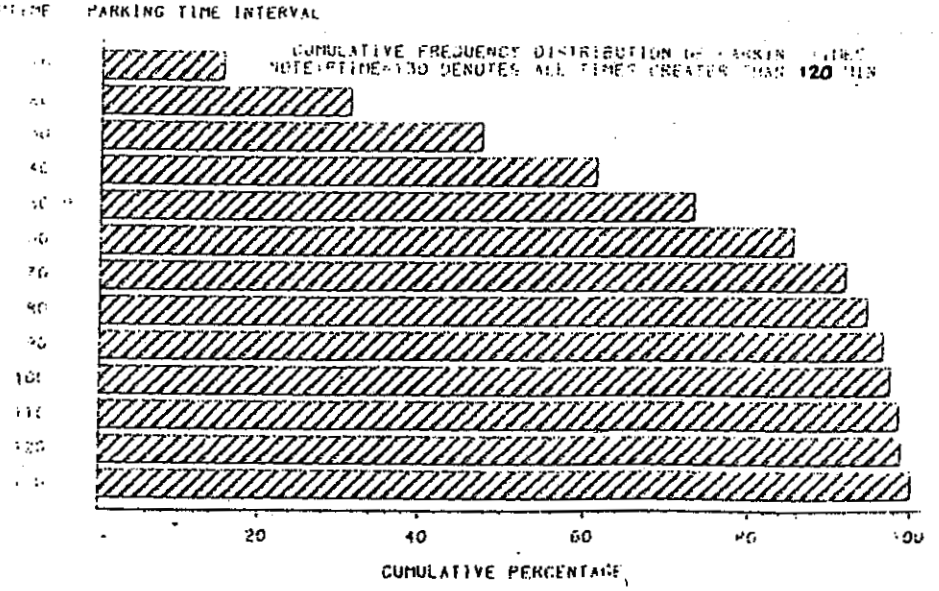
PERCENT	CUM. PERCENT
17.13	17.13
19.38	36.52
14.33	50.84
14.61	65.45
19.10	84.55
8.99	93.54
3.37	96.91
1.12	98.03
1.12	99.16
0.84	100.00
0.56	100.00

STORE=6



PERCENT	CUM. PERCENT
16.45	16.45
6.76	23.21
6.03	29.24
12.43	41.67
16.64	58.31
16.64	74.95
10.43	85.38
5.12	90.50
4.20	94.70
2.19	96.89
1.10	97.99
0.91	98.90
1.10	100.00

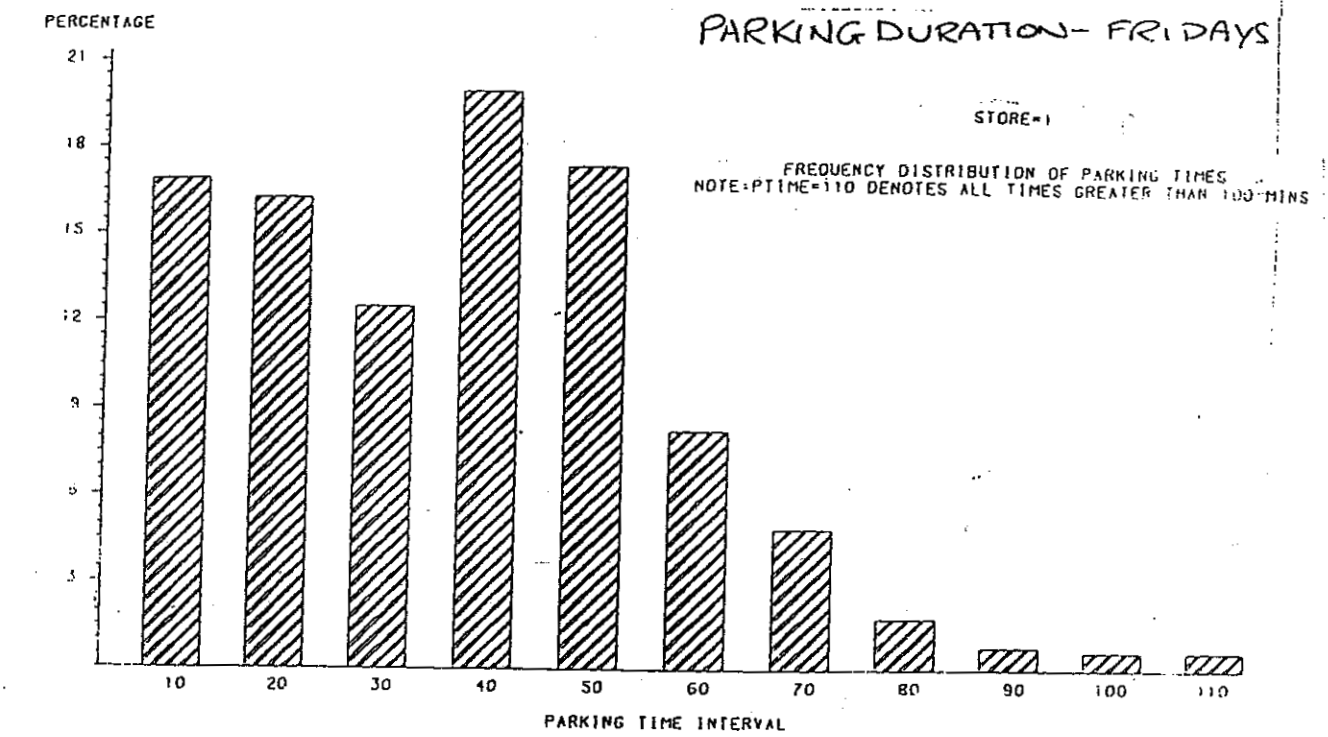
STORE=10

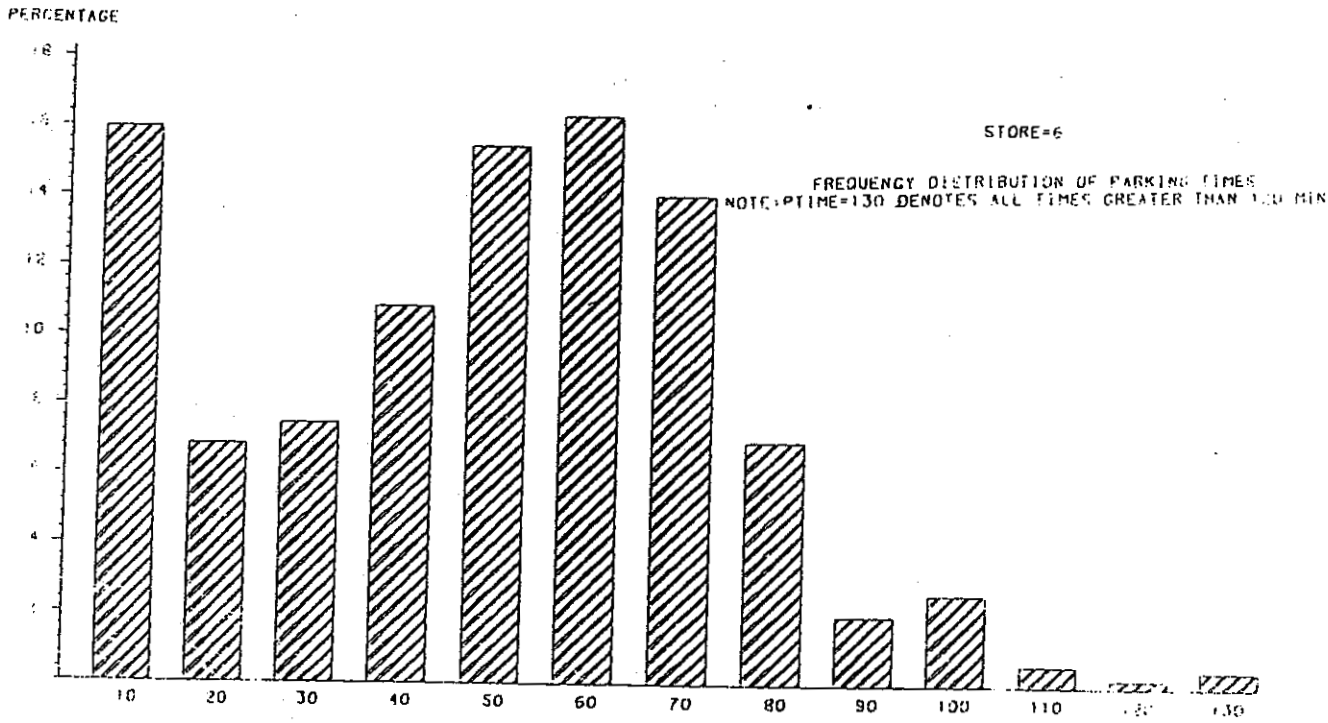


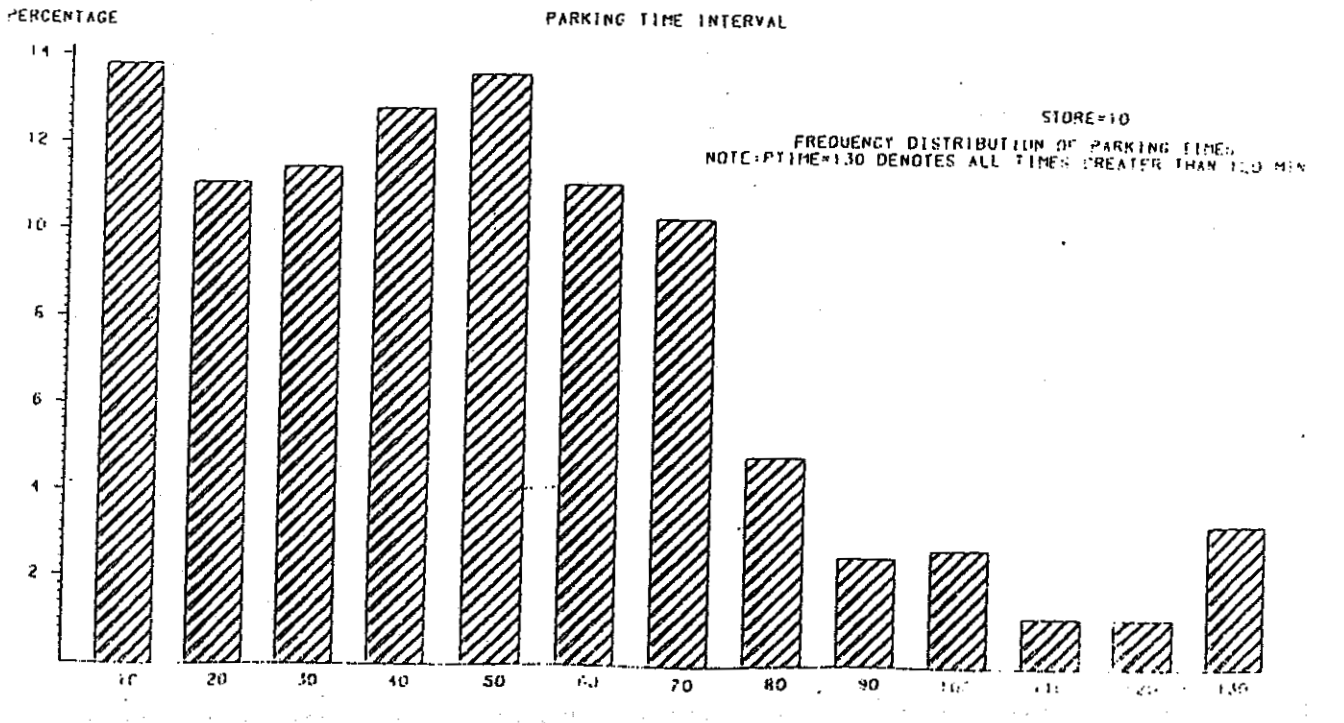
PERCENT	CUM. PERCENT
15.31	15.31
16.30	31.62
16.06	47.68
13.93	61.61
11.79	73.40
12.30	85.70
6.52	91.92
2.63	94.55
1.88	96.43
0.88	97.31
1.13	98.44
0.25	98.69
1.31	100.00

FIG 3.2

PARKING DURATION- FRIDAYS

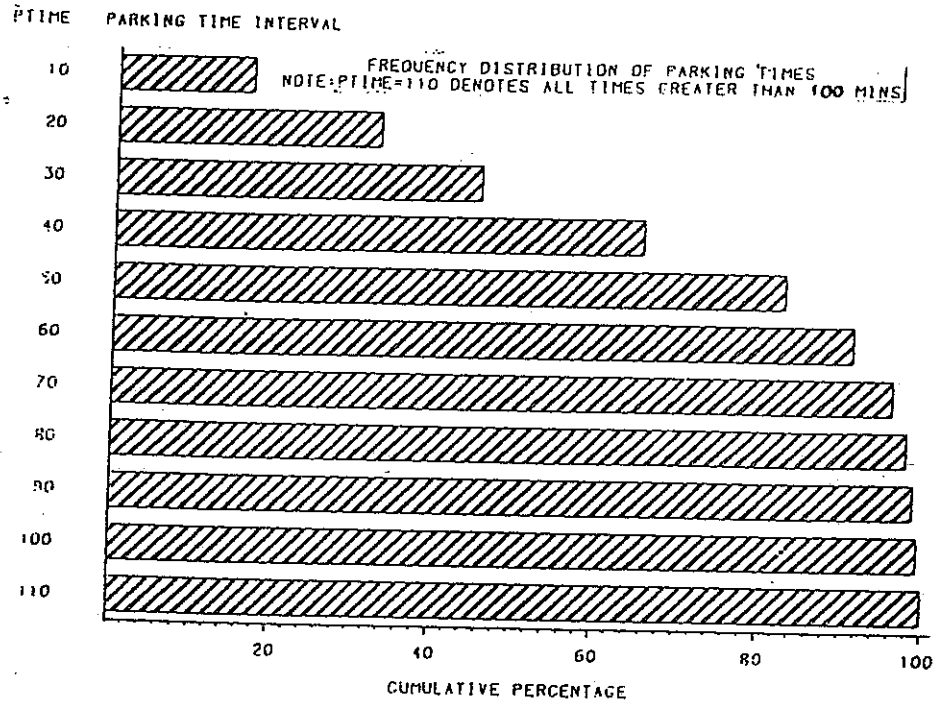






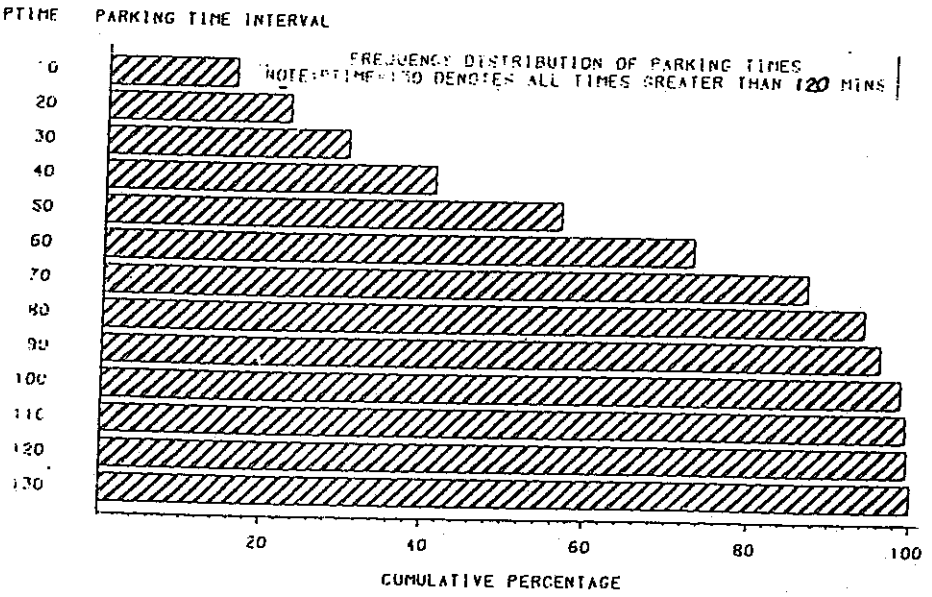
PARKING DURATION – FRIDAYS

STORE=1



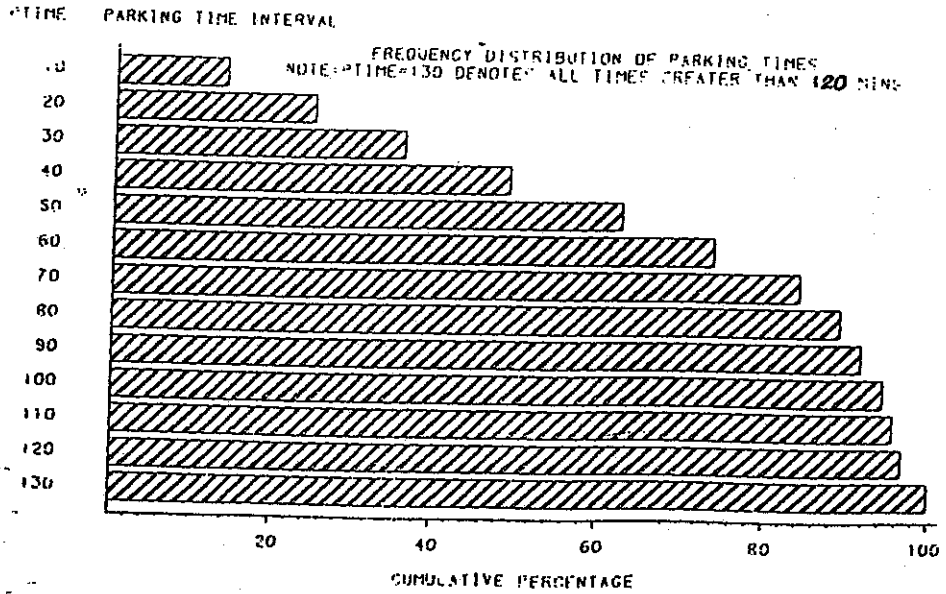
PERCENT	CUM. PERCENT
16.88	16.88
16.23	33.12
12.50	45.62
19.97	65.58
17.37	82.95
8.28	91.23
4.87	96.10
1.79	97.89
0.81	98.70
0.65	99.35
0.65	100.00

STORE=6

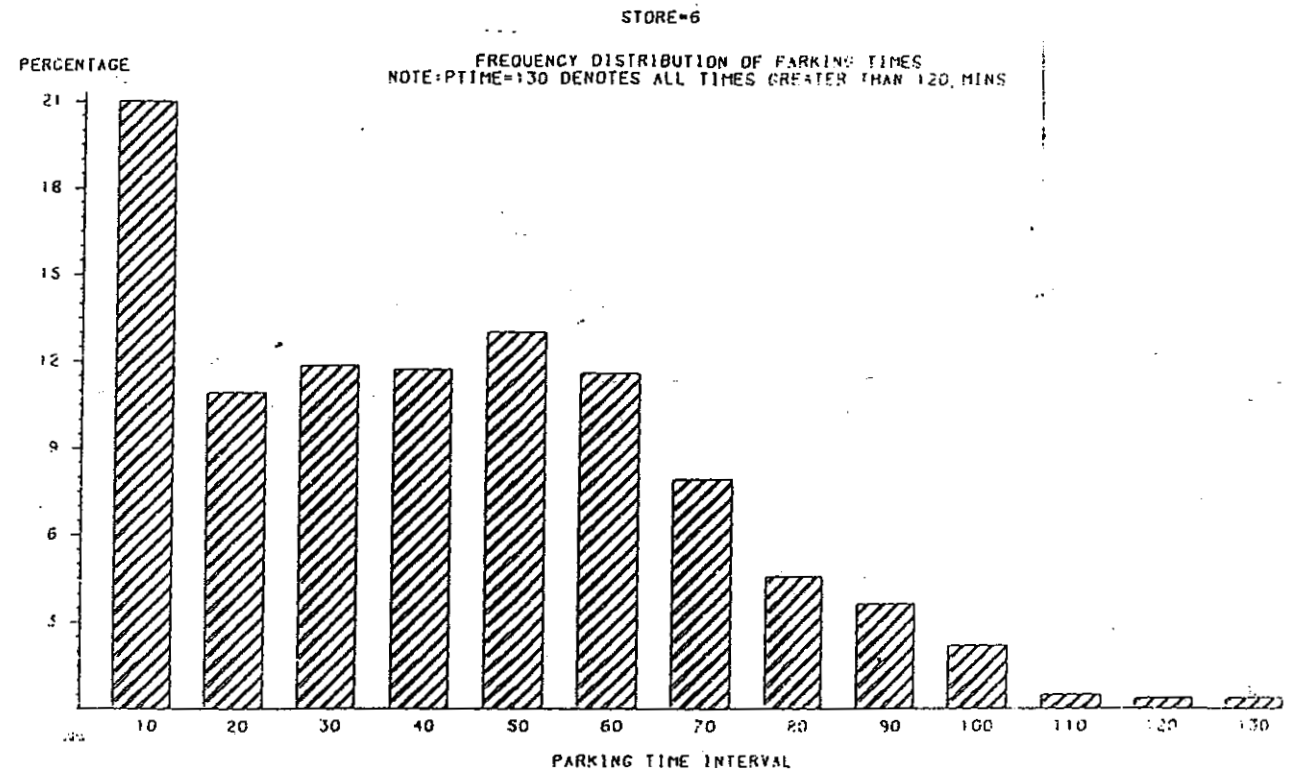


PERCENT	CUM. PERCENT
15.96	15.96
6.86	22.82
7.48	30.30
10.85	41.15
15.46	56.61
16.33	72.94
14.09	87.03
6.98	94.01
2.00	96.01
2.62	98.63
0.82	99.45
0.25	99.50
0.50	100.00

STORE=10



PERCENT	CUM. PERCENT
13.84	13.84
11.09	24.90
11.48	36.38
12.84	49.22
13.62	62.84
11.09	73.93
10.31	84.24
4.86	89.11
2.53	91.63
2.72	94.36
1.17	95.53
1.17	96.69
3.31	100.00


STORE=6
PERCENTAGE
FREQUENCY DISTRIBUTION OF PARKING TIMES
NOTE:PTIME=130 DENOTES ALL TIMES GREATER THAN 120 MINS
21
18
15
12
9
6
10
20
30
40
50
60
70
80
90
100
110
120
130
PARKING TIME INTERVAL

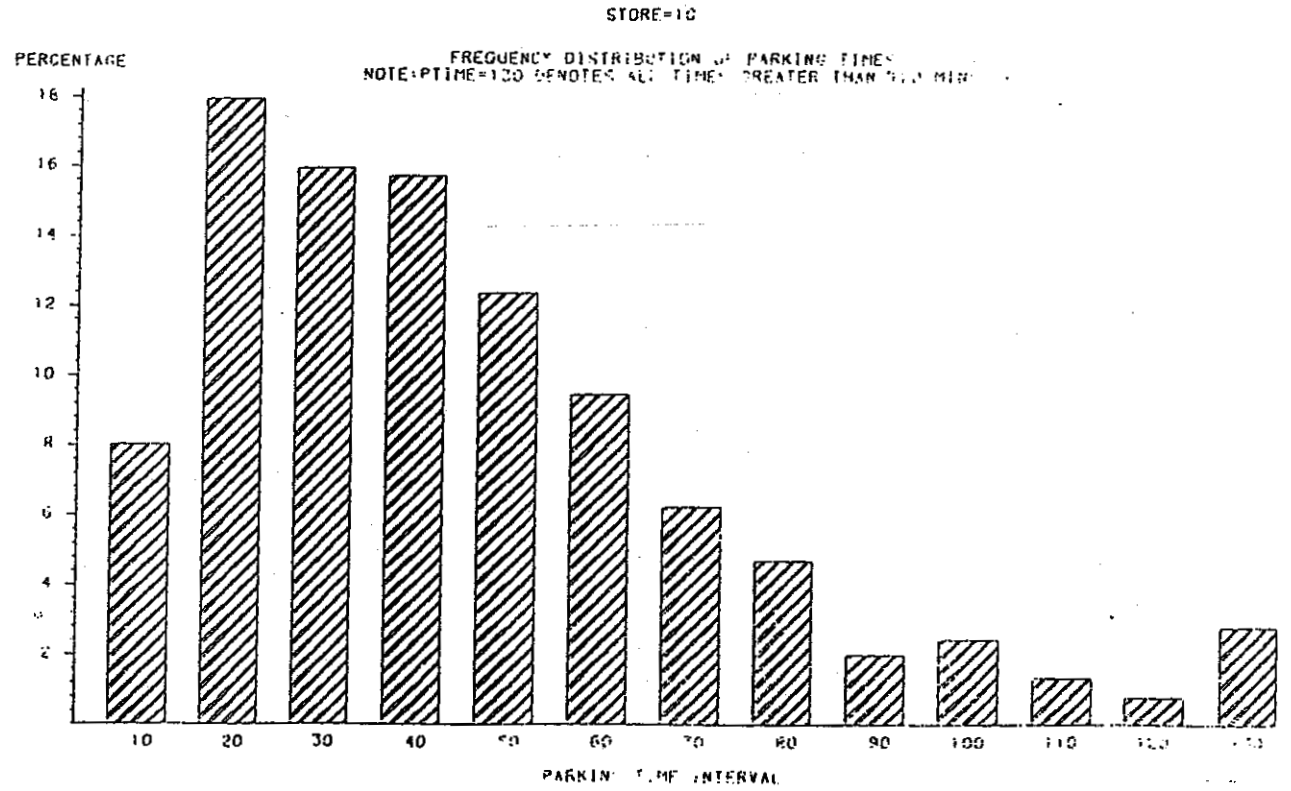
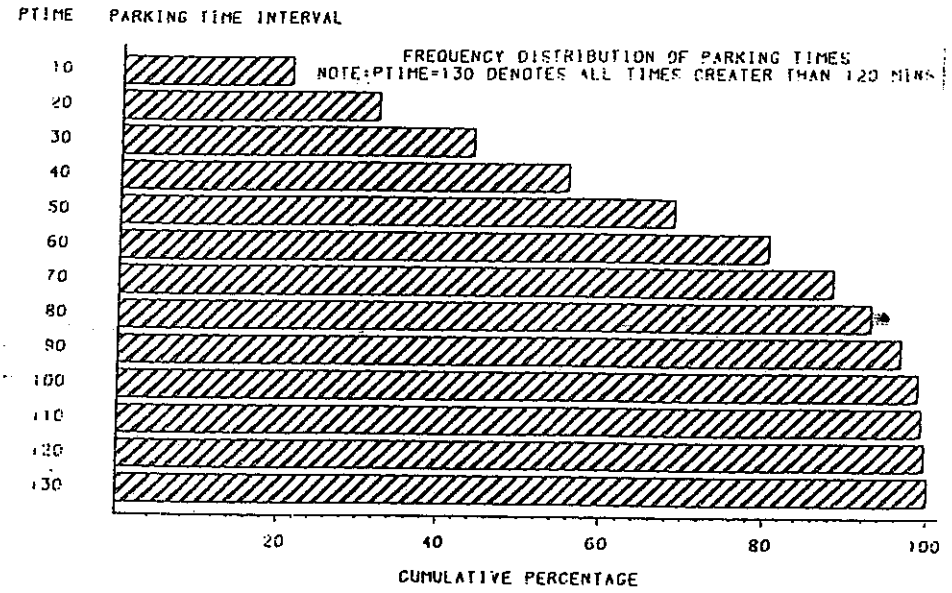

STORE=10
PERCENTAGE
16
14
12
10
8
6
4
2
10
20
30
40
60
80
90
100
PARKING TIME INTERVAL

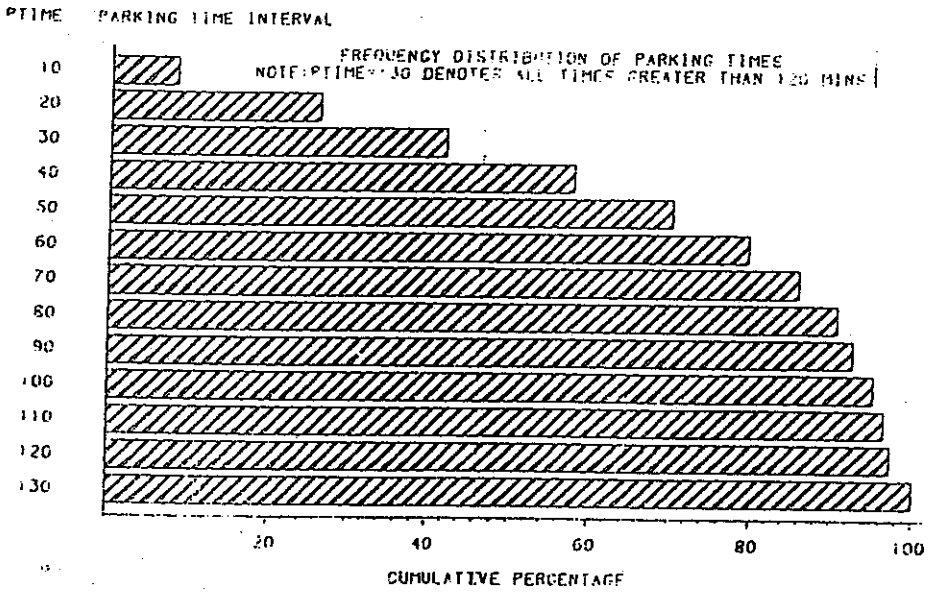
FIG 3.5

STORE=6



PERCENT	CUM. PERCENT
21.22	21.22
10.94	32.16
11.85	44.01
11.72	55.73
13.02	68.75
11.59	80.34
7.94	88.28
4.56	92.84
3.65	96.48
2.41	98.70
0.52	99.22
0.39	99.61
0.39	100.00

STORE=10



PERCENT	CUM. PERCENT
8.04	8.04
17.99	26.03
15.98	42.01
15.75	57.77
12.40	70.17
9.50	79.66
6.26	85.92
4.09	90.01
2.01	92.03
2.45	94.48
1.34	95.82
0.78	96.61
3.39	100.00

FIG 3.6

A P P E N D I X 1

A1. Regression Analyses

A1.1 Corrected Parking Index (CRPI) as a Function of Store Size

The values obtained for CRPI were analysed to determine whether any simple correlations existed with store size. Both linear and non-linear (logarithmic and polynomial) regression analyses were applied to the data. However, no statistically significant or sensible correlations were obtained. Linear regression gave results (ie. R^2 values) as good as the non-linear approaches. It is possible that further analysis may yield better correlations by, for example, including those stores having similar characteristics.

Table A1.1 shows the linear regression parameters for CRPI versus Retail Floor Area (RFA) by day of week. All the stores except one (the store which exhibited atypical vehicular activity) have been included. Figures A1.1 to A1.3 depict graphically the linear regression equations presented in Table A1.1 together with the 90% confidence limit lines for the mean (inner) and individual values (outer), for Thursday, Friday and Saturday respectively. By inspecting Table A1.1 and Figures A1.1 to A1.3, it can be seen that only a weak relationship between CRPI and RFA has been revealed.

Turner[1] also investigated the possibility of a relationship between Parking Index and store size. Using results from a number of studies in the UK he also found that it was not possible to explain the variation in Parking Index on the basis of store size alone.

A1.2 Corrected Flow Index (CRFI) as a Function of Store Size

Flow Indices were also analysed by simple regression techniques to determine whether a statistically significant relationship existed with retail floor area. The regression parameters obtained are given in Table A1.2.

Table A1.2 shows that although the relationships are not statistically significant at the 95% level, they are nevertheless, an improvement on those obtained by regressing CRPI on RFA - up to nearly 44% of the variation in CRFI being explained by RFA.

Table A1.1 Linear Regression Parameters for CRPI versus Retail Floor Area by Day of Week.

Day of the week	No. stores in sample	Intercept	Coefficient*	R^2
Thursday	9	6.768	-0.0293	0.039
Friday	11	9.000	-0.0652	0.108
Saturday	11	9.969	-0.0826	0.105

*Coefficient of Retail Floor Area (RFA) where RFA in m^2(x100)

Table A1.2 Linear Regression Parameters for CRFI versus Retail Floor Area by Day of Week.

Day of the week	No. stores in sample	Intercept	Coefficient*	R^2
Thursday	9	7.439	-0.0822	0.255
Friday	8	9.549	-0.1334	0.435
Saturday	9	9.089	-0.1049	0.246

*Coefficient of Retail Floor Area (RFA) where RFA in m^2(x100)

Table A1.3 Hourly Two-way Flow Indices (Vehicles per 100 m^2 RFA) derived from Predictive Equations

	FLOW INDICES				
	STORE SIZE (RFA (m^2))				
Predictive Equation	1000	2000	3000	4000	5000
Turner (1) x2 (Stores with petrol & other facilities)	42.09	36.30	32.91	30.50	28.64
Turner (2) x2 (Stores without petrol or other facilities)	33.59	26.54	23.12	20.96	19.43
This Research (Corrected Flow Index = 4 x (-0.1334 x RFA/100 + 9.549))	32.86	27.52	22.19	16.85	11.52

Figures A1.4, A1.5 and A1.6 give graphical representations of the regression lines (again, showing 90% confidence limits for both the mean and individual values), for Thursday, Friday and Saturday respectively.

Turner[1] obtained statistically significant mathematical relationships between Flow (in this case Entry Flow), and store size by using the values derived for stores in Table 3.4. The most statistically significant relationships were:-

Turner (1) For stores with petrol facilities:

Hourly Peak Entry Flow Index = $30.67 - 4.18 \times \ln(RFA)$

(R^2=0.79, 6 d.f.)

Turner (2) For stores without petrol facilities:

Hourly Peak Entry Flow Index = $36.74 \times (RFA)^{-0.34}$

(R^2=0.99, 3 d.f.)

where: Hourly Peak Entry Flow Index = Vehicles per 100 m^2 RFA;
RFA = Retail Floor Area (m^2) x 100; and
ln = natural logarithm

Turner's expressions for Entry Flow Index have been used to derive Hourly Two-way Flow Indices (by doubling the predicted values) for stores in the size range 1000 m^2 to 5000 m^2 and are presented in Table A1.3 with values predicted by the most significant relationship obtained by linear regression for this study (ie using regression parameters for Friday : see Table A1.2).

From Table A1.3 it is apparent that the simple linear relationship obtained for this research predicts Flow Indices (CRFI) close to those of Turner's for stores without petrol or additional facilities for RFA up to 3000 m^2. Above this store size however, the difference between Turner's Indices and values predicted by the simple linear function for this research becomes larger as store size increases - a consequence of the functions used in Turner's equations (Power and Logarithmic) versus the Linear form used for this research.

A1.3 Correlation between Accumulation and Flow

The relationship between accumulation and two-way flow was investigated initially to provide a means whereby missing values of vehicle flow "lost" at certain times during the survey period (as a consequence of the methodology) might be replaced. The aggregate correlation (ie. the correlation obtained by incorporating all the surveyed stores into the regression) proved to be highly statistically significant and was subsequently used to derive the "sliding scale" design values for Parking Index given in Section 4.2.

The regression of 15 minute two-way flow on accumulation for all the survey days and all the surveyed stores (a total of 1117 data points) is shown graphically in Figure A1.7. 99% confidence limits for the mean (inner dotted) and individual values (outer dotted) are shown.

The resultant expression was:-

$$\text{15 minute 2-way flow}^{*} = 0.574 \times \text{Accumulation}^{!} + 33.895$$

(* for period 'n'; ! at end of period 'n')

The above correlation is significant at the 99.9% level, with nearly 86% of the variation in two-way flow explained by parking accumulation ($R^2 = 0.859$).

A P P E N D I X 2

Table A2.1 Frequency Distributions of Stores whose Peak Accumulation and Two-way Flow Occurred in a Given Time Period - by Day of Week (ALL Surveyed Stores Included)

	NUMBER OF STORES WHOSE PEAK OCCURRED IN TIME PERIOD			
	THURSDAY		FRIDAY	
Time Period	Accumulation	Two-way Flow	Accumulation	Two-way Flow
1601 - 1615				
1616 - 1630				
1631 - 1645	1		1	1
1646 - 1700			3	1
1701 - 1715	1	2	1	1
1716 - 1730	1	2	2	1
1731 - 1745		1		1 (1736)
1746 - 1800		1	(1748)	1
1801 - 1815		(1803)	1	2
1816 - 1830	2 (1823)			1
1831 - 1845	1	1	1	
1846 - 1900		2	2	
1901 - 1915	1	1	1	
1916 - 1930	3			
1931 - 1945				
1946 - 2000				
TOTALS	10	10	12	9

	SATURDAY	
Time Period	Accumulation	Two-way Flow
1001 - 1015		
1016 - 1030		1
1031 - 1045		
1046 - 1100		1
1101 - 1115	1	1
1116 - 1130	3	
1131 - 1145	4 (1143)	
1146 - 1200	1	4 (1156)
1201 - 1215	3	1
1216 - 1230		1
1231 - 1245		
1246 - 1300		
1301 - 1315		
1316 - 1330		
1331 - 1345		
1346 - 1400		
1401 - 1415		
1416 - 1430		
1431 - 1445		1
1446 - 1500		
TOTALS	12	10

(Figures in parentheses denote Mean Times)

Table A2.2 Frequency Distributions of Stores whose First Maximum Peak 15 minute Inflow and Outflow Occurred in a Given Time Period - by Day of Week. (ALL Surveyed Stores)

Time Period	NUMBER OF STORES WHOSE PEAK OCCURRED IN TIME PERIOD THURSDAY Inflow	Outflow	FRIDAY Inflow	Outflow
1601 - 1615				
1616 - 1630				
1631 - 1645	1		1	1
1646 - 1700			3	
1701 - 1715	2	1		3
1716 - 1730	2	1		
1731 - 1745	(1743)	1	1(1733)	1
1746 - 1800	2	2		2(1755)
1801 - 1815	1		2	
1816 - 1830	1	(1830)	2	
1831 - 1845		1		
1846 - 1900	1	1		
1901 - 1915				
1916 - 1930		1		
1931 - 1945		1		1
1946 - 2000		1		1
TOTALS	10	10	9	9

Time Period	SATURDAY Inflow	Outflow
1001 - 1015		
1016 - 1030	1	
1031 - 1045		
1046 - 1100	1	
1101 - 1115	1	
1116 - 1130	3	
1131 - 1145	2(1143)	
1146 - 1200	1	3
1201 - 1215		2
1216 - 1230		4(1226)
1231 - 1245		
1246 - 1300		
1301 - 1315		
1316 - 1330		
1331 - 1345		
1346 - 1400		
1401 - 1415		
1416 - 1430		
1431 - 1445	1	1
1446 - 1500		
TOTALS	10	10

(Figures in parentheses denote Mean Times)

A P P E N D I X 3

A3. Evening (5 pm) 15 minute two-way flow as a proportion of the maximum 15 min. two-way flow

The two-way flows at each store during the 15 minute period ending at 5 pm were compared with the maximum observed 15 minute two-way flow. The results, set out in Table A3.1 show that for both Thursday and Friday, the mean average flow rate was about 80% of the maximum value. The widest range was for Thursday.

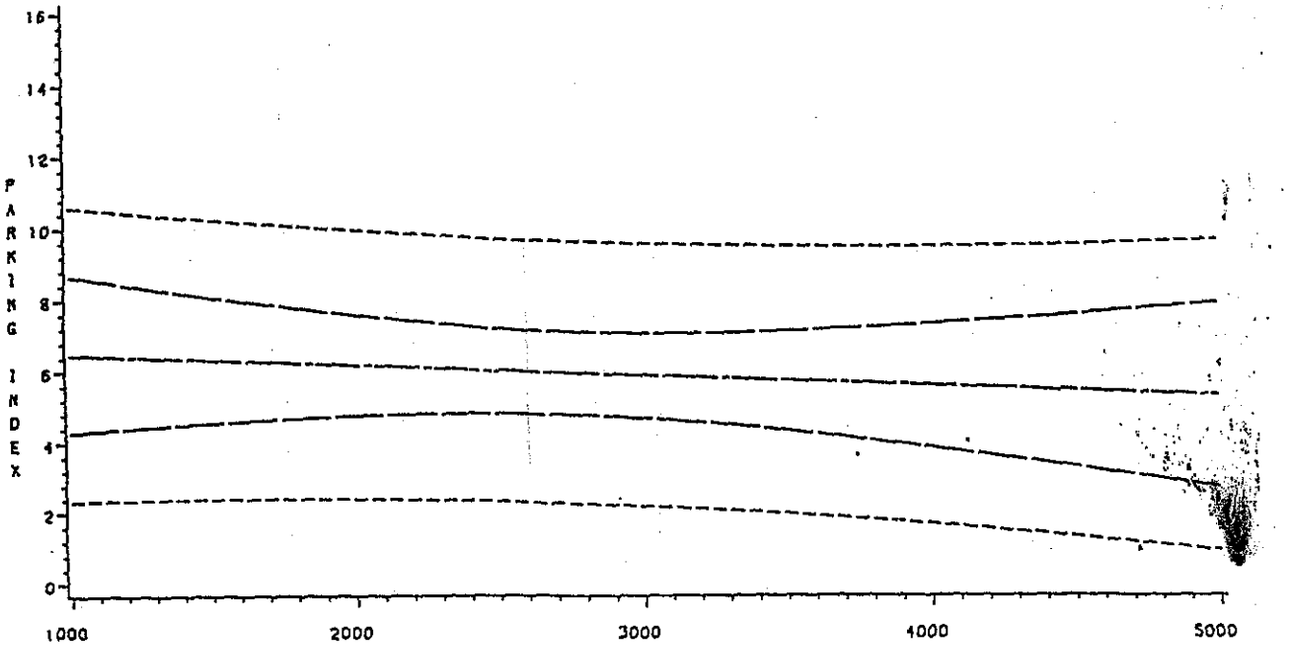
Table A3.1 Two-way 15 Minute Flow Ending at 5.00 pm as a Percentage of the Peak Flow by Store for Thursday and Friday.

STORE & DAY	Two-way 15 min. Flow as a Percentage of the Peak
THURSDAY	%
1	--
2	85.4
3	--
4	90.2
5	95.7
6	65.7
7	73.1
8	--
9	60.6
10	78.3
11	76.8
12	--
13	81.4
	Mean = 78.6
FRIDAY	
1	--
2	78.3
3	--
4	89.7
5	87.1
6	80.6
7	85.0
8	--
9	89.4
10	81.5
11	79.5
12	--
13	69.8
	Mean = 82.3

FIG A1.1

PARKING INDEX(CRPI) VS RFA

90% CLS FOR MEAN (INNER) & INDIVIDUAL VALUES (OUTER)
THURSDAYS

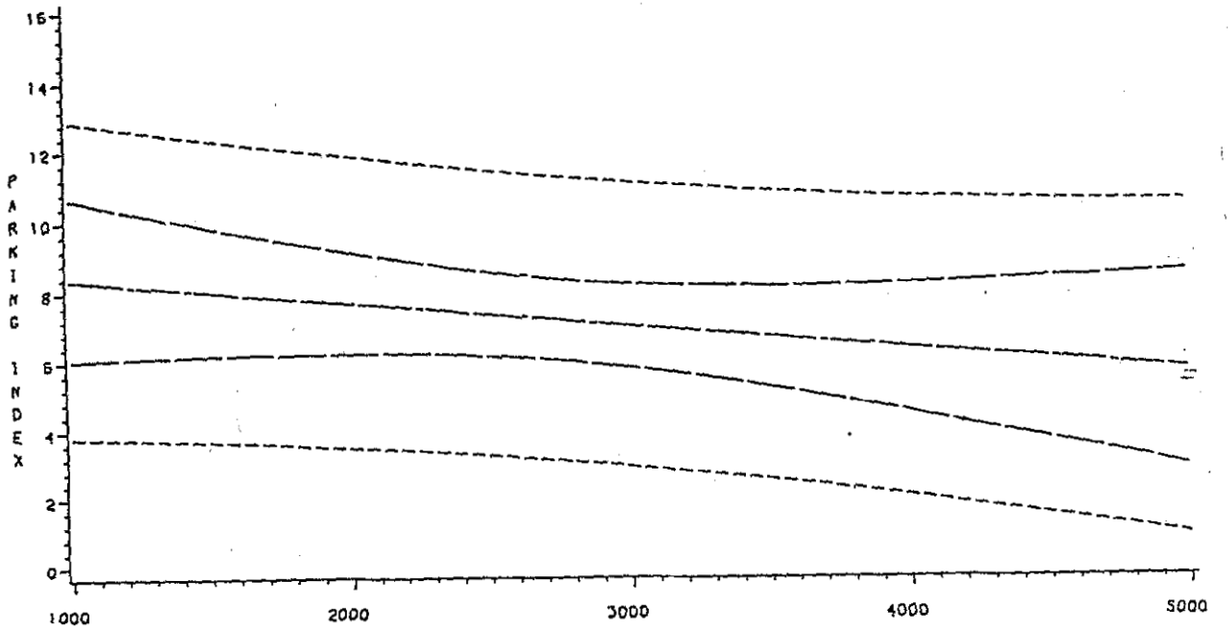


EQUN \ CRPI = -0.293*RFA+6.768 (R-SQ=0.039, 9 STORES)
WHERE RFA = RETAIL FLOOR AREA (SQ.M÷1000)

FIG A1.2

PARKING INDEX(CRPI) VS RFA

90% CLS FOR MEAN (INNER) & INDIVIDUAL VALUES (OUTER)
FRIDAYS

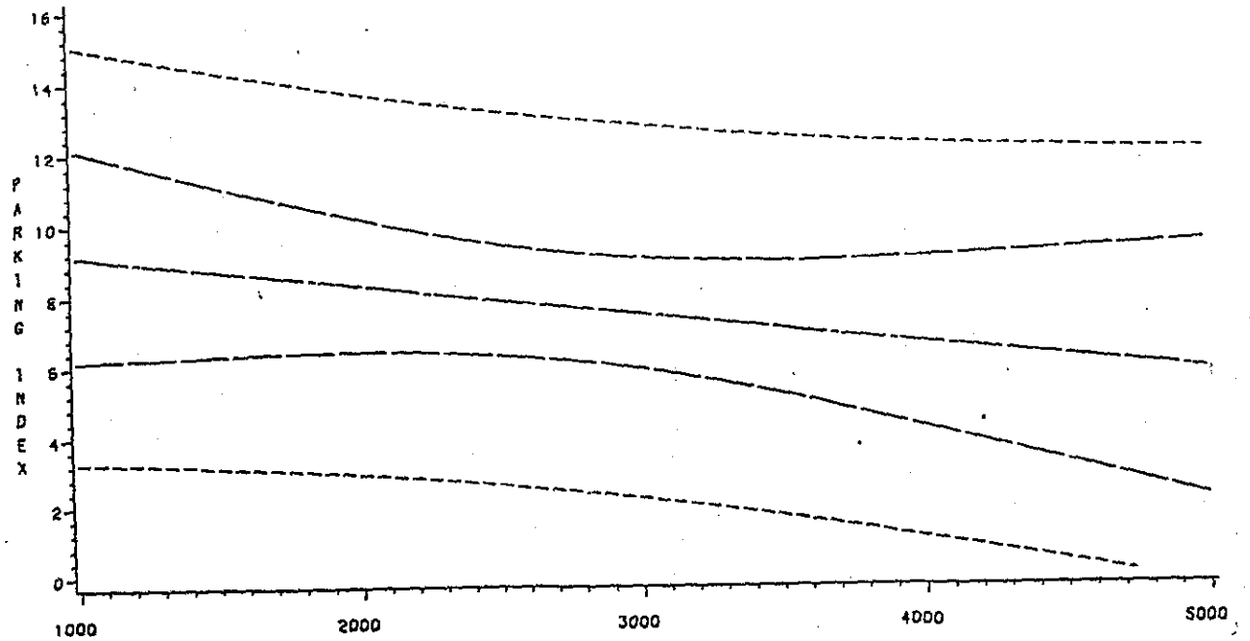


EDUN : CRPI = -0.652*RFA+9.000 (R-SQ=0.108, 11 STORES)
WHERE RFA = RETAIL FLOOR AREA (SQ.M*1000)

FIG A1.3

PARKING INDEX(CRPI) VS RFA

90% CLS FOR MEAN (INNER) & INDIVIDUAL VALUES (OUTER)
SATURDAYS



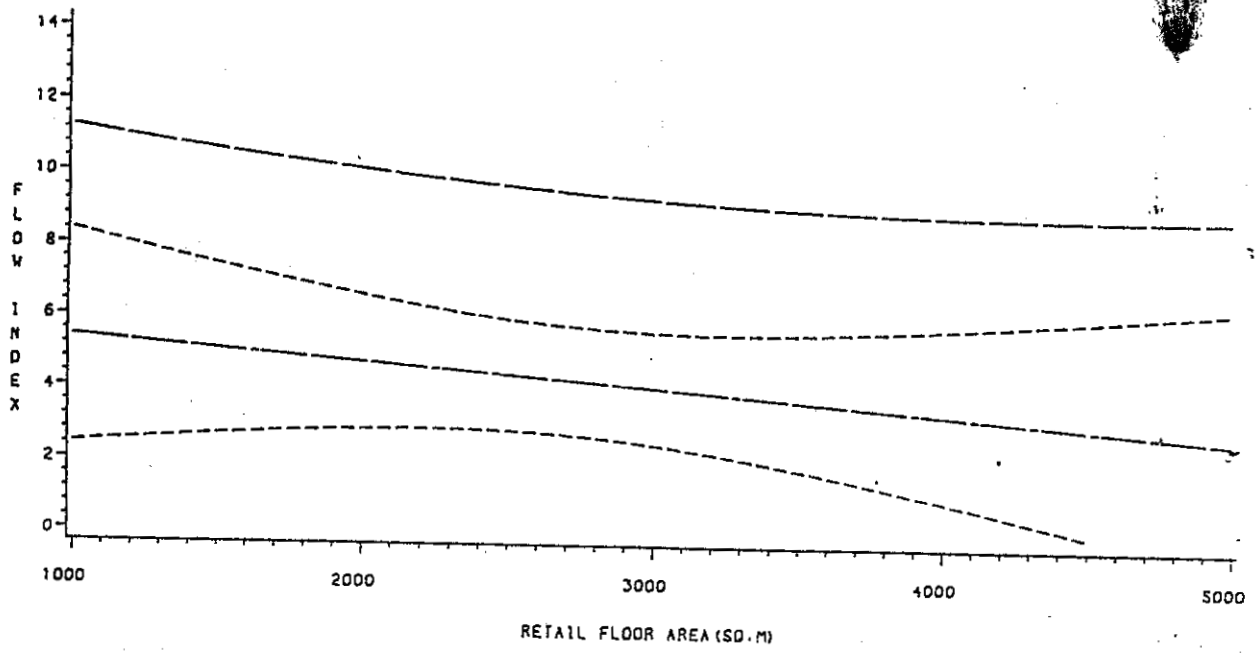
EQUN : CRPI = -0.826*RFA+9.969 (R-SQ=0.105, 1) STORES)
WHERE RFA = RETAIL FLOOR AREA (SQ.M*1000)

FIG A1.4

FLOW INDEX(CRFI) VS RFA

90% CLS FOR MEAN (INNER) & INDIVIDUAL VALUES (OUTER)

THURSDAYS



EQUN : CRFI = -0.822*RFA+7.439 (R-SQ=0.255, 9 STORES)

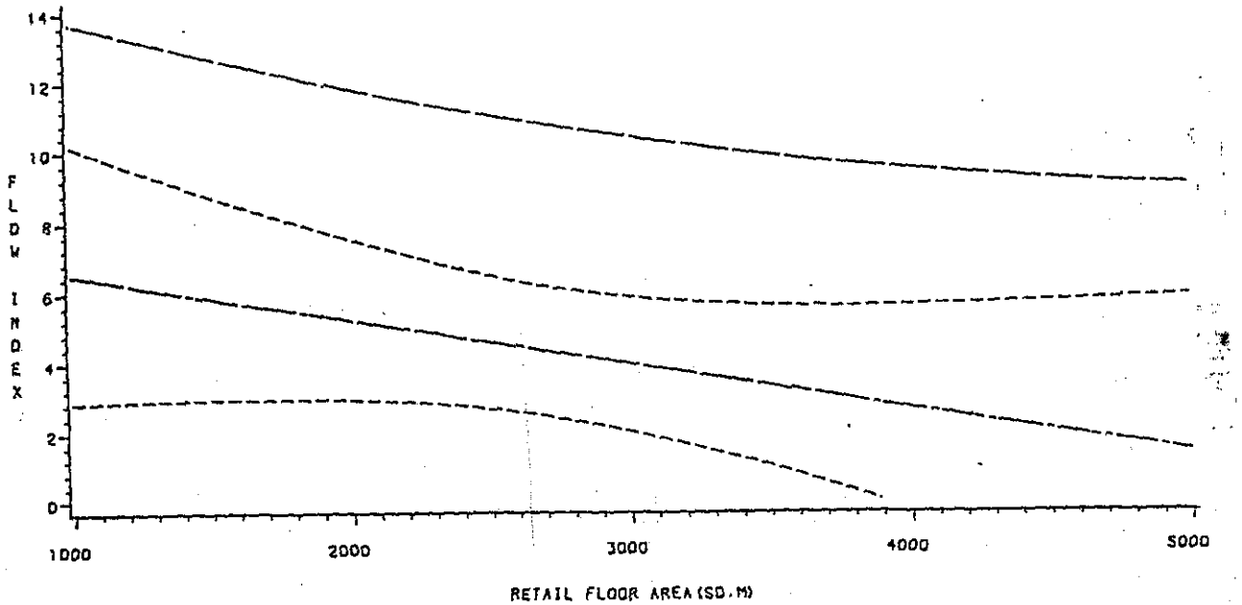
WHERE RFA = RETAIL FLOOR AREA (SQ.M*1000)

CRFI DERIVED FROM 15 MIN. 2-WAY FLOWS

FIG A1:5

FLOW INDEX(CRFI) VS RFA

90% CLS FOR MEAN (INNER) & INDIVIDUAL VALUES (OUTER)
FRIDAYS



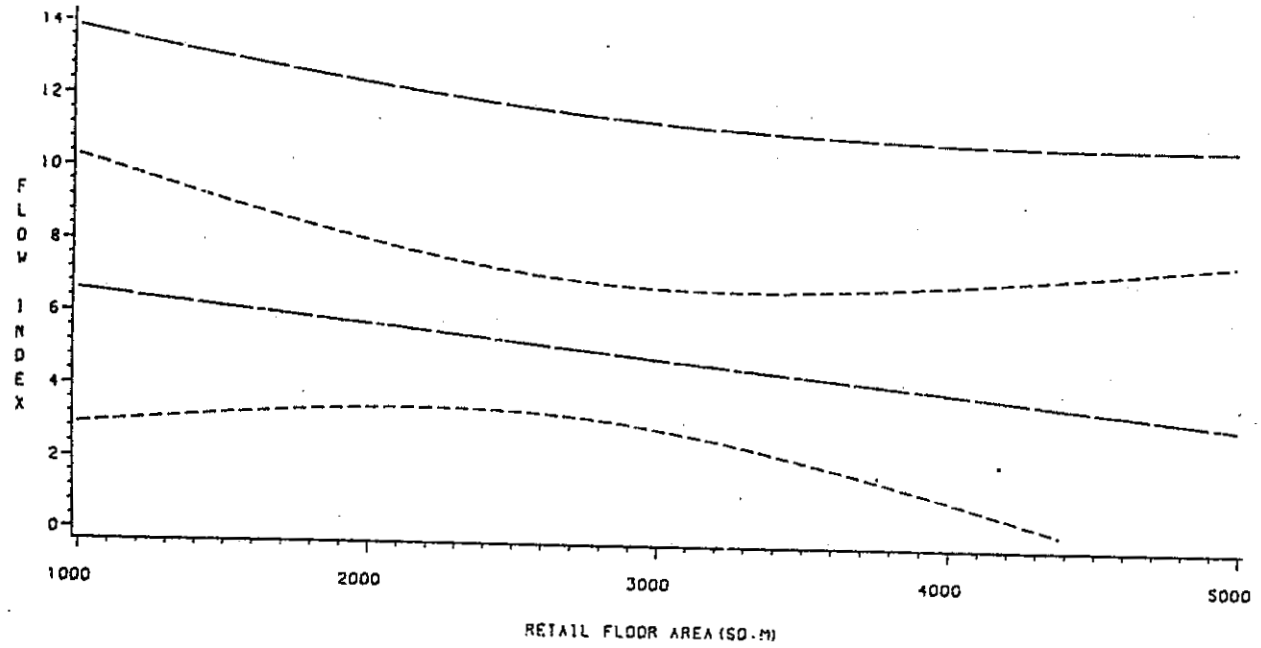
EDUN : CRFI = -1.334*RFA+9.549 (R-SQ=0.435, 7 STORES)
WHERE RFA = RETAIL FLOOR AREA (SQ.M*1000)
CRFI DERIVED FROM 15 MIN. 2-WAY FLOWS

FIG A1.6

FLOW INDEX(CRFI) VS RFA

90% CLS FOR MEAN(INNER) & INDIVIDUAL VALUES(OUTER)

SATURDAYS



EQUN : CRFI = -1.049+RFA*9.089 (R-SQ=0.246, 9 STORES)

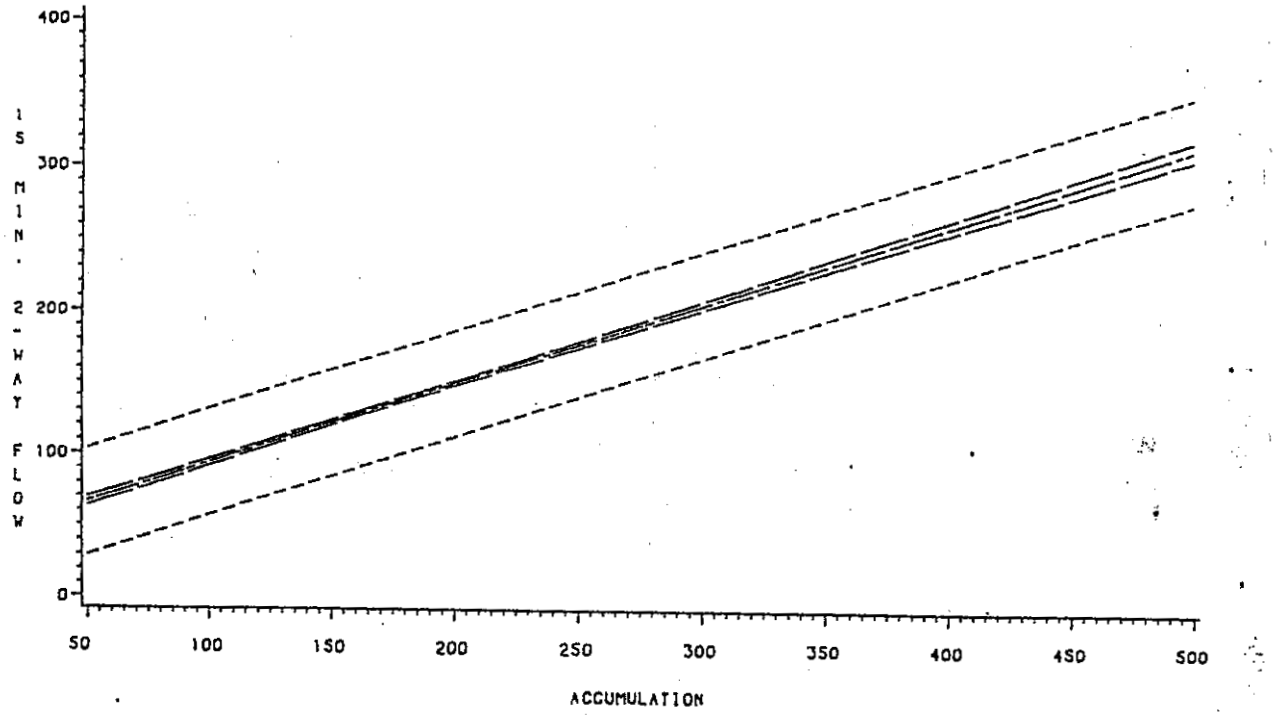
WHERE RFA = RETAIL FLOOR AREA (SQ.M*1000)

CRFI DERIVED FROM 15 MIN. 2-WAY FLOWS

FIG A1.7

2-WAY FLOW VS ACCUMULATION

LINEAR REGN. 99% CLS FOR MEAN(INNER) & INDIVIDUAL VALS(OUTER)
THURSDAYS, FRIDAYS & SATURDAYS



EQUN : 15 MIN. 2-WAY FLOW = 0.574*ACCUMULATION + 33.895
R-SQUARE=0.859 D.F.=1115

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