SPATIAL BEHAVIOUR IN THE RETAIL ENVIRONMENT

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Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy, October, 1991

ABSTRACT

This research has focused on the development of techniques for the collection, analysis and presentation of large movement and behavioural data sets. The research has followed three strands: the investigation of pedestrian flow networks in the central business district, the relationship of pedestrian flow and retail turnover, and the study of movement and behaviour of customers in-stores.

This thesis reports on the development of a self contained time-lapse camera system. The cameras were used to record flow conditions and people in both the city centre and in-store environments. For each person seen in the films a number of demographic and behavioural variables were extracted. These were then used as the data base for computer modelling systems.

The investigation of the potential development of a turnover interface was necessary to test whether the variables extracted from the film were of any predictive value. It was found that it was possible to segregate the shopping from the non-shopping population on the basis of the data collected.

Two movement models were developed. The first, an Origin-Destination model called WONKA, was based on the network estimation procedures used in vehicular modelling. WONKA was applied in both environments for the prediction of paths through the studied network. PRETTY, a customer simulation and animation program, recreated the recorded data and allowed the user to select data sets according to any combination of the recorded variables. Subsequently a probable path module was added to PRETTY as it became apparent that the tight theoretical basis of WONKA was not suited to the free layouts of many stores.

ACKNOWLEDGEMENTS

There are a number of people who have made this research both possible and enjoyable:

1) Ian Conman for invaluable design advice, providing ladder stability beyond the call of duty, and council on general floral matters.

2) Chris Lewis for providing the quality drawings in this thesis.

3) Hilary, Melanie and the Tall One for putting me up and putting up with me. I apologise if my visits have been too frequent and too lengthy.

4) Janet "Sticks" Beckett for being the RAT pin cushion and herding Spaniards

5) Hugh Phillips for having faith in the research and finding funds for the RAT in its time of need.

6) Tabby for excusing me from numerous comparative surveys of footwear outlets and revealing the delight of Bacon and Potato bake.

7) John Winn for printing the text and pictures and being available at most hours of the day.

Both my tutors have been very supportive and have suffered the vagaries of my behaviour. Roy has perfected his own special brew of survey anti-freeze. I offer a special thanks to Michael for being so generous and helpful. Hopefully he has enjoyed these last few years as much as I have. May I take this opportunity too apologise for falling asleep at 2:00am and loading the cameras incorrectly.

Finally I must thank the two people whose reckless gambling made me realise that D-Day was approaching fast. My dad better not squander his winnings.

Simon Thornton October 4th 1991

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NETWORK ELUCIDATION

This research was initiated by a request from Thorntons PLC, a national confectionery retailer, to develop a method of untangling the fundamental patterns of pedestrian movement in a city centre. In a large city centre Thorntons typically operates between 3 and 6 retail outlets. The company is dependent on attracting passing pedestrians into the store. Because the product ranges offered in each store are identical it is important that each store serves a distinct pedestrian network. If the branches serve the same network either the stores under perform or the pedestrians swell (figure I.1). With detailed pedestrian movement information the company would be able to assess new sites and review the degree of overlap between the company's existing outlets. Thus the research tried to investigate the multiple branch location problem and the factors affecting micro-site, as opposed to trading area or neighbourhood, performance.

The full range of pedestrian data collection techniques were assessed and a number tried in the field. A prototype time-lapse camera system was designed, built and operated. A ten day survey recorded a number of variables from over 7,000 pedestrians. Two 60 street, three day, city centre surveys have since been completed

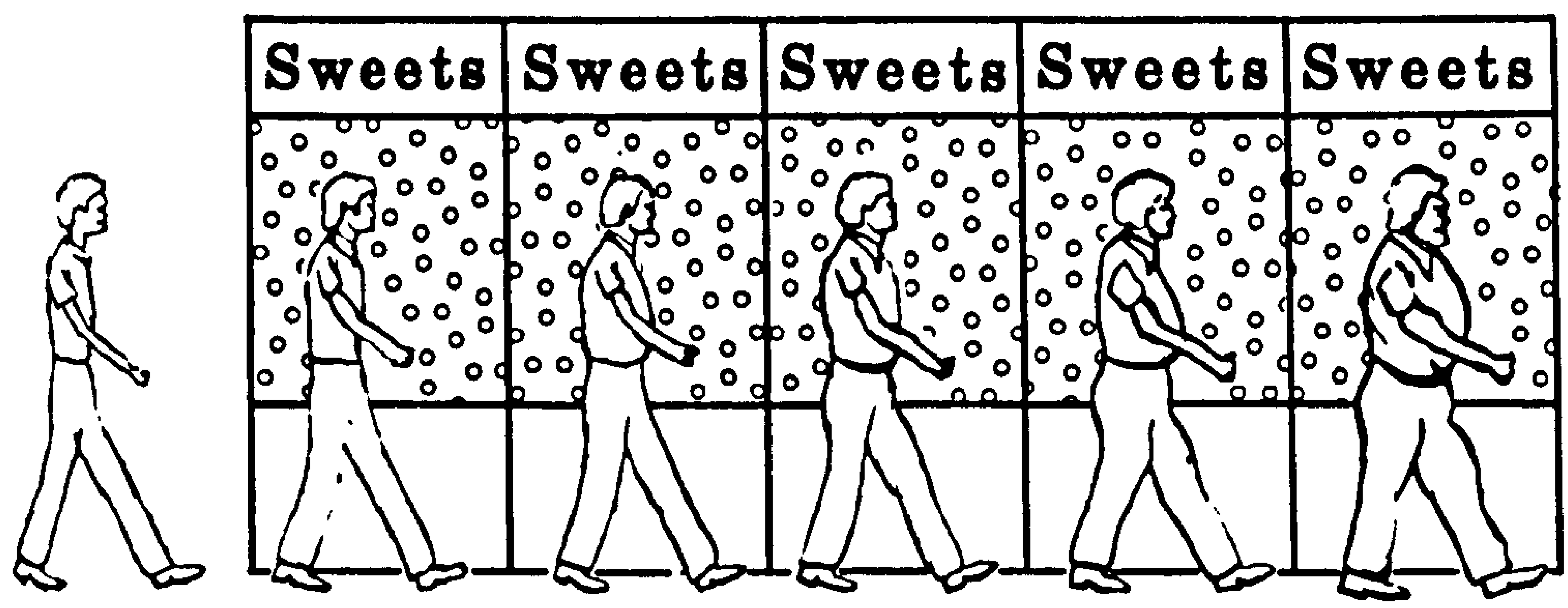


Figure I.1 Turnover = Pedestrian Volume Fallacy with in excess of 200,000 pedestrians recorded. This data became available too late to be fully analysed and included in this thesis but a brief comparative analysis has been given. Finally an Origin-Destination model that constructed pedestrian networks from the film data was derived. This should be useful in future research when assessing the effects of competition.

CROSSING THE THRESHOLD

Subsequently following the initial work there was an attempt to determine relationships between the pedestrian flows observed from the time-lapse surveys, their demographic structure and the turnover of a store (figure I.2). The derivation of a turnover interface would allow the company to probe the pedestrian network database and find the best potential sites for a retail outlet. This section of the research also served the purpose of validating the techniques used previously and the type of information gathered.

A detailed record of the behaviour and store response of over 3100 pedestrians was collected. Continuous video film had to be used because of the type of data required but the extraction time was very high. A number of numerical techniques were used to classify the data a build a predictive base.

IN-STORE

The last stage of the research involved moving from the street environment to that of the store (figure I.3). This work was sponsored by Boots PLC, a major national retailer, with the aim of monitoring and modelling customer behaviour within the controlled environment of a retail store. Initially this work studied only spatial movement and


TURNOVER INTERFACE
PEDESTRIAN DATA BANK
×
=£1
=25p
=20p
=50p
x
y
?
=
TURNOVER ESTIMATE

Figure I.2

in-store flow networks using the techniques that had been successfully applied in the city centre environment. However it quickly became apparent that other aspects of customer behaviour needed monitoring for the sake of completeness. Thus the scope of the analysis grew to encompass queuing, congestion, staff interaction and product viewing. New data processing and modelling techniques were developed and these have subsequently been re-used in the city environment.

A fully operational miniaturised time-lapse system was constructed and used in six in-store surveys. Over 50,000 observations of customer movement and other behaviours have been recorded. A suite of analysis and presentation programs have been written and applied to the data sets. These programs have enabled the companies to identify the store features that have caused particular spatial usage patterns and thus to rectify any perceived difficulties.

The research presented here is ongoing and as such there are a number of loose ends. These are being neatened and straightened in later work, as and when the opportunity presents.

From Street to Store

Figure I.3

CHAPTER 1

ASSESSING POTENTIAL STORE LOCATIONS

There has been a significant amount of work done in the field of assessment of store locations, both potential and existing, but most of it has been focused not on the micro-scale, i.e. the street level, but on the macro and meso- scales that predict performance within a city or neighbourhood. A number of researchers have identified the need for research into the micro-locational factors of store success (Breheny 1986 and Dawson 1980). Some of the larger scale techniques will be discussed briefly and their inapplicability to the problem in hand explained.

Analogue Models

The concept of predicting the performance of a potential site via the use of analogues or comparisons was first introduced by Applebaum (1968). Applebaum used the historical trading records of existing stores to predict site potential. The analogue process involves matching the site to stores with similar characteristics. The variables gathered should be as comprehensive as possible (Drummey 1984). The information used includes the demographic nature of the trade area, consumer behaviour patterns, effects of competition and micro-site factors.

The main data gathering occurs during a customer spotting survey. Between 300 and 400 customers at each of the analogue stores are asked where they live and the amount of the weekly food bill, in the case of a grocery chain, and the proportion of that spent in the survey store. Demographic information is also recorded to see how typical they are of the area. The customer's home address is then marked on a map of the area together with a series of concentric rings whose radii increase at, say, half a mile a time. The trading area is defined as the smallest ring that contains 80% of all the customers. The next stage is to determine the drawing power of the store on each ring from the survey data and the sales per capita per ring. These figures are averaged across a group of analogues and then used to predict sales on the basis of the population data at the new site. At all stages through the process the researcher can modify the data to take account of differences between the analogue and potential stores.

The degree of subjectivity in the method has been widely criticised (Drummey 1984, Breheny 1986, Davidson et al 1988 and McGoldrick 1990). The lack of formal structure and the degree of interpretation necessary mean that the results are bound to vary between researchers. It also requires a suitable analogue set on which to base the prediction. Drummey states that the success of the forecast is dependent on the extent and quality of the data collection effort, and/or the experience and common sense of the analyst. As the size of the problem increases so does its complexity (Applebaum 1965) and this makes it hard to make consistent analogue judgments and understand the reasons for performance differences (Breheny 1986).

Multiple Regression

In order to formalise the store location assessment process and remove the conjectural element found in analogue forecasting many workers suggest using multiple regression analysis (Davies 1977, Jones and Mock 1979, Wilson 1984, Breheny 1986, Davidson et al 1988, McGoldrick 1990 and Simkin 1990). Multiple regression is a statistical technique that derives the equation with the formulation of the regressed, or predictive, variables that best describes the observed turnover. The relevant data from the potential site can then be put into the equation and the expected level of turnover calculated.

As with the analogue technique the researcher gathers as much information about the variables that are thought to control store performance from a number of stores. The variables used to build the model can be classified into either store or catchment area characteristics (Breheny 1986). Some researchers suggest that only stores with similar attributes, as with the analogue approach, should be used in any one model (Jones and Mock 1979, Wilson 1984, Davies 1977, Davidson et al. 1988). A stepwise regression is commonly used. This has the benefit of showing the importance of the variables to store success and indicates those that need not be measured in future, thus reducing the cost of the procedure.

For a reliable model to be developed there have to be a reasonable number of analogous stores. Rogers (1987) suggests that 30 stores are needed but McGoldrick (1990) implies 15-20 are sufficient. If the company changes trading format a new model has to be developed. Bowlby et al (1985) describe two techniques for overcoming the problem of a lack of analogous stores. Both revolve around the break up of the catchment area into cells and the treatment of each cell as an observation as opposed to each store. Although this provides an answer to a scarcity of stores there are problems in that the true basis of the model, the number of stores, is weak. There are also problems in using variables without true causal relationships and the danger that variables that are collected and used in a model actually have an inconsistent effect on sales. As with the analogue approach the model is only as good as the data put into it.

Wilson (1984) suggests that linear regression is more convenient than polynomial forms and the recommendation of the linear form seems widespread (Claus et al 1972, Davies 1977, Jones and Mock 1979, Bowlby et al 1985, McGoldrick 1990). As with any statistical technique certain mathematical conditions have to be met in order to satisfy the theory of the model. It is important to ensure that the relationships between the sales and each of the variables are linear. These need to be transformed if not, using functions such as the logarithmic or exponential, to a straight line (Wilson 1984). Multicolinearity, or correlation of the variables, breaks one of the fundamental conditions of a regression model. The variables should be independent of each other otherwise the model will become unstable (McGoldrick 1990). Preprocessing of the data using techniques such as principal components analysis can overcome inter-dependence. In cases of heteroscedasticity, where the variance of the data is not constant about the regression line, it is unwise to use the model for prediction because the condition suggests that there is an underlying trend in the data (Davis 1977). The presence of autocorrelation in the residuals, regular deviation of the data points from the regression line, suggests that the model does not provide an adequate description of the data. When using a statistical technique it is important to make sure that the data conforms with the technique's assumptions (Davies 1977, Rogers 1987, McGoldrick 1990). However multiple regression analysis has become popular and Davies (1977) reports 75-80% accuracy.

Trade Area Mapping and Computer Databases

Trade area maps are used in a number of the techniques mentioned here but do not provide a predictive model on their own (McGoldrick 1990). The technique involves developing a map of customers homes and tying in information on demographics, average spends and use of competing outlets. Data can be gathered from customer spotting surveys (see above) or customer databases of product guarantees, transactions etc. The map results can be combined with some of the commercially available geographic databases such as Pinpoint and ACORN to provide detailed market area statistics for inclusion in turnover models. McGoldrick (1990) notes the success that some retailers have achieved with these types of systems.

Gravity or Spatial Interaction Models

Gravity models determine potential shopping levels by relating customer movements to the attractiveness of an area and the effort involved in getting there. The basic formulation of the gravity model is thus:

$$P_{ij} = \frac{F_j/t_{ij}b}{\sum_{j=1}^{n} F_j/t_{ij}b}$$

P_{ij} = The probability of a customer at i visiting j
F_j = The floor space of centre j
t_{ij} = The travel time from i to j
b = A parameter whose value indicates the willingness to travel for each type of good

The model is based on the Newton's theory of gravitational attraction where the attraction of two bodies is proportional to their mass but inversely proportional to the square of their separation. The model was originally transferred to the field of retail location by Reilly and subsequently by Huff (McGoldrick 1990).

Most of the development of the gravity model has centred around the measures of attractiveness and friction of distance (Rogers 1984 and McGoldrick 1990). In the equation above these factors are accounted for by the floor space and travel time measures. Stanley and Sewall (1976) added a component of store image to the basic model. A number of researchers have tried to replace actual distances with measures of perceived distance or other aspects of travel deterrence (McGoldrick 1990). Guy (1987) reports on three modifications to the standard model. Firstly it is possible to alter the distance decay function for each origin thus allowing the incorporation of mobility and price sensitivity data. Secondly the definition of mass can be enhanced by using a number of independent variables for both the origin and the destination. Finally competing destinations can be included.

The basic inadequacies of the attraction/friction measures have led to the development of other spatial interaction models such as the multiplicative competitive interaction model and multinomial logit models (McGoldrick 1990). Ghosh and Craig (1986) developed a procedure for determining the optimal location of a number of branches. They modified a maximal covering model to take account of non distance measures of accessibility and to maximise profit rather than coverage. A maximal covering model allocates the centres of demand to nodes in a network and the probability of facility usage is determined by the accessibility and the attributes of the store. The model then seeks to maximise the level of total utilisation.

Spatial interaction models are usually criticised for the simplicity of their inputs and assumptions. Rogers (1984) highlighted four problems with gravity models:

1) Large amounts of field work are required and accurate sales estimates for competing stores are hard to obtain.

2) It is necessary to estimate the expenditure of the area for the particular store type.

3) The limited number of explanatory variables means that consumer behaviour has to be averaged. This presents difficulties for stores whose market is highly segmented.

4) There is no statistical measure of reliability.

This type of model is usually used to model location in a regional or city-wide context and as such is not so suitable to the retailer who is dependent of site specific locational factors (Bowlby et al 1985). There must always be doubts that the vagaries of shopping behaviour can be accounted for in such large scale numerical equations. There is a tendency for many modellers to adjust the coefficients, Rogers (1984) terms them fiddle factors, to make the model fit the observed pattern.

MICRO-SITE ASSESSMENT

For a number of different types of retailers micro-locational considerations can outweigh those of the trading area. This is not to say that trade area considerations are unimportant but that the micro locational issues dominate. This is true for Nelson's (1958) "suscipient" retailer. A suscipient retailer is one who can not generate trips whose primary purpose is to visit his store. Their success is dependent on traffic generated by other retailers or land uses and thus their location and exposure to the customers of other stores is vital. Between different retailers there will be large variation in the importance of various micro-site factors. Bowlby et al (1985) suggested that the residuals from a larger scale multiple regression analysis (see above) may show the effect of micro locational factors. Davidson et al (1988) suggested the use of discriminant analysis to determine the factors that account for performance variation between stores whilst Jones and Mock (1979) specified cross tabulation analysis. With any modelling approach it is important to confirm that it is not model errors that have caused the results (Bowlby et al 1985). Most companies have determined through experience the micro-site factors that determine success.

The most common form of micro-site assessment is a relatively informal check list approach (Pyle 1926, Wenzlick 1930, Paver and McClintock 1935, Nelson 1958, Claus, Rothwell and Bottomley 1972, Craig et al 1984, Breheny 1983, Bowlby et al 1985, Cox and Brittain 1988, McGoldrick 1990). Typical checklists note such factors as:

1) pedestrian flows, composition and daily variation
2) availability and cost of parking
3) type of street (pedestrianised or vehicular)
4) location of street crossings
5) location of public transport facilities
6) size, frontage and orientation of the store,
7) location of competing and complementary stores
8) location of the main traffic generators

The items are usually rated during a site visit. The checklist has the advantage reducing the likelihood of overlooking important micro-locational factors (McGoldrick 1990) but on its own can not predict turnover.

Usually the micro-scale factors are included with the trading area characteristics in the models described above. Bowlby et al (1985) suggest using the ratings from the checklist to build a separate micro-scale multiple regression model. If the number of stores is too low for a regression model the authors suggest a common sense analysis. There are some problems with using such checklist data for numerical analysis because of its subjective nature. The residuals and predicted scores may be a result of an individuals perception of an area and not representative of actuality.

Anderson (1985) overcame the problems of subjective checklists by linking the performance of small stores to the presence of anchor tenants in shopping centres. By using a multiple regression analysis Anderson discovered that both profit and sales of a particular fashion company were related to the presence of large anchor tenants and the design of the store. Two of the anchors, J.C.Penny and Sears, had a negative effect on sales and profit. Interestingly it was the old design that was more successful. There was no attempt to include staff variables in the model and the trade area buying power index that was included in the model was not associated with success.

THE THORNTONS' SITUATION

The problem faced by Thorntons is in some ways unique. Thorntons retails its own products from small, sub 1000 square feet, stores. The products are marketed on the quality of the ingredients and their freshness. There are no other national retailers who have speciality stores in this field. Most confectionery is sold through departments within larger chains, such as Woolworth, or from small CTN units (CTN stands for confectionery, tobacco and news retailers). The company has very little in the way of direct competition within its quality product field although this is slowly increasing. The company's own research has shown that over 50% of the purchases made in its stores are triggered by seeing a Thorntons' store. Therefore the company is very dependent on attracting the pedestrians passing its sites.

The role of pedestrian flow networks had always been acknowledged by the company but their importance became apparent during a refurbishment program that the company put into effect during 1985. It became evident that in certain circumstances it was possible to close stores within a multiple branch city centre and not lose trade but in other cases if a store was closed the trade would not transfer to the remaining stores. Thus in choosing a new site or reviewing existing ones, the company had to assess not only if there was the required pedestrian traffic near the site, in order to generate the impulsive trade, but also whether that traffic had already been exposed to a Thorntons' unit elsewhere in the town. This latter concern formed the initial focus of the research and has been termed the multiple branch location problem. In examining the multiple branch location problem a site can not be treated in isolation. The whole pattern of pedestrian movement and behaviour within the city centre has to be examined. The traditional methods of store location assessment and performance prediction, discussed above, did not seem to cater for such micro-locational variation.

THE MULTIPLE BRANCH LOCATION PROBLEM

The multiple branch location problem has four crucial controls that need to be understood and assessed, namely:

1) Site factors that cause people to stop and shop.

2) "Generative" capacity, or locational dependency on the presence of other traders, of the branch.

3) The relationships between the product sold, the purchase status and the people making the purchase.

4) The degree of interaction between the company's own stores and those of competitors.

There are numerous other controls on the actual turnover levels achieved, such as company "image" or customer "need". However, either these should not affect locational performance as opposed to performance in general, or they are accounted for in the categories above. The advantage of studying one company and not a series of competitors is that many of the variables, such as product range, price and store ambience, are constant throughout the stores. Although the initial stages of the research were only concerned with the last category, interaction between stores, it is important to understand the role of the first three in the list.

SITE FACTORS

There are obviously many factors that influence a site's potential turnover. For any given company turnover potential is controlled by the relationships between the physical character of the site, the internal controls, and the location/ pedestrian flow situation, the external controls.

1) External Factors

The external category encompasses any factor that influences the number and character of pedestrians passing the shop and their propensity to spend in the locale. Examples include the presence of consumers, pavement width, proximity of pedestrian crossings, the surrounding retail facilities and/or other land uses. External factors are largely out of a retailer's control. If a retailer has little or no generative power the volume and structure of the passing pedestrians should entirely reflect the external controls on the site.

2) Internal Factors

The internal category concerns the given features that vary between sites and will affect the volume of passers by and/or the probability of them feeling the desire to stop and shop. In assessing trading levels it is important to try to separate theoretically store from site. The site puts physical limitations on what type of store the retailer can operate. The most important controls are the length of street frontage, the location and orientation of the frontage in relation to the flows and the floor area of the unit.

As the study is primarily geographical and mainly concerned with potential turnover it was considered reasonable to give a figure for the numbers expected through the door. However, during the calibration of any turnover model the store front, internal design and image factors of existing stores would have to be understood and standardised. The role of the store as a physical unit as opposed to the operational aspects of retailing will be examined later.

GENERATIVE CAPACITY.

Generative capacity and product/customer relationships are inextricably bound up with each other. Any discussion of micro-location must try to assess the dependency of a retailer upon the flow outside the shop. The degree of dependency is determined by the nature of the products being sold. Nelson (1958) puts forward the terms "generator", "shared" and "suscipient" to describe the drawing power of a retail outlet. A generator is a store that creates its own traffic and could survive without the presence of other companies. As out-of-town traders have shown, there are true generators, outlets whose location is determined by the trade area as opposed to micro-site considerations. Such stores can survive without associated shops, for example furniture warehouses and out-of-town supermarkets. Shared and suscipient traders are to varying degrees dependent on other companies to attract their customers into the neighbourhood. However Nelson's terminology becomes rather abstract within the city centre. The dominance of multiple-purpose trips make it unlikely that there is a principal retail outlet, or single generator within any one trip. The theory of cumulative generation makes far more sense:

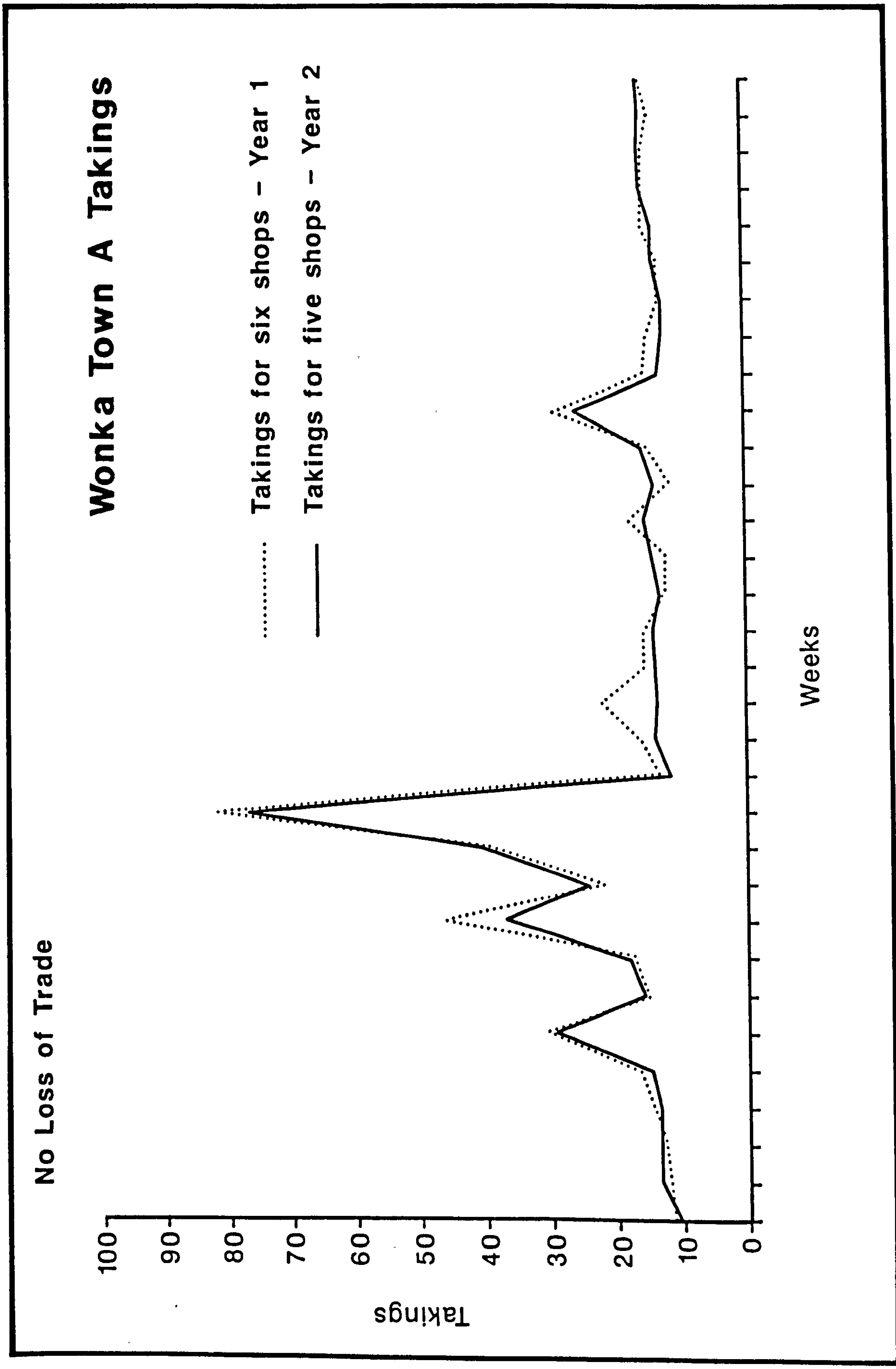
> "A given number of stores dealing in the same merchandise will do more business if they are located adjacent or in proximity to each other than if they are widely scattered."(Nelson 1958)

As this study is concerned only with small outlets (< 1000 sq ft) shopped by a high proportion of impulse visitors it will be assumed, for reasons of caution, that the business is largely suscipient, i.e. dependent on traffic generated by other stores, and thus success is dependent on the shops' location relative to that of the main areas of generative capacity. The pedestrian, who is after all the dominant town centre shopper, has a well chronicled walk length (e.g. May, Turvey and Hopkinson 1985) and his perception of distance can have a great effect on behaviour (e.g. Meyer 1977 and Coshall 1985). No shop whose customers are pedestrians can afford to locate far from a major pedestrian network.

PURCHASE STATUS, PRODUCTS SOLD AND PURCHASERS

The discussion of dependency given above is largely theoretical as in reality it is determined by the status of the purchases being made. There are essentially two type of purchase: impulse and pre-planned. Impulse purchases have been defined "as articles that are frequently bought on the basis of unplanned, spur of the moment decisions" (Davidson et al 1988). Pre-planned purchasing indicates an intent to purchase before there is any sensory contact with the product or a cue. Pre-planned purchasing can involve either intent to buy from one store or intent to shop for a comparison product from one of a number of stores. A product's purchase status may vary seasonally and according to who is buying it. In the case of Thorntons, for example, chocolates might be bought as a treat throughout most of the year on an impulsive basis but at seasonal times bought as a pre-planned gift. There are also variations in status across the product range which means that some items are bought in a pre-planned manner, such as Easter eggs, whereas others are bought on impulse.

McGoldrick (1990) identifies 3 forms of impulsive buying. Firstly there are generally planned purchases where the customer recognised a need but chooses the specific product in the store.

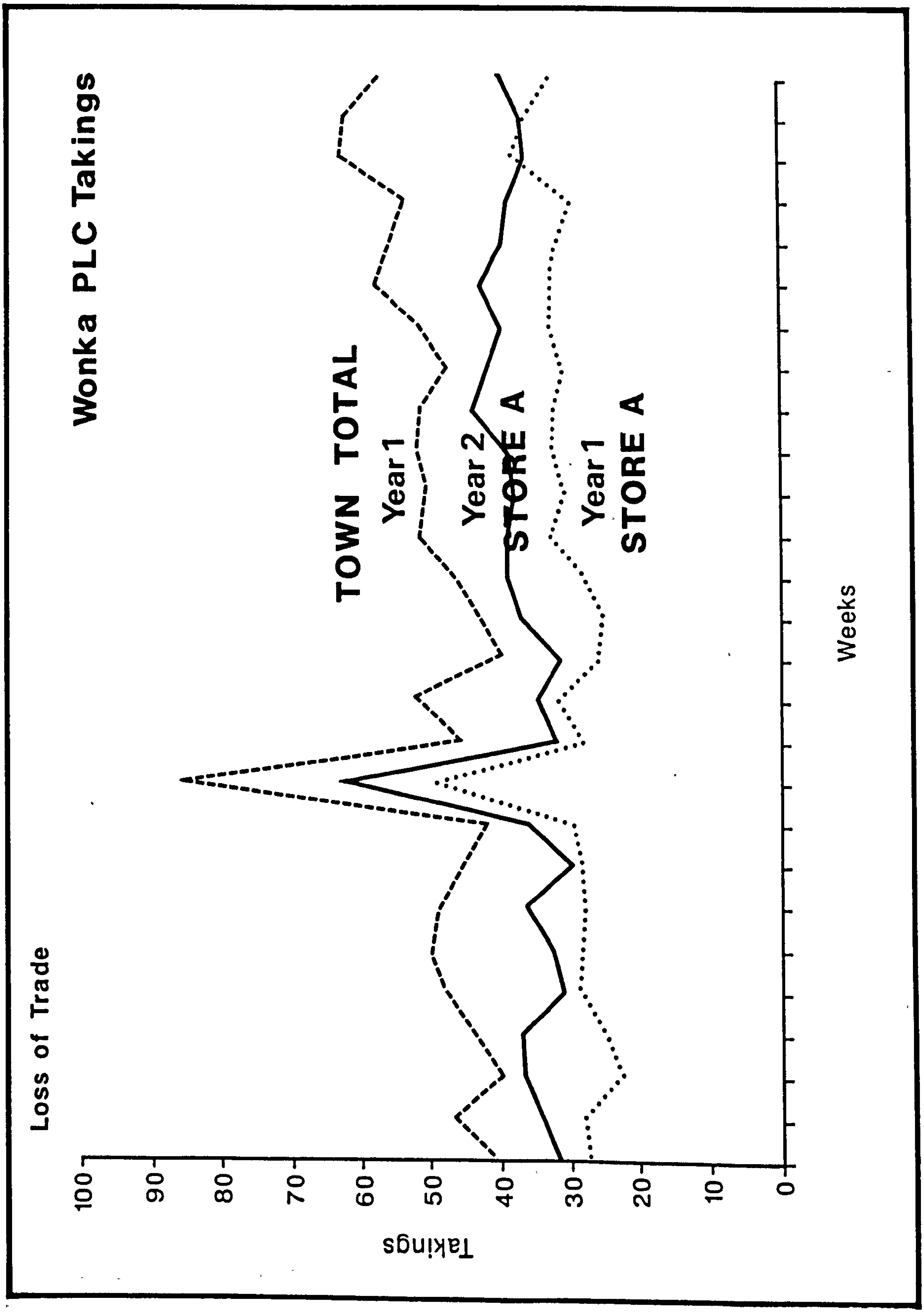


Wonka Town A Takings
No Loss of Trade
Takings for six shops - Year 1
Takings for five shops - Year 2
Takings
Weeks
100
90
80
70
60
50
40
30
20
10
0

Figure 1.1

Secondly the customer decided to buy a product because some cue reminded him of the product. Finally there are entirely unplanned purchases. Many customers make secondary impulsive purchases when they are in store but in terms of impulsive store entry, the focus of this section of the study, the second category must be dominant. The window display and signage act as prominent cues for the company and are responsible for much of its business.

The importance of the distinction in purchase status can be seen in the following examples. As mentioned earlier the retailer concerned operates from small sites and is classed as suscipient because of the high ratio of impulse visits. In the first case (figure 1.1) the company shut down a unit that served the office district of the town with most of the purchasing occurring in lunch hours and very low volumes of pedestrian flow past the shop. The nearest company unit left open was half a mile away. There was very little fall-off in trade for the city as a whole which implies that the people who had been using the unit before it closed were making pre-planned purchases and they were prepared to walk to the other store to obtain the products. The fall-off at peak periods was probably due to seasonal factors such as queuing increasing the perceived effort of the purchase. The second example (figure 1.2) shows the effect of closing down a unit in an area that was primarily used for shopping. The fall-off was marked, suggesting that the majority of the purchasing at the ex-unit had been impulse or low effort pre-planned and/or that the two shops were located on essentially different pedestrian networks. There were no significant differences in the product sales profiles of the two stores that were closed.



Wonka PLC Takings
Loss of Trade
TOWN TOTAL
Year 1
Year 2
STORE A
Year 1
STORE A
Takings
Weeks
100
90
80
70
60
50
40
30
20
10
0

Figure 1.2

It seems reasonable to assume that pre-planned purchasing is controlled by the customer's perceptions of the effort involved in the purchase, usually a function of the distance to the shop, and his perception of the reward such a purchase will bring. This perceived effort/sales elasticity highlights the need for the store to be located on or very near to the pedestrian flow. Thus in considering the necessary locational ingredients for store success at a given site it is necessary to answer three questions:

1) What type of pre-planned purchase is being made: a store and product-specific, a store-specific, or an idea or product-specific? It is important to make the distinction between types of pre-planned purchase. If an individual belongs to the first category he will come to the store. Idea- or product-specific purchasing may involve a customer examining a number of alternatives from the range of shops within the evoked, or considered, set. Store-specific purchasing involves a customer search for a product within one store. Thus the opportunity for sales is dependent largely on whether the shop is amongst the pedestrian's considered alternatives.

2) Of those who have made a pre-planned decision to visit the shop how many people will make an effort to come, and how far will they travel off their route? As seen in the example above in locational terms low effort pre-planned shoppers can be treated as impulse shoppers.

3) How many of the passers by could reasonably be considered to be potential impulse visitors/purchasers?

It is thought that any attempt to predict turnover will be additive because some purchasers will not be random impulse based elements of the pedestrian flow, but purposive. In simplistic equation terms the conclusion is :

$$\text{TURNOVER} = \text{PEDESTRIAN VOLUME} \times f(\text{IMPULSE}) + \text{PRE-PLANNED}$$

The degree of both pre-planned and impulse shopping will vary according the points noted above.

SITE INTERACTION

Turnover prediction for the size of outlet under investigation can rarely be achieved via a non-spatial formula such as the type envisaged by Paver and McLintock (1935):

$$\text{TURNOVER} = f(\text{PEDESTRIAN VOLUME})$$

The role of competition and pedestrian inertia has to be accounted for in the case of a suscipient retailer. If the formula above was correct the whole town centre would be filled with the most profitable form of retailing.

When a company is proposing to operate only one store in a town, the location problem is often considered to be quite simple. Most people would say things such as "put the shop where it's busy" or "put it next to Marks and Spencers" (the traditional definition of a "prime" site). However there are several reasons for examining other sites:

1) there may be multiple and distinct pedestrian flow systems within the centre that could offer valuable positions

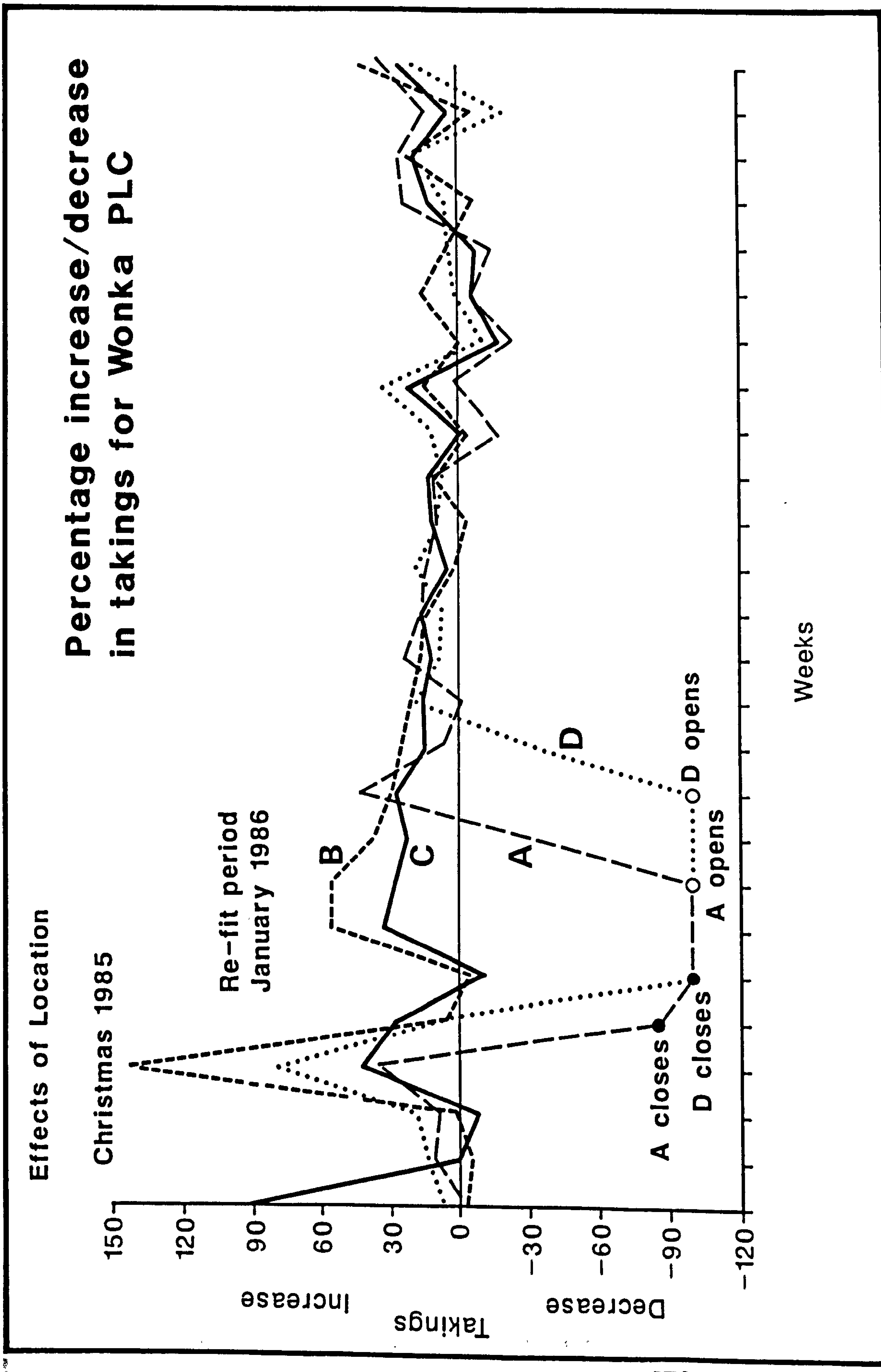
2) the lack of ideal units in the "prime" areas

3) the variation of pedestrian psychology and structure within the centre.

1) Flow Patterns in Complex City Centres

A complex centre is one that has a number of significantly different pedestrian networks with very little pedestrian exchange between them. Figure 1.3 illustrates relationships between complex centres and turnover. This example is taken from the four shops that Thorntons operated in Nottingham. Two shops "A" and "D" were closed for refitting, leaving shops "B" and "C" trading but as the figure shows they picked up very little of the business lost by the two that were closed. The relatively small distance between the shops (<800 metres) implied that there were at least three essentially separate trading zones. Business was lost because there was very little overlap of the pedestrian networks involved.

Many retail workers have tried to build elements of competition into turnover forecasting models and some of these have had an element of spatial control (e.g. Craig, Ghosh and McLafferty 1984, Bowlby et al 1985, Breheny 1986). This has usually been achieved by multiplying the distance between competitive units by the floor space (or some other measure of trade volume). This provides a rather inadequate answer as the distance measure is rarely related to the trip histories and trip futures of the passer-by. It may prove to be the case that a pedestrian who passes by a competing shop does not pass the store in question, so it may be regarded as a non-competing outlet. In the case of the multiple branch retailer, a pedestrian who has already passed a shop will have no desire to enter a second and make a purchase unless he did not notice or like the first, which is obviously a design or management problem, or unless the time taken to pass by both shops is greater than the product's lifetime (the "Ratners' Earring Syndrome"!) and



Percentage increase/decrease in takings for Wonka PLC
Effects of Location
Christmas 1985
Re-fit period January 1986
A closes
D closes
A opens
D opens
A
B
C
D
Takings
Increase
Decrease
150
120
90
60
30
0
−30
−60
−90
−120
Weeks

Figure 1.3

the consumer has again generated the need to purchase. With any potential new site one has to determine how trading at that position will affect the turnover of the other shops.

The identification of distinct pedestrian networks within the centre therefore will reduce the tendency for duplication or neglect of trading sites and enable both competitive positioning and the maximisation of the city's contribution to a retailer's profits.

2) The Lack of Ideal Sites

Sites can be unsuitable for a number of reasons, the two most common being the size of the unit and the rental. Although the boom in rental levels seen in the 1980's has halted, the cost of making locational mistakes is extremely high. The costs of fitting out the store, staffing and promoting it mean that errors have to be avoided.

The cost problem is made more acute for impulse-based retailers because of their dependence on zone A space (figure 1.4) and wide street frontages. For rent assessment purposes retail space is measured from the shop window backwards. The first 20 ft is zone A, the second 20ft is zone B and charged at half the zone A rate, etc. Rental rises have also made the problem of unit size more acute. Most redevelopment is based on a minimum 1000sq ft unit. Traders often find it difficult to fully utilise these larger units. The task of finding lines that are complementary to the retailer's traditional profit centres is not an easy one and thus the burden of larger sites is hard to bear. One way around this problem and that of low population is to reduce the size of the Thorntons unit. This has been done by developing the franchise network. Each franchise unit requires approximately 200 square feet of selling space and thus can be operated in areas that would otherwise be unfeasible.

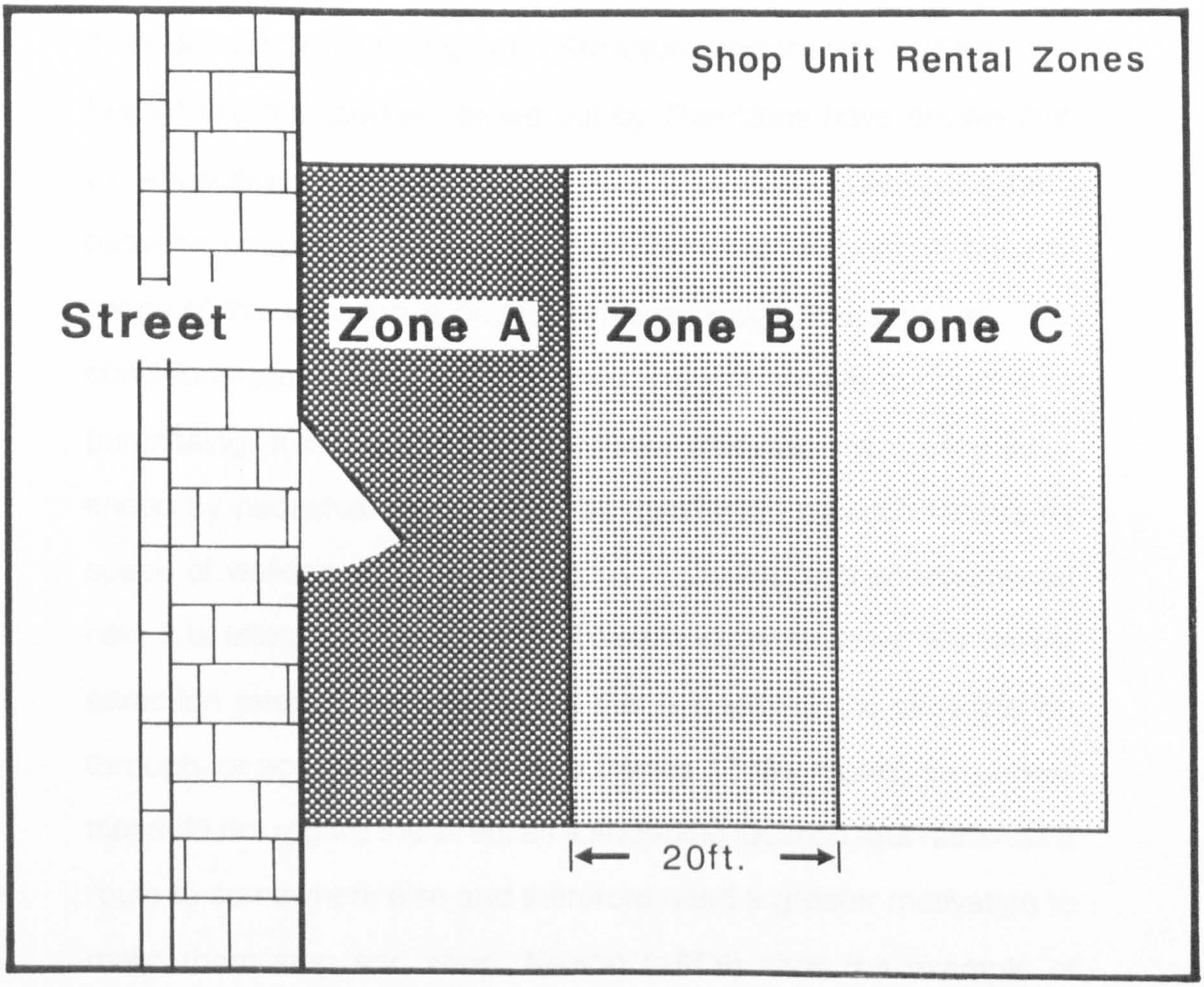


Figure 1.4

The older peripheral area and secondary centres of the CBD tend to offer more units of a suitable size and the rentals, which are usually related to the volume of pedestrians passing, tend to be lower.

3) Pedestrian Psychology and Structure and the Micro-Site

Recent informal studies carried out by Thorntons have shown that the variability in their shops' pedestrian attraction rates, the ratio between people passing by to those entering, is great. A primary cause of this variation is pedestrian psychology and structure. The conditions present in the busy street are not always conducive to purchasing. It is thought that purchase motivation is greatly influenced by pedestrian psychology as manifested by such factors as speed of walking, social associations, crowding and environmental risk. It is often the case that the busiest locations have the lowest attraction rates. It is thought that this is because the sites are on through, or access (Bennison and Davies 1978), routes, i.e. pedestrians do not regard the street as a shopping location, but rather as a route to somewhere else and therefore need a greater motivation to make them stop and shop. Nelson (1958) cites the example of Chicago's Madison Street and the failure of most types of store to attract viable business levels from the very high levels of pedestrian flow. Paver and McClintock (1935) monitored both traffic and sales levels and found that although there was some agreement between the two there were numerous periods when the curves bore no relation to each other. Analysis of variations in pedestrian psychology and its affect upon penetration rates could have important implications for outlet design and window layout. However, as yet there seems to be little work done and the effects, whilst not unknown, need to be understood.

Penetration rates are also controlled by the character of the passing pedestrian. Nelson (1958) and Davidson et al (1988) point to the importance of examining the structure of pedestrian flows. There will be a greater probability of a pedestrian stopping if he falls within the market segment to which the product is targeted. A flow with lower buying power could either buy less in total value terms (Nelson 1958) or buy products of lower value or pricing points. Consumer profiling, originally based around census and later around secondary VALS measures, features strongly in trade and catchment area studies as well as in marketing and advertising. There is little to be gained, except error and bad judgment, from according equal importance in calculation to all groups unless the market penetration and average purchase for each is the same. Micro-site assessment must take into account potential variations in product sales profiles as it is a vital factor in the profitability equation.

SEGMENTATION OF PEDESTRIAN FLOWS

There are many possible axes of segmentation, Davidson et al (1988) suggests 12 demographic and psychographic variables: Age , sex, family size, family life cycle, income, occupation, education, religion, race, social class, lifestyle and personality. The problems lies in deciding which variables are going to be valuable and which can feasibly be measured. After due consideration of the specific problem it was thought that six structure dimensions were of great importance to turnover:

1) Age structure

2) Socio-economic or VALS structure

3) Sex

4) Pedestrian speed

5) Pedestrian associations

6) Crowding or pedestrian density.

The first three variables are demographic in nature and are commonly used in consumer behaviour research and product targeting (Blackwell and Engel 1982, Chisnall 1985, McGoldrick 1990, Davidson et al 1988, and others). The last three are primarily behavioural/psychological but variable five has a demographic life cycle implications. Variation in propensity to make an impulse purchase depends to a large extent on whether the product on offer is targeted to the pedestrian.

DEMOGRAPHIC VARIABLES

Socio-economic Classification

There is general agreement that income differences will not sufficiently explain varying purchasing habits (e.g. Martineau 1958, Wasson 1969, Chisnall 1985). As a result attempts have been made to derive a measure that seeks to take account of the social and cultural aspects of an individual's consumption. Social class can be derived in three ways, the reputational, subjective and objective methods (Chisnall 1985). The emphasis in socio-economic grading, a common tool in marketing and store assessment procedures, is on objective measures such as occupation or income. The socio-economic measure used by the government of United Kingdom is based on a classification of occupations (see table 1.1).

Table 1.1: Socio-economic Groups (after Chisnall 1985)

Socio economic Group	Occupation Categories
1	Professional
2	Employees/Managers
3	Intermediate & Junior non-manual
4	Skilled manual
5	Semi-Skilled
6	Un-skilled

Attempts to relate socio-economic class to purchasing have met with varying degrees of success (Bruce 1974, Chisnall 1985). Thorntons has a profile similar to other confectionery companies (see table 1.2):

Table 1.2: Thorntons' Customers Socio-economic Profile

Socio economic Group	Percentage of Customers	National Percentage
1 and 2	21%	18.6
3	36%	20.0
4	29%	33.4
5	15%	19.5
6	3%	8.6

Within this profile the average amount spent by each of the groups varies. The profile is biased towards the higher groups (1, 2 and 3) when compared to the U.K. average. The value of average purchases is noticeably higher in the 1&2 socio-economic groups.

Gender

Market research had shown that the majority of the company's customers were female. This is true of most confectionery companies. In a recent company study over 80% of the customers were female. Thus it is important to determine variation in the gender structure of the pedestrian flows.

Age

The company's age profile is slightly younger than the national average with 45% of customers being between the ages of 15 and 35.

BEHAVIOURAL/PSYCHOLOGICAL VARIABLES

The last three measures relate to pedestrian behaviour and psychology. The effects of these variables upon purchasing behaviour is relatively unknown. Their potential impact and reasons for inclusion will now be discussed.

Pedestrian Social Associations

Associations must have an influence on behaviour although as yet the relationships are unknown. McGoldrick (1990) reports on the process of personal values approaching the norms of a close social group. Associations have also been used to categorise the stages of the family "life-cycle". As Davidson et al (1988) and Ghosh (1990) point out different types of product are bought at different stages in the life cycle. As an individual moves through the life cycle his tastes and motivations change. Chisnall (1985) notes the differing ages at which professional and manual workers assume family responsibility and reach the peak of their earning power.

In the micro-scale situation we are more concerned with the impact of an observed pedestrian social association on behaviour as opposed to the more general influences. For example, what behavioural differences will occur through a wife shopping with her husband as opposed to with her children or on her own? There are associative relationships within the purchase decision. It is known that women buy a lot of sweets for their children (Doyle 1981). If the child is present on the shopping trip the chance of the associative purchase must be increased. Chisnall (1985) discusses the effects of assertive children on food shopping as part of wider child/parent conflicts. Bruce (1974) comments upon the affect of husbands joining the weekly food trip and the resultant increase in average spend. From a non-commercial pedestrian perspective Grayson (1975) reports on the affect that social groupings have on road-crossing behaviour. The trip itself may be the result of an intended purchase that is centred around the association. All these factors indicate the need for a closer integrated study of association complexes.

PEDESTRIAN SPEED

The influence of speed has not been understood but seems to have a noticeable effect. Bennison and Davies (1978) remark on people who use a street as a through route. Those who are "going somewhere", will generally walk faster than those who are shopping, who "are there" and are actively engaged in window shopping or other in shopping activities. The area of dead space, caused by slower moving pedestrians milling around shop windows, has long been recognised in pedestrian planning literature (e.g. Older 1968). Variations in walking speed have been discovered in all the surveys conducted so far in this research and by many other workers (Henderson 1971 and 1972, Older 1968, Bornstein and Bornstein 1976 and Fruin 1971). During the surveys conducted for this project velocities tended to be higher in weekday morning and evening periods as people were travelling to and from work. On Saturdays, average velocities were lower as more people were shopping.

Speed variations can be caused by many factors, such as pedestrian density restricting movement, the weather and social associations. In simplistic terms it is assumed that faster moving pedestrians will have less time in visual contact with the shop and recognise its cues (smell can be important in the case of bakers and coffee shops), less time to generate an impulse to purchase, and will require a greater motivation to stop and shop. In a recent study of grocery shopping, Iyer (1989) showed that increased knowledge of an environment and heightened time pressure reduced the number of impulse purchases. This supports Nelson's (1958) hypothesis that the failure of stores on Madison Street, Chicago, was a result of the traffic being predominantly regular commuters who were in a hurry. While speed is not intended as a finite measure of purchasing intent it may well serve as an valuable indicator.

CROWDING

Crowding, or pedestrian density, should have a significant effect upon propensity to purchase. Whilst the two terms, density and crowding should not be taken to be equal (Stokols 1972) measurement of individuals' perceptions of crowding intensity on such a large scale is impossible. Stokols defines crowding as

> "a situation in which the restrictive aspects of limited space are perceived by the individuals exposed to them".

The degree of perceived crowding will vary with a number of factors. These can be categorised into three classes: physical environmental qualities, personal attributes and the social setting. The presence of a large number of strangers, as in the pedestrian environment, will increase the perception of crowding (Stokols 1972). Perceived levels of crowding will also vary according to an individual's expectations of traffic (Eroglu and Harrell 1986) and seasonal and climatic factors.

In terms of pedestrian flow and retail sales there are two areas of interest. Firstly the effect of crowding on retail sales and secondly the effect on flow volumes. In a city centre situation, where spatial interference and competition is common, psychological stress caused by the repeated ingress of unknown people into Hall's (1966) social distance zone will be high. As Bornstein and Bornstein (1976) have shown such levels of environmental conflict and stimulation will lead to the overloading of an individuals processing capacity; Milgram's state of "overload" (see Bornstein and Bornstein 1976). The result of overload is a general increase in purposefulness and walking speed. Other writers (Stokols 1972) report an increase in male aggressiveness in crowded situations. As the spacing between pedestrians decreases, the amount of human concentration devoted to the movements of others and subsequent evasion tactics, increases. Stokols (1972) argues that such awareness will increase the perception of crowding. Thus crowding reduces the time that pedestrians have to notice the surroundings in which they move.

Work on the effects of crowding on retail trade are somewhat limited. Eroglu and Harrell (1986) report on various store atmosphere studies that have shown that perceived crowding and subsequent service delays negatively affect store patronage. They propose three potential responses to crowding in the retail environment, these are termed adaptive strategies. Firstly the individual can limit the amount of store and product information recognition. Secondly they can reduce contact with other people and adopt defensive strategies in regard of counter position and staff attention. The third mechanism is the reduction of shopping time and concentration on the pre-planned items and reduction of impulsive buying. There is also the possibility of damage to the perceived image of the store which will affect subsequent behaviours. These responses are a direct result of an individual having to devote more of his mind to the task of moving within the environment and the state of sensory overload.

People have images of streets and areas in the same way as they do of stores. If the image is poor the street will be avoided and a different route chosen. Avoidance may occur as a pedestrian looks up the street and sees the density of traffic. During a full town study conducted during 1990 it was seen that many people, especially those over 30 took such evasive action (chapter 4). Thus crowding not only affects the behaviour of those present on a street but also that of those not there.

THE ROLE OF THE STORE

Although it is desirable to treat the store and site as two separate entities this is in practice very difficult. In order to be able to isolate the store from the system it is important to understand how it works and the role of its various components in the attraction and retention of customers. Buttle (1984) highlighted three store design aims:

1) Attract the optimal number of shoppers into the store

2) Encourage them to spend more

3) Balance the desire to increase profit with the need to make the trip pleasurable

Aims two and three will be discussed in chapter 7. The attraction of customers into the store is achieved through the reputation of the company and the appearance of the store. Examination of the reputation of the company lies outside the spatial focus of this project but it is affected by factors such as price/quality perceptions and past experience. There is a brief description of the role of the store facade below.

The store front has to perform three functions (Green 1986):

1) Provision of an attraction to the store

2) Presentation of a symbol of the store and its "offer"

3) Creation of a physical transition between the street and the store

In terms of attracting customers to the store it is the first two functions that are of importance. The third, the creation of a transition, depends on the type of store being operated. In the case of low commitment stores if the perceived threshold is too great customers will be deterred from entering whereas in high commitment store, such as a quality jewellers, a strong threshold may be desirable. Thorntons' store front, the window display and signage, forms a critical cue for potential shoppers. As noted earlier up to 50% of customers do not intend to enter until they see the store. As Pegler (1988) stated:

> "it (the store front) is the first and most important opportunity to tell the customer about a store. The front must accurately convey to the customer who you are and what you sell."

The store front has to present the correct mix of the three functions to its market.

In attempting to attract interest to the store the facade has to cater for the different types of pedestrians in the street and the type of journey they are on. Some pedestrians will not be shopping and using the street purely for access. Other pedestrians may either be shopping from a list, and thus have a pre-determined path, or shopping purely for pleasure, the traditional window shopper. The facade has to be able to attract the out of focus attention of the list shopper whilst also appealing to the more acute retail awareness of the window shopper. If the initial facade generated interest is great enough the store will be approached.

The pedestrian is faced with three alternatives, direct entry to the store, external examination of the window display, or resuming the trip. The actual behaviour will depend on a number of factors such as the level of store and product knowledge, the busyness of the store, and the perception of the threshold. The value of the window in the Thorntons' case is to allow customers the opportunity to examine the products and prices without having to make any commitment. In recent times there has been a tendency for companies to replace the traditional closed back window with an open design that allows potential customers to see into the store without actually having to enter. If a pedestrian likes the products in the window he can enter the store knowing what to expect in the interior.

A thorough understanding of the store controls on turnover has to be obtained before an accurate site model can be produced. Both the human and physical elements to store attraction need examination. Some of the physical elements are controlled by the site and in the case of Thorntons, the other elements, such as lighting and shelf design, should be relatively constant throughout the group. The human elements, for example display and staff quality, will vary considerably through the company but there are techniques to account for such variation (chapter 5).

SUMMARY

Micro-locational factors are vital to the success of many suscipient, impulse based retailer. The majority of the existing location assessment models do not address adequately such issues, tending to concentrate of the large trade area controls. In the case of Thorntons and other small store retailers with numerous competitors it is desirable to have detailed pedestrian network information and understanding. It is exposure to a pedestrian flow with the correct demographic structure and in the right frame of mind that enables the retailer to operate profitably. Flow pattern information would allow a retailer to avoid both site duplication and missed opportunities. Information concerning the social, demographic and psychological texture of the flow networks would allow a retailer to match the products on sale to micro-areas with the greatest potential market. The six structure variables noted above were included because they lay within the scope of the project's geographical framework. It was thought that they would be measurable on the scale required and yield a sound basis for prediction and decision making.

CHAPTER 2

PEDESTRIAN MEASUREMENT

The present research was initiated by a request to develop a system that would enable the evaluation of the retail potential of sites and assess the degree of trading overlap between stores. The previous chapter discussed the constraints on potential site turnover and the role of pedestrian traffic in the case of the company concerned, Thorntons. The aim of this chapter is to review the various techniques that have been used by other workers in the pedestrian field and assess their suitability for this research.

METHODS OF GAINING PEDESTRIAN UNDERSTANDING

There are three categories of techniques for gaining an understanding of pedestrian movements: modelling, direct measurement and a hybrid of the two. All methods have their drawbacks mainly as a result of the size and complexity of the pedestrian system. The important point of the present work is not the determination of general maps of pedestrian density or busyness but the elucidation of the flow networks and nuances of movement patterns at the micro CBD scale. Each of the possible routes will be discussed in the light of the project's objectives.

MODELLING AND HYBRIDS

Predictive modelling

Numerous modelling methods have been developed for the prediction of pedestrian traffic. The majority of pedestrian modelling systems are hybrid in nature in that they require large amounts of data for their derivation and calibration. For example the City of Coventry (TEST 1973) derived equations for the prediction of pedestrian activity from retail and service floor space and bus frequency. Hasell (1974) in an attempt to assess pedestrian traffic generation examined the number of pedestrians entering five types of retail store in London and determined potential traffic in terms of pedestrian trips per 100sq feet per week. Such techniques have questionable reliability because of the generalisation of variables and non-applicability to other locations (T.E.S.T. 1975). There is no consideration of the relative accessibility of the sites and the effect of competition. The T.E.S.T. report also condemns the Coventry study because there is no weather variable in the system. Lovemark (1972) reports on a survey that showed that a fall in temperature from 25^{O}C to -5^{O}C halved the number of shopping pedestrians. As will be seen later rain plays an important part in the level of traffic flow. The potential degree of variability is highlighted in Smyth's (1974) discussion of the trip generation potential of various classes of land use.

Gravity Models of Pedestrian Activity

A number of researchers have attempted to develop gravity models of pedestrian traffic. Morris (1962) categorised trip motivations into four classes to develop a gravity model for the central area of

Washington DC. In this case retail attraction was deemed to be proportional to the number of store employees and inversely proportional to the distance. The generation of office buildings was related to the number of employees in the building and the number of visitors to it. This gave a factor of 2.1 trips per employee. From these standard values and an expected walk length a prediction of 1980 traffic levels were obtained. Ness et al (1969) and Hill et al (1964) both used gravity models to investigate pedestrian activity in Canadian towns.

A simple gravity model was used to predict traffic levels in 1980 by Sandahl and Percival (1972). The model was based on the premise that movement is a result of pedestrian accumulation around interesting objects. Other goal orientated trips were included by measuring factors such as parking spaces and bus stops. The authors admit that the model does not cover the sequence of visits and only calculates density and not flow.

Scott (1974) attempts to develop a theoretical model of pedestrian distribution in a basic network. Pedestrians are given a fixed energy budget and the streets have a varying level of attractiveness depending on the level of retail provision. As Scott notes the model raises more questions than it solves.

Trip Chaining

Trip Chaining models might be used to determine interaction and purchasing levels, a recent example being the development by Borgers and Timmermans (1986) of O'Kelly's (1981) model of demand in multi- stop and multi-purpose trips. Such models have good development potential and could be used to produce pedestrian network data but require large data inputs to account for temporal variability and provide the necessary accuracy for the off-centre, low pedestrian volume areas. However, as pointed out in a detailed review of trip chaining models (Thrill and Thomas 1987) such methods do not provide the necessary accuracy, micro scale detail and spatial coverage required by multiple branch retailers.

Problems with Predictive Modelling

The T.E.S.T. (1975) review cites four problems with the modelling of pedestrian activity. Firstly the micro scale of the pedestrian network requires all potential streets and alleys to be incorporated. It is also possible for pedestrians to jump links by using the building as a route as opposed to the pavement. Thirdly route choice is affected by factors other than speed variation such as quality of the stores and safety of the routes. This means that a number of descriptive attributes have to be added to the model. Finally access trips, such as walking to the office or going to work, are hard to incorporate as they are so different in nature to complete trips.

As Ness (1972) points out the derivation and calibration of such pedestrian predicting models would require detailed movement data and there will always be questions as to their transportability and centre-wide reliability at the micro-scale. So far there seems to have been little attempt to model the population as discreet units, such as marketing segments, but there is no reason to suggest that the models described above could not be recreated for each group of interest. None of the models seem able to take account of the dynamics of pedestrian choice related to crowding and route selection and the variation of such response through the cross section of different pedestrians. As will be seen later on there is evidence of major route choice changes being caused by fluctuating pedestrian traffic conditions. Whilst the goal of being able to predict pedestrian behaviour seems laudable the reality appears to be some way off.

Origin-Destination Modelling

One traffic modelling technique that has not been used in the pedestrian environment is that of Origin-Destination modelling. Garbrecht (1973) employed a similar approach when he used Markov transition matrices to model the behaviour of people moving across a car park. The system was formalised with either links or intersections being treated as states. The transition matrix gave the probability of passing from one state to another. The system should work in a non uniform environment but only in terms of route choice, not duration. There are many reports on the subject of creation of network or Origin-Destination (O-D) matrices and Van Zuylen and Willumsen (1980) provide a review of the basic techniques. O-D model consists of a matrix of the probabilities of moving from link to link. The rows and columns represent the routes or links of the network. A cell in the matrix will only have a value if both the row and column link are connected by a junction. Thus the matrix describes turning and path behaviour in the network. The main difficulty in generating an O-D model is the determination of the turning probabilities between links. Turning probabilities can be either measured directly, which is expensive, or numerically estimated, which maybe inaccurate. There are techniques for assessing error levels and thus pin pointing areas that need better data.

DIRECT MEASUREMENT

There are a number of techniques that have been used to collect pedestrian data. Of these four represent practical methods of information gathering: remote sensing, tracking or stalking, questionnaires, and point counts. Other counting methods were noted, such as the moving observer method used by Haas and Morrall (1967) and later on by Hewitt and White (1974) during a traffic survey. Garbrecht (1970) suggested tagging pedestrians whilst Jacobs (1968) suggests sending subjects out on "standard shopping trips" and noting trip details from them. However they were considered to be impractical either due to cost constraints, potential inaccuracies or ethical considerations.

Remote Sensing

There seem to have been only two studies that have used an airborne remote sensing or, as Fruin (1971) put it, sky count approach, namely Pushkarev and Zupan (1971) and Lautso and Murole (1974). In the latter study, an area of 2.5 by 4 Km in the centre of Helsinki was surveyed using a number of data capture methods, the principal being aerial photography. The aircraft flew nine times a day taking overlapping photographs, to allow stereo interpretation, from an altitude of 600m. Pedestrians were counted on the ground at the time of the aircraft overflight to enable calibration of the photo data. The average number of pedestrians (n_0) was determined via the following equation:

$$q = n_0 \times (v/l)$$

where q = pedestrian flow
n = pedestrian numbers
v = pedestrian speed
l = length of street

The determination of n was based on the assumption that areas had similar variations in hourly traffic flows. Pushkarev and Zupan (1971) used a helicopter to take aerial photographs. From the extracted data a number of equations were derived that related pedestrian activity to the amount of retail, office and restaurant space. Unfortunately there was no form of costing for this type of survey. The method seems to be of little use for this project for a number of reasons:

1) **Possible Shading of Large Areas.** This problem was noted by Lautso and Murole and overcome by estimating volume "on the basis of pedestrian volume of the surrounding area". The narrow streets found in many centres will increase the proportion of areas in shade. There are three other closely related problems:

a) Pushkarev and Zupan noted problems during the evening with lighting and the subsequent deep shadows. The result was that a two thirds sampling technique had to be used. The survey was conducted during the early summer period at 5pm. There is no mention of how the method performs in the low light conditions found on early winter evenings of the Christmas trading period.

b) Clear weather is essential.

c) Covered shopping centres present an intractable photographic problem.

2) **No Directionality or Trip History Data.** This problem is acknowledged by the authors who state that "the model does not attempt to determine from where to where the pedestrians walk, but where they walk". Directional information is essential for the determination of flow networks, could possibly be obtained by

flying lower but legal factors must be taken into consideration. Pushkarev and Zupan (1971) supplemented their photographic data with manual counts and interviews.

3) No Social Structure or Psychology Data. It is hard to see how such data could be obtained via this method without employing a supplementary ground survey. For example in both studies the authors had to run a questionnaire in addition.

It was felt that because of the problems listed above this form of mass data gathering was not suitable for the centre that was being studied but that in a larger scale survey it may form the only practical route of gaining an insight into the pedestrian usage of the streets.

Tracking and Observation

The technique of tracking (also known as "stalking") is one of the standard methods of analysing pedestrian flows. Tracking consists of an observer following a pedestrian and making a note of the route travelled and aspects of the pedestrian's behaviour. Tracking studies can be either "obtrusive", where the pedestrian is aware of being followed or "unobtrusive", which is more common, where the subject remains unaware of the tracking exercise. Weiss and Boutourline (1962) accompanied visitors around the World's Fair and noted the route taken and the visitors' activities in a trip log. The authors argued that their subjects' behaviour remained unaffected by the presence of obtrusive observers, however subsequent studies have thrown considerable doubt on this assertion. In a survey of museum visitors Bechtel (1970) found that visitors who knew that they were participating in the study exhibited different movement behaviour from those who were unaware of the survey. Similarly more recent studies of jaywalking behaviour have shown that pedestrian behaviour does change when the subjects know that they are being observed (Russell et al 1976, and Hill and Roemer 1977).

Winkel and Sasanoff (1966) used unobtrusive tracking to study visitor behaviour in Seattle's Museum of History and Industry. Investigators were issued with stop-watches and floor-plans of the museum and instructed to record the behaviour of visitors. Other workers have copied this approach in subsequent studies (e.g. Hill 1978 and Hill 1984). Garbrecht (1971) monitored movement across a car park from a vantage point on a tall building but this is only effective over a short trip. Other workers have used micro observation to record speed (Hoel 1968, Bowerman 1973 and Bornstein and Bornstein 1976). Brown (1991) tracked 436 people in a planned shopping centre. Brown makes the point that in the same time over 3,000 questionnaire responses could have been gathered. As will be seen in chapter 7 unobtrusive tracking studies have also been used to monitor the movement and behaviour of shoppers within large retail establishments and form a common tool for retailers. Hill's (1984) main conclusion was that for city-wide surveys tracking may not provide the best method of studying pedestrian movement and that alternative methods such as questionnaire techniques should be considered due to the time taken for the collection of data.

A brief tracking study was undertaken in Nottingham City centre (Thornton et al 1987) on three mornings in December and January. This yielded 102 tracks with an average trip time of 5 minutes. Both demographic and behavioural information was encoded on the tracking sheets. The tracking process was time consuming and to some extent frustrating because many of the tracks were short journeys between shops. In the light of the tracking survey undertaken in Thornton et al (1987) Hill's conclusion seems justified.

Questionnaires

The use of questionnaires in pedestrian movement studies is wide spread. The form of the questionnaire can vary from the drawing of a cognitive map, to the itinerary and recollection of a trip, and to the most common method based on the content or experiences of the trip.

Cognitive Mapping

Cognitive maps have been used quite effectively as a form of questionnaire and information gathering. For example, MacKay et al (1975a, 1975b) asked two groups of supermarket shoppers, 139 people in total, to rank 8 supermarkets in order of preference and then rate four variables according to their importance in store choice. The subjects then drew a map showing their departure point and all the stores in question. In the same study students were asked to sketch city centre street and shop layouts so as to examine variations in perception. Bonnes-Dobrowolny and Secchiaroli (1983) asked respondents to indicate on a scale map the area they considered to be the centre of Milan. Other users of cognitive maps include Marchand (1974), who used them to examine how people perceive their community space, and Mazze (1974), in his study of the shopping movements of 150 graduate households. The two main problems of employing this method in the context required by this study seem to be:

1) Gaining a reasonable sample size from a representative cross section of people. The Marchand study issued 2000

forms and received 81 useful maps, mainly from the middle classes.

2) The problem of aggregating the data into a usable form for the later stages of the study.

Images, Emotions, and Environment

Questionnaires do offer the opportunity of collecting data on feelings and experiences. Churchman and Tzamir (1981) used interviewing, together with other techniques, to examine how perceptual variations affected movement in a shopping centre. Bradford (1975), in a study of intra-urban behaviour in Leicester, used paired comparison tests to assess perceived accessibility and preferences. Meyer (1977) assessed variations in perception of distance within the shopping centre by asking shoppers to evaluate the distances to three points that were in fact equidistant from the centre. The discrepancies between reality and perception were used to assess and understand shopper behaviour. Cadwallader (1975) asked supermarket shoppers to assess the time distance to each of five supermarkets in an attempt to derive a model of store patronage. Other workers have used similar cognitive distance tests to assess behaviour (Thompson 1963, Coshall and Potter 1987).

Lautso and Murole (1974) used questionnaires as a supplement to aerial photography to determine pedestrian experience. Pedestrians were asked to name one good and one bad street they had visited and then to explain their feelings by choosing descriptive comments from a supplied list. Similar work was done by Bishop (1975) in his study of user responses to pedestrianisation. May et al (1982) used quality rankings in a survey of Barnsley town centre. Such data can be valuable in the determination of "shopping" as opposed to "access" movements. The post trip accuracy of such emotional data is questionable. Johnson and Mannell (1983) avoid such problems via the link of a questionnaire to a photographic simulation of the shopping environment. However informative perceptual data may be about the potential shopper such information can not be obtained in sufficient quantity to be useful.

Purpose or Motivation Questionnaires

The aim of understanding the purpose or motivation of a trip is important in a pedestrian study as it provides information on potential shopping levels. Motivational studies aim to determine what the respondent is doing and why he passes a certain location. Demetsky and Morris (1973), in their discussion of general data requirements for pedestrian analysis, state that such questions are vital for the classification of respondents. Lewis (1974), in his study of movements in Leicester, asked shoppers about the motives that controlled their movement. The Cleveland Downtown Agency for Transportation Action (Fruin 1971) used a motivation element in a study of pedestrian reluctance to walk due to bad image factors. Usually motivational questions play an important role in the classification of respondents, i.e. into classes such as shopper or office worker. As such they are commonly found in other types of questionnaires and formed the basis of many of the gravity models discussed earlier.

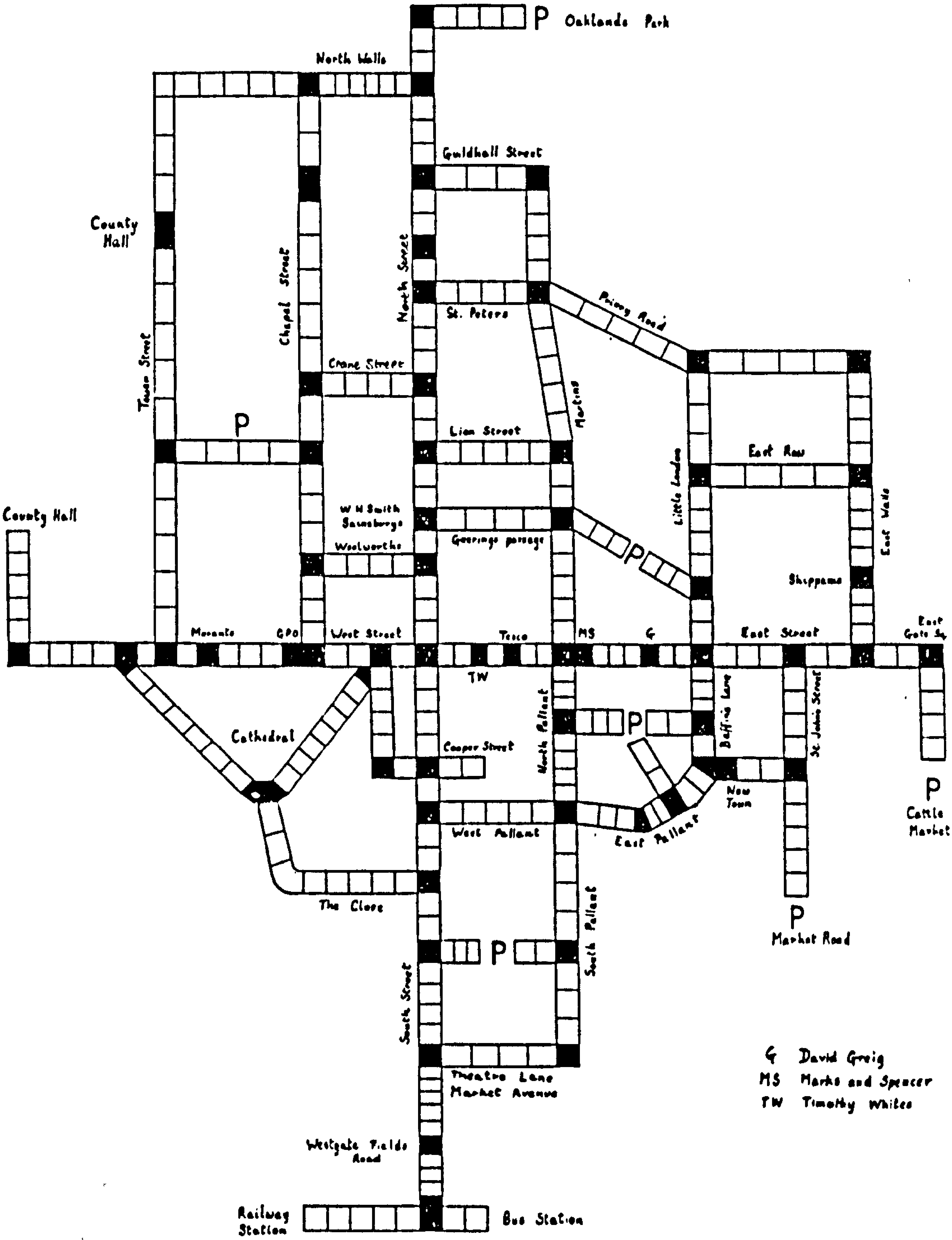
Itinerary and Aided-Recall Questionnaires

With itinerary questionnaires the respondent is asked to list, in sequence, the shops or routes used in the trip. Bennison and Davies (1978) performed an itinerary questionnaire of 1470 shoppers to differentiate between purchasing locations and avenues of access.

The studies of Boal (1963) and Yuill (1967) utilised itinerary data collected from about 4500 shoppers during their trips. Marchand (1974) ran an itinerary survey of the trip from home to the local station in parallel with the cognitive mapping exercise. Morris (1962) interviewed shoppers at store entrances to gain trip histories and destination information for the calibration of his gravity model. Pushkarev and Zupan (1971) interviewed pedestrians entering or leaving a building or transit station to determine trip length and motivation. McMillen (1976) used a trip end interview to gain information on route choice, duration and road crossing delays.

The most useful form of questionnaire for network estimation encountered is the aided recall type. Hart and Thompson (1968) used the method to assess conflict between vehicles and pedestrians in Chichester. Pedestrians were given a base map of the centre (figure 2.1) and asked to plot where they had been and their potential route post questionnaire. About 2800 movement maps were obtained. Borgers and Timmermans (1986) used the method, together with questions on shopping itinerary, to calibrate their route choice model. The survey points were located at trip ends. No attempt was made to produce flow network maps. Hart and Thompson point out that the primary problem with such data is not its collection but analysis. Lack of computers in the Chichester study meant that analysis of the patterns of pedestrian movement was impossible. The aided-recall method, unlike other questionnaire types, seems to offer the potential of collecting a viable quantity of data and of developing the detailed network picture required as it not only shows the streets that pedestrians visited but the order of the trip and the turning flows between streets. There is however no

Chichester Town Centre



From: Journal of the Town Planning Institute,
54, 7, pp. 338 - 42

Figure 2.1

data on pedestrian speed, the potential surrogate for shopping interest, but this could be partially alleviated by marking on the plan the shops that were visited.

Problems with Aided-Recall

There are three problems that preempt the use of an aided-recall type of questionnaire in this study:

1) Error

There has been little work on the assessment of error in movement questionnaires. Hill's (1984) study reports that 13% of respondents produced an inaccurate replication of their journey whilst only 27% produced precise information. Such error may well be due to the pedestrian forgetting the less interesting or notable parts of the journey. It must remembered that although they are of less interest they may well offer viable sites.

One would assume that the error would increase in proportion to the trip length and the demographic characteristics of the interviewee. Hart and Thompson interviewed pedestrians in mid-trip and asked them to mark on their future route. Such speculative data can not be reliable. The interview should be performed in the later stages of the trip (Borgers and Timmermans 1986), to gain as much trip information as possible and minimise the amount of information that the respondent forgets.

2) Temporal Variability

As noted by Copley and Maher (1973), there is the possibility of temporal variation in movement patterns such as natural variation within the week and year as well as that caused by redevelopment. Variability makes it important that data is collected over as long a time period as possible in order to obtain a reliable data set. There are two methods for obtaining temporality with questionnaires:

a) The diary method. This method involves the formation of a panel of people who agree to record their behaviour over a period of time, thus creating a set of diaries. The method has been used in several studies, for example Hudson (1974), Mackay (1973a, 1973b), Davies (1973), Burnett (1978), Wrigley (1980), Daws and Bruce (1971). There does not seem to have been any such work done on micro-scale study. The problems with diary data collection for such a study would be the cost and management of the scheme.

b) Multiple surveys staged throughout the year. It would be desirable to conduct a minimum of one survey at Christmas, one in the early autumn and one in the summer. Obviously such repeat work increases the costs of the information.

3) Logistics

The logistics of carrying out a centre wide survey rule out questionnaires as a viable option. In Hart and Thompson's experience the collection of 2800 full trip responses took 640 man hours, an average of about 14 mins/response. To obtain a reasonable temporal sample in a major city centre would cost in excess of 12,000 pounds. There would be an enormous management problem in organising enough interviewers to cover the exits of the centre. Hart and Thompson employed 80 people and obtained a 10% sample of pedestrians. In a town such as Nottingham a 10,000 person sample would require a labour force upwards of 400. There would be additional costs incurred during the compilation and analysis of the data.

Point Counting

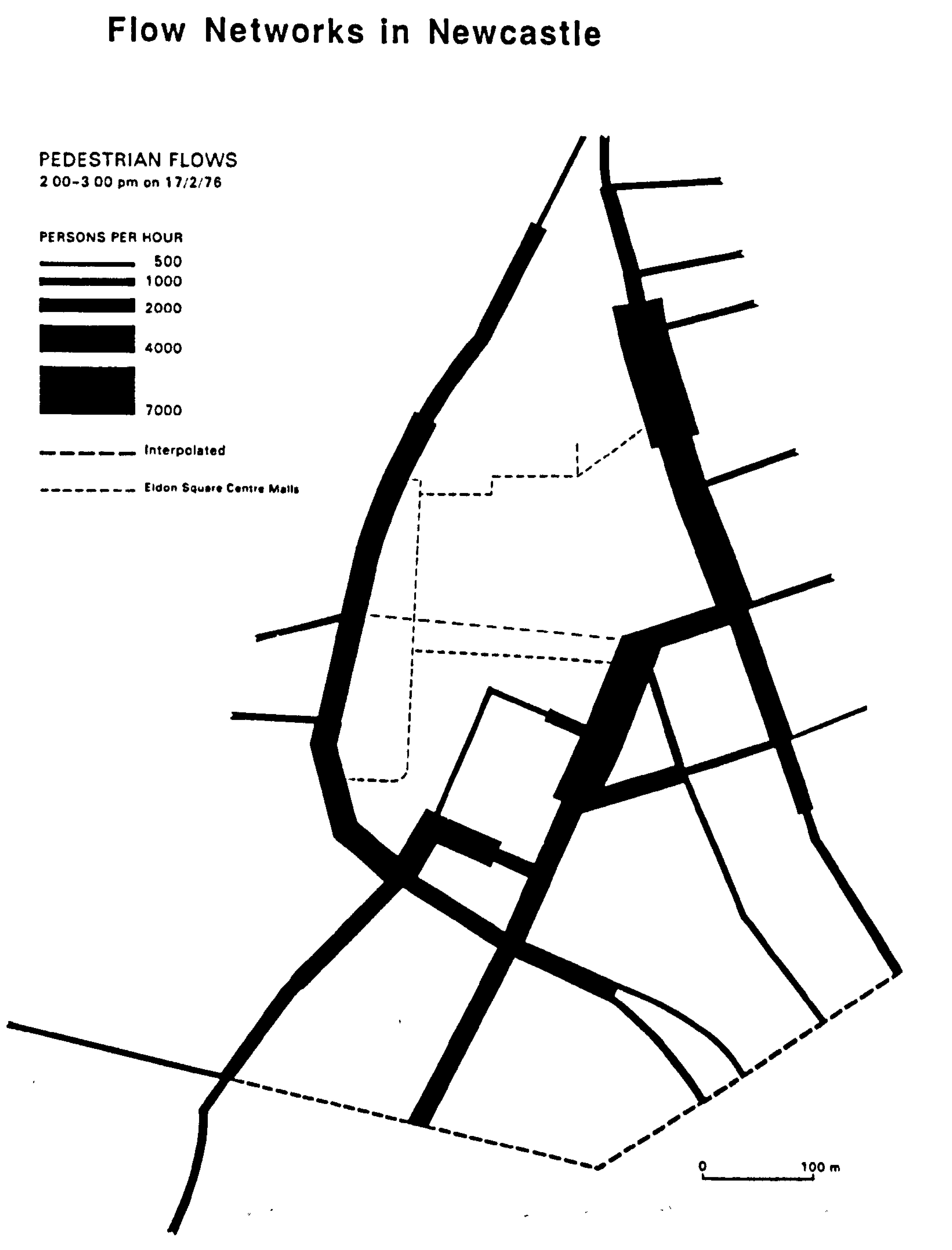
Point counting is the standard method of flow data collection. As

Nelson (1958) states:

> "Rents and land values in the downtown areas of many cities are almost directly proportionate to the volume of pedestrian traffic on the sidewalk."

For many years pedestrian counting has been one of the principal tools of the site assessor's checklist (Pyle 1926, Wenzlick 1930, Paver and McClintock 1935, Nelson 1958, Claus, Rothwell and Bottomley 1972, Craig, Ghosh and McLafferty 1984, Breheny 1983, Bowlby, Breheny and Foot 1985, Cox and Brittain 1988). Hasell (1974), Smyth (1974), and Leake and Turner (1982) all use pedestrian counts to assess generation rates of retail facilities and hence imply trading volumes. Bunce (1983), Abratt (1985) and others point to the control of pedestrian flows through anchor location. Dependency of trade on flow volumes is well recognised but as mentioned earlier, the relationship is complex.

As far as has been gathered no workers have progressed from their point counts and developed network models that describe patterns of pedestrian trips in the way that traffic engineers have used vehicle counts. The closest that has been achieved is simple plotting of flow rates on a map. For example Bennison and Davies (1978) treat each street in isolation to those around it (figure 2.2). There is no statement or knowledge of the trip patterns of the pedestrians counted at a location. It is the aim of the modelling in this study to translate these point counts into a map of networks. This facility has been achieved using a modified form of origin destination (O-D) modelling. The model and an example of its application will be discussed in chapter 3.



From: Tijdschrift voor Econ. en. Soc. Geografie 69 (1978) Nr. 5

Figure 2.2

METHODS OF POINT COUNTING

Manual counts

The most common form of measurement is hand counting (Fruin 1971). Counters are placed throughout the area under study and record the pedestrian traffic passing, usually with the aid of a hand tally counter or clicker. Fruin states that an experienced counter can accurately record one way flows of up to 10,000 people per hour (pph). Directionality data can be obtained via two way counting which Fruin claims can be performed by a single counter at rates of up to 2,000 pph. However conditions have to be ideal, i.e. the flow rate must be stable. In normal conditions high frequency density waves are present, caused by such factors as pelican crossings or bus stops, so practical counting capacity is reduced.

In a pre-Christmas hand counting trial it was found impossible to record accurately non directional flow rates of 6,000 pph because of the presence of waves in the flow. It would therefore be prudent to assume lower counting capacities so as to increase reliability. The pre-Christmas peak flows on Clumber Street, Nottingham, were estimated to be in the order of 14,000 pph which, for accurate measurement of volume and direction, would require about 10 counters. Two alternative methods of counting high flows are the division of the street into counting zones and the erection of funnels to separate the flow directions. However, restriction of capacity at peak periods may well lead to pedestrians seeking easier routes. While not considering the inconvenience caused to pedestrians and the trade lost by retailers, interference by the measurers is to be avoided at all times as the results could not be treated as accurate or reliable.

While it is recognised that there will be few streets with such a high flow rate as Clumber Street, the number of workers needed to mount a centre wide survey, covering 60 streets, would be very high. The manning problem is often skirted by the use of a short counting procedure (e.g. Morris 1962, Fruin 1971, Hasell 1974, Bennison and Davies 1978, PMRS 1984). The counts are then multiplied up to give hourly and weekly pedestrian figures. Short counting may overcome manning levels but the effects of medium frequency waving become very important. Some methods are naive in the assumptions that are made. For example one technique calculates weekly pedestrian volumes on the basis of 8 count periods, totalling 24 minutes (PMRS 1984). This survey method allows for 4 counts on Friday and 4 on Saturday , each of 3 minutes. The counts at the various points are also not taken contemporaneously but staggered as the counter moves from one position to another. Most short term variation, caused by factors such as pedestrian crossings, occurs in a one minute time frame. Medium term fluctuations will not be covered by such a small number of short counts. Such data must be regarded as unreliable because of the low number of samples. It would be much better to take 24 one minute samples. Sampling procedures for the measurement of such a variable phenomenon must aim to gain as broad a picture as possible.

The use of traditional hand counting techniques is impractical for this study. If hand counting were the method chosen the necessary demographic and behavioural data would have to be obtained by another technique, as in many of the pedestrian surveys discussed above.

Electronic Eye

An electronic eye system consists of a light beam and a photo activated counter placed at either side of the pathway. Every time the beam is broken, in this case by a moving pedestrian, the counter registers a movement. Fruin (1971) reports the use of an electronic eye, or broken beam, devices which are attractive because of the very low cost of a system, typically about 100 pounds. However use is restricted to single lane flows because of under counting. For example, if a pedestrian stands in the beam all other passing pedestrians will not register on the counter because the system only registers every time it is broken. Broken beam devices are often used on store entrances to enable calculation of measures such as the average "spend" of each customer, proportion of people entering the shop who purchase etc. A broken beam system was tried by the RAT during a later stage of the project at a wide store entrance but error rates were found to be unacceptable. At some stages the counter only registered 54% of the true flow. It is anticipated that in a wider, more crowded street situation the errors could only increase.

Pressure Pads

Cameron (1974, 1977) reports on the development of a pressure pad recording system. During initial calibration the system over counted by 15-20%. By 1977 Cameron reported accuracy of +/- 2%. While this method seems to provide high data accuracy, pure volume counts are not the data requirement: directional and speed data are also required. Pressure systems are used to record vehicular speed and direction but Cameron's equipment was not that advanced. If the method could be made to record directionality then the other variables could be sampled by questionnaire but this does not seem to be possible at present.

Time-lapse Photography

Use of time-lapse photography in pedestrian studies is fairly wide spread. However the potential of time lapse photography as a means of data capture in marketing studies seems to be relatively unexplored except for Underhill (1989). Time lapse systems have a relatively high capital outlay but the operating and film analysis costs are low.

The first two examples are not time-lapse in the strict sense but are nevertheless included. Older (1968) used a cine camera to examine variations in the restriction of movement with pedestrian density changes. Collis (1975) examined peoples' tolerance to pedestrian density on pavements using photographic means. As pedestrians were seen to step off the pavement a photograph was taken and later analysed to assess their density tolerance. Welke (1968) examined pedestrian delay to vehicles at a four arm junction. Photographs were taken at the rate of 1 frame every 2 seconds. The results were used to design crossing mechanisms. Navin and Wheeler (1969), in their examination of pedestrian flow characteristics, used a rate of 4 frames per second, but only actually analysed every fourth picture. Speed was measured from the displacement of pedestrians from frame to frame. The results included analysis of the reduction in flow capacity caused by bi-directional, as opposed to one way, flows.

The relationship between speed, volume and convenience at varying levels of concentration in both walkways and stairs was examined by Fruin (1971). Fruin derived his "level-of-service concept" by the analysis of time-lapse photography. Child behaviour at unmarked road crossing sites was studied by Grayson (1975). Grayson's study worked on a frame rate of 2 per second. Khisty (1985) used a frame rate of 18 per second (almost continuous) to analyse crossing conflicts in corridors. All these studies provide data volume at a level that would be impossible to obtain in any other way.

Stills offer a number of advantages over other data collection methods, the four most important being:

1) Permanence. Data can be extracted as and when required. As Grayson (1975) points out: "there is no need to select in advance the items of behaviour to be observed". Although numerous passes of the film are to be avoided there is the facility to extract new variables from the film if required. During this project there have been numerous occasions on which it was necessary to refer back to the film for clarification of seeming erratic behaviours.

2) Data on Actual Behaviour. Time-lapse photography offers the opportunity to record actual behaviour patterns not post trip recollections. This is very important especially for variables such as speed which may vary considerably through the duration of a trip.

3) Variable Sample Rate. The facility to vary the time between shots allows the user to minimise the effects of short term fluctuations in flow rates.

4) Cost and Coverage potential. The operating costs of a time-lapse system are low, the main cost item being the initial capital outlay.

Video

The recent proliferation of compact video cameras and their use in vehicular traffic studies has meant that this continuous media had to be considered as a possible alternative. Trials were carried out using a video camera from the same vantage point as the camera used. The medium proved impractical for three reasons:

1) Cost of equipment. The cost of a video camera is approximately three times the cost of the cameras and controllers used in the full town survey.

2) As yet videos have relatively poor picture quality. It was found during the later video analysis (chapter 5) that data extraction took a considerable length of time. Operator fatigue rates were high due to instability of the picture. The process of viewing a pedestrian and then rewinding to get the next subject was very time consuming.

3) Poor performance in low light conditions. The video image failed a lot earlier than a standard camera thus shortening the potential duration of winter surveys.

Other problems that would be encountered in the full scale study include the provision of power for a full day and the tape running time. Whilst these problems are not insurmountable the prospect of servicing 60 camera units twice or three times a day was.

CONCLUSIONS

In the light of the above findings it was decided to develop a time-lapse system of data collection and then an Origin-Destination model to describe the network. The camera system used has undergone a number of revisions as requirements changed and more money became available. Three systems have been used by the RAT. Firstly during the feasibility study a cheap and relatively simple system was assembled. The objects of assembling a cheap but flexible system were two fold: firstly to test whether the technique could be used to gather the necessary data, and secondly to enable changes to be made and a full specification determined before the final units were built. Once the system was tested a number of alterations were made and a more compact purpose built system built. The third system was smaller and ultimately more reliable than the second. Each change was effected because of operational problems that were discovered in the previous version. The long term goal of developing a self-contained time-lapse system was achieved in the latter two system developments. The initial system and subsequent developments will be discussed in chapter 7.

The O-D method of modelling is attractive because it is focused on the network and is designed to model patterns of movement on any scale. The models are transportable because there are no governing rules related to floor space and attraction as found in a gravity situation. Detailed movement and trip data are not required to generate an O-D model. The models are developed from a simple series of relatively cheap point counts. They are able to respond to differing pedestrian circumstances as long as there is sufficient point count data available. For example, to model peak flows a series of point counts must be taken in similar conditions. Thus pedestrian responses to the environment are accounted for in the data that built the model. The model does not seek to explain traffic in terms of what may cause a situation, as do gravity and trip chaining models, but takes a known situation and develops a circulation pattern from it. The development of the network model will be discussed in chapter 3.

CHAPTER 3

MODELLING PEDESTRIAN FLOW NETWORKS

A primary concern of this study was to test the feasibility of generating network data from point counts. The long term aim was to allow the data collected from street photographs to be transformed into a detailed network model. This chapter discusses the problems of developing an Origin-Destination model and the implementation of a model on a sample data set. Unfortunately a complete full scale data set was not available in time to be included in this work.

ORIGIN DESTINATION MODELLING

An Origin-Destination model consists of a matrix of probabilities that describe the likelihood of moving between the links of a network system. Norman et al (1979) describe an O-D model as a turning flow matrix. The technique used to derive the O-D matrix depends on the location of the traffic counts and the level of information available. O-D models are usually derived from sparse or incomplete data sets and a number of techniques have been developed to help overcome information deficiencies (Mekky 1979, Van Zuylen and Willumsen 1980, Willumsen 1981, Irving, Oakley and Ramsey 1986, Mountain, Maher and Maher 1986a and b). The problem faced in a pedestrian study is that of deciding on the number of survey points that give adequate coverage. Sparse coverage when dealing with a subject as fickle as the pedestrian invites error but cost limitations mean that there cannot be blanket camera coverage. Thus it is necessary to balance the amount of data that can be collected with the acceptable degree of error in the model.

The O-D model conceptualises a traffic system as a network of links and junctions. A link is a route that has no turning possibilities apart from the two junctions at either end. The junction is the area that joins and enables people to move between links. The O-D matrix is a matrix of turning flows. Each row represents a source link and each column a destination link. If two links are connected the corresponding cell will contain the probability of moving from the source to destination link. Unconnected links have no value in the cell because there is no associated junction. If two links are not directly connected the probability of moving between the links and the potential routes can be obtained by examining the link connectivity of the matrix and multiplying the probabilities of the respective cells. Thus trip and potential route probabilities can be determined.

TURNING FLOW ESTIMATION

There are three methods of obtaining the necessary turning flow estimates:

1) Direct Measurement

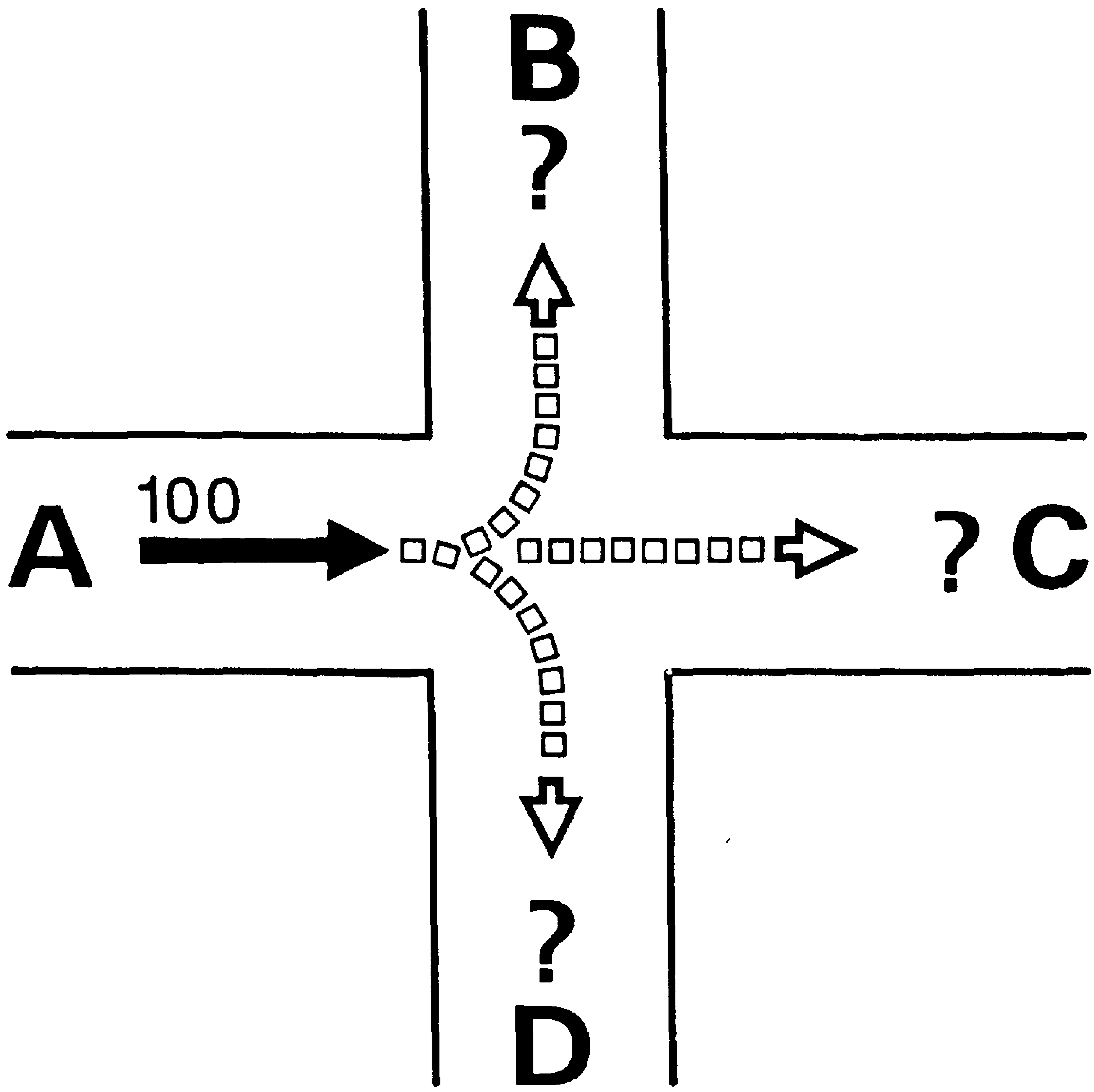
Turning flows can be measured and then the observations incorporated into the O-D model. Bell (1984) provides a brief review of the influence of prior information. Mountain, Maher and Maher (1986a, 1986b) show the use of a modified Bayesian approach through the incorporation of prior probabilities. Turns can be measured at all junctions or just at key sites. The probabilities can then be either fixed in the model or allowed to drift according to the flow volumes noted on the links.

The major problem associated with the use of prior information on turning flows is that of its collection and reliability. The cost of monitoring turning flows is high because of the number of possible turns. For example a four link intersection, a typical cross roads, has 12 possible turns ignoring return flows. It would be possible to move time-lapse collection units to junctions and thus record turning flows but the chance of a pedestrian appearing on two time-adjacent photographs, especially when turning a corner, is low. This problem could be solved by using a continuous data capture method, perhaps video, but as mentioned earlier this is not feasible option or manual counting.

Turning flow data unreliability comes from two sources. Firstly most turning flow measurements are samples because of the cost of collection. Because of the low budgets available to this type of work the samples would be very small and temporal variability is high. Secondly, and more importantly given the retail context of this work, pedestrian behaviour at junctions is very atypical of a shopping trip (Fruin 1971, Khisty 1985, Ashworth 1971 and Grayson 1975). In order to able to predict retail potential it is behaviour on the street not at a road crossing that should be measured.

2) Numerical Estimation

The low cost of obtaining traffic data on a constrained link via automatic counting systems has encouraged workers to measure the link flows and estimate the turning flows. If the volume of traffic entering and exiting a junction is known for each of the links connected via the junction the model must determine the transfers between links (figure 3.1). Such models are based on the assumption that the flows into a junction should equal the flows out.



Solution via 2 methods

1 Hypothesis of apportionment

2 Measurement of turning flows at junction and introduction of prior probabilities into model

Figure 3.1

A number of workers have developed such estimation systems (Jeffreys and Norman 1977, Van Zuylen 1979, Marshall 1979, Mekky, and Hauer and Shin 1981). Error levels can be high. Van Zuylen reports errors of 55% but he reduces this by including *a priori* information. Van Zuylen also notes that accuracy increases as the duration of the modelled period increases.

Hauer and Shin 1981 suggested apportioning turning flows from a link on the basis of the relative proportion of flows leaving the junction by the other links. The apportionment system used is thus:

$$N_{ab} = N_b / (N_b + N_c + N_d)$$

where N_{ab} is the number turning from link a into link b, and N_b, N_c, N_d are the number exiting the junction via links b,c, and d. As pointed out by Hauer and Shin:

> "The real content of the mathematical argument does not go much beyond the intuitive reasoning above."

Once the initial apportionment of junction turning flows has been made the model tries to maximise agreement between observed inflows and outflows. Error reduction is achieved by the reapportionment of those flows with high disagreement between real and predicted values. Hauer and Shin (1981) provide estimates of accuracy which for an urban street network are acceptable. However there is no estimation of error in a pedestrian situation which, unlike the vehicular, is not known to have bias in turning ratios (see below). Thus this type of system should perform better in the pedestrian environment.

3) Hypothesis Generated Solution

Turning flows can be estimated according to some hypothesis of behaviour. Mountain and Westwell (1983) suggest that general rules of thumb or experience may be used. They suggested that average turning proportions may be used, for example 80% go straight on, 10% turn left and 10% turn right, in preference to Van Zuylen's (1979) proportions of 50% ,25% and 25%. The authors also suggested that further accuracy may be obtained by the development of average turning proportions for different types of junctions. Garbrecht (1970) proposed a random walk hypothesis for a pedestrian matrix where the probability of turning down any link was equal. Hauer, Pagitas and Shin (1981) and Mountain and Steele (1983) have attempted to assess errors associated with prior information. Mountain and Steele find that the errors associated with turning-flow estimation increase with the simplicity of the assumptions and the degree of generalisation made. The derivation of typical pedestrian turning flows for junction types does not seem practical or desirable because of the variability of motivation for each turn.

SUMMARY OF EXISTING O-D MODELS

The problems associated with method 1 and 3 meant that a mathematical hypothesis of turning flow apportionment had to be used. The technique chosen was based on the Hauer and Shin method outlined earlier. The reasons for this choice were threefold:

1) the data requirements could be easily met from the camera surveys envisaged

2) the error levels were reasonable

3) the numerical process of apportionment is simple and logical.

An O-D matrix has many potential solutions as it represents an under determined set of equations. As Van Zuylen (1979) states

"The constraints of the in- and outflows do not determine the turning flows uniquely". The correct solution could only be obtained if there was complete information on all movements within the network. Although there is no unique solution to a link count model it is possible to derive an accurate, sensible solution to the observed link counts.

THE SURVEY MODEL - WONKA

During February 1987 a computer network model of the type described by Hauer and Shin was written. The computer model has two essential parts. The first part produces a stable turning matrix solution to the link counts. Stability is obtained through a process of iterative error reduction. The second section allows the investigation of routes based on the injection of flows into the stable matrix solution. The system iterates for a predetermined number of cycles and produces a matrix of flow network usage from the given injection point. The system allows the user to plot the output from an injection series. The model was altered during the in-store surveys to counter instability in cases of low observed flow rates. There have been a number of alterations to the output system that allow rapid hard copy production.

Model Theory

As mentioned earlier, the model allocates the flow coming into a junction from a link in proportion to the flows observed on the other links coming out of the junction. Thus, if a junction has three arms or links, called A, B, and C, and the flow along link A is 1000 pedestrians per hour, and the flows out along B and C are 1500 and 500 respectively, then the apportionment of the 1000 input would be 750 leaving the junction by B and 250 leaving by route C.

However such an equilibrium situation is a rare occurrence. Discrepancies between flows around a junction can be caused by a multitude of factors, for example differing sample times, inaccurate counting, or an incomplete network model. Thus it is necessary to devise a method that seeks to redistribute flows according to the surpluses and deficits between the apportioned turning flows and those observed on the links. Errors that can not be smoothed by this process need to be highlighted so that the measurements and network can be checked.

Algorithmic Approach to Estimation of Turning Flows

Initially a matrix representing the observed flows along all links to all their respective connected links is constructed. At the start only total observed flows towards and out of each junction are available. These effectively are the row and column sums of the matrix. The columns represent the flows out of junctions from the link, and the rows flow into a junction and along the link. Thus each link has a corresponding row containing flows from itself and a column containing flows into itself. The problem is to distribute the sum for the row or column, the total observed flow on a link, to the appropriate part of the matrix so that the overall error is minimised. The following stages take place:

1) **Estimation.** Working on the hypothesis of proportionality, the flow on each link towards a junction is apportioned to the other links connected by the junction to it. This operation on the link outflows (the rows of the matrix) ensures that the total modelled outflow agrees with the survey counts along the link. However these may not agree with the total flows seen coming out of a junction, the observed column sums.

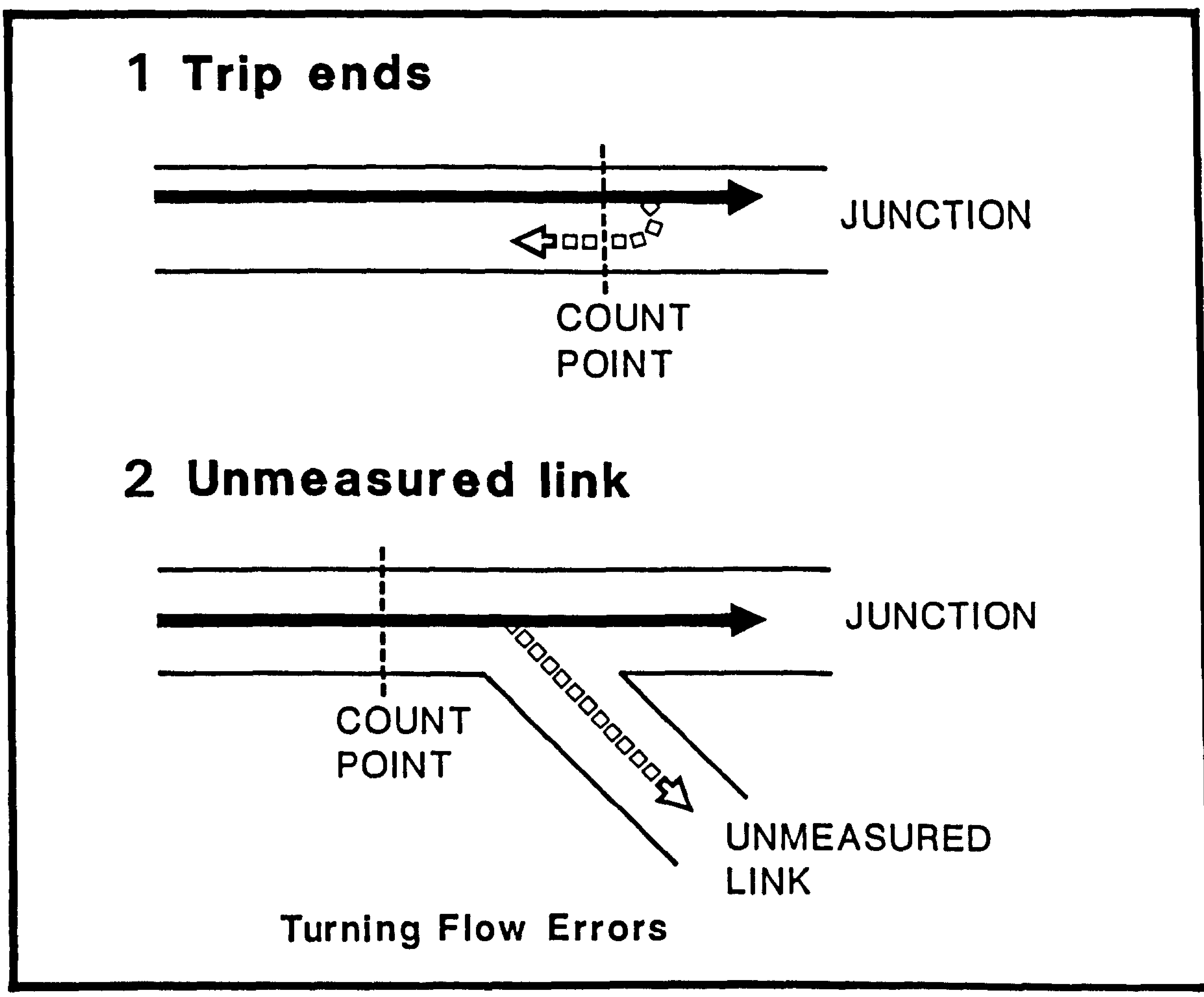
2) **Measurement of Predicted Outflow Error.** By calculating the column sums and comparing these with the survey counts, it is possible to determine the degree of under or over estimation of the outflow along the links. The outflows are then adjusted according to the degree of error calculated. At this stage overall error in the predicted flows are tested and if they are below a preset tolerance the iteration process stops.

3) **Iteration.** The process of error estimation outlined in stage 2 is repeated but this time for the flows towards the junctions, the rows. Predicted flows from stage 2 are adjusted according to the degree and sign of the error. Again the total error is checked.

4) The model iterates around stages 2 and 3 alternating between rows and columns until the total error is below the preset level or until the model is stable and no error reduction is achieved between iterations.

Residual Error

When a stable situation is achieved the program identifies junctions where it has proved impossible to reduce the error level. Most of the junctions will have a degree of residual errors and it is up to the user to determine a threshold below which such errors will not be investigated. Residual errors can be caused by three factors. Firstly serious counting deficiency. Small inaccuracies in counts are to be expected and these will not be picked up but major inadequacies will be pinpointed. The other two forms of error are induced by the model itself (figure 3.2), one by the theoretical basis of the model and the other by under-specification of the network.



1 Trip ends
JUNCTION
COUNT
POINT
2 Unmeasured link
JUNCTION
COUNT
POINT
UNMEASURED
LINK
Turning Flow Errors

Figure 3.2

"U" Turns and the "Coffee Shop" Effect

The main cause for concern with the hypothesis of proportionate apportionment is that pedestrians are unable to turn around within a link i.e. to re-emerge from a link by the junction that they entered. Thus there are bound to be residual errors at major destinations within the network. The model has a system that identifies such difficulties and allows pedestrians to do "U" turns. When a major residual error is determined the pedestrians represented by that error are made to "U" turn in the link. This has been named the "coffee shop" effect.

Solution to the "Coffee Shop" Problem

The links with high error levels noticed by the program are treated as "coffee shops". The program siphons the appropriate number of people off into the coffee shop so that they never reach the problem junction, and then from the coffee shop back the way they came, so that they are included in the flow back down the street. The user is informed of each link on which the model has found a coffee shop.

Error Due to Network Insufficiency

It is important for the network that the model is based on to be as complete as possible. If a link is omitted from the model the iterative error reduction process is unlikely to succeed. The program itself cannot determine whether a residual error is in fact a "coffee shop" or a missing link in the network so it is the duty of the operator to examine the reported errors and decide which are due to incorrect network specification. In the case of a missing link the flow on the link must either be measured and control tests done on the link surrounding it or the flow can be temporarily estimated from the degree of error in the system. These missing links have been term "Piltdowns".

Model Resumption

Once the causes of the residual error have been established the model operates from a position of increased knowledge. Certain streets have significant "U" turners added but to add new links the model must be stopped and the network updated. The model then restarts the iteration process on the basis of the updated matrix. When the total errors in the system reach the second preset level or the decrease in error between iterations is very small the program halts and writes out the stabilised matrix of turning flows. These are then used in the later injection program.

WONKA - MODELLING FLOWS IN NOTTINGHAM CBD

In order to test the operation of the O-D model and its computer implementation the program was run using a sample data set obtained by Nottingham City council. The City Planning Department collected pedestrian point count data for 57 routes that formed a good network description of the retail centre of the city (figure 3.3). Because of budgetary constraints the survey did classify observed volumes according to directional flow data but it was assumed that the flows were equal in either direction. The recent full scale surveys have shown that this assumption is in many cases invalid as flows have tidal properties. However as the model can not work with a non directional data set it was necessary to split traffic in some way and at the time this seemed to be the most rational basis. A full explanation of the program's operation can be found in Thornton et al (1987).

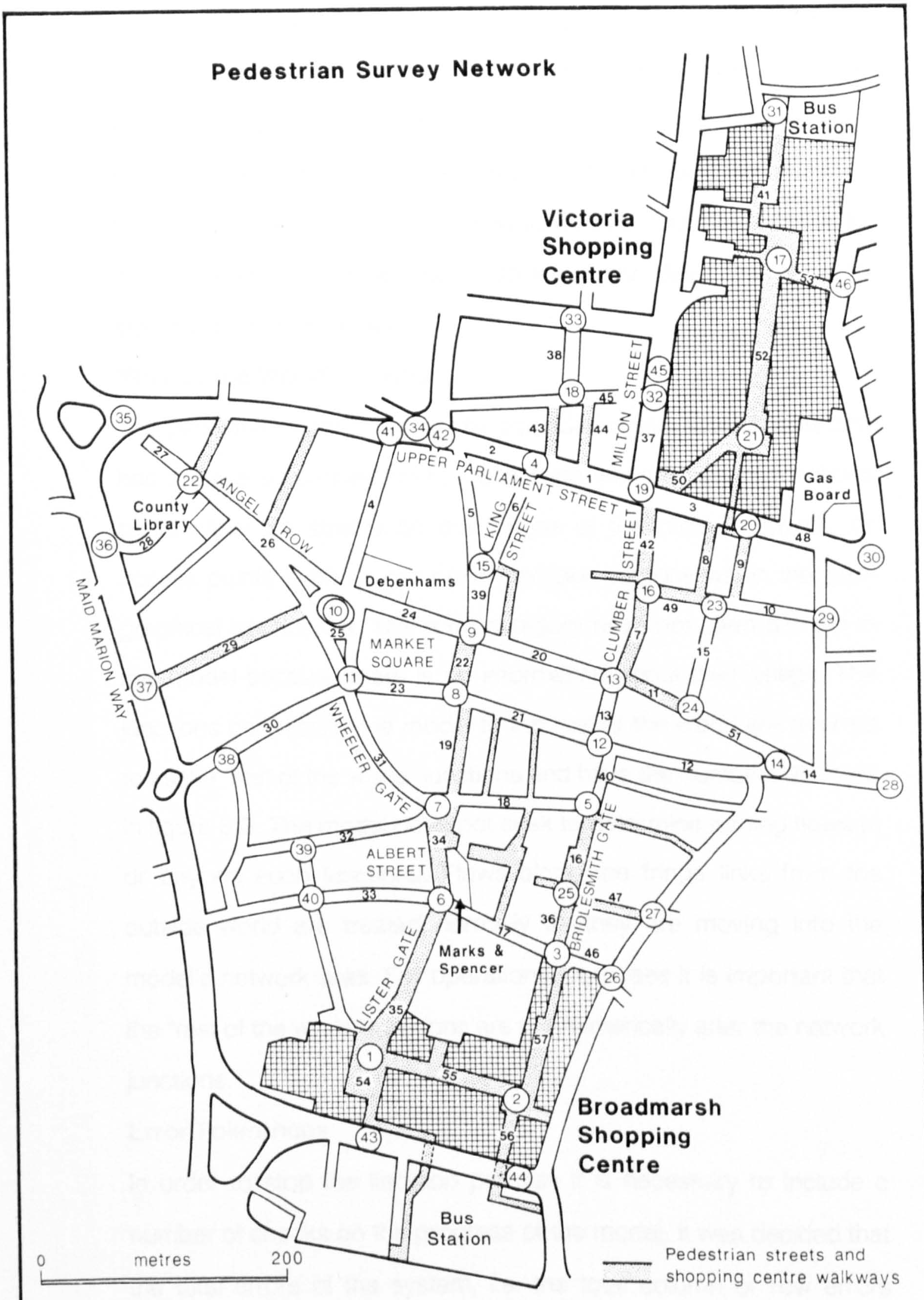

Pedestrian Survey Network
Victoria Shopping Centre
Bus Station
Gas Board
UPPER PARLIAMENT STREET
MILTON STREET
KING STREET
CLUMBER STREET
ANGEL ROW
County Library
MAID MARION WAY
Debenhams
MARKET SQUARE
WHEELER GATE
ALBERT STREET
BRIDLESMITH GATE
Marks & Spencer
LISTER GATE
Broadmarsh Shopping Centre
Bus Station
0 metres 200
Pedestrian streets and shopping centre walkways

Figure 3.3

Data Requirements

The data necessary to run the O-D program, called WONKA, is minimal. The two controlling variables are the total number of links and the number of the first "rest of the world" junction (see next section). Then for each link the model needs to know the number of the junction at each end and the flow towards it. The model needs to have a number of tolerances set so that it can determine when to stop the iteration process.

"Rest of the World" Junctions

The pedestrian system can not be considered as a sealed entity and has to have so connection to the outside world. Such connections could either be streets on the fringes of the model network, or access points such as car parks and bus stations within the geographical boundaries. The latter category have not been defined in this model because there is no information about their usage. The junctions connecting the model to the rest of the world are referred to as the "rest of the world" junctions and have the numbers 26 to 45 in figure 3.3. The model does not seek to determine turning flows at or beyond such junctions. Flows along the fringe links from the outside world are treated normally as they are moving into the model's network area. For operational purposes it is important that the "rest of the world" junctions are put numerically after the network junctions.

Error Tolerances

In order to stop the iteration process it is necessary to include a number of checks on the progress of the model. It was decided that the total errors of the system, i.e. the total column or row errors would be used as a break.

Table 3.1: Row Sum Proportionate Flow Error

1	2	3	4	5	6	7	8	9	10
-.001	.000	.000	.000	.161	.157	.000	.001	.001	.000
.000	.001	-.429	.000	.000	.000	.000	.000	.321	-.002

11	12	13	14	15	16	17	18	19	20
.000	.008	.000	-.018	.001	.002	.189	.045	-.002	.001
.000	.049	-.068	.000	.000	.020	.006	.000	.052	.000

21	22	23	24	25	26	27	28	29	30
.054	.000	.001	.000	.000	.000	.346	.346	.000	.002
.000	.001	.000	-.001	.002	-.473	.000	.000	.000	.000

31	32	33	34	35	36	37	38	39	40
-.003	.045	.188	-.241	.000	-.020	.000	.007	.000	.057
.053	.000	.000	-.064	.201	-.012	.000	.000	-.191	-.002

41	42	43	44	45	46	47	48	49	50
.000	.000	-.008	-.008	.005	.006	.004	.322	.001	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000	-.122

51	52	53	54	55	56	57
.000	.111	.000	.000	.000	.013	.010
.016	.000	.000	.000	-.014	.000	.003

Average proportionate error for iteration 7 = .0492

Table 3.2: County Library

	TO:	26	27	28	TOTAL	ACTUAL
F	26	853.	450.	488.	1791.	1803.
R	27	435.	0.	32.	467.	463.
O	28	472.	32.	0.	504.	500.
M						
TOTAL:		1760.	482.	520.	2762.	2766.

Table 3.3: Clumber Street & Long Row

	TO:	7	11	13	20	TOTAL	ACTUAL
F	7	0.	154.	628.	917.	1699.	1700.
R	11	154.	0.	102.	149.	405.	405.
O	13	628.	102.	0.	605.	1335.	1335.
M	20	917.	149.	605.	0.	1671.	1671.
TOTAL:		1699.	405.	1335.	1671.	5110.	5111.

The individual row and column errors were not used because it was accepted that these might have high error levels due to the "Coffee Shop" and "Piltdown" effects. The primary error tolerance was used as the indication for terminating the first iteration. It was normally set at 5%. This means that the process would halt when the total numerical error between predicted and observed flows was under 5%. The second cycle was usually terminated when the average error fell below 1%. Because the model may not reach these error levels it was necessary to check error reduction between cycles. If error decay did not exceed the preset value the iteration process stopped.

The First Iterative Stage

During the first stage total errors reduced as expected to the preset 5% threshold after 7 iterations. The table 3.1 below shows the residual errors for both directions, 1 and 2, of each link. Negative values indicate underestimation of flows along a link to a junction, and positive ones overestimation. The 0.000 represent links connected to the "rest of world" or links with no error. If an error is recorded a correspondingly high value of the opposite sign can on a link connected by the junction in question.

There are a number of links that display a greater than 10% under- or overestimation of flows. These are links 3, 5, 6, 9, 17, 26, 27, 28, 33, 34, 35, 39, 48, 50 and 52. As expected all links with positive error share common junctions with those displaying negative error. The junctions and links involved are shown in figure 3.4. As mentioned earlier such errors can be caused by two model factors. After due examination it was decided that three links had coffee shops and there was one missing link.

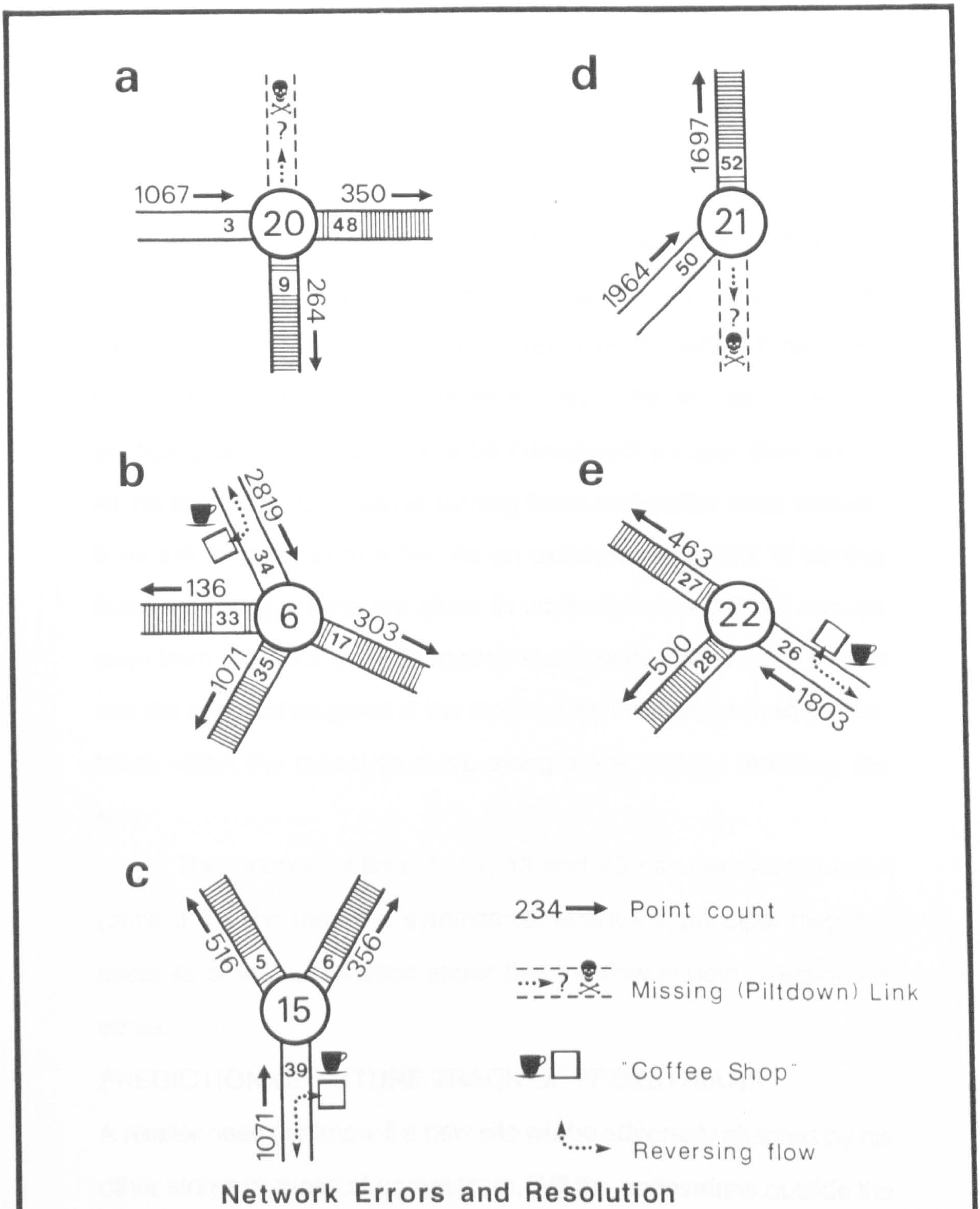

a
1067
350
3
20
48
9
264
d
1697
52
21
1964
50
b
2819
34
136
33
6
303
17
1071
35
e
463
27
22
500
28
26
1803
c
516
5
6
356
15
39
1071
234
Point count
Missing (Piltdown) Link
"Coffee Shop"
Reversing flow
Network Errors and Resolution

Figure 3.4

The missing link was the result of pedestrians using a Boots store as a cut-through. At this stage a "Piltdown" situation was treated as two "coffee shops". The model would have to be stopped if the network were to be modified. After the identification of the problem areas and their numerical rectification the program initiated the second iterative cycle.

A tolerance level of 1% error was met after 12 iterations. The maximum error for any one link was 4.6% and this was found on link 34, the sight of an original "coffee shop". Link 34, Albert Street was the location of Marks and Spencer and lay in the middle of the two shopping centres. Thus it must be considered a major destination. At the end of the program all turning flows and coffee shop populations are written out to a file. As an example the matrix of turning flows for two junctions are given in tables 3.2 and 3.3. As can be seen from table 3.2 the 853 "coffee shop" pedestrians were written into the principal diagonal of the matrix. This location allowed pedestrians within the model to move along a link without reaching the end.

The junction of links 7, 11, 13 and 20 has nearly zero error (table 3.3). The matrix is symmetrical about the principal diagonal because of the assumption earlier that the flow in both directions is equal.

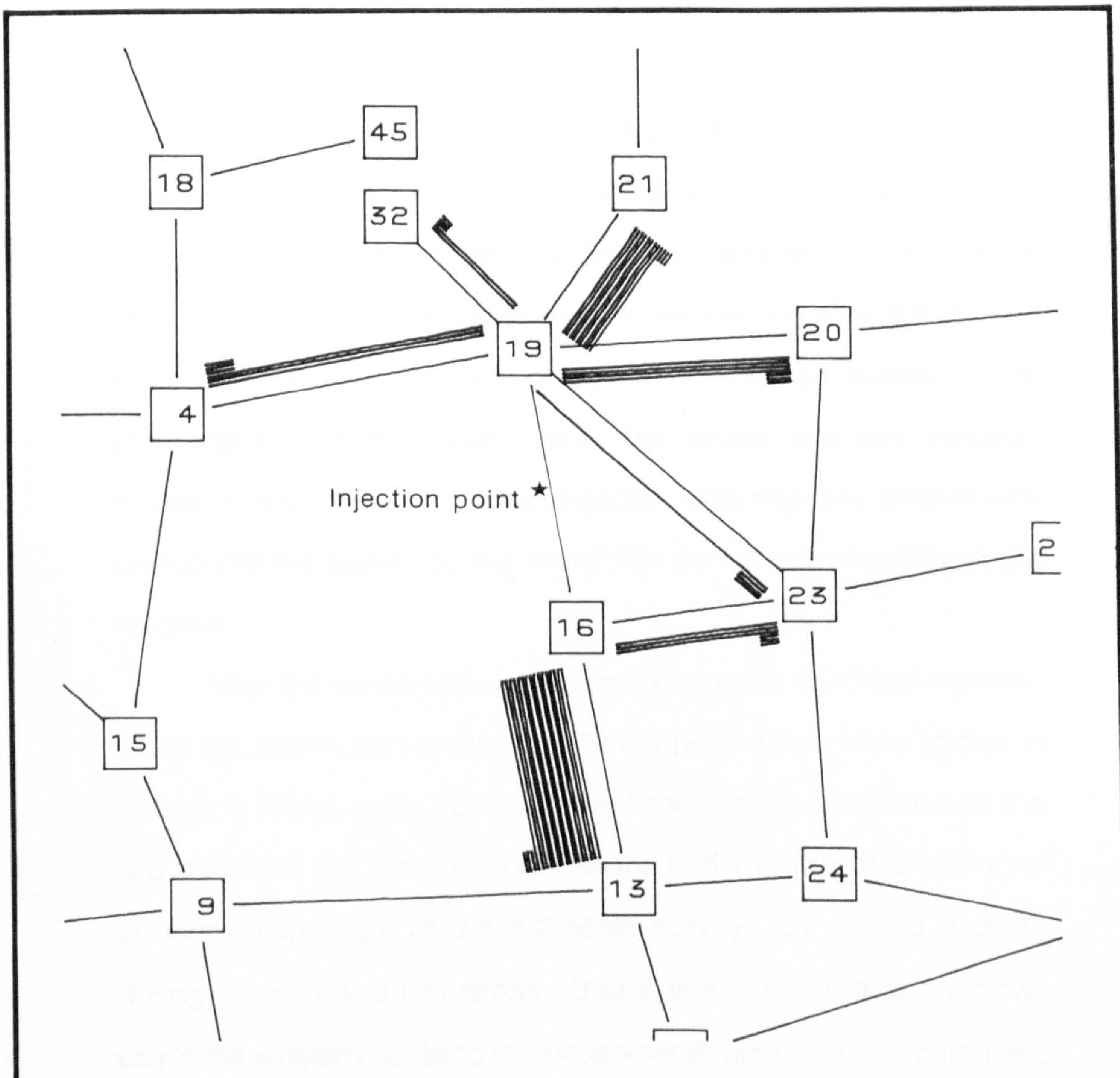
PREDICTION OF FUTURE TRACK OF PEDESTRIANS

A retailer needs to know if a new site will be adversely affected by his other stores or those of competitors. Will the pedestrians outside the store represent an untapped market or have they already been exposed to a similar range of merchandise at either the company's own stores or one of its competitors? In the former case turnover will not be split between sites and will be maximised. In the latter case the same population of pedestrians will pass all sites and turnover will be split between the shops. Two examples of such effects have been discussed in chapter 2.

To this end a further program was written that allowed pedestrian path prediction. The system was not combined into one program because the generation of the turning flow matrix took about 40 minutes. Once the matrix had been derived the other program could operate from the WONKA output file of stable turning flows. The program, called INJECT, allowed the user to predict pedestrian routes and to obtain graphical output of the predicted solution. The version of this program developed during the later in-store surveys allows hardcopies to be obtained on an inkjet printer as well as a graph plotter.

INJECT - Path prediction in the Nottingham City Network

INJECT takes the stable WONKA turning flow data and converts the figures into transition probability matrices that describe the probability of moving from one link to its connected neighbours. The program then asks the user to select a link or series of links into which the user wants to inject theoretical people. Injections can be made in either direction along a link. The model moves people through the network over a set number of time periods. The model is based on uniform time periods where each time period allows pedestrians to move one link. Thus there is no attempt to replicate real time. The inclusion of differential speeds and accounting for link lengths is not important because we are only seeking to discover site exposure not to monitor street conditions. Knowledge of street conditions comes from the detailed survey data.



Flow Prediction: Clumber Street

Figure 3.5

The plot shown in figure 3.5 shows the result of injecting 1000 pedestrians in both directions on the northern section of Clumber street (link 42) over 1 time period. The plot indicates the diffusion of pedestrians from the link and emphasises the north-south axis of the area. The thickness of the plot is dependent on the volume of pedestrians. The tick occurs at the end to which the flow is moving. In the later model this plotting system was changed to a wedge. The injection street has no flow recorded on it. This is because the first time period is taken to be the one after the pedestrians were injected. Thus a fresh injection will always appear on the links adjacent to their start point. The model has two injection modes. Firstly there is continual injection whereby new pedestrians are fed into the system during every time period and secondly single injection.

After the model has run ten time periods in continual injection mode the distribution of Clumber Street pedestrians is as shown in figure 3.6. Flows south from Clumber Street split evenly between the two tracks to the Broadmarsh Centre and the top of the Market Square. In the light of the full scale surveys conducted recently during autumn and Christmas 1990 it would seem that the flows down the westerly route to the Broadmarsh are underestimated and the flows along the Market Square are high. This may be due to under counting on the key street called the Lions. Counting flows on the Lions is difficult because it merges with the Market Square in a large open space. Northerly flows concentrate in the Victoria Centre. The flows to the Hockley area are seen also.

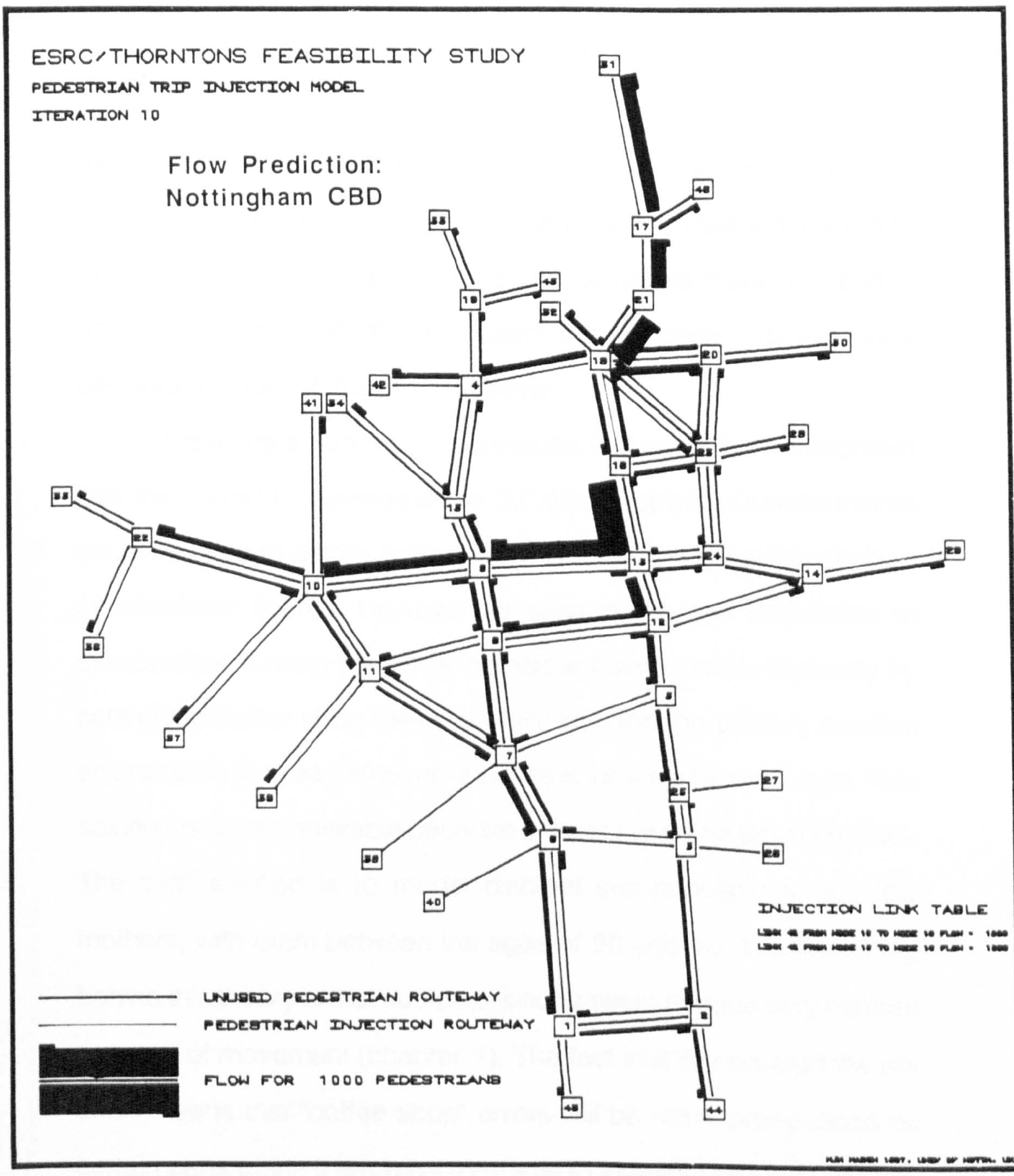

ESRC/THORNTONS FEASIBILITY STUDY
PEDESTRIAN TRIP INJECTION MODEL
ITERATION 10
Flow Prediction:
Nottingham CBD
INJECTION LINK TABLE
UNUSED PEDESTRIAN ROUTEWAY
PEDESTRIAN INJECTION ROUTEWAY
FLOW FOR 1000 PEDESTRIANS

Figure 3.6

MODEL SUMMARY

Wonka

The theory behind WONKA had to be simple because the quality of the data available in terms of transportation modelling was low. The system of relative apportionment makes sense if there is no turning flow information. One area of concern is that the model does not allow pedestrians to turn within a street unless there is a numerical imbalance at a junction. This means that it is impossible for a trip to have the same inward and outward route unless there are "coffee shops" in the network. It would seem that no other O-D technique can take account of this problem either.

There are a number of techniques that could be incorporated into the model to overcome the "U" turn problem. Questionnaires could be used to gather estimates of "U" turns and possibly develop standardised figures. However as seen during the discussion of standardised turning flows this method is questionable. Secondly by setting the coffee shop tolerance very low and the primary iteration error tolerance at say 10% more coffee shops will be produced. This solution is not so desirable because it is not based on empirical data. The third solution is to model discreet sub-populations, e.g. C2 mothers, with pram between the ages of 30 and 40. The reasoning behind this theory is that sub-populations seem to have very marked patterns of movement (chapter 1). The fact that the populations are small means that "coffee shop" errors will be more pronounced as certain parts of the town have very little to interest particular groups. This was shown during the full town survey. It is hoped that such selective modelling on the full town data will yield the information required.

Inject

Inject does not present any theoretical problems because all the model assumptions are made in WONKA. The injection program worked well but there was some dispute concerning the display of the flow volumes. It is intended that the program should have a more flexible input system as found in the diffusion module of PRETTY (chapter 7). With PRETTY the user is able to move a cursor around the screen to select the injection point. The process of continually referring back to the link plan is tedious and sometimes confusing.

INJECT is important in that it allows site exposure to be determined. As yet the model has not been tailored to such a requirement but with further work this would be possible. For example it would be desirable to be able to tag injected pedestrians as they passed a site so that if they circulated again they would not be counted twice. The need for other facilities will become apparent as the model makes the transition from a feasibility test bed to an operational system.

CONCLUSIONS

This chapter has reported on an attempt to ascertain patterns of network information from a time lapse camera survey. The complexity of pedestrian movement patterns means that there has to be compromise and smoothing in order that the modeller can make sense of the network. The degree of error in the system is unknown but other researchers have found the levels to be relatively low. It is hoped that the use of sub-population modelling will add certainty. The goal of determining whether pedestrians passing one store will also pass another does seem feasible. Whether such replication will affect turnover levels is unknown.

CHAPTER 4

PEDESTRIAN MEASUREMENT

This chapter reports primarily on the developmental and survey work undertaken in December 1986 but there is also a brief discussion on subsequent operational changes effected in the late part of 1990 and early 1991. The aim of this chapter is threefold. Firstly there will be a discussion of the development of the survey system. Secondly the data variables collected will be discussed and finally some preliminary findings of the surveys on one street will be discussed. The surveys of the whole town centre will only be mentioned briefly as these became available too late to be fully analysed and included in this thesis.

The first prototype time-lapse system

The time-lapse system developed during the feasibility study is shown in Figure 4.1. A BBC micro-computer controlled the camera via a simple reed switch circuit plugged into the user port. The computer was programmed to send a 5V output through the user port to the reed switch at the moment that the operator required. The reed switch circuit, designed by Dr T. Cross, then passed a short duration electrical pulse via a cable to the remote socket on the camera's motor winder thus taking a photograph. The camera used was an Olympus OM10, a standard 35mm SLR camera fitted with a wide angle lens.

The Prototype Time-Lapse System

Figure 4.1

A camera controller program was written in BASIC which allowed the user to set various survey time parameters and then translated the commands into camera firings. The basic survey parameters were the start time and duration of the survey, the interval between shots and whether multiple shots, necessary for speed estimation, were required. Variable interval length is useful because of the restriction on the total number of photographs that can be taken with any one camera. By altering the sample rate through the day it is possible to gain more detail during periods of peak activity such as mornings and lunchtimes. The gap length between successive pairs of shots could also be set upwards of one second apart. This variability was necessary as it was not known how quickly people would move out of the field of view of the camera. If the gap length is increased the sample time increases also but the number of people for which it is possible to obtain a speed reading falls because fewer people appear on both images. The system could be programmed a number of days before it was due to operate but in practice it was not done until the morning of the survey.

The camera was fixed in a heavy duty weather proof box. The perspex face of the box had a 13cm diameter hole drilled out and a plate of glass attached to maximise optical quality. The entry point for the camera firing cable was sealed with a silicon rubber paste. An aluminium cover was put around the box to stop rain covering the glass plate. The inside of the metal surround was painted matt black to cut down reflections. During the survey it became apparent that the extra shielding was not necessary as rain droplets settling on the glass plate did not degrade picture quality to any marked degree. Because of the size of the whole system and vulnerability of the computer only the camera unit was exposed to the elements. The box was mounted on a variable length square section steel arm via a universal joint so that it could be moved easily in three planes. This allowed the camera to be pointed at any section of street as required. The camera was placed through an open window and the whole assembly was supported by a heavy steel frame and base. The later developments meant that both the camera and the controller could sit in the weather proof box and there was no need for any external connections once the unit was in place.

THE CLUMBER STREET SURVEY

Camera Servicing

Prior to running the feasibility survey it had been decided that it would be impractical to change films more than once a day in a full multi-camera survey so it was deemed that this should also be the case for the preliminary study. During the later full town surveys it took approximately thirty man hours to prepare the 60 units for the next day's survey. The work took place during the night with three teams of two people each changing the film and resetting the units. Although it would be possible to change films during the day there might have been problems if a changeover occurred when a sample was due. A system that worked successfully in the in-store environment was to place two units at each site with only one operational at any one time. As one camera finished firing the second started. During a camera's dormant period it was removed and fresh film loaded. The unit was then reprogrammed and put back into place. However this needed four operators as opposed to two and would doubled the equipment requirements.

TIME-LAPSE SURVEY AREA

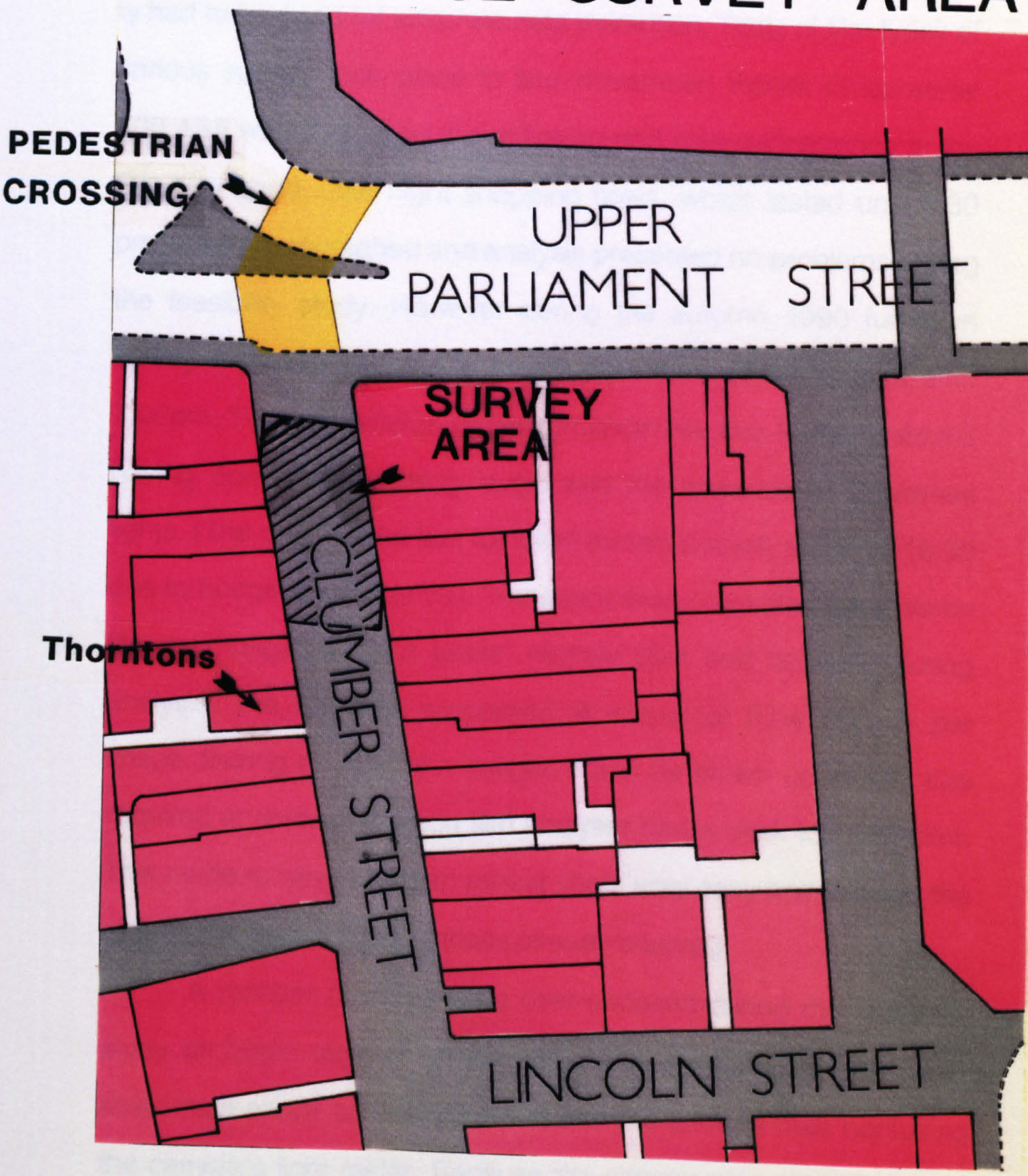


Figure 4.2

Light Levels

The early sunsets of December meant that the system had to be able to operate in very low light conditions, the majority of which came from shop windows and Christmas decorations. Picture quality had to be good for accurate data extraction. Trials of film types of various speeds took place in late November. Kodak Ektachrome 400 ASA was chosen as the definition and light performance of the film was good. Late night shopping flows, which lasted until 8.30 pm, were photographed and analysis presented no problems during the feasibility study. However during the autumn 1990 full town survey it proved impossible to get data from all the streets after 7.00pm. This degradation of performance was due to many streets having poor street lighting levels and the absence of Christmas lights. (The data for the last full town survey actually stops at 16.30 due to budgetary problems). Transparencies presented other benefits over negatives and prints, namely cost and flexibility during analysis. The film was processed at a cost of 0.04 pounds per image. During analysis the images could be blown up to any size required at no cost as each film analyser had a desk top projector. This made moving between repeat shots very easy and allowed the operator to mark off pedestrians already counted.

A number of slides were over-exposed during the feasibility study on bright days when the street was wet. The surface water acted as a mirror between the sun and the camera thus confusing the camera's light meter. Because the camera was placed so high up the angle of the camera's view coincided with that of the sun. During the full town surveys the cameras were placed about 15 feet off the ground and these problems did not recur. The lower camera height also eliminated potential masking problems from trees and other hanging obstacles.

DATA COLLECTED

In early December 1986 the time-lapse system was placed on the third floor of the Thorntons' shop on Clumber street for the feasibility survey (figure 4.2). The camera was placed through an open window on the end of the supporting arm and was operated intermittently for nearly three weeks. Various problems were encountered but these were mostly a result of operator error. Correct setting of repeat times for the successive shot option took four days to get right, thus rendering speed estimation impossible on these days. Twice the film failed to wind on due to incorrect loading. There were no practical problems with the equipment which worked flawlessly throughout the snow, fog and frost. On average 36 frames were taken per day (at least one every half hour). Due to the repetition necessary for speed estimation, only half the pictures could be considered discrete samples.

The Data Variables

During the feasibility study the six structure dimensions mentioned in chapter 2 were all recorded from the film together with an additional variable, direction, which was essential for the network modelling process. During the full town wide survey a number of additional variable and classes were added to the analysis. Both the original six and the additional variables will be discussed below.

1) Sex

The sexing of a pedestrian caused very few problems (Grayson, 1975, concurs). The gender of a pedestrian was obtained through an examination of their head, clothes and gait. During the full scale survey traffic seen on pedestrianised streets was also recorded in this variable. Six traffic categories were:

1) Bus or Coach

2) Private Car/Motor Bike

3) Delivery Vehicle

4) Emergency Services

5) Service Vehicle

6) Taxi

This variable was added because Nottingham City Council were interested in the wider aspects of pedestrian behaviour and traffic conflicts in restricted areas.

2) Age

Age estimates were again based on the physical characteristics of the pedestrians. Ages were recorded at marker intervals, for example 18 to 22 year olds would be recorded as being 20. Senior citizens were generally recorded as being 65. It was recognised that it was impossible to judge age exactly but the 5 year grouping and later agglomeration of the data set meant that small errors were not critical. It was important however to insure that the estimates made by an individual and across the team of analysers are consistent. Prior to employing a film analyser, a four hour training session was given and subsequently, checks of data quality made.

3) Socio-economic Class

The socio-economic class assessments are essentially value based because the appearance of the pedestrian is of critical importance. For example if the pedestrian was wearing low quality clothes there is a high probability that he or she comes from one of the poorer market segments. The aim was to come to a rational assessment based upon the type and quality of clothes that the subject wore and other aspects of his appearance. The premise is that for a particular age group the indicator would act as a surrogate for buying power. As such the measure does not conform rigorously to the standard employment classification of socio-economic class whose predictive marketing value has been regularly criticised (e.g. Chisnall 1985). The six categories used as a base were:

1) High professional/Executive
2) Executive/Professional
3) | Clerical/Office worker
4) | Skilled Worker/Tradesman
5) Semi Skilled/Unskilled Worker
6) State Income/Gypsies etc

Traditionally senior citizens are included in class 6 but for the purposes of this study they are judged in the same manner as all other pedestrians.

The analyser must be aware that a subject can take any number of clothing styles but still retain the same status. Therefore it is essential to analyse appearance in the context of the trip. It is unlikely that a young professional person will wear a suit on a Saturday shopping outing or a mechanic his overalls. Obviously their situations have not changed. Initially estimation took quite a time but as an analyst gained more experience of the subtle variation between people the process speeded up considerably. There were a number of analysers that had difficulty with this type of assessment. Some analysers felt uncomfortable in putting subjects in a low category because they felt that they were in some way criticising the individual. The tendency was to concentrate the subjects into classes 3, 4 and 5. If such "bunching" was noticed the film analysers were instructed on the nature of the measure and given reassurance over the judgmental process. However the problem recurred as will be seen later in the chapter.

Errors in Age & Socio-Economic Class Estimation

If the errors of estimation are consistent then they should not be critical for two reasons:

1) The data is not used in an absolute sense. Pedestrians are modelled in groups, e.g. 30-40 year olds or group 3 and 4 mothers, so pinpoint accuracy is not essential.

2) During calibration for turnover estimation purposes a similar photographic interpretation procedure was employed within shops to determine what various types of people are buying. Therefore, if a man is interpreted as being of socio-economic class 4 on the street, instead of 3, and also 4 within the shop the error will not be of consequence. The classification is not intended to be used in conjunction with any customer profile using the official socio-economic profile or a derived segmentation system such as that devised by ACORN (Chisnall 1985).

During the feasibility study a small test of accuracy was done using 2nd year geography undergraduate students. Six pedestrians were selected from a slide and the students asked to estimate sex, socio-economic class and age. The results given in the table 4.1 below were encouraging. Standard deviations of the age estimates were between 2.8 and 7.1 years. The largest variation occurred in the estimation of the age of an OAP. As such this is not serious because those over 60 are generally put in one analysis category. The socio-economic group estimates had standard deviations of 1 group. Whilst such levels of variability are undesirable it must be noted that the students had never attempted such an exercise before and had very little idea of the basis of judgment.

Table 4.1: Estimation of Age and Socio-economic Class

Pedestrian Case	Mean Age	Std Dev Age	Mean Class	Std Dev Class
1	28.4	5.5	2/3	0.6
2	23.4	2.8	3/4	1.2
3	61.9	7.1	3	1.0
4	23.1	5.2	4	1.0
5	50.1	4.8	2/3	0.6
6	50.2	5.2	3	0.6

Mention of the fundamental inadequacy of socio-economic class as a measure of purchasing potential has already been made. However as will be seen in the development of a turnover interface (chapter 6) the variable measured did help discriminate between shoppers and non-shoppers. At this stage it is difficult to see a surrogate that could be obtained unless a simultaneous questionnaire was attempted and even then the benefit of doing so, in terms of increased predictive accuracy, is questionable.

4) Direction of Movement

Estimating the direction of movement presented few difficulties. If a pedestrian was judged to be moving a positive value was given, otherwise a value of 0 was recorded. During the feasibility study direction was recorded in geographic terms, i.e. to or from the Victoria Centre. In order to make the job of moving between film rolls easier during the full scale surveys this measure was changed to direction relative to the camera. People were deemed to be walking across the street if they moved at more than 45 degrees to the main axis of the road. If the direction of movement was uncertain the pedestrian was put in the "aimless" category. In the case of the double shot sample it was possible for a pedestrian to move one way on one photo and another on the second. In such a case the pedestrian was recorded twice, once with each direction.

5) Speed

Speed was estimated using the successive shot facility of the time-lapse system. After a number of experiments the repeat time between frames was set at 3 seconds. On average two thirds of people appeared on both photographs and thus their speeds could be assessed. The likelihood of a pedestrian skipping both frames was low as even with a short survey area their speed would have to be in excess of 7 m/sec, a very fast run! Distance travelled was determined by counting the number of paving stones, or other regular street covering, covered between frames. This had the advantage of not being affected by the perspective of the camera. The distance covered was measured from midway between the pedestrian's feet, in other words directly below the body. Pedestrians who did not occur on both photographs were given a speed of -1 to allow easy exclusion in later analysis and to avoid confusion with those people who were stationary.

6) Social Association Category

As with the measures of age and socio-economic class, recording social associations requires a degree of conjecture. It was decided that a few general classes should be used for data extraction which could be made more specific during analysis by the inclusion of some of the other variables. For example category 4, partners, can range from a pair of teenage sweethearts to a pair of senior citizens. Separation of the two is possible by including the age variable.

Seven categories were used:

0 - Alone
1 - With friends
2 - Pushing prams
3 - Child/Parent/Grandparent
4 - With partner of the opposite sex
5 - In a family group (mother, father and at least one child)
6 - Pushing or in a wheelchair

There was enough room in the file to record up to three associations for each pedestrian. This proved to be ample space. During the feasibility study the case numbers of the pedestrian's associates were recorded also but this proved relatively expensive to collect (about 10 seconds per pedestrian) and of no substantial benefit during the later analysis. There were no difficulties encountered in this part of the analysis even when the umbrellas were up due to the oblique view of the camera.

ADDITIONAL VARIABLES FOR THE FULL TOWN SURVEY

Four additional variables were collected during the full surveys. Three of these were included to aid data processing and flow modelling. The fourth, location in the street, was included as a result of work done during the investigation into the derivation of a turnover interface.

Time of Day

During the feasibility survey the data files had a different structure to those of the full town study. Initially the time of the image was placed before the data from the image but because of the increased use of dBase IV and a new presentation system based on animation each pedestrian record had a note of the time.

Figure 4.3

Flow Variability - Example 1

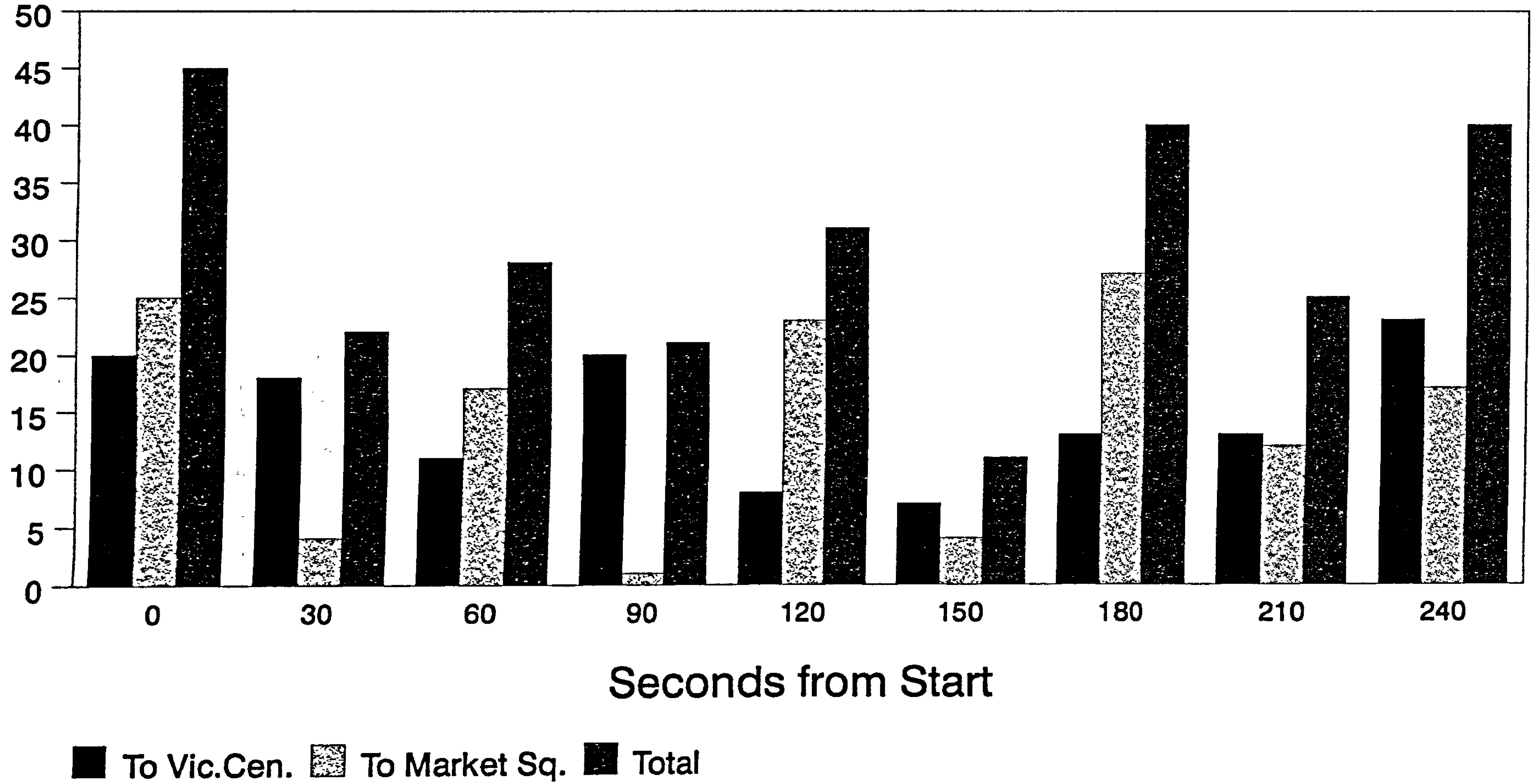
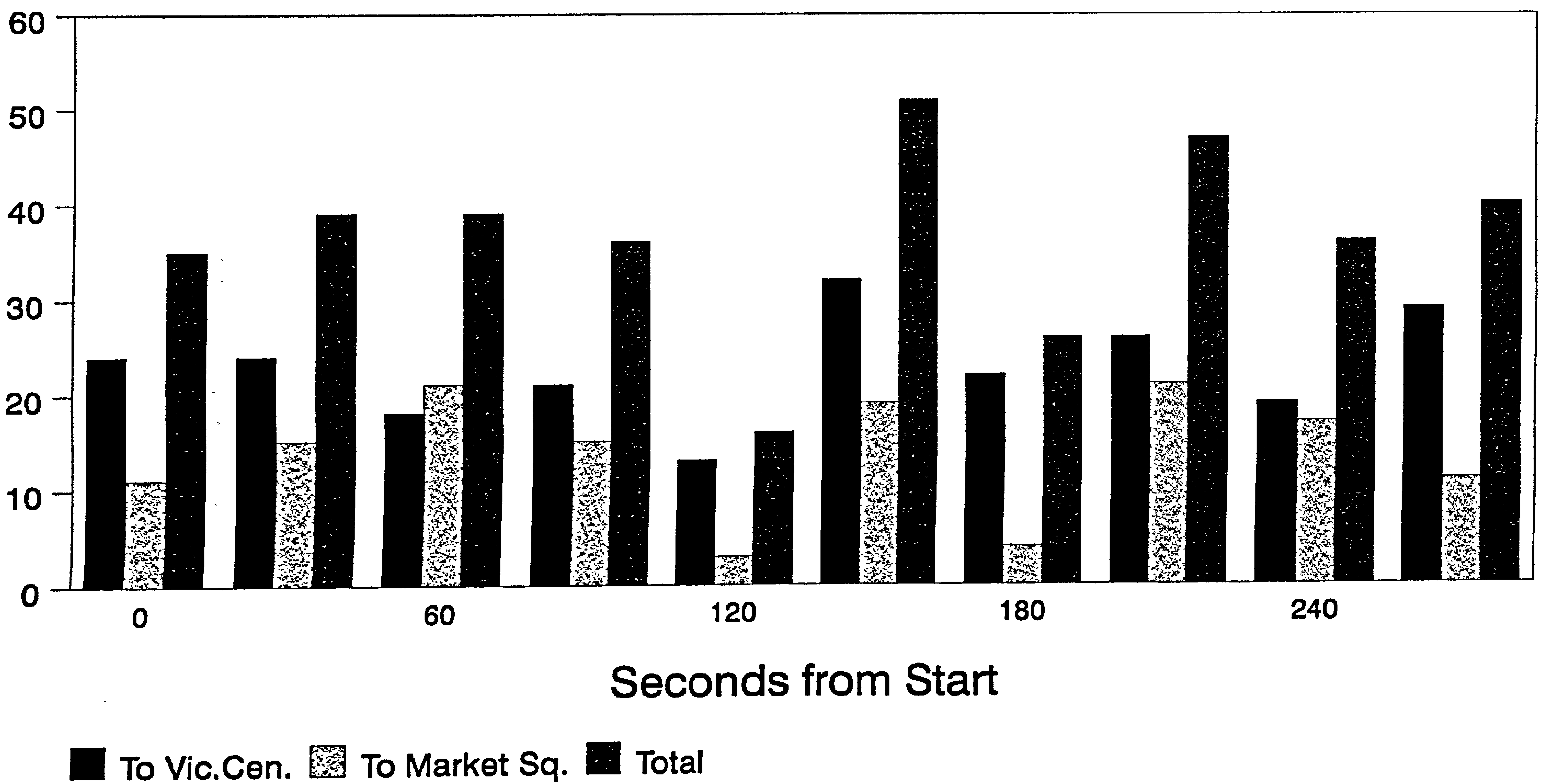


Figure 4.4

Flow Variability - Example 2



Type of Street

This variable was used to indicate whether the survey street was pedestrianised or not.

Location on the Street

The pedestrian's location across the width of the street was recorded. Three values were used to classify pedestrians as either on the left-hand pavement, the right-hand pavement or in the middle of the street. During the video work reported in chapter 5 distance from the store front was found to affect store interest. However the use of a scalar measure in a full scale survey would be impractical due to the time taken to accurately measure distance from a photograph and the "snake" pattern of pedestrian movement. The measure used indicates whether a pedestrian is on the correct side of the street for a site.

Percentage of the Area Obscured

This was recorded so that later calculations of the flow rate would only be based on the area that was visible to the camera. Lorries and market stalls often obscured the view of the cameras and thus reduced the area of the survey. The reduction in survey area rarely exceeded 50% and did not compromise the length of the area surveyed and thus the sample time. The usual situation was for a lorry or a bus to obscure part of one side of the street.

DATA ANALYSIS

Photo analysis time

Time for extraction seems to be linearly related to the number of pedestrians present on the photos. For example a photo of 150 people (about 13000pph) would take about 2.5 hours to analyse whereas one with 5 would take about 3 minutes. The average rate was about 1 minute per person. During the full town survey most cameras did not record the speed variable and this reduced the time per person to 40 seconds. Data was typed direct to computer for later analysis. During some of the store surveys data was marked on prepared data forms but these proved counter productive because the second translation introduced another source of potential error, and the analysis time increased.

Flow rates

The derivation of flow volumes from time-lapse photography is not as simple as it may seem. Ramsay (1986) points out that there is still debate about what actually constitutes flow; is it throughput or density? The collection of speed data allows the derivation of both measures. Fruin (1971) states that:

Flow = Numbers x Average Velocity

Density can easily be obtained from the number of people on the photograph and the space occupied. However it was noted during the surveys that density varies as much across the width of the street as it does along it (see chapter 5). Whilst such formulae grossly simplify the concept of flow, retail exposure to pedestrians and the conditions experienced by them are important to the success of suscipient retailers. The choice of measure used depends on the purpose of the survey. The flow rates quoted later on are based on Fruin's equation.

Effect of sample time and interval on flow rate

In order to assess the degree of variability two 5 minute manual line counts were performed around 5pm on a late night shopping Wednesday. A total of 1296 pedestrians crossed the measuring point. At the same time as the counts were taking place the camera took a shot every 30 seconds. The graphs shown in figures 4.3 and 4.4 represent the number of pedestrians seen each photograph for both of the 5 minute counts. The figures show both total numbers and number flowing in each direction.

The effective sample time of the time-lapse system depends of the length of the survey area and average speed of the pedestrians. In the feasibility study the survey area was about 25 metres long which with an average speed of 1 m/s gives an average sample time of 25 seconds. The successive shot effectively increases this to nearly 30 seconds. During the full scale 1990 survey the lengths of the areas recorded varied from about 25 to 60 metres. (The range was necessary because some of the less busy streets would have had very low numbers of people and the busiest streets would have cost too much to analyse). The flow rates derived from the full surveys took account any difference in survey area.

The problem with this data capture method is that pedestrian waves occur in conditions of medium to low density. The number of people seen on the image depends on when the picture was taken in respect to the peaks and troughs in the flow rate. At times of high density the flow is more even because the lack of room and restricted personal space tends to make people travel at or near to the average speed (Bowerman 1973). Problems with short term variability can be overcome by careful camera positioning. For example the very top section of Clumber Street is greatly affected by the controlled pedestrian crossing at the top of the street (figure 4.2). This crossing operates a one minute cycle with 40 seconds allotted to vehicular movement and 20 seconds to pedestrians. Thus if the camera were monitoring the area just below the crossing it would be possible for it to sample only at times when the crossing was closed or at the time of the peak rush as pedestrians moved off from the curb. By positioning the viewing point so that the queue at the crossing is included, the camera does not run the risk of sampling at either the peak or ebb of flow. It is vital that short term causes of variability are understood prior to camera positioning so that the best locations can be chosen.

Medium term variability, such as that caused by bus arrivals and natural flow variations are harder contingencies to anticipate. However because there is little regularity in the peaks and troughs it is unlikely that the system would always sample an extreme situation. The effect of medium term variability was monitored in a later part of the research and it was found that although there are wide variations in the measured flow rate at any one time, on a longer time scale the total flow rate predicted varied by very little (chapter 5). Thus it would seem unnecessary to sample the volume of traffic and its composition at different rates. If such a scheme were put in place it would increase the work required and the costs involved substantially.

FULL TOWN - PRELIMINARY ANALYSIS

Before it was possible to perform any analyses on the data sets it was necessary to be able to select pedestrians according to different combinations of the recorded variables. During the preliminary study the ability to manipulate the data came solely from the SPSS package. By the time of the later surveys a PC based database package had been acquired. This package, dBase IV, added a lot of flexibility to the system because it speeded up the analysis and allowed different combinations of variables and approaches to be tried.

Numbers Surveyed

Three pedestrian time-lapse surveys have been completed. The feasibility survey in 1986 recorded 7,200 individuals, with duplicate occurrences of the same person from the repeat shots giving a total data set size of about 10,000 observations. Ten days of film were analysed. The two 1990 surveys simultaneously covered 60 routes in the city centre. The first full scale survey occurred in September 1990 and the second in December 1990. The data from the films became available during March 1991. Over 100,000 pedestrians were seen and recorded in each survey. Although the numbers recorded in the two surveys was similar the volume of pedestrians was noticeably higher in the December survey. Budget difficulties had meant that the areas of street analysed had to be cut in order to reduce the number of observations and thus the cost. Comparison of the two adjusted Saturdays' pedestrian volumes show that the September Saturday had only 64% of the December level.

Flow variation between the two full surveys

There was a general increase in traffic during the December 1990 survey. Saturday showed the biggest increase in the total area adjusted observations with Wednesday having the second largest increase (table 4.2). The importance of Saturday as a shopping day is shown in table 4.3. The December weekday/Saturday increases were noticeably higher than those of September.

Table 4.2: Pedestrian Traffic Change September/December

Wednesday: September/December: 120%
Friday : September/December: 115%
Saturday : September/December: 155%

Table 4.3: Weekday/Saturday Change in Pedestrian Traffic

September: Wednesday/Saturday: 160%
September: Friday/Saturday : 150%
December : Wednesday/Saturday: 200%
December : Friday/Saturday : 190%

CLUMBER STREET RESULTS

preliminary pedestrian analysis

The analysis presented here is a preliminary one only, intended to display the variable nature of the pedestrian flow in Clumber Street. The purpose is to indicate the types of pedestrians occupying the street at different times of day, both during the week and on Saturday, in order to demonstrate the type of data which could be input to the WONKA model.

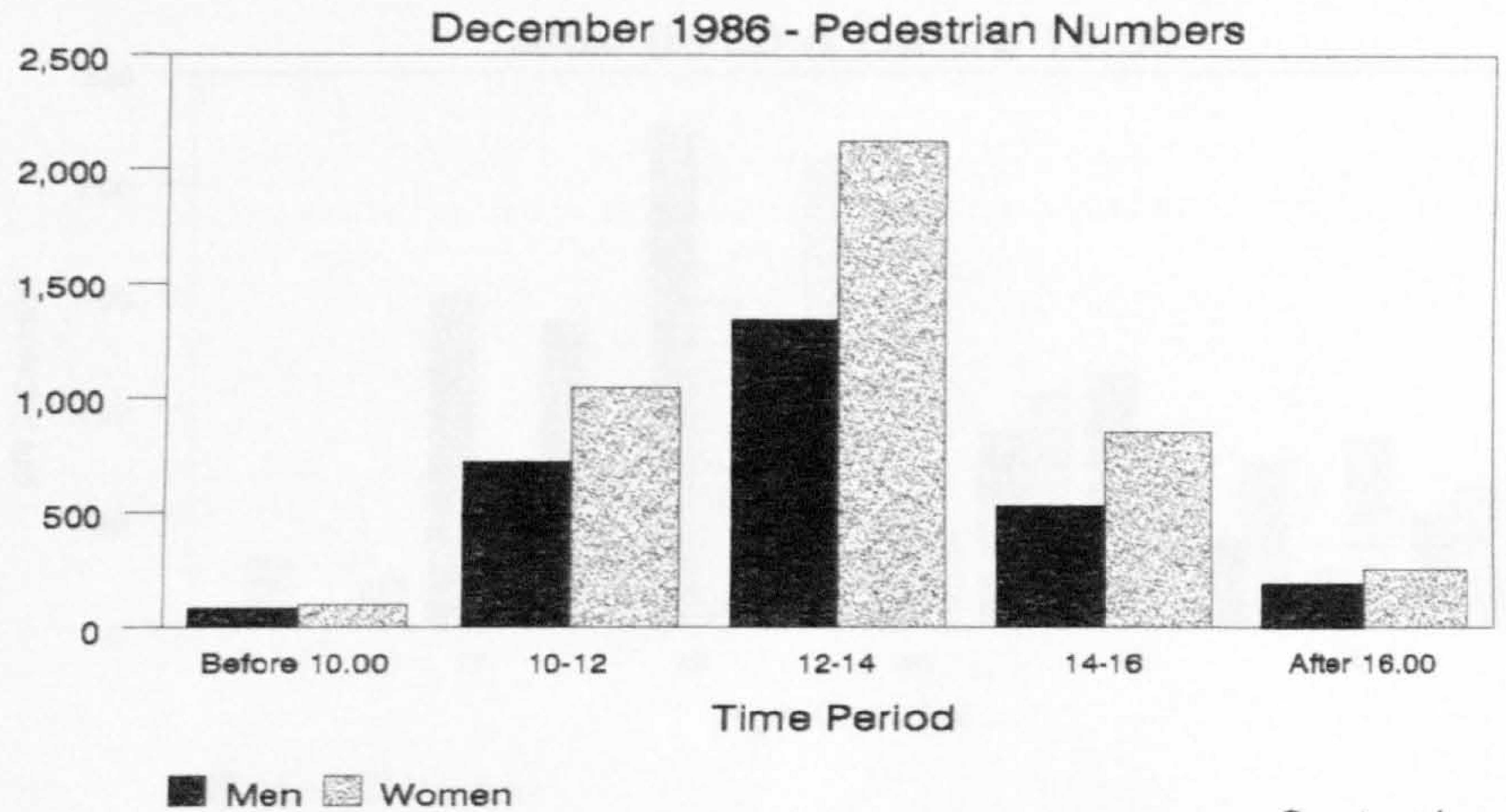
Male and female weekday variation

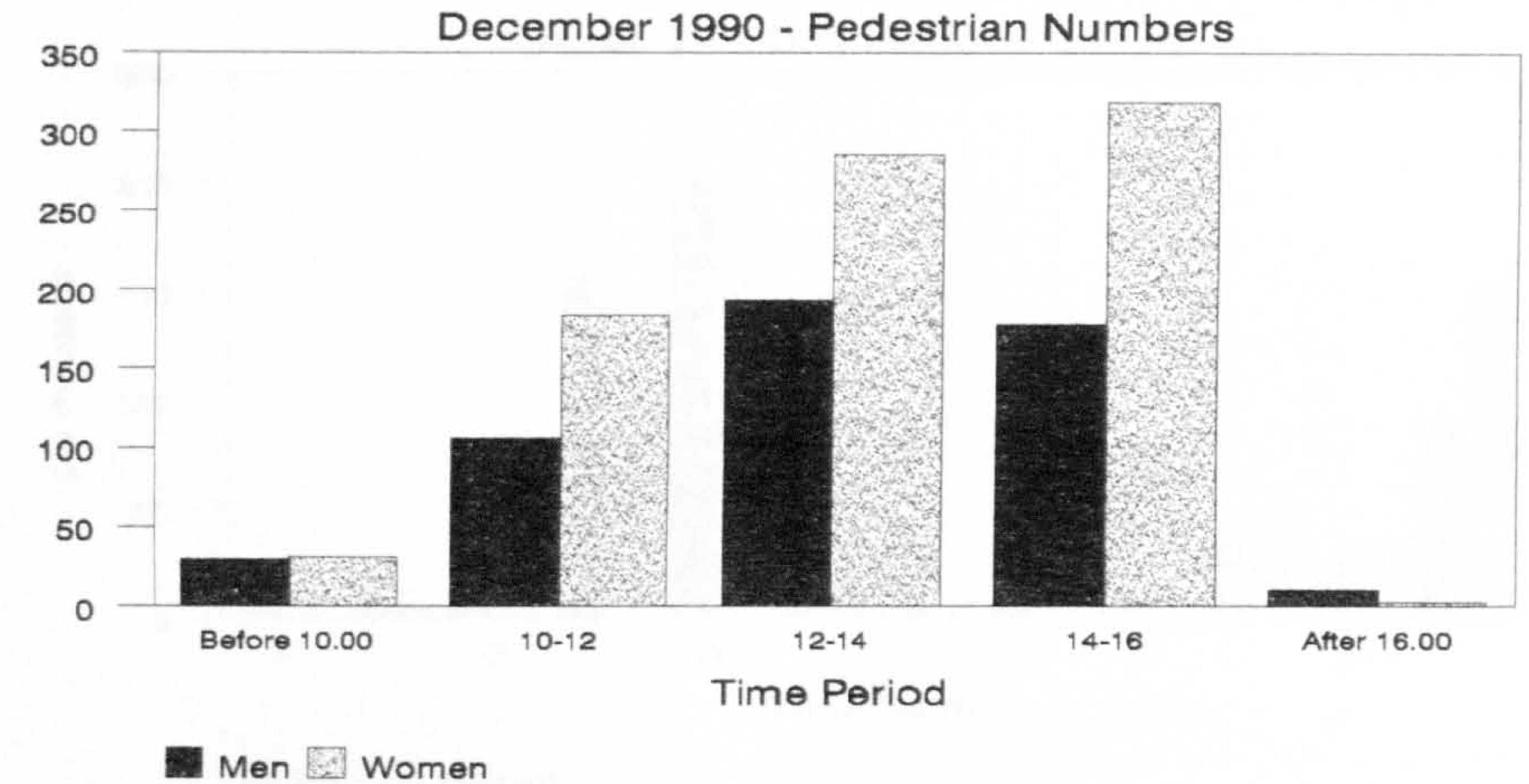
The measured volume of pedestrians for the three surveys can be seen in figure 4.5. Pedestrian numbers built up from low levels in the early morning to a peak during the mid-day period followed by a decay in flow rates during the afternoon. There were a number of differences between the survey periods. Firstly the December 1990 volumes did not decay after lunch. This might be a result of the influence of late night shopping. During the 1986 survey two out of the eight weekdays had late night shopping whereas during the 1990 survey one out of the two days surveyed had extended shopping hours. The very low flow rates noted after 16.00 during the December survey were due to poor light and the sponsoring body's desire to reduce costs.

Variation in Age Profiles

Figures 4.6, 4.7 and 4.8 show the daily variation of age profiles for both sexes during the three survey periods. The time periods are not the same owing to scanty data after 16.30 during December 1990.

Figure 4.5
Volume of Pedestrians in the Three Surveys





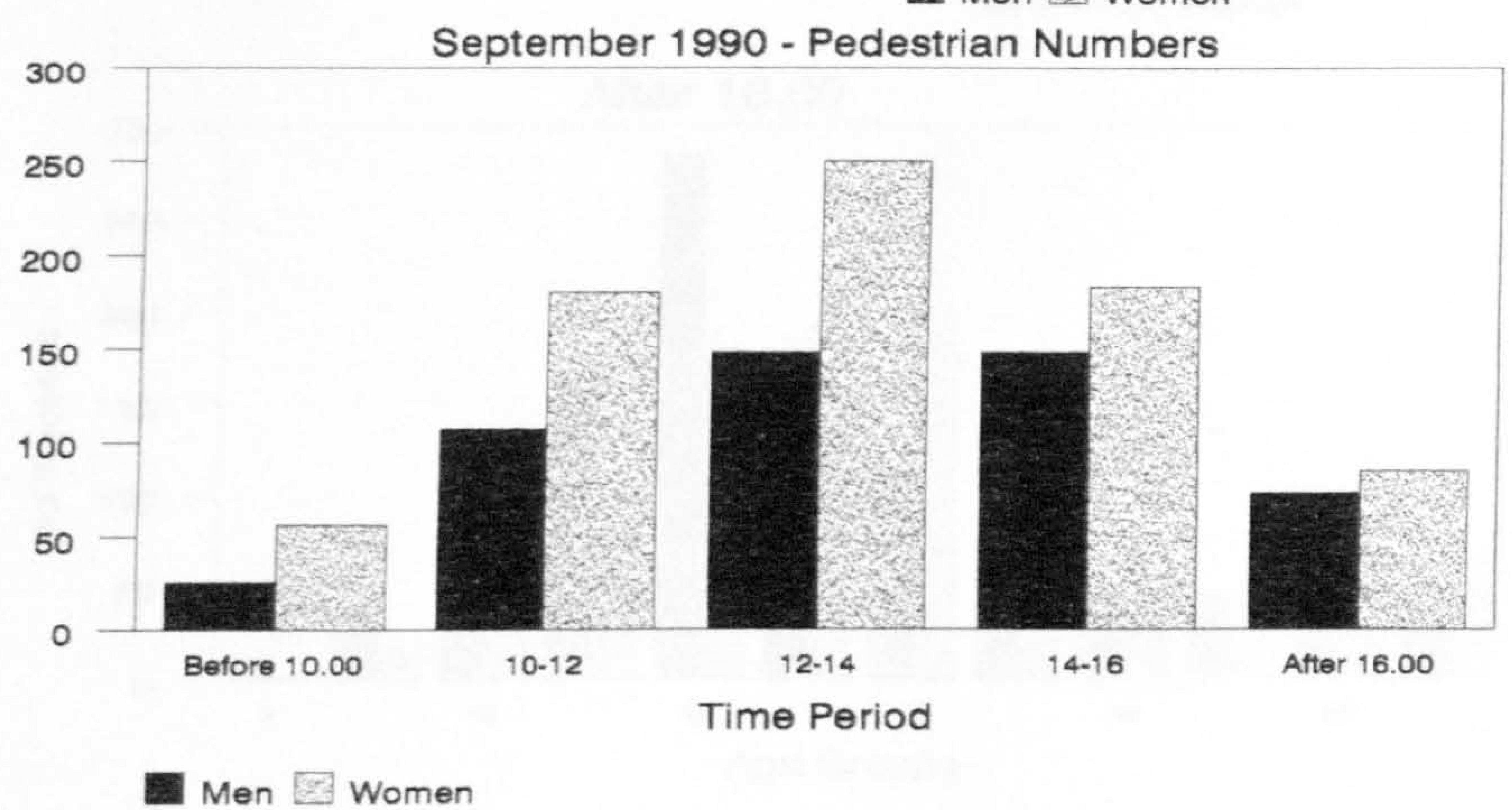


Figure 4.6

Male and Female Age Profiles - December 1986

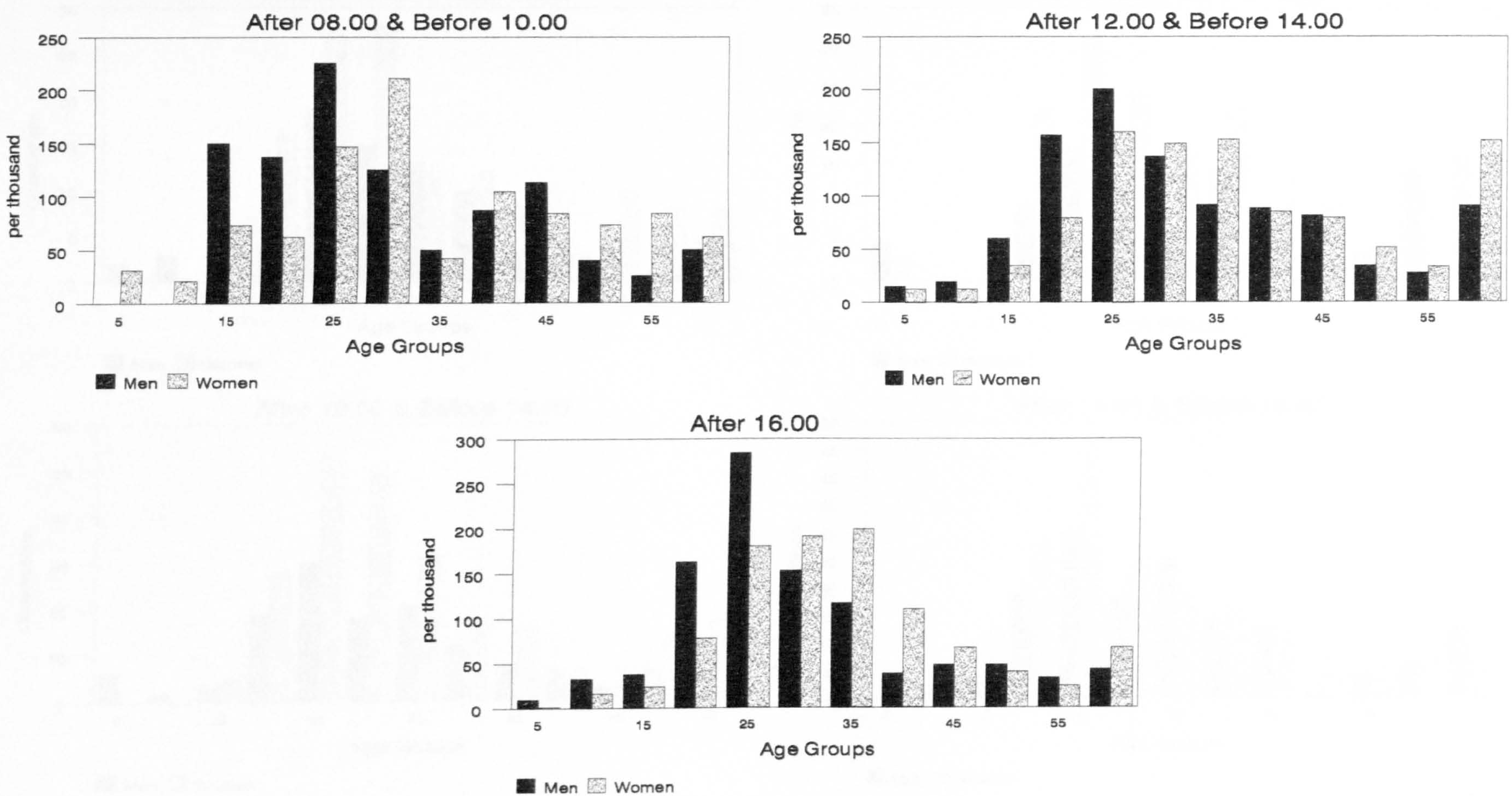


Figure 4.7

Male and Female Age Profiles - September 1990

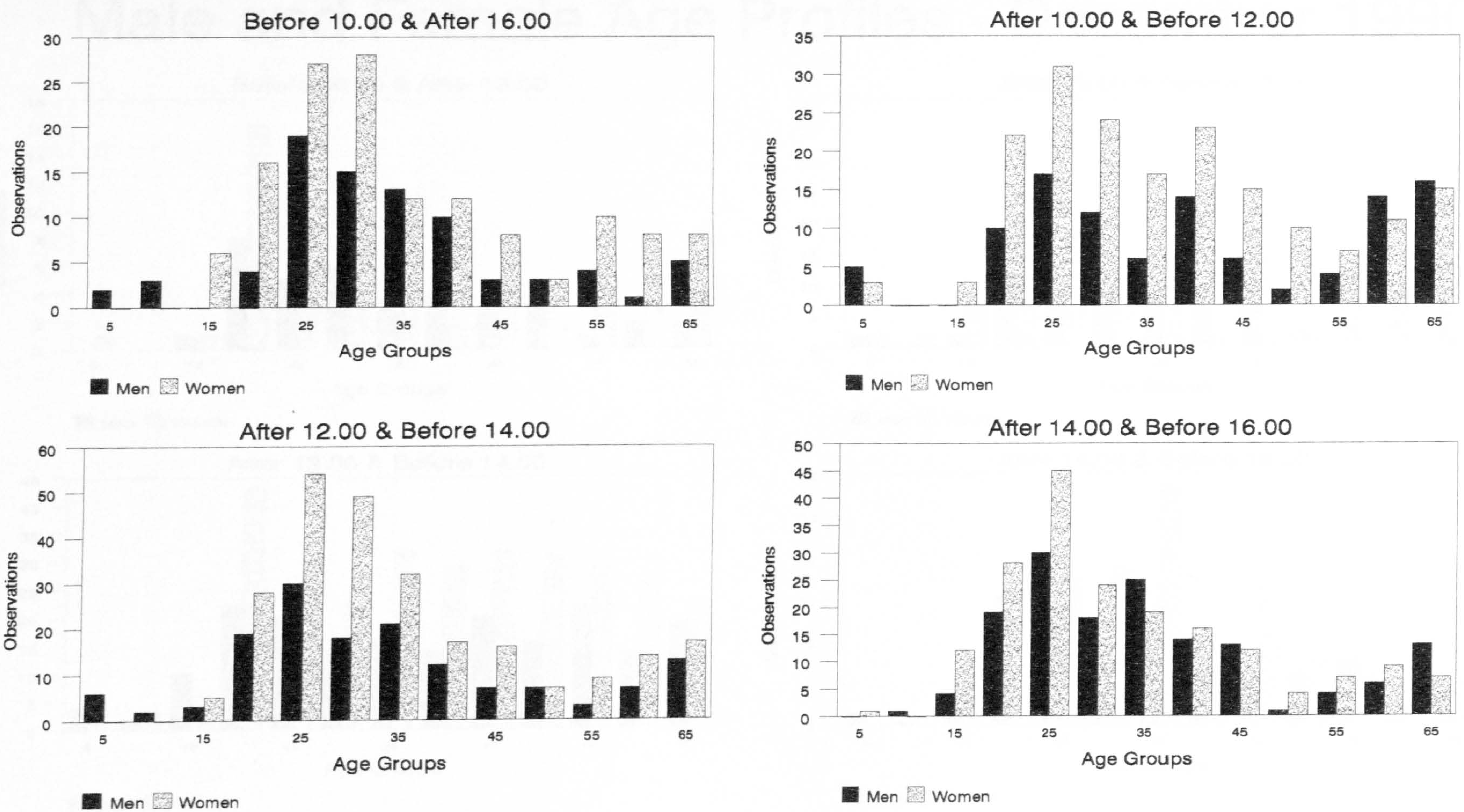
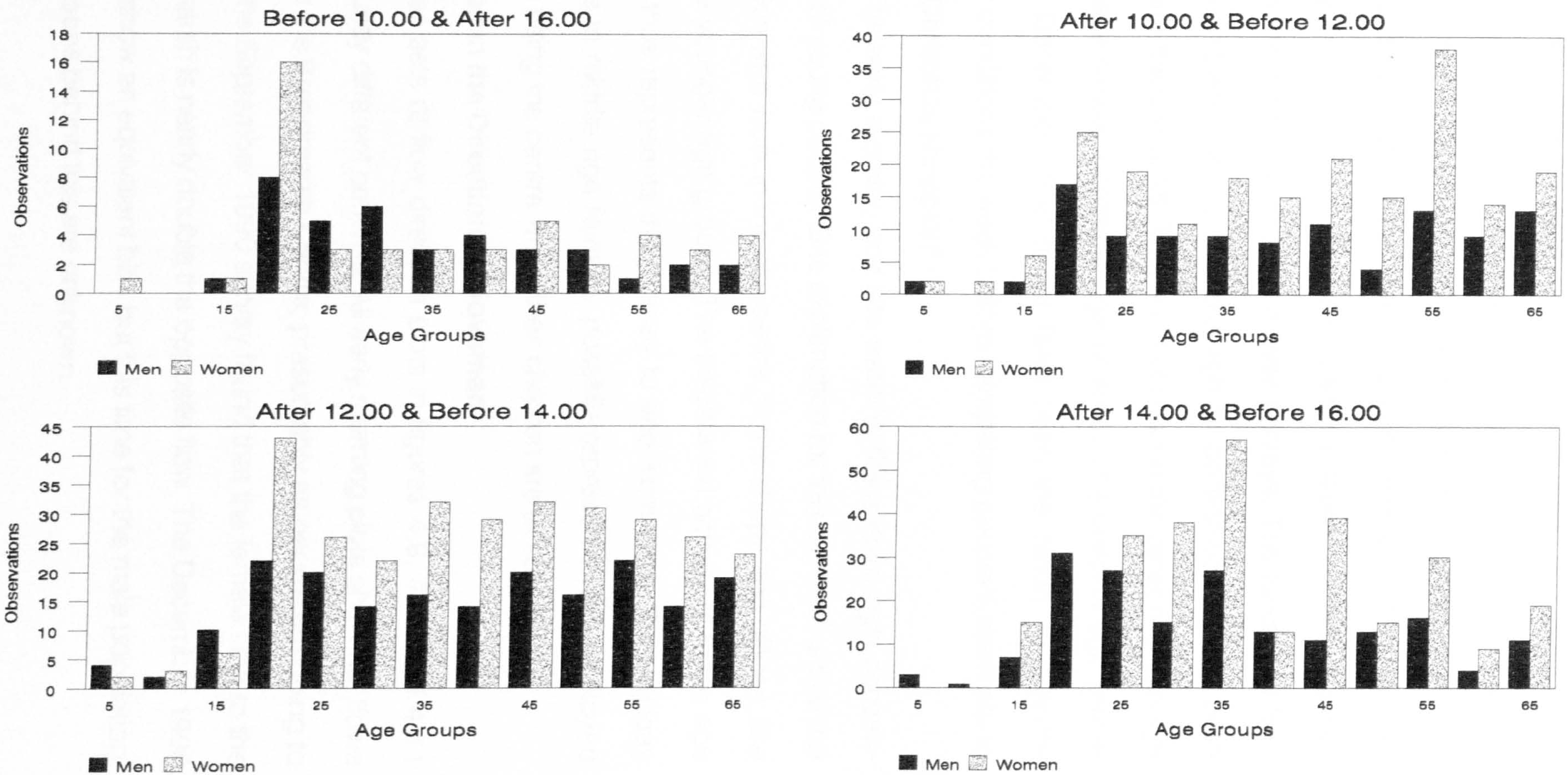


Figure 4.8

Male and Female Age Profiles - December 1990



The two later surveys differ from December 1986 because the two lunch periods were not typical of the late morning and early afternoon periods. This was especially true for the female population. The December 1990 plots either side of lunch show distinct peaks in the 55 and 35 year groups that were not seen at lunchtime. The relatively high proportion of senior citizens seen in 1986 was not visible in the central period of the later surveys. The lunchtime flow recorded in December 1990 had a high proportion of people of both sexes over the age of 35. This was not seen in the other two surveys which have similar lunchtime age profiles. The uniform age profile seen in December 1990 might have been the result of extreme weather conditions the week before hampering people's attempts to "do the Christmas shopping".

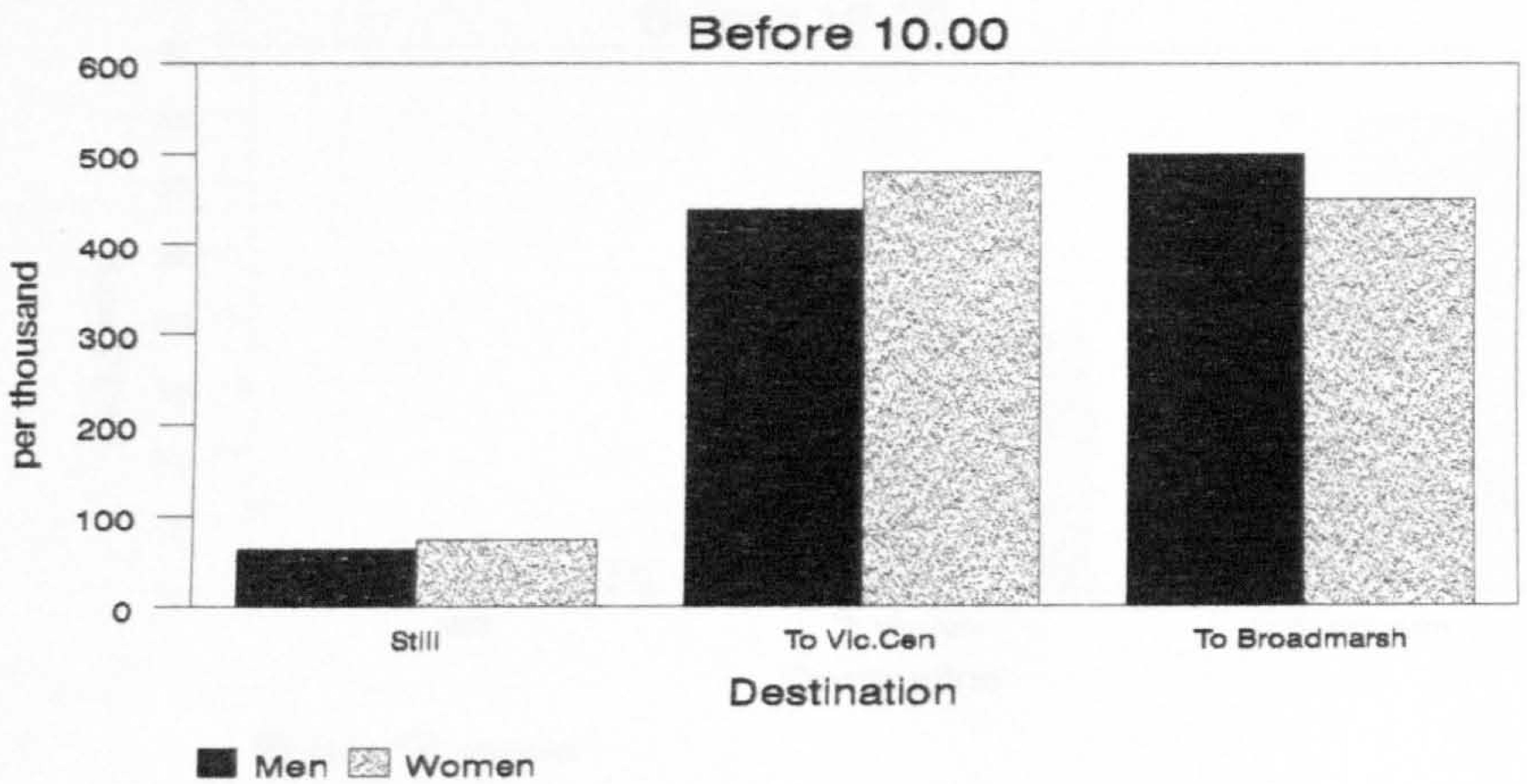
The early morning and late evening flows have high concentrations of young people. One explanation for this contrast is that the population who work in the city centre, in the shops and offices, are from the younger age groups. The heightened activity of these age groups thus represents the journey to and from work. The midday increase in middle age females possibly represents non-employed females using the centre whilst their children are at school.

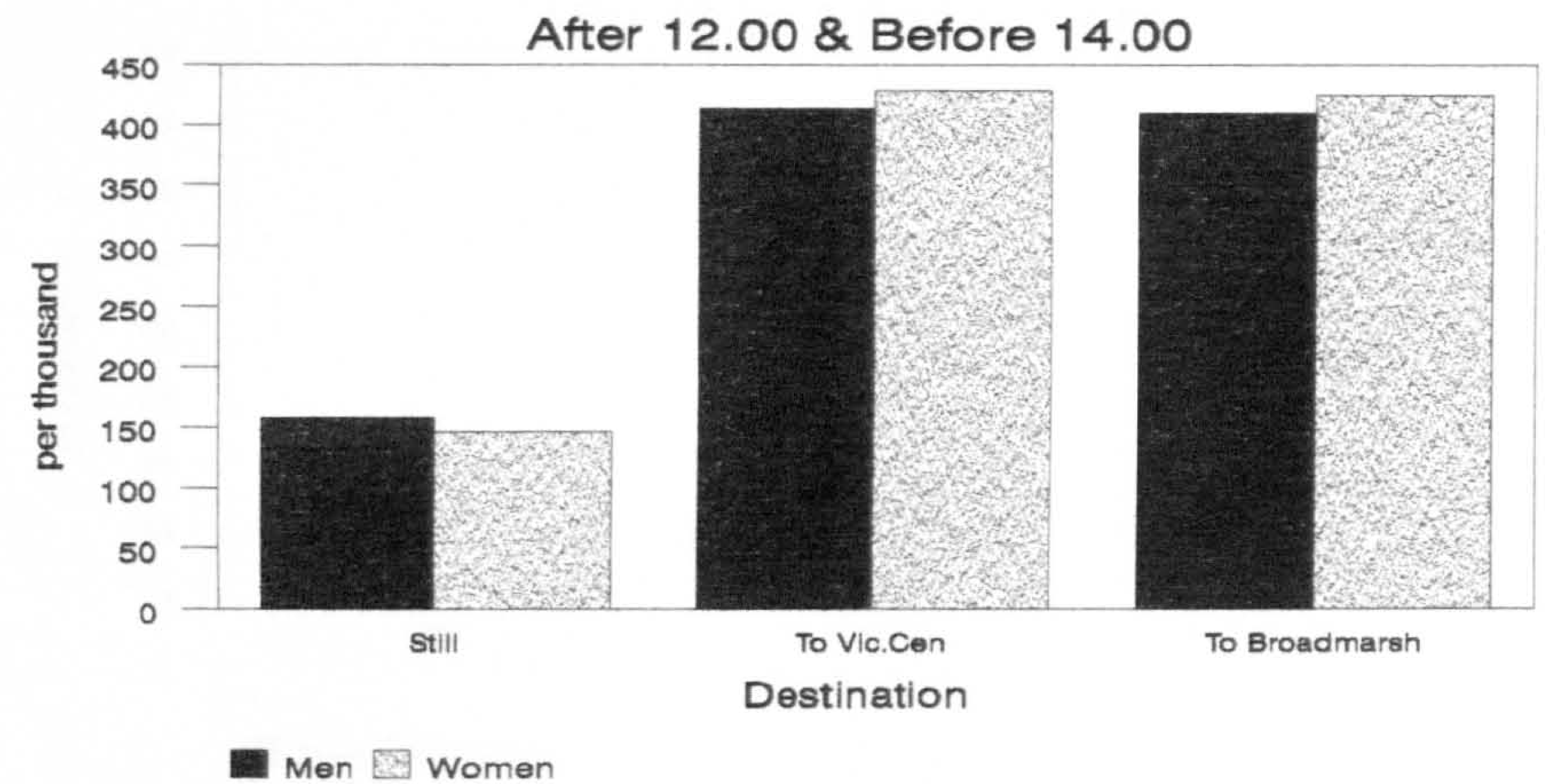
Variation in the Direction of Movement

The three sets of flow direction plots in figures 4.9, 4.10 and 4.11 show subtly different patterns. All early morning plots show net flows towards the Broadmarsh Centre, presumably as people are going to work. The September 1990 survey found that the female flow to the Broadmarsh is nearly double the opposite flow. The December 1990 figures show an equivalent bias but this time for the male population. The reasons behind this are unknown.

Figure 4.9

Flow Direction on Weekdays - December 1986





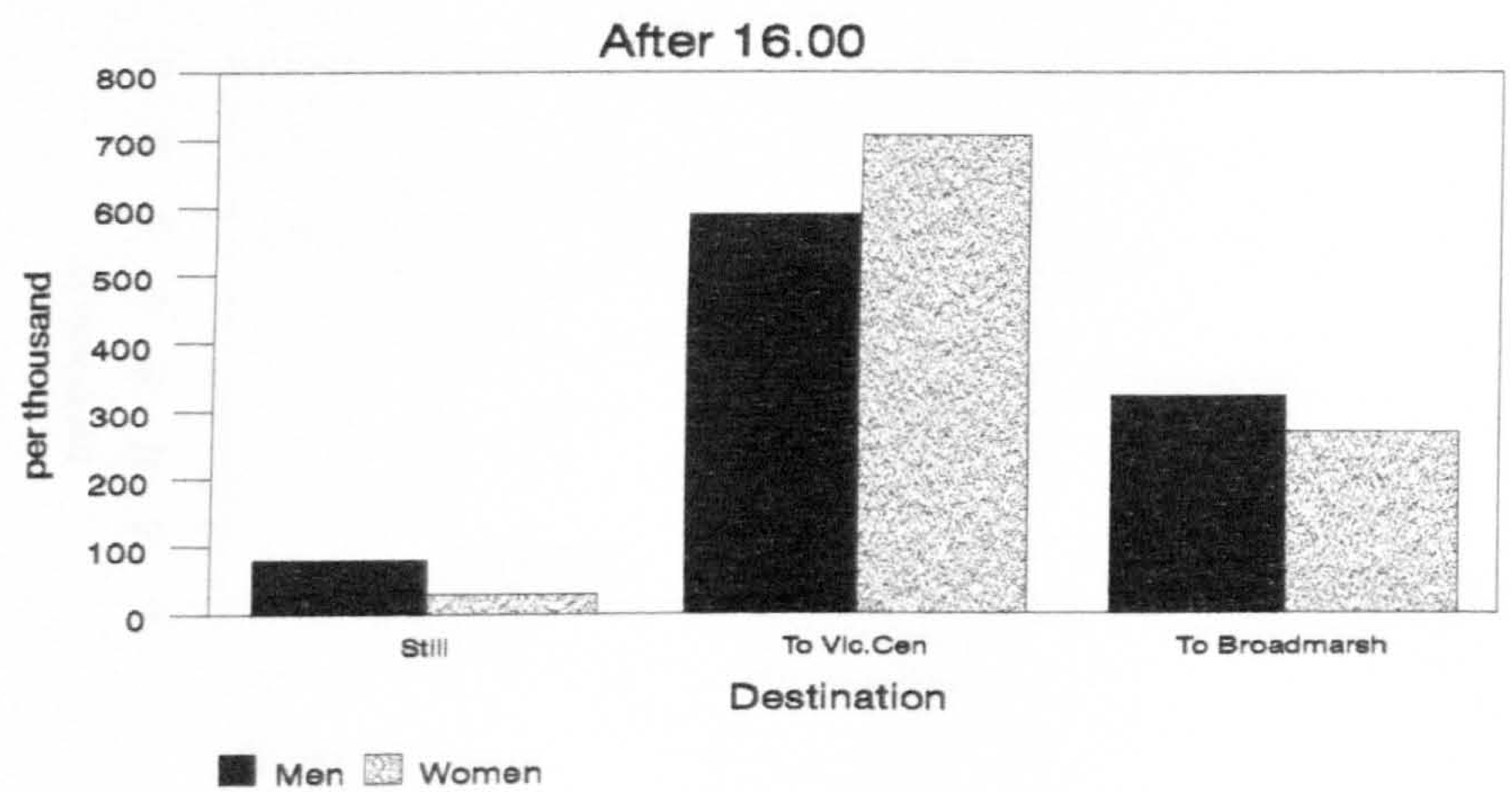
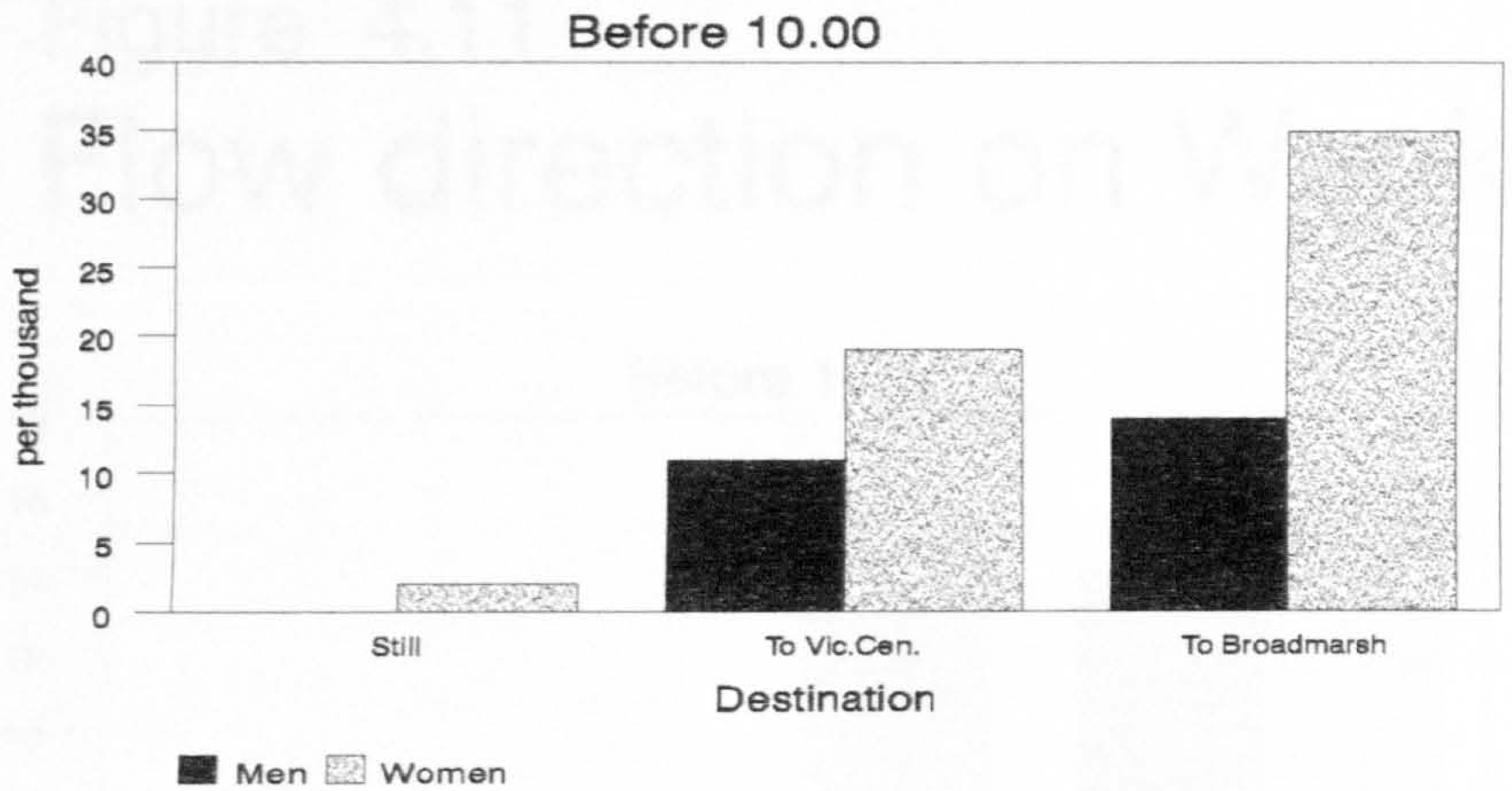
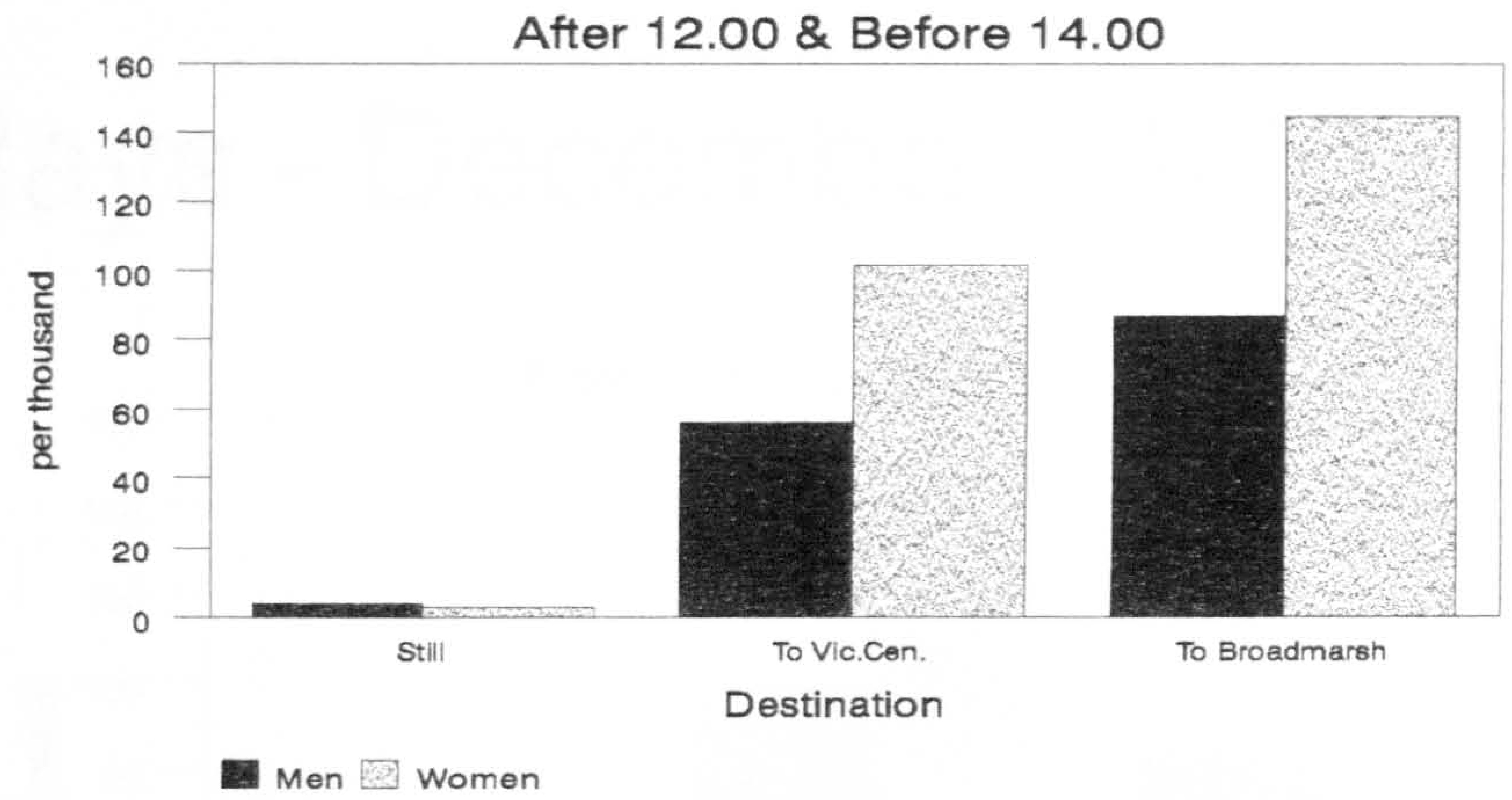


Figure 4.10

Flow Direction on Weekdays - September 1990





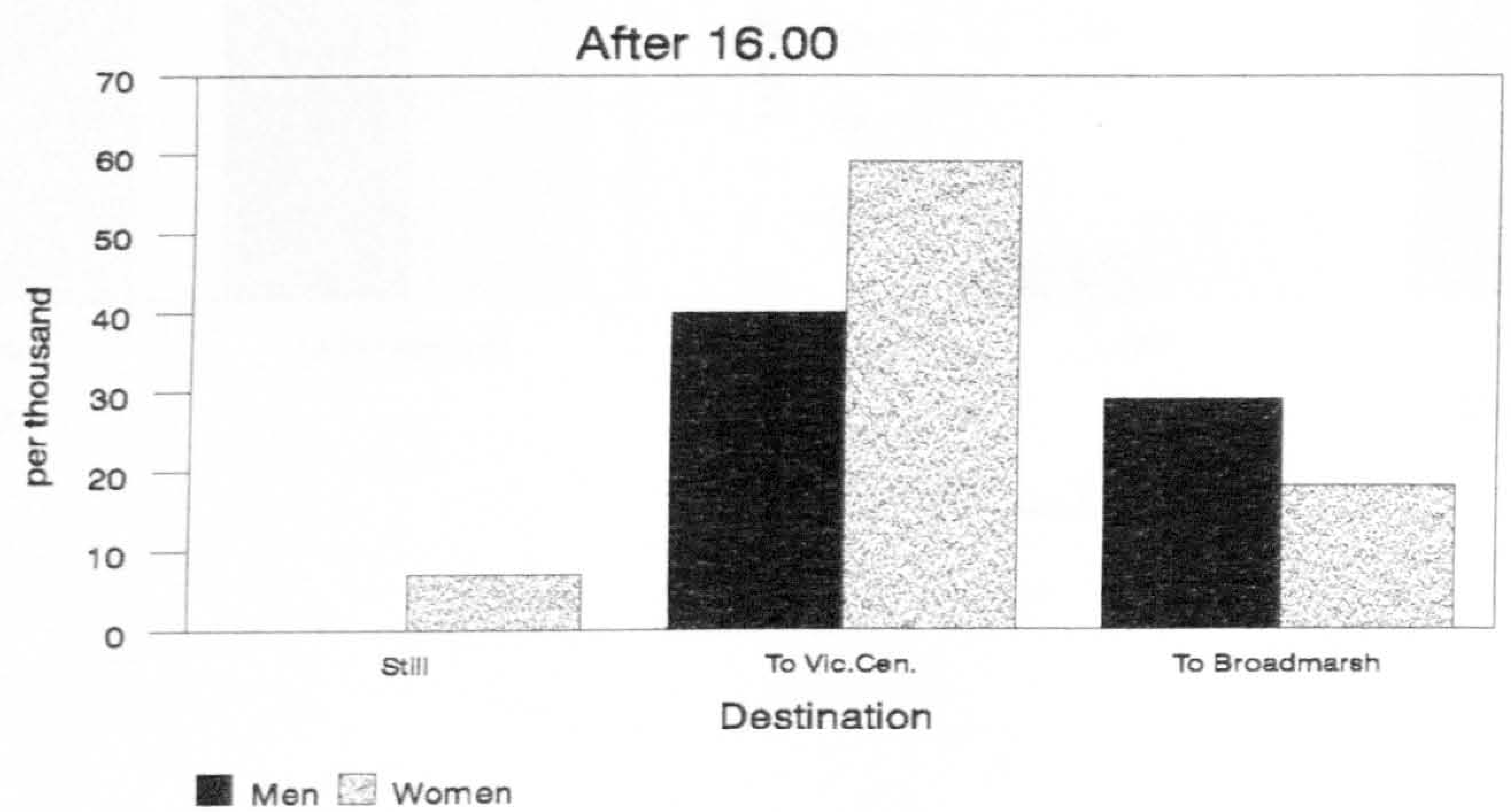
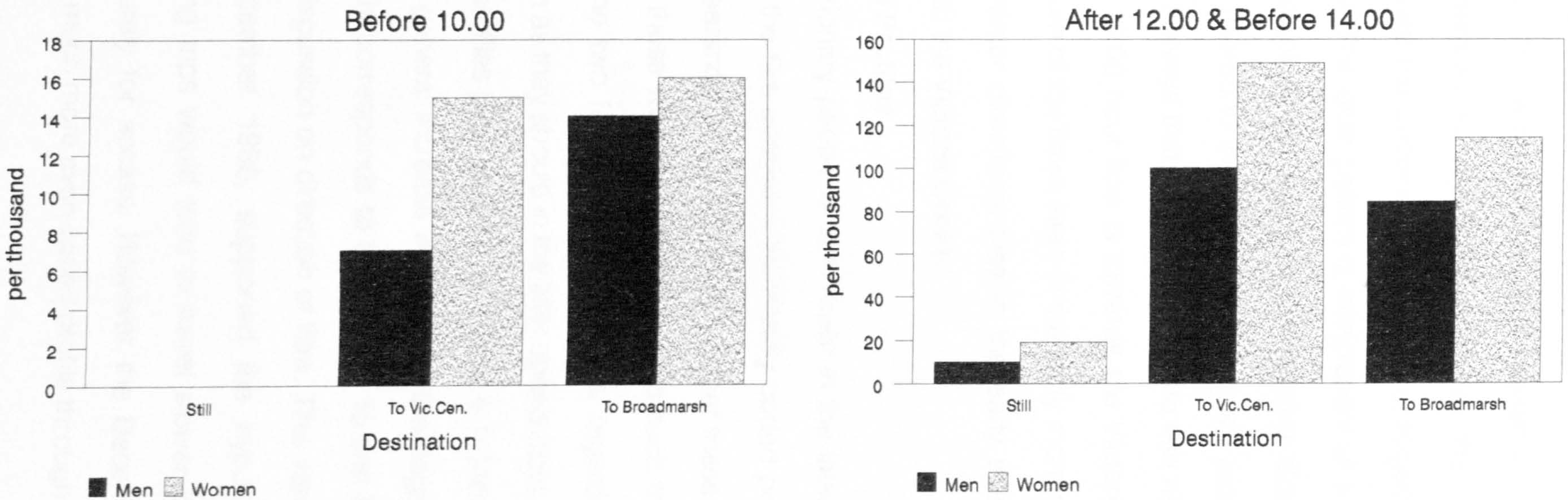


Figure 4.11

Flow direction on Weekdays - December 1990



The Lunchtime patterns present a more confusing picture. The first survey showed no flow bias and a relatively high proportion of stationary pedestrians. The later two surveys presented opposing patterns. The September survey flows continue the morning's Broadmarsh bias whilst the December 1990 have changed to give a Victoria Centre bias. The latter pattern is reminiscent of a Saturday pattern that often displays net flows to the Victoria Centre. This switch may well be related to the variations in the age profiles seen earlier. For the two surveys that provided adequate late night cover the dominant post 16.00 hour flow is towards the Victoria Centre. This reflects the return of the flows seen in the early morning period. Females have a greater directional bias in the early evening with about 70% flowing to the Victoria Centre.

Variation in Speed Profiles

The number of stationary people is also lower in the later two surveys. A number of the film analysers incorrectly coded people who made a single appearance on the film meaning that these could not be separated from those who were stationary. As such the stationary numbers for the two full surveys should be regarded with a degree of suspicion as they should in the later speed plots.

The speed profiles (figures 4.12, 4.13 and 4.14) for the three surveys showed a general increase in speed at the beginning and end of the day. This corresponds to the journey to and from work mentioned in the discussion on direction of flow. This variation, first discovered in December 1986, supported the hypothesis that people on shopping trips would tend to travel slower than those using the route purely for access. However the December 1990 survey displayed a much more even speed profile through the day.

Figure 4.12
Male & Female Weekday Speeds - December 1986

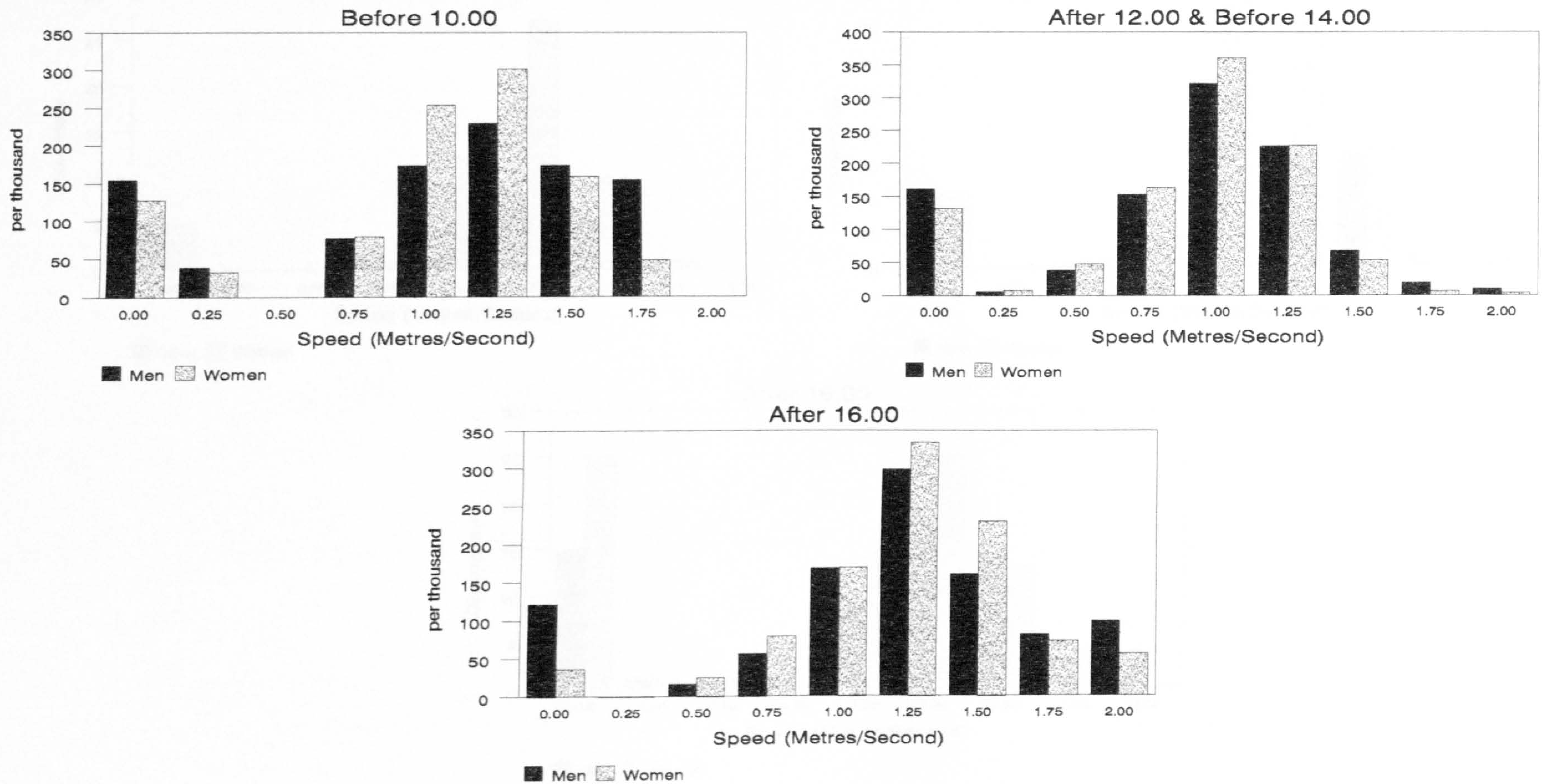


Figure 4.13

Male and Female Weekday Speeds - September 1990

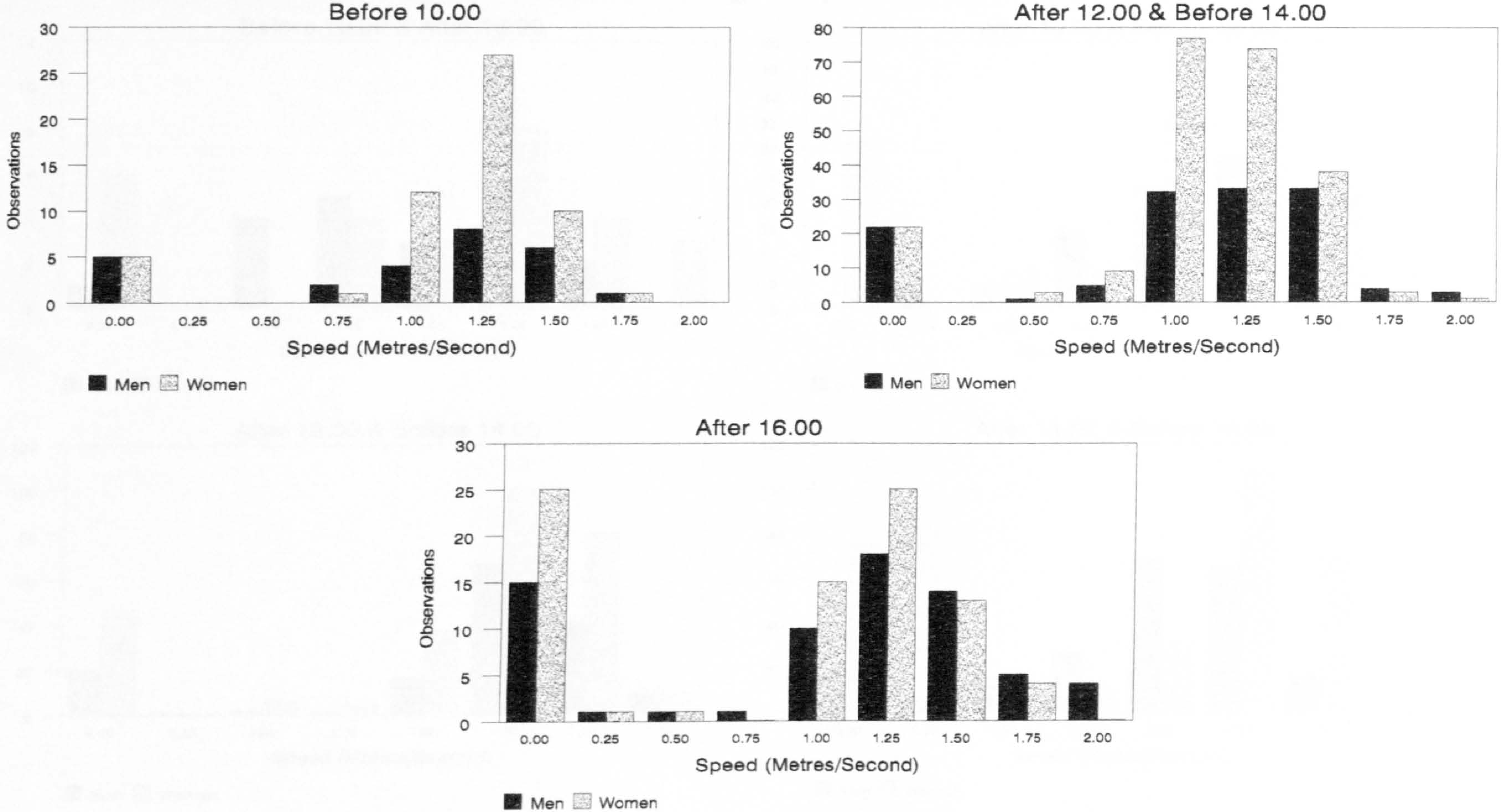


Figure 4.14

Male and Female Weekday Speeds - December 1990

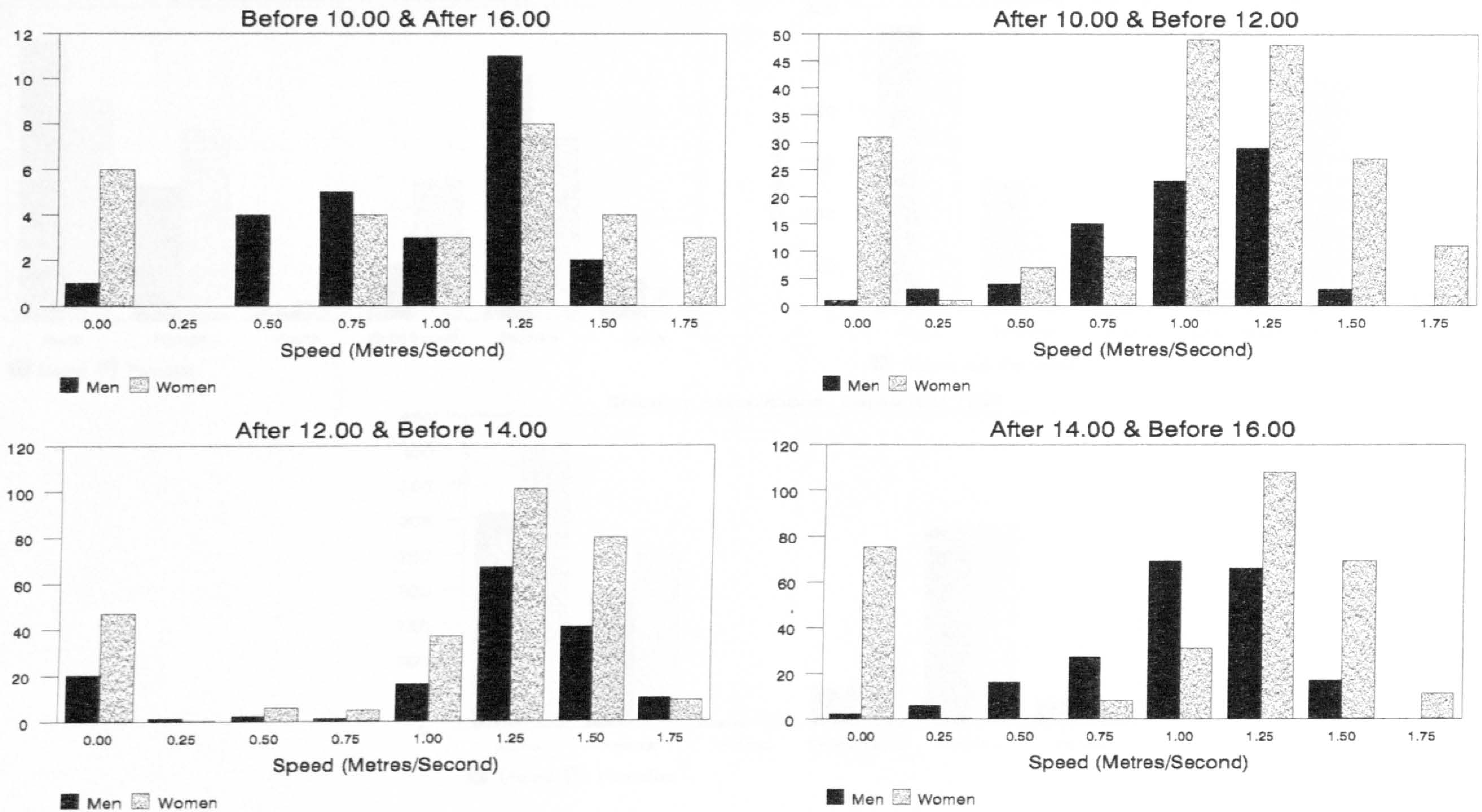
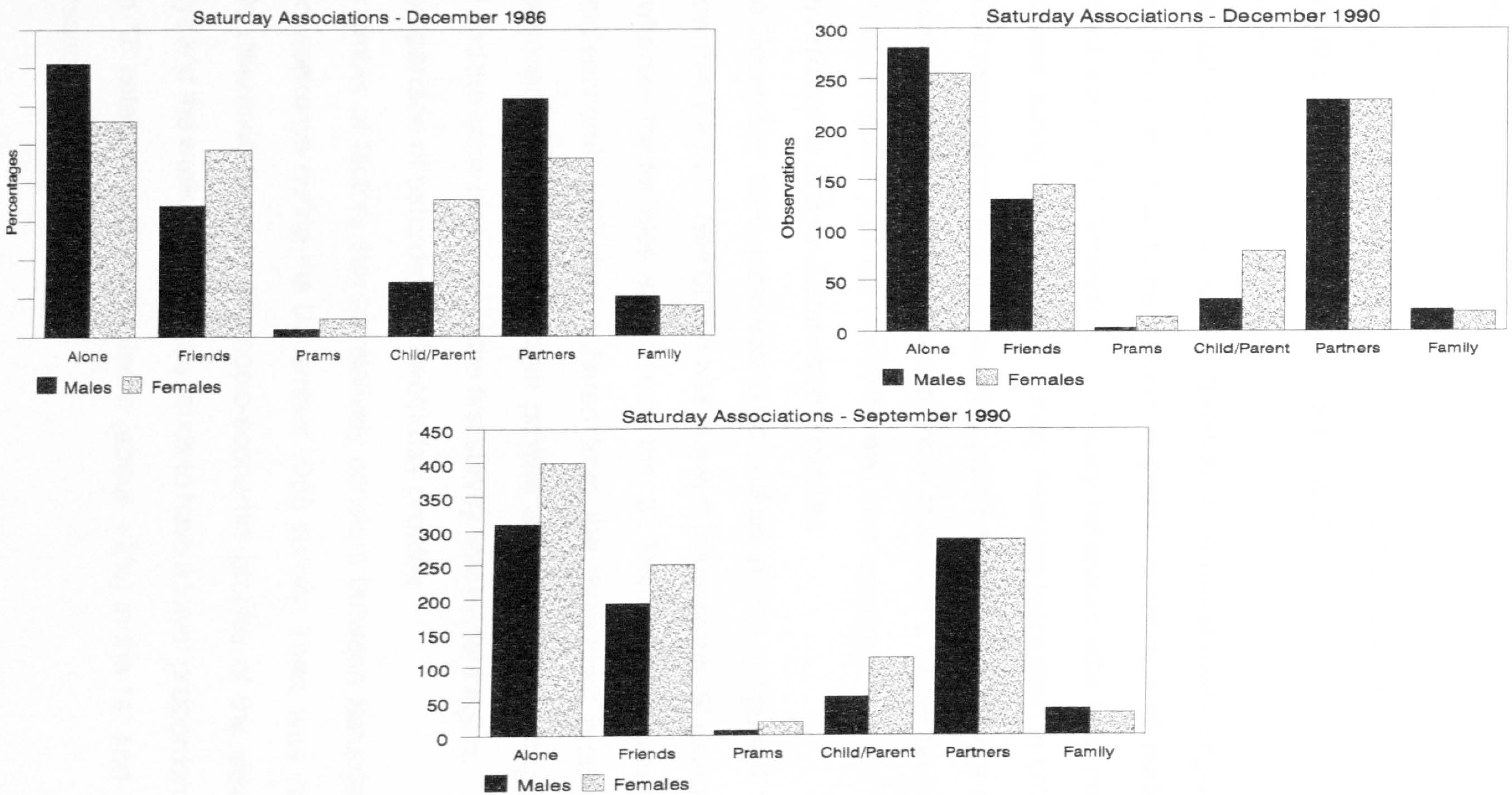


Figure 4.15

Male and Female Associations on Saturdays



The faster speeds did not decline to the extent seen in the other two surveys but there was an increased proportion of slower midday traffic. The faster profile may have been caused by the inclement weather mentioned earlier reducing the time available to shop. There was very little difference in average speeds for the two sexes.

Male and female pedestrians on saturdays

Variations in Associations

The association profiles for the three surveys are shown in figure 4.15. Throughout all three surveys a greater proportion of males walked alone than females. This solitary behaviour was less pronounced during the September survey. Females were seen in child parent associations and also pushing prams approximately twice as frequently as males. Males pedestrians in town had a higher probability of being with partners (male/female) than females.

Variations in Socio-Economic Profiles

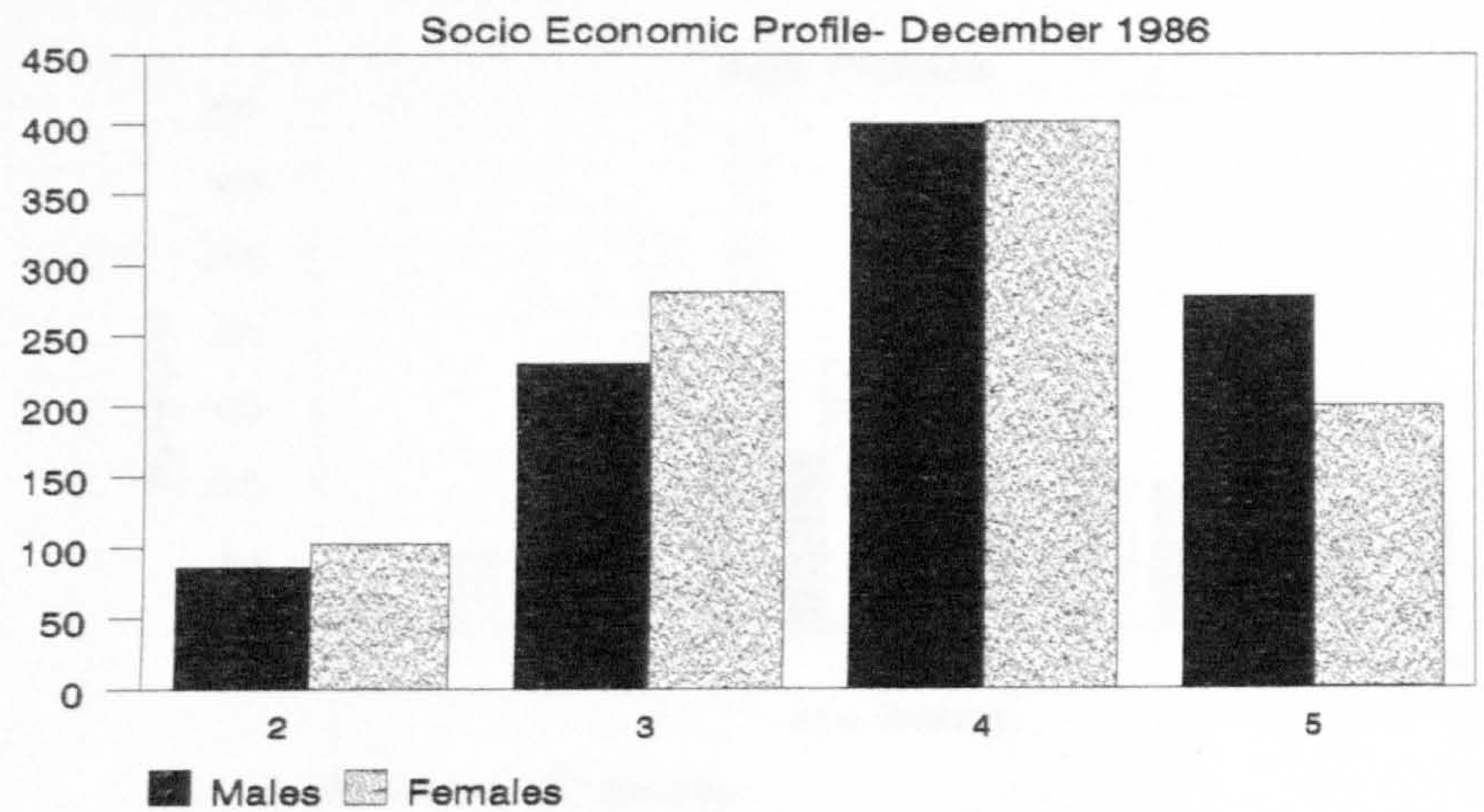
The December 1986 socio-economic profiles shown in figure 4.16 show that the male distribution was skewed towards the "5" category whereas the females was towards the "3". The two later surveys' socio-economic indicators suffered from the "bunching" problem mentioned earlier. However both profiles are centred on category "4" and the same bias seen in the first survey was evident again.

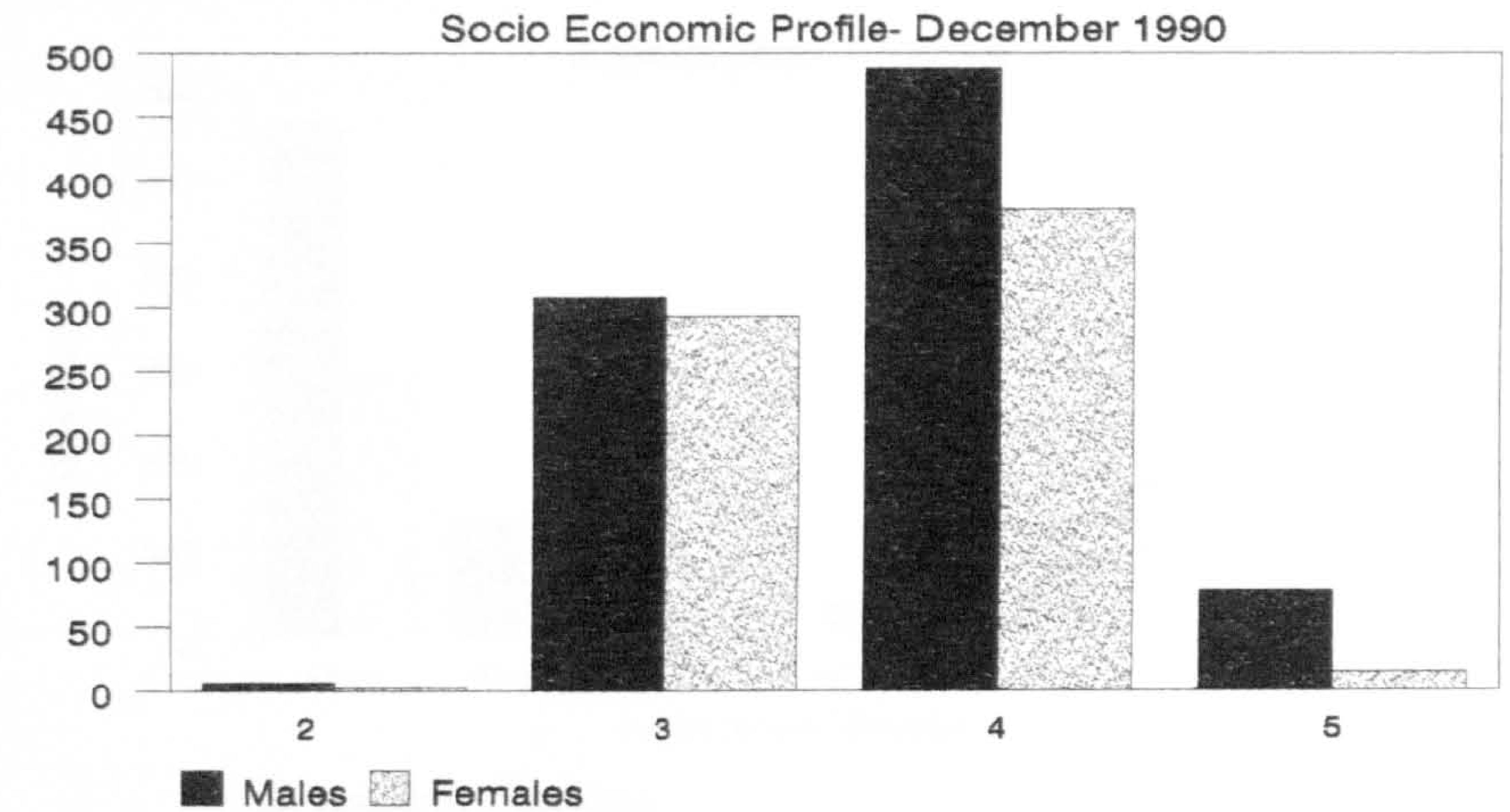
Comparison of saturday and weekday profiles

A number of factors stayed relatively constant between Saturdays and weekdays during the December 1986 survey. There was very little difference between the socio-economic profiles of the weekdays and the weekend. Saturday tends to have a lower proportion of the "3" category and slightly more (about +2%) in the "4" and "5" classes.

Figure 4.16

Male and Female Socio-Economic Groups on Saturdays





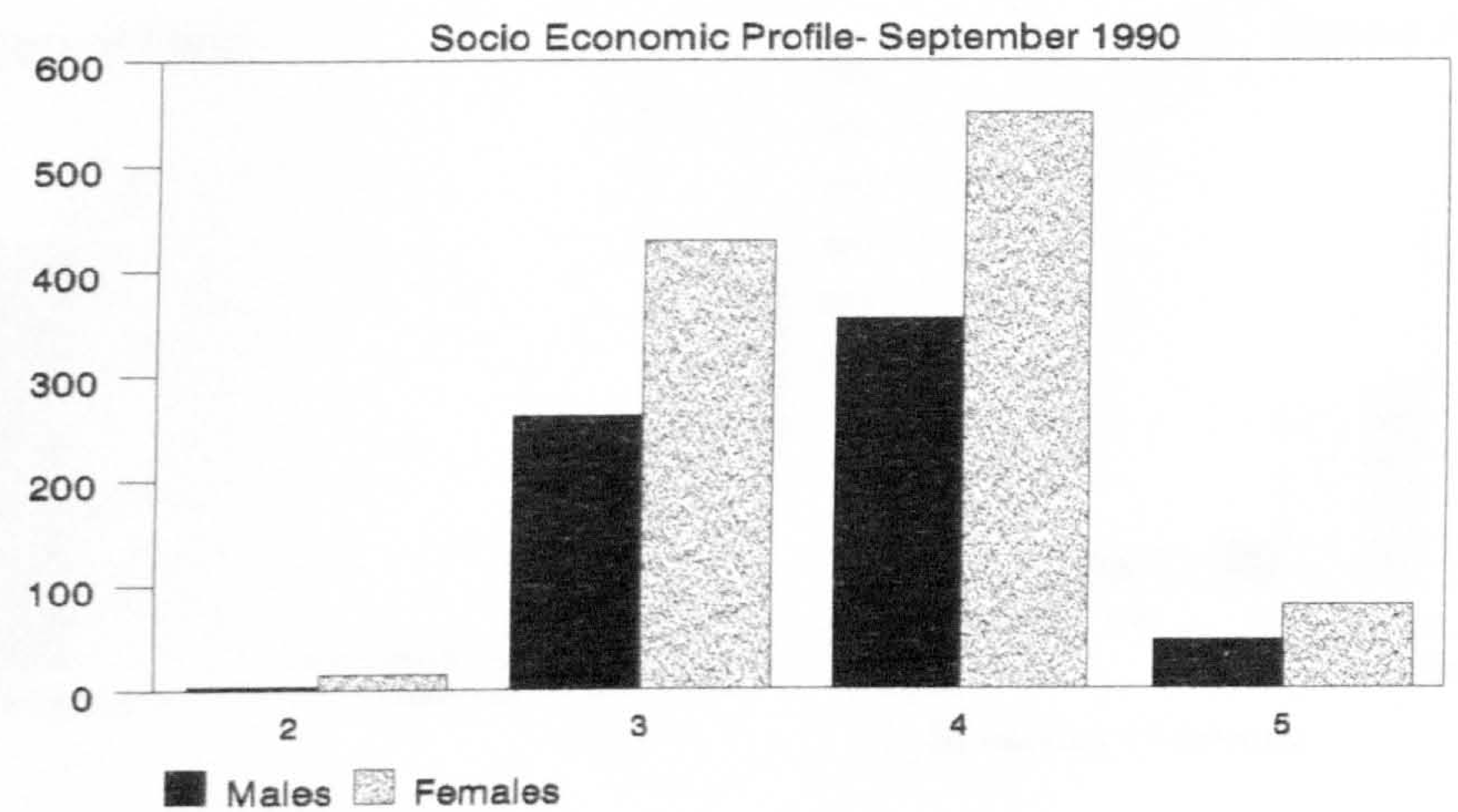


Figure 4.17

Weekday/Saturday Comparison - December 1990

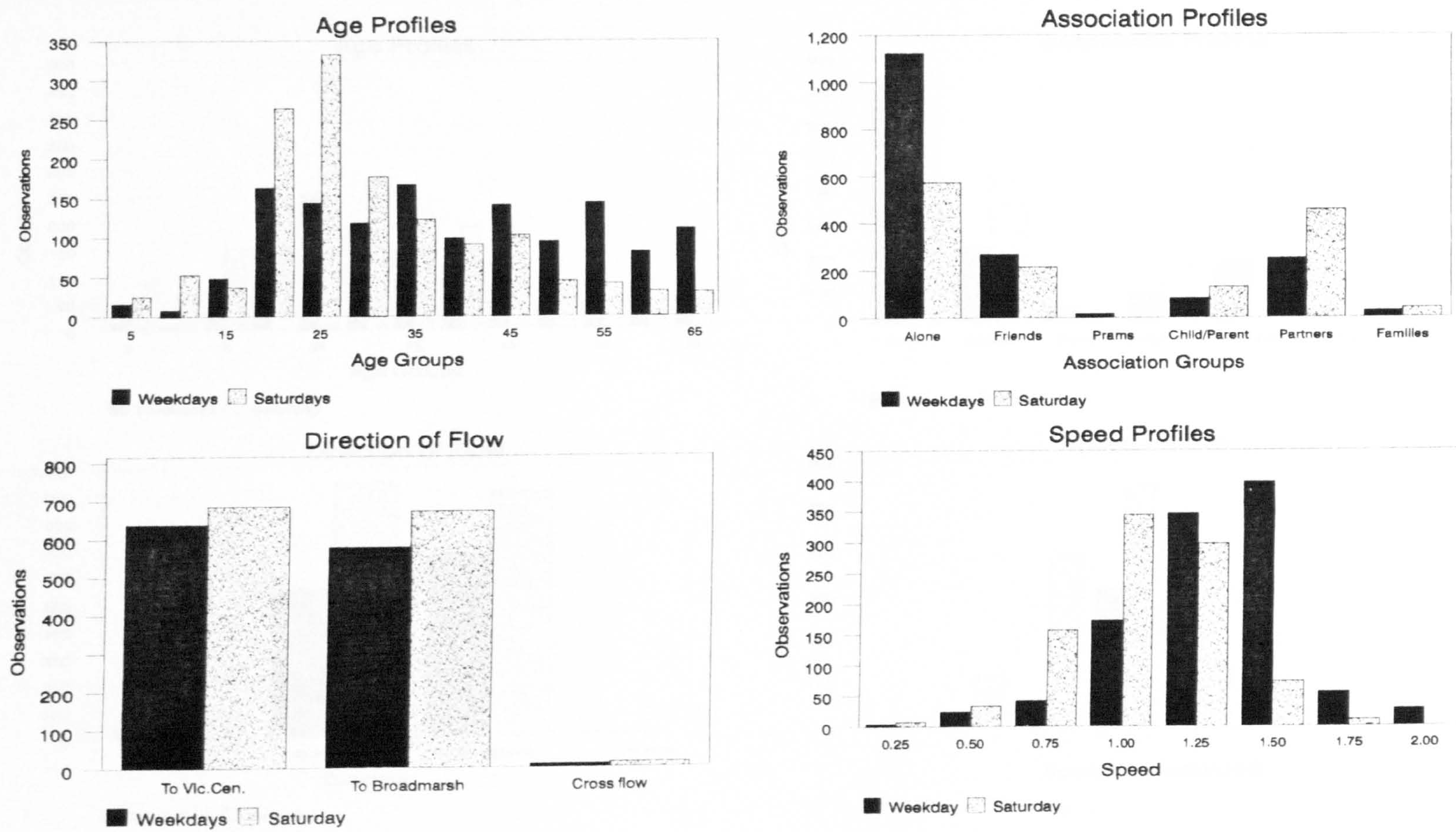


Figure 4.18

Weekday/Saturday Comparisons September 1990

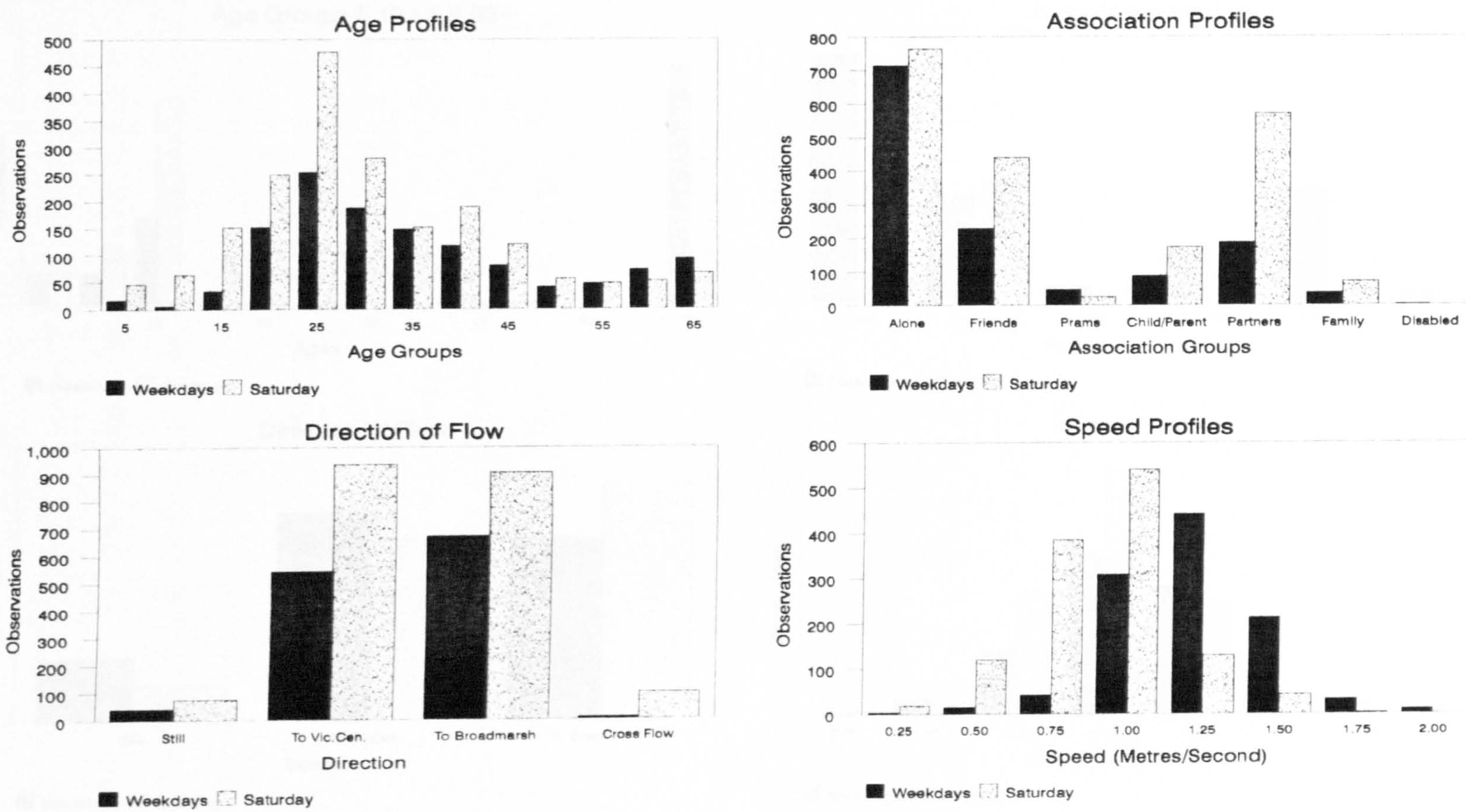
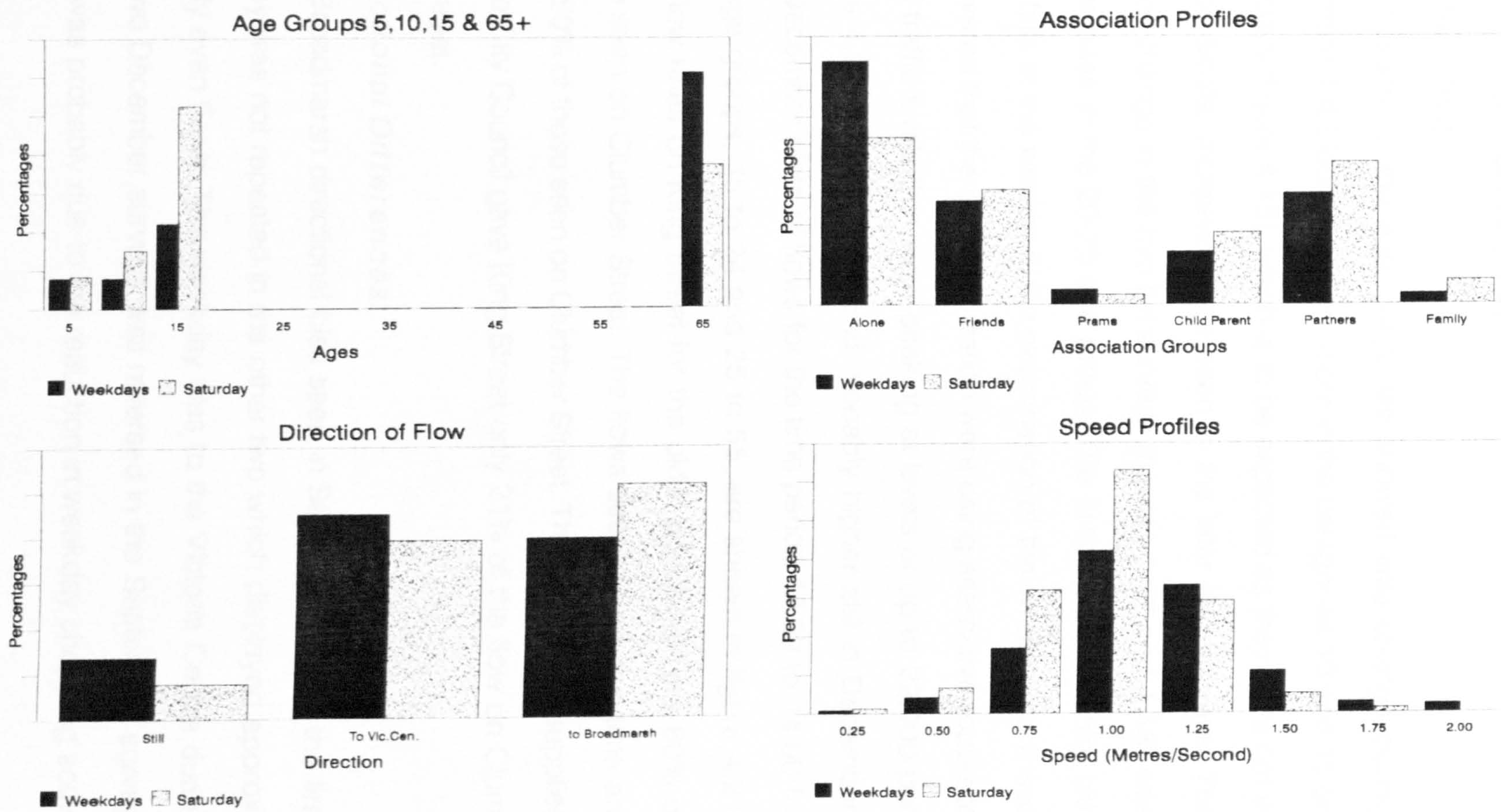


Figure 4.19

Weekday/Saturday Comparison - December 1986



The female/male ratio remained at about 60:40 throughout the week and Saturday. Figures 4.17, 4.18 and 4.19 show the factors that had the greatest variability.

Age Variation

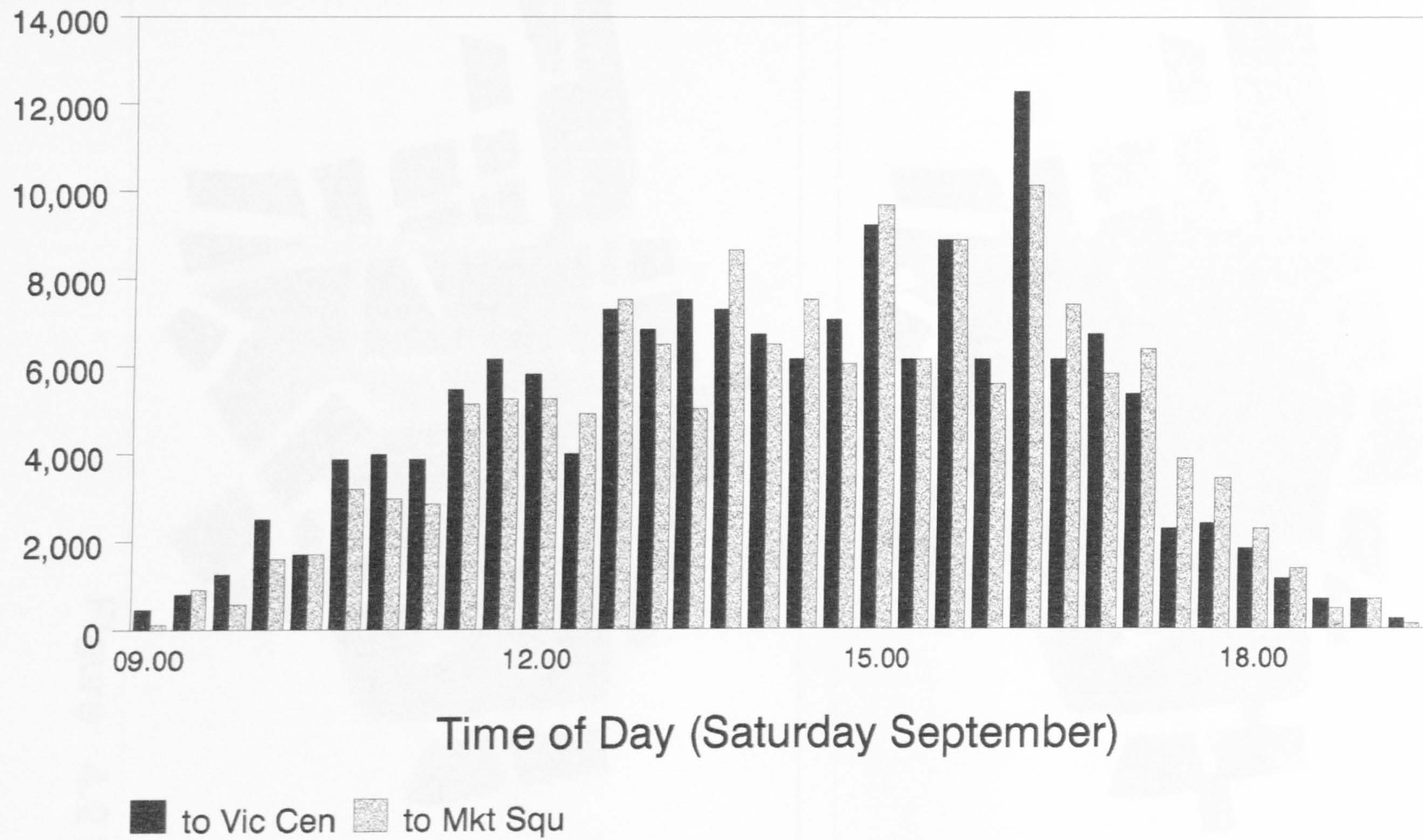
The majority of the age categories showed little change during December 1986 but there were more in the categories 10 and 15 on Saturdays (figure 4.19), which is to be expected as they were not at school. Similar increases were seen in the later two surveys. The biggest change in the two full surveys (figures 4.17 and 4.18) was the increase in the 20-25 age group. The proportion of senior citizens falls at the weekend. On examination of the whole area it was discovered that the older population were using alternative routes to avoid traffic levels that were peaking at levels of up to 22,000 pph (figure 4.20) in September and probably higher still in December. The December plots of flows for the time period 12.00 to 14.00 for two age groups, 15 to 24 and 25 to 55, are shown in figure 4.21. The flow rates on King Street for the older population are 60% of those seen on Clumber Street. The flows seen during this time are over 50% of those seen on Clumber Street. The count data supplied by the City Council gave King Street only 21% of the flow on Clumber Street.

Directional Differences

The Broadmarsh directional bias seen in Saturday flows in the first survey was not repeated in the other two which displayed approximately even flows. The weekday bias to the Victoria Centre during the two December surveys was reversed in the September survey. This was probably due to the reduction in weekday shopping activity.

Figure 4.20

Clumber Street North Tidal Flows



FLOWS BETWEEN 12:00 & 14:00 -SATURDAY 1990 (December)

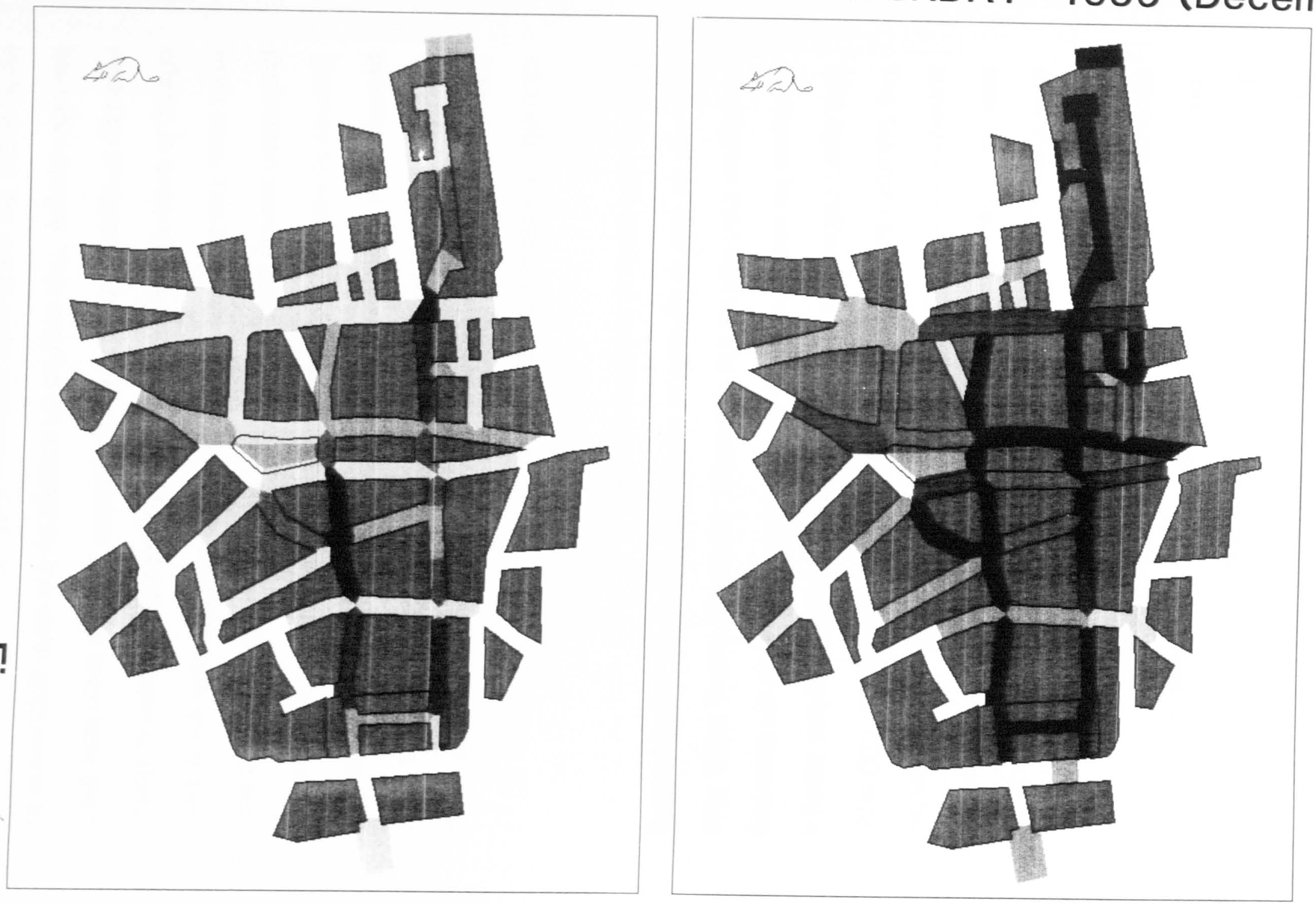


Figure 4.21

Association Variation

All the plots show a general increase in sociability on Saturday. All Saturdays witnessed an increase in the proportion of partnership groups and that of accompanied pedestrian children in town. The proportion of prams seen in street fell on Saturdays, presumably because of the perceived effort of manoeuvring them.

Speed Variation

In all three surveys weekday pedestrians travelled faster than those seen on a Saturday. The weekday speed distributions of the later surveys were centred on the higher velocities (1.25 and 1.50 m/s). The Saturday speed distributions were all centred around 1.00 m/s. This again indicates support for the hypothesis about speed being a surrogate for shopping traffic. The velocity distribution on Saturday was tighter than that for the weekdays, especially during 1986. This may well be due to barriers to movement restricting a pedestrian's ability to walk at his or her desired rate.

CLUMBER STREET SUMMARY

The Saturday and weekday flow patterns reflected the differing functions of Clumber Street. During weekday mornings and evenings the street serves primarily as an access route for the "journey to work". During the middle of the day the full spectrum of pedestrian activity can be seen, with pedestrians on shopping and work trips. The lunchtime period is the busiest as people leave their offices in order to eat and socialise. The Saturday pattern is dominated by shoppers. The younger population arrive in town later than the older people. This may be an attempt by the older population to try to avoid the peak early afternoon rush. The weekend average speeds are lower than the weekday suggesting a decrease in time pressure and/or an increase in congestion.

CONCLUSIONS

Overall the time lapse data collection system worked well. During the full scale surveys there were a few problems with a particular make of camera but the causes have been identified and hopefully remedied. The film performed in low light conditions and it was possible to extract data into the winter evenings. The data gathering system was able to provide both the quantity and range of data required. Faith in the data comes from the fact that the sample interval does not seem to affect total predicted volumes (chapter 5) and the sheer size of the data sets with in excess of 220,000 pedestrians observed.

The failure to produce reasonable estimates of socio-economic groupings was disappointing. However there were a number of individuals for whom this type of assessment presented no dilemmas. The problem arose because of the judgmental aspect of the measure and the feeling that the analyser was being critical of the subject. This would seem to be a problem caused by poor training and supervision. The predictive validity of the assessments will be discussed in relation to the development of the turnover interface in chapter 6.

If there is no specific area of interest the scope and volume of the database generated during a full town survey can be quite daunting. Some interesting patterns have been noted but there are undoubtedly many more. What the examples have demonstrated is the complexity and variability of the pedestrian environment. This supports the view put forward earlier that it is essential to survey the whole centre simultaneously and over as long a time period as possible. Whilst the time lapse technique employed has a number of drawbacks the system did provide the required data and the costs were low.

CHAPTER 5

CROSSING THE THRESHOLD - PEDESTRIAN RESPONSE TO A STORE

Introduction

This chapter reports on a continuous video survey of pedestrian behaviour in the immediate vicinity of the store. In order to monitor pedestrian reactions to the store two video cameras were used to survey the street behaviour and subsequent store patronage. The six pedestrian structure variables used in the time-lapse street surveys and a number of supplementary variables were recorded from the films and a database of both customers and non-customers was constructed. Pedestrians displaying various categories of store response were analysed according to the demographic and behavioural data noted. The results confirm many of the assumptions made earlier about the relative importance of the variables and justify their inclusion in the survey work. Chapter 6 will use the data gathered here to attempt to investigate the feasibility of predicting turnover from pedestrian flows.

In chapter 1 the processes of pedestrian/store interaction were discussed in detail. The function of this section of the project was to see if the variables collected during a time-lapse survey were related to differing levels of store response. Because of the time and financial limitations of the survey, only one Thorntons' store was examined and only for one day, no definitive rules could be established but it was thought that the study would provide endorsement of the data choices made in chapters 1 and 2.

DATA COLLECTION TECHNIQUES

During the discussions on the small shop and its dependence on the pedestrian flow passing its doors it was hypothesised that six pedestrian structure variables would largely control turnover. In order to examine a store's ability to attract customers, termed its penetration rate, in relation to the hypothesised turnover determinants it was deemed necessary to use continuous data collection techniques. The use of a time-lapse system was ruled out for two reasons. Firstly there was the need to compare the shopping and non-shopping populations in order to determine whether the former came from distinct sub-sections of the population. The temporal uncertainty of a pedestrian entering the store rendered it impossible to ascertain a customer's past and future pedestrian behaviour. Secondly there was a desire to examine the extent of certain aspects of the pedestrian/store interaction, namely the time spent at the store's window, the capacity of the window to stop pedestrians and the number of people who actually noticed that the shop existed. Therefore it was desirable to construct a complete flow history of the vicinity of the shop. For the same reasons given in the discussion on data capture techniques in chapter 2 a permanent photographic record was required. Although there has been previous criticism of video data capture this type of media offered the only feasible method of extracting the necessary detailed level of data.

The technique employed for this section of the project involved two video cameras, one with an outside view of the shop window and the street around the display and the other covering the trading area of the shop. Both cameras were fitted with wide angle attachments and were of the Sony video 8 format. The first camera returned a street coverage of about 50 sq metres. Figure 5.1 shows the recorded area in context of the whole of the pedestrianised street. Also shown is the superior areal coverage of the still camera that was used the previous December. Although the study was undertaken in early June there were no problems with foliage causing obstruction to the cameras view. Both video cameras had a continuous running time of three hours and gave a view of all the customers who entered the store and many that passed.

The data was collected from the same section of Nottingham as used in the December 1986 survey, namely the top half of Clumber Street. This repetition was deemed desirable as it would allow comparisons between this work and that of the previous December. Also the effects of still frame sampling and seasonal variations could examined. A brief study of the possible effects of sampling during the flow calibration exercise was given in chapter 4. The wave effects noted could have a significant impact on a pedestrian's inclination to stop and spend. If the flow rate was low but packed into short high density flows the crowding concerns may become paramount. During the day of the survey the pedestrian density was generally low.

The drawback of such concentration on physical measurement is the ignorance that remains about the perceptions and motives that hold people back from purchasing. There is no account of customer psychology. McGoldrick (1990) states that direct observation is a useful supplement but cannot itself distinguish between planned and impulse purchases. However this approach was necessary because of the need to tie into the WONKA system to develop the turnover interface.

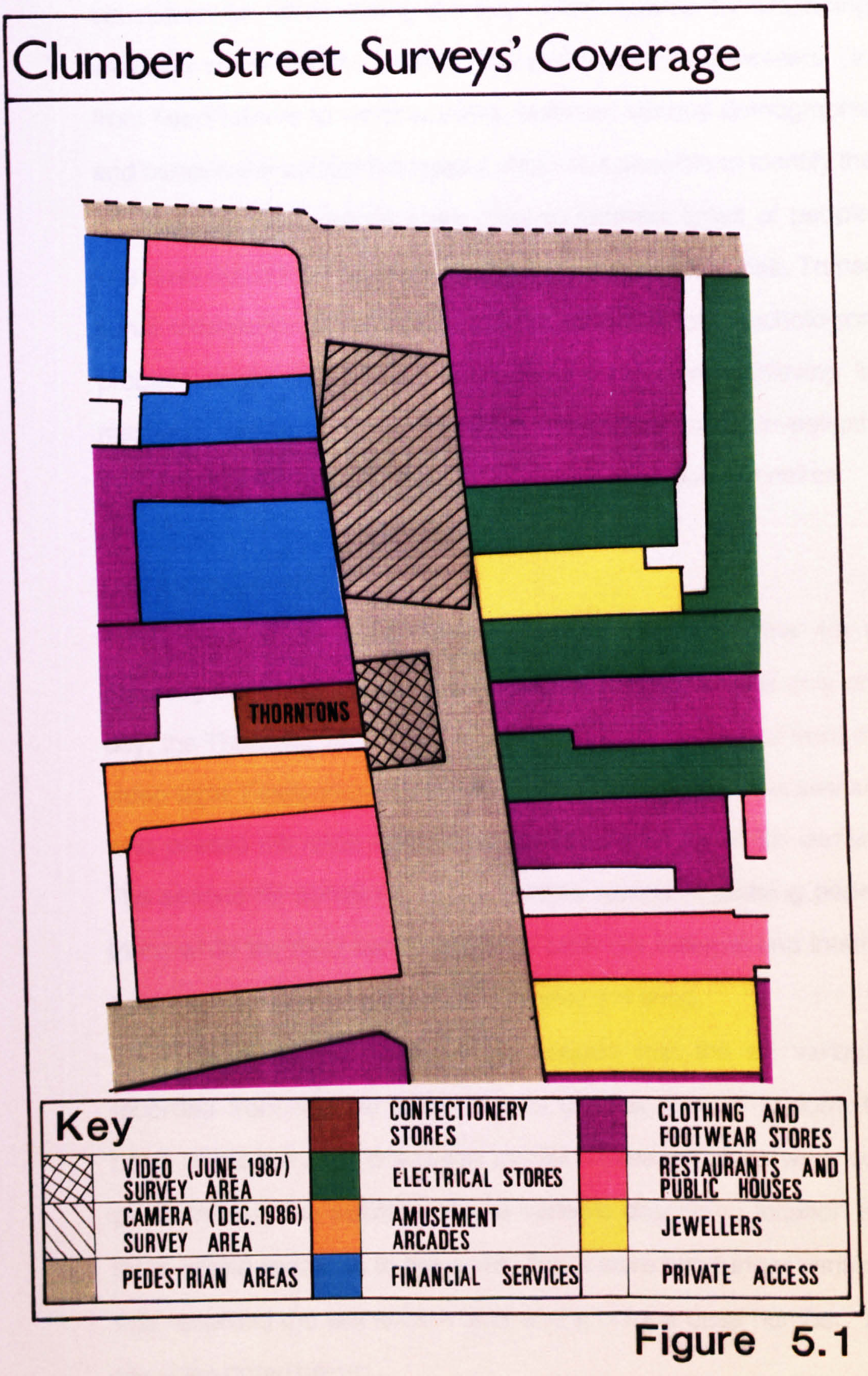

Clumber Street Surveys' Coverage
THORNTONS
Key
VIDEO (JUNE 1987) SURVEY AREA
CAMERA (DEC. 1986) SURVEY AREA
PEDESTRIAN AREAS
CONFECTIONERY STORES
ELECTRICAL STORES
AMUSEMENT ARCADES
FINANCIAL SERVICES
CLOTHING AND FOOTWEAR STORES
RESTAURANTS AND PUBLIC HOUSES
JEWELLERS
PRIVATE ACCESS

Figure 5.1

The interface had to be based on variables obtainable from the transparencies taken during the town wide survey. By examining variability in the rate of transition from pedestrians to customers, i.e. from head turners to window users, between various demographic and behavioural pedestrian types it should be possible to identify the importance of the various store cues to different types of people. The cues could then be fine tuned to their target audiences. Transitional information will facilitate the identification of psychological problem areas and barriers that prevent the store achieving its maximum potential. Once identified Thorntons could investigate these problems further using techniques such as questionnaires.

DATA COLLECTED

Three days of surveying were undertaken, Thursday the 4th to Saturday the 6th of June 1988. Owing to time constraints only one day, the Thursday, was analysed. Three files were created from the video tape. Firstly there was a continuous record of all pedestrians who passed the shop within the field of view of the video camera. The second file contained a 10% sample record of passing pedestrians while the third had a record of both the external and internal behaviour of all those people who entered the shop.

As mentioned earlier it was hoped that the six variables recorded from the transparencies in chapter 2 were to form the basis of the turnover prediction model. These variables were supplemented by the addition of one variable describing location and three noting reactions to the store. There were two further variables that recorded the last known time and a unique case number. The variables noted being:

1) Last recorded time
2) Case number
3) Age
4) Sex
5) Socioeconomic status
6) Direction
7) Speed
8) Social associations
9) Head turn towards shop
10) Distance from window at first sign of shop interest
11) Time spent looking at window
12) Shop entry

Variables one to eight are similar to those extracted from the transparencies in the previous study and therefore need no further explanation. The remaining four variables were specifically related to pedestrian interaction with the store and provide a vital link between pedestrian and customer. The third file had a further 12 variables that described interior behaviour and purchasing for use in a separate project.

Head Turn Towards Shop

This measure was taken as the first sign of interest in the store. The supposition being that if the interest generated by scanning eyes was great enough it would lead to a turning head. In Iyers' (1989) terminology this could be described as cue recognition. It was deemed futile to try to investigate eye scanning due to the logistical problems involved. If the interest level was not great enough to lead to head turning then it was deemed to be insignificant. Once a head had turned there is a greatly increased likelihood of the store lying in the 12^{o} arc of heightened perception (Fruin 1971). The non head turning population contained two types of people, those who saw but were not interested and those who did not even see the store.

Recognition of head turning was an easy task due to the positioning and quality of the video cameras. As the video tape gave a continuous record analysis of head turning movements was made less ambiguous as they could be seen in context of the pedestrian's path and the street. Thus head movements towards other stores were distinguishable.

There was one point of concern in that those people who were deemed to have made straight for the store without a head turning incident may well have turned their heads prior to coming into view of the camera. Unfortunately with the given budget there was nothing that could be done about this inadequacy.

The proportion of those showing an interest in the window will vary according to a number of presently unrecorded factors such as the visual appeal of the window. As mentioned earlier such effects could be removed by the use of stringent controls in further studies.

Distance from the Shop Window

Distance was recorded for two reasons. Firstly to test the assumption that there is slower moving traffic around the store front (Older 1968) and secondly because the further the pedestrian is away from the store the greater the effort required to deviate towards it. As Clumber street is pedestrianised, distance from the shop window should have less effect than in a more standard pavement / road / pavement layout. In the latter case crossing the road provides a more significant barrier than the distance alone.

Distance was recorded perpendicular to the store front. If the pedestrian turned his head or entered the store directly then the distance measurement represents the perpendicular distance from the store front at the first sign of interest.

Time at Shop Window

In order to assess the extent to which the window was used as a detailed information source the total time that a person spent at the window was recorded. Window usage forms an assessment of Green's (1986) second store front function, the presentation of the store's 'offer'. The window shopper is inspecting the presentation of the store's retail 'offer'. The window, with its display of products, prices and special offers, allows the uncertain pedestrian a low commitment opportunity to shop. If the pedestrian is impressed he will become a customer.

Only the time that a pedestrian was stationary and actually facing the window was noted. Unfortunately, deciding whether the customer was actually looking at the window or through it was not possible. One idea had been to place a third camera behind or microphone above the window so that customer/window interaction could be studied more closely. The use of an external microphone recording on this third tape would also have allowed the examination of responses to the window. Such a technique would yield valuable information on the perception of such factors as pricing and presentation.

Entry into Shop

This variable is in effect the last in the chain of events. The four stages from pedestrian, through head turner and window shopper, to customer have all been noted. Entry is the final measure in this study as it was felt that to focus on purchasing would be too connected with the internal situation. As stated earlier potential turnover is the goal and the third marker for this is store entry. Both store entry and window usage are more store dependent than head turning but the locational effects on turnover need recording (Nelson 1957). Store entry was confirmed by using the in-store camera and was recorded as a simple binary value.

ANALYSIS TIME

Data was gathered for 3171 pedestrians in total: 1937 people in a continuous record lasting from seventeen minutes past nine to eleven o'clock; and 1017 from the 10% sample starting at eleven and running to sixteen minutes past three. The third file containing the in-store data for all customers of that day held 217 people. The extraction of data for the first two files took 240 hours. In comparison the December 1986 photographic analysis took 130 hours with over twice the pedestrians noted. Although the number of variables extracted was greater in this instance it is felt that the conclusion made previously that video recording for a town wide pedestrian survey was not economic would seem, on the basis of this study, to be true.

THE EFFECT OF SAMPLING

The second data file was constructed using a 10% sample from the continuous video tape. The sample was obtained by analysing the first 10 units of tape from every 100. The units were read off the video recorders tape counter. 10 units per 100 gave a sample rate of approximately 25 seconds of film per 250 seconds. Any pedestrian that was on or came onto frame during that time was fully analysed. This is in line with the procedure used during the time-lapse survey of December 1986. The video's tape counter could be checked by cross referencing with the clock mounted in-store in the view of the second camera.

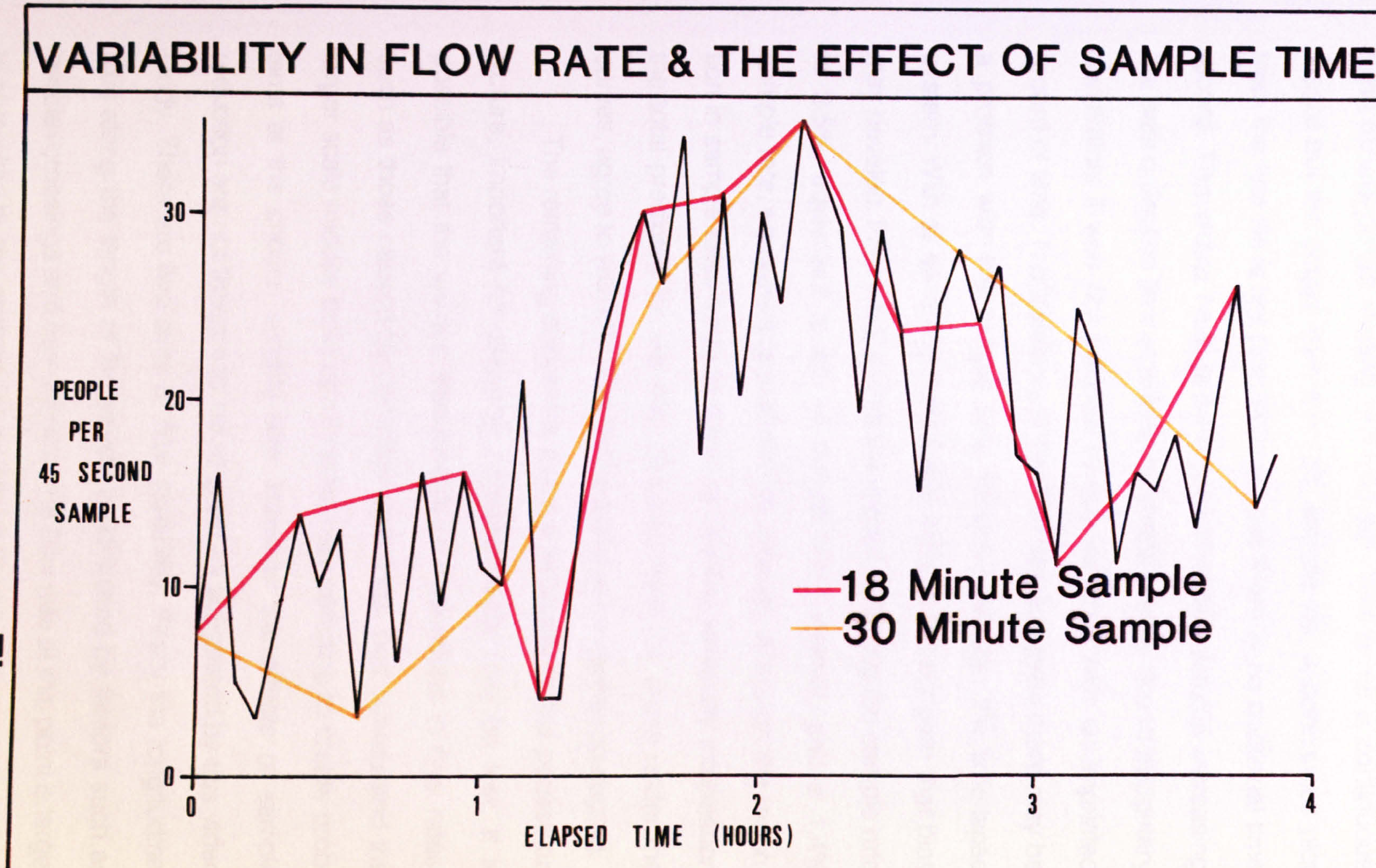

VARIABILITY IN FLOW RATE & THE EFFECT OF SAMPLE TIME
PEOPLE
PER
45 SECOND
SAMPLE
30
20
10
0
0
1
2
3
4
ELAPSED TIME (HOURS)
18 Minute Sample
30 Minute Sample

Figure 5.2

Variability in Flow Rate

Figure 5.2 shows how the flow rate varied over a two hundred and thirty minute period starting at 11.00 am. This is not a continuous record but the output from the 10% sample file. A continuous plot from the first file is not possible because there is no continual time record. This would have proved hard to obtain without increasing the data collection time significantly. Unfortunately due to budgetary constraints it was not possible to buy cameras with an imprinted record of time. The instability of the flow rate suggests there may be a problem with the sample time obtained through the time-lapse system. With all sampling techniques there is the concern that bias may develop. Figure 5.2 shows the impact of cutting the sample rate to 2.5%, equivalent to an 18 minute firing interval, and a 1.4% sample rate, equivalent to a 30 minute interval. Although the reduction in sample rates leads to a loss of detailed variability information the total predicted for the day, obtained from the areas under the curves, agree to with 4%. This would seem to be very encouraging.

The remaining concern is that the variability of the pedestrian picture, important for planning considerations, may be lost. It is possible that the various frequencies of fluctuations in flow rates, such as those caused by controller crossings, bus arrivals and the larger scale midday build up of traffic, may combine to create problems at the chosen sample rate. However the effects of sample reduction are not thought to be as great as suggested by this video study. There are two axes of flow variability. Firstly the longitudinal axis along the length of the street, is controlled by factors such as pelican crossings and bus arrivals. The flow rate at this point is largely controlled by the crossing at the top of Clumber Street.

Flow Density Variations

Figure 5.3

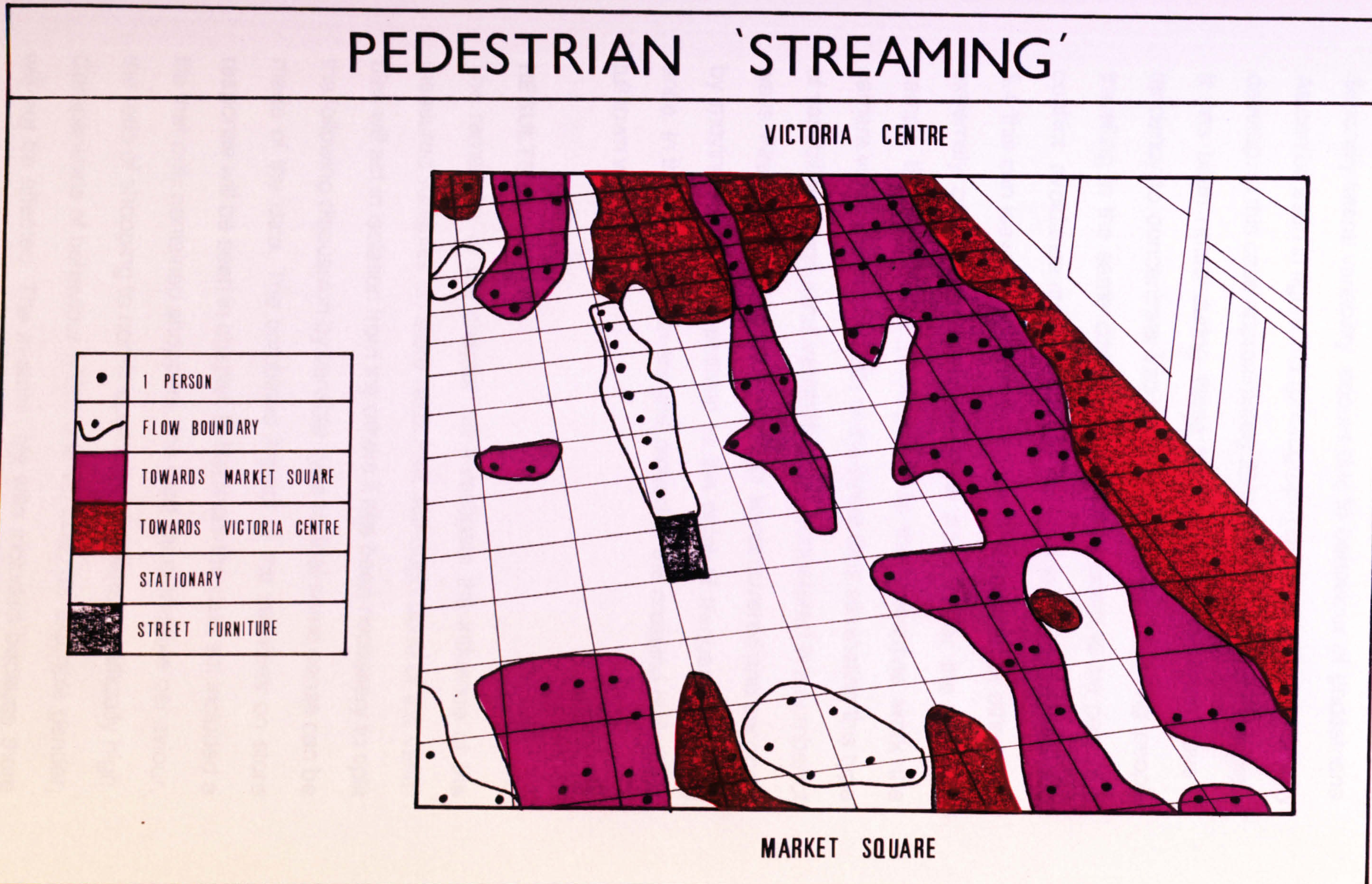

PEDESTRIAN 'STREAMING'
VICTORIA CENTRE
MARKET SQUARE
1 PERSON
FLOW BOUNDARY
TOWARDS MARKET SQUARE
TOWARDS VICTORIA CENTRE
STATIONARY
STREET FURNITURE

Figure 5.4

Secondly lateral variability occurs due to behaviour of pedestrians. As can be seen in figure 5.3 (photograph) great variations in density develop. In this case approximately 25% of the street is unoccupied. It has been noted during these surveys that pedestrian have a tendency to concentrate into a flowing body by following people travelling in the same direction. This would seem to be part of a conflict avoidance strategy. As can be seen in the figures 5.3 and 5.4 this can leave large areas of the street empty whilst others are extremely crowded. It would be quite possible for the video to sample the hole in the photograph. In the time-lapse work the camera views the whole width of the street thus eliminating this type of variability. Longitudinal variability can be countered in a number of ways. Firstly by increasing the length of street covered and secondly by moving the camera position to the point of frequency disturbance. In this case the camera was moved to the crossing during the full town wide survey.

RESULTS

The remainder of the chapter will investigate the influence of the measured variables on store response. Although none of the variables will act in isolation from the others it has been necessary to split the following discussion by variable type so that some sense can be made of the data. The combined impact of the variables on store response will be seen in chapter 6. Because the data set included a file that only contained shoppers, the third file of in-store behaviour, the ratio of shopping to non-shopping pedestrians is artificially high. Comparisons of behaviour within one variable, for example gender, will not be affected. The in-store file was included because there were so few shoppers in the early morning period and it provided a valuable source of information.

The Measured Variables and Store Response

The customer profile of the company generally matches that noted during the survey. Thorntons' customer profile is more feminine and has a better social profile than the majority of the confectionery market. There were interesting changes in the way certain groups responded to the store and used its features for shopping. The hypothesis that store success in capturing customers is determined by a number of personal attributes acting in conjunction seems to be supported. This variability will be examined in the context of the accepted company profile, the functionality of the store and the hypotheses of variable importance. In this section the impact of each variable on store response will be examined individually.

SOCIAL/DEMOGRAPHIC EFFECTS ON STORE RESPONSE

The Role of Gender

The variability of gender interest in the store largely reflects the customer profile of the company (table 5.1). Within the company as a whole females account for 80% of all customers. This gender ratio was closely matched in this study as 80.5% of customers were female.

Table 5.1: Proportion of Sexes and Response to Store

5.1.a: Entering Store		5.1.b: Turning Heads	
Female	80.5%	Female	74.4%
Male	19.5%	Male	25.6%

However the relative proportions using the window show a significant variation from the expected values. The male proportion of head turners is 25.6%. Thus the fall off between male store interest and custom is far greater than that for females. This is probably due either to the feminine nature of confectionery and appeal of the store or the non shopping nature of trip. If the former is the case the company may seek ways to improve the secondary attraction of males to the store.

Table 5.2 Male/Female Variation in Store Interest

	FEMALE	MALE
Head Turners	27.3%	12.4%
Window Users	12.2%	5.2%
Customers	11.6%	3.7%

(figures show percentage of each sex showing an interest)

There are two other points of interest involving the gender ratios. Firstly the ratio of those entering without use of the window. As noted earlier this translates roughly to preplanned shoppers. Here the male proportion has risen to 42.8%. This suggests that there is male shopping potential within the mid week period but that it is focused and largely planned.

The second notable point is given by the use of the window as a detailed information source. There is a slight increase in use of the window by males. This may be due to two factors. Firstly it was noted during the analysis that male partners would often wait outside while females entered. Often the decisions were made together outside but the male did not take part in the actual purchase. This may represent the same type of role playing often displayed in supermarkets (Davies and Bell 1991). Secondly males might use the window as an effective means of reducing shopping time and cutting down on in-store uncertainty.

Table 5.3: Proportion of Sexes and Response to Window

5.3a: Window Looks		5.3b: Blind Entry	
Female	78.9%	Female	57.1%
Male	21.5%	Male	42.8%

The role of Socio-Economic Group

The socio-economic profiles measured during this survey differ from those of the company and of the population in general. This is due to two factors. Inaccuracy of measurement is bound to occur owing to the nature of the assessment procedure. The implication is that the distribution becomes more concentrated with this type of analysis. However this was not the case in the Saturday profiles obtained by the same analyser during the December survey. This suggests the second reason that the profile of the available weekday pedestrian population was actually quite different to the U.K. average. The profiles recorded in June were quite similar to those found during weekdays in December. Such variability raises the possibility of alternating the window display with a weekday window and a Saturday window tailored to the expected traffic.

Table 5.4 shows the response of the various socio-economic categories to the store. Parts a) and b) of the table are interesting in that they show the affect of the company's image. The lower three groups all show a lower positive response to the store than the higher categories. A similar effect is seen in the detailed use of the window although here the decline in class 4 is less marked. The profile of the preplanned shoppers is very high with 28.6% coming from group 2. This may suggest either that they are more aware of their requirements, have a greater knowledge of the shopping area or are under greater perceived time pressure.

Table 5.4: Socio-economic Group and Response to Store

5.4.a: Head Turning Only

Class 1	0.19%
Class 2	7.08%
Class 3	49.91%
Class 4	36.31%
Class 5	6.33%
Class 6	0.19%

5.4.b: Head Turn & Entry

Class 1	0.00%
Class 2	11.63%
Class 3	65.12%
Class 4	20.93%
Class 5	2.33%
Class 6	0.00%

5.4.c: Examine Window Only

Class 1	0.00%
Class 2	10.53%
Class 3	56.84%
Class 4	31.58%
Class 5	1.05%
Class 6	0.00%

5.4.d Examine & Entry

Class 1	0.00%
Class 2	28.57%
Class 3	57.14%
Class 4	0.00%
Class 5	14.29%
Class 6	0.00%

The Role of Age

Table 5.5 a and b show how the company fares in the attraction of various age groups. Both the elderly and the young (21 to 25 years of age) show a low transition between the number seeing the store and then entering. This is may be due to the cost of the products on display. The failure to translate elderly interest into custom is disappointing because the survey was carried out on pension day. The window display has more success in attracting the middle age groups from 26 to 40.

The dominance of the elderly examining the window (table 5.5.c) arises for two reasons. As mentioned earlier elderly male husbands often waited outside and secondly the window provides the opportunity to avoid the high pressure decision making situation often encountered inside. On a weekday the store is often empty so that as soon as an individual enters there is a member of staff present asking the customer's requirements. Such pressure may deter the elderly who are often conscious of being less mentally agile than the rest of the population (Gelder et al 1989).

Table 5.5: Age and Response to Store

5.5.a: Head Turn, no Entry

16 to 20	9.30%
21 to 25	23.26%
26 to 30	4.65%
31 to 35	2.33%
36 to 40	4.65%
41 to 45	4.65%
46 to 50	2.33%
51 to 55	4.65%
56 to 60	6.98%
61 to 65	32.56%
over 65	4.65%

5.5.b: Head Turn & Entry

16 to 20	8.63%
21 to 25	14.29%
26 to 30	14.63%
31 to 35	12.30%
36 to 40	11.71%
41 to 45	7.74%
46 to 50	4.99%
51 to 55	2.79%
56 to 60	5.20%
61 to 65	12.18%
over 65	4.10%

5.5.c: Examining Window Display

16 to 20	4.21%
21 to 25	5.26%
26 to 30	6.32%
31 to 35	6.32%
36 to 40	5.26%
41 to 45	3.16%
46 to 50	6.32%
51 to 55	7.37%
56 to 60	10.53%
61 to 65	33.68%
over 65	9.47%

The Role of Social Associations

Association categories seem to have an important role in effecting store entry. Three distortions can be noted in tables 5.6.a and 5.6.b. Partner groups display a high degree of resilience to the store whereas child and friendship groups have a heightened response. Associations also appear to effect the shopping technique employed by the subject. The use of the window shown in Table 5.6.c shows the previously stated habit of partners to remain outside and the use of the display by child/parent groups. This may well be a strategy by the parent to reduce the demands of the child as the range in the window is invariably smaller than inside.

Table 5.6: Association Group and Response to Store

Table 5.6.a: Head Turn, no Entry

Alone	59.71%
With Friends	12.52%
With Prams	4.36%
With Children	7.44%
With Partners	15.97%

5.6.b: Head Turn & Entry

Alone	58.14%
With Friends	23.26%
With Prams	0.00%
With Children	11.63%
With Partners	2.33%

5.6.c: Examining Window Display

Alone	59.38%
With Friends	12.50%
With Prams	2.08%
With Children	13.54%
With Partners	12.50%

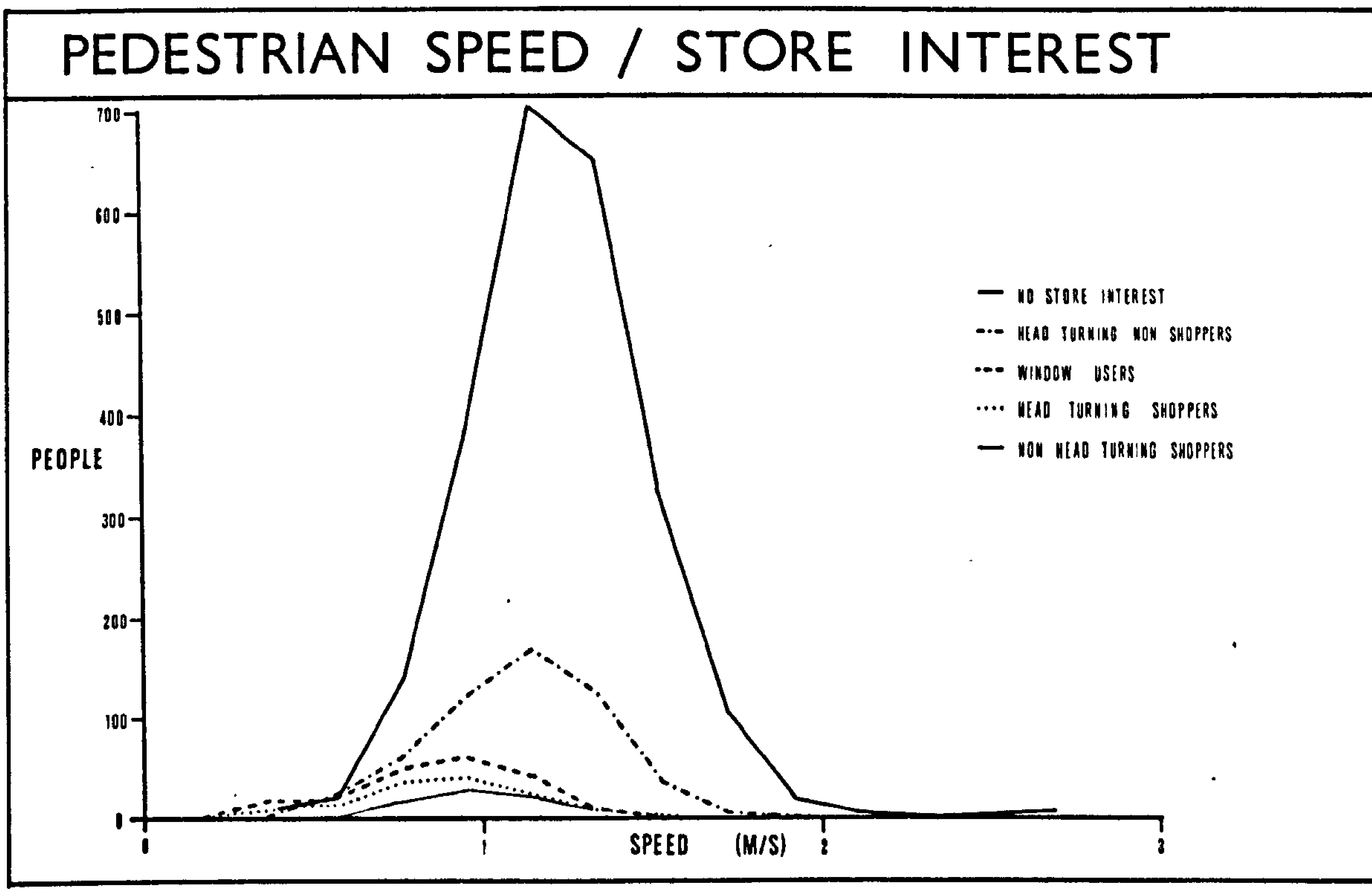
BEHAVIOUR VARIABLES AND STORE RESPONSE

The effect of Pedestrian Speed

Much play has been made of the theoretical importance of pedestrian speed on the propensity to stop and shop. Figure 5.5.A shows the velocity profiles for different categories of pedestrian. This shows that the groups with a high degree of store interest, the window users and shoppers, have markedly slower velocity profiles than the other two groups. This variation in the velocity of shopping and non-shopping population was suggested by the temporal variation in the December survey results. Thus the hypothesis that speed is an important indicator is valid. Whether speed will be of any predictive value will be discussed later.

The finer detail of the shopping population can be seen in figure 5.5.B. The mode value is consistent through the three groups. However the traditional theory that the window shopper travels generally slower than the rest of the population is borne out by the skewed nature of the curves. In chapter 1 note was made of two types of shoppers, window and list, based on the hypothesis that the

A:


PEDESTRIAN SPEED / STORE INTEREST
700
600
500
400
300
200
100
0
PEOPLE
0
1
2
3
SPEED (M/S)
NO STORE INTEREST
HEAD TURNING NON SHOPPERS
WINDOW USERS
HEAD TURNING SHOPPERS
NON HEAD TURNING SHOPPERS

B:

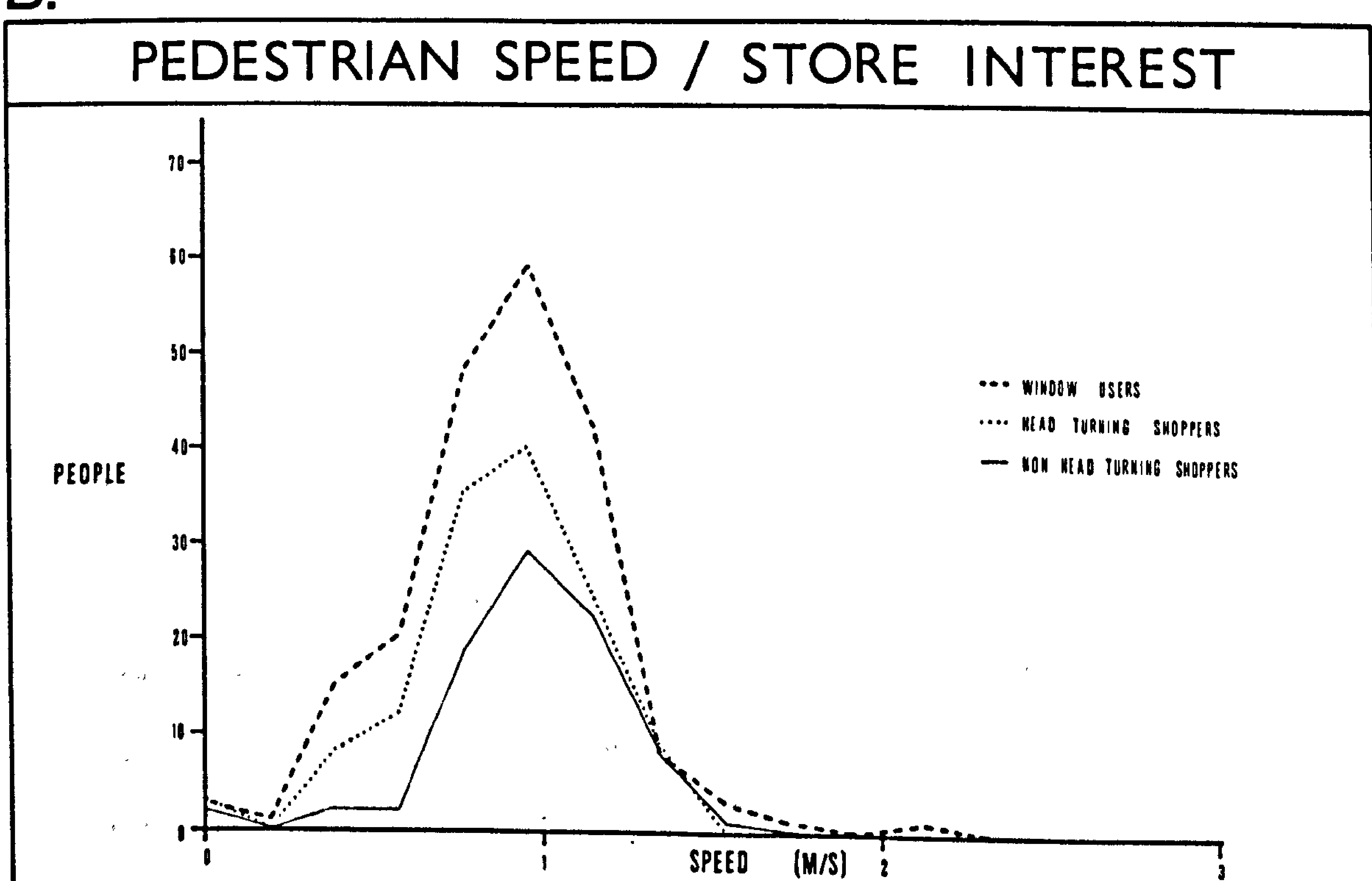

PEDESTRIAN SPEED / STORE INTEREST
70
60
50
40
30
20
10
0
PEOPLE
0
1
2
3
SPEED (M/S)
WINDOW USERS
HEAD TURNING SHOPPERS
NON HEAD TURNING SHOPPERS

FIGURE 5.5

head turning shopper's store entry is more likely to be impulsive than the non-head turning shopper (a "list" shopper), because in the latter's case store visibility was not of importance to store entry. Evidence to support the earlier classification of pedestrians can be found by comparing the average speeds of each category (table 5.7). These figures support Iyer's (1989) impressions of the importance of time pressure on shopping.

Table 5.7: Average Speeds for Pedestrian Types

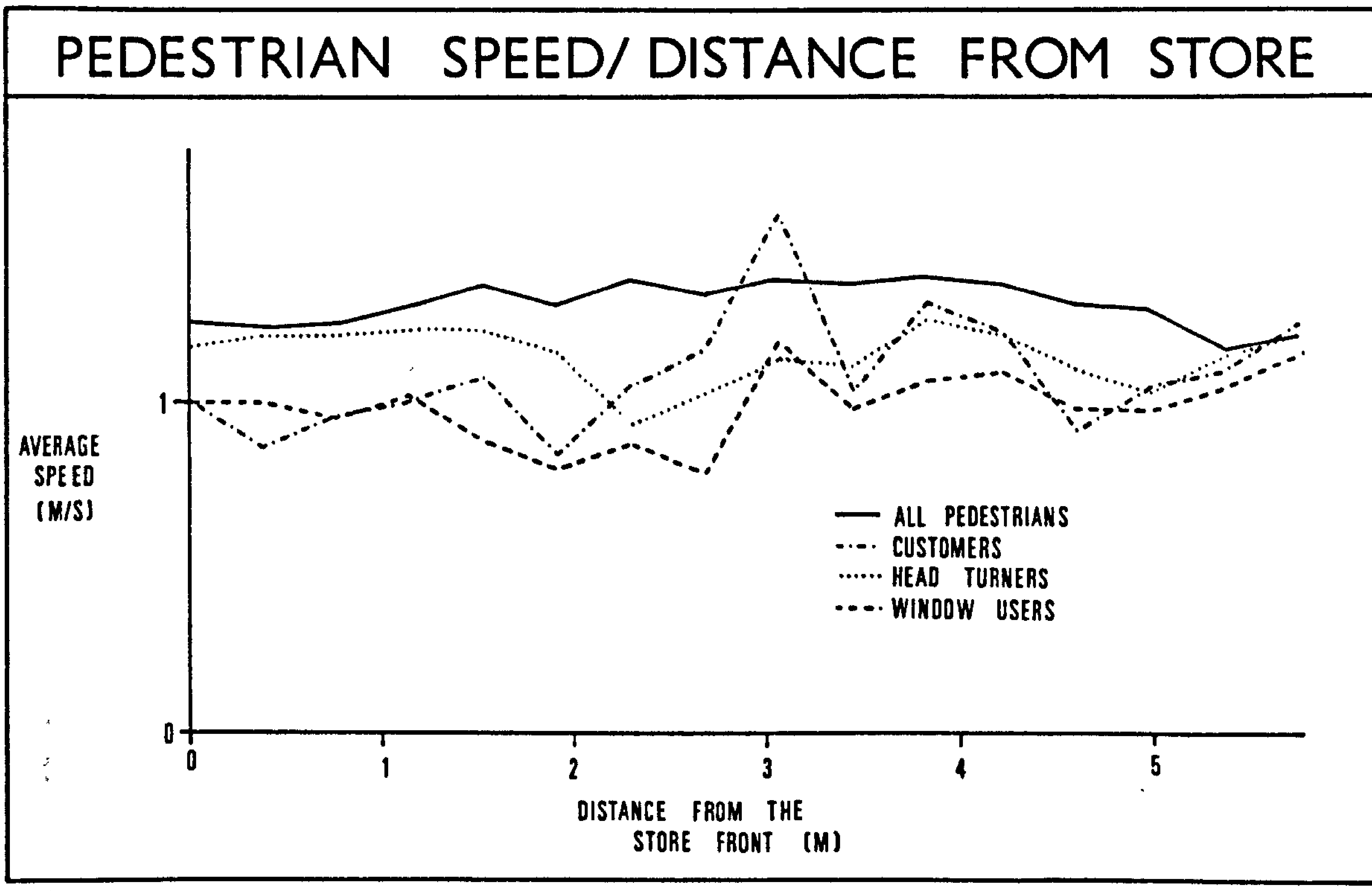
No Store Interest	1.37 m/s
Head Turning Non Shoppers	1.25 m/s
Non Window Using Shoppers	1.13 m/s
Head Turning Shoppers	1.04 m/s
Window Users	1.00 m/s

The Effect of Distance from the Store Front

Figure 5.6.A shows the average velocity against distance from the window of the four important subsections of the population. There is increased variability in the shoppers' average speed compared to that of other pedestrians. The curve follows that of the window shoppers until 2m from the store front but then becomes generally higher. This is due to the decrease in the proportion of window users to shoppers (see figure 5.6.B).

The greatest variation in velocity occurs 2 to 3m from the store front. This variety implies that in this area there will be a higher number of pedestrian confrontations but the low density of pedestrians will alleviate the problem. This variation may well have been caused by the line of street furniture and trees in this zone. Although there was only the tree and dustbin in the frame the eddying effects of the outlying furniture will have had an impact on behaviour in the frame (figure 5.7). The velocity conflicts would not have been helped by the furniture. The impact of the furniture on flow numbers can be

A:


PEDESTRIAN SPEED/ DISTANCE FROM STORE
AVERAGE SPEED (M/S)
1
0
0
1
2
3
4
5
DISTANCE FROM THE STORE FRONT (M)
ALL PEDESTRIANS
CUSTOMERS
HEAD TURNERS
WINDOW USERS

B:

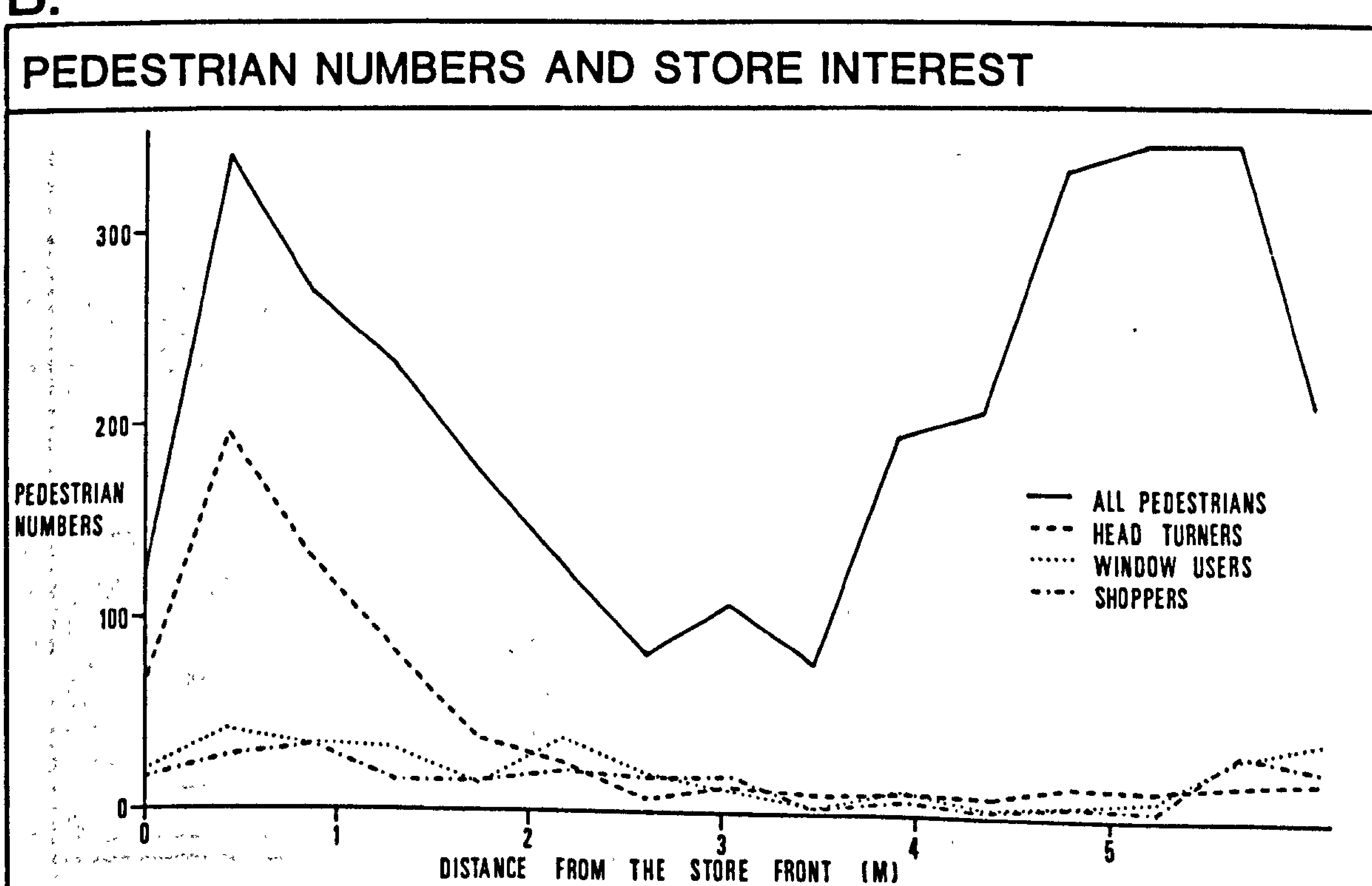

PEDESTRIAN NUMBERS AND STORE INTEREST
PEDESTRIAN NUMBERS
300
200
100
0
0
1
2
3
4
5
DISTANCE FROM THE STORE FRONT (M)
ALL PEDESTRIANS
HEAD TURNERS
WINDOW USERS
SHOPPERS

FIGURE 5.6

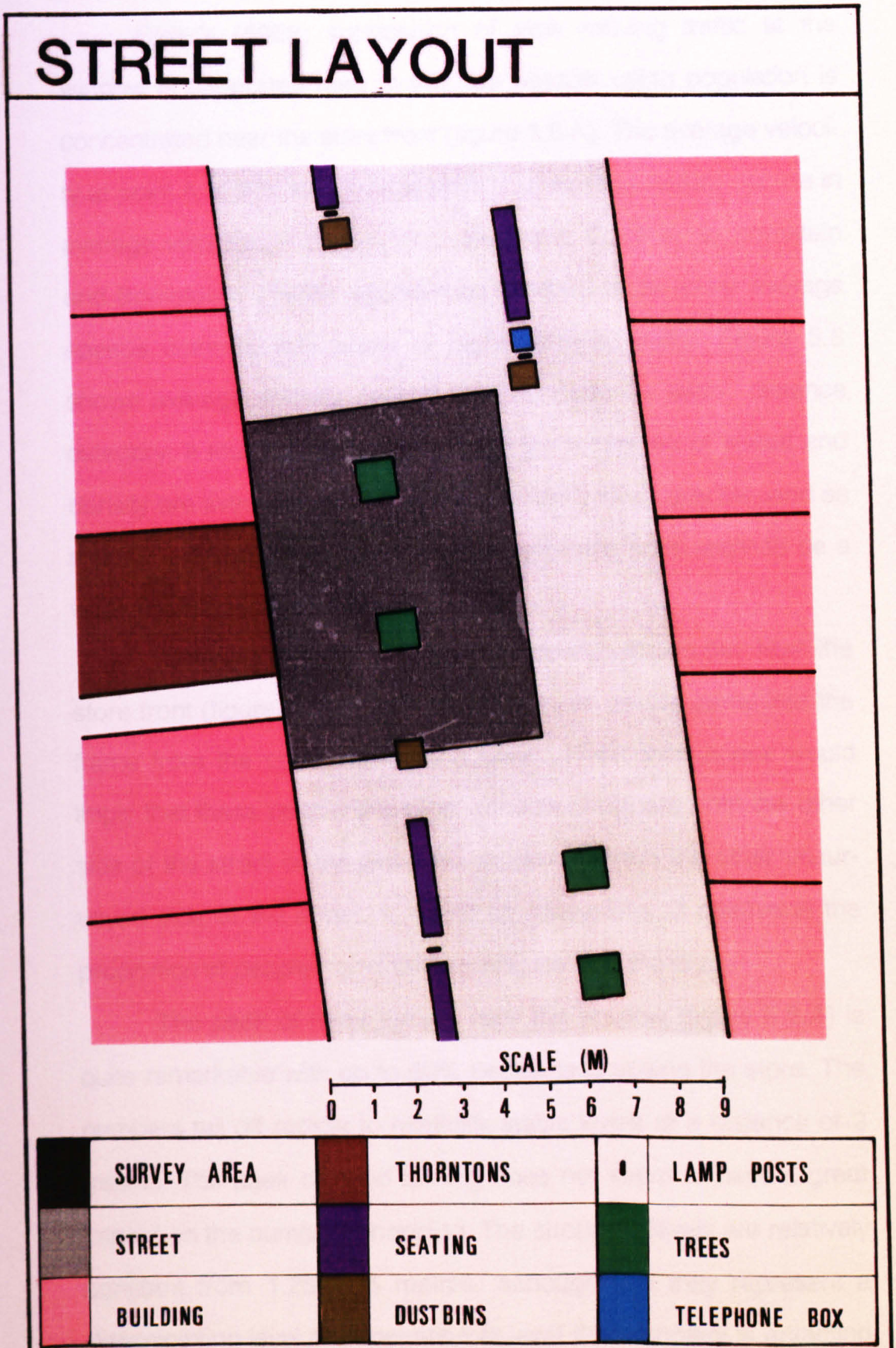

STREET LAYOUT
SCALE (M)
0 1 2 3 4 5 6 7 8 9
SURVEY AREA
THORNTONS
LAMP POSTS
STREET
SEATING
TREES
BUILDING
DUSTBINS
TELEPHONE BOX

Figure 5.7

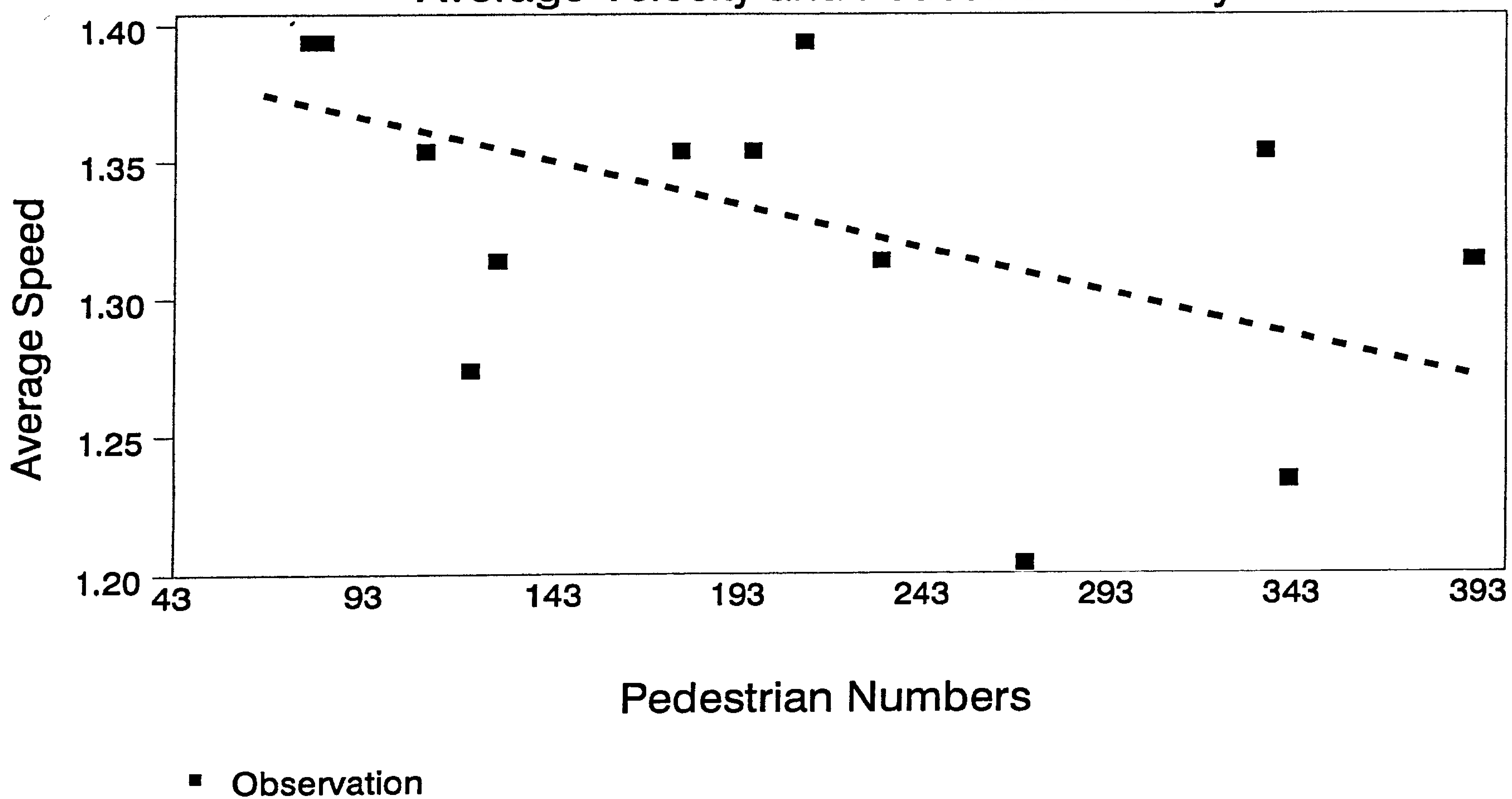
seen in figure 5.6.B. The furniture seems to be fulfilling its role of providing for variety in trip behaviour and motivation.

Older's (1968) supposition of slow moving traffic at the window is supported here in that the window using population is concentrated near the store front (figure 5.6.A). The average velocity at point A is 14% less than at point B. There is a further decline in average velocities 4 metres from the street. Contrary to Bornstein and Bornstein's (1976) theories on overload these lower average speeds coincide with areas of higher density traffic. Figure 5.8 shows average velocity against total numbers for each distance category. It must be remembered that the measures of speed and density are averaged over the whole period so can only be used as a guide. Although the picture is confused there does seem to be a weak inverse relationship.

There is a secondary peak of window shoppers 5m from the store front (figure 5.6.A). Two thirds of these people came into the frame from the other side of the street. Their obliqueness would imply that these people are either window shoppers from the other side of the street or the expected proportion from the other unsurveyed side of the street. It would be interesting to determine the proportion of people from this area who noticed the shop.

The peak of head turners near the window (figure 5.6.A) is quite remarkable with up to 60% pedestrians seeing the store. The numbers tail off rapidly to relatively stable levels at a distance of 2 metres. The peak of head turning does not seem to have a great impact on the numbers shopping. The shopping levels are relatively constant from 1.25 to 5 metres. Although this may represent a disappointing level of penetration at least the company is attracting

Figure 5.8
Average Velocity and Pedestrian Density



interest from its store front cues which may prompt need or aid recognition at some later stage.

The population that presents a greater challenge is found further out in the street. There seems to be very little casual interest in the store from these pedestrians. This may be explained through the increase in average velocity and distance from the store. The increase in distance has a number of effects. Firstly the effort needed to shop increases primarily due to the psychological stress of crossing the traffic stream. As the distance increases the visual impact of the store front diminishes. Thirdly the view of the store will be obscured by other pedestrians. In order to increase impact at these distances it may be necessary to use different techniques such as overhanging signs, increasing the vertical presence of the store or appealing to the freer senses such as smell. This latter option works well with food retailers most notably bakers, coffee retailers and restaurants.

Directional Variability

The flow patterns are much as found in the December test. In the morning there was a significant difference with the predominant flow being to the Market Square (table 5.8). The deficit does reduce during the morning but there was insufficient data to test the afternoon return flows.

Table 5.8: Variability in Flow Direction

5.8.a: Flows 9:15-11:00,		5.8.b: Flows 11:00-13:00	
To the Vic Centre	33.0%	To the Vic Centre	39.8%
To Market Square	66.7%	To Market Square	59.7%
Crossing Street	0.3%	Crossing Street	0.5%

The differential visibility of the store had a smaller effect than expected. Space constraints on site have resulted in the right hand side of

Store View Flowing Towards the Market Square

Figure 5.9

Store View Flowing Towards the Victoria Centre

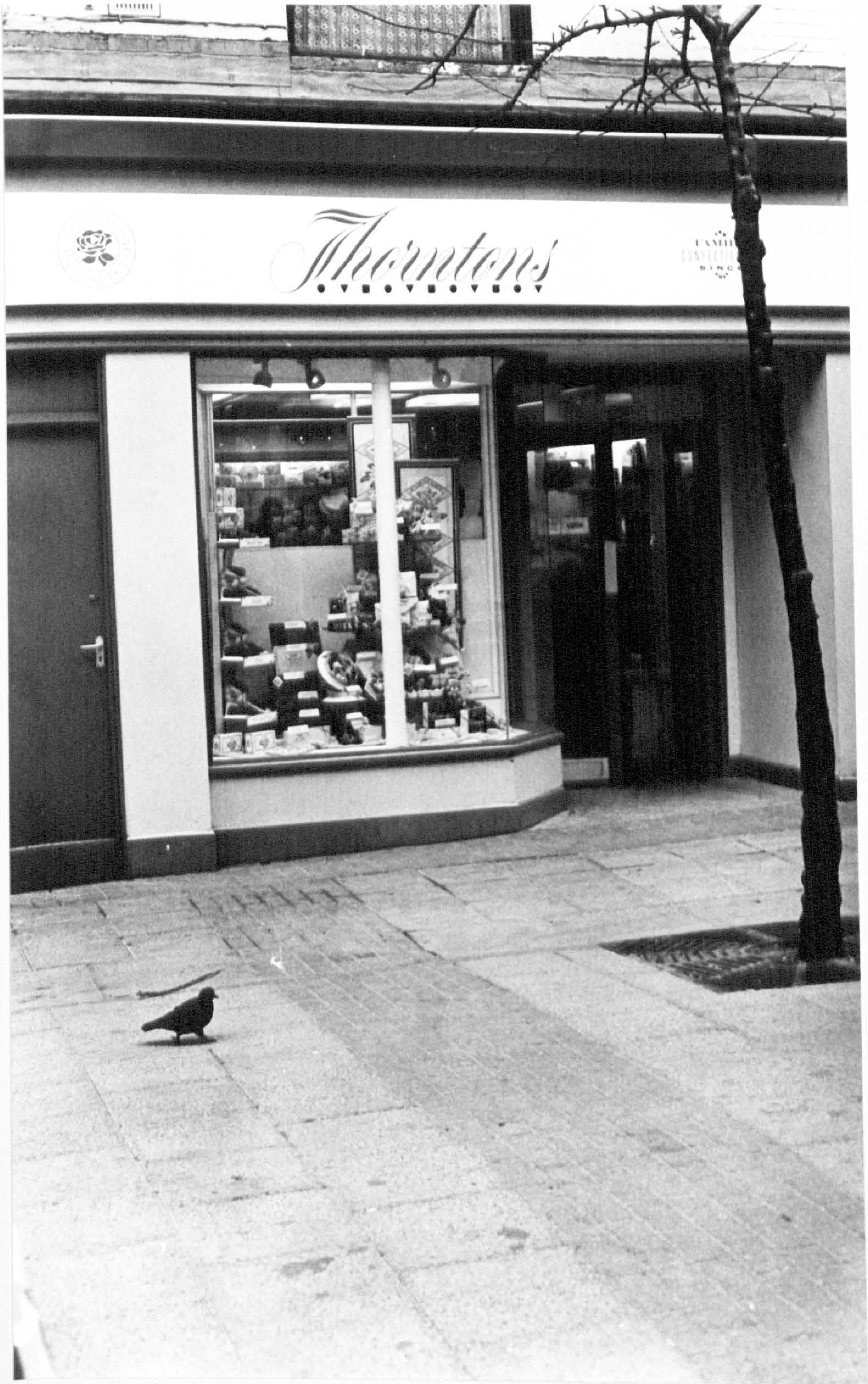


Figure 5.10

the front having no window display. The two photographs in figures 5.9 and 5.10 give the view on approach taken at the same angle and distance. At this distance from the store window those moving towards the Market Square are exposed to a combined window and signage area 34% greater than those pedestrians approaching the Victoria Centre. This means that the latter group have a much reduced opportunity to see the shop. In the event head turners comprised 20.4% of those travelling to the Market Square and 18.2% of those going to the Victoria Centre. However there was only a slight increase in store and window usage.

The difference in head turning is made more notable because of variations in average velocity and in the proportion of women between the two flows. The flow to the Victoria Centre was 57% female whereas the flow to Market Square was only 52% female. Similarly the flow to the Market Square had an average velocity of 1.31 ms^{-1} whereas the other was 1.24 ms^{-1}. This may well be caused by the sloping ground. The structural differences between the flows may explain the poorer transition from head turning to shopping in the southerly direction.

CONCLUSIONS

This analysis was not intended to answer all possible questions about pedestrian structure and store patronage but some interesting findings did result from it. The gender and socio-economic profiles of store interest matched that of the company with the majority of interest been shown by class 3 and 4 females. However the profiles of pre-planned shoppers were distinctly biased towards males and classes 2 and 3. The dominance of the 20 to 40 year olds was noticeable with respect to impulsive entry as was the use of the window by the elderly. The latter behaviour suggest that the company may be wise to highlight the lower priced goods in the window. The success of the store in attracting those with children and friends was noted as was the failure to reach the partner audience. The range of average speeds for each category was surprising but the pattern did match that expected. Those pedestrians moving fast enough do not find the store facade an sufficient cue for them to stop and shop. The apparent lack of relationship between distance and store entry is unexpected although the peak of interest at the store front was. These findings indicate that it is important to know what parts of the store are prompting entry decisions and who uses the different cues so that the facade can be tailored to their concerns.

There were a number of pleasing results from this survey. Firstly the affect of sample time on flow prediction did not seem to be important if the flow was calculated over a two to three hour period. At the three sample rates that were being considered for the full town surveys total volume predictions were almost identical. Secondly the six structure variables did seem to be related to store response and patronage. The theory that video was an unfeasible option for data capture was confirmed as the technique was cumbersome and frustrating. The findings of this preliminary analysis helped to congeal the concepts for numerical treatment that are presented in the next chapter.

SPATIAL BEHAVIOUR
IN THE
RETAIL ENVIRONMENT

PART TWO

by Simon John Thornton, B.A.

Thesis submitted to the University of Nottingham
for the degree of Doctor of Philosophy,
October, 1991

CHAPTER 6

PEDESTRIAN FLOW/TURNOVER PREDICTION INTERFACE

Introduction

The pedestrian flow model developed in chapter 3 and the primary information gathered to generate it, do not provide the retailer with an answer to the question of new outlet viability. The WONKA model provides a method of predicting pedestrian flow networks, volumes and composition. The next step is to seek relationships between turnover and the nature of pedestrian flow. Such rules when combined with the flow model would allow an acquisitions manager to assess the potential contribution that a store could make to the company's operating profit.

This chapter reports on a test of the feasibility of determining the levels of store patronage from the type of data collected during a time-lapse survey. There is a brief discussion of the way in which the physical and human aspects of a store can affect the level of turnover achieved and some of the techniques that could be used to standardise variation between branches. The data collected during the video survey (chapter 5) is used to form the basis of the model. A number of grouping techniques are used to provide clusters of people that have similar demographic and behavioural characteristics. These groups were then tested to monitor the level of store interest shown by their constituents. Shoppers were found to congregate in certain of the groups suggesting that this method could form the basis of turnover estimation.

The turnover interface is envisaged as a probability statement. It was felt that there would be no method of absolute prediction, i.e. person A will definitely enter, but that it would be possible to filter the types of people most likely to come in. For example if a hundred young mothers passed the shop 5% of those travelling at a certain speed could be expected to make a purchase whereas only 1% of those travelling faster would be expected to stop and shop. These probabilities would vary according to the characteristics of site and store. Davidson et al (1988) in their discussion on site analysis state that such compositional work may reveal "variations not apparent from casual observations". Ideally the hope is that the shopping population will be concentrated into a number of sub-cultures within the whole pedestrian population. This would allow more specific and accurate predictive statements than are at present possible.

THE ROLE OF THE STORE

In this work on potential turnover, the store, as opposed to the site, should not have any bearing on the predicted value. It is the site that imposes the limit on turnover for a given company. The role of the store is to maximise the potential offered by the site. As stated in chapter 1 site potential is controlled by internal and external factors. Internal factors are limited to trading area, visibility and frontage; external factors are much more numerous and complex. This project has not investigated the role of individual external influences on pedestrian behaviour. Rather it has focused on the pedestrians themselves as these form the basis of turnover prediction through WONKA.

In order to create a stable turnover model it will be necessary to try to understand how the store influences turnover so that measurements can be corrected. There are two areas that require study. Firstly the variation in stores' ability to attract business and secondly the effect of competition and site interaction.

Variability in Store Performance

Because Thorntons' product range and price structure can be held constant between different stores, variation in store performance is controlled by both physical and human factors. Physical factors include layout, lighting, site constraints and other elements of design. Human factors such as quality of service, window display and shelf stocking reflect the running of the store. In the longer term if an accurate predictive base is to be built from a number of stores it will be necessary to take account of variability in these controls.

The isolation of the physical factors is aided by the small size of the company's stores and the uniformity of their design. Most of the variability between units is due to changes in site characteristics. Fortunately these are confined to sales area, display area and window area. By undertaking surveys similar to this one in tightly controlled situations the impact of physical change may become clear.

The human elements of retail profitability, such as managerial quality and display appeal, are strictly controlled by retailers as they form vital inputs into the system. Window display and shelf layout are directed from head office. The greatest constraint in this case, window display, is controlled through a centralised display team. Photographs and product maps of the seasonal corporate display are distributed for the local staff to implement. Commercially available computer systems (Buttle 1984) are designed to provide optimum shelf layouts direct from head office. In a full test displays could be implemented by a central display team. Staff and managerial quality are well known to the company and are rated for store monitoring. Davidson et al (1988) discuss the appraisal of employee performance using measures such as productivity, attitude, personal influence etc. Rodgers(1989) argues that area managers' ad hoc store visits "should be formally integrated into an organised review". In the absence of company measures ratings could be achieved by examining staff effort in such areas as shelf stocking and customer service via an in-store video camera. The accuracy of these measures is always going to present a major problem but with the help of the company a true indication may be obtainable.

Competition and Site Interaction

The competition and site interaction element of store success may be answerable now that a number of full town surveys have been completed. Now that the full town survey data is available it will be possible to construct accurate flow networks and thus see how the turnover of a store is related to the patterns of pedestrian flow and the location of the competing outlets. Unfortunately there has not been sufficient time to conduct and include this sort of analysis in this project. Until that data is available distance measures such as that of Craig, Ghosh and McLafferty (1984) could be used although their inadequacy must be remembered.

THE TURNOVER PREDICTION INTERFACE

The formation of subcultures or distinct groupings of pedestrians was achieved using a three stage process. Initially the data was preprocessed using principal components analysis. The next stage was to feed the modified data into a cluster analysis. Cluster analysis seeks to divide the total population into distinct groups by clustering individuals whose descriptive variables have similar values. The final stage was to feed the cluster solutions into a multiple discriminant analysis in order to check that the cluster were distinct and reallocate the pedestrians to their nearest cluster centre.

Cluster Analysis

In using cluster analysis there are two decisions that need to be taken, namely the type of clustering algorithm to use and the variables that will form the basis of the clustering. When the clustering is complete it is also necessary determine how many clusters are required and to test whether they are actually distinct from each other.

Cluster analysis is a method of classifying data into discrete groupings. Mather (1976) suggests that clustering techniques can be divided according to whether they are either agglomerative or divisive and subsequently whether hierarchical or nucleated. Agglomerative methods have been preferred traditionally because they can treat all variables simultaneously and are more suited to rapid computation. As Mather points out the problem with the various clustering techniques is that they rarely produce the same results. Thus the choice of technique depends upon the nature of the data and the philosophical basis for the technique. All forms of classification or taxonomy are highly subjective and numerical techniques are no real exception.

The two styles of cluster analysis, hierarchical and nucleated or non-hierarchical, have two main differences; firstly their joining algorithms and secondly their starting point. Hierarchical techniques start by calculating a similarity matrix which contains the measure of the similarity of all points to each other. The most similar two cases are then combined into a single cluster. The similarity matrix is recalculated using the cluster centre instead of the original data points and the next most similar pair is joined. This process continues until all points are grouped into a single cluster. The joining order and distance between joining pairs can be displayed in a dendrogram. The nature of the dendrogram reflects the hierarchical nature of the technique and structure of the clustering. The user then has to look through the joining order and by examining the similarity levels between joining clusters decide where a sensible solution is found. Thus it is possible to take all solutions from 1 to *n* clusters.

Non hierarchical techniques are based on a fixed number of cluster centres or seed points. These are input before the program can run. The problem comes when trying to decide how many clusters there are in a data set if there is no prior knowledge of its nature. Mather (1976) reports on a technique for calculating the appropriate number of clusters. The technique starts with a user supplied, fixed number of clusters, C_{max}, and groups the data around the floating seed points or centroids. The similarity measure used is Euclidian distance. The centroids are then redefined according to the members' distribution. The process then iterates moving points to the nearest centroid and recalculating the centroid position until no reduction in the total squared distance is obtained. The reduction in cluster numbers is performed by combining the two clusters that have the least impact on the squared deviations of the cluster groups. The best fit solution is gained by an *F*-ratio test on the residual sum of squares value for each cluster solution from C_{max} to

C_{min}. This technique does attempt to solve the cluster number problem but does not seem ideal because the whole solution is not recalculated so many points will not be in the correct cluster.

The technique used here is a hierarchical procedure known as an unweighted pair group centroid. The program was supplied by Dr M.J. McCullagh. The cluster algorithm is unweighted because the influence of a cluster is determined by the number of members present in the cluster. Thus if one cluster has 10 members and another has one member the former will have ten times the pull of the latter. The similarity is measured between the centroids of cluster pairs. A centroid in this case being the multivariate mean. The similarity measure used was Euclidian distance as the correlation coefficient is less effective if there is a lot of variation within the data (Davis 1973) owing to the range being compressed.

Data Selection

A number of cluster solutions were generated by using the data in three different ways. The difference between the techniques was the inclusion and treatment of the association variables. The first solution was generated without the use of social association information. The other two differed in their treatment of the presence/absence association information. The three techniques showed much variation in their ability to differentiate shopping clusters from the rest of the population.

The three techniques were based on a common group of five variables. These were chosen because of their potential importance to store interest and patronage. These were age, sex, class, speed and distance from the window. These data were independent in the sense that they were recorded prior to any knowledge of store entry.

Direction was not included as it was felt that whilst it had an effect on the store's performance this was largely the result of the store's design, not the direction of traffic. Tests were done with the inclusion of direction. However because of its binary nature the impact of direction on cluster formation was as great as the gender descriptor. It is thought that an indication of trip motivation is implied in pedestrian speed which would be a less site dependent variable.

The measure of social associations posed a number of problems due to its non-numerical nature. To a degree gender also suffers from this conundrum but associations are more complex because of the number of categories and the potential for multiple associations. There are three ways to treat binary data. Firstly to leave it as a 1/0 score, secondly to scale all the variables to a common range (Mather 1976) or thirdly to try to rate the associations on a scale according to the "degree" of association. In chapter 5 it was seen that the child/parent and friend associations had a positive impact on store interest whilst the partner relationship had a negative effect. For this reason the association information was condensed down to two binary dummy variables. The first variable stated whether the person was in a child/parent or friend association. The second stated whether the person was in a partnership. In one of the analyses there was no further pre-processing of social associations, in the other the two scales were put through the same principal components analysis as the other variables.

The other variables giving an indication of store interest were left out of the analysis because they could not be measured in the time-lapse street survey and they were the ones to be predicted from the results of the cluster analysis.

Data Used

In all 3171 pedestrians were recorded by the three sample techniques mentioned in chapter 5. These three groups were merged for the subsequent tests in order to boost the sample size, and hence statistical reliability, and to produce time independent results. This introduced bias because the third file in-store file was based on those people who came into the shop. Therefore there was a much higher percentage of shoppers than might otherwise be expected. It is important to remember that the penetration figures given are boosted significantly by the file combination. Table 6.1 shows the impact on the penetration figures if the third file containing in-store data is omitted.

Table 6.1. Pedestrian Store Interest

	Files 1 & 2		All Files	
	No	%	No	%
Head turners	580	19.6	670	21.1
Window shoppers	95	3.2	291	9.2
Customers	52	1.8	263	8.3
Total	2954		3171	

Data Processing

The problem with Euclidian distance as a measure of similarity in the clustering program is the potential lack of orthogonality between the axes (Mather 1976). This can be corrected by performing a principal components analysis on the original data. At this stage a varimax rotation was performed to maximise the variance explained by the new axes. A problem with PCA is that the new variables are not as clearly defined as the original variables. As this procedure was not being used to simplify the data through a reduction of variable numbers but only achieve orthogonality, there was only a slight shift in the line of the axes.

At the same time as the PCA it was thought desirable to standardise the axes. This was done to remove the effects of differential scaling which would have put a huge weight on the variables with the highest values, namely age. The treatment of binary data such as sex and social associations by this method is more complex. Standardisation does not fulfil the aims expressed by Mather (1976) of placing all variables on the same scale but it did place the variables into a more even range.

Table 6.2: The 3 Data Structures Used In Analysis

Option 1
5 Structure Variables
--> PCA
--> Clustering

Option 2
5 Structure Variables
+ 2 Condensed Associations
--> PCA
--> Split by Gender
--> Clustering

Option 3
5 Structure Variables
--> PCA
+ 2 Condensed Associations
--> Split by Gender
--> Clustering

As shown in table 6.2 one of the association files had all variables standardised and the other only the five principal ones. Preliminary tests and subsequent difficulty of analysis led to the division of the association files according to gender prior to clustering. This variable was already known to be the primary basis of cluster formation.

Table 6.3: Eigen values and contribution to Variance

Table 6.3.a: Five Principal Variables

	Eigen Values	%Contrib-ution	Accumulated % Contribution
	1	2	3
1	1.4454	28.9087	28.9087
2	1.0906	21.8114	50.7201
3	0.9391	18.7826	69.5026
4	0.9042	18.0842	87.5868
5	0.6207	12.4132	100.0000

Table 6.3.b: Female Standardised Association File

	Eigen Values	%Contrib-ution	Accumulated % Contribution
	1	2	3
1	1.4139	23.5642	23.5642
2	1.1987	19.9778	43.5420
3	1.1342	18.9033	62.4453
4	0.9168	15.2792	77.7245
5	0.8418	14.0300	91.7545
6	0.4947	8.2455	100.0000

Table 6.3.c: Male Standardised Association File

	Eigen Values	%Contrib-ution	Accumulated % Contribution
	1	2	3
1	1.5473	25.7889	25.7889
2	1.2937	21.5618	47.3508
3	0.9783	16.3048	63.6555
4	0.8830	14.7174	78.3729
5	0.8271	13.7854	92.1583
6	0.4705	7.8417	100.0000

Thus four association files were submitted two female and two male.

Principal Component Analysis

The principal component analysis was carried out on the 3171 cases. Three files submitted to the PCA program are examined here. Firstly the file containing the five principal variables, sex, age, class, speed and distance, and then the female and male standardised association files. This section will examine the results and impact of including a measure of association. Table 6.3 show the eigen values extracted from the two submitted files. As shown in table 6.2 the binary association file was created from the PCA output of the non association file.

The percentage contribution refers to the amount of total variance described by each eigen vector. If all the eigen vectors were of equal descriptive importance the eigen values would be 1.0 and percentage contribution would be 20% in the first file and 16.6% in the association files. If any eigen values fall significantly below 1.0 they can be discarded without much information loss. However in this case all eigen values were deemed to be significant as the maximum amount of information was required to produce effective separation during clustering.

Table 6.4. Similarity Matrix using Pearson R Coefficient for the Five Principal Variables

	Sex	Age	Class	Speed	Dist
Sex	1.00	-0.08	0.09	0.23	0.08
Age	-0.08	1.00	-0.12	-0.27	-0.06
Cls	0.09	-0.12	1.00	-0.07	0.10
Spd	0.23	-0.27	-0.07	1.00	0.06
Dst	0.08	-0.06	0.10	0.06	1.00

The correlation matrix shown in table 6.4 shows the degree of similarity between the variables. There is a slight correlation between speed and the age and sex variables. This means that young males move faster then average. However the similarity is too low to be of significance.

The eigen-vectors produced by the PCA of the first file are given below (table 6.5). These vectors show the relationship between the original variables' axes and the new axes or eigen vectors created by the PCA.

Table 6.5. Eigen Vector Composition for the Five Components

	Component				
	1	2	3	4	5
Sex	0.49	-0.01	0.40	-0.66	-0.39
Age	-0.53	0.06	0.60	-0.34	0.50
Cls	0.21	0.76	-0.38	-0.31	0.38
Spd	0.59	-0.45	0.05	0.08	0.67
Dst	0.28	0.47	0.59	0.59	-0.04

Explanation of the new axes is not clear as each of the original variables can have a large effect on the eigen vector. As will be seen below understanding of the eigen vectors becomes simpler after varimax rotation.

Varimax Rotation and Variable Loadings

The next stage of data processing was varimax rotation of the eigen vectors. This is a technique which seeks to maximise the variance of the loadings of the variables on each factor. This process usually results in the reduction in the number of variables describing each component. For example in table 6.6 below the pre and post rotation loading for each variable on component one of the first file can be seen.

Table 6.6. Effect of Varimax Rotation on Variable Loading for the Five Principal Variables

	Prior Rotation	Post Rotation
Sex	0.4976	0.9910
Age	-0.5336	-0.0302
Class	0.2136	0.0475
Speed	0.5864	0.1185
Distance	0.2798	0.0360

Thus component 1 can be termed the sex factor. Because of the minor correlations shown in table 6.4 there is also a slight influence from speed.

The rotated loadings matrices in table 6.7 show how each variable is represented by the eigen vectors. Each rotated axes lies close to one of the original variables. This is to be expected as all the eigen vectors were retained and the similarity between variables was low.

The slight correlations mentioned above have led to some secondary influence in vectors representing age, speed and sex in the first file. The male and female rotated loadings matrix have their first and last eigen vectors reversed. With males speed is the basis of the first eigen vector and age the last. The other vectors have the same order but the interpretation is much the same as the levels of explanation are equal in both cases.

CLUSTER ANALYSIS

An early trial run using unfiltered data had produced a very high proportion of clusters with a few young members in each. In order to remove such spurious effects two types of filtering were used. In the first file all children under the age of 15 were aggregated into the

Table 6.7. Rotated Loadings Matrix

Table 6.7.a: Five Principal Variables
Rotated Eigen Vectors

	1	2	3	4	5
Sex	0.99	0.05	-0.03	0.04	0.12
Age	-0.03	-0.06	1.00	-0.03	-0.13
Cls	0.05	1.00	-0.06	0.05	-0.04
Spd	0.12	-0.04	-0.14	0.03	0.98
Dst	0.04	0.05	-0.02	1.00	0.03

Table 6.7.b: Female Standardised Association File
Rotated Eigen Vectors

	1	2	3	4	5	6
Age	0.98	-0.04	-0.03	0.02	0.00	-0.14
Class	-0.02	0.02	0.03	-0.99	0.01	-0.05
Speed	-0.15	-0.16	0.02	0.06	-0.04	0.97
Dist	-0.03	0.01	0.99	-0.03	0.03	0.02
Frd/chd	-0.04	0.98	0.01	-0.02	-0.10	-0.15
Partner	0.00	-0.09	0.03	-0.01	0.99	-0.04

Table 6.7.c: Male Standardised Association File.
Rotated Eigen Vectors

	1	2	3	4	5	6
Age	0.16	0.11	-0.01	0.10	0.04	0.97
Class	0.04	-0.06	0.05	-0.99	-0.02	-0.09
Speed	-0.97	0.07	0.01	0.04	-0.13	-0.16
Dist	-0.01	-0.05	0.99	-0.05	0.03	-0.01
Frd/chd	0.07	-0.98	0.05	-0.06	-0.06	-0.10
Partner	0.13	0.06	0.03	0.02	0.98	0.03

same group prior to running the cluster analysis. In the association files children were removed. The under 15's were filtered out due partially to their small number, 54, but primarily owing to their lack of independence in the mid-week shopping process. The survey had stopped before school closing time. The associations of the children show that 87% were accompanied by their parents. As both parents and their known associations were retained, their children's presence was still catalogued. This filtering technique was the best method of getting separation of the main body of the data into tighter clusters.

Choice of a cluster solution

The decision of which cluster grouping provided the best solution involved two processes. Firstly deciding which was the best solution for each of the techniques and then which of the techniques provided the best definition. The greatest differentiation between cluster members behaviour would be obtained if each cluster had only one member. There would be either 0% or 100% store interest. The aim of clustering was to make some sense of the mass of data collected so the solution required would lie somewhere 2 and C_{max} groups. The cut off point for C_{max} was arbitrary but was in effect determined by the desire to compress the data into usable predictive clusters. A sensible cut-off point for C_{max} was thought to be 100 clusters. If more than 100 clusters were used the proportion of clusters having a significant number of members would be low. The splitting of the data into the two genders allowed more detailed breakdown of the data. There was also a machinery constraint that placed an upper limit of about 125 clusters. This was due to the time the program took to run on a PC, about 8 hours, and the storage constraints of the computer. The program that was used was set to produced cluster solutions at all levels from 2 to 100 groups.

The determination of the cluster cut off point to be used was in this case not so much a significant break point in the dendrogram in terms of inter-cluster similarity as a question of which cluster solution gave the greatest separation of shop interest from pure pedestrian activity. There are two measures that were important in solution choice. Firstly the proportion of individuals in each cluster showing store interest, termed penetration. If there was no variation between the observed and expected values then the whole exercise has not worked. If however certain clusters had increased concentrations of interest then it shows that the process is working and potential customers did have different characteristics to the general population. The second measure was the degree of concentration of potential shoppers into clusters with above expected levels of store interest, termed inclusion. The purpose of these two measures was to find a level of clustering beyond which there is little predictive benefit to be gained.

An iterative process was used to find the last group division worthwhile. At strategic cluster solutions the cluster members were tested to see the proportions showing interest in the store (i.e. head turners, window examiners and store entrants). After various experiments a number of sample points were chosen. These points were 50, 60, 70, 80, 90 and 100 groups.

MULTIPLE DISCRIMINANT ANALYSIS OF THE CLUSTERS

A series of multiple discriminant analyses of the sample cluster solutions were undertaken. The purpose of the discriminant test was two fold. Firstly to determine whether the clusters formed in the pedestrian classification were in fact distinct from one another. Davis (1973) states:

> "the problem is to find a linear combination of these variables which produces the maximum difference between the previously defined groups."

The second reason was to allow the allocation of uncertain data to the existing cluster centres. It was hoped that this allocation facility could be used in predicting store penetration rates for other sites.

During the clustering process a number of small groups were formed as well as the larger clusters. As a cluster's size was reduced so was its predictive reliability. Thus any cluster with fewer than 10 members was not retained as a seed group for the MDA. The discarded clusters' members were retained and treated as uncertain cases.

Before progressing with the MDA it is necessary to test whether the clusters were the same. To do this an F-ratio test was calculated from Wilks Lambda. In all chosen cluster solutions the null hypothesis was rejected at the 0.01 level of significance. These results were supported by comparison of the between and within group sums of squares and cross products (SSCP) matrices. These showed much greater variability between rather than within the groups. There were a number of problems associated with the use of these statistical tests that arose from the non normality of the data. This was partially overcome in the non association file by dividing the clusters according to the gender of the groups and each sex was tested separately. Division of the association clusters did not prove possible because the definition of the associations was not complete. This led to a masking of the other variables in the discrimination of the groups.

The discrimination process is based on the extraction of eigen values of the matrix representing the ratio of within-group to between-group SSCP (Mather 1976). The eigen values indicate the strength of the discrimination axes. If the sexes are treated separately class is the best male cluster discriminator. Female age proves the second strongest discriminator as opposed to class in the combined test.

As mentioned earlier, the inclusion of the two association categories led to a masking of the other variables and their powers of discrimination. In the standardised form the two association variables accounted for 99.9% of the discrimination. In the raw binary form the associations accounted for under 5%. This was because their presence/absence nature had been exaggerated by the standardisation process. The impact that this has on method and solution choice will be seen later.

There was a further test that showed the significance of retaining eigen vectors for the discrimination analysis. This test is the Chi-squared significance test of residual discrimination. The null hypothesis is that the discriminating power of the eigen vectors is due to chance. If the Chi-squared value exceeds the tabled level then the hypothesis is rejected. The test indicated that in all the chosen solutions, all the roots are powerful discriminators at the 0.01 level of significance.

Cluster Overlap and Predictive Capacity

Once the discrimination axes had been formed it is necessary to test whether each of the clusters were actually distinct. This was done by seeing if the cluster means were significantly different from each other. The problem was deciding what value makes the clusters distinct. A value of 1 was chosen because this was twice the maximum cluster combination distance of the chosen group solutions. At a value of 1.0 all of the groups could be distinguished.

Although the cluster centres could be effectively separated this did not mean that there was no overlap between clusters. The usual method of testing cluster overlap is by plotting the data. With so many cases and four or six axes this graphical technique did not seem to be of much use. As a test of the tightness and distinction of the clusters and to stabilise the solutions all the data from the seed clusters were fed into the discriminant analysis as uncertain cases together with the small cluster members. Once the data had been allocated according to the cluster centres it was possible to see how many people had moved clusters and whether the predictive capacity had fallen.

Table 6.8 shows the outcome of this reprocessing on a typical cluster solution. Overall 12% of the people moved clusters. Generally the larger clusters show a net loss of constituents. However this does not seem to affect the concentration of shopping interest into certain categories. The extreme peaks of interest seen in some of the original clusters had been reduced but there was an increase in the concentration of the interested pedestrians in clusters with above average penetration, called the retained clusters. This meant that the possibility of cluster exclusion had actually increased. Within the female population the new allocation had 857 pedestrians in clusters with below average window interest compared with 843 before and 1253 with below average store entry probability as

Table 6.8: Reallocated Pedestrians from Multiple Discriminant

Analysis Showing Numbers moving from each group and Store Interest. (for explanation of the groups constituents see tables 6.11 and 6.12.)
(Only groups with 10 or more members are shown)

Number in Group	Chng	Head Turn %	No	Window Shop %	No	%	Enter Shop No
98	5	35.7	35	12.2	12	5.1	5
62	1	6.5	4	4.8	3	3.2	2
6	3	3.3	2	1.6	1	1.6	1
51	2	7.8	4	3.9	2	2.0	1
58	0	10.3	6	5.2	3	0.0	0
99	17	26.3	26	8.1	8	0.0	0
98	18	27.6	27	6.1	6	1.0	1
29	0	34.5	10	27.6	8	13.8	4
63	4	0.0	0	0.0	0	0.0	0
127	21	1.6	2	0.8	1	1.6	2
58	2	15.5	9	5.2	3	19.0	11
172	28	2.3	4	0.6	1	0.6	1
87	11	1.1	1	1.1	1	2.3	2
99	7	2.0	2	0.0	0	0.0	0
16	0	25.0	4	6.2	1	0.0	0
55	0	12.7	7	1.8	1	0.0	0
96	7	55.2	53	14.6	14	11.5	11
57	0	31.6	18	12.3	7	0.0	0
108	27	62.0	67	22.2	24	6.5	7
23	0	34.8	8	30.4	7	34.8	8
39	0	79.5	31	35.9	14	41.0	16
159	13	50.9	81	14.5	23	3.1	5
190	58	34.7	66	12.1	23	8.9	17
36	0	36.1	13	16.7	6	27.8	10
70	7	51.4	36	34.3	24	40.0	28
15	2	53.3	8	26.7	4	53.3	8
45	0	2.2	1	2.2	1	4.4	2
37	0	2.7	1	0.0	0	0.0	0
306	89	5.6	17	2.0	6	3.3	10
94	2	19.1	18	9.6	9	19.1	18
24	1	12.5	3	12.5	3	16.7	4
66	2	0.0	0	0.0	0	6.1	4
156	5	5.8	9	5.1	8	3.2	5
101	10	12.9	13	9.9	10	6.9	7
39	2	33.3	13	28.2	11	23.1	9
28	1	3.6	1	7.1	2	10.7	3
24	11	50.0	12	20.8	5	45.8	11

opposed to 1067. Only store entry was affected in the male population, the number with a below average probability increased from 962 to 986. The proportion of all interested pedestrians now in the retained clusters had also increased. The MDA process had in effect redistributed the interested pedestrians into a smaller number of focused clusters.

Eighteen cluster solutions were tested from the three methods to see which gave the best predictive performance. The data was resubmitted through the MDA for each set of cluster centres and the prediction of store interest is contained in table 6.10. The two measures influencing method and solution choice, the percentage inclusion and the percentage penetration, are given. Both measures are calculated from those groups having an above expected level of interest in each category. Any group having below average levels of interest was excluded from this table.

As can be seen the average penetrations of the retained cluster sets are much better than the average values (see table 6.9) and in most cases the percentage of each category included is over 75%. The male clusters have higher relative penetrations at over twice the expected values whilst the females are generally just below this figure. This implies that the male shopper is more distinguishable.

Table 6.9. Male/Female Variation in Store Interest

	FEMALE	MALE
Head Turners	27.3%	12.4%
Window Users	12.2%	5.2%
Customers	11.6%	3.7%

(figures show percentage of each sex showing an interest).

Although the survey was attempting to predict store entry it was felt unwise to concentrate solely upon the entry ratios because of possible interference from the human and physical aspects of the store. The choice of a particular solution was made by ranking the percentage of each store interest category and then summing the three values. This put equal weight on all three measures of store interest.

In a full scale study the focus may be restricted to the head turning and store entry categories. To make sure that the high inclusion values were not solely a result of a dilution in penetration levels, store interest was checked and in the case of low values the solution rejected. In making a choice of a particular solution great care must be taken because of the very short temporal nature of this study. Behaviour will change throughout the year as motivations shift from personal purchases to gift orientated shopping. Behaviour will also be affected by short time scale effects such as day of the week and the weather. However as this set of results is available a choice should be made.

The 90 cluster non association female solution had the best rank figures, the second choice was the binary association 50 cluster solution. The males have a number of possible solutions but in the end the standardised association 50 cluster solution was chosen. This was because no category of interest had below average values. With the male cases the inclusion of associations had a beneficial impact on the segregation of store interest but with females this did not seem to be important.

Table 6.10: Type Inclusions and Average Penetration

of the Retained set

Table 6.10.a: Female Cluster Solutions
No Association

Cluster	Head Turners		Window users		Shoppers	
	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation
50	76.7	51.7	85.7	16.1	63.9	14.6
60	81.2	49.4	70.0	19.9	61.3	20.4
70	81.9	48.8	83.3	18.8	74.5	19.5
80	85.2	48.2	68.7	22.4	77.6	21.4
90	84.6	48.6	83.6	19.5	82.3	21.4
100	87.8	50.0	80.2	18.8	70.4	28.1

Table 6.10.b: Female Cluster Solutions
Binary Association

Cluster	Head Turners		Window users		Shoppers	
	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation
50	82.3	48.7	85.7	18.7	77.2	20.5
60	84.3	49.0	84.3	19.1	71.1	23.2
70	85.6	48.8	82.0	19.6	64.6	28.4
80	81.0	50.1	82.0	19.9	74.7	22.8
90	81.8	49.7	82.5	20.2	73.8	23.7
100	81.6	49.7	76.0	22.2	76.7	25.0

Table 6.10.c: Female Cluster Solutions
Standardised Association

Cluster	Head Turners		Window users		Shoppers	
	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation	Incl -uded	Penetr -ation
50	71.5	48.8	66.8	22.0	70.4	22.7
60	85.4	47.4	72.8	21.3	65.0	26.0
70	84.5	47.6	70.9	21.9	66.0	25.9
80	84.9	47.5	78.3	20.9	70.9	27.5
90	86.0	47.0	77.9	21.6	70.4	29.8
100	85.2	48.7	81.6	20.8	68.4	31.1

Table 6.10.d: Male Cluster Solutions
No Association

Cluster	Head Turners Incl -uded	Head Turners Penetr -ation	Window users Incl -uded	Window users Penetr -ation	Shoppers Incl -uded	Shoppers Penetr -ation
50	80.8	32.2	79.1	16.4	85.5	18.3
60	78.4	30.0	76.6	13.1	84.2	11.0
70	79.4	28.7	84.2	12.5	89.3	10.3
80	85.0	27.1	85.6	11.5	82.4	13.3
90	80.0	29.5	81.7	12.0	84.3	15.0
100	82.6	27.8	78.6	13.3	86.0	14.1

Table 6.10.e: Male Cluster Solutions
Binary Association

Cluster	Head Turners Incl -uded	Head Turners Penetr -ation	Window users Incl -uded	Window users Penetr -ation	Shoppers Incl -uded	Shoppers Penetr -ation
50	87.4	28.2	77.1	9.3	86.0	8.9
60	88.8	26.4	78.1	10.7	86.0	9.0
70	90.4	25.2	78.6	14.7	88.0	8.9
80	89.2	24.5	78.6	12.8	88.0	12.5
90	83.2	27.0	81.4	12.7	96.0	11.9
100	83.8	27.0	84.3	11.8	90.0	11.1

Table 6.10.f: Male Cluster Solutions
Standardised Association

Cluster	Head Turners Incl -uded	Head Turners Penetr -ation	Window users Incl -uded	Window users Penetr -ation	Shoppers Incl -uded	Shoppers Penetr -ation
50	89.8	24.1	81.4	11.5	88.0	10.5
60	89.0	24.5	83.2	11.4	86.3	10.2
70	88.0	24.9	84.3	11.4	84.0	9.8
80	86.2	25.1	77.1	12.4	84.0	10.7
90	86.8	25.3	86.8	12.1	86.0	13.2
100	86.8	25.7	86.8	11.9	86.0	13.0

PHYSICAL DESCRIPTION OF CLUSTERS

The Male Clusters

An approximate translation of the cluster centres and the level of store interest for each of the chosen cluster centres is given in table 6.11. The groups are split as before according to the three possible association categories. Further breakdown is dependent on the other attributes. Many of the categories and their penetration ratios provide confirmation of the earlier findings. For example clusters close to the window (1,5,9,10 and 16) have higher head turning levels. Clusters with higher speeds (2,7,13,14 and 15) also show generally less interest in stopping at the store. However within these clusters subtle variations are apparent. There are marked differences in behaviour between the 13th and 14th clusters. Cluster 13 has high levels of window usage and store entry which is a result primarily of its better socio-economic profile. Cluster 9 has an increased fall in interest as commitment levels rise when compared to cluster 10. This is most probably due to the lower average age of the former.

Some clusters show an increase in interest as commitment rises. Three groups fall into this category in clusters 3, 11 and 13. Cluster 3 represents slow moving, high status, pensioners. Cluster 11 is probably influenced by its association category whilst cluster 13 has a very good socio-economic profile. This may reflect the presence of "list" or purposeful shoppers but could be a result of head turning out of the survey area.

Interestingly, clusters 2, 4, 6, 7 and 14 contain over half of all the male pedestrians but only 6% of all the people who entered the store. These low levels of store interest are the result of the combi

Table 6.11: Cluster Centres for Male Solutions and Levels of Store Interest

	1 Partner	2 Friend/ Child	3 Distance	4 Age	5 -ve Socio Economic Status	6 -ve Speed	STORE PENETRATION Head Turn	Window Use	Store Entry
1	-0.2501 Alone	0.5653	-1.1354 Close	-1.4928 Old	-0.3607 Average	0.0725 Average	31.5	5.3	4.2
2	-0.2501 Alone	0.5644	0.6627 Intermediate	-1.4887 Old	0.0521 Average	-0.1554 Fast	3.8	1.9	0.9
3	-0.2481 Alone	0.5645	0.5448 Intermediate	-1.9849 Very Old	-0.7741 Low	1.5765 Very Slow	6.6	13.2	16.6
4	-0.2509 Alone	0.5651	-0.8175 Close	0.6786 Middle	-0.8515 Low	-0.2437 Fast	13.0	0.6	0.0
5	-0.2507 Alone	0.5650	-1.0581 Close	0.4123 Middle	0.7680 Good	0.0129 Average	27.6	2.0	3.9
6	-0.2504 Alone	0.5647	0.8596 Far	0.5060 Middle	-0.6383 Low	0.0748 Average	1.0	0.0	0.3
7	-0.2503 Alone	0.5641	0.7510 Far	0.2854 Middle	1.0565 Good	-0.1722 Fast	0.7	0.0	0.7
8	-0.2519 Alone	0.5644	0.6125 Intermediate	1.0016 Young	0.7737 Good	1.4683 Slow	12.7	18.3	9.0
9	2.1122 Partners	-0.7546	-1.2717 Close	0.8167 Young	-0.1445 Average	0.0824 Average	36.0	6.1	2.0
10	2.1119 Partners	-0.7544	-1.4003 Close	-1.0876 Old	0.0740 Average	-0.1310 Fast	48.5	18.1	6.1
11	2.1127 Partners	-0.7557	0.8566 Far	0.6564 Young	0.1303 Average	0.0370 Average	4.3	3.3	6.5

12	2.1130	-0.7555	0.8404	-1.4677	-0.0983	-0.1858			
	Partners		Far	Old	Average	Fast	13.0	8.7	8.7
13	-1.4102	-2.3250	-0.0867	-0.5666	2.1147	-0.1247			
	Friends/Children		Intermediate	Middle	Very Good	Fast	7.7	11.5	27.0
14	-1.4093	-2.3232	0.4941	-0.0095	-0.2841	-0.1178			
	Friends/Children		Intermediate	Middle	Average	Fast	2.1	1.0	0.0
15	-1.4110	-2.3229	-1.3094	0.4370	-0.4582	-0.2251			
	Friends/Children		Close	Middle	Average	Fast	9.5	0.0	4.7
16	-1.4107	-2.3230	-1.4213	0.3377	0.7834	1.3840			
	Friends/Children		Close	Middle	Good	Slow	47.0	17.6	35.0

nation of speed, low socio-economic status and distance from the store window. Cluster 16 has very high levels of store interest when compared to the other male groups. This is due to the association category, their high status and the low average speed. This group do not use the window as an information source to any great degree preferring instead to move straight into the store.

The Female Clusters

The female solution (table 6.12) gives a description of the cluster centres and shows the levels of store interest exhibited by each group. As in the male findings, female behaviour follows the patterns seen in the earlier discussion. All four factors are important in explaining response to the store. Some of the groups have extremely high levels of store interest. Clusters 6 and 7 both have levels of store entry around 47%. These clusters contain young, above average status, slow moving people. Fall off between head turning and entry is low. Clusters 1, 2 and 3 show the effects of velocity and socio-economic status. Cluster 2, a low status high speed group, has average levels of head turning but no transition to store entry. However groups 1 and 3 have improved status and are travelling slower. This translates to much better store entry. Cluster 4 also suffers from very low transition levels. The profile of the cluster is good but its high speed implies it is not a group of active shoppers.

Clusters 11, 12 and 17 have higher levels of store entry than head turning. This is the result of a number of factors. Clusters 11 and 12 represent people entering the store from the other side of the street. Their slow speed and the desire to cross traffic streams is indicative of a "shopping" bias in the trip. The difference in shopping levels is accounted for by the socio-economic status of the clusters.

Table 6.12: Cluster Centres for the Female Solution and Levels of Store Interest.

	Distance	Socio-Economic Status	Age	Speed	STORE PENETRATION Head Turn	Window Use	Store Entry
1	-1.0734 Close	0.9334 Low	1.3791 Old	0.3727 Average	54.5	15.8	14.8
2	-0.9780 Close	1.2579 Low	1.1763 Old	-1.1749 Fast	32.8	3.0	0.0
3	-1.0317 Close	-0.6324 Good	0.8362 Old	-0.0508 Average	65.1	18.4	14.5
4	-1.0403 Close	-0.5950 Good	-0.6952 Young	-0.5170 Fast	48.2	3.5	4.7
5	-0.8402 Close	0.8286 Low	-0.5490 Young	0.0627 Average	34.5	3.1	12.1
6	-0.9646 Close	-0.8360 Good	-0.8029 Young	1.0289 Slow	51.8	27.1	46.9
7	-1.1674 Close	-0.0747 Average	-1.0569 Young	2.1717 Very Slow	64.7	35.3	47.0
8	0.6857 Average	-0.8230 Good	-0.2766 Middle	-1.8021 Very Fast	1.9	0.0	5.8
9	0.6482 Average	0.7075 Low	-0.7999 Young	-1.8531 Very Fast	2.1	0.0	2.1
10	0.9147 Far	-0.1792 Average	-0.6059 Young	-0.1122 Average	5.5	1.6	3.2
11	0.9210 Far	-1.0454 Good	-0.5420 Middle	1.0003 Slow	19.0	12.0	25.0

12	1.1179	1.3228	-0.4708	1.2434			
	Far	Low	Middle	Slow	12.9	16.1	19.4
13	1.1848	1.4896	-0.4650	-0.2343			
	Far	Low	Middle	Average	0.0	0.0	6.0
14	1.0296	0.6297	1.3872	0.0079			
	Far	Low	Old	Average	5.5	4.9	3.1
15	0.9126	-0.9682	1.0993	-0.4415			
	Far	Good	Old	Fast	12.6	8.7	6.8
16	0.6830	-0.9043	1.4257	0.9387			
	Average	Good	Old	Slow	37.0	37.0	28.3
17	0.7495	-2.0591	-0.0097	-0.0363			
	Average	Very Good	Middle	Average	13.9	8.3	16.7

It is interesting to note that the lower status group makes more use of the window as a detailed information source.

Clusters 8, 9, 10, 13 and 14 have very low levels of store interest. These groups account for 33.8% of the total female flow. The low levels of the first two groups are probably a result of high velocity. The interest of group 10 is affected by the distance from the store front. Groups 13 and 14 have low social status and are in the middle of the street at the extremes of the survey area.

The members of group 16 responded well to the store with an equal number turning their heads and using the window. However there was a slight fall off in store entry which could have been caused by either a lack of appeal in the window display or the store front may have created too great a threshold (Green 1986).

CONCLUSIONS

The relative lack of data meant that it would not be possible to address the task of constructing a stable predictive turnover interface. In order to do this a number of further surveys should be carried out with the aim of determining how the weather and season affect behaviour so that these factors can be taken into account in the predictive process. The impact of further work is unsure and two outcomes are possible. Firstly the numbers in each of the cluster types might change relative to each other as trip motives alter. The second outcome might be the development of different groups as people unable to come to town on the Thursday display different characteristics. Unfortunately it was not possible to test the predictive capacity of the cluster solutions with the other existing, December 1986, data set. The December survey data had no record of store interest and no measure of distance from the store.

This section of research has still not addressed the question of pre-planned shopping. It has been seen during the cluster analysis that some clusters show increased interest as commitment rises. Such reversal of the norm is indicative of either pre-planned shoppers or people seeing the store from outside the survey area (see chapter 5). The amount of pre-planned shopping may be accounted for in the cluster solutions, i.e. each cluster may have a fixed proportion of pre-planned shoppers and indeed the pre-meditated shopper may be grouped in particular clusters as seen in those with increasing interest. The other clue may come from the types of product sold. Certain products are more likely to bought in a pre-planned manner and this might be determined through interview. Product sales of a store could then be used to try to establish the extent of preplanned shopping. This knowledge could then be used to try to identify the type of patterns and processes behind pre-planned shopping.

There are still some areas that require investigation. For example non-pedestrianised streets provide a barrier to flow between opposite pavements. This is bound to restrict impulse purchasing as the perceived effort required to cross a road can be high. Local effects such as the presence of a pedestrian crossing or a bus stop again may produce different groups or shift the balance between the known groupings. At present such factors will have to evaluated intuitively.

This work has provided clear support for the theory that pedestrian structure and behaviour have a profound effect on store performance. The impact on trading will vary between types of store but in this case it has been possible to separate groups with heightened levels of store interest. This conclusion has two benefits. Firstly it enables the property manager to formalise the pedestrian element of site selection. Once the high penetration groups are known, the flow past each potential site can be evaluated in these terms during the site visit. Secondly it provides encouragement to continue the investigation into the effect of flow patterns and spatial competition on store turnover.

CHAPTER 7

CUSTOMER CIRCULATION IN STORES

The aim of this chapter is to investigate the possibility of transferring the data collection and analysis techniques developed in the City centre work to the confined in-store environment. Boots, a major U.K. retail chain, approached the RAT to see if it was possible to devise a store wide monitoring system that would tell the company where people were in the store, where they did not go and what the conditions were like at various points within the store. They had the belief that many of their stores were not creating the right environment for the retail exchange process and as a consequence some of the stores were under performing. There was also the desire to understand how customers move within the store and the effect of psychological cues such as queuing and display systems.

This chapter will initially discuss the similarities between the store and pedestrian environments and then some of the aims of a store designer and the common layouts employed. The standard techniques of in-store behavioural investigation are discussed in context of the focus of the research. The development of the chosen survey method, time-lapse photography, and the data requirements are considered. Finally the theory and development of the analysis and presentation programs are explained. The following chapter (8) will illustrate some examples of the survey and analysis systems in operation.

STREET AND IN-STORE ENVIRONMENT SIMILARITIES

Conceptually the in-store environment is in many ways very similar to the city centre. Products, or merchandise categories, can be likened to stores in their capacity to affect movement and behaviour. Products like stores have different generative capacity (Nelson 1958). In the retail world products are classified according to their drawing power. Davidson et al. (1988) distinguish between impulse and demand goods. Impulse goods are bought on the basis of unplanned decisions and no particular pattern can be attached to their purchase. Demand goods are usually staple items but also include products such as cars and white goods.

Buttle (1984) reports on the strategic placing of demand goods drawing customers through the store. Spatial associations between products generate particular traffic patterns that vary according to customer type. Secondary products, like small city centre retailers, are "suscipient" and require traffic generated by other items.

The aisles or routes within the store are analogous to streets in the city centre. They provide the means by which customers are able to move around the trading area to the products that they require. At junctions and along the aisle lengths the shopper is faced with the same directional questions faced by the pedestrian in towns. In the retail environment it is important to make destinations clear and routes attractive. A number of workers (Buttle 1984 and Davidson et al 1988) describe the different types of route such as go tracks, which are designed to move people around the store and into browsing areas deliberately designed to slow pedestrians down and encourage shopping. Route usage is controlled by aisle widths, attractiveness, crowding, product categories and potential destinations.

The similarities between the two environments provided a consistent theoretical background to allow transfer of the techniques developed in the earlier work. In many respects the internal environment provides a much better base for a movement study. Firstly the number of access points is limited and their positions are known. This allowed detailed knowledge of store numbers to be obtained. In the city centre it is possible to enter the pedestrian environment on any street in the network. The reduction in total survey area allows more complete coverage of the flow system. Because the whole of the in-store environment was monitored, it was possible to track people through the store sighting them at various points on their trip although in practice this proved too time consuming. From an operational viewpoint the "in-store" environment is more stable and does not suffer from extremes of cold or light thus increasing the reliability of the camera systems.

STORE DESIGN AND SALES

The function of any store is to facilitate sales of the products held within it. In pursuit of increased sales Buttle (1984) highlights three aims of retailers:

1) Attract the optimal number of shoppers into the store.

2) Encourage customers to spend more

3) Balance the desire to maximise profit with the need to make the customer's shopping trip pleasurable.

Grid-Iron Layout

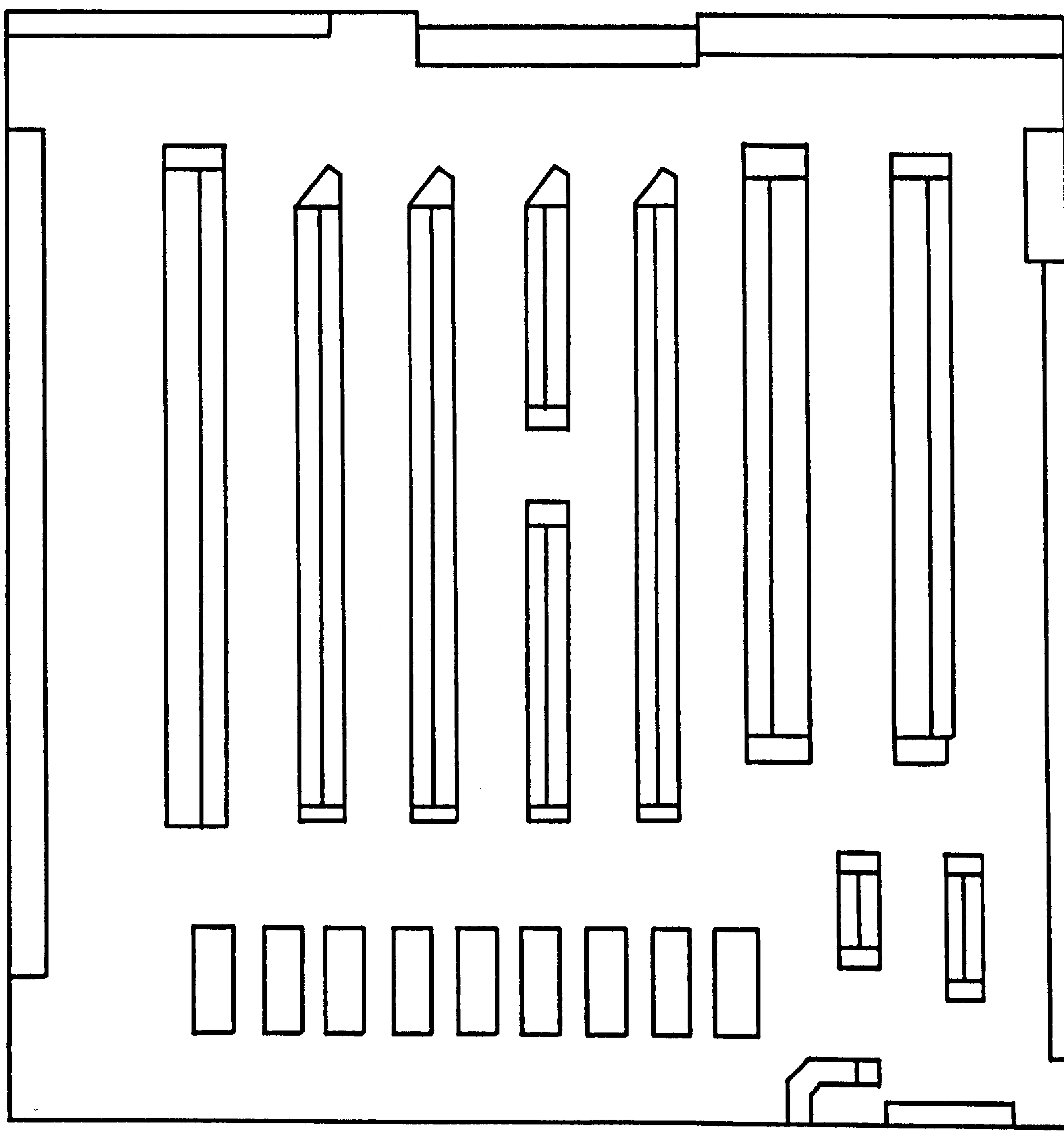


Figure 7.1

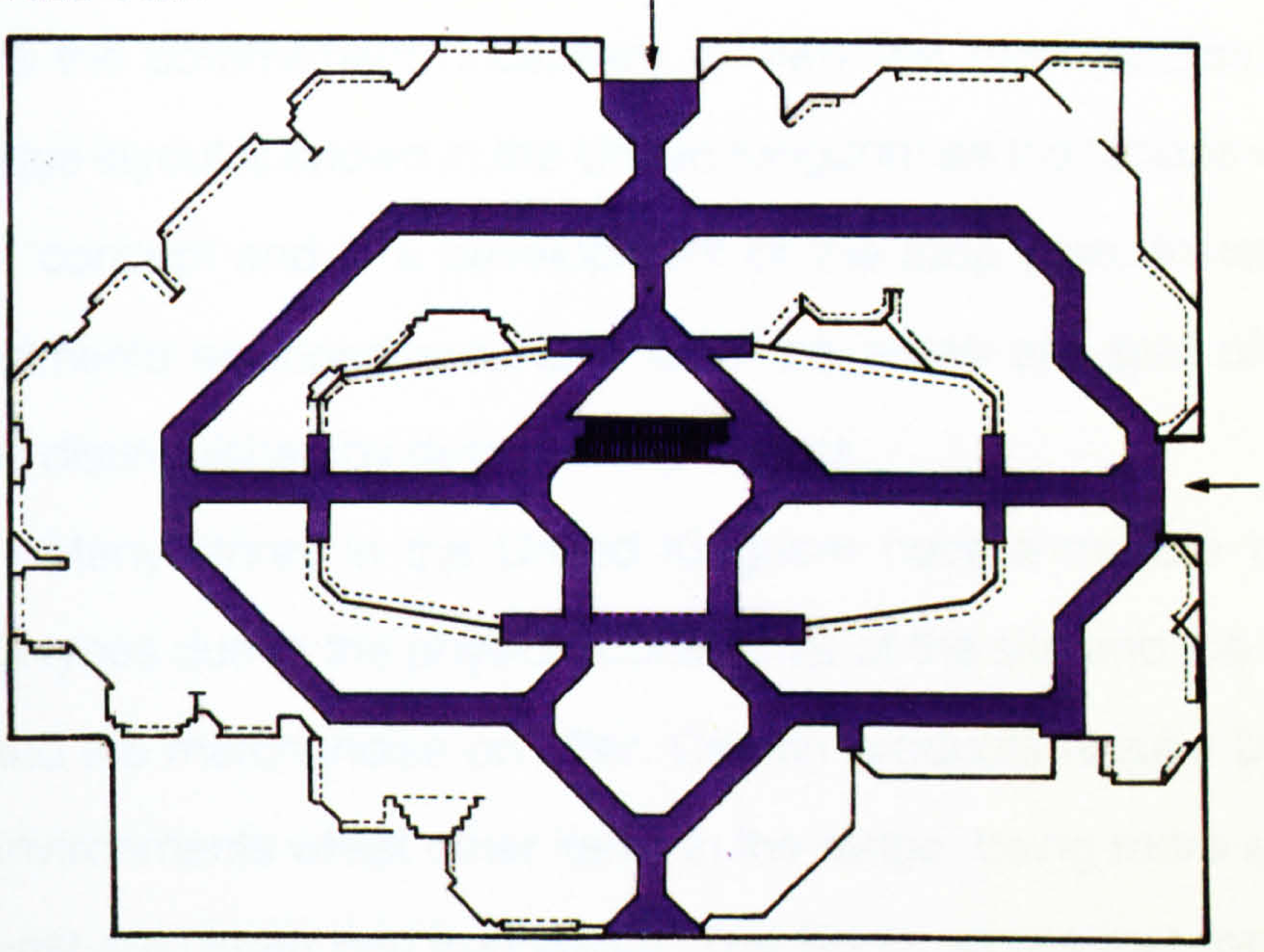
This part of the project is only concerned with the latter two. Increasing customer spend through traffic manipulation as opposed to other techniques, such as display and pricing, can be achieved by altering store layout and the repositioning of items and departments within the store. As mentioned earlier route usage is affected by a number of factors within the purview of the store planner. The Progressive Grocer (1975) noted during its study of supermarket shopping that the longer the time spent in a store the greater the amount of money spent. In effecting any change in layout it is important to make the shopping experience as pleasurable as possible to increase the amount spent in each trip and encourage return visits.

Typical Store Layouts

Store layout is crucial to the success of a store. The type of plan used has to suit the merchandise on offer as different types of product require different types of selling area. Davidson et al (1988) identifies three basic types of store plan; the grid iron, the free flow and the loop. Ghosh (1990) adds a fourth category, the "boutique", to the list. The grid iron pattern (figure 7.1) is commonly seen in supermarkets and according to several authors is favoured in this setting because it exerts control on the flow pattern and exposes the maximum amount of merchandise. The free flow system (figure 7.2.A) lacks the uniformity of the grid and aims to create a more relaxed atmosphere and encourage browsing. There are main aisles to encourage store penetration and low thresholds to movement into the browsing areas. Such a layout is suited to purchases such as clothing that require a higher commitment than foods. Davidson et al (1988) defines the loop (figure 7.2.B) as a series of free flow areas arranged about a wide curving pathway known as a loop or

TYPICAL STORE LAYOUTS

A: FREE FLOW



B: LOOP

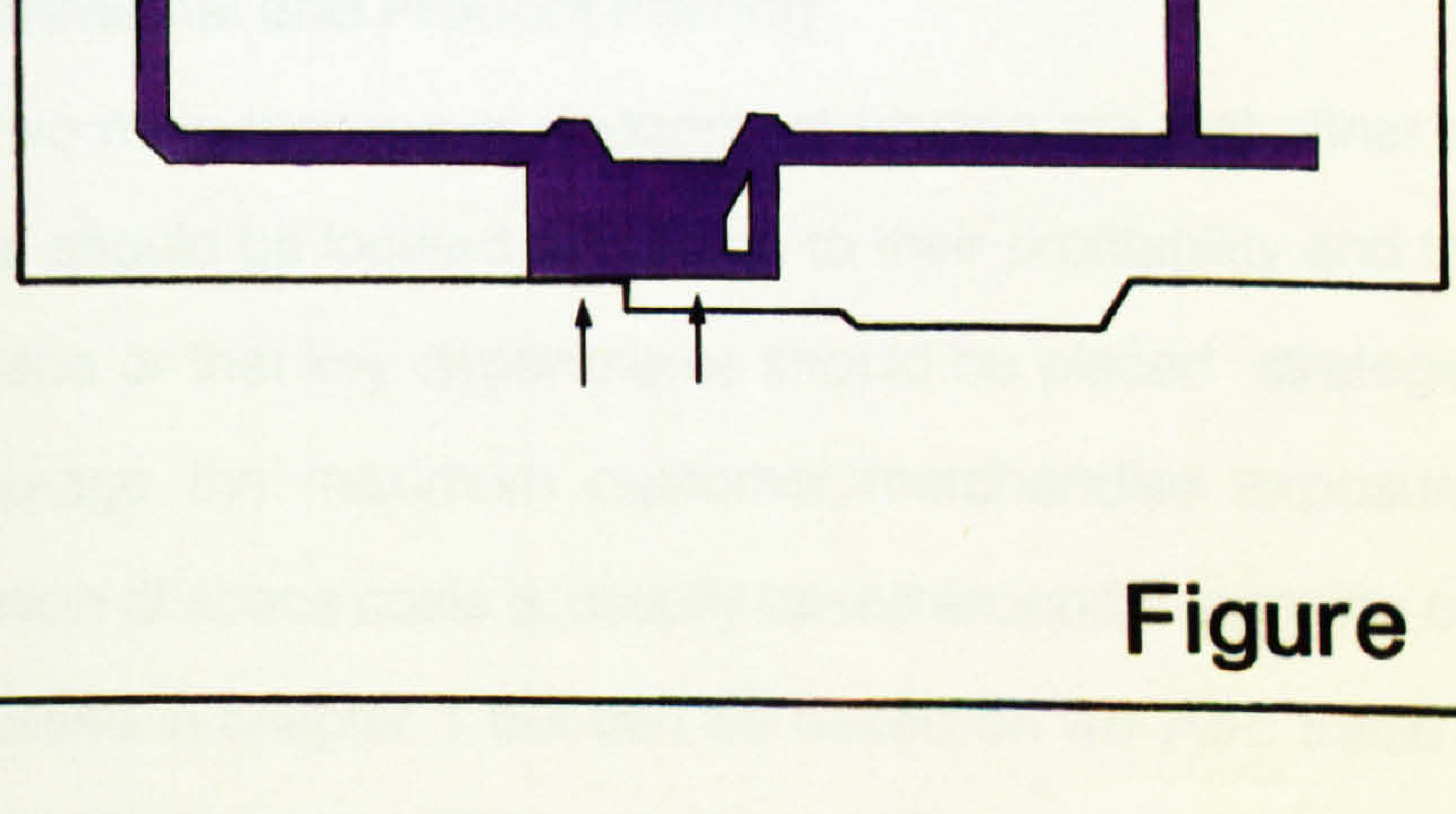


Figure 7.2

track. The loop lowers the effort needed to move through the store thus encouraging full store shopping. If an interesting department is seen the customer can move off the loop and into the area without having to fight through a number of other departments first. This lowers the commitment necessary to view the merchandise. The boutique layout is known in the United Kingdom as the "shops within shop" concept and is a development of the loop plan. Instead of departments arranged around a loop the areas are split off into stores distinguished by design and products.

Many stores in the United Kingdom have a mixture of the layout types due to the physical constraints of the site and the building and the merchandise on offer. Certain products require browsing environments whilst other items in the range, being more staple, are best sold in an grid iron layout. The Boots stores that form the majority of those surveyed carry a vast range of products and as a result many of the layouts incorporate a wide variety of design philosophies. This style mixture was thought to be a major problem as it can cause overload and confusion in the shoppers mind. When designing the store and planning the merchandise layout it is necessary to understand how people will interact with it.

Departmental and Product Placing

The two main theories of department placing are that either departments should be located according to their profitability and the cost of space or that key departments should be placed strategically to encourage the maximum customer/merchandise exposure. The valuation of space costs is usually based around the zoning concept discussed in chapter 1 but can be based on *ad hoc* traffic counts within stores (Davidson et al 1988). This latter approach seems a little uncertain because the traffic is generated by the departments as well as the physical layout of the store in terms of aisles and escalators etc. Thus traffic is not a true reflection of space value. The strategic placement of key departments is best seen in the supermarketing environment. The vegetable, frozen foods, fresh meats and bakery are spaced in such a way as to encourage maximum store exposure. Increasing exposure is further aided by micro location of product category within the department. Buttle (1984) reports on the creation of a bounce pattern by placing the demand categories on alternate sides of an aisle. However as McGoldrick (1990) points out the customer must not feel he is being taken somewhere he doesn't want to be.

Merchandise Display

Davidson et al (1988) cite two functions of display. Firstly the need to arouse interest in the merchandise and aid its sale and secondly to reinforce the retailer's image in the customer's mind. The second of these factors is not so important in a study of movement but a third, maintenance of customer interest in the store, does influence subsequent behaviour. If the environment becomes unattractive shopping inertia will re-establish itself and customers will seek an exit.

PREVIOUS WORK IN STORE MOVEMENT

Previous movement and behavioural analysis work in the retail field has largely been conducted using three data collection techniques (Granobois 1968); inventory or purchase audits, entry/exit interviews and direct observation. Two other techniques, electronic counting and photographic/video recording, have also been used.

Inventory Audits or "Basket" Studies

Granobois (1968) reports the use of audits to monitor response to price or merchandising changes. Attempts have also been made to examine customer shopping baskets to determine linkages between the products bought and use the product locations to map behaviour. Basket analysis is now more easy because the availability of EPoS data (Rogers 1985) identifies all the products that each customer purchases. This type of data can be useful in the tactical positioning of departments in a store to maximise merchandise exposure (Buttle 1984). However "basket" data does not facilitate the recreation of trips as the location of the product gives a limited number of known points of the trip but does not give the sequence of purchases or examine those areas of the store that were visited but not purchased from. Inventory or purchase audits do not themselves give an idea of how people use the store and as such are not suitable for this project.

Interviews

Interviewing is a common technique for research into in-store behaviour. Interviews are normally conducted at entry or exit points and can cover a range of topics. Granbois (1968) reports on the use of entrance interviews to determine the nature of purchases planned prior to using the store in question and the demographic structure of the customers. Kollat and Willett (1967) used both in-store and home interviews during an investigation of impulse purchasing behaviour. Later studies of impulsive buying by Weinberg and Gottwald (1982), and Cobb and Hoyer (1986) also used interviews.

One of the major problems with questionnaires is the difference between the stated and actual behaviour of the respondents and the lack of recall of minor, seemingly inconsequential events. Discrepancies in stated and actual behaviour can be caused by two factors. Firstly subjects may change their mind upon entering the store and secondly they may not give an accurate account of their intentions/actions. The former can be overcome in a number of ways. Johnson and Welch (1989) suggest using both entry and exit interviews to assess the difference between intentions and actions. Kollat and Willett (1967) and subsequently Iyer (1989) used comparison of pre-visit lists and actual purchases to assess the degree of impulse purchasing. The latter source of error can be eliminated by using other techniques to support interviews. Cobb and Hoyer (1986), Iyer (1989) and Granbois (1968) supplemented an interview with a record of in-store behaviour. Weinberg and Gottwald (1982) interviewed customers after their behaviour had been recorded on film. Apparently no researcher has attempted to use the Hart and Thompson (1968) aided recall technique to produce movement plots.

This research required as near a blanket survey as could be obtained and it was felt that the intrusion of an army of interviewers would cause too much of a disruption and the interference with the subjects may make the results unreliable. For the purposes of this type of work interviews could not be relied upon to give accurate movement data. However interviews could be used to investigate particular problem areas if it was thought necessary.

Tracking or Direct Observation

A common method of obtaining information on customer behaviour is by tracking them through the store. Rogers (1985) states that "In-store tracking studies are a simple, long established research technique". Unlike questionnaires no real research background is required as the tracker only has to mark the customers path on the store plan. As mentioned earlier several workers report the use of observation in conjunction with interviewing. Wells and Lo Sciuto (1966) used direct observation to monitor customer behaviour in a single aisle in the supermarket environment. Observers stood in the aisle and noted customer "episodes". Only those people who had an apparent intention to buy were observed. The Progressive Grocer (1975) used in-store tracking to monitor behaviour in supermarkets.

As several of the proponents of this technique point out simple track data can be enhanced with purchase and product handling information. The Progressive Grocer (1975) study used such measures to develop a hesitation index from the ratio of those who handle products but don't buy to those who do buy. Anomalies in these types of ratios can be used to target subsequent questionnaires. Rogers (1985) suggests marking the plan with an 'X' or a '0' to mark such events. The problem with direct observation is that there is no data on the motivations for behaviour and this can lead to misinterpretation (Doyle and Gidengil 1977, McGoldrick 1990).

This technique would seem to be limited because of the time taken to complete the track. The Progressive Grocer study (1975) recorded 817 tracks in 144 hours but there is no mention of the number of trackers. In this case the average time in-store was 34 minutes implying a tracking rate of under 2 tracks per person per hour. In the Wells and Lo Sciuto study the observers averaged only 2.5 tracks, or "episodes" an hour. In order to get the required data set it would be necessary to flood the store with trackers which would raise serious questions of data reliability.

Electronic Monitoring Techniques

Electronic techniques are frequently used to provide an estimation of the numbers of people entering a store. The most common method employed is the broken beam counter. Studies conducted by the Retail Analysis Team have shown that as in the case of pedestrian work the accuracy is questionable. In a survey conducted in the Arndale Centre, Luton a single light beam and counter were placed at the 10 metre wide entrance to the Boots store. The counter registered a person as the beam was broken. The equipment was set at a level of 0.75m. This was deemed the optimal height to avoid double counting through people's legs but also to make sure that most children were included in the count. A control count was obtained through a continual video record of the door area. Over a three and a half hour survey period the counts ranged from 54% to 99% of the true flow figure. This inaccuracy was caused by people loitering in the doorway shielding the counter and thus multiple customer entries. Stationary people would cause serious problems for a store wide broken beam counter system. Pressure pads have been used to monitor pedestrian traffic levels (Cameron 1974) but no evidence of their use in-store has been found. Electronic counter techniques also suffer from a lack of directional and behavioural data.

Photographic Techniques

Photographic techniques are a development of typical tracking studies. The recording media varies from the continual, video or cine cameras, to time-lapse systems. Both techniques have been tried in-store by the RAT.

Continuous Video

Video presents an appealing option for in-store surveys due to the ease of use and the availability in many stores of comprehensive security camera systems (McGoldrick 1990). Weinberg and Gottwald (1982) used video cameras to record and analyse impulsive buying sequences. During the work reported in chapter 5 a simultaneous study investigated in-store behaviour by the use of video filming. The technique proved to be a good basis for the analysis and classification of micro behaviour. A camera was fitted with a wide angle lens and was positioned to give a view of the whole of the store interior (180sq ft). It proved possible to record head and eye movements, product handling, product queries and the search and purchase sequences. In most areas of the store analysis presented no real problems but at the rear of the camera's view the ability to distinguish between units was diminished. In order to counter this display areas were agglomerated to remove uncertainty. However this had the effect of reducing the value of the data. If a record of micro behaviour is required then video or some other near continuous record is required. However in this study a comprehensive analysis of the patterns of all customers in much larger stores was the objective. As stated in chapter 5 the time taken to analyse the film was enormous and in a multi camera situation would be prohibitive.

Time Lapse Camera Surveys

In a study that aims to record the performance of the store in terms of handling the people inside and allowing them to shop within it, it is more important to view the whole store at an instant than a small sample of complete individual tracks taken at various times during the day. A multi camera time lapse system allows the rapid collection of data throughout the whole store as the data logging is separated from the data collection. This technique does not seek to predict individual behaviour because in terms of store performance it is not the individual that is important but typical aggregate tracks and patterns of behaviour.

The use of time lapse camera systems in the retail field does not seem wide spread. Underhill (1989) used time lapse camera systems to monitor customer behaviour at checkouts but the operational aspects are not discussed in detail. A time lapse system was used for the in-store surveys because it fulfilled the data requirements of the project and the cost of performing the survey were not excessive.

CAMERA EQUIPMENT AND DEVELOPMENT

The time-lapse system used in December 1986 was too bulky to be transferred to the in-store environment. In order for the system to be acceptable to the retailer each survey unit had to be small and unobtrusive both visually and aurally. The main task therefore was to miniaturise the camera controller. A 15 by 10 cm battery powered computer was designed by Dr Tom Cross for this purpose. There were three essential units on the printed circuit board (PCB). Firstly there was a low power Z88 microprocessor which formed the heart of the unit. The software instruction set was put onto an EPROM. The memory of this chip can be erased and rewritten thus permitting software updates if required. The third vital chip was a reed switch that sent the shutter close signal out to the camera. The camera was operated via a jack plug as before. The real time clock was derived from the timing crystal whose frequency was fine tuned by a variable capacitor. It was possible to communicate with and command the computer via a socket. The terminal used was a Psion organiser. Special RS232 circuitry was added to the Psion in order to reduce the strain on the controller's batteries.

The software to drive the system was designed to be as flexible as possible. Seven commands were available to the operator:

1) Set present time
2) Set survey start time
3) Set survey stop time
4) Set gap between sample time
5) Set number of shots in each sample
6) Set interval between multiple shots
7) Activate controller
8) De-activate control sequence

In order for the unit to know when to operate it had to be given the correct time and the time that the survey was to run. The gap time between shots was determined by the requirements of the survey and posed a fixed limit on the duration of it. Commands five and six were designed to allow the gathering of speed data if desired. Once the controller was programmed and activated the unit could be sealed and left alone.

The initial batch of circuit boards were very temperamental as the boards had been over-etched during manufacture. Tiny cracks had been created in the copper tracks which acted as additional capacitance. The result was that the boards either would not start or occasionally failed once they had been started. These problems were rectified through the purchase of a set of professionally produced boards.

The cameras used for this section of the project were mainly Olympus OM2SP's. The basic camera was fitted with an auto winder and a bulk film back which increased its capacity from 36 to 250 shots. The camera was fitted with a wide angle 28mm lens. This increased both the view angle and the depth of field meaning that more of the image was in focus when compared to a standard 50mm lens. There were a number of initial problems with the cameras but these were ironed out with a little modification to the internal connectors. The most recent survey also used 20 Ricoh FF9-Ds. The Ricoh is a standard auto focus compact camera but it has a remote firing facility with a jack input, a data back and the ability to set the focus to infinity. As each Ricoh only holds 40 pictures it was necessary to reload the units if they were to maintain the same firing rate as the Olympuses. The firing rate was kept constant by placing two Ricoh units at each location and alternating their operation. There have been very few operational difficulties with these cameras.

The camera housing was weatherproof to the IP67 standard. This allows the unit to be placed outside in any conditions which was desirable for town surveys. The box consisted of a opaque back with a clear perspex front. A 13 cm hole was drilled through the perspex and a clear glass plate fitted. The computer was fixed to the inside rear of the box and the external terminal socket to the side. The camera was held in position by means of a screw through the box into the tripod thread. Foam was placed between the camera and the box to provide sound proofing. The glass plate was masked over and the exterior of the unit painted the same colour as the survey store and the interior painted matt black to avoid any internal reflections off the glass front. The box had a flexible mount attached to the rear that allowed movement in two dimensions. The units can be mounted almost anywhere either on stands, shelving brackets or pillars. During the surveys there has been no known complaint about the units and a very low awareness of their presence.

Surveying Procedures

The typical camera survey component of an in store survey can be divided into five sections. An initial inspection of the store is conducted to find potential camera mounting sites and to check the field of view from these locations, by taking experimental pictures from each potential site. Once these pictures have been processed final locations are determined by marking the practical field of view on the plan and seeing which combination of sites gives the best coverage. The number of cameras used depends on settling the compromise between minimising the amount of film to analyse and maximising the coverage of the survey area and the picture quality. Blind spots and views with sharp lighting contrast, which can upset the cameras light meter, have to be avoided.

Prior to the start of a survey the cameras units are mounted before store opening in their chosen positions, loaded with film and programmed. The normal interval between shots during a survey is one minute giving a standard survey period of 4 hours. This can either be in one block or split according to the times of interest. At the end of the day all film is removed and the cameras set up overnight for the next days operation.

DATA COLLECTED

Two types of data were extracted form the film. Data describing the personal characteristics of age, sex, socio-economic group and social associations have been consistent throughout the research and similar classification difficulties arose as discussed before. The second category was behavioural in that the data classified where the person was, the time of the sample and what activities were being undertaken.

Camera Number

This variable recorded the camera number from which the individual was sighted. Each camera was given a number that allowed cross referencing from the data to the store plan. Each camera covered a certain area of the store so incorrect placings could be recorded and investigated. It was common practice to stagger the firing times of the cameras through the one minute interval time so the camera number could be used to determine the exact time of the photo.

Location

A customers location was recorded on an X-Y grid that had been laid over the store plan (figure 7.3). Each grid square was approximately 1 metre square. The photo interpreter determined the position of the customer on the photo and found the corresponding place on the plan. Only two analysers had difficulty with this spatial positioning, and this became quickly apparent.

Time of Sighting

The time of the sighting was important for the subsequent analysis procedures. Initially a record of the time was obtained from an analogue clock placed in the field of view of the camera but in the newer Ricoh units the information was printed on film by the data back. Although the interval between the shots had been set as a constant it was important to have a record of the actual time because of the initial unreliability of the cameras and the subsequent uncertainty that this caused.

FLOOR & GONDOLA PLAN

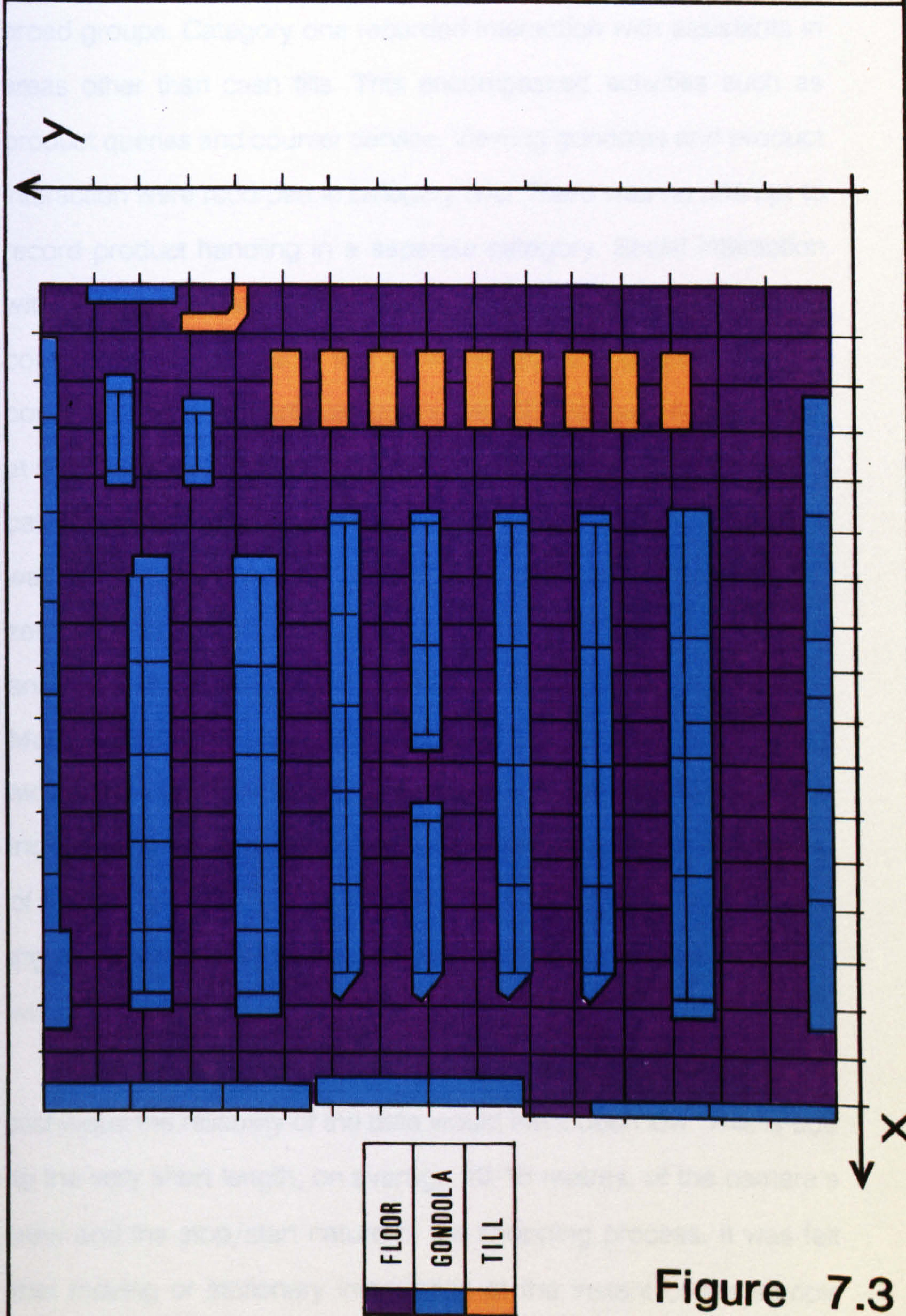


Figure 7.3

Activity

In order to gain an insight into what people were doing in the various parts of the store each customer's activity was classified into six broad groups. Category one recorded interaction with assistants in areas other than cash tills. This encompassed activities such as product queries and counter service. Viewing gondolas and product interaction were recorded in category two. There was no attempt to record product handling in a separate category. Social interaction with other customers was recorded in category three. It was quite common to see groups of four or more people engaged in lengthy conversations. The fourth category covered time spent being served at the checkout and paying for products. Queuing was recorded in category five whether it was for service or for the checkout. If there was no particular behaviour the customer was registered in category zero. The categories chosen reflected the concerns of the retailer and were not intended as a basis of a behavioural study.

Movement

Movement was recorded as a a binary yes/no variable. Movement is indicated by a number of customer characteristics such as blurring of limbs or a walking pose. The element of inaccuracy in the recording of movement is unknown because it is impossible to check without a continual data gathering technique.

Although an idea of speed may have been useful with this technique the reliability of the data would have been low. This is due to the very short length, on average 10-15 metres, of the camera's view and the stop/start nature of the shopping process. It was felt that moving or stationary information at the instant of the sample would provide the most practical and useful information base.

MOVEMENT DIRECTION

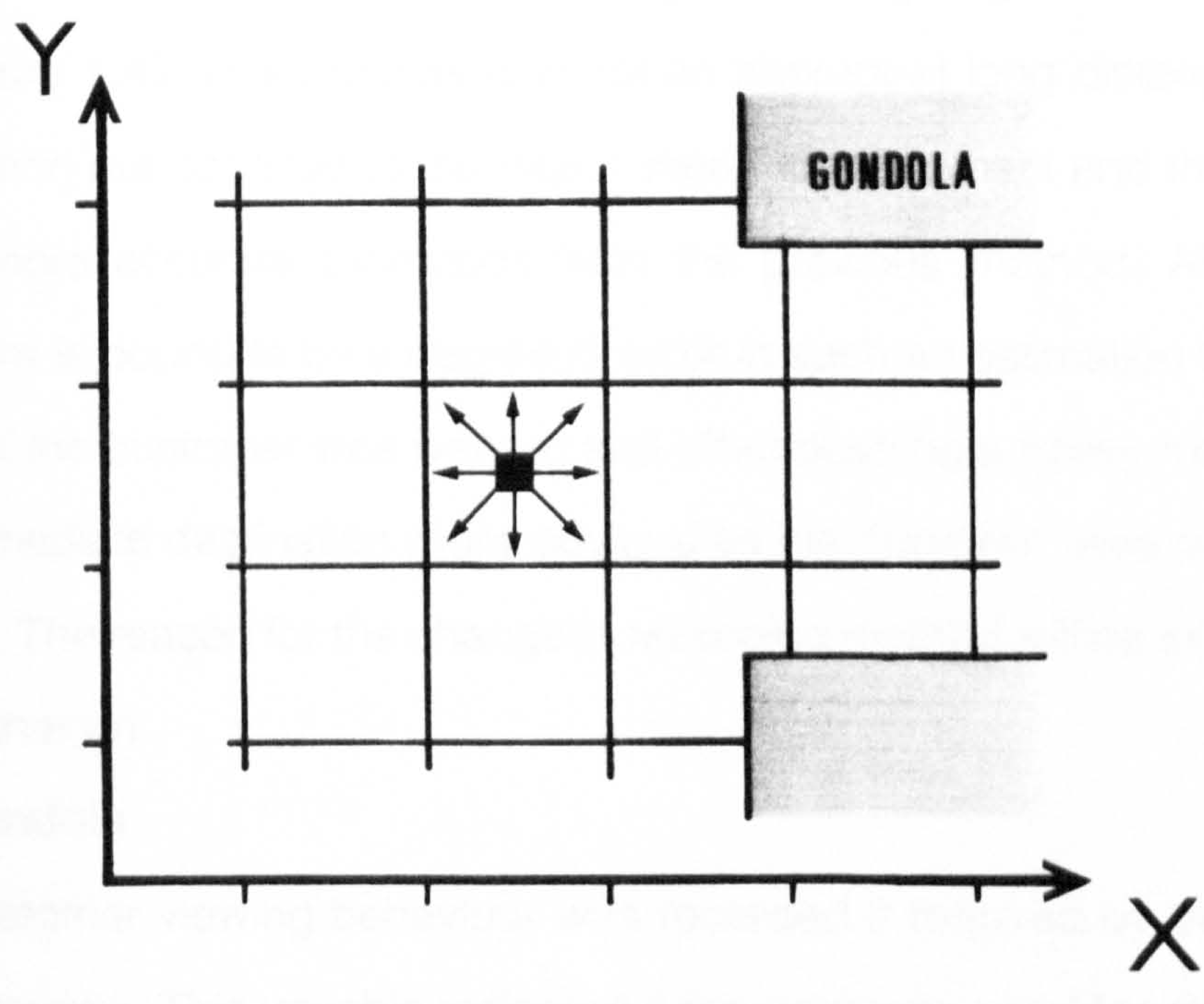


Figure 7.4

Direction

If a customer was seen to be moving his direction of movement was recorded for the subsequent modelling processes. The method of recording this variable changed as the modelling emphasis switched from the WONKA style flow map to a probable path diffusion model. Initially direction was recorded with reference to the node to which the customer was travelling as in the town surveys. However during the last two in-store surveys the X and Y coordinates of the square to which the customer was thought to be going were recorded (figure 7.4). This process was not an attempt at long distance estimation but confined to the next 1 metre of movement and thus was a more accurate estimation than the previous method. Although there is bound to be a degree of error in such an estimation the fact that the customer was walking and often pushing a trolley made the immediate destination more obvious as his "footprint" was substantial. The reason for the change in recording method will be explained further on.

Gondola

Customer viewing behaviour was recorded if required by the client company. This variable indicated if the area was used for shopping or merely transition from one part of the store to another. Sales data could be used but viewing is a better measure as it is a much earlier stage in the purchase process. Product viewing suggests that the area is being 'shopped' whether products are bought or not.

Each of the display units, commonly called gondolas, were divided into sections and allocated a number. In order to keep within the computer system limits the number of zonal subdivisions was limited to about 100. Efforts were made to maintain a constant size of unit but this became difficult with gondola ends, promotional units, till areas and small "island" gondolas. Analysis of viewing behaviour from the film was helped by the large area of each display section and the customer cues such as product handling.

There was no attempt to rate the level of interest shown in the products. In the Thorntons in-store work it had been possible to note product handling and detailed examination as well as customer queries through the video's sound track. Gathering this data was too time consuming for the this type of project. If viewing were to be the focus of the survey the data collection technique might have to be modified.

Customer Tracking

During the initial surveys attempts were made to track each individual through the photographic record of the store. This lead to a great increase in the amount of analysis work and for many of the clients the data was not as useful as statistical average behaviour. This is a more reliable predictor of store performance. Tracking was accomplished by laying the film from each of the cameras over a light box and examining the films with a magnifying glass. This proved to be very tiring for the photo interpreters. When tracking was discontinued it became possible to use a desktop projector which magnified each shot to A4 size. This proved to be a much better arrangement and reduced analysis time considerably.

COMPUTER MODELLING OF CUSTOMER DATA

Once the film had been analysed it was necessary to manipulate the data so that in-store behaviour patterns could be understood. To this end two major computer programs were used. The first, WONKA, has been described earlier (chapter 3). The flow model didn't require any modifications to work in the internal environment but the data did require substantial reprocessing. The second, PRETTY, is an animation program which allows the regeneration of the behaviour recorded on film and subsequently in a database. The recreation of behaviour can either take the form of a display of actual movement and densities, or the calculation and display of the probable movement paths of customers from one area to another. PRETTY also allows the investigation of viewing behaviour. Both models could be built using any preselected data set. Ashton Tate's dBaseIV was used to extracted the required data set according to any combination of the variables recorded on the film.

WONKA

In order to make the pedestrian WONKA model applicable to the in-store data it was necessary to perform a substantial amount of data preprocessing. The store had to be divided into links and nodes according to the same criteria used in the town surveys. Each link has to have only two nodes, one at each end. Figure 7.5 shows a typical link and node layout superimposed on a store plan's location grid. This meant that each locational grid square had to be allocated to a theoretical link. In the early form of link based directional measure, (recording the node headed towards) there was no need for further processing, but in the later grid based form each possible destination square had to classified into a nodal direction. The dBaseIV package was used to extract present location, movement and destination data from the customer database. If a customer was not moving towards either node they were classified as non-movers. Once this allocation procedure is complete it is possible to run the WONKA model.

LINK AND NODE OVERLAY

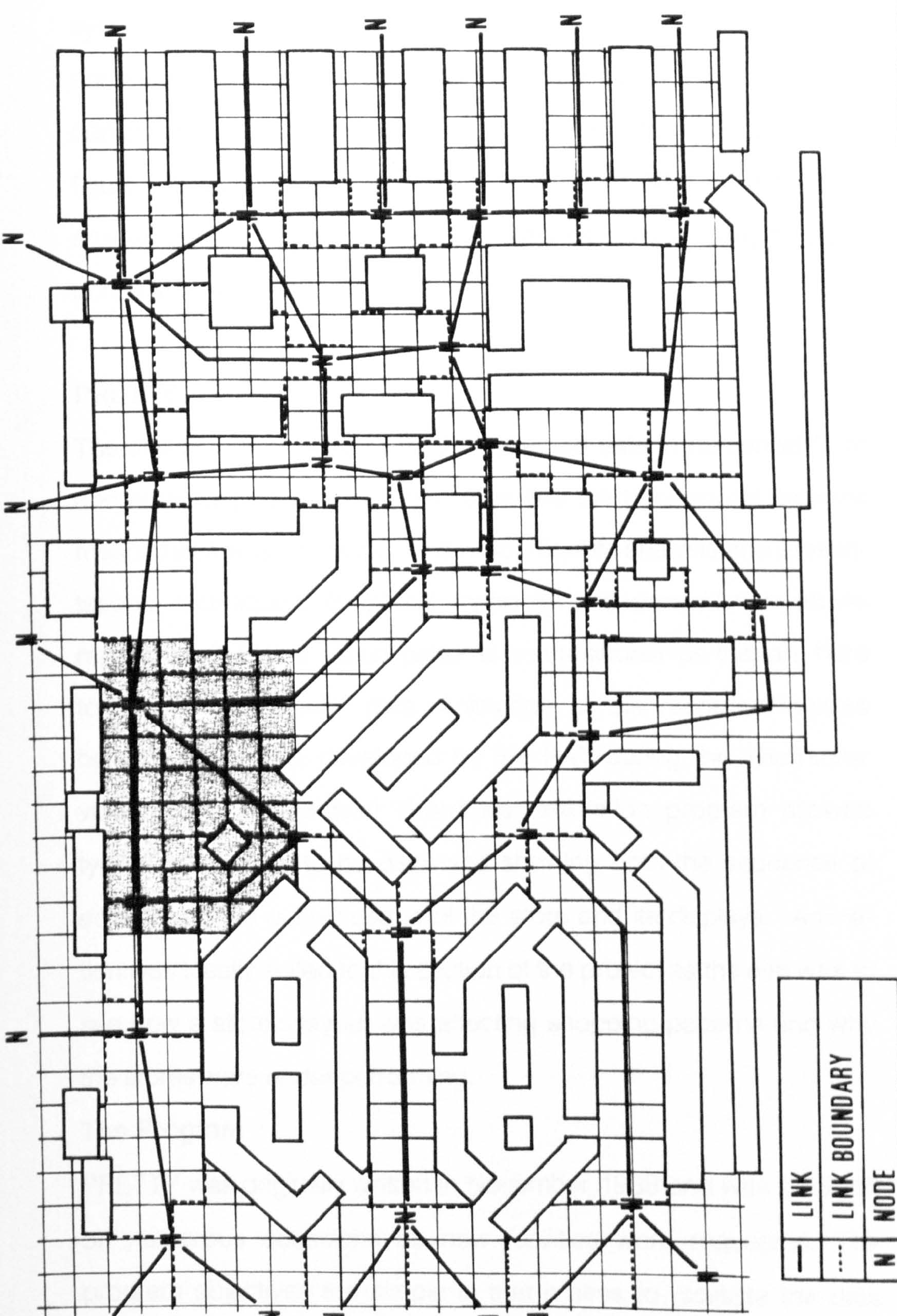


Figure 7.5

The problem with formalising movement in such a way is that the strict link/node system does not always suit a store. In a grid iron style store where there are definite aisles and turning points the system works well but in a loop or free flow environment where there are few barriers to movement and open spaces the simple two way constriction of the link is inappropriate. The Luton plan shown in figure 7.5 is an example of the failure of the WONKA system. The shaded area highlights an example of the difficulty in trying to categorise an open area.

PRETTY

The difficulty in understanding the collected data in numerical form and conveying to other interested parties the behavioural patterns meant that it was necessary to develop flexible analysis and presentational techniques. Graphical mapping and presentation allows rapid assimilation of spatial patterns and relationships that are hard to obtain from tabular data. Animation of the recorded in-store behaviour was first developed by the RAT during the Thorntons' video work. The original Thorntons' animation program allowed typical behaviours to be displayed showing both the sequence of activity and the overall usage of the store and its displays. Animation was ideally suited to this section of the project as the aim was to see how a store's layout was affecting shopping patterns and why the stores were under performing.

The Program

PRETTY was originally written in November 1988 and was modified on numerous occasions as new facilities were requested. The program objectives are simple in that it aims to recreate the data gathered from the film on a store plan displayed on a computer monitor. The basic animation criteria are location and viewing, i.e. what product displays were being looked at. The program starts from the beginning of a time ordered data set and displays on screen the location and viewing pattern of all the people present in the supplied data set in the first time period. (The time period is determined by the gap between the firing of the camera units.) At the next time period the program determines which people have moved from their original location and relocates them to the appropriate part of the store. Newly sighted people are put in their appropriate place whilst those that have left the store are removed from the list of "alive" or present people. PRETTY cycles through the data set exactly recreating what was recorded from the film. At the end of the animation sequence a final display of the aggregate distribution of observed people is displayed on the monitor. The animation and density mapping modules provide a method of observing the development of the pattern of movement in the survey environment by using computer animation linked to the survey data base to display exactly what happened during any period of survey time. Animation time can be set to any multiple of real time allowing hours of survey to be viewed in minutes on the screen.

Program Mechanics - The Colour Lookup Table

The mechanics of the program revolve around a colour lookup table. The graphics controller is able to maintain and display a look up table of 256 logical colours. Each logical colour is assigned to a physical part of the store be it floor or display area. The program calculates the number of people on a particular square in the given time period and sets the logical colour to the required brightness.

This process repeats itself for all the areas shown on screen. The floor and display areas work from different base colours thus aiding the distinction between the two. Because of the finite number of individual colours there is often the need to agglomerate the grid squares used for the locational analysis into larger animation areas. In order to maintain sampling accuracy each of the animation areas should contain the same number of floor grid squares. If one animation area had four grid squares whilst another had only two it would not be possible to compare the results of both without first adjusting for the discrepancy. Because of the analysis problems mentioned earlier display areas are out of necessity already quite large. If the use of product displays was not important it would be possible to turn the facility off and transfer the logical colours set aside for the animation of viewing behaviour to the locational side of the program or vice versa (figure 7.6).

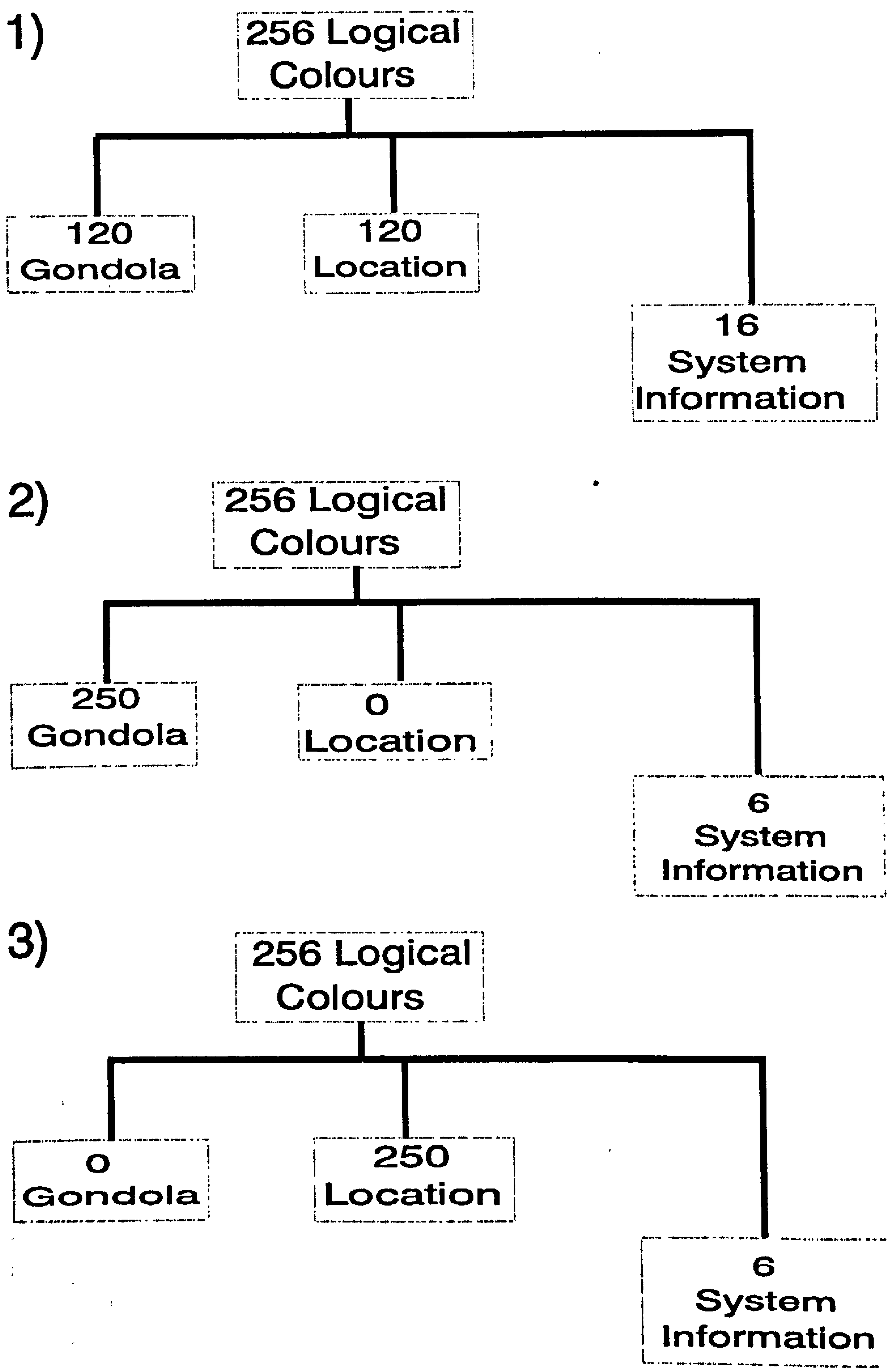
Diffusion modelling

The problem encountered with the simplistic link and node approach used by WONKA was that the specification of a restrained network system did not suit the free flow layouts commonly seen in large stores (figure 7.5). As customers seen in the stores were assigned to a grid location and their direction given relative to the grid it was possible to design a new model of probable movement based on the grid cells.

The problem of determining customers' movements from patch to patch can be overcome by using a simple transition probability scheme related to each patch and its adjacent neighbours. This module was written entirely by Dr M.J. McCullagh. If a customers were seen moving their direction was recorded in the grid cell

Figure 7.6

Possible Divisions of the Lookup Table



coordinates. These locations and directions were turned into probabilities of movement by dividing the numbers moving from one square to another and by the numbers on the source square. This process is repeated for all adjacent squares and a matrix of transition probabilities is constructed. The matrix also takes into account those customers who remain on the same square. Modelling errors can occur if an area is poorly surveyed. For example there was a large recorded flow into an area but no flow seen coming out. The model can detect such cases of positive feed back and numerically compensate for the imbalance. With all such models the predicted results are only as good as the data provided.

Display Options

Within the basic PRETTY model there are a number of options that affect the type of analysis or the display of the results. These can be divided into two categories. Firstly there are routines available to alter the type of data displayed. The two main options are the ability to gain final counts of total customer location and viewing figures. This allows comparative analysis of customer usage of the various parts of the store. For example some parts may be busy but with low viewing activity, whilst others may have little traffic but a high relative viewing figure. Once this is discovered further runs of the program can be made with selected data sets to determine the type of people are in each area. These totals for different parts of the store can be written to file for additional analysis. Another facility allows the user to set crowding thresholds. The user has to decide on the threshold level based on factors such as trolley size and usage, and animation area size. If the number of people in an animation area exceeds the threshold this is displayed on screen thus showing critical crowding levels and the areas that they occur. At the end of the sequence the final display prints out the total occurrence of the critical level during the selected period.

Output Options

The majority of other options are concerned with the style of display and the production of hard copies of the monitor. The animation can be either in colour or black and white. There is also the facility to invert the brightness range. This is used because on the screen the busiest areas should be shown in the lightest colours whereas in a hard copy they should have the darker tones. It is also possible for the user to zoom in and out of areas of particular interest thus allowing more detailed inspection without straining the users' eyes.

The production of hard copies is a three stage process. Firstly the user has to select the area of interest. This is done by placing a window on the screen and moving and sizing it as required. The selected area is then dumped into a file which is printed using a separate program called INKJET. Screen dumps can be either in colour or black and white. The colour system is limited by the types of printer currently available. A full colour screen dump measures about three foot square and takes about three hours to print. The black and white option is printed on a standard A4 sheet and takes about 15 minutes. The printer used, a Hewlett Packard Deskjet, can produce 10 visually distinct grey levels at the full screen resolution of 1024 by 768 pixels. The selective window system for areas of interest was incorporated to allow A4 colour prints to be made but this meant that only a small area of the screen could be reproduced. WONKA was also modified to allow screen dumping.

CONCLUSIONS

The development of a self-contained camera systems gave a great deal of flexibility in terms of survey location and camera sighting. Once a quality set of PCBs were obtained the camera controller worked without hesitation. The large film back cameras have proved unreliable but if extreme care was taken they presented few problems. As far as we can tell very few people have noticed the camera units during a survey. Even during the half hourly replacement of the small Ricoh units very few people even look at them. It would seem that the survey method has not had an impact on customer behaviour.

The development of the programs required a great deal of time owing to the complexity of the animation process and the range of display and output options. PRETTY has proved very successful in communicating the spatial patterns of movement and behaviour. The modal limitations of WONKA have been overcome through the probable path module of PRETTY. This method of path prediction is more robust than WONKA and has a better theoretical base. Movement estimation is limited to short 1 metre lengths and customers can move in any of eight directions. The application of the techniques outlined here can be seen in the following chapter (8).

CHAPTER 8

STORE PROBLEMS & SURVEY SOLUTIONS

This chapter reports on five in-store surveys to demonstrate the approach to problems encountered in real stores, the camera tracking surveys employed, and the results and solutions obtained. The first survey was carried out in a large store with concentration on movement patterns. The second and third surveys, in a small store, examined a store before and after a refit and was more concerned with queues and the relation between the number of customers passing a gondola and the amount of attention it received. The fourth survey was concerned with a single department in a big shopping centre store, and the use of its floor space in relation to preexisting go-track routes. The final example covered the whole of a supermarket and highlights the problem of congestion. There is a discussion of the general findings from all the surveys and of the operational aspects of the survey and analysis systems.

OUTER LONDON SHOPPING CENTRE SURVEY - ROMFORD

Background

The shopping centre of Romford serves a very wide catchment area with shoppers coming from the local area and from counties east of London. There are three main shopping days owing to the presence of a large open market on Wednesday, Friday and Saturday. Many shoppers arrive on specially chartered coaches bringing a steady

ROMFORD STORE PLAN

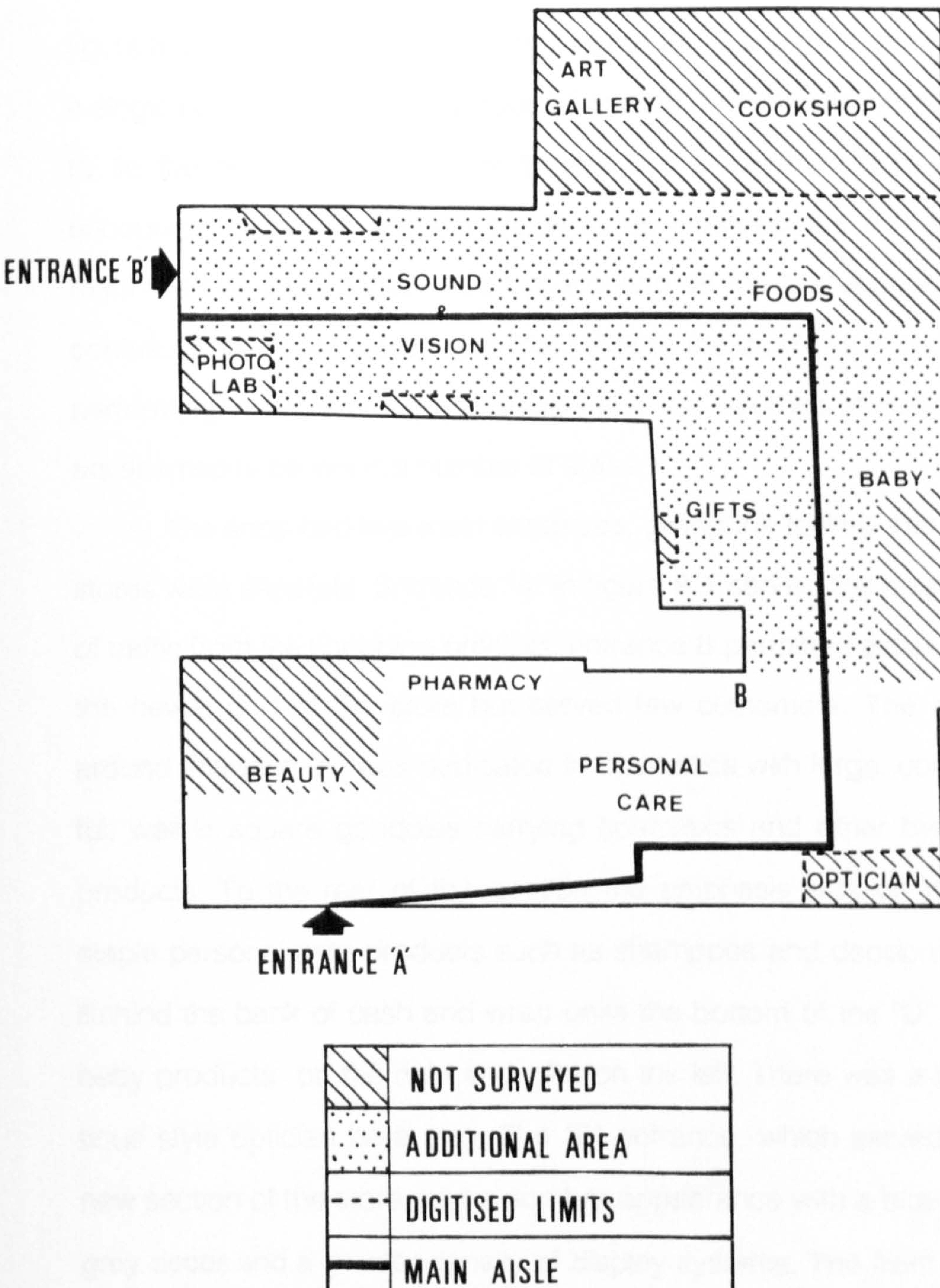


Figure 8.1

stream of "aliens" into the centre. The store, one of the Boots company's, has the dual role to play of both serving the local population's regular needs and providing higher cost items, such as electrical goods and cookware, for the visitors.

The store had a unusual plan which had been caused by the company incorporating additional space as it became vacant (see figure 8.1). The total selling area was about 2400 square metres on a single floor. The store was designed around a main aisle intended to tie the two phases of development into a coherent unit and encourage people to use the whole store. However the management felt that this concept was not working as the layout seemed confusing and there were signs that parts of the store were underperforming in terms of expected sales and the volumes of customers seemed to be low in a number of areas.

The shop had two main entrances, giving the feeling that the stores were separate. Entrance "A" in figure 8.1 served the majority of traffic from the shopping precinct: entrance B permitted access to the newer part of the store but served few customers. The area around entrance "A" was dedicated to cosmetics with large, colourful, well lit square gondolas carrying cosmetics and other beauty products. To the rear of this section the emphasis was on more staple personal care products such as shampoos and deodorants. Behind the bank of cash and wrap units the bottom of the "U" had baby products on the right and gifts on the left. There was a boutique style optician here also. The "B" entrance, which served the new section of the store, had a sombre appearance with a blue and grey decor and a greater density of display systems. The front section was an audio visual area offering photo processing, records and small audio/visual electrical goods. To the left of the go-track there was an artistic print gallery and behind this another boutique selling cookware. It was estimated that the company carried about 200,000 different product lines in the store.

The store encompassed a number of conflicting design philosophies leading to sharp contrasts in trading style and layout criteria. The older traditional part of the store adopted a supermarket style design with long gondolas on a grid layout. There was no demarcation between design walkways and shopping areas. Other areas embodied the newer philosophy of demarcation between go-tracks, thoroughfares, and browsing areas. The gondolas in these areas were arranged either perpendicular to or herring boned off the go-track. The rear of the store, the bottom leg of the "U" shape, was a mixture of the two ideas. There was a main aisle, but the surface was not distinguishable from the floor around it and the areas immediately to either side were grid like. Aisle widths in this area were not great considering that prams were expected to use the areas. The baby area, carrying bottled foods, clothes, nappies and accessories such as prams and books, had a mixture of styles. The result of these factors was that the bottom of the "U" was failing to make its projected turnover. This seemed to be due to a lack of traffic in the area but the actual points of failure were obscure. The retailer hoped that a camera tracking survey could isolate the main aspects of how shoppers were using the store space.

Survey Coverage

The store was too large for the available camera units to cover completely, as only the 10 Olympus camera units were available. For this reason, and budget constraints, only the main flow areas of the store were covered. The survey area was decided upon by the company and the RAT in the light of the perceived problem areas. Figure 8.1 shows the unsurveyed areas as shaded. The survey, conducted at the beginning of December 1988, lasted for three days: Wednesday, Friday and Saturday, covering the critical three hour period from 10.30 to 13.30. This period was chosen because the hourly turnover levels were at their highest and during a pre-survey visit this period had seemed to be the busiest. Each camera took one picture a minute. There were a large number of non-local Christmas shoppers providing higher than normal traffic. This proved beneficial to the survey as the store's design defects were amplified.

Two days of the film were analysed by a team of two out-workers and 600 man-hours in total with over 10,000 people sighted. Gondola viewing information was not recorded in this case because it was not required. The data was transferred into dBaseIV and the WONKA files extracted.

Survey Findings - Older Store Area

Very few people reached the rear of the U shaped store. However the reasons for this depended upon the door by which the customers entered the shop. The WONKA flow map in figure 8.2:A shows the stabilised dispersal of those who entered the shop by the main doors. Fewer than 5% penetrated into the lower part of the store. The reason for this was found using the animation program to display non-moving customers. These stationary customers were found to concentrate in queues around a row of four of cash and wrap units and the personal care area. The blocking effect of this stationary mass was enhanced by the position of an island gondola

DIFFUSION FROM THE DOOR

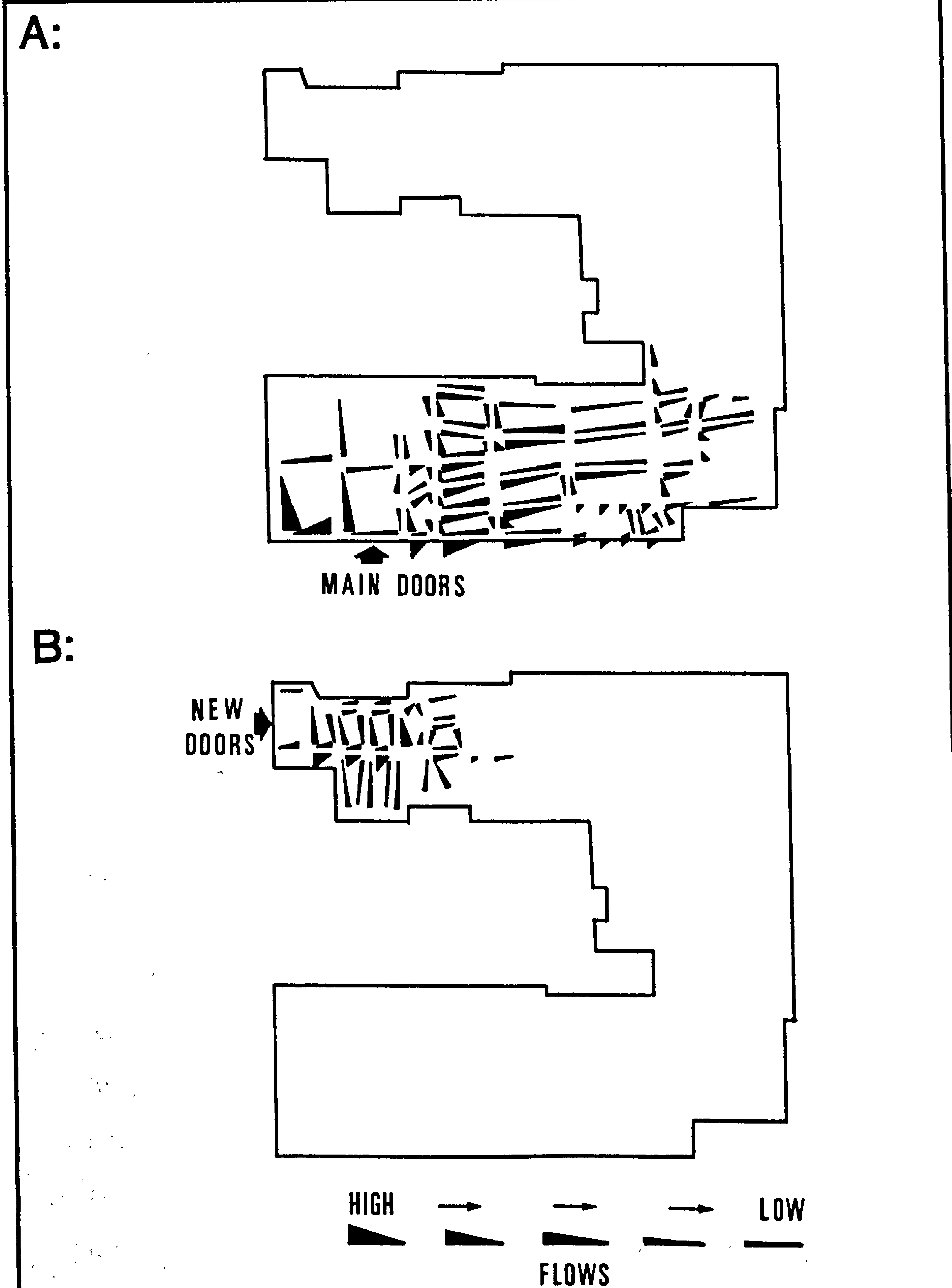


Figure 8.2

unit at the corner of the design walkway giving the impression of aisle termination before reaching the rear of the store. This effectively closed off the rear of the store to the majority of shoppers. Such an effect is noted in McGoldrick (1990).

Another run of the program, this time using moving customers, showed that the design path did not carry the majority of pedestrians. Instead there is a general dispersion of people using the feed routes with relatively little use of the interconnecting side aisles. The main transitional walkway between the two sections was not the design path but was a route following the inside wall of the shop via the narrow aisle at "X". The traffic that penetrated via the cash and wrap areas generally made for the baby area rather than the rest of the store. Redesign in this area, as a direct result of the survey, has greatly helped to solve the store's circulation problems.

Survey Findings - Additional Store Area

The newer part of the store provided a marked contrast to the situation at the opposite side of the store. There seemed to be active circulation within the area (see figure 8.2.B), and a much more effective central go-track feeding people into the shop and allowing people to move off the track to browse.

However once again under 5% of the injected population travelled into the rear of the store. Contrary to the aisle and cash and wrap problems encountered in the old store the lack of penetration here seemed to be caused by the shop-within-shop concept that employed distinct colour changes between one area and another. Unfortunately this colour barrier was reinforced by physical and other design criteria. There was a large roof hanging display which restricted headroom to about 2.5m, where the ceiling height was otherwise over 3m. This banner stretched almost the full width of the store thus creating a effective psychological threshold to further movement (Green 1986). The effect of a marked transition and blockage to movement was complemented by a large structural pillar just in front of the sign.

As a result of this survey a number of changes were enacted. The major modification was the simplification of the main go track. The track was straightened up and overhead signage made smaller. Gondola units were moved slightly away from the track to enable the customers to see more of the store from the access route. As part of this process major merchandise lines were moved off the gondolas immediately on the track to reduce congestion. Aisle widths and general space in the rear section of the "U" were increased to create a less conflict prone environment thus giving customers more time to shop. The changes resultant form this work have led to an 18% increase in turnover levels.

MIDLANDS SMALL TOWN SURVEYS - EVESHAM

Background

This store was positioned in the centre of Evesham, a market town which had a large number of shops but few of the major national multiples. The centre served a modest local population but gains regular trade from a large area around. In terms of the local shopping hierarchy the town was below such larger centres as Cheltenham, Worcester or Gloucester. The shopping area was not concentrated but spread about a mile and a half along two perpendicular streets. There was a lot of tourist business exemplified by the large number of tea rooms in the town.

EVESHAM PRE & POST REFIT

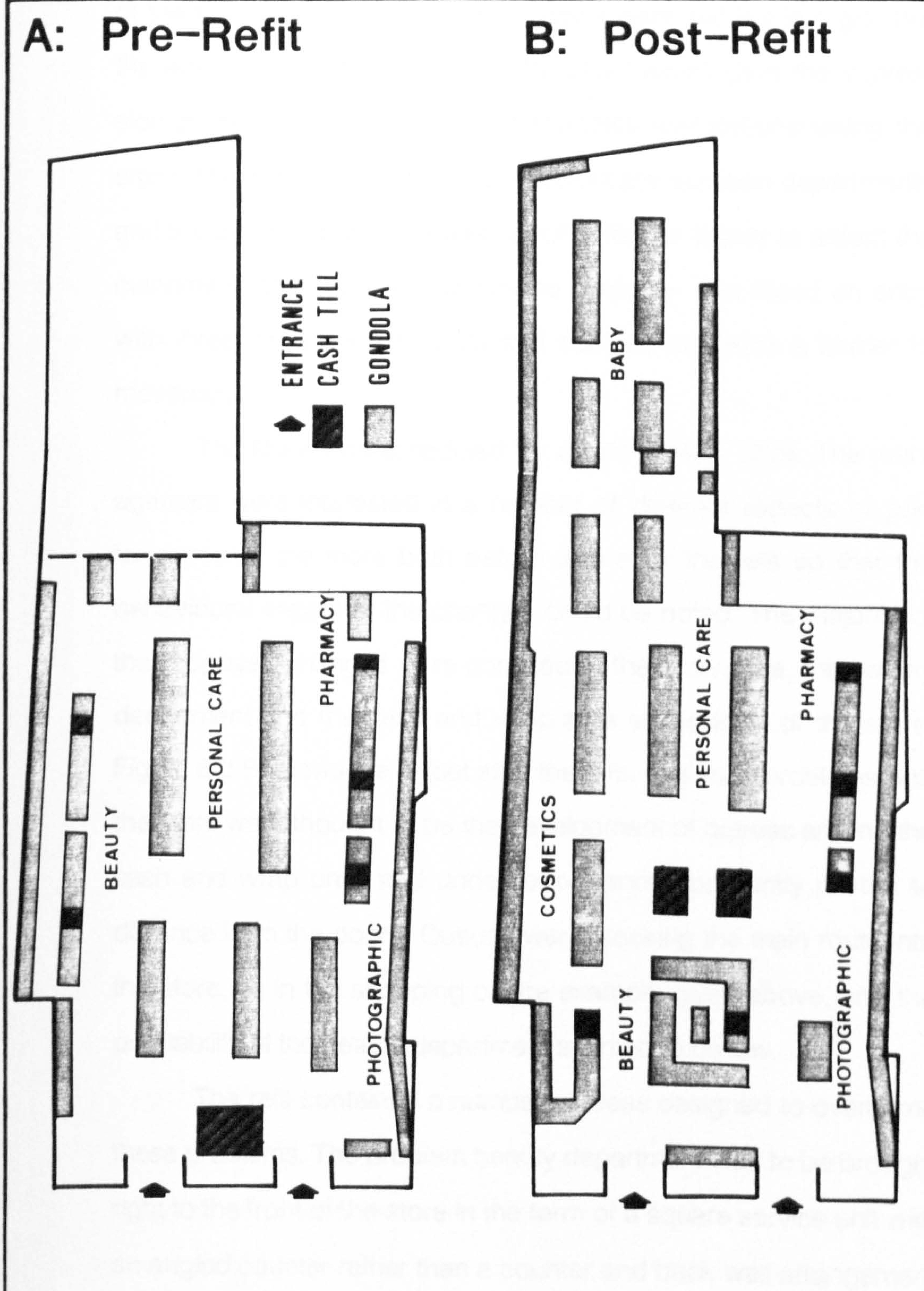


Figure 8.3

The store had a trading area of 340 square metres. The physical character of the store was far from ideal with a large number of structural pillars, over 8, and a confined rectangular area at the rear of the store (figure 8.3.A). The gondolas were laid out in a grid but the aisles were not continuous. The offset aisles gave the impression of the store being full of merchandise and foreshortening the store. There was little attempt to differentiate between departments and the overhead signage was not of sufficient quality to attract the customers' attention. In addition the customer was faced on entry with three large gondola ends that seemed to create a barrier to movement.

The store was scheduled for a refit in May 1989. The management were interested in a number of different aspects of performance of the store both before and after the refit so that the behavioural impact of the changes could be noted. The majority of the proposed changes were confined to the entry area, the beauty department and the cash and wrap area at the front of the store. Figure 8.3.B shows the layout after the refit. The main problems with the store were thought to be the development of queues around the cash and wrap units and underperformance apparently related to distance from the doors. Queues were blocking the main route into the store, as in the shopping centre example given above, and the profitability of the beauty department seemed to be low.

The refit contained a number of ideas designed to overcome these problems. The problem beauty department was to be brought right to the front of the store in the form of a square service unit with an angled counter rather than a counter and back wall arrangement placed along a side wall as was typical company policy in a small store. A previous survey for the company had shown that there was very little interest in the products displayed behind the type of high counter commonly used. The company wanted to try a new style of beauty area before undertaking a series of refits in similar stores. The cash and wrap units were to be moved deeper into the store with a slightly greater area for queuing customers. It was hoped the new layout would present a clearer view of the rear of the store to customers as the two main aisles were straight and unimpeded.

Survey Coverage

Two surveys were carried out, one before the refit in March 1989 to provide a yardstick for the proposed changes, and the other after the store had settled into the new trading format in September of the same year. Five cameras units were used for the pre-refit survey covering the busiest three hour period on a typical Saturday but excluding the rear of the store. The post-refit survey ran for a similar Saturday period but with full coverage. The previously described survey was only concerned with movement through the store: the second one was also very concerned with how the store was "shopped" and in particular if the designed browsing areas were working. Data related to gondola viewing was therefore an essential requirement.

Pre-Refit Survey Findings

As a general indication of flow patterns a WONKA flow model of the whole survey period was undertaken. This showed a uniform pattern of flows on the central aisles but the beauty area had relatively low flow rates and there was little penetration to the rear, unsurveyed section of the store. The path from the doors to the pharmacy was busy but there was evidence that the transfer of this traffic to the other floor areas via the cross aisles was poor.

The Cash and Wrap Area

The animation program showed the tills were coping with the customer traffic until noon when there was a marked increase in queue length which caused blocking of the main aisle. This change in the summary PRETTY customer density maps is shown in figure 8.4 for the 2 hour period before noon and in figure 8.5 for the 1 hour period after noon . The rough grid of numbers in the figures 8.4 and 8.5 refers to the number of people observed during the chosen time period for subdivided floor areas, and to the number of "looks" received by each section of a gondola in the same time period. Four times more people were observed in the period 1000-1200 compared with the number observed in the hour after noon. The standardised counts for those periods show that there were about 1600 sightings per hour in the earlier period compared with 900 in the later one. Thus to obtain a fair comparison between the figures the values seen in the post-noon model should be approximately doubled when compared with the pre-noon situation.

Reexamination of data and replay of the animation sequence revealed the increase in queue length and changes in the density pattern were due to one of the tills shutting down during its operator's lunch break. As Grayson (1975) pointed out the availability of a pictorial record is one of the major benefits of time-lapse photography.

The single queue development also led to a marked change in the pattern of gondola viewing activity. The counts for each of the gondola sections are derived from the viewing data gathered from the film. If a person is seen looking at a gondola section that will

All Customers Before Noon

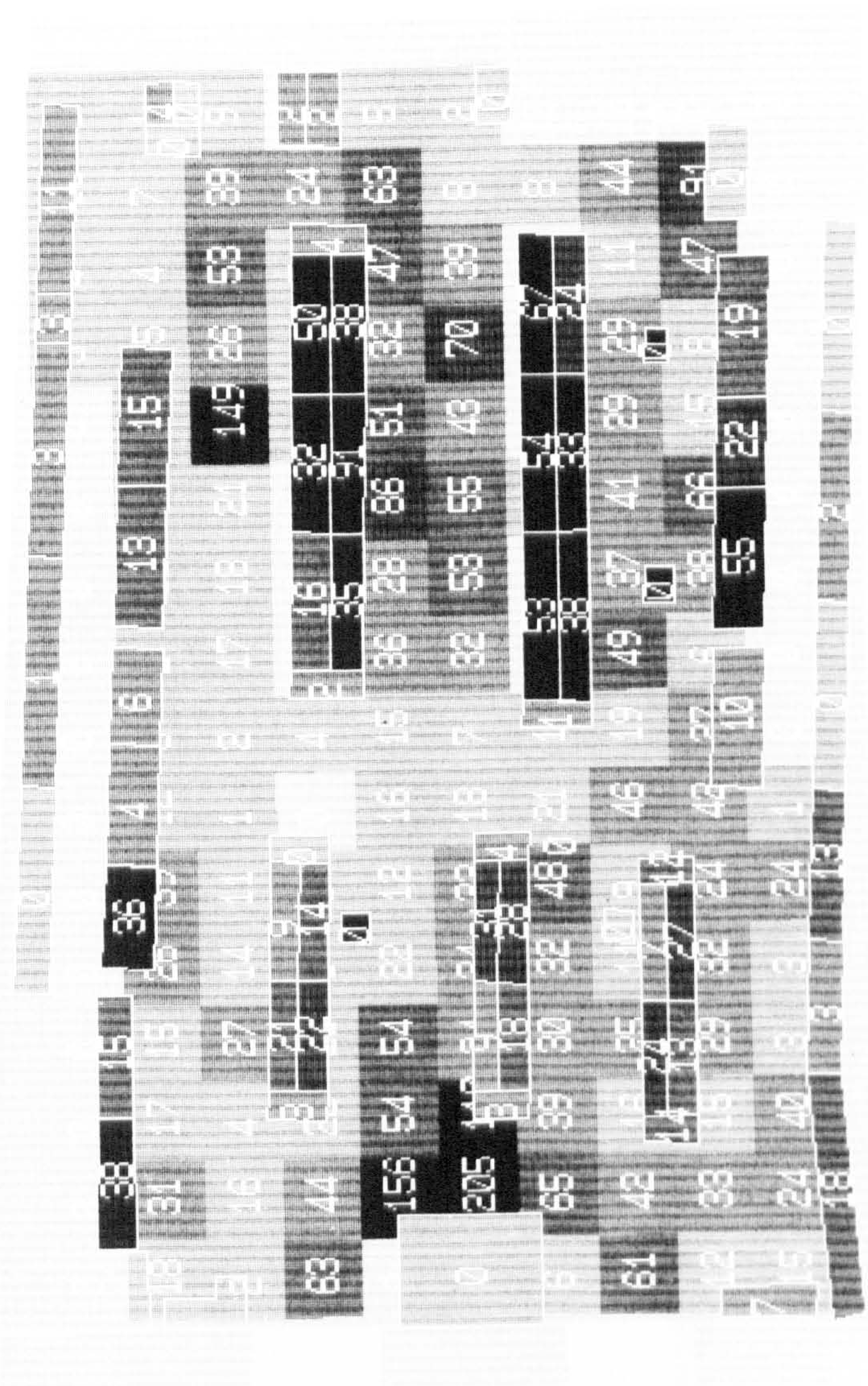


Figure 8.4

All Customers Between 12.00 & 13.00

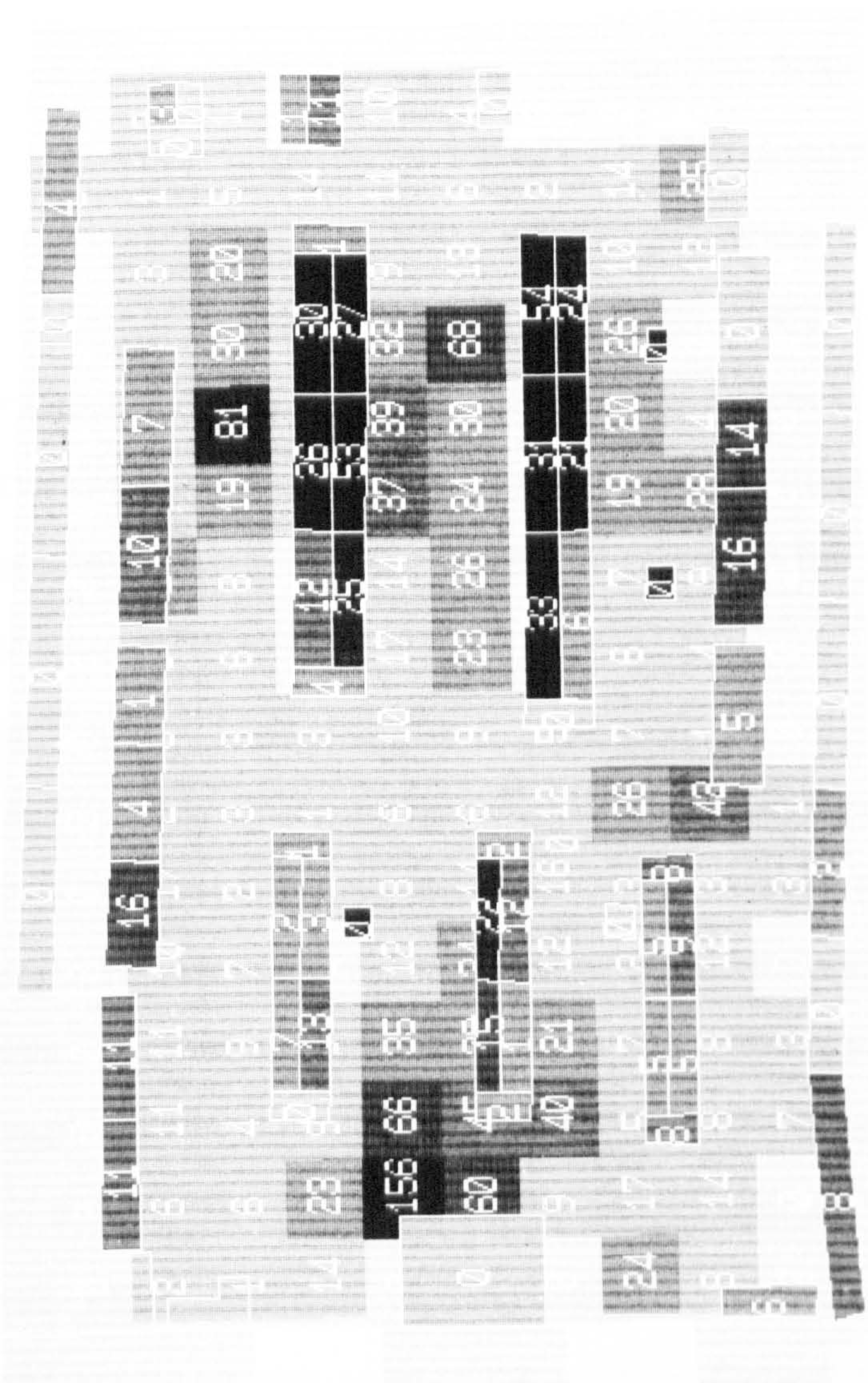


Figure 8.5

register a value of 1 in a PRETTY output. The central aisle has 160 people per hour before noon and 147 per hour afterwards. This reduction in flow, caused by till closure and queue lengthening, has not impacted on the total viewing numbers, but the previously even balance between the two sides of the aisle has shifted to the benefit of the lower gondola with its viewing increasing from 26 looks per hour (lph) to 40 (a look per hour means that refers to the number of people recorded as viewing a gondola in a hour long period. The increase in viewing can be explained by the closure of one till leading to increased waiting times and the presence display of impulse goods on one facing gondola and male aftershave on other. The conclusion is that although the increased queue has blocked flow into the aisle there has been no impact on customer viewing and there has been an overall beneficial effect on the ratio of viewing to non-viewing customers.

The Top and Bottom Aisles

The top and bottom aisles were affected negatively by till closure. The flow in the top aisle reduced to two thirds its pre-noon level with a consequent drop in viewing figures for the gondolas. This suggested a change in character from a browsing area for the beauty department to a corridor of movement for those people unable to use the central aisle. The most striking feature of this part of the store was the lack of viewing along the rear of the top wall. This behaviour was also seen in the in-store Thorntons study and previous Boots studies and would seem once again to be the result of the type of high counter modules used. These units force customers to interact with assistants through narrow channels and prevent many shorter individuals seeing the back wall at all.

All Customers

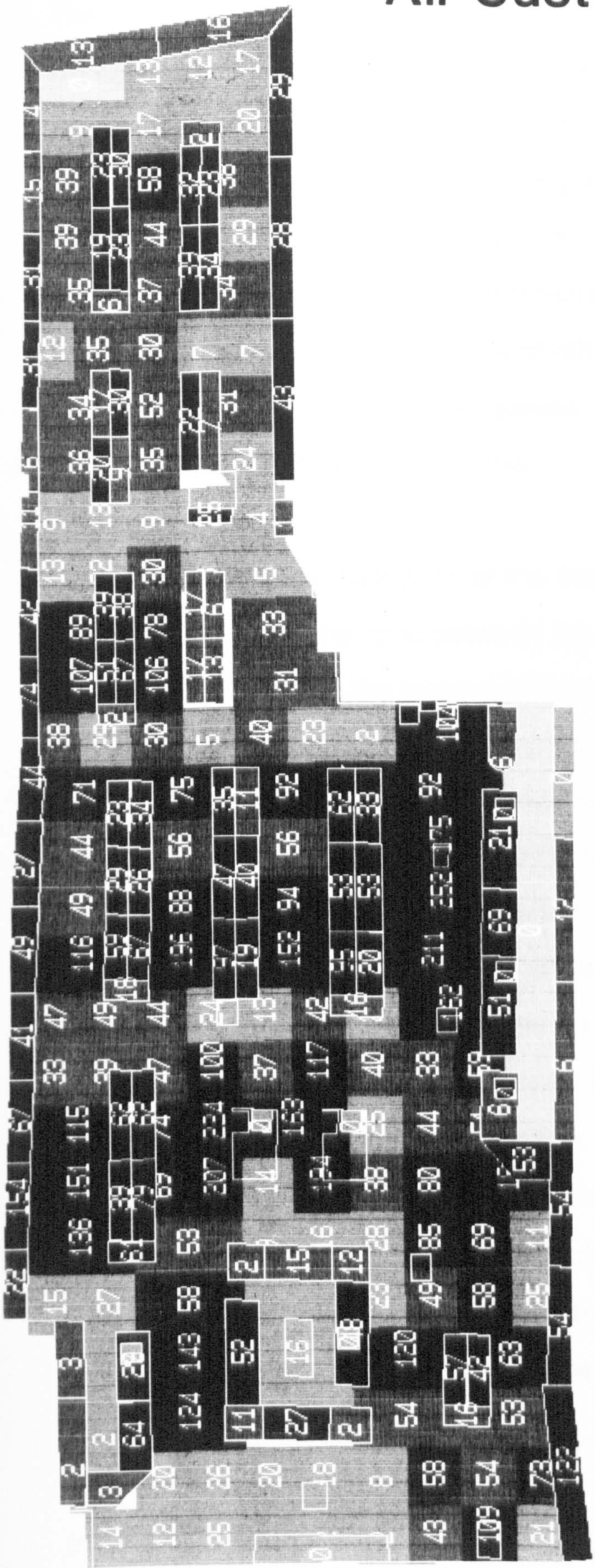


Figure 8.6

The lower aisle suffered a cut in flow rate to about one third of its previous value combined with a massive reduction in gondola viewing from 53 lph to 14 lph. Reference to the survey photography showed that a queue had been forming along this aisle but then moved to the centre aisle following lower till closure, resulting in a virtually unshopped lower aisle. Merchandise along both sides of this lower area was confectionery and other impulse items and as such ideally suited to slow moving queues. If a till was to be closed it would be better to close the other one.

The Rest of the Store

The central, personal care area of the store was busiest. In some areas look ratios - the ratio between the number of people seen passing a gondola and the number of looks it receives - higher than 0.8 were found. This implied interest on the part of the customer, if not actual purchase. Very low look ratios achieved by most gondola ends were surprising. As Ghosh (1990) points out the time a customer has to notice products is very short. The view data in the RAT data base tends to register positive interest in a gondola item rather than a quick glance. Possible causes for these low ratios include either dull displays resulting in customer indifference and few purchases, or rapidly understood displays of one item resulting in reasonable sales. As no sales data was made available to the RAT for the time of survey no conclusions could be drawn. Two gondola ends were successful but it is felt that this was due to the merchandise rather than their positioning. These two units carried Easter Eggs.

Post-Refit Survey Findings

In general the post-refit survey showed the new store layout to be working much better than previously (figure 8.6). The increased space behind the till area removed the queues previously blocking a large part of the sales area, allowing customers to move more easily throughout the store. There had also been major operational changes within the store. Staff had been trained to look out for potential queuing and told to redirect customers to other tills if problems were about to develop.

The extra aisle in the former beauty department created a very effective browsing area. The removal of the counter from this area led to a massive increase in the usage of the back wall display space. The removal of high commitment items from the central areas of the store to this peripheral space freed other areas to serve both as access routes and regular demand style shopping. The placement of comparative products in this browsing area was good policy as it allowed those who did not require assistance time to make the right purchase.

The two main problems with self service can be shrinkage (theft) and providing adequate information to customers. The shrinkage problem may not arise but can be countered (Deevey 1985). The product information problem can be surmounted in a number of ways. Firstly by providing more information both on packaging and on the gondola and secondly by retaining a counter service nearby and encouraging staff to move onto the floor in order to help individuals.

Unfortunately penetration into the rear of the store could not be compared directly with the previous survey but the numbers flowing down the aisles to the rear had increased. This was primarily due to the increased visibility of the rear of the store from the entrance.

The gondola viewing data in figure 8.6 showed there was significant interest in the rear of the store which contained baby clothes, nappies and foods, products for which the retailer may not be the customer's first choice.

There was a problem with product placement related to bunching of customers at the bank of gondolas immediately behind the cash tills. This bunching was caused by locating popular lines on facing gondolas. Such problems could be allayed by adopting a staggered system of placement similar to Buttle's (1984) bounce pattern. Product location and potential traffic generation should be given careful consideration within the frame of reference of store functionality and flows as shown by the survey.

Gondola Ends

The problem of lack of gondola ends viewing and utilisation has continued. In supermarkets ends are used as promotional units and mixed product clearance areas. The theory behind the "Gondola End" is that they promote sales in the displayed categories by as much as 30%, and are therefore considered prime locations. This may well be the case but performance should also increase due to the vastly increased sales area and the usual fluorescent signs emphasising the "Special Offer". The pre and post surveys examined two different types of gondola end: the blanket "Special Offer" or blunt approach, and the creative merchandising approach where the gondola end is used to give high prominence to a line that otherwise might not be seen or looked for.

The difference between the two categories in terms "looks" is interesting. The most looked at ends were a creative glass peninsular unit and a standard blanket display. The latter was the prime gondola end in the shop because of the high volume of traffic moving past. The third best site was an attractive manufacturer supplied hair dye unit which received 37 "looks". The reason for this high count (excellent in relation to the traffic) became apparent when male behaviour was analysed from the survey data and re-checked on the film. Over 60% of the interest was from single males who admired the provocative poster above the unit.

The importance of women in the male areas of the store showed clearly in the survey results. There were more women looking at male shaving products than men! In the photographic and video consumables section the numbers were about equal. This has implications for the way that these products are marketed as the target is not just male aspirations but female aspirations for their men.

DEPARTMENT SURVEY IN A SHOPPING CENTRE - LUTON

Background

The store, another Boots unit, was located in a large Arndale centre in the centre of a large town, Luton, about 40 miles north of London. There was a marked spatial separation within the centre between stores catering for a high or low class customer base. The surveyed unit is located in the area with a better demographic profile, but there is a large market quite close by that attracts lower social groupings to the store.

This was the first two floor shop that the RAT has visited. However the extent of the survey was limited to a single department on the ground floor (figure 8.7). The size of the floor area meant that the store carried the full range of products. As a result of the varied

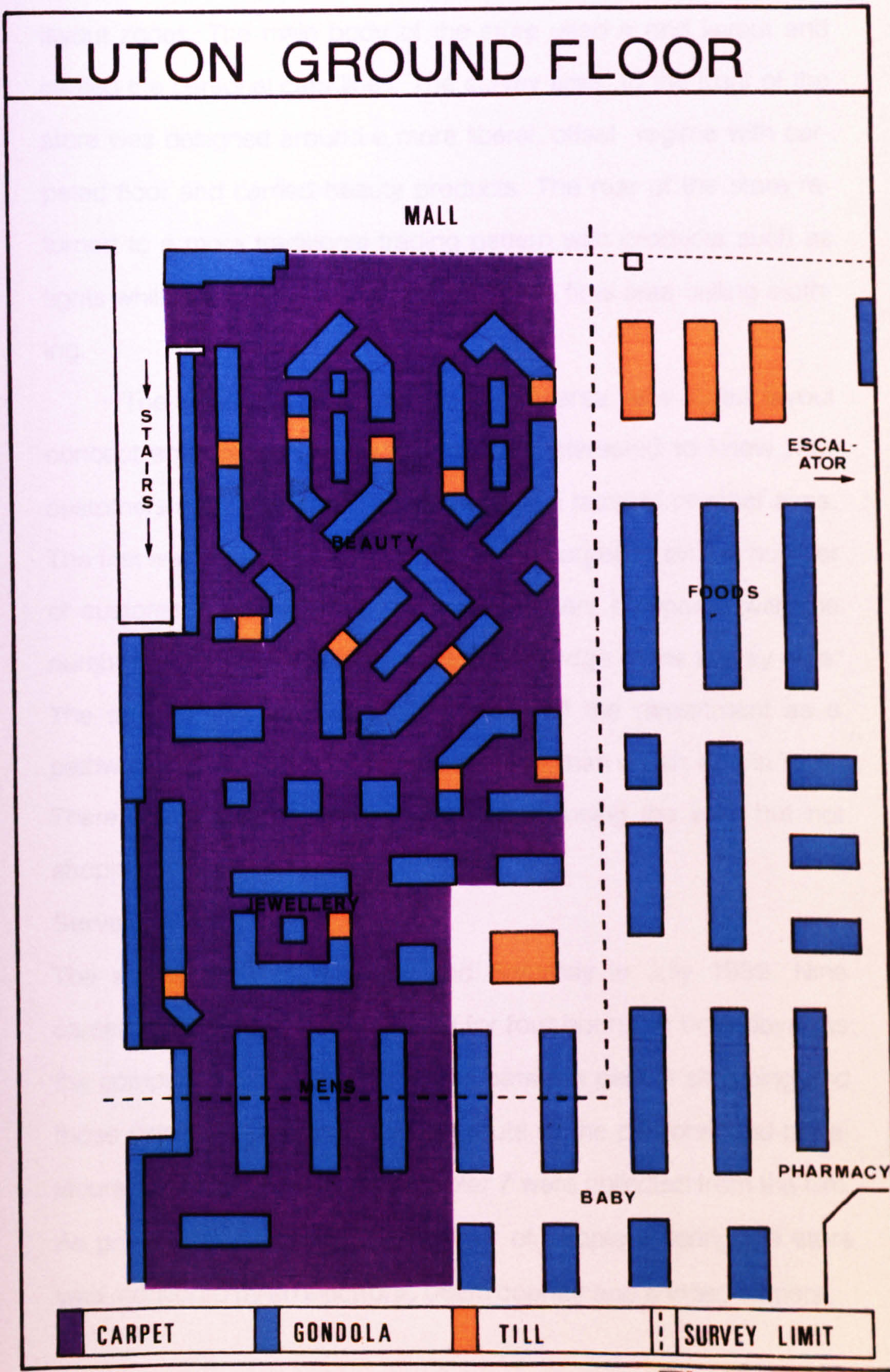

LUTON GROUND FLOOR
MALL
STAIRS
ESCALATOR
BEAUTY
FOODS
JEWELLERY
MENS
BABY
PHARMACY
CARPET
GONDOLA
TILL
SURVEY LIMIT

Figure 8.7

scope of the merchandise the ground floor of the store had four layout zones. The main body of the store used a grid layout and carried the personal care lines. The survey area to the front of the store was designed around a more liberal, offset regime with carpeted floor and carried beauty products. The rear of the store returned to a more traditional trading pattern with products such as tights while the fourth area was a small free flow area selling clothing.

The focus of the survey, the beauty area, was a new layout concept and as such the company was interested to know how customers used the area. The survey had a number of other aims. The first was to determine the effect of the carpeting on the number of customers moving through the department compared with the number using the linoleum go track on the edge of the survey area. The second was to investigate the use of the department as a pathway to other areas of the store rather than as an end in itself. There was a feeling that customers were using the area but not shopping there.

Survey coverage

The survey covered a Friday and Saturday in July 1989. Nine cameras were used, each running for four hours on both days. As the company wanted to differentiate between people shopping and those using the area as a through route all the personal and behavioural variables discussed in chapter 7 were collected from the film. As previously mentioned the number of people entering the store was monitored by an electronic beam counter and a video camera.

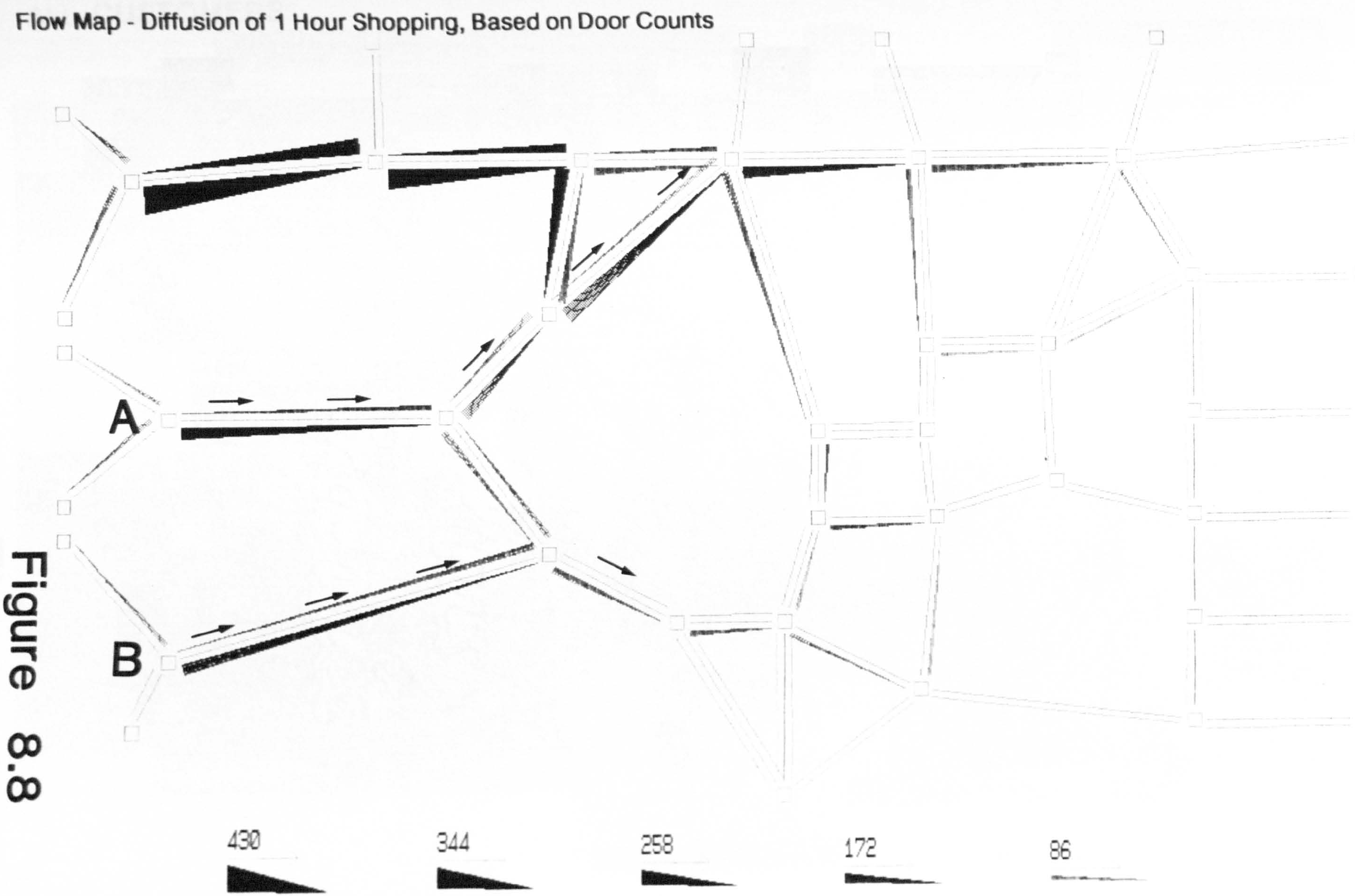

Flow Map - Diffusion of 1 Hour Shopping, Based on Door Counts
A
B
430
344
258
172
86

Figure 8.8

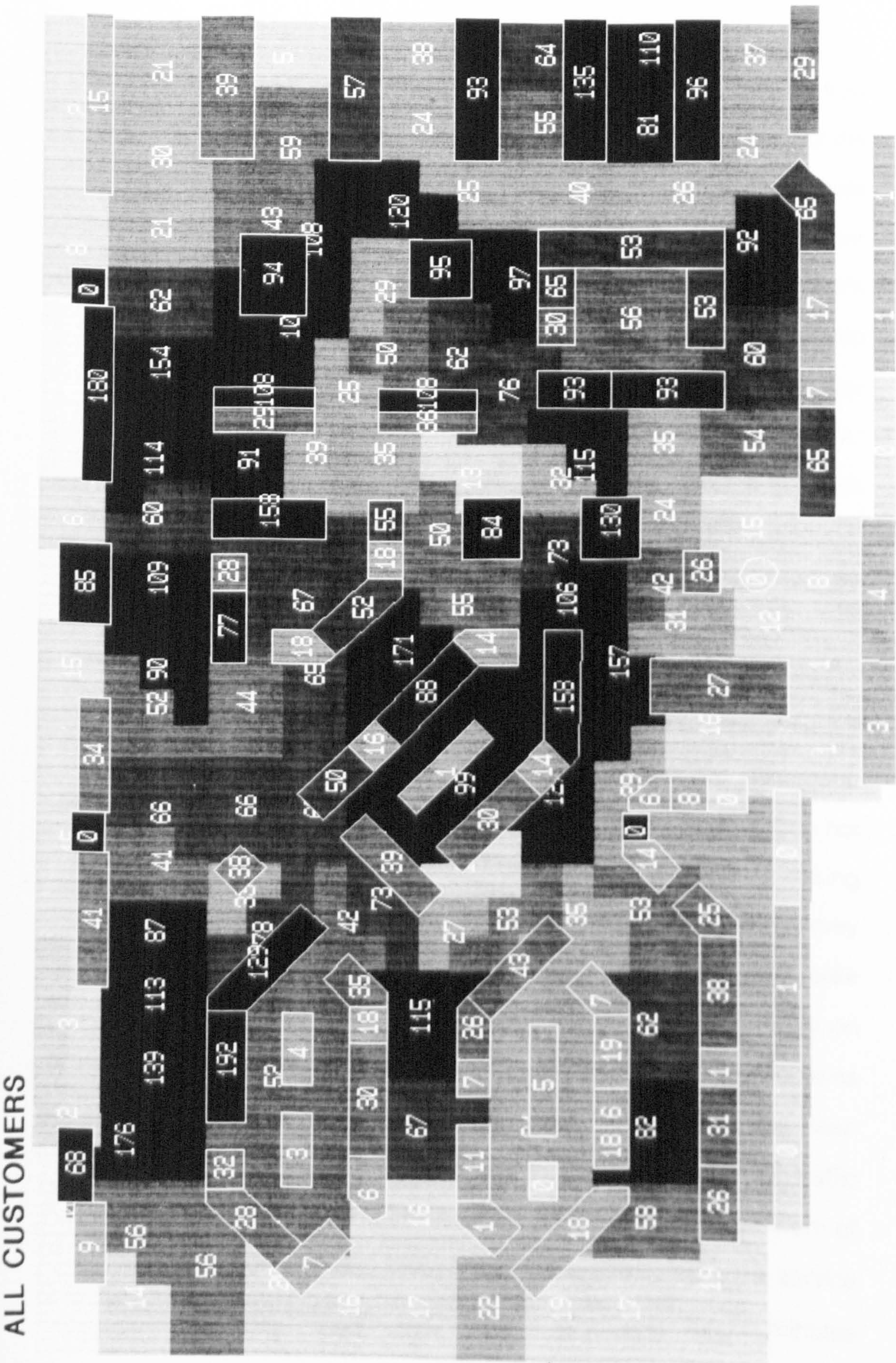


Figure 8.9

Survey Results

1) The Go Track and Customer Dispersal

The flow map shown in figure 8.8 shows the WONKA derived flow patterns based on the numbers seen entering during one hour of the survey period. As expected the go track acted as the main route carrying just over 50% of predicted people into the store. The other two routes from A and B in the carpeted area carried about 25% each. The two secondary tracks differ in that track "A" feeds up into the go track whilst track "B" is acting as a secondary feed to the rear of the store. It is interesting to note that most of the traffic from "A" flows back up to the go track. Diffusion of flow from the go track decreases with distance from the door. The success of the diagonal tracks in dispersing customers can be seen in the PRETTY plot for all customers (figure 8.9).

The good spread of customers shown in figure 8.9 shows that the design concept of the area was successful but there were a number of problems created by the product and service placement. The positions of the cash and wrap units shown on figure 8.7 do not seem to be ideal as the stationary customers are effectively blocking the chosen pathways (figure 8.10). During the Saturday survey period the high levels of traffic at the beginning of the main aisle were caused by the two facing tills and the No7 make up range on the angled gondola. This product caused particular problems because it appeals to younger consumers who are, as has been noted during the later town wide surveys, less affected by high traffic densities thus increasing the potential traffic levels. The problem of perceived crowding and blockages was exacerbated by a service trolley that had been left in the middle of an aisle for 76 minutes

STATIONARY CUSTOMERS FRIDAY AND SATURDAY

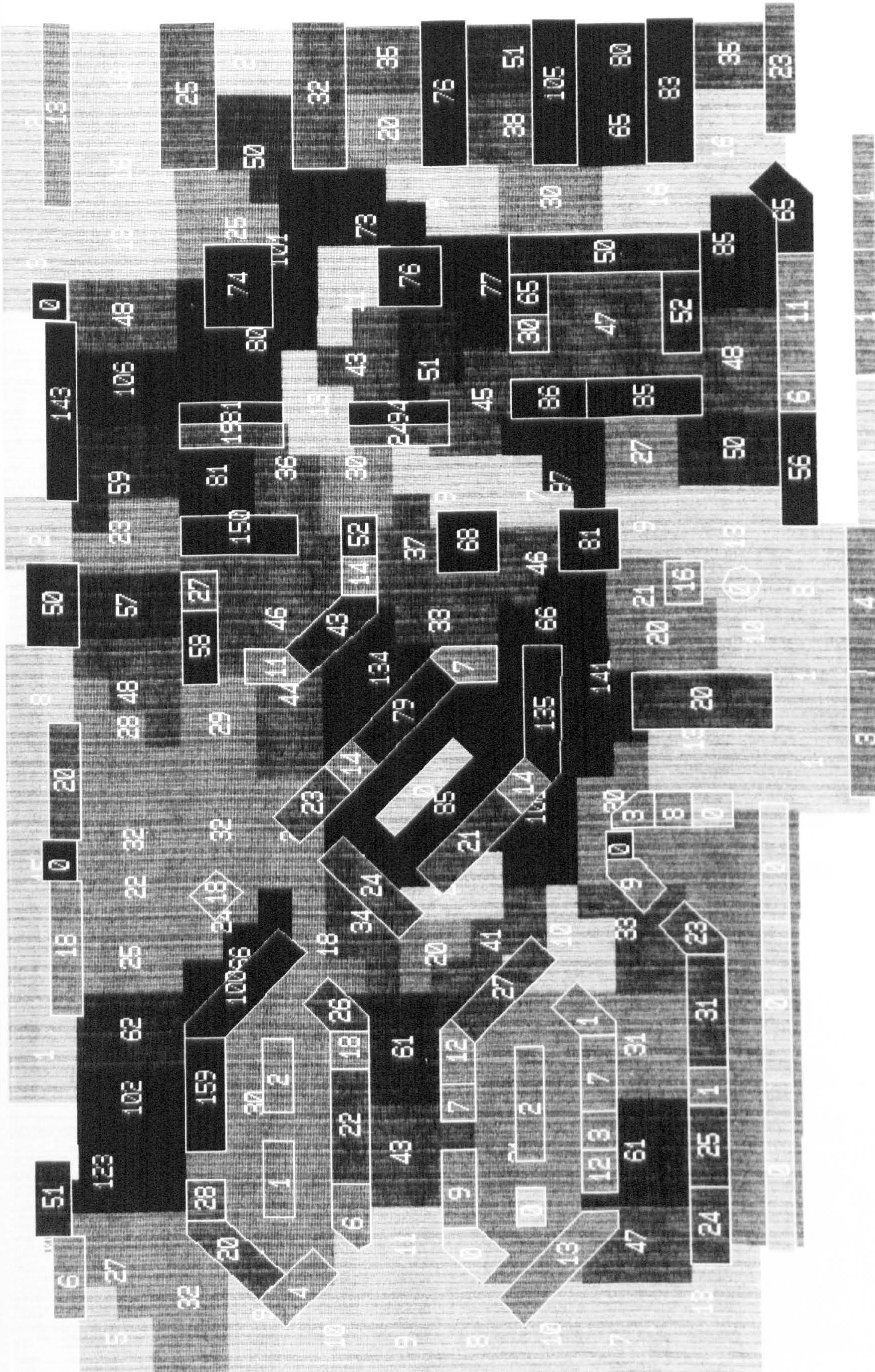


Figure 8.10

during the survey period. As Stokols (1972) and Eroglu and Harrell (1986) noted an area cluttered with physical objects will seem more crowded than one well ordered.

2) Daily Variation

The numbers viewed per hour on the two days were similar: 1,300 sightings on Friday and 1,600 on Saturday. However the distribution of customers varied markedly between the two days. On Friday the customers were more evenly spread across the survey area. The go-track flows were similar on both days, but on Saturday there were patches of high density which increased the probability of blockages occurring. Similar clots could be seen in the paths through the hexagonal counter area. The accessory and male products areas were significantly more busy on the Saturday. On Saturday there was an increase in activity around the summer sale/half price counter. These behavioural shifts are in part a reflection of the change in customer profiles between the two days.

3) Age/Sex - Patterns of Variability

Table 8.1 gives the total numbers of sightings within each photo-estimated age group. The most notable points are the ratio of women to men and the concentration of Friday women into the 25 to 35 age group. There were few areas of common interest for the female shoppers but the males were more homogeneous in their behaviour. The series of PRETTY charts in figures 8.11 to 8.15 summarise the Saturday differences for females of different ages.

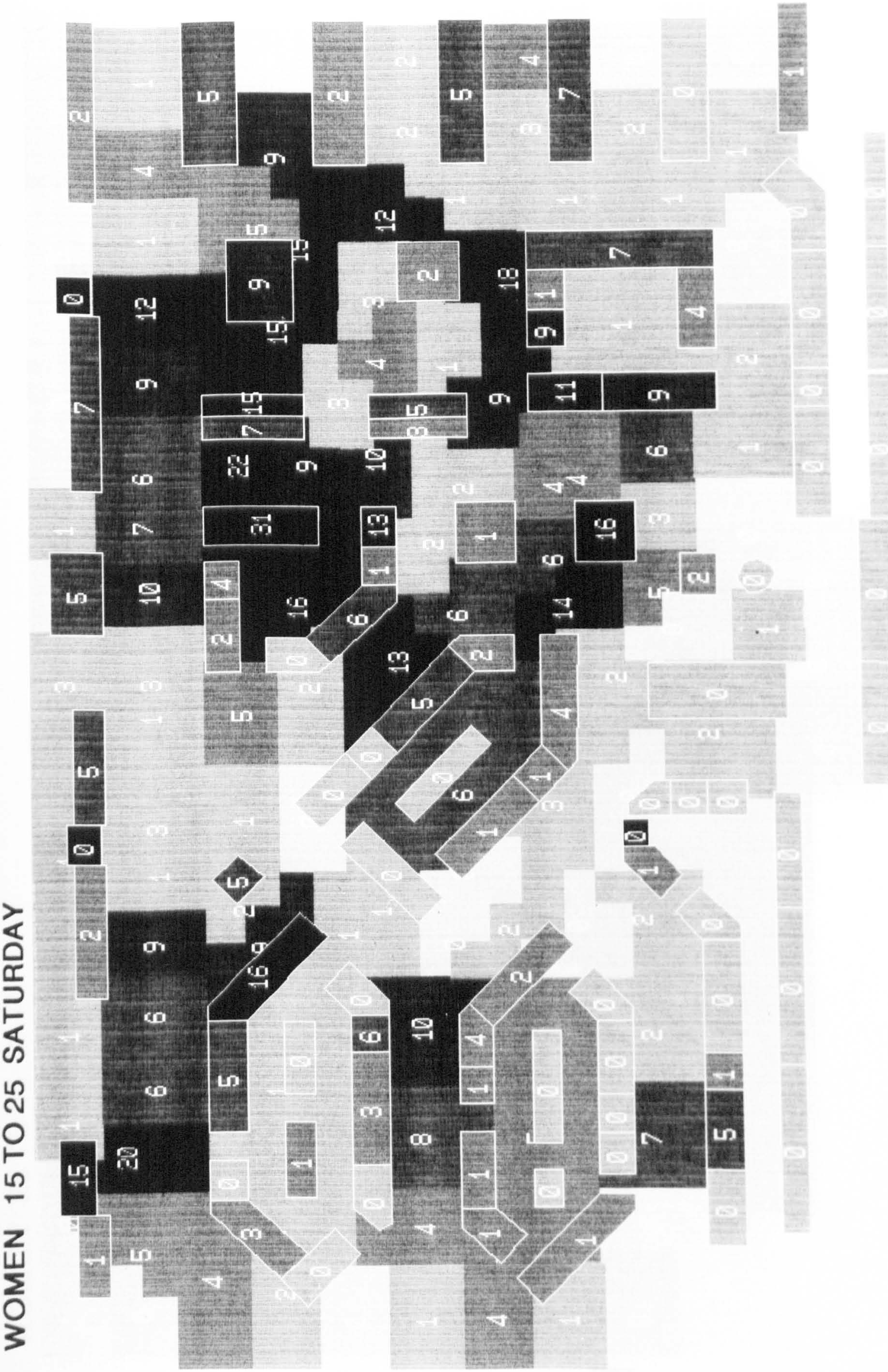


Figure 8.11

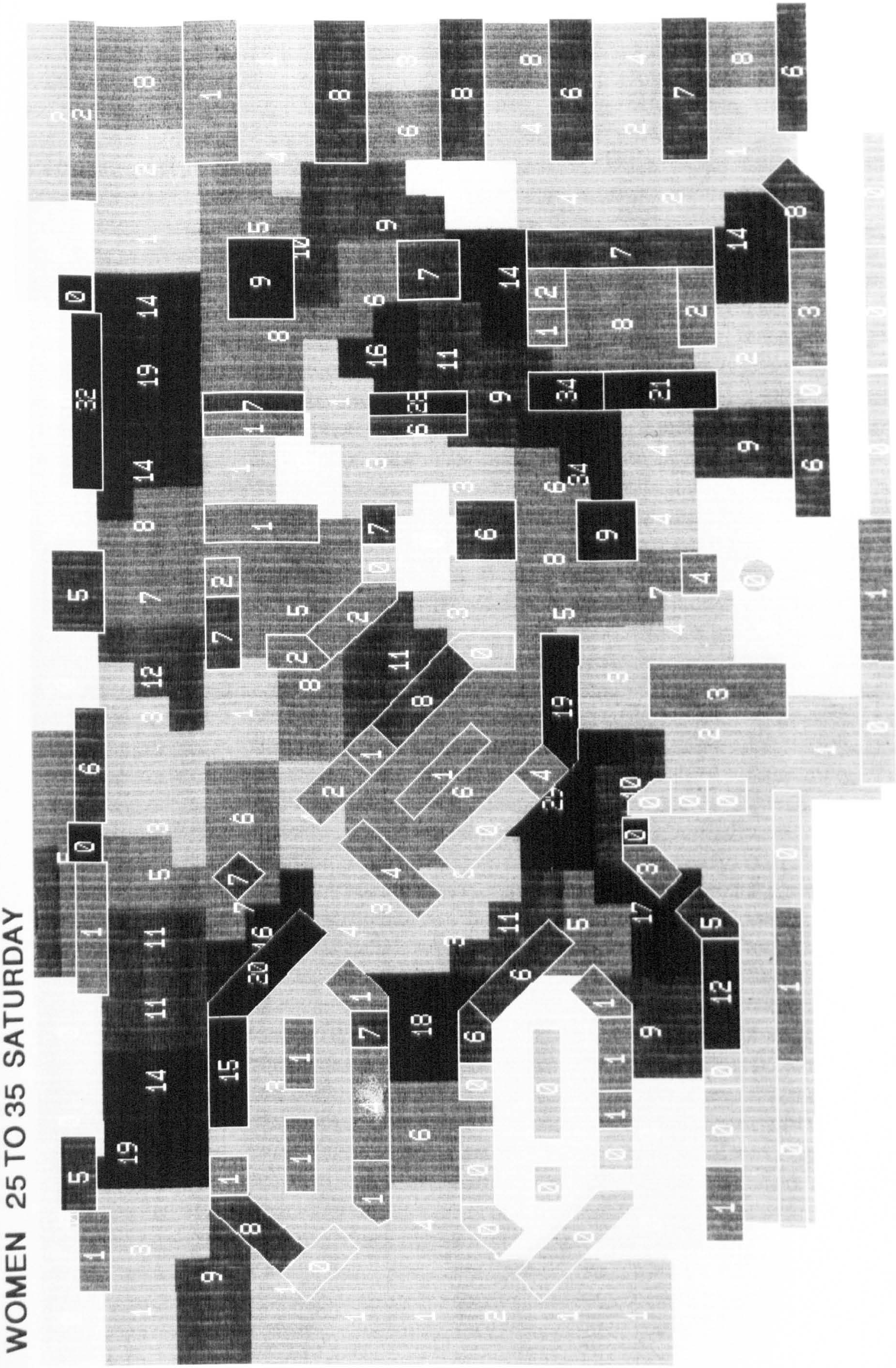
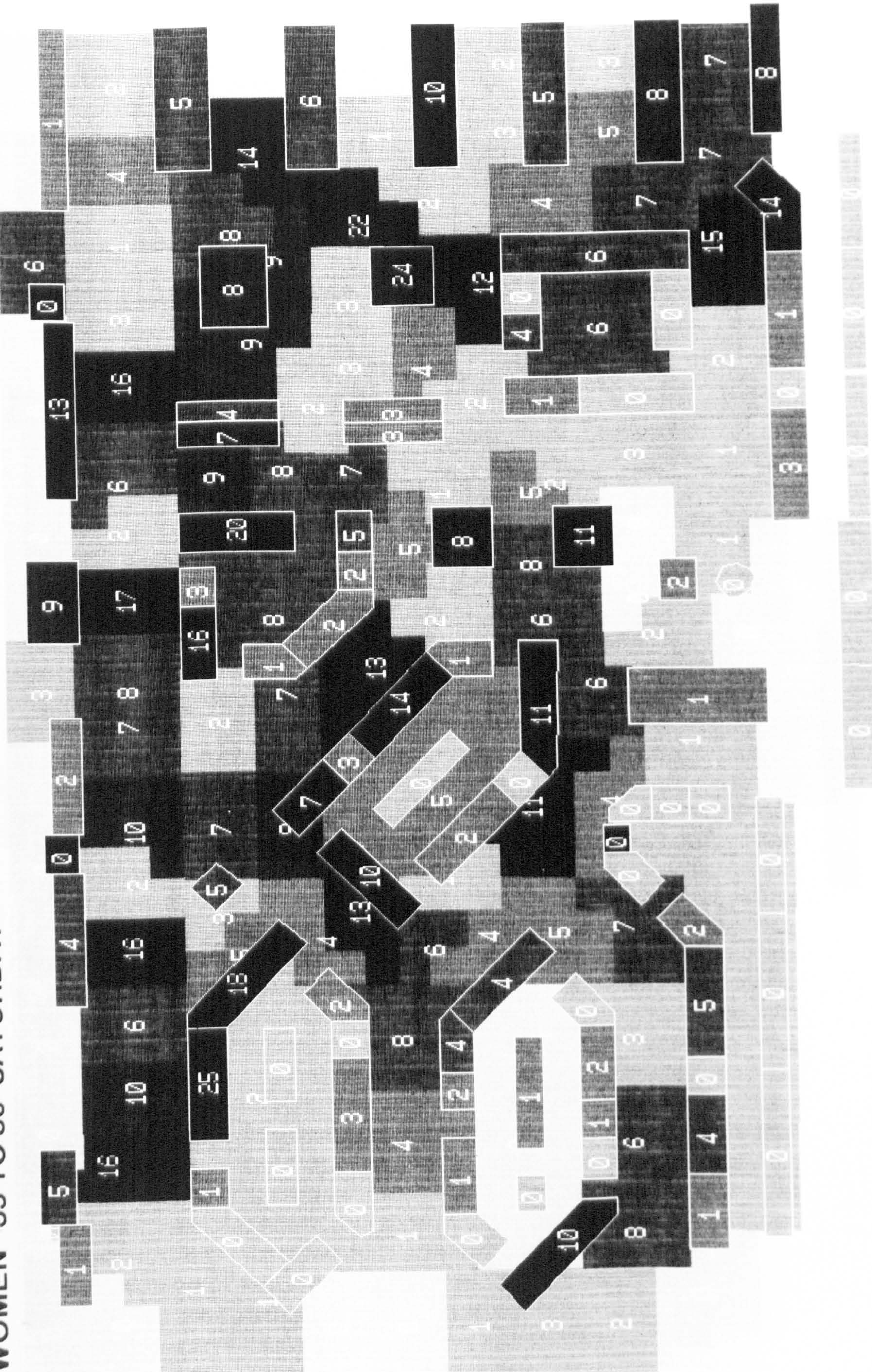


Figure 8.12



WOMEN 35 TO 50 SATURDAY

Figure 8.13

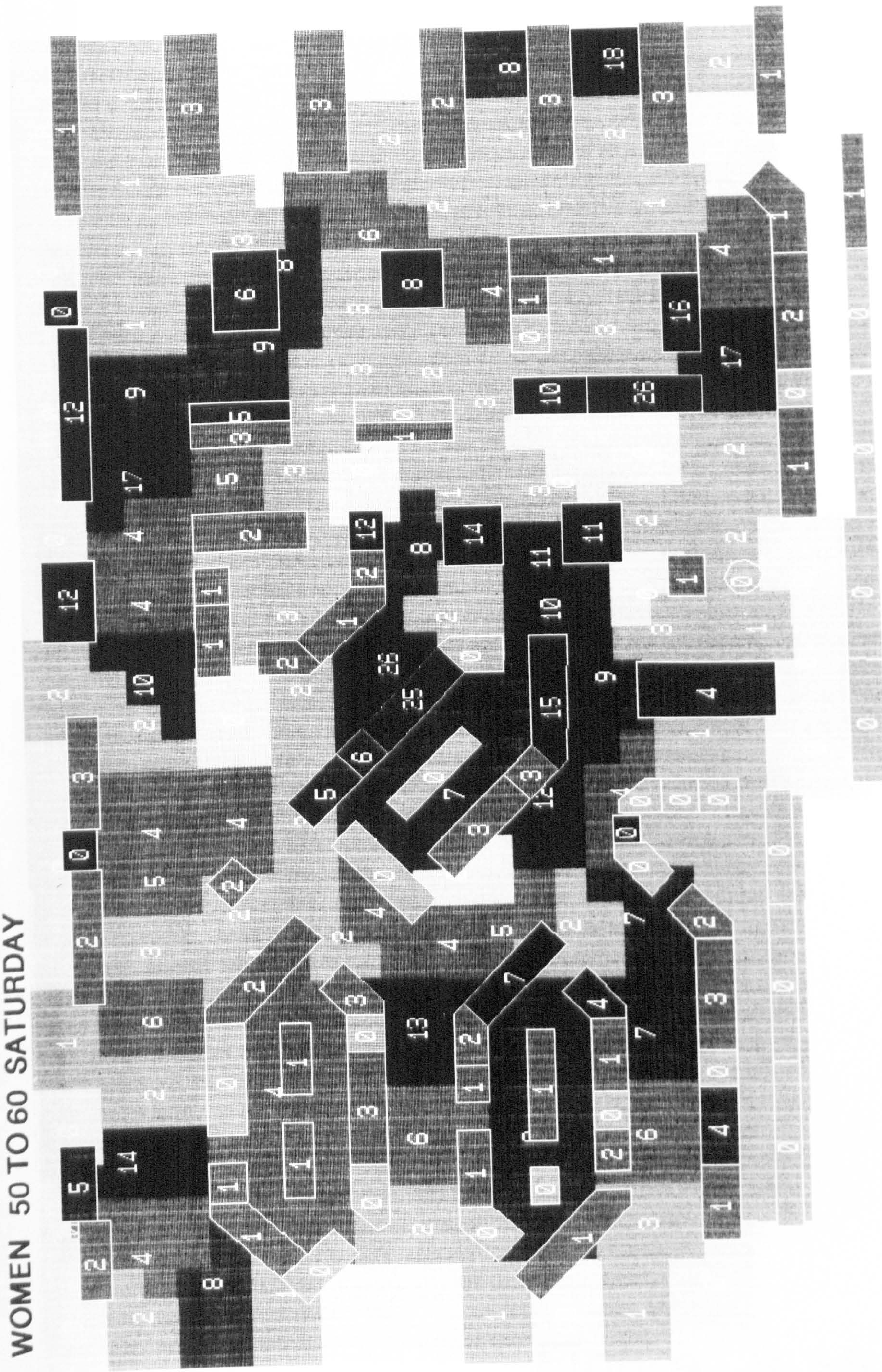


Figure 8.14

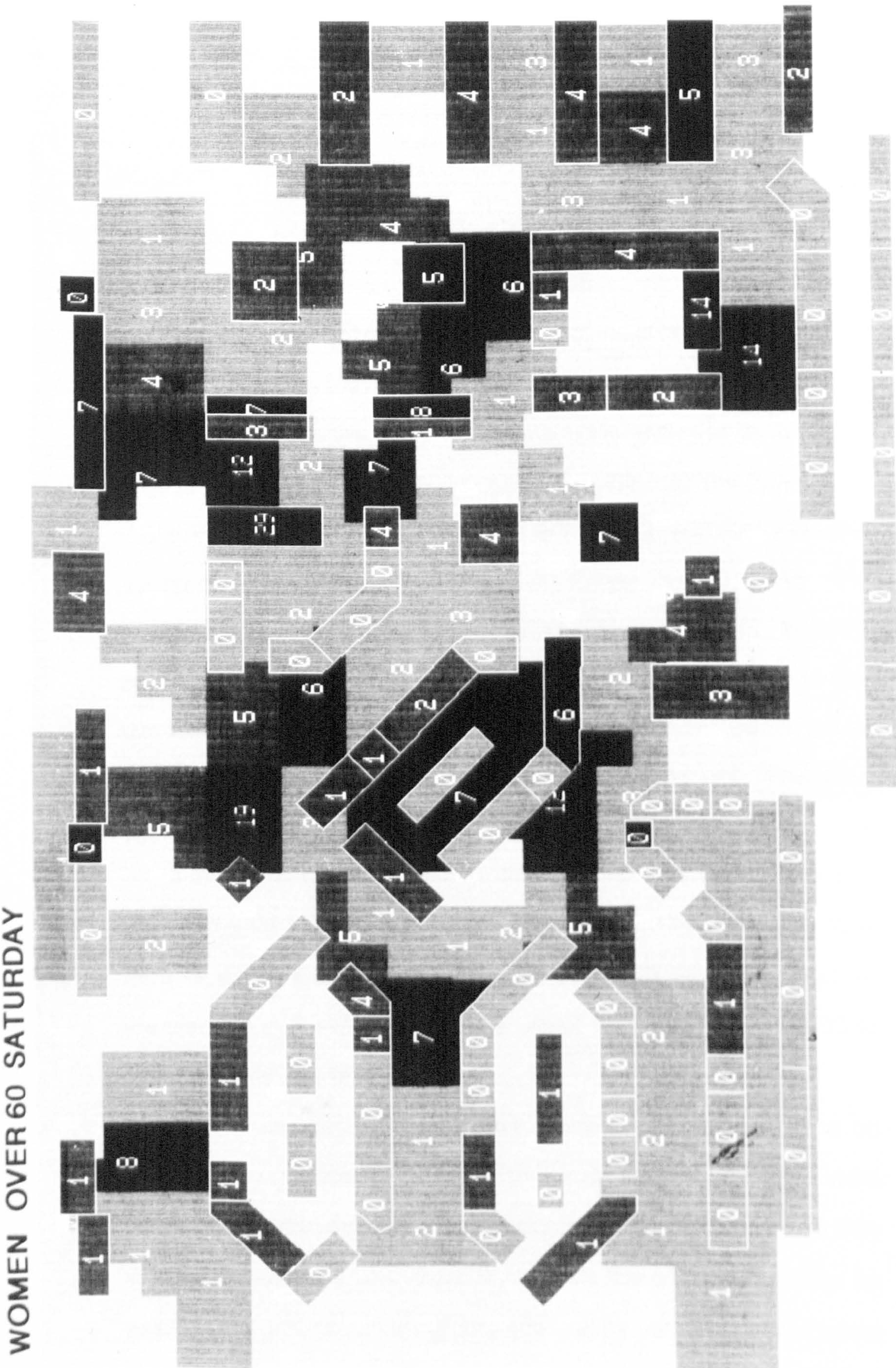


Figure 8.15

Table 8.1. Age Groups and Daily Variation

	WOMEN		MEN	
	Friday	Saturday	Friday	Saturday
15 to 25	245	441	70	97
25 to 35	1006	657	155	256
35 to 50	339	522	77	245
50 to 60	312	413	109	175
60 plus	219	227	68	42

The females aged 15 to 25 showed distinct variation between Friday and Saturday. On Friday there was a relatively high penetration of this age group into the entrance area but little attraction to its target area of cut price and cheap products. On Saturday the group was found in the rear of the survey area both at the summer sale and young female products gondolas. On Friday the 15 to 35 year groups had a strong attraction to the counter facing the frontal cash and wrap unit carrying No7 cosmetics. On Saturday the tail of this unit took on much greater importance. The 35 to 60's had the greatest interest in the lower frontal top of the range unit. This area formed the focus for the 50 to 60's but was of less importance to the 35 to 50's with an average look ratio of 0.45. The rear of this unit attracted a lot of interest from the 25 to 35's on Friday with a look ratio of about 0.25 but on Saturday although the traffic had increased the look ratio had fallen to about 0.15. On Friday the 35 to 50's paid little attention to the unit.

The younger males had little interest in the survey area on either Friday or Saturday. Animation results showed that men were taken into the survey area by their partners rather than because they wished to visit. This was demonstrated by the animation results for association groups including partners and by very low male interest levels ("looks") shown in the products.

Survey Conclusions

The carpet/linoleum threshold did not seem to create any barrier to movement but did channel activity to the rear of the store. However the concept of the go track was somewhat disrupted due to poor placement decisions and operational management. There was some evidence that customers were using the area as a bypass but this may well have been a result of crowding on the main route. There would seem to be no detrimental effect from this. The spread of customers is in line with the appeal of the products on offer and the "look" ratios are quite high. As in all previous surveys there was very little interest in the behind counter display units. This problem was not confined to displays on the rear walls. Display units in the middle of the island gondolas also had very low "look" values. The major finding of this survey was the bad effect that poor product placement and operational management could have on a store. Small scale examples of human blockages had been seen in the other surveys but their impact in this case was much more serious.

A SUPERMARKET SURVEY - SHERBOURNE

Background

This survey was the first supermarket that the RAT had surveyed. The company in question, Gateway, had developed a new concept of a high quality, medium size store situated in small regional centres such as market towns. This store was located in Sherbourne, a market town with a good demographic profile and no existing local supermarket provision. The company wanted to see how the store was performing before any further stores were built.

STORE AND PRODUCT PLAN

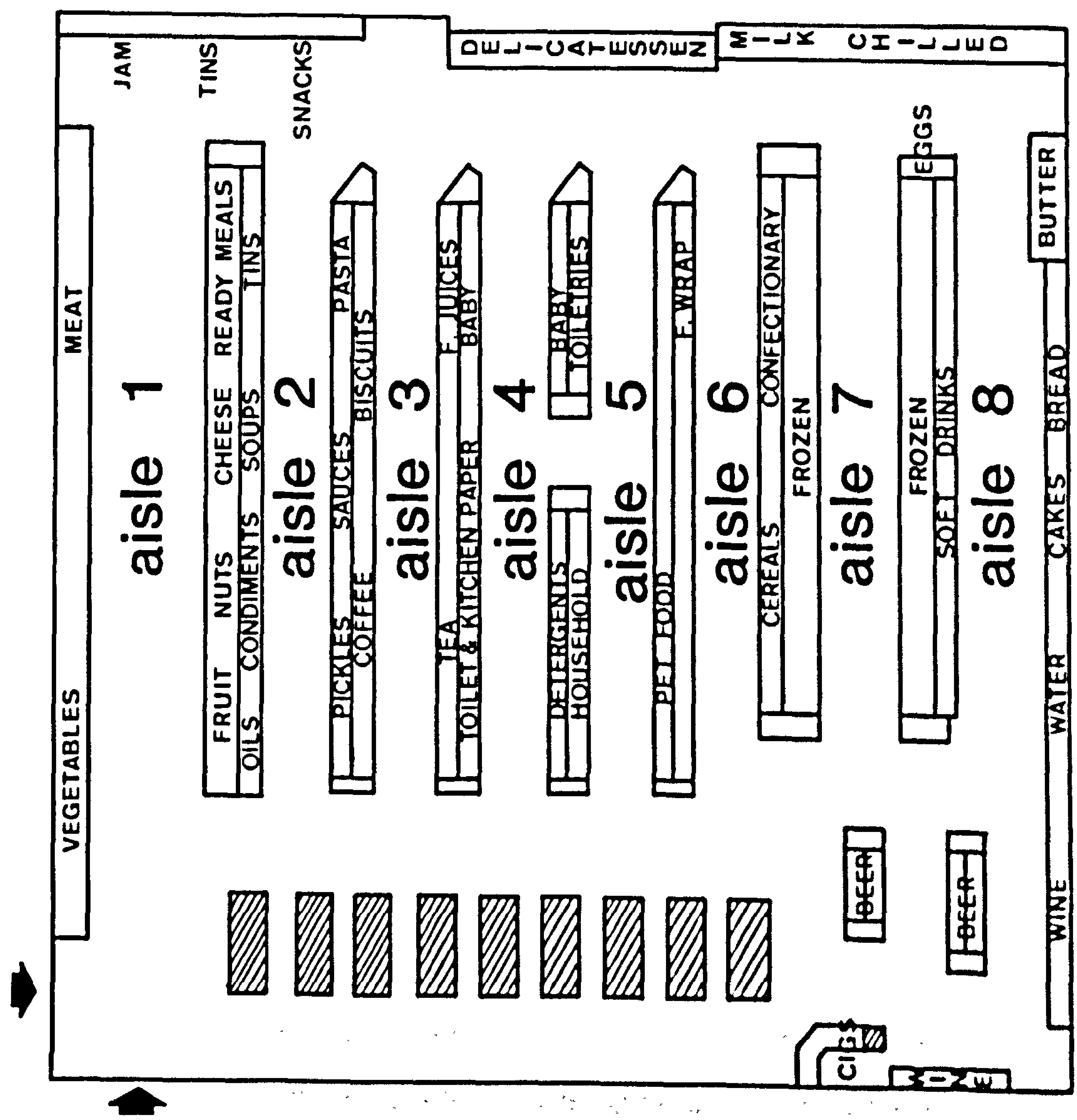


Figure 8.16

The store had only recently been built and followed a typical grid iron supermarket plan (figure 8.16). As such this was the first store surveyed that had been built to accommodate a specific internal layout. This style of layout is designed to encourage customers to snake through all the aisles and then exit the store. The first aisle carried the fresh produce to dispel any shopping inertia (Buttle 1984) and the next two aisles held demand items such as canned foods, tea and coffee together with other products such as biscuits. These three aisles were continuous to encourage customers to shop the whole range of displayed merchandise. The next two aisles had a cross over point half way along. This break was designed to allow the delicatessen customers to collect their service ticket and then shop the surrounding area and return easily when their turn arose. These aisles also carried a wide range of goods. The remaining three aisles were again continuous. The frozen foods were in their traditional place towards the end of the circuit. The last aisle mixed demand categories such as the bread section with soft drinks and cakes. At the end of the last aisle there was an alcoholic drinks section whose design had the visual concept of a wine cellar.

Survey Coverage

The whole store was covered by using 20 camera locations. This meant that in addition to the 10 large camera units 20 smaller Ricoh units had to be used (two for each location). The survey was conducted on a Friday evening (from 5.00pm to 7.00pm) and a Saturday morning (from 10.30am to 12.30pm). At the same time a video record was taken of the entrance and exit to see how many people came into the store. In this survey all of the cameras' firing times were the same. In all there were 13,100 customer sightings which detailed the behaviour of 621 customers. This means that on average each customer was in the store for approximately 21 minutes. There were also 1910 records of staff presence on the trading floor or at the tills.

As this was a survey to discover how the store functioned all the variables were recorded from the film. By this time the rate of analysis had speeded up considerably because there were 15 people working on the film and the method of recording the data had changed from the light table to the desktop projector. The film took 300 man-hours to analyse.

SURVEY FINDINGS

The three images shown in figures 8.17, 8.18 and 8.19 show the probable path of people once they have entered the store. The flows followed the zig-zag or "snake" pattern found elsewhere until the end of aisle 3. At this point there were considerable back flows into aisle 2 and a number of people who miss aisles 4 and 5 and go to straight to the delicatessen. One would have expected the numbers to have been higher as the nature of the merchandise should encourage browsing and hence a longer stay in the area. Once the snake was broken it did not re-form. The reasons for the breakdown were the delicatessen, at which customers had to wait for service, and congestion which is discussed later.

The main exit route from the shopping to the checkout area was aisle 7, the frozen food aisle. The lower aisle had relatively low levels of traffic. It is the traditional design philosophy to place the frozen foods towards end of the store as shoppers perceive the need to leave after their selection to reduce thawing (Buttle 1984).

FIGURE 8.17

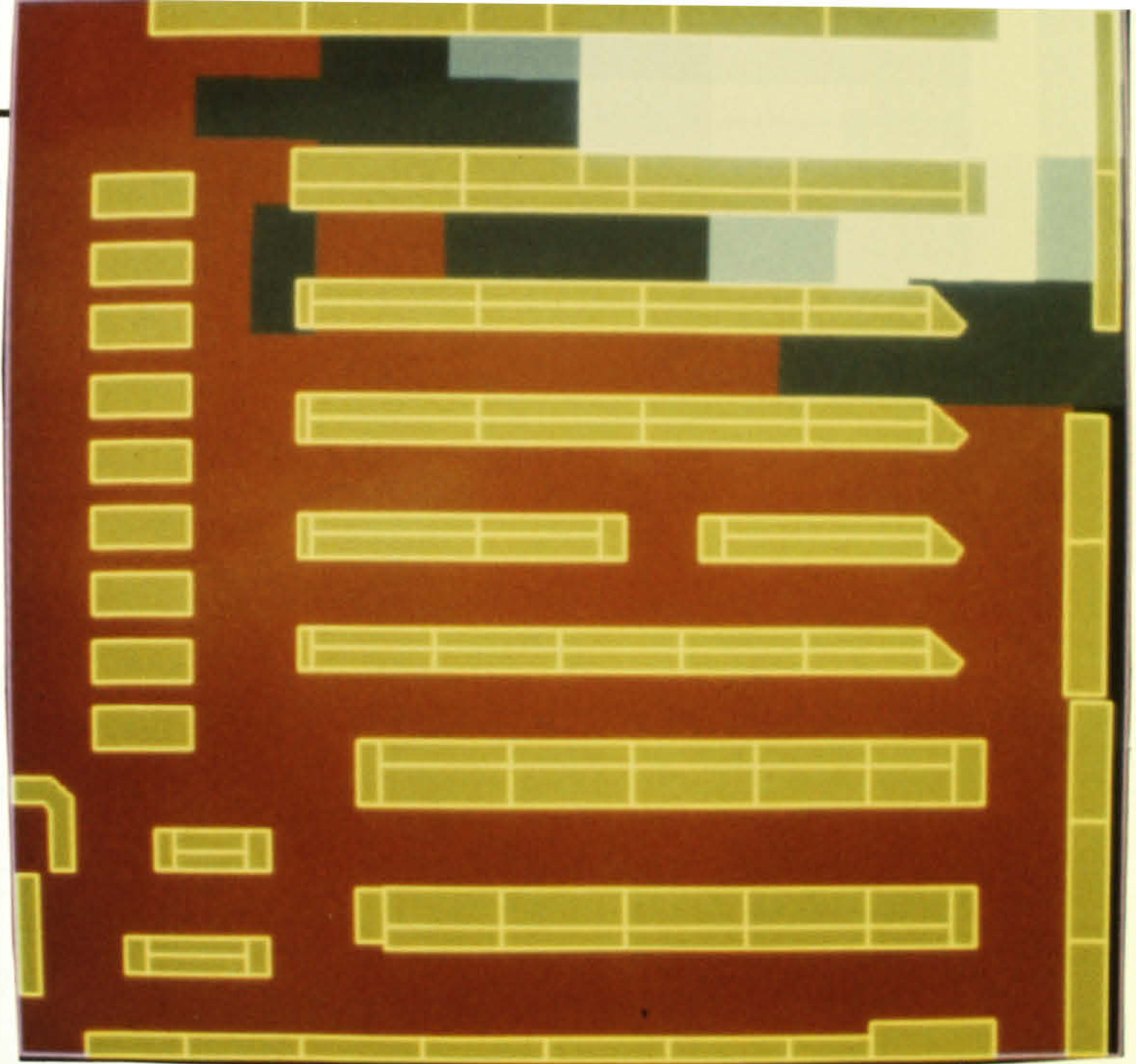


FIGURE 8.18

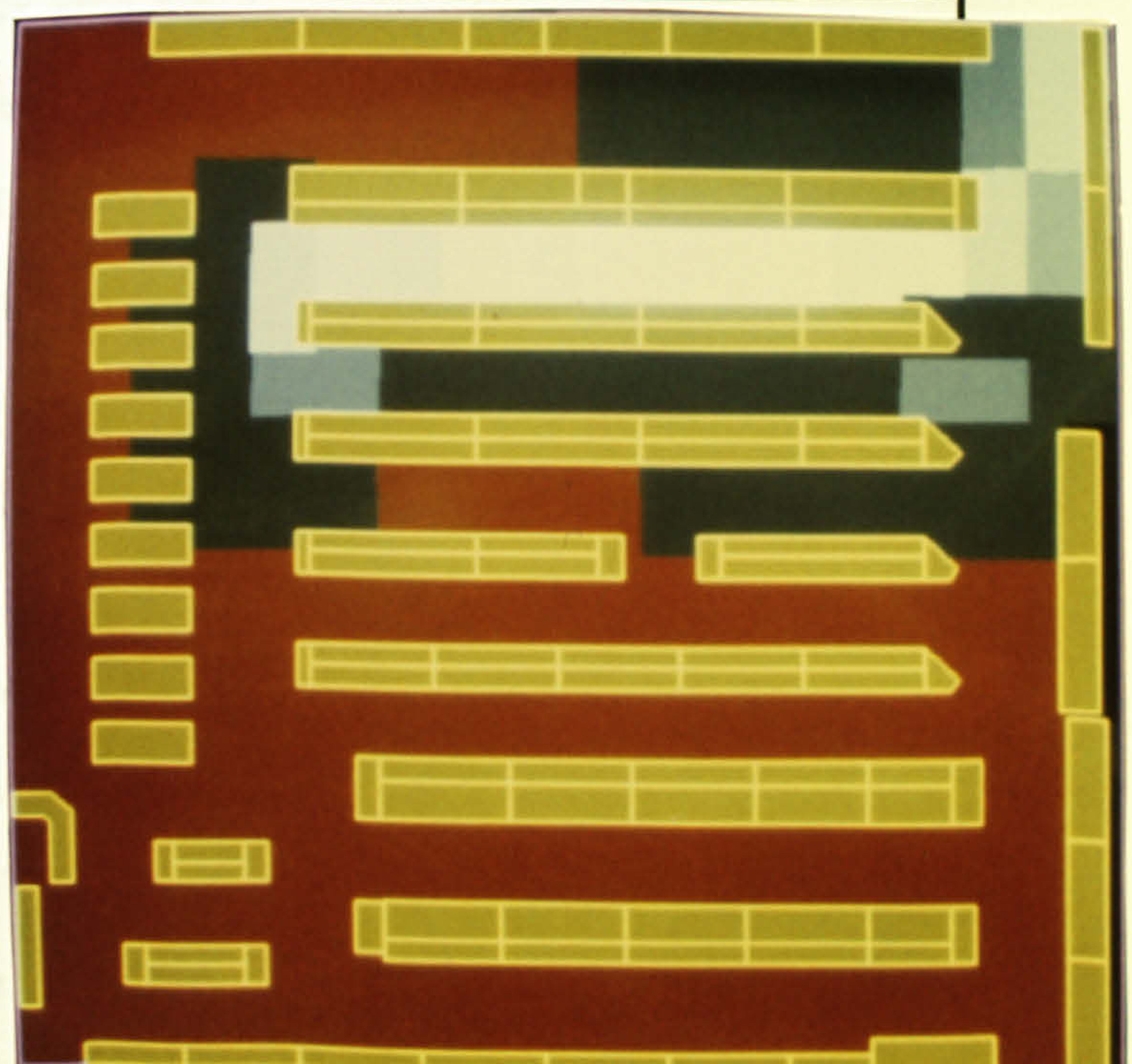
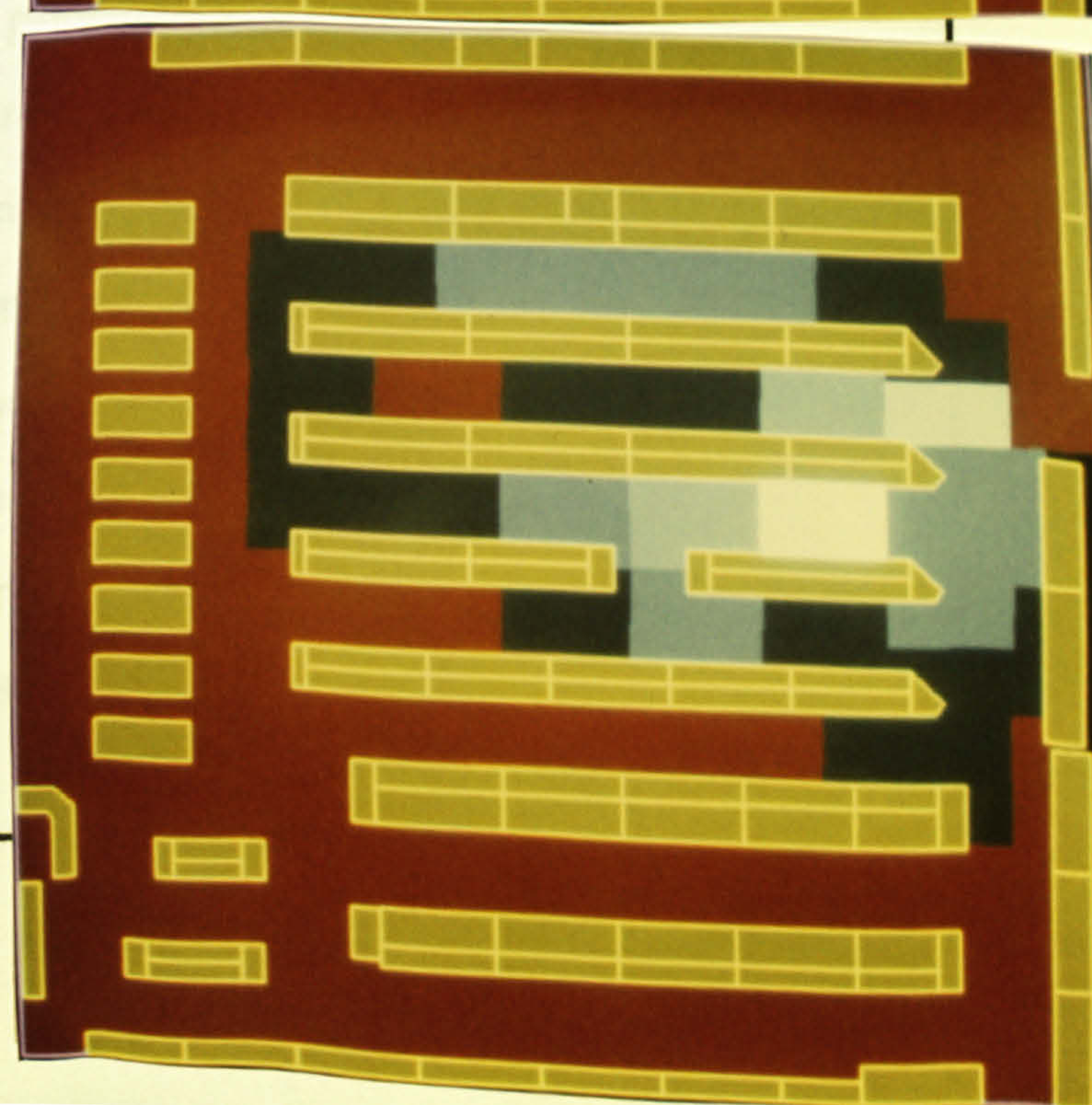


FIGURE 8.19



The Progressive Grocer (1975) argues that this type of location at the end of the store hampers the performance of frozen goods but this is not the case here with the aisle recording the second highest traffic levels (figure 8.20). The lower aisle containing generative demand items, such as bread, and high profit lines, such as bottled drinks, had under half the traffic. The problem in this area seemed to stem from the delicatessen. Customers moving down from the service area had had their "snake" pattern disturbed and had the choice of how to resume their shopping. The greatest percentage moved down the back wall along the dairy chiller units thus making the choice of aisle less obvious. From that location the frozen food aisle was the most open. It would seem that it is the dairy chiller unit as opposed to the confectionery at the start of aisle 6 that is most attractive to the ex-Delicatessen customer. This suggests that a resiting of these departments would be sensible.

Congestion

During periods of normal traffic levels the store was seen to cope well with the traffic levels. However during the peak times, after 6pm on Friday and from 11am on Saturday critical traffic states were a common occurrence. A critical traffic state was deemed to occur when four or more people occurred in one of the outlined areas (normally 4 by 2 metres). Fruin (1971) reports a "circle of trust" at an area of 0.8 by 1.3m at which personal contact is possible and a smaller 0.5 by 0.8m area at which contact can be avoided but personal encroachment is high. The latter level is usually adopted in queues. At higher densities special codes of conduct are required to avoid contact and intimacy. Fruin states that if a person is to be "comfortable" a much larger area is required. Thus each customer

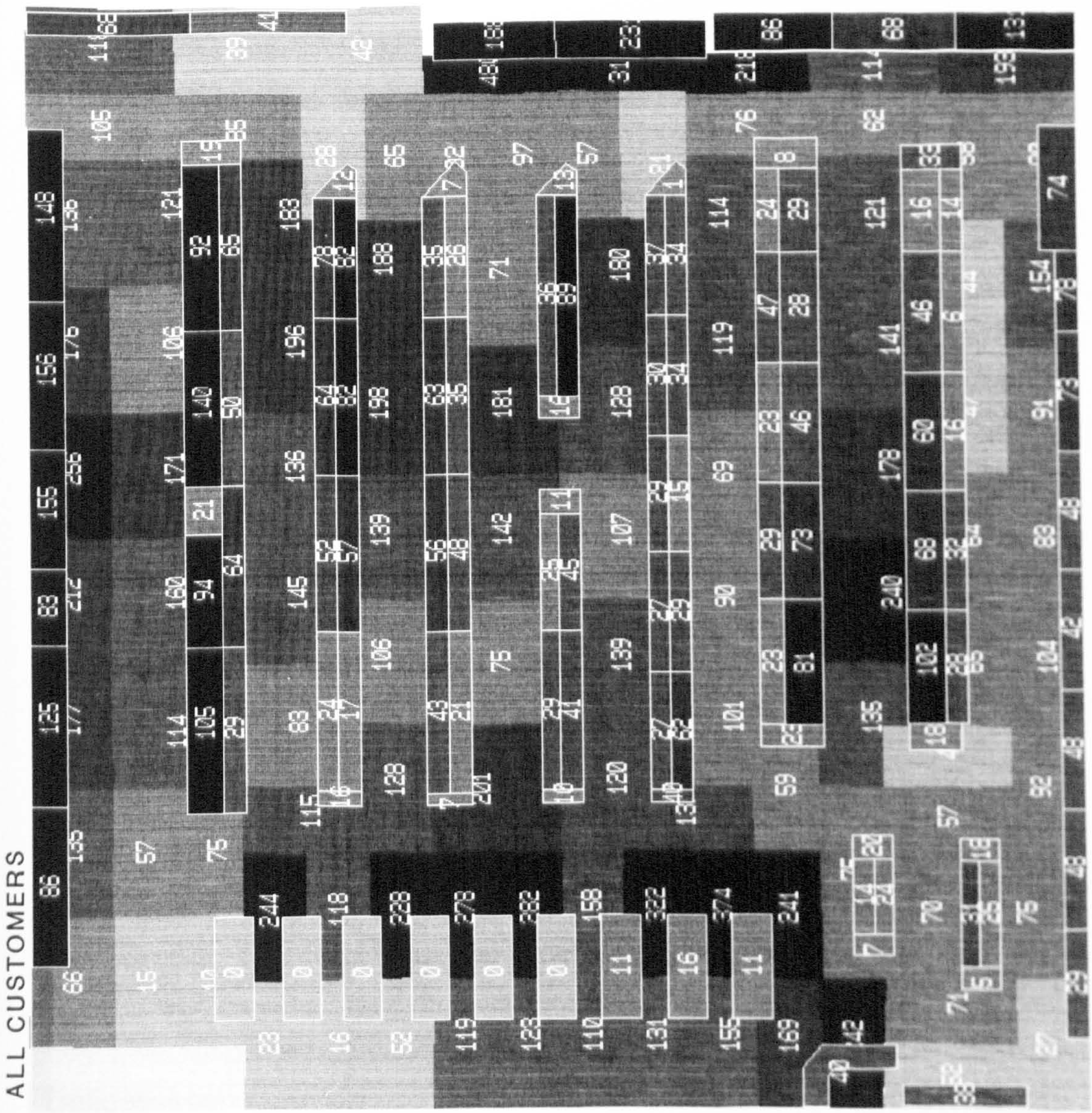


Figure 8.2

needs a minimum of 1.0 by 1.0 metres. If a customer has a trolley this may increase to 1.0 by 2.0 metres. Unfortunately there was no record made of trolley usage but on the basis of recollection about 50% of all customers were in charge of one. Therefore using the threshold level of 4 people per area 75% of the area would be used by the customers and 25% would be free to allow movement. The causes of the critical traffic levels can be divided into three categories: checkout queues, counter service queues (delicatessen) and congestion.

Checkout Queues

On average 26% of a customer's time in the store was spent queuing and being served at the checkouts. This translates to an average of just over five minutes. This figure compares well with the 6.5 minutes recorded in the Progressive Grocer (1975) and probably reflects the impact of laser scanning tills and other developments. Generally the queues were confined to the region immediately adjacent to the tills but there were times when this traffic spilled over to the aisle ends (figure 8.21). One area in particular exceeded the blocking threshold 57% of the time and its two neighbours 18%. At such times the ends of the aisles were effectively sealed off with the result that firstly the other shoppers had to increase their effort, and secondly the design flow path of the store was broken.

Delicatessen Queues

Queuing in the delicatessen area did not present many congestion problems as there was a flow route open for over 90% of the time. What was slightly worrying was that the few occasions that the routes were blocked coincided with blockages at the other end. This may have had an adverse impact of shopper psychology as some

QUEUING AND CONGESTION

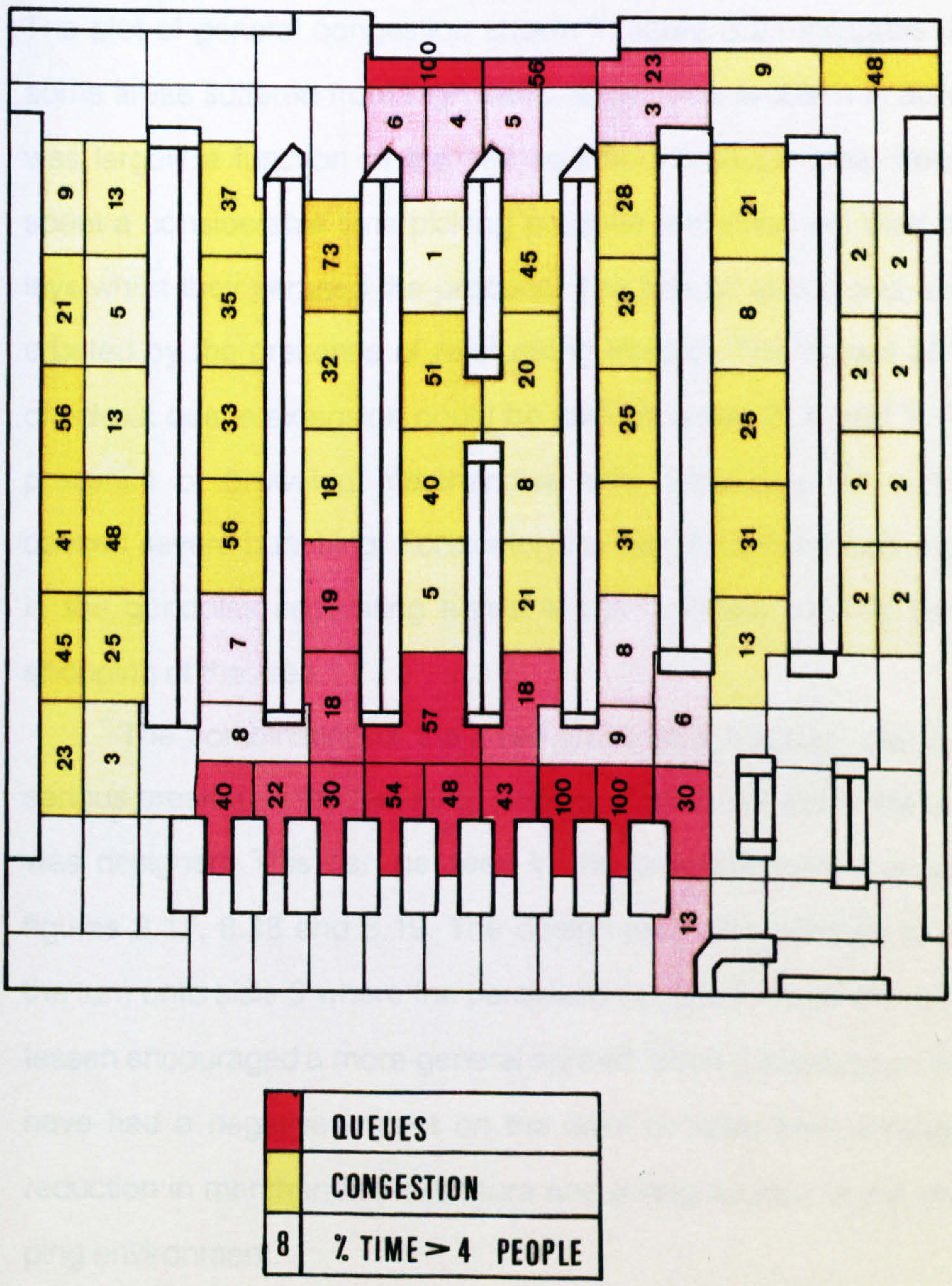


Figure 8.21

customers shifted their focus away from the products to the task of manoeuvring their trolley around the store. This might have been detrimental to the sales of secondary impulse items.

General Congestion

The plot of general congestion shown in figure 8.21 indicates that some areas suffered from high traffic levels. The problem in aisle 1 was largely a function of the self selection produce area. People spent a considerable time picking produce and often left their trolleys whilst they perused the produce. The lack of space was exacerbated by the presence of re-stocking trolleys. The impact of the checkout queue extension could be seen in aisles 3, 4 and 5. The presence of browsing merchandise and customers "U" turning caused severe bunching. Fortunately for the store there was a gap in the gondolas separating aisles 4 and 5 which allowed partial shopping of the area.

The combination of the three types of congestion caused a serious breakup in the "snaking" pattern of flows for which the store was designed. This can be seen in the probable path images in figures 8.17, 8.18 and 8.19. The design path was adhered to until the turn onto aisle 3 where the perceived congestion and the delicatessen encouraged a more general spread. Such a breakdown must have had a negative impact on the level of sales both through a reduction in merchandise exposure and a degradation of the shopping environment.

Gondola Viewing

Examination of the percentage of customers viewing a gondola as they pass it reveals some interesting results. Figure 8.22 shows the

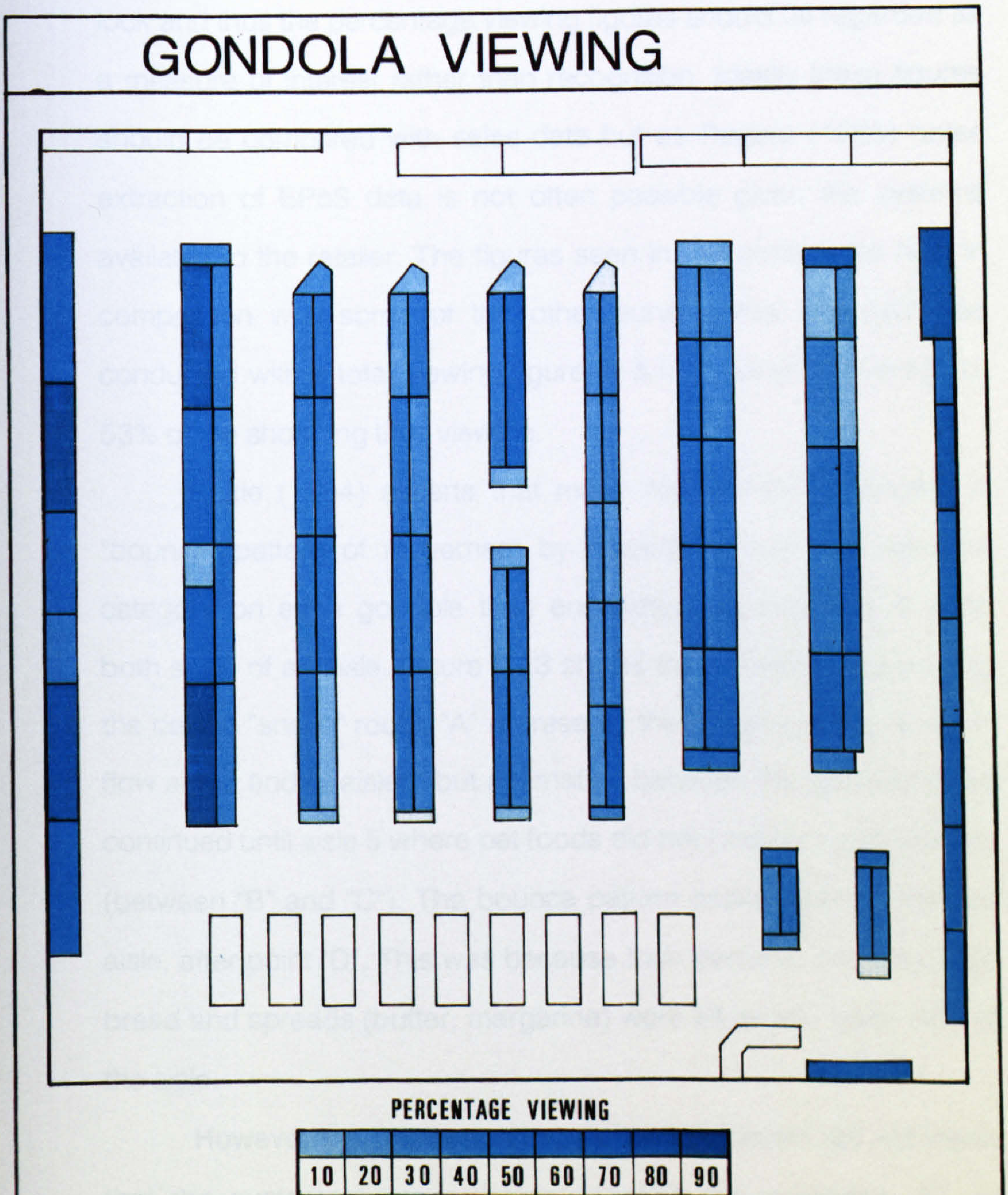


Figure 8.22

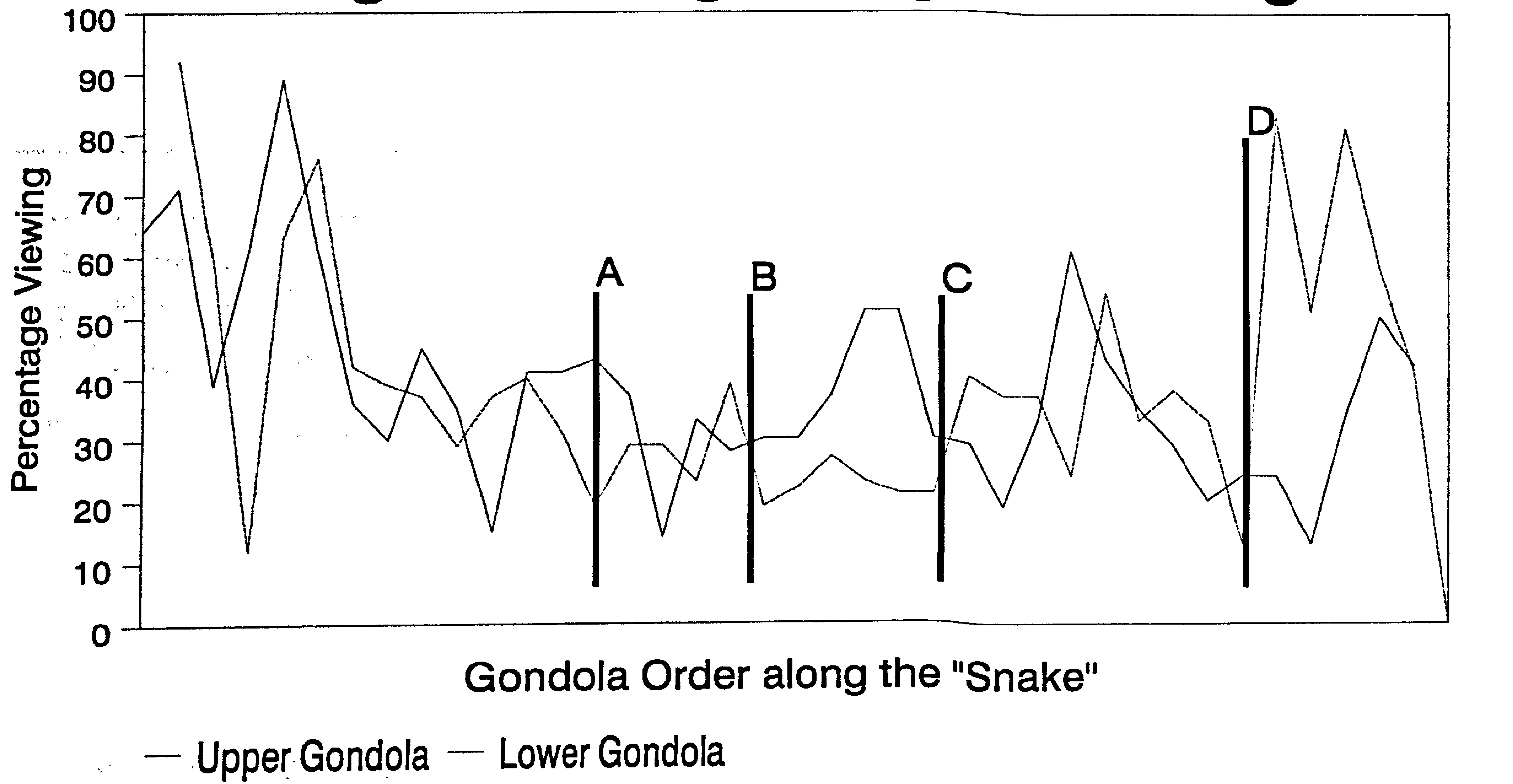
viewing data for each of the gondola sections calculated from the numbers viewing a particular gondola and the numbers in the immediate vicinity. Because of the nature of time-lapse photography it is more likely to record positive interest in a display than a passing look and thus the percentage viewing figures should be regarded as a measure of interest rather than recognition. Ideally these figures should be compared with sales data but as Rogers (1985) notes extraction of EPoS data is not often possible given the systems available to the retailer. The figures seen in this study were high in comparison with some of the other surveys that the RAT had conducted with a total viewing figure of 5132 giving an average of 53% of the shopping time viewing.

Buttle (1984) asserts that many retailers try to develop a "bounce" pattern of movement by placing at least one demand category on each gondola thus encouraging customers to shop both sides of an aisle. Figure 8.23 shows the bounce pattern along the design "snake" route. "A" represents the breakup of the smooth flow at the end of aisle 3 but alternation between the gondola sides continued until aisle 5 where pet foods did not present much interest (between "B" and "C"). The bounce pattern broke again in the last aisle, after point "D". This was because high demand items such as bread and spreads (butter, margarine) were all on the lower side of the aisle.

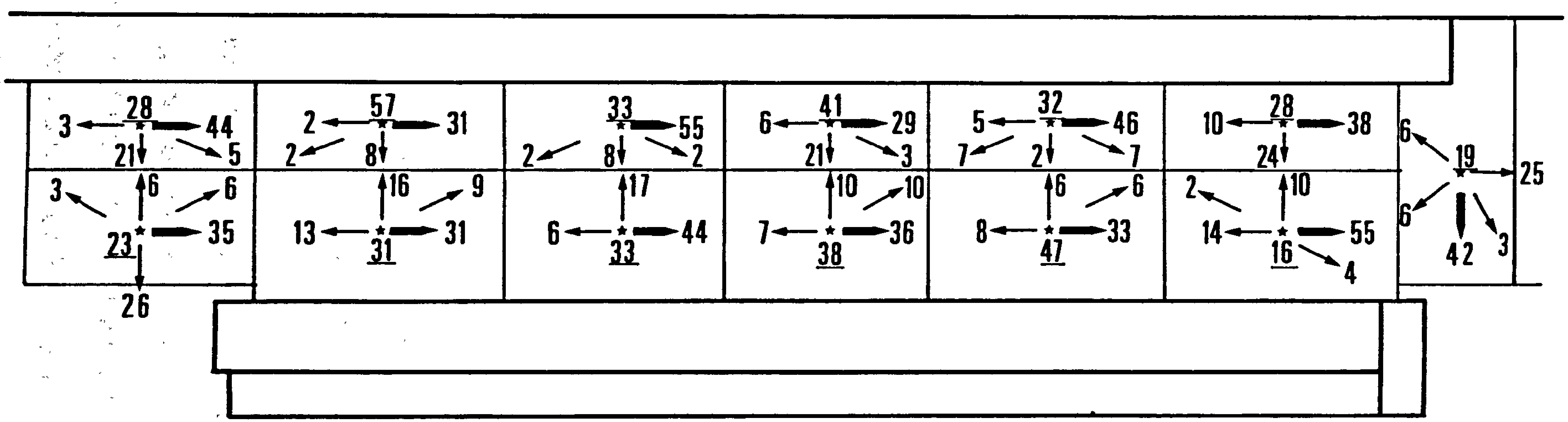
However this alternation in peak viewing levels did not mean that the customers are crossing between the gondolas. As an example the movement directions of customers on aisle 1 are shown in figure 8.24. A significant number of people stayed within the same animation unit. This indicated that a customer on one of

Figure 8.23

Percentage Viewing along the Design Path



FLOW ON THE FIRST AISLE



→17	FLOW DIRECTION & PERCENTAGE	▬►	PRIMARY DIRECTION	45	PERCENTAGE STILL

Figure 8.24

the two squares that make up each unit moved only to the other square. This pattern of movement along the gondolas was also seen in the values of parallel flows which in all cases exceeded the levels of cross flows which rarely went beyond 20% of movements. Thus it would seem that customer inertia is at work as people prefer to stay on one side and only cross when the desire is strong enough.

CONCLUSIONS

In the analysis of customer spatial behaviour in the seven stores that the RAT has surveyed PRETTY has shown itself to be a very flexible tool both for the analysis and presentation of behavioural patterns. Much of the benefit of the system comes from the ability to animate subsets of the general population. As the database contains the full list of variables recorded during the film analysis it is possible to break down the population into groups such as young single women pushing prams or married old aged pensioners. It is also possible to monitor those people who are stationary and then subdivide that group into people queuing, looking at products or talking to staff. The ability to select out particular types of customers allows hypotheses about the reasons for store usage anomalies to be tested. The availability of a film record of behaviour has also been essential as it allows re-examination of the operational situation during the survey. The analysis system has been of great benefit to the retailers that have used it.

The development of the probable path modelling module was very beneficial during the supermarket study as it facilitated the discovery of the point at which design flow paths failed and thus highlighted why the store is not working as intended. The WONKA system had problems in more open store environments and did not make full use of the fine detail of the data. One extra aspect of this PRETTY module that has not been shown here is the ability to develop different diffusion models for different populations or time periods. This allows the user to model the response to aisle or till closure and compare such behaviours to "normal" conditions. For example the retailer could close a cross aisle off for half an hour and monitor the customers before and during the change. The impact of small changes can thus be tested and assessed.

Store Design

The surveys reported here were commissioned to examine particular store layout and design problems, and to suggest remedies. A number of general conclusions applicable to store design are listed below:

a)The total number of people in the stores was far higher than the retailer thought. In one typical survey it was found that there were on occasion five times the number of people in the store as thought by the store planners. Purchaser counts grossly underestimated the number of people in the store. Usually the purchaser was accompanied by an association group (family, friends etc) of some sort. This conclusion has a direct effect on the planning of aisle widths and general layout sizes.

b)The build up of queues must not be underestimated otherwise flow patterns will be uncontrollable and trade will suffer. In the case of checkouts additional space can be allowed and a more responsive system of operation employed. The ticketing system for counter service seems to be only partially successful as many people take defensive action and wait for their turn rather than shopping elsewhere and returning. Problems at counter service units can be alleviated by providing good self service products nearby.

c)In order to get customers to move to an area they must know what is there. If a corner gondola or an island unit blocks the view of the area it severely reduces the numbers of customers moving there. This was seen in both the supermarkets and other types of store. The need for clarity is increased with the use of design paths or go-tracks.

d) Immobile social gatherings in stores play an important role in congestion. Groups of five or more holding animated conversations commonly blocked aisles for up to 20 minutes at a time. In many cases these stationary social groups exhibited no buying behaviour while in the store.

e)Cross aisles tended to be underused compared with the major longitudinal paths. However in the case of the supermarket they provide a vital safety valve if congestion occurs. It may be prudent to include a number to cope with peak traffic although as Buttle (1984) notes these may reduce merchandise exposure. This could be done with removable units.

f)The generative capacity of merchandise must be carefully considered. In many cases popular merchandise has been located on either side of design paths. The lively interest generated has at times led to great congestion and effective pathway closure. Such products do not need the best locations and should be used to move people into and around the store.

g)The generally held theory that gondola ends are high value display areas was not borne out in these surveys. The viewing figures were generally low. The sales of items displayed on gondola ends may rise, but possibly only in relation to the increased exposure.

h)The personal variables of a customer had an enormous influence in determining parts of a store visited, time in store, movement behaviour, and the viewing of merchandise. Very different patterns were observed for different groups in terms of both time of day and day of week.

Future Developments

One of the major disappointments with this work has been the failure of the retailers to provide computerised sales data. All the stores surveyed used a full EPoS system that recorded unique product codes but, as with Rogers (1985), few retailers were able to extract this information from their systems. A simple viewing ratio has been used in the examples given above to assess gondola performance. If sales data from EPoS records and possibly DPP (Direct Product Profitability) information were available gondola performance could be analysed in terms of viewing, sales and profit. This would allow a company to identify where problems existed in a store. Figure 8.25 shows what could be achieved. The first two layers of the information cake, covering customer movement and viewing, can be supplied by the camera tracking surveys to whatever level of detail may be required. The addition of detailed sales information at the product level from EPoS till records allows detailed analysis of the relation between customer viewing and sales. It is then possible to determine whether low sales of a product are due to too few customers in the vicinity of the product, or perhaps, due to a lack of interest shown by the customers in the gondola display in terms of the

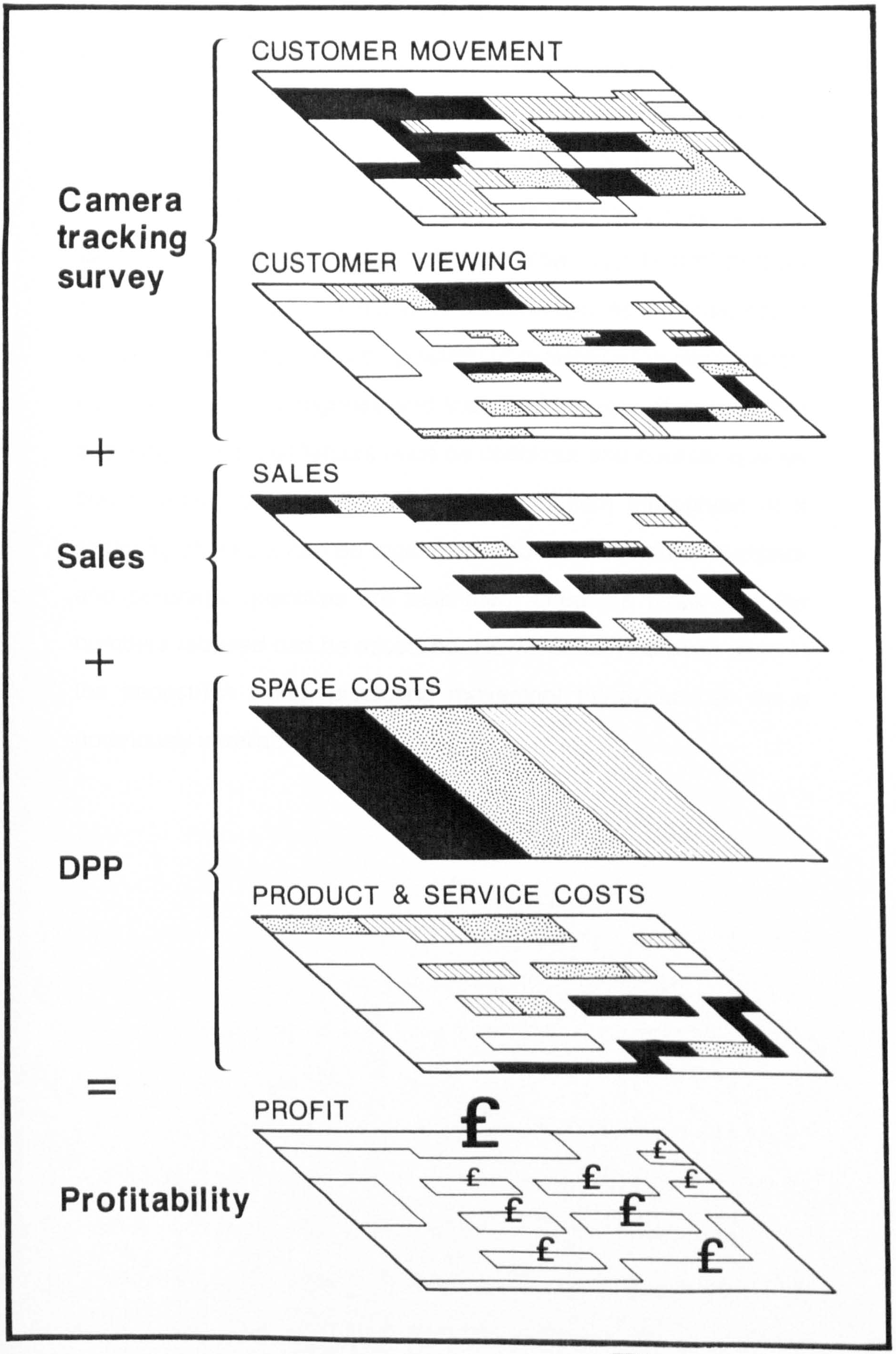

Camera tracking survey
CUSTOMER MOVEMENT
CUSTOMER VIEWING
+
Sales
SALES
+
DPP
SPACE COSTS
PRODUCT & SERVICE COSTS
=
Profitability
PROFIT
£

Figure 8.25

number of looks the product receives. DPP information completes the data base in terms of space cost and product and service costs. The performance of different sectors of the store can be only be truly determined once the full set of layers has been generated.

The longer term aim of this project is to develop purely predictive models of store usage so that potential layouts and product placements could be tested prior to construction. As the database of behaviour develops it may be possible to determine the relationships between product categories and lines and the role of aisle widths and lengths. Certain factors such as checkout and counter queues could already be modelled. The speed of item throughput at a scanning checkout can be measured. Provided customer numbers and purchase quantities are estimated, checkout times and the numbers required can be assessed. However, as has been seen in the pedestrian world, predicting movement behaviour can be a notoriously unreliable process.

RESEARCH CONCLUSIONS: FUTURE DIRECTIONS

The main thrust of this research has been the development of analysis techniques that can be used to illustrate the vagaries of pedestrian and customer spatial behaviour. The data analyses presented in this thesis were by no means intended as a definitive examination of the data but as a demonstration of the flexibility of both the collection, analysis and presentation systems that have been developed since October 1986.

Overall there have been few major difficulties with this research even though the scale of the software development and data collection effort has been large. This is one of the major advantages of cooperative research. There have been a few problems associated with the estimation of demographic information from photographs but the results of the turnover prediction interface have validated the techniques employed. The success of the clustering exercise has been very pleasing. The range of variables collected from the time-lapse films is under constant review and in future surveys it may prove worthwhile including other variables such as culture or dropping others according to the requirements of the funding body.

A number of common behavioural strands have been identified throughout this research. For example, people using streets for access and shopping trips and the way the pedestrian profile changes throughout the day. The early morning and evening rush of the younger office and shop workers surrounds the more gentle shopping activities of the more mature pedestrians. The effect of path deviation caused by perceived crowding has been noted both in the pedestrian and in-store environments. In the town environment older pedestrians used King Street and Upper Parliament Street to bypass the crowded Clumber Street. High density waves in the flow numbers were seen in Clumber street and these must negatively affect the perceived environment. In the store environment congestion could be seen to brake flow paths and lead to early store exits. In a number of stores service queues were seen to completely close off sections of the store. It has not been possible to examine the effect on purchasing levels of crowding due to lack of sales data but defensive posturing, i.e. staking a claim to an area, and the low use of behind counter units has been seen in the Boots' beauty areas. Social gatherings have been a common feature of the survey results and it would seem that very few retailers compensate for such activity in store design.

The research pursued in this thesis has proved somewhat frustrating. The three avenues followed, pedestrian network modelling, the turnover interface and in-store behaviour, all have high promise but for various reasons, usually financial constraint, it has not been possible to take them to their natural conclusions. Work continues in the fields outlined in this thesis and it is hoped that a similar rate of progress will be maintained.

FLOW NETWORKS

The pedestrian data recently collected will facilitate the construction of flow networks segmented according to the demographic data. As discussed in chapter 3 sub-division of the population into demographically distinct groups might decrease the potential uncertainty caused by the "Coffee" shop effect. Work is about to resume on the building of city centre flow network models from the data provided by the two full city wide surveys. The development of these models will aid the assessment of potential competition between sites and the potential viability of trading units.

THE THRESHOLD

The research into the turnover prediction interface was encouraging. The aim of separating potential customers from the mass of pedestrian traffic was achieved. These findings confirmed that the basis of the project, the use of observable, surrogate variables, would aid the recognition of potential customers. The lack of customer interest data from different sites and over longer time periods means that an interface could not be built and verified. Janet Beckett, another member of the RAT, is currently devising an automatic pedestrian tracking system. This computer based system should enable the collection and analysis of sufficient data sets for the full definition of store interfaces.

IN-STORE

The in-store research effort has been hampered by the inability of the retailers to obtain their own detailed sales information. The PRETTY system as it stands is incomplete because of this data shortage. Provision of sales and cost data would permit a thorough investigation of the spatial variation in customer behaviour and store performance (see figure 8.25). As in the case of window and store usage discussed in chapters 5 and 6 such data would allow a company to identify where problems existed in a store. The trading success of departments and product ranges can be only be accurately assessed once a full information set is available.

THE FUTURE

Ideally the longer term aims of all strands of this research are to develop and test predictive models of movement behaviour. In the both the city centre and in-store environments such predictive models would be used to assess the impact of change and new developments. The growing database of movement and shopping behaviour should form a sound basis for this type of work although the routes to Valhalla are at present unknown.

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APPENDIX A - PROGRAM LISTINGS

****

The computer source code listed here is a result of collaborative programming between M.J.McCullagh and S.J.Thornton. Four programs are listed. The first three programs listed were developed for use both in city centre wide and in-store flow modelling (chapter 3). WONKA is the program that takes the raw flow data and derives a stable solution from it. INJECT allows the user to inject people into a link and specify the duration of the model period. FLOWMAP displays the INJECTed flow distribution and allows hard copy production. The final program, PRETTY, is the animation program used solely in store (chapter 7).

****

```
      PROGRAM WONKA
C***********************************************************************
C
C       WONKA  - ORIGIN DESTINATION THAT CALCULATES TURNING FLOWS
C                FROM LINE COUNTS. ERRORS FROM ESTIMATED FLOW VOLUMES
C                ARE REDUCED ITERATIVELY BY ADJUSTING THE ESTIMATED FLOW
C                RATES TOWARDS THE OBSERVED VALUES.
C       DATA   - DATA REQUIREMENTS ARE THE FLOW ON EACH LINK TO EACH
C                JUNCTION AND THE NUMBER OF THE FIRST "REST OF THE WORLD
C                LINK.
C
C       FOR INSTRUCTIONS TO PROGRAM READ THORNTON ET AL. (1987)
C
C***********************************************************************
      COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1       ERRS(2,250),CFE(2,250),TEA(2,250),
     2       COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3       IPEDFL
C
C......LAST MODIFIED FOR ROMFORD STUDY IN FEBRUARY 1989, TO ENSURE THAT
C......THERE IS ALWAYS A FLOW (ALBEIT SMALL) BETWEEN LINKS.
C
C......GET DATA FILE
      CALL READIT
C......CREATE CONNECTIVITY MATRIX FOR LINKS VIA JUNCTIONS
      CALL CONNEC
      MARK=0
```

```
C......CALCULATE THE PRELIMINARY ESTIMATE OF FLOWS
  100         CALL PRELIM
C......PRINT FIRST ASSIGNMENT OF PEDESTRIAN FLOWS
              ITER=0
              TERROR=0.0
              IF(MATPRN.EQ.1) THEN
                CALL PEEDAL(ITER,ERROR)
              ENDIF
C......NOW ITERATE ROUND AND ROUND AND ROUND AND ROUND......
  103         ITER=ITER+1
              WRITE(*,200)ITER
              CALL COLSUM(HUMAN)
              CALL REPORT('COLUMN')
              CALL ROWSUM(DIVINE)
              CALL REPORT('ROW')
              ERROR=AMAX1(HUMAN,DIVINE)
              WRITE(*,207)ITER,ERROR
              IF(ERROR.GT.TOL) THEN
                 IF(ABS(TERROR-ERROR).GT.TTOL)THEN
                  TERROR=ERROR
                  GOTO 103
                ENDIF
              ENDIF
C......CHECK INDIVIDUAL ERRORS FOR FLOWS AT JUNCTIONS
              CALL COFFEE(KOFERR)
C......CHECK FOR COFFEE-SHOPS, AND ADJUST TOLERANCES FOR SECOND CYCLE
              IF(KOFERR.EQ.1.AND.MARK.EQ.0) THEN
                TOL=STOL
                MARK=1
                GOTO 100
              ENDIF
C......ADD COFFEE SHOP EFFECT PEOPLE FOR BOTH DIRECTIONS ALONG THE LINK
C......TO THE PRINCIPAL DIAGONAL OF PED
              DO 101 I=1,LINKS
                PED(I,I)=TEA(1,I)+TEA(2,I)
  101         CONTINUE
C......PRINT OUT FINAL FLOWS FOR PEDESTRIANS
              CALL PEEDAL(ITER,ERROR)
                STOP
  200         FORMAT(//,' ITERATION NUMBER ',I3,/)
  207         FORMAT(/,' AVERAGE PROPORTIONATE ERROR FOR ITERATION',I3,
     1               ' = ',F6.4)
              END

              SUBROUTINE COFFEE(KOFERR)
              COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1               ERRS(2,250),CFE(2,250),TEA(2,250),
     2               COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3               IPEDFL
C......LOOK FOR COFFEE SHOP ERRORS - ONES WHERE THE FLOW IN ONE
C......DIRECTION TURNS ROUND BEFORE PASSING INTO THE NODE AT THE
C......END OF THE LINK, AND RETURNS TO WHENCE IT CAME.
              WRITE(*,201)
              KOFERR=0
              DO 101 I=1,LINKS
                DO 102 J=1,2
                  IF(ERRS(J,I).LT.-COFTOL) THEN
                    KOFERR=1
                    K=J*2-1
                    CFE(J,I)=ABS(ERRS(J,I))
                    TEA(J,I)=CFE(J,I)*JUNK(I,K+1)
                    WRITE(*,200)I,JUNK(I,K)
                  ENDIF
  102           CONTINUE
  101         CONTINUE
              RETURN
  200         FORMAT(' COFFEE SHOP ON LINK ',I3,' LOOKING TOWARDS JUNCTION ',
     1               I3)
  201         FORMAT(//)
              END

              SUBROUTINE PEEDAL(ITER,ERROR)
              COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1               ERRS(2,250),CFE(2,250),TEA(2,250),
     2               COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3               IPEDFL
```

```
C......PRINT OUT PEDESTRIAN FLOW INFORMATION
C           IF(ITER.EQ.0) THEN
C             CALL OUTPUT('INITIAL ASSIGNMENT OF FLOWS',PED,LINKS,LINKS,
C     1                   100,100,1,IERR)
C           ELSE
C             CALL OUTPUT('FINAL ASSIGNMENT OF FLOWS',PED,LINKS,LINKS,
C     1                   100,100,1,IERR)
C           ENDIF
            IF(ITER.NE.0) THEN
              WRITE(*,204)
              DO 101 I=1,LINKS
                DO 102 J=1,2
                  K=J*2-1
                  IF(TEA(J,I).GT.0.) THEN
                    WRITE(*,203)I,JUNK(I,K),TEA(J,I)
                  ENDIF
                  CFE(J,I)=JUNK(I,K)
  102           CONTINUE
  101         CONTINUE
              CALL OUTPUT('LINK-JUNCTION TABLE',CFE,2,LINKS,2,100,1,IERR)
              CALL OUTPUT('FINAL FLOW ERRORS',ERRS,2,LINKS,2,100,2,IERR)
              WRITE(*,207)ITER,ERROR
            ENDIF
C......WRITE OUT PEDESTRIAN FLOW/TURNING DATA TO FILE IF REQUESTED
            IF(IPEDFL.EQ.1) THEN
C......PEDFLOW USES A COMPRESSED DATA FORMAT WHERE ONLY NON-ZERO ENTRIES
C......ARE RECORDED. THIS IS DONE BY RECORDING THE ROW/COLUMN AND THEN
C......VALUE OF NON-ZERO VALUES, AND SIMILARLY FOR TEA-SHOPS.
              WRITE(11,201)LINKS,LINKS
              DO 103 I=1,LINKS
                DO 105 J=1,LINKS
                  IF(PED(I,J).NE.0.0)WRITE(11,202)I,J,PED(I,J)
  105           CONTINUE
  103         CONTINUE
              I=0
              WRITE(11,202)I,I,PED(1,1)
C......WRITE OUT NUMBER OF PEDESTRIANS IN COFFEE SHOPS FOR EACH LINK
              DO 104 I=1,2
                DO 106 J=1,LINKS
                  IF(TEA(I,J).NE.0.0)WRITE(11,202)I,J,TEA(I,J)
  106           CONTINUE
  104         CONTINUE
              I=0
              WRITE(11,202)I,I,TEA(1,1)
            ENDIF
            RETURN
  201       FORMAT(' ',2I4)
  202       FORMAT(' ',2I4,F7.3)
  203       FORMAT(' COFFEE SHOP POPULATION FOR LINK ',I4,
     1             ' LOOKING TOWARDS JUNCTION ',I4,
     2             ' IS ',F7.0)
  204       FORMAT(//)
  207       FORMAT(/,' AVERAGE PROPORTIONATE ERROR FOR ITERATION',I3,
     1             ' = ',F6.4)
            END

            SUBROUTINE REPORT(NAME)
            CHARACTER*(*) NAME
            CHARACTER*70 TITLE
            COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1             ERRS(2,250),CFE(2,250),TEA(2,250),
     2             COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3             IPEDFL
C......REPORT ERROR FOR INDIVIDUAL LINK CONNECTIONS
            TITLE=NAME//' SUM PROPORTIONATE FLOW ERROR FOR ALL LINKS'
            CALL OUTPUT(TITLE,ERRS,2,LINKS,2,100,2,IERR)
            RETURN
            END

            SUBROUTINE READIT
            CHARACTER*20 FNAME
            CHARACTER*1 ANS
            COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1             ERRS(2,250),CFE(2,250),TEA(2,250),
     2             COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3             IPEDFL
```

```
C......OPEN FILE CONTAINING PEDESTRIAN FLOW DATA
          WRITE(*,*) ' INPUT BASIC LINK DATA FILE NAME'
          READ(*,200) FNAME
          OPEN(10,FILE=FNAME,ACCESS='SEQUENTIAL',STATUS='OLD',
     1         FORM='FORMATTED',ERR=999)
C......GET NUMBER OF LINKS, AND REST OF THE WORLD NODE NUMBER
          READ(10,*)LINKS,MAXNOD
C......READ JUNCTION NUMBER AND FLOW DATA FOR EVERY LINK
          DO 100 I=1,LINKS
            READ(10,*)(JUNK(I,J),J=1,4)
  100     CONTINUE
          WRITE(*,*)'GIVE PRIMARY ERRTOL, SECONDARY ERTOL: '
          READ(*,*)TOL,STOL
          WRITE(*,*)'GIVE ITERTOL, AND MAGIC FACTOR: '
          READ(*,*)TTOL,WIZARD
          WRITE(*,*)'COFFEE SHOP TURNING FLOW EFFECT TOLERANCE: '
          READ(*,*)COFTOL
          WRITE(*,*)'PRINT INITIAL ASSIGNMENTS (Y/N)? '
          READ(*,200)ANS
          MATPRN=1
          IF(ANS.EQ.'N')MATPRN=0
          WRITE(*,*)'CREATE A PEDESTRIAN FLOW FILE ON DISK (Y/N)? '
          READ(*,200)ANS
          IF(ANS.EQ.'N') THEN
            IPEDFL=0
          ELSE
            IPEDFL=1
            OPEN(11,FILE='PEDFLOW',STATUS='UNKNOWN',ACCESS='SEQUENTIAL',
     1           FORM='FORMATTED')
          ENDIF
          RETURN
  999     write(*,*)'helppppppp..'
  200     FORMAT(A)
          END

          SUBROUTINE CONNEC
          COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1              ERRS(2,250),CFE(2,250),TEA(2,250),
     2              COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3              IPEDFL
C......ZERO THE LINK CONNECTIVITY, FLOW, AND ERROR MATRICES. SET THE
C......COFFEE SHOP EFFECT VECTOR TO 0, TO INDICATE PROPORTION HAVING
C......COFFEE. SET TEA TO ZERO TO CLEAR THE NUMBER OF PEOPLE IN THE
C......COFFEE SHOPS.
          DO 105 I=1,LINKS
            DO 100 J=1,2
              ERRS(J,I)=0.
              CFE(J,I)=0.
              TEA(J,I)=0.
  100       CONTINUE
            DO 106 J=1,LINKS
              JUN(I,J)=0
              PED(I,J)=0.0
  106       CONTINUE
  105     CONTINUE
C......CALCULATE CONNECTIVITY
          DO 101 I=2,LINKS
            DO 102 J=1,3,2
              NODE=JUNK(I-1,J)
              IF(NODE.LT.MAXNOD) THEN
                DO 103 K=I,LINKS
                  DO 104 L=1,3,2
                    IF(NODE.EQ.JUNK(K,L)) THEN
                      JUN(I-1,K)=NODE
                      JUN(K,I-1)=NODE
                    ENDIF
  104             CONTINUE
  103           CONTINUE
              ENDIF
  102       CONTINUE
  101     CONTINUE
          RETURN
          END

          SUBROUTINE PRELIM
          COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
```

```
     1            ERRS(2,250),CFE(2,250),TEA(2,250),
     2            COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3            IPEDFL
C......CALCULATE PROPORTIONATE FLOWS FROM EVERY LINK TO EVERY OTHER
C......LINK AT A NODE
      DO 100 I=1,LINKS
        DO 101 J=1,3,2
          NODE=JUNK(I,J)
          IF(NODE.LT.MAXNOD) THEN
            SUM=0
            DO 102 K=1,LINKS
              IF(I.NE.K) THEN
                IF(NODE.EQ.JUN(I,K)) THEN
                  IF(JUNK(K,1).NE.NODE) THEN
                    L=2
                    M=2
                  ELSE
                    L=4
                    M=1
                  ENDIF
                  SUM=SUM+JUNK(K,L)-TEA(M,K)
                ENDIF
              ENDIF
  102       CONTINUE
            DO 103 K=1,LINKS
              IF(I.NE.K) THEN
                IF(NODE.EQ.JUN(I,K)) THEN
                        IF(SUM.EQ.0.0) THEN
                                  PED(I,K)=0.01
                                  GOTO 101
                        ENDIF
                  IF(JUNK(K,1).NE.NODE) THEN
                    L=2
                    M=2
                  ELSE
                    L=4
                    M=1
                  ENDIF
                  N=L/2
                  PED(I,K)=(JUNK(K,L)-TEA(M,K))/SUM*
     1                     (JUNK(I,J+1)-TEA(N,I))
                ENDIF
              ENDIF
  103       CONTINUE
          ENDIF
  101   CONTINUE
  100 CONTINUE
      RETURN
      END

      SUBROUTINE COLSUM(ERROR)
      COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1            ERRS(2,250),CFE(2,250),TEA(2,250),
     2            COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3            IPEDFL
C......CALCULATE A COLUMN SUM FOR EVERY LINK, COMPARE WITH REALITY,
C......AND ADJUST THE FLOWS TOWARDS REALITY (HA BLOODY HA), ALLOWING
C......FOR THE COFFEE SHOP EFFECT.
      ERROR=0.
      N=0
      DO 100 I=1,LINKS
        DO 101 J=1,3,2
          NODE=JUNK(I,J)
          IF(NODE.LT.MAXNOD) THEN
            SUM=0.
            N=N+1
            DO 102 K=1,LINKS
              IF(I.NE.K) THEN
                IF(NODE.EQ.JUN(K,I)) THEN
                  SUM=SUM+PED(K,I)
                ENDIF
              ENDIF
  102       CONTINUE
            L=J/2+1
            M=MOD(J+2,4)+1
            WALKER=JUNK(I,M)-TEA(L,I)
```

```
                IF(WALKER.EQ.0.0) THEN
                  DIVINE=0.001
                          GOTO 999
                ENDIF
                DIVINE=(SUM-WALKER)/WALKER
 999            ERRS(L,I)=DIVINE
                ERROR=ERROR+ABS(DIVINE)
                DIVINE=1.-DIVINE*WIZARD
                DO 103 K=1,LINKS
                  IF(I.NE.K) THEN
                    IF(NODE.EQ.JUN(K,I)) THEN
                      PED(K,I)=PED(K,I)*DIVINE
                    ENDIF
                  ENDIF
 103            CONTINUE
              ENDIF
 101        CONTINUE
 100      CONTINUE
          ERROR=ERROR/N
          RETURN
          END

          SUBROUTINE ROWSUM(ERROR)
          COMMON /WINF/ JUNK(250,4),PED(250,250),JUN(250,250),
     1           ERRS(2,250),CFE(2,250),TEA(2,250),
     2           COFTOL,TOL,STOL,TTOL,WIZARD,LINKS,MAXNOD,MATPRN,
     3           IPEDFL
C......CALCULATE A ROW SUM FOR EVERY LINK, COMPARE WITH REALITY,
C......AND ADJUST THE FLOWS TOWARDS REALITY (HA BLOODY HA), ALLOWING
C......FOR THE COFFEE SHOP EFFECT.
          ERROR=0.
          N=0
          DO 100 I=1,LINKS
            DO 101 J=1,3,2
              NODE=JUNK(I,J)
              IF(NODE.LT.MAXNOD) THEN
                SUM=0.
                N=N+1
                DO 102 K=1,LINKS
                  IF(I.NE.K) THEN
                    IF(NODE.EQ.JUN(I,K)) THEN
                      SUM=SUM+PED(I,K)
                    ENDIF
                  ENDIF
 102            CONTINUE
                L=J/2+1
                WALKER=JUNK(I,J+1)-TEA(L,I)
                IF(WALKER.EQ.0) THEN
                       DIVINE=0.001
                  GOTO 999
                ENDIF
                DIVINE=(SUM-WALKER)/WALKER
 999            ERRS(L,I)=DIVINE
                ERROR=ERROR+ABS(DIVINE)
                DIVINE=1.-DIVINE*WIZARD
                DO 103 K=1,LINKS
                  IF(I.NE.K) THEN
                    IF(NODE.EQ.JUN(I,K)) THEN
                      PED(I,K)=PED(I,K)*DIVINE
                    ENDIF
                  ENDIF
 103            CONTINUE
              ENDIF
 101        CONTINUE
 100      CONTINUE
          ERROR=ERROR/N
          RETURN
          END

          SUBROUTINE OUTPUT(TITLE,X,M,N,M1,N1,IFORM,IERR)
          CHARACTER*(*) TITLE
          DIMENSION X(M1,N1)
C......WRITE OUT A TABLE HELD IN X, WITH TITLE IN TITLE, ON THE SCREEN
          WRITE(*,200)TITLE
          CALL PRINTM(X,M,N,M1,N1,IFORM,IERR)
          RETURN
```

```
200       FORMAT(//,' ',A)
          END

          SUBROUTINE PRINTM(A,M,N,M1,N1,IFORM,IERR)
          DIMENSION A(M1,N1)
          IERR=0
          DO 100 IB=1,N,10
            IE=IB+9
            IF(IE.GT.N)IE=N
            WRITE(*,200,ERR=102)(I,I=IB,IE)
            DO 101 J=1,M
              IF(IFORM.EQ.1) THEN
                WRITE(*,201,ERR=102)J,(A(J,K),K=IB,IE)
              ELSE
                WRITE(*,202,ERR=102)J,(A(J,K),K=IB,IE)
              ENDIF
101         CONTINUE
100       CONTINUE
          RETURN
102       WRITE(*,*)'WRITE ERROR IN PRINTM'
          IERR=1
          RETURN
200       FORMAT(/,' ',4X,10I7)
201       FORMAT(' ',I5,10F7.0)
202       FORMAT(' ',I5,10F7.3)
          END
```

```
      PROGRAM INJECT
C*************************************************************************
C
C     INJECT - PROGRAM TO CONVERT FLOW PEDESTRIAN MATRIX INTO DIRECTIONAL
C              TRANSITION PROBABILITY MATRICES, AND THEN ALLOW MODELLING OF
C              PHOTO DATA TO DEMONSTRATE DISPERSION OF PEDESTRIANS INTO THE
C              NETWORK
C     DATA   - USE WONKA OUTPUT FOR PROBABILITIES AND ORIGINAL DATA FOR
C              CONNECTIVITY
C
C*************************************************************************
      COMMON /PEDGRF/
     1       JUN(250,250),JUNK(250,4),INJECT(2,250),
     2       PED(250,250),TEA(2,250),FLOWS(2,250),PERM(2,250),
     3       MLINK,LINKS,MAXNOD,NIT,ITER,ITINT,ISIZ,
     4       LXMN,LXMX,LYMN,LYMX,NNOD,
     5       XMN,XMX,YMN,YMX,FLMAX,SCALE
      WRITE(*,*)'MODEL OF PEDESTRIAN MOVEMENT USING FLOW ',
     1          'MATRIX FROM WONKA'
      CALL READIN
C......CALCULATE PEDESTRIAN TRANSITION PROBABILITIES. THESE WILL
C......INDICATE THE PROPORTION OF ANY FLOWS THAT PASS FROM ONE LINK
C......TO ANOTHER.
      CALL TPROB
C......INPUT PHOTO DATA
      CALL PHOTON
C......PERMEATE THE INJECTION PEDESTRIANS THROUGHOUT THE NETWORK
      CALL MIASM
      STOP
      END

      SUBROUTINE MIASM
      CHARACTER*30 FNAME
      COMMON /PEDGRF/
     1       JUN(250,250),JUNK(250,4),INJECT(2,250),
     2       PED(250,250),TEA(2,250),FLOWS(2,250),PERM(2,250),
     3       MLINK,LINKS,MAXNOD,NIT,ITER,ITINT,ISIZ,
     4       LXMN,LXMX,LYMN,LYMX,NNOD,
     5       XMN,XMX,YMN,YMX,FLMAX,SCALE
C......REPETITIVELY PERMEATE THE MATRIX WITH PEDESTRIANS INSERTED INTO
C......THE NETWORK AT THE INJECTION LINKS
C
C......ZERO THE FLOWS ALONG THE LINKS
      DO 104 I=1,LINKS
        DO 105 J=1,2
          FLOWS(J,I)=0.
          PERM(J,I)=0.
  105   CONTINUE
  104 CONTINUE
C......GO ROUND AND ROUND ITER TIME PERIODS
      DO 106 NIT=1,ITER
C......INJECT FLOWS AT INJECTION POINTS
        DO 108 I=1,LINKS
          DO 107 J=1,2
            FLOWS(J,I)=FLOWS(J,I)+INJECT(J,I)
  107     CONTINUE
  108   CONTINUE
C......PERFORM ITERATION FROM INJECTION POINTS
        DO 100 I=1,LINKS
          DO 101 J=1,3,2
            L=(J+1)/2
            NODE=JUNK(I,J)
            IF(NODE.LT.MAXNOD) THEN
              DO 102 K=1,LINKS
                IF(NODE.EQ.JUNK(K,1)) THEN
                  M=2
                ELSE
                  M=1
                ENDIF
                IF(I.NE.K) THEN
                  IF(NODE.EQ.JUN(I,K)) THEN
                    PERM(M,K)=PERM(M,K)+PED(I,K)*FLOWS(L,I)
                  ENDIF
                ELSE
                  PERM(M,K)=PERM(M,K)+TEA(L,I)*FLOWS(L,I)
                ENDIF
```

```
 102              CONTINUE
                ENDIF
 101            CONTINUE
 100          CONTINUE
C......SAVE NEW FLOWS BACK INTO FLOWS FROM PERM
              DO 109 I=1,LINKS
                DO 110 J=1,2
                  FLOWS(J,I)=PERM(J,I)
                  PERM(J,I)=0.
 110            CONTINUE
 109          CONTINUE
C             IF(NIT.EQ.1.OR.NIT.EQ.ITER.OR.MOD(NIT,ITINT).EQ.0) THEN
C......DRAW FLOWS FROM INJECTION SOURCES
C               CALL FLOWDRAW
C             ENDIF
 106        CONTINUE
C.. WRITE FLOWS OUT TO FILE FOR PLOTTING THROUGH WELTEMP
            WRITE(*,*) ' INPUT PLOT FILE NAME: '
            READ(*,200) FNAME
            OPEN(11,FILE=FNAME)
            WRITE(11,*)LINKS,FLMAX
            DO 201 I=1,LINKS
              IFL1=INT(FLOWS(1,I))
              IFL2=INT(FLOWS(2,I))
              WRITE(11,*) JUNK(I,1),IFL1,JUNK(I,3),IFL2
C             WRITE(*,*) JUNK(I,1),IFL1,JUNK(I,3),IFL2
201         CONTINUE
200         FORMAT(A)
            RETURN
            END

            SUBROUTINE PHOTON
            COMMON /PEDGRF/
     1             JUN(250,250),JUNK(250,4),INJECT(2,250),
     2             PED(250,250),TEA(2,250),FLOWS(2,250),PERM(2,250),
     3             MLINK,LINKS,MAXNOD,NIT,ITER,ITINT,ISIZ,
     4             LXMN,LXMX,LYMN,LYMX,NNOD,
     5             XMN,XMX,YMN,YMX,FLMAX,SCALE
C......GET INJECTION DATA FROM USER BASED ON PHOTO COUNTS IN STREETS
            DO 100 I=1,2
              DO 101 J=1,LINKS
                INJECT(I,J)=0
 101          CONTINUE
 100        CONTINUE
            WRITE(*,*)' '
            WRITE(*,*)'NUMBER OF INJECTION POINTS: '
            READ(*,*)LPED
            DO 102 I=1,LPED
              WRITE(*,*)' '
              WRITE(*,*)'FOR INJECTION ',I,' GIVE THE FOLLOWING DATA '
              WRITE(*,*)'NUMBER OF LINK: '
              READ(*,*)L
              DO 103 J=1,3,2
                WRITE(*,*)'FLOW INJECTION TOWARDS NODE ',JUNK(L,J),
     1                    ' TO BE: '
                M=(J+1)/2
                READ(*,*)INJECT(M,L)
 103          CONTINUE
 102        CONTINUE
            WRITE(*,*)'HOW MANY TIME PERIODS DO YOU WANT TO RUN? '
            READ(*,*)ITER
            RETURN
            END

            SUBROUTINE READIN
            CHARACTER*30 FNAME
            COMMON /PEDGRF/
     1             JUN(250,250),JUNK(250,4),INJECT(2,250),
     2             PED(250,250),TEA(2,250),FLOWS(2,250),PERM(2,250),
     3             MLINK,LINKS,MAXNOD,NIT,ITER,ITINT,ISIZ,
     4             LXMN,LXMX,LYMN,LYMX,NNOD,
     5             XMN,XMX,YMN,YMX,FLMAX,SCALE
C......SET MAXIMUM NUMBER OF LINKS THAT CAN BE HANDLED
            MLINK=250
C......OPEN FILE CONTAINING PEDESTRIAN FLOW DATA
            OPEN(10,FILE='WONKA.OUT',ACCESS='SEQUENTIAL',STATUS='OLD',
```

```
    1            FORM='FORMATTED')
200           FORMAT(A)
C......GET NUMBER OF LINKS, AND REST OF THE WORLD NODE NUMBER
              READ(10,*)LINKS,MAXNOD
              IF(LINKS.GT.MLINK-2) THEN
                WRITE(*,*)'YOU WONT GET A COMPLETE KEY!'
              ELSEIF(LINKS.GT.MLINK) THEN
                WRITE(*,*)'THIS DATA SET IS TOO BIG TO HOLD!'
                STOP
              ENDIF
C......READ JUNCTION NUMBER AND FLOW DATA FOR EVERY LINK
              DO 100 I=1,LINKS
                READ(10,*)(JUNK(I,J),J=1,4)
C......ZERO JUNCTION IDENTIFICATION MATRIX
                DO 105 J=1,LINKS
                  JUN(I,J)=0
  105           CONTINUE
  100         CONTINUE
C......CALCULATE CONNECTIVITY
              DO 101 I=2,LINKS
                DO 102 J=1,3,2
                  NODE=JUNK(I-1,J)
                  IF(NODE.LT.MAXNOD) THEN
                    DO 103 K=I,LINKS
                      DO 104 L=1,3,2
                        IF(NODE.EQ.JUNK(K,L)) THEN
                          JUN(I-1,K)=NODE
                          JUN(K,I-1)=NODE
                        ENDIF
  104                 CONTINUE
  103               CONTINUE
                  ENDIF
  102           CONTINUE
  101         CONTINUE
              CLOSE(10)
C......READ PEDESTRIAN FLOW/TURNING DATA FROM FILE, AND TURN IT INTO
C......A TRANSITION PROBABILITY MATRIX. NB: PEDFLOW USES A COMPRESSE
C......DATA FORMAT WHERE ONLY NON-ZERO ENTRIES ARE RECORDED. THIS IS
C......DONE BY RECORDING THE ROW/COLUMN AND THEN VALUE OF NON-ZERO
C......VALUES, AND SIMILARLY FOR TEA-SHOPS.
              OPEN(10,FILE='PEDFLOW',STATUS='OLD',ACCESS='SEQUENTIAL',
    1            FORM='FORMATTED')
C......GET SIZE OF LINKS MATRIX
              READ(10,*)I,J
              IF(I.NE.LINKS.OR.J.NE.LINKS) THEN
                WRITE(*,*)'PEDFLOW FILE NOT THE SAME SIZE AS DATA FILE'
                STOP
              ENDIF
C......ZERO THE PED AND TEA MATRICES
              DO 111 I=1,LINKS
                DO 112 J=1,LINKS
                  PED(I,J)=0
  112           CONTINUE
                DO 113 J=1,2
                  TEA(J,I)=0.
  113           CONTINUE
  111         CONTINUE
C......GET NON-ZERO FLOWS ON LINKS
  106         READ(10,*)I,J,A
              IF(I.NE.0) THEN
                PED(I,J)=A
                GOTO 106
              ENDIF
C......GET NON-ZERO TEA SHOPS
  107         READ(10,*)I,J,A
              IF(I.NE.0) THEN
                TEA(I,J)=A
                GOTO 107
              ENDIF
              CLOSE(10)
  110         RETURN
              END

              SUBROUTINE TPROB
              COMMON /PEDGRF/
    1              JUN(250,250),JUNK(250,4),INJECT(2,250),
```

```
     2              PED(250,250),TEA(2,250),FLOWS(2,250),PERM(2,250),
     3              MLINK,LINKS,MAXNOD,NIT,ITER,ITINT,ISIZ,
     4              LXMN,LXMX,LYMN,LYMX,NNOD,
     5              XMN,XMX,YMN,YMX,FLMAX,SCALE
C......CALCULATE TRANSITION PROBABILITIES ALONG LINKS FOR POTENTIAL
C......TURNINGS AT NODE AT EACH END OF THE LINK
C
C......CALCULATE TOTALS
            DO 100 I=1,LINKS
              DO 101 J=1,3,2
                NODE=JUNK(I,J)
                IF(NODE.LT.MAXNOD) THEN
                  SUM=0.
                  DO 102 K=1,LINKS
                    IF(I.NE.K) THEN
                      IF(NODE.EQ.JUN(I,K)) THEN
                        SUM=SUM+PED(I,K)
                      ENDIF
                    ELSE
                      L=(J+1)/2
                      SUM=SUM+TEA(L,K)
                    ENDIF
  102             CONTINUE
C......CALCULATE UNI-D T-PROBS
                  DO 103 K=1,LINKS
                    IF(I.NE.K) THEN
                      IF(NODE.EQ.JUN(I,K)) THEN
                        IF(SUM.EQ.0.0) THEN
                          PED(I,K)=0.
                        ELSE
                          PED(I,K)=PED(I,K)/SUM
                        ENDIF
                      ENDIF
                    ELSE
                      L=(J+1)/2
                      IF(SUM.EQ.0.0) THEN
                        TEA(L,K)=0.
                      ELSE
                        TEA(L,K)=TEA(L,K)/SUM
                      ENDIF
                    ENDIF
  103             CONTINUE
                ENDIF
  101         CONTINUE
  100       CONTINUE
              RETURN
            END
```

```
                PROGRAM FLOWMAP
C**************************************************************************
C
C     FLOWMAP   -   THIS IS THE DISPLAY AND OUTPUT SYSTEM FOR THE WONKA
C                   AND INJECT PROGRAMS.
C     DATA      -   FLOW INFORMATION FOR EACH LINK AND DIRECTION AND THE
C                   GEOGRAPHIC LOCATION OF EACH NODE AND ANY KINKS.
C
C**************************************************************************
                INTEGER NOD(2,200)
                INTEGER*2 LUT(768)
                 INTEGER*2 NPOL,ICOL,IP,NODE
                INTEGER ROWBEG,ROWEND,COLBEG,COLEND
                CHARACTER*1 ANS
                common /sdime/ NOD,NODE
                call pinit
                call clrcwp
                call spat(256)
                ROWBEG=10000
                ROWEND=0
                COLBEG=10000
                COLEND=0
                CALL SCALM(ROWBEG,ROWEND,COLBEG,COLEND)
                CALL NODRAW(ROWBEG,ROWEND,COLBEG,COLEND)
                CALL GREYGEN
                CALL FLOWDRAW
200             FORMAT(A)
                CALL RLUTM(255,0,LUT)
                CALL DUMPIT(LUT,ROWBEG,ROWEND,COLBEG,COLEND)
                STOP
                END

                SUBROUTINE GREYGEN
                INTEGER*2 A(3)
                DO 10 I=1,10
                  DO 11 J=1,3
                    A(J)=100+(I*15)
11                CONTINUE
                  IC=7+I
                  CALL WLUT(IC,A(1))
10              CONTINUE
                RETURN
                END

                SUBROUTINE DUMPIT(LUT,ROWBEG,ROWEND,COLBEG,COLEND)
                INTEGER LUT(768),ROWBEG,ROWEND,COLBEG,COLEND
                CHARACTER*1 KAR
                CHARACTER*40 NAME
                INTEGER COLUMN(1030)
                INTEGER*1 BUF(1030),BYTINT
                INTEGER*2 MR,NC
C......ENQUIRE WHETHER THE USER WANTS TO DUMP AN IMAGE TO A SCREEN
C......DUMP FILE READY FOR LATER PRINTING. DUMPING IS A COLUMN AT A
C......TIME STARTING WITH THE RIGHTMOST COLUMN (COLEND), FROM ROWBEG
C......TO ROWEND.
                WRITE(*,*)'DUMP SCREEN TO FILE? '
                READ(*,200)KAR
  200           FORMAT(A)
                IF(KAR.EQ.'Y'.OR.KAR.EQ.'y') THEN
                  WRITE(*,*)'FILE NAME TO USE? '
                  READ(*,200)NAME
                  OPEN(1,FILE=NAME,FORM='UNFORMATTED')
                  COLBEG=MAX0(COLBEG-10,1)
                  COLEND=MIN0(COLEND+10,1023)
                  ROWBEG=MAX0(ROWBEG-10,1)
                  ROWEND=MIN0(ROWEND+10,767)
                  MR=ROWEND-ROWBEG+1
                  NC=COLEND-COLBEG+1
                  CALL BAR('DUMPING SCREEN IMAGE',NC,0)
                  DO 101 I=1,768
                    BUF(I)=BYTINT(LUT(I))
  101             CONTINUE
                  WRITE(1)(BUF(I),I=1,768)
                  WRITE(1)NC,MR
                  L=0
```

```
          DO 100 I=COLBEG,COLEND
            J=COLEND-I+COLBEG
            L=L+1
            CALL MOVETO(J,ROWBEG)
            CALL RIMAGE(1,MR,COLUMN)
            DO 102 K=1,MR
              BUF(K)=BYTINT(COLUMN(K))
 102        CONTINUE
            WRITE(1)(BUF(K),K=1,MR)
            CALL BAR(' ',NC,L)
 100      CONTINUE
          CLOSE(1)
          CALL BAR(' ',NC,-1)
        ENDIF
        RETURN
        END

      SUBROUTINE BAR(KARS,LENGTH,NOW)
      CHARACTER*(*) KARS
      SAVE LAST
C......DRAW A PERCENTAGE COMPLETION DIAGRAM WHEN REQUESTED. THE
C......TOTAL NUMBER OF COUNTS MUST BE GIVEN IN LENGTH. A CALL OF BAR
C......WITH NOW OF ZERO SETS UP THE BAR, AND ONE WITH NOW OF -1 WILL
C......ENSURE MOVING ONTO A NEW LINE.
      IF(NOW)101,102,103
C......FINAL CR
 101  WRITE(*,202)
 202  FORMAT('+100% - COMPLETE')
      RETURN
C......INITIAL OUTPUT LINE
 102  WRITE(*,200)KARS
 200  FORMAT(/,' ',A,/,'   0% - WORKING')
      LAST=0
      RETURN
C......INCREMENTAL PERCENTAGES
 103  J=FLOAT(NOW)/FLOAT(LENGTH)*100.+0.5
      I=FLOAT(LAST)/FLOAT(LENGTH)*100.+0.5
      LAST=NOW
      IF(I.GT.0.AND.J.GT.I) THEN
              WRITE(*,201)J
 201          FORMAT('+',I3,'%')
            ENDIF
      RETURN
      END

            INTEGER*1 FUNCTION BYTINT(I)
            INTEGER I
C......PUT THE VALUE IN INTEGER I OF UNSIGNED SIZE 0-255 INTO SIGNED
C......INTEGER*1 BETWEEN -128 TO +127. ANY VALUE LARGER THAN 127
C......BECOMES NEGATIVE: +128=-128....+255=-1
            IF(I.LT.128) THEN
              BYTINT=I
            ELSE
              BYTINT=-256+I
            ENDIF
            END

            SUBROUTINE LIMITS(ROWBEG,ROWEND,COLBEG,COLEND,IY,IX)
            INTEGER ROWBEG,ROWEND,COLBEG,COLEND,IY,IX
            ROWBEG=MIN0(ROWBEG,IY)
            ROWEND=MAX0(ROWEND,IY)
            COLBEG=MIN0(COLBEG,IX)
            COLEND=MAX0(COLEND,IX)
            RETURN
            END

             SUBROUTINE FLOWDRAW(IPLOT)
             INTEGER NOD(2,200),JUNK(260,4)
               INTEGER*2 NPOL,ICOL,IP,NODE
             INTEGER NEWDE(10,10)
            CHARACTER*30 FNAME
            CHARACTER*6 WORD
            common /sdime/ NOD,NODE

             REAL THICK,FLMAX,FX,FY,TX,TY,UX,UY,NX,NY
            FLMAX=0.
```

```
            WRITE(*,*) ' INPUT FLOW FILE NAME '
            READ(*,200) FNAME
            OPEN(10,FILE=FNAME,ACCESS='SEQUENTIAL',STATUS='OLD',
     1      FORM='FORMATTED')
            FLMAX=0.
            READ(10,*) LINKS
            DO 20 I=1,LINKS
              READ(10,*) (JUNK(I,J),J=1,4)
              IF(JUNK(I,2).GT.FLMAX) THEN
                 FLMAX=JUNK(I,2)
              ENDIF
              IF(JUNK(I,4).GT.FLMAX) THEN
                 FLMAX=JUNK(I,4)
              ENDIF
20          CONTINUE
             DO 10 I=1,LINKS
             J=JUNK(I,1)
             K=JUNK(I,3)
C... LX AND LY ARE THE LATERAL DISPLACEMENTS BETWEEN THE TWO NODES
C... OF LINK I
             LX=NOD(1,J)-NOD(1,K)
             LY=NOD(2,J)-NOD(2,K)
            X=FLOAT(LX)
            Y=FLOAT(LY)
             HYP=SQRT(X**2+Y**2)
             RATIO=10/HYP
C... SET LINE STARTS OUTSIDE THE NODE SQUARES
             IF(LX.GT.0.AND.LY.GT.0) THEN
               LX=ABS(LX)
               LY=ABS(LY)
              LSTX1=NOD(1,J)-LX*RATIO
              LSTX2=NOD(1,K)+LX*RATIO
               LSTY1=NOD(2,J)-LY*RATIO
               LSTY2=NOD(2,K)+LY*RATIO
             ELSEIF(LX.LE.0.AND.LY.GT.0) THEN
               LX=ABS(LX)
               LY=ABS(LY)
               LSTX1=NOD(1,J)+LX*RATIO
               LSTX2=NOD(1,K)-LX*RATIO
               LSTY1=NOD(2,J)-LY*RATIO
               LSTY2=NOD(2,K)+LY*RATIO
             ELSEIF(LX.LE.0.AND.LY.LE.0) THEN
               LX=ABS(LX)
               LY=ABS(LY)
               LSTX1=NOD(1,J)+LX*RATIO
               LSTX2=NOD(1,K)-LX*RATIO
               LSTY1=NOD(2,J)+LY*RATIO
               LSTY2=NOD(2,K)-LY*RATIO
             ELSEIF(LX.GT.0.AND.LY.LE.0) THEN
               LX=ABS(LX)
               LY=ABS(LY)
               LSTX1=NOD(1,J)-LX*RATIO
               LSTX2=NOD(1,K)+LX*RATIO
               LSTY1=NOD(2,J)+LY*RATIO
               LSTY2=NOD(2,K)-LY*RATIO
             ELSE
               WRITE(*,*) 'ERROR IN THE LINE JUMPING'
             ENDIF
C... CAN INSERT TEA DRINKERS BY GIVING THIS SOME THICKNESS
              CALL SCCOL(6)
               CALL MOVETO(LSTX1,LSTY1)
               CALL LINETO(LSTX2,LSTY2)
C... START ON THE TRIANGLE
             NLX=NOD(1,J)-NOD(1,K)
             NLY=NOD(2,J)-NOD(2,K)
              UY=LX/HYP
               UX=LY/HYP
               NY=(LX/HYP)*5
              NX=(LY/HYP)*5
C.. CALCULATE LINE THICKNESS AND FLOW TRIANGLE DIRECTION.
             DO 31 II=2,4,2
              THICK=0.
              FX=0.
              FY=0.
              IF(JUNK(I,II).GT.(FLMAX/12)) THEN
                 IPEN=(JUNK(I,II)/FLMAX)*9+8
```

```
                   ITHICK=JUNK(I,II)/FLMAX*20+1
                 ELSEIF(JUNK(I,II).GT.(FLMAX/100)) THEN
                   ITHICK=1
                   IPEN=8
                 ELSE
              GOTO 31
                 ENDIF
                  FY=ABS(UY)*(5+ITHICK)
                  FX=ABS(UX)*(5+ITHICK)
C...
C... FILL IN FLOW TRIANGLE. FIRST DETERMINE THE DIRECTION OF THE
C... INCREMENT AND THE TOP AND BOTTOM POINTS FOR ALL THE COMBINATIONS
C... OF RELATIVE POINT POSITIONS
C...   FX = THE THICKNESS OF THE TRIANGLE - THE FURTHEST POINT FROM THE
C...      BASE LINE
C...   TX = THE FIXED TOP POINT OF THE TRIANGLE
C...   UX/UY = THE UNIT VECTOR OF THE TRIANGLE - NEEDED TO GET A RIGHT
C...      ANGLE
C...
                IF(NLX.LT.0.AND.NLY.LT.0) THEN
                  IF(II.EQ.4) THEN
                    UY=ABS(UY)
                    UX=-UX
                    FX=LSTX1-FX
                    FY=LSTY1+FY
                      TX=LSTX2-NX
                     TY=LSTY2+NY
                   ELSE
                    UX=ABS(UX)
                    UY=-UY
                    FX=LSTX2+FX
                    FY=LSTY2-FY
                     TX=LSTX1+NX
                     TY=LSTY1-NY
                   ENDIF
C... THIS IS THE SAME FOR NLY GT 0 AND NLY EQ 0
                 ELSEIF(NLX.LT.0.AND.NLY.GE.0) THEN
                  IF(II.EQ.4) THEN
                    UX=ABS(UX)
                    UY=ABS(UY)
                    FX=LSTX1+FX
                    FY=LSTY1+FY
                     TX=LSTX2+NX
                     TY=LSTY2+NY
                   ELSE
                    UY=-(UY)
                    UX=-(UX)
                    FX=LSTX2-FX
                    FY=LSTY2-FY
                     TX=LSTX1-NX
                     TY=LSTY1-NY
                   ENDIF
                 ELSEIF(NLX.GE.0.AND.NLY.GE.0) THEN
                  IF(II.EQ.4) THEN
                    UY=-(UY)
                    UX=ABS(UX)
                    FX=LSTX1+FX
                    FY=LSTY1-FY
                     TX=LSTX2+NX
                     TY=LSTY2-NY
                   ELSE
                    UX=-(UX)
                    UY=ABS(UY)
                    FX=LSTX2-FX
                    FY=LSTY2+FY
                     TX=LSTX1-NX
                     TY=LSTY1+NY
                   ENDIF
                 ELSEIF(NLX.GT.0.AND.NLY.LE.0) THEN
                  IF(II.EQ.4) THEN
                    UX=-UX
                    UY=-UY
                    FX=LSTX1-FX
                    FY=LSTY1-FY
                     TX=LSTX2-NX
                     TY=LSTY2-NY
```

```
              ELSE
               UY=ABS(UY)
               UX=ABS(UX)
               FX=LSTX2+FX
               FY=LSTY2+FY
                TX=LSTX1+NX
                TY=LSTY1+NY
              ENDIF
             ELSE
              IF(II.EQ.4) THEN
               UX=ABS(UX)
               UY=ABS(UY)
               FX=FX+LSTX1
               FY=FY+LSTY1
                TX=LSTX2+NX
                TY=LSTY2+NY
              ELSE
               UX=-UX
               UY=-UY
               FX=LSTX2-FX
               FY=LSTY2-FY
                TX=LSTX1-NX
                TY=LSTY1-NY
              ENDIF
            ENDIF
           THICK=FLOAT(ITHICK)
              CALL TRIANGLE(THICK,FX,FY,TX,TY,UX,UY,IPEN)
31         CONTINUE
10          CONTINUE
           CALL SCALE(FLMAX)
200        FORMAT(A)
            RETURN
            END

           SUBROUTINE SCALE(FLMAX)
            REAL THICK,FLMAX,FX,FY,TX,TY,UX,UY,NX,NY
           CHARACTER*6 WORD
           X=800
           Y=750
           DO 10 I=2,10,2
             CALL MOVETO(IX,IY)
             IPEN=I+7
             THICK=I*2.
             FX=X-70
             FY=Y-THICK
             UX=0
             UY=-1
             TX=X
             TY=Y
             CALL TRIANGLE(THICK,FX,FY,TX,TY,UX,UY,IPEN)
             IX=FX
             IY=FY-(5+2*I)
             IPEN=5
             CALL ARROW(IX,IY,IPEN)
             NUM=INT(FLMAX/10)*I
             WRITE(WORD,201)NUM
201          FORMAT(' ',I4)
             CALL WRITEP(IX,IY-20,WORD)
             X=X-150
10         CONTINUE
           RETURN
           END

           SUBROUTINE ARROW(IX,IY,IPEN)
           CALL SCCOL(IPEN)
           CALL MOVETO(IX,IY)
           CALL LINETO(IX+50,IY)
           CALL LINETO(IX+45,IY-5)
           CALL MOVETO(IX+45,IY+5)
           CALL LINETO(IX+50,IY)
           RETURN
           END

           SUBROUTINE WRITEP(IX,IY,NAME)
           CHARACTER*(*) NAME
           INTEGER*2 NUM
```

```
C......LEFT JUSTIFY THE CONTENTS OF NAME, AND SEND IT TO PLUTO AS AN
C......INTEGER STRING BEGINNING (TLC) AT IX,IY.
              CALL LENGCH(NAME,L)
              IF(L.NE.0) THEN
                I=1
  100           IF(NAME(I:I).EQ.' ') THEN
                  I=I+1
                  GOTO 100
                ELSE
                  CALL OUTCHR(IX,IY,NAME,I,L)
                ENDIF
              ENDIF
              RETURN
              END


        SUBROUTINE LENGCH(USRCHR,JS)
        CHARACTER*(*) USRCHR
C......RETURN THE NUMBER OF CHARACTERS (JS) HELD IN USRCHR BEFORE THE
C......RIGHTMOST BLANK.
C
C......GET LENGTH OF STRING
        IL=LEN(USRCHR)
C......FIND FIRST NON-BLANK CHARACTER (STARTING FROM THE RIGHT)
        DO 100 I=1,IL
        JS=IL-I+1
        IF(USRCHR(JS:JS).NE.' ')GOTO 101
  100   CONTINUE
C......SET NON-BLANK STRING LENGTH TO ZERO IN CASE NO CHARACTERS ARE
C......FOUND
        JS=0
C......POSITION OF LAST NON-BLANK CHARACTER IS NOW STORED IN JS
  101   RETURN
        END

              SUBROUTINE OUTCHR(IX,IY,NAME,I,L)
              CHARACTER*(*) NAME
              CALL MOVETO(IX,IY)
              DO 101 J=I,L
                NUM=ICHAR(NAME(J:J))
                CALL PCHAR(NUM)
  101         CONTINUE
              RETURN
              END

                SUBROUTINE TRIANGLE(THICK,FX,FY,TX,TY,UX,UY,IPEN)
                REAL THICK,FX,FY,TX,TY,UX,UY
                INTEGER ITHICK,IFX,IFY,ITX,ITY
               ITHICK=INT(THICK)
               ITX=INT(TX)
               ITY=INT(TY)
                   CALL SCCOL(IPEN)
               DO 10 I=1,ITHICK
                   IFX=INT(FX)
            IFY=INT(FY)
                 CALL MOVETO(IFX,IFY)
                  CALL LINETO(ITX,ITY)
                  FX=FX-UX
                  FY=FY-UY
10            CONTINUE
                RETURN
                END

               SUBROUTINE NODRAW(ROWBEG,ROWEND,COLBEG,COLEND)
              INTEGER ROWBEG,ROWEND,COLBEG,COLEND
C... NODE DRAWING ROUTINE
C             INTEGER LNUM(10,20,2)
              INTEGER NOD(2,200)
              INTEGER NL(2,4)
               INTEGER*2 NPOL,ICOL,IP,NODE,OX,OY
              common /sdime/ NOD,NODE
               DO 10 I=1,NODE
                 NL(1,1)=NOD(1,I)-5
                 NL(2,1)=NOD(2,I)-5
                NL(1,2)=NOD(1,I)+5
                 NL(2,2)=NOD(2,I)-5
```

```
              NL(1,3)=NOD(1,I)+5
              NL(2,3)=NOD(2,I)+5
              NL(1,4)=NOD(1,I)-5
              NL(2,4)=NOD(2,I)+5
             DO 998 J=1,4
               CALL LIMITS(ROWBEG,ROWEND,COLBEG,COLEND,NL(2,J),NL(1,J))
 998         CONTINUE
            CALL POLYLINE(NL,4,6)
10         CONTINUE
            RETURN
            END

           SUBROUTINE SCALM(ROWBEG,ROWEND,COLBEG,COLEND)
           INTEGER NOD(2,200),NOUT(2,50)
            INTEGER*2 NPOL,ICOL,IP,NODE
           CHARACTER*1 KAR
           common /sdime/ NOD,NODE
C... FIND THE LIMITS OF THE CO-ORD DATA
           OPEN(10,FILE='NODE.DIG')
           READ(10,*) XMIN,YMIN,XMAX,YMAX
C... READ IN THE NODE CENTRES
C... NODE=NUMBER OF NODES IN DATA
C... NOD(2,50)=ARRAY OF NODE CENTRE LOCATIONS
C... READ IN NODE CENTRE LOCATIONS
           I=1
90         READ(10,*,END=1000) NOD(1,I),NOD(2,I)
           I=I+1
           GOTO 90
1000         NODE=I-1
           XFACTOR=1000/(XMAX-XMIN)
           YFACTOR=700/(YMAX-YMIN)
           IF(XFACTOR.LT.YFACTOR) THEN
              YFACTOR=XFACTOR
           ENDIF
C... SCALE THE NODES TO FIT
           DO 41 I=1,NODE
               NOD(2,I)=ABS(NOD(2,I)-YMAX)
               NOD(1,I)=(NOD(1,I)-XMIN)*YFACTOR+10
               NOD(2,I)=NOD(2,I)*YFACTOR+10
41         CONTINUE
           OPEN(11,FILE='SHOP.DIG')
           READ(11,200,END=52) KAR
61         READ(11,*,END=51) N,NP
             READ(11,*,END=52) (NOUT(1,I),NOUT(2,I),I=1,NP)
           DO 50 I=1,NP
             NOUT(1,I)=(NOUT(1,I)-XMIN)*YFACTOR+10
             NOUT(2,I)=ABS(NOUT(2,I)-YMAX)*YFACTOR+10
           CALL LIMITS(ROWBEG,ROWEND,COLBEG,COLEND,NOUT(2,I),NOUT(1,I))
50         CONTINUE
           CALL POLYLINE(NOUT,NP,2)
           GOTO 61
200        FORMAT(A)
51         RETURN
52         WRITE(*,*) ' BUGGER'
           RETURN
           END

       SUBROUTINE POLYLINE(IV,NH,NCOL)
C... DISPLAY ROUTINES FOR SHOP BEHAVIOUR DATA
           INTEGER IV(2,50)
           CALL SCCOL(NCOL)
           CALL MOVETO(IV(1,1),IV(2,1))
             DO 10 I=2,NH
               CALL LINETO(IV(1,I),IV(2,I))
10           CONTINUE
           CALL LINETO(IV(1,1),IV(2,1))
           RETURN
           END
```

```
      PROGRAM PRETTY
            INCLUDE 'AWEFUL.COM'
C*************************************************************************
C     PRETTY  -  PROGRAM TO ANIMATE THE DATA GATHERED DURING AN IN-STORE
C                SURVEY.
C     DATA    -  SURVEY DATA IN TIME AND CAMERA ORDERED SEQUENCE
C
C......PRETTY: MENU SYSTEM ADDED BY MJM 28/6/89, AND GONDOLA DISPLAY
C......MODIFIED TO GIVE LOOK INFORMATION ON ANIMATION, THEN TOTALS
C......IN FINAL MODE. ALL ROUTINES IN Lower Case ARE TAKEN FROM THE
C......PROSPERO F77PC LIBRARY.
C
C......PRETTY: A PROGRAM TO DISPLAY CUSTOMER MOVEMENT ROUND A STORE
C......AUTHOR: MJM, 22/11/88, MODIFIED TO ALLOW NUMERICAL DATA TO BE
C......DISPLAYED, AND TO CORRECT THE ODD ERROR: MJM, 20/6/89.
C
C********************** AWEFUL.COM FILE ***********************************
C
C
C    INTEGER FLOOR(50,50),FLRCNT(256),FLRTOT(256),POLNUM(500),
C     1         POLCHK(256),LUT(3,256),GONCNT(256),GONTOT(256),NOWCOL(3),
C     2         PHYFLR(3),PHYGON(3),PHYCUS(3),PHYSEE(3),PEOPLE(5000),
C     3         STACK(200),ALIVE(15,200),LOOKGN(2,200),SCNCDS(2,5000),
C     4         SCNPOL(400),POLCEN(2,400),
C     5         LIMPOL,FLOORX,FLOORY,FMINX,FMAXX,FMINY,FMAXY,CROWD,
C     6         CUSTOM,QUICK,CITEMS,TOTPOL,LOGMAX,OFFCOL,FLUPOL,GONPOL,
C     7         CAMERA,LASTFL,POLMAX,ROWBEG,ROWEND,COLBEG,COLEND,
C     8         XOFSET,YOFSET,SCRENX,SCRENY,CDSMAX,LINTOT,LINMAX,BLKWHT,
C     9         INVERT
C          COMMON FLOOR,FLRCNT,FLRTOT,POLNUM,
C     1         POLCHK,LUT,GONCNT,GONTOT,NOWCOL,
C     2         PHYFLR,PHYGON,PHYCUS,PHYSEE,PEOPLE,
C     3         STACK,ALIVE,LOOKGN,SCNCDS,
C     4         SCNPOL,POLCEN,
C     5         LIMPOL,FLOORX,FLOORY,FMINX,FMAXX,FMINY,FMAXY,CROWD,
C     6         CUSTOM,QUICK,CITEMS,TOTPOL,LOGMAX,OFFCOL,FLUPOL,GONPOL,
C     7         CAMERA,LASTFL,POLMAX,ROWBEG,ROWEND,COLBEG,COLEND,
C     8         XOFSET,YOFSET,SCRENX,SCRENY,CDSMAX,LINTOT,LINMAX,BLKWHT,
C     9         INVERT
C
C*************************************************************************
C......SET UP THE ARRAYS TO NULL CONDITIONS
            CALL SETUP
C......GO TO MENU SYSTEM
            CALL ACTION
            END

            SUBROUTINE ACTION
            CHARACTER*78 NAME
            CHARACTER*1 KAR
            INTEGER ANIM,CUST,DIGI,GOND,LINE,FLOR,PROP,VIEW,PERF,GNUM
            REAL RATE
            INCLUDE 'AWEFUL.COM'
C......ALLOW USER TO PICK THE OPTIONS HE NEEDS AND THEN RUN THEM
C
C......DEFINE THE OPTION SWITCH NAMES
C           ANIM - 1 WILL GIVE AN ANIMATION SEQUENCE, 0 INDICATES NO FILE
C           CUST - 1 GIVES DISPLAY COUNT, -1 GIVES NO DISPLAY (OF CUSTOMER
C                  DENSITY ON THE FLOOR OF THE SHOP.
C           DIGI - 1 INDICATES DIGITISING FILES HAVE BEEN PICKED UP, 0 THAT
C                  THEY STILL NEED TO BE PICKED UP.
C           GOND - 1 SWITCHES ON GONDOLA DISPLAY, -1 GIVES NO SHOW.
C           LINE - 1 SWITCHES ON LINEWORK DISPLAY, -1 GIVES NO SHOW.
C           FLOR - 1 SHOWS LINWORK AROUND THE FLOOR POLYGONS, -1 OMMITS THE
C                  LINEWORK, BUT STILL DISPLAYS THE FLOOR POLYGONS.
C           PROP - 1 DISPLAYS ANY DESIRED VALUES AS PROPORTIONS, -1 GIVES
C                  AN ABSOLUTE VALUE DISPLAY.
C           RATE - SPECIFIES THE ANIMATION RATE IN SECONDS PER REAL MINUTE.
C           VIEW - 1 SHOWS GONDOLA LOOK COUNTS, -1 DOES NOT.
C           PERF - 1 INDICATES ANIMATION HAS BEEN PERFORMED FOR THIS FILE
C                  AND 0 INDICATES IT HAS NOT YET BEEN SO.
C           GNUM - 1 INDICATES GONDOLA NUMBERS WANTED, -1 INDICATES COUNTS.
C......SET THE OPTION DEFAULTS
            ANIM=0
            CUST=-1
            DIGI=0
```

```
            GOND=1
            LINE=1
            FLOR=-1
            PROP=-1
            RATE=1.0
            VIEW=-1
            PERF=0
            GNUM=-1
            CALL SETCLR
            CALL PERCOL
C......OPEN A LOG FILE TO HOLD PROBLEM CASES FOR LATER EXAMINATION
            OPEN(2,FILE='PROBLEMS.DAT')
C......PUT UP THE BASIC MENU IN ITS OWN WINDOW - NEVER TOUCHED AGAIN
            CALL BANMEN
C......OUTPUT CHOSEN OPTION LINE BELOW THE MENU NOW DISPLAYED
  100       CALL TextWindow(1,14,80,19)
            CALL TextFrame(.TRUE.)
            CALL ERASE
            NAME='ACTION OPTIONS : '
            IF(ANIM.EQ.0)CALL CONCAT(NAME,'No animation file,',1)
            IF(ANIM.EQ.1)CALL CONCAT(NAME,'Animation ready,',1)
            IF(DIGI.EQ.0)CALL CONCAT(NAME,'No digitising,',1)
            IF(DIGI.EQ.1)CALL CONCAT(NAME,'Digitising ready,',1)
            IF(PERF.EQ.0)CALL CONCAT(NAME,'No animation yet.',1)
            IF(PERF.EQ.1)CALL CONCAT(NAME,'Results ready.',1)
            CALL LENGCH(NAME,L)
            WRITE(8,200)NAME(1:L)
  200       FORMAT(' ',A)
            NAME='DISPLAY OPTIONS: '
            IF(FLOR.EQ.1)CALL CONCAT(NAME,'Floor lines,',1)
            IF(FLOR.EQ.-1)CALL CONCAT(NAME,'Bare floor,',1)
            IF(LINE.EQ.1)CALL CONCAT(NAME,'Perm lines,',1)
            IF(LINE.EQ.-1)CALL CONCAT(NAME,'No perm lines,',1)
            IF(GOND.EQ.1)CALL CONCAT(NAME,'Show gondolas,',1)
            IF(GOND.EQ.-1)CALL CONCAT(NAME,'No gondolas,',1)
            IF(BLKWHT.EQ.1) THEN
              CALL CONCAT(NAME,'B&W,',1)
              IF(INVERT.EQ.1)CALL CONCAT(NAME,'Inversion.',1)
              IF(INVERT.EQ.-1)CALL CONCAT(NAME,'No inversion.',1)
            ENDIF
            IF(BLKWHT.EQ.-1)CALL CONCAT(NAME,'Colour.',1)
            CALL LENGCH(NAME,L)
            WRITE(8,200)NAME(1:L)
            NAME='COUNT OPTIONS  :'
            IF(CUST.EQ.1)CALL CONCAT(NAME,'Customer counts on,',1)
            IF(CUST.EQ.-1)CALL CONCAT(NAME,'Customer counts off,',1)
            IF(VIEW.EQ.1)CALL CONCAT(NAME,'Gondola counts on,',1)
            IF(VIEW.EQ.-1)CALL CONCAT(NAME,'Gondola counts off,',1)
            IF(GNUM.EQ.-1) THEN
              IF(PROP.EQ.1)CALL CONCAT(NAME,'Proportional.',1)
              IF(PROP.EQ.-1)CALL CONCAT(NAME,'Absolute.',1)
            ELSE
              CALL CONCAT(NAME,'Identifiers only.',1)
            ENDIF
            CALL LENGCH(NAME,L)
            WRITE(8,200)NAME(1:L)
            WRITE(8,203)RATE
  203       FORMAT('  ANIMATE SPEED  : ',F5.1,
     1             ' Computer seconds per minute elapsed.')
C......SET UP RESPONSE WINDOW, GET OPTION WANTED NEXT, AND THEN
C......INTERPRET IT
            CALL DIAMEN(0)
            WRITE(8,201)
  201       FORMAT('+ CHOOSE OPTION NOW: ')
            READ(8,202)KAR
  202       FORMAT(A)
            CALL G2CNVU(KAR)
            IF(KAR.EQ.'A') THEN
C......(A)NIMATION-FILE
              CALL OPENIT('CUSTOMERS','CUSTOMER.TXT',3)
              ANIM=1
              PERF=0
            ELSEIF(KAR.EQ.'B') THEN
C......(B)LACK & WHITE OUTPUT ONLY TO THE SCREEN
              BLKWHT=1
              CALL SETCLR
```

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                CALL PERCOL
              ELSEIF(KAR.EQ.'C') THEN
C......(C)USTOMER-COUNT IS TO BE DISPLAYED AFTER ANIMATION
                CUST=-CUST
              ELSEIF(KAR.EQ.'D') THEN
C......(D)IGITISING - FETCH IT FROM THE FILES THE USER HAS PROVIDED
                CALL FETDIG
                DIGI=1
              ELSEIF(KAR.EQ.'E') THEN
C......(E)XECUTE-ANIMATION, BASIC SHOP WITH FLOOR/GONDOLA NUMBERS.
C......CHECK THAT DATA FILES HAVE BEEN OBTAINED AND THEN DRAW EVERYTHING
C......AND THEN DO THE ANIMATION.
                IF(DIGI.EQ.0) THEN
                  CALL FETDIG
                  DIGI=1
                ENDIF
C......CHECK THAT AN ANIMATION FILE IS AVAILABLE
                IF(ANIM.EQ.0) THEN
                  WRITE(8,211)
  211             FORMAT(
     1            '  FETCHING CUSTOMER MOVEMENT AND VIEW DATA FILE....')
                  CALL OPENIT('CUSTOMERS','CUSTOMER.TXT',3)
                  ANIM=1
                ENDIF
C......PUT UP THE BASIC DISPLAY
                CALL GENERA(FLOR,LINE,-1,GOND,-1,-1,PROP)
C......CLEAR THE ANIMATION MEMORY AND THEN PERFORM ANIMATION SEQUENCE
                CALL NEWANI
C......SWITCH ON THE DISPLAY OF THE FLOOR AND THE GONDOLAS
                CALL WLUTM(254,1,LUT)
                CALL ANIMAT(RATE,NTOT)
C......RESET LOOK UP TABLE TO SHOW THE TOTALS FOR FLOOR AND GONDOLA
C......POLYGONS AS A SHADING SCALE
                CALL ABSPIC
                PERF=1
                WRITE(8,204)NTOT
                CALL WAITIT
              ELSEIF(KAR.EQ.'F') THEN
C......(F)INAL COUNTS - REPEAT A SHADING/DENSITY RESULT ALREADY DONE,
C......WITH OR WITHOUT COUNT TOTALS ETC, AND CERTAINLY WITHOUT ANY
C......ANIMATION IF ALREADY PERFORMED.
                IF(PERF.EQ.1) THEN
C......NOW DRAW THE VIEW WITH COUNTS AND SHADINGS DISPLAYED, IF DESIRED
                  CALL GENERA(FLOR,LINE,CUST,GOND,VIEW,GNUM,PROP)
                  CALL ABSPIC
                ELSE
                  WRITE(8,212)
  212             FORMAT(
     1            '  YOU MUST PERFORM AN ANIMATION BEFORE FINAL DISPLAY!')
                  CALL WAITIT
                ENDIF
              ELSEIF(KAR.EQ.'G') THEN
C......(G)ONDOLA-LAYOUT TO BE SHOWN/UNSHOWN ON SCREEN
                GOND=-GOND
              ELSEIF(KAR.EQ.'I') THEN
C......(I)NVERT THE BLACK AND WHITE SCALE FOR SHADINGS ONLY
                INVERT=1
              ELSEIF(KAR.EQ.'K') THEN
C......(K)OLOUR OUTPUT TO SCREEN
                BLKWHT=-1
                CALL SETCLR
                CALL PERCOL
              ELSEIF(KAR.EQ.'L') THEN
C......(L)INEWORK - DISPLAY LINEWORK ONLY
                LINE=-LINE
              ELSEIF(KAR.EQ.'M') THEN
C......(M)ARK-FLOOR
                FLOR=-FLOR
              ELSEIF(KAR.EQ.'N') THEN
C......(N)O-INVERT OF BLACK AND WHITE
                INVERT=-1
              ELSEIF(KAR.EQ.'P') THEN
C......(P)ERCENTAGE-VALUES: ALL CUSTOMER AND VIEW VALUES TO BE
C......EXPRESSED AS PERCENTAGES
                PROP=-PROP
              ELSEIF(KAR.EQ.'Q') THEN
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C......(Q)UIT
              CALL InitScreen
              GOTO 101
            ELSEIF(KAR.EQ.'R') THEN
C......(R)EAL-TIME-RATE
              WRITE(8,205)RATE
  205         FORMAT('  RATE IS PRESENTLY ',F4.1,
     1              ' SECS PER ANIMATION MINUTE')
              WRITE(8,206)
  206         FORMAT('  WHAT RATE DO YOU REQUIRE? ',\)
              READ(8,*)RATE
              IF(RATE.LT.0.0001.OR.RATE.GT.99.0) THEN
                WRITE(8,208)
  208           FORMAT('  SILLY! TRY AGAIN')
                CALL WAITIT
              ENDIF
            ELSEIF(KAR.EQ.'S') THEN
C......(S)AVE-SCREEN, DUMPS A SCREEN TO DISK FILE. DUMP THE LUT AND
C......THE WRITTEN PORTION OF THE SCREEN
               CALL DUMPIT(LUT,ROWBEG,ROWEND,COLBEG,COLEND)
            ELSEIF(KAR.EQ.'V') THEN
C......(V)IEW-COUNTS, SET TO 1 IF GONDOLA VIEWONG COUNTS ARE TO BE
C......DRAWN, AND -1 IF NOT.
              VIEW=-VIEW
            ELSEIF(KAR.EQ.'X') THEN
C......(X)ECUTE-COUNTS, SHOW THE COUNT NUMBERS FOR THE FLOOR/GONDOLAS.
C......CHECK THAT DATA FILES HAVE BEEN OBTAINED AND THEN DRAW EVERYTHING
C......AND THEN DO THE ANIMATION.
              IF(CUST.EQ.1.OR.VIEW.EQ.1) THEN
                IF(DIGI.EQ.0) THEN
                  CALL FETDIG
                  DIGI=1
                ENDIF
C......CHECK THAT THE AN ANIMATION FILE IS AVAILABLE
                IF(ANIM.EQ.0) THEN
                  WRITE(8,211)
                  CALL OPENIT('CUSTOMERS','CUSTOMER.TXT',3)
                  ANIM=1
                ENDIF
C......CHECK WHETHER THE ANIMATION HAS BEEN PERFORMED YET
                IF(PERF.EQ.0) THEN
C......PUT UP THE BASIC DISPLAY
                  CALL GENERA(FLOR,LINE,-1,GOND,-1,GNUM,PROP)
C......CLEAR THE ANIMATION MEMORY AND THEN PERFORM ANIMATION SEQUENCE
                  CALL NEWANI
C......SWITCH ON THE DISPLAY OF THE FLOOR AND THE GONDOLAS
                  CALL WLUTM(254,1,LUT)
                  CALL ANIMAT(RATE,NTOT)
C......RESET LOOK UP TABLE TO SHOW THE TOTALS FOR FLOOR AND GONDOLA
C......POLYGONS AS A SHADING SCALE
                  CALL ABSPIC
                  PERF=1
                  WRITE(8,204)NTOT
  204             FORMAT('  THERE WERE ',I4,
     1                 ' PEOPLE IN THE ANIMATION PROCESS',/,
     2                 '  DISPLAYING DENSITIES OF ',
     3                 'CUSTOMERS AND GONDOLA VIEWS')
                  CALL WAITIT
                ENDIF
C......NOW DRAW THE VIEW WITH COUNTS DISPLAYED.
                CALL GENERA(FLOR,LINE,CUST,GOND,VIEW,GNUM,PROP)
              ELSE
                WRITE(8,209)
  209           FORMAT('  NO SCREEN COUNT OPTIONS SWITCHED ON!')
                CALL WAITIT
              ENDIF
            ELSEIF(KAR.EQ.'Z') THEN
C......(Z)ERO-POPULATION STORE OTHERWISE KNOWN AS EMPTY, BUT 'E' HAD
C......ALREADY BEEN USED (hEMPTY WAS SUGGESTED).
              IF(DIGI.EQ.0) THEN
                CALL FETDIG
                DIGI=1
              ENDIF
C......PUT UP THE BASIC DISPLAY
              CALL GENERA(FLOR,LINE,-1,GOND,-1,GNUM,PROP)
            ELSEIF(KAR.EQ.'1') THEN
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```
C......(1)-ALL-COUNTS, GIVES TABLE OUTPUT AND A GRAPHIC DISPLAY ON
C......THE SCREEN. ^P CAN BE USED TO ACTIVATE THE SYSTEM PRINTER FOR
C......A SCREEN DUMP IF WANTED.
C
C......DRAW THE WHOLE LUT KEY FOR POLYS AND GONDOLAS (ON A NEW SCREEN),
C......AND COMBINE THE GONDOLA TOTAL LOOKS WITH THE FLOOR TOTAL LOOKS.
              IF(PERF.EQ.1) THEN
                K=GONPOL+OFFCOL+1
                DO 102 I=K,TOTPOL
                  FLRTOT(I)=GONTOT(I)
  102           CONTINUE
                CALL DRWKEY(OFFCOL+1,POLMAX+OFFCOL,FLRTOT,PROP,
     1                      'TOTALS FOR FLOOR TILES AND GONDOLAS')
C......NOW DO THE SAME ON THE TEXT SCREEN IN CASE THE USER WANTS A LIST
              CALL PRINON
                CALL DUMTAB(OFFCOL+1,LASTFL,FLRTOT,PROP,
     1                      'FLOOR POLYGON TOTALS')
                CALL DUMTAB(GONPOL+OFFCOL+1,POLMAX+OFFCOL,GONTOT,PROP,
     1                      'GONDOLA LOOK TOTALS')
                CALL PRINOF
              ELSE
                WRITE(8,210)
  210           FORMAT('  YOU HAVE NOT EXECUTED AN ANIMATION YET!')
                CALL WAITIT
              ENDIF
             ELSEIF(KAR.EQ.'2') THEN
C......(2)-FLOOR-COUNT, GIVES TABLE OUTPUT AND A GRAPHIC DISPLAY ON
C......THE SCREEN. ^P CAN BE USED TO ACTIVATE THE SYSTEM PRINTER FOR
C......A SCREEN DUMP IF WANTED.
C
C......DRAW THE FLOOR KEY (ON A NEW SCREEN)
              IF(PERF.EQ.1) THEN
                CALL DRWKEY(OFFCOL+1,GONPOL+OFFCOL,FLRTOT,PROP,
     1                      'ABSOLUTE FLOOR COUNTS')
C......NOW DO THE SAME ON THE TEXT SCREEN IN CASE THE USER WANTS A LIST
                CALL PRINON
                CALL DUMTAB(OFFCOL+1,LASTFL,FLRTOT,PROP,
     1                      'FLOOR POLYGON TOTALS')
                CALL PRINOF
              ELSE
                WRITE(8,210)
                CALL WAITIT
              ENDIF
             ELSEIF(KAR.EQ.'3') THEN
C......(3)-GONDOLA-COUNT, GIVES TABLE OUTPUT AND A GRAPHIC DISPLAY ON
C......THE SCREEN. ^P CAN BE USED TO ACTIVATE THE SYSTEM PRINTER FOR
C......A SCREEN DUMP IF WANTED.
C
C......DRAW THE GONDOLA KEY (ON A NEW SCREEN)
              IF(PERF.EQ.1) THEN
                CALL DRWKEY(GONPOL+OFFCOL+1,POLMAX+OFFCOL,GONTOT,PROP,
     1                      'ABSOLUTE GONDOLA COUNTS')
C......NOW DO THE SAME ON THE TEXT SCREEN IN CASE THE USER WANTS A LIST
                CALL PRINON
                CALL DUMTAB(GONPOL+OFFCOL+1,POLMAX+OFFCOL,GONTOT,PROP,
     1                      'GONDOLA LOOK TOTALS')
                CALL PRINOF
              ELSE
                WRITE(8,210)
                CALL WAITIT
              ENDIF
            ENDIF
            GOTO 100
C......FINAL COMPLETION
  101       RETURN
            END

            SUBROUTINE ABSPIC
            INCLUDE 'AWEFUL.COM'
C......CHANGE ALL LOGICAL COLOURS TO SHOW TOTALS FOR EACH FLOOR LITTLE
C......LINK AND GONDOLA POLYGON.
C
C......SCALE THE LITTLE LINKS FOR B/W DISPLAY OF DENSITY
            J=OFFCOL+1
            K=0
            DO 109 I=J,LASTFL
```

```
            K=MAXO(FLRTOT(I),K)
  109     CONTINUE
          S=FLOAT(255-MAXO(PHYFLR(1),PHYFLR(2),PHYFLR(3)))/FLOAT(K)
          DO 107 I=J,LASTFL
            CALL INCPOL(FLRTOT(I),I,PHYCUS,PHYFLR,S)
  107     CONTINUE
C......SCALE THE GONDOLA INTENSITIES IN A SIMILAR MANNER
          J=POLNUM(GONPOL+1)
          K=0
          DO 110 I=J,POLMAX
            K=MAXO(GONTOT(I),K)
  110     CONTINUE
          S=FLOAT(255-MAXO(PHYSEE(1),PHYSEE(2),PHYSEE(3)))/FLOAT(K)
          DO 111 I=J,POLMAX
            CALL INCPOL(GONTOT(I),I,PHYSEE,PHYGON,S)
  111     CONTINUE
C......WRITE THE NEWLY UPDATED LUT TO THE GRAPHICS SYSTEM.
          CALL WLUTM(254,1,LUT)
          RETURN
          END

          SUBROUTINE ANIMAT(TIM,NTOT)
          CHARACTER*(*) STRING,FILE
          CHARACTER*16 ERROR
          INTEGER ID,KAMERA,FLX,FLY,HOUR,MINS,GOND,SUB,OLDCAM,
     1            OLDMIN,PERSON,LIVING
          INTEGER*4 INCTIM,LASTIM,NEXTIM
          REAL TIM
          INCLUDE 'AWEFUL.COM'
C......ANIMATE THE DISPLAY OF CUSTOMERS IN A SHOP.
C
C......SET UP A WINDOW TO SHOW THE ANIMATION TIME AND PUSH THE PREVIOUS
C......ONE SO IT CAN BE POPPED LATER.
          CALL TextWindow(15,15,65,21)
          CALL PushWindow
          CALL TextFrame(.TRUE.)
          CALL ERASE
C......TAKE THE NUMBER OF SECONDS TO PASS PER MINUTE OF REAL TIME,
C......AND CALCULATE THE TIME IN HUNDREDTHS OF A SECOND PER CAMERA.
          NTOT=0
          WRITE(8,202)
  202     FORMAT(
     1    ' **** PRETTY: ANIMATION SIMULATION UNDERWAY ****',/,
     2    '                ** ANIMATION CLOCK **',///,
     3    '                     ******')
          CALL TextWindow(33,18,47,20)
          CALL TextFrame(.TRUE.)
          CALL ERASE
          INCTIM=TIM/5.*100.+0.5
          CALL TIMEIT(LASTIM)
C......ANIMATION VARIABLES ARE: PERSON ID; CAMERA NUMBER; FLOOR GRID X;
C......FLOOR GRID Y; HOUR; MINUTE; GONDOLA; SECTION OF GONDOLA.
C......REPETITION OF ID IS WHEN PERSON IS SEEN BY MORE THAN ONE CAMERA
C......DURING A GIVEN MINUTE. THE FILE IS SORTED BY HOUR, THEN MINUTE,
C......THEN CAMERA NUMBER (TO GIVE INTERVALS WITHIN A MINUTE WHERE THEY
C......EXIST), AND THEN BY PERSON ID. BELOW IS A FRAGMENT OF A POSSIBLE
C......HYPOTHETICAL FILE, BUT ONLY THE CAMERA/ID SORTING IS VISIBLE AS
C......ALL TIMES ARE 13:31.
C
C         136 1 13 3 13 31 0 0
C         142 1 9 7 13 31 7 2
C         143 1 20 11 13 31 34 1
C         142 2 25 4 13 31 25 2
C         143 3 20 11 13 31 34 1
C         141 4 23 10 13 31 37 2
C         142 5 13 7 13 31 0 0
C
C......SET STARTING CAMERA AND MINUTE TO UNLIKELY NUMBERS
  101     OLDCAM=-1
          OLDMIN=-1
C......GET A RECORD
          ERROR='CASE VARIABLES'
  103     READ(3,*,END=102,ERR=100)ID,KAMERA,FLX,FLY,HOUR,MINS,GOND,SUB
C......CHECK FOR CAMERA CHANGE. AS THE CUSTOMERS ARE SORTED BY TIME AND
C......THEN BY CAMERA, THE SMALLEST TIME SUBDIVISION IS BY CAMERA.
C
```

```
C......A CHANGE IN CAMERA INDICATES A CHANGE IN TIME, AND WE NEED TO
C......CHECK WHETHER ANYBODY HAS 'DIED' AND SHOULD BE REMOVED FROM THE
C......DISPLAY.
             IF(OLDCAM.NE.KAMERA) THEN
C......CHECK WHETHER ELAPSED TIME IS SUFFICIENT TO CARRY ON
  108          CALL TIMEIT(NEXTIM)
               IF(NEXTIM.LT.LASTIM+INCTIM) THEN
                 GOTO 108
               ELSE
                 IF(OLDMIN.NE.MINS) THEN
                   WRITE(8,201)HOUR,MINS
  201              FORMAT('+ ',I2,':',I2,' HOURS')
                   CALL TIMEIT(LASTIM)
                   OLDMIN=MINS
                 ENDIF
               ENDIF
C......APPOINTED TIME HAS ARRIVED, SO CONTINUE.
               CALL WLUTM(254,1,LUT)
               IF(QUICK.NE.0) THEN
C......CHECK ANY LIVING PEOPLE TO SEE IF THEY HAVE BEEN SEEN ON ANY OF
C......THE CAMERAS IN THE LAST CYCLE, AS THIS IS CHANGE OF CAMERA TIME.
C......IF NOT THEN KILL THEM OFF.
                 DO 105 I=1,QUICK
                   PERSON=ALIVE(CAMERA+1,I)
                   IF(PERSON.NE.0) THEN
                     ALIVE(KAMERA,I)=0
                     LIVING=0
                     DO 104 J=1,CAMERA
                       IF(ALIVE(J,I).EQ.1)LIVING=1
  104                CONTINUE
                     IF(LIVING.EQ.0)CALL DEAD(PERSON)
                   ENDIF
  105            CONTINUE
               ENDIF
               OLDCAM=KAMERA
             ENDIF
C......CHECK FOR A LEGITIMATE LOCATION
             IF(FLX.LT.FMINX.OR.FLX.GT.FMAXX.OR.
     1          FLY.LT.FMINY.OR.FLY.GT.FMAXY) THEN
               WRITE(2,200)ID,FLX,FLY
  200          FORMAT(' ** PERSON ',I4,' OFF FLOOR AT X=',I3,' Y =',I3,
     1                ' **')
               GOTO 103
             ENDIF
C......CHECK FOR PERSON ID (FROM FILE) BEING ALIVE AT THE MOMENT
             IF(PEOPLE(ID).EQ.0) THEN
C......PERSON IS PRESENTLY DEAD. RESURRECT THEM INTO THE DATA BASE
               CALL CREATE(ID,KAMERA,FLX,FLY)
               NTOT=NTOT+1
             ELSE
C......PERSON IS ALIVE AT THE MOMENT, ONLY NEED TO UPDATE THEIR
C......LOCATION ON THE SCREEN, AND CAMERA POSITION, IF NECESSARY
               CALL UPLINK(ID,KAMERA,FLX,FLY)
             ENDIF
C......MODIFY THE GONDOLA LOOKS FOR THIS PERSON
             CALL UPGOND(ID,GOND,SUB)
             GOTO 103
C......FINISHED FILE. KILL EVERYBODY OFF
  102        IF(QUICK.NE.0) THEN
               DO 106 I=1,QUICK
                 PERSON=ALIVE(CAMERA+1,I)
                 IF(PERSON.NE.0)CALL DEAD(PERSON)
  106          CONTINUE
             ENDIF
C......RESET TO THE FULL ANIMATION WINDOW FROM THE CLOCK WINDOW
             CALL TextWindow(15,15,65,21)
             GOTO 109
C......READ ERROR, TRY AGAIN OUTSIDE THIS ROUTINE
  100        WRITE(8,203)ERROR
  203        FORMAT('  ERROR IN ',A)
             CALL WAITIT
C......RETURN THE SCREEN TO ITS NORMAL DIALOGUE/INTERACTION STATE
  109        CALL DIAMEN(1)
             REWIND 3
             RETURN
             END
```

```
            SUBROUTINE BANMEN
C......CLEAR THE SCREEN AND THEN PUT UP THE BANNER AND MENU
            CALL TextWindow(1,1,80,13)
            CALL TextFrame(.TRUE.)
            CALL ERASE
            WRITE(8,200)
  200       FORMAT(10X,
     1      '  ****** PRETTY: CUSTOMER MOVEMENT DISPLAY PROGRAM ******',/,
     2      10X,
     3      '  ******       VERSION 2.0 - MJM - JULY 1989       ******',/,
     4      10X,
     5      '  ******             RETAIL ANALYSIS TEAM          ******',//,
     6      '  DISPLAY: (C)ustomer count, (G)ondola layout, (L)inework, ',
     6      '   (M)ark floor',/,
     8      '             (P)erc values,    (R)eal time rate, (V)iew counts',
     9      /,
     9      '  LISTING: (1)All counts,    (2)Floor-count,   (3)Gondola cou',
     1      'nt',/,
     2      '  FETCH:   (A)nimation file, (D)igitising files',/,
     3      '  EXECUTE: (E)xecute Anim,   (F)inal Display,  (Q)UIT Prog,  ',
     4      '  (S)ave screen,',/,
     5      '             (X)ecute Counts   (Z)eropop Store',/,
     6      '  MISCELL: (B)lack & white,  (I)nvert b/w,     (K)olour graph',
     7      ', (N)o inversion')
            RETURN
            END

        SUBROUTINE BAR(KARS,LENG,NOW)
        CHARACTER*(*) KARS
        SAVE LAST
C......DRAW A PERCENTAGE COMPLETION DIAGRAM WHEN REQUESTED. THE
C......TOTAL NUMBER OF COUNTS MUST BE GIVEN IN LENG. A CALL OF BAR
C......WITH NOW OF ZERO SETS UP THE BAR, AND ONE WITH NOW OF -1 WILL
C......ENSURE MOVING ONTO A NEW LINE.
        IF(NOW)101,102,103
C......FINAL CR
  101   WRITE(8,202)
  202   FORMAT('+ 100% - COMPLETE')
        RETURN
C......INITIAL OUTPUT LINE
  102   WRITE(8,200)KARS
  200   FORMAT(' ',A,/,'    0% - WORKING')
        LAST=0
        RETURN
C......INCREMENTAL PERCENTAGES
  103   J=FLOAT(NOW)/FLOAT(LENG)*100.+0.5
        I=FLOAT(LAST)/FLOAT(LENG)*100.+0.5
        LAST=NOW
        IF(I.GT.0.AND.J.GT.I) THEN
              WRITE(8,201)J
  201         FORMAT('+ ',I3,'%')
           ENDIF
        RETURN
        END

            SUBROUTINE BELL
            INTEGER*4 LASTIM,NEXTIM
C......MAKE A NOISE FOR 1/10 SECOND
            CALL TIMEIT(LASTIM)
            CALL Sound(1000)
  100       CALL TIMEIT(NEXTIM)
            IF(LASTIM+10.GT.NEXTIM)GOTO 100
            CALL SoundOff
            RETURN
            END

        SUBROUTINE CONCAT(TEXTA,TEXTB,ISPACE)
        CHARACTER*(*) TEXTA,TEXTB
C......CONCATENATE TEXTA AND TEXTB INTO TEXTA. IF NOT ALL (OR ANY), OF
C......TEXTB CAN BE GOT INTO TEXTA, THEN TRUNCATE THE RIGHT HAND PORTION
C......ISPACE IS THE NUMBER OF SPACES TO BE INSERTED BETWEEN THE STRINGS
C
C......GET USEFUL LENGTHS OF TEXTA AND TEXTB
        CALL LENGCH(TEXTA,LENA)
        CALL LENGCH(TEXTB,LENB)
```

```
C......HOW MUCH ROOM IS THERE ALTOGETHER IN TEXTA?
       LENMAX=LEN(TEXTA)
C......CHECK FOR ROOM FOR TEXTB STRING, AND CALCULATE TRUNCATION LIMIT
       LIMIT=MINO(LENMAX-LENA-ISPACE,LENB)
       IF(LIMIT.GT.0) THEN
C......AT LEAST SOME OF TEXTB CAN BE INSERTED INTO TEXTA
         LENA=LENA+ISPACE
         TEXTA=TEXTA(1:LENA)//TEXTB(1:LIMIT)
           ENDIF
           RETURN
       END

           SUBROUTINE CREATE(ID,KAMERA,FLX,FLY)
           INTEGER ID,KAMERA,FLX,FLY
           INCLUDE 'AWEFUL.COM'
C......PUT PERSON ID INTO THE DISPLAY DATA BASE
           QUICK=QUICK+1
           IF(QUICK.LE.CUSTOM) THEN
C......SPACE EXISTS IN WHICH TO PUT THE CUSTOMER. GET A PLACE TO USE,
C......AND REMEMBER WHERE THIS CUSTOMER IS LOCATED IN THE STACK.
             LOC=STACK(QUICK)
             PEOPLE(ID)=LOC
C......CLEAR CAMERA RECORD FOR THIS PERSON, THEN UPDATE THE CAMERA
C......ENTRY USED FOR THIS SIGHTING.
             DO 104 I=1,CAMERA
               ALIVE(I,LOC)=0
  104        CONTINUE
             ALIVE(KAMERA,LOC)=1
C......STORE ID OF PERSON, CAMERA NUMBER, AND LOCATION ON THE GRID
             ALIVE(CAMERA+1,LOC)=ID
             ALIVE(CAMERA+2,LOC)=KAMERA
             ALIVE(CAMERA+3,LOC)=FLX
             ALIVE(CAMERA+4,LOC)=FLY
C......SET THE LOOK AT GONDOLA MARKER TO ZERO
             LOOKGN(1,LOC)=0
C......PUT THE PERSON ON THE SCREEN
             CALL ONLINK(ID,FLX,FLY)
           ELSE
C......TOO MANY CUSTOMERS ALIVE AT THIS TIME
             WRITE(8,200)
  200        FORMAT('  NO ROOM FOR MORE CUSTOMERS - CHANGE DIMENSIONS')
             CALL WAITIT
             CALL InitScreen
             STOP
           ENDIF
           RETURN
           END

           SUBROUTINE DEAD(PERSON)
           INTEGER PERSON
           INCLUDE 'AWEFUL.COM'
C......REMOVE A PERSON FROM THE ALIVE AND KICKING TABLE
           LOC=PEOPLE(PERSON)
           CALL OFLINK(PERSON,ALIVE(CAMERA+3,LOC),ALIVE(CAMERA+4,LOC))
           CALL UPGOND(PERSON,0,0)
           PEOPLE(PERSON)=0
           ALIVE(CAMERA+1,LOC)=0
C......RETURN THE ALIVE ENTRY TO THE STACK FOR REUSE
           IF(QUICK.LT.1) THEN
             WRITE(8,200)
  200        FORMAT('  STACK CORRUPTED. TOO MANY RETURNS')
             CALL WAITIT
             CALL InitScreen
             STOP
           ELSE
             STACK(QUICK)=LOC
             QUICK=QUICK-1
           ENDIF
           RETURN
           END

           SUBROUTINE DIAMEN(IOPT)
C......RETURN THE SCREEN TO ITS NORMAL STATE (DEFAULT DIALOGUE AND
C......INTERACTION AREA)
C......IF IOPT IS 1 THEN WE NEED TO POP UP THE OLD BACKGROUND.
           IF(IOPT.EQ.1)CALL PopWindow
```

```
            CALL TextWindow(1,20,80,25)
            CALL TextFrame(.TRUE.)
            CALL ERASE
            RETURN
            END

            SUBROUTINE DRWRAT(ROWEND,COLEND)
            INTEGER ROWEND,COLEND
C......DRAW THE RAT, JUST AT THE BOTTOM RIGHT OF THE PRESENT USED
C......SCREEN LIMIT.
            INTEGER NRAT1(10,15),NRAT2(10,15)
            OPEN(1,FILE='RAT.DAT')
            CALL SCCOL(2)
            READ(1,*) NL
            KKOL=MIN0(COLEND,850)
            KROW=ROWEND+10
            DO 10 I=1,NL
              READ(1,*) NP
              DO 20 J=1,NP
                READ(1,*) NRAT1(I,J),NRAT2(I,J)
                NRAT2(I,J)=((ABS(70-NRAT2(I,J)))/3)+KROW
                NRAT1(I,J)=(NRAT1(I,J)/3.5)+KKOL
                ROWEND=MAX0(ROWEND,NRAT2(I,J))
                COLEND=MAX0(COLEND,NRAT1(I,J))
 20            CONTINUE
              CALL MOVETO(NRAT1(I,1),NRAT2(I,1))
              DO 30 J=2,NP
                CALL LINETO(NRAT1(I,J),NRAT2(I,J))
 30           CONTINUE
 10         CONTINUE
            CLOSE(1)
            RETURN
            END

            SUBROUTINE DRWKEY(BOT,TOP,COUNT,PROP,TITLE)
            INTEGER BOT,TOP,COUNT(256),PROP
            CHARACTER*(*) TITLE
            INTEGER PERC(256)
            INCLUDE 'AWEFUL.COM'
C......DRAW A SERIES OF BOXES TO REPRESENT ALL COLOURS, AND FILL EACH
C......OF THEM WITH THE APPROPRIATE LOGICAL COLOUR. THESE WILL LATER
C......BE ANNOTATED AFTER ANIMATION TO SHOW THE NUMERICAL LEVELS REACHED
C......BY EACH COLOUR. THE FIRST LOGICAL COLOUR TO DISPLAY IS BOT, AND
C......THE LAST IS TOP. USE AS MANY LINES AS NEEDED AND APPORTION BOT TO
C......TOP BETWEEN THEM. THE VALUE TO BE PLOTTED IS HELD IN COUNT. PROP
C......IS 1 IF PERCENTAGE OUTPUT IS TO BE USED, -1 FOR ABSOLUTE VALUES.
            CALL CLRCWP
            CALL USEDSC
            CALL ABSPIC
            CALL PERCEN(COUNT,PERC,BOT,TOP,PROP)
            IF(TOP-BOT+1.LT.120) THEN
              LINES=(TOP-BOT+1)/10+1
            ELSE
              LINES=12
            ENDIF
            NUM=(TOP-BOT)/LINES+1
            IYSP=(SCRENY-YOFSET-100)/12
            IHT=IYSP/3
            ISTO=BOT-1
            INC=(SCRENX-XOFSET)/NUM
            CALL OTITLE(XOFSET,YOFSET*2,TITLE,OFFCOL)
            IY=YOFSET+40
            DO 100 I=1,LINES
              IBEG=ISTO+1
              ISTO=MIN0(IBEG+NUM-1,TOP)
              IX=XOFSET
              DO 101 J=IBEG,ISTO
                K=J-BOT+1
                CALL RECTAL(IX,IY,INC,IHT,J,1,OFFCOL,K,PERC(J))
                IX=IX+INC
 101          CONTINUE
              IY=IY+IYSP
 100        CONTINUE
C......UPDATE PLOTTED LIMITS FOR THIS GRAPHIC SCENE.
            ROWBEG=1
            COLBEG=1
```

```
          ROWEND=IY
          COLEND=INC*LINES
          CALL DRWRAT(ROWEND,COLEND)
          RETURN
          END

          SUBROUTINE DUMPIT(LUT,ROWBEG,ROWEND,COLBEG,COLEND)
          INTEGER LUT(768),ROWBEG,ROWEND,COLBEG,COLEND
          CHARACTER*1 KAR
          CHARACTER*40 NAME
          INTEGER COLUMN(1030)
          INTEGER*1 BUF(1030),BYTINT
          INTEGER*2 MR,NC
C......ENQUIRE WHETHER THE USER WANTS TO DUMP AN IMAGE TO A SCREEN
C......DUMP FILE READY FOR LATER PRINTING. DUMPING IS A COLUMN AT A
C......TIME STARTING WITH THE RIGHTMOST COLUMN (COLEND), FROM ROWBEG
C......TO ROWEND.
          WRITE(8,201)
  201     FORMAT('  DUMP SCREEN TO FILE? ',\)
          READ(8,200)KAR
  200     FORMAT(A)
          IF(KAR.EQ.'Y'.OR.KAR.EQ.'y') THEN
            WRITE(8,202)
  202       FORMAT('  FILE NAME TO USE? ',\)
            READ(8,200)NAME
            OPEN(1,FILE=NAME,FORM='UNFORMATTED')
            COLBEG=MAX0(COLBEG-10,1)
            COLEND=MIN0(COLEND+10,1023)
            ROWBEG=MAX0(ROWBEG-10,1)
            ROWEND=MIN0(ROWEND+10,779)
            MR=ROWEND-ROWBEG+1
            NC=COLEND-COLBEG+1
            CALL BAR('DUMPING SCREEN IMAGE',NC,0)
            DO 103 I=1,3
              BUF(I)=0
  103       CONTINUE
            DO 101 I=1,765
              BUF(I+3)=BYTINT(LUT(I))
  101       CONTINUE
            WRITE(1)(BUF(I),I=1,768)
            WRITE(1)NC,MR
            L=0
            DO 100 I=COLBEG,COLEND
              J=COLEND-I+COLBEG
              L=L+1
              CALL MOVETO(J,ROWBEG)
              CALL RIMAGE(1,MR,COLUMN)
              DO 102 K=1,MR
                BUF(K)=BYTINT(COLUMN(K))
  102         CONTINUE
              WRITE(1)(BUF(K),K=1,MR)
              CALL BAR(' ',NC,L)
  100       CONTINUE
            CLOSE(1)
            CALL BAR(' ',NC,-1)
          ENDIF
          RETURN
          END

          INTEGER*1 FUNCTION BYTINT(I)
          INTEGER I
C......PUT THE VALUE IN INTEGER I OF UNSIGNED SIZE 0-255 INTO SIGNED
C......INTEGER*1 BETWEEN -128 TO +127. ANY VALUE LARGER THAN 127
C......BECOMES NEGATIVE: +128=-128....+255=-1
          IF(I.LT.128) THEN
            BYTINT=I
          ELSE
            BYTINT=-256+I
          ENDIF
          END

          SUBROUTINE DUMTAB(IBEG,ISTO,COUNT,PROP,TITLE)
          INTEGER IBEG,ISTO,COUNT(256),PROP
          CHARACTER*(*) TITLE
          INTEGER PERC(256)
          CHARACTER*8 TEXT
```

```
C......WRITE OUT THE FLOOR/GONDOLA INFORMATION AS A TABLE ON THE SCREEN
C......FROM ELEMENT IBEG TO ELEMENT ISTO OF ARRAY COUNT. USE ABSOLUTE
C......TOTALS IF PROP IS -1, ELSE USE PERCENTAGES. THE TABLE TITLE IS
C......GIVEN BY TITLE.
C
C......GET PERCENTAGES IF NEEDED
            CALL PERCEN(COUNT,PERC,IBEG,ISTO,PROP)
C......OUTPUT THE TABLE
            WRITE(8,200)TITLE
  200       FORMAT(//,' ',A)
            LOOP=(ISTO-IBEG)/10+1
            NMAX=ISTO-IBEG+1
            L=0
            DO 100 I=1,LOOP
              K=L+1
              L=MIN0(K+9,NMAX)
              WRITE(8,201)(J,J=K,L)
  201         FORMAT(/,' OBJECT:',10I7)
              IF(PROP.EQ.1) THEN
                TEXT=' PERCEN:'
              ELSE
                TEXT='  COUNT:'
              ENDIF
              M=K+IBEG-1
              N=L+IBEG-1
              WRITE(8,202)TEXT,(PERC(J),J=M,N)
  202         FORMAT(A8,10I7)
  100       CONTINUE
            RETURN
            END

            SUBROUTINE ERASE
C......ERASE THE ALPHA WINDOW AND HOME THE ALPHA CURSOR
            CALL ClrScr
            RETURN
            END

            SUBROUTINE FETDIG
            INCLUDE 'AWEFUL.COM'
C
C*********************** FETCH DATA FROM FILES ***********************
C
C......FETCH FLOOR POLYGON FILE. FLUPOL IS ZERO BECAUSE THERE IS NO
C......POLYGON OFFSET FOR THE FIRST POLYGON FILE READ IN.
            FLUPOL=0
            KARRY=0
            CALL ERASE
            WRITE(8,200)
  200       FORMAT('  FETCHING FLOOR POLYGON DIGITISED DATA FILE.......')
            CALL GETPOL('FLOOR POLYGONS','FLORLINK.DAT',KARRY)
            LASTFL=KARRY
C......FETCH GONDOLA POLYGON FILE. GONPOL IS THE POLYGON NUMBER
C......OFFSET TO USE AS THE BASE OF THE GONDOLA POLYGON FILE.
            GONPOL=KARRY
            WRITE(8,201)
  201       FORMAT('  FETCHING GONDOLA POLYGON DIGITISED DATA FILE.....')
            CALL GETPOL('GONDOLA POLYGONS','GONDOLA.DAT',KARRY)
            POLMAX=KARRY
C......FETCH ANY LINEWORK AS NECESSARY TO ENHANCE THE FLOOR PLAN
            WRITE(8,202)
  202       FORMAT('  FETCHING THE DIGITISED LINEWORK DATA FILE........')
            CALL GETLIN('LINEWORK','LINEWORK.DAT',KARRY)
            LINTOT=KARRY
C......FETCH THE FLOOR TO LITTLE LINK TABLE
            WRITE(8,203)
  203       FORMAT('  FETCHING THE FLOOR GRID TO LITTLE LINK FILE......')
            CALL FTABLE('FLOOR TABLE','FLORGRID.DAT')
            RETURN
            END

            SUBROUTINE FIRECT(IX,IY,NUM,IHT,KOLA,LOG)
C......DRAW A RECTANGLE, TLC IS IX,IY, WIDTH IS NUM, HEIGHT IS IHT,
C......THE LOGICAL COLOUR TO USE FOR FILLING IS LOG, AND THE OUTLINE
C......COLOUR IS KOLA.
            CALL SCCOL(KOLA)
            CALL MOVETO(IX,IY)
```

```
              CALL LINETO(IX,IY+IHT)
              CALL LINETO(IX+NUM,IY+IHT)
              CALL LINETO(IX+NUM,IY)
              CALL LINETO(IX,IY)
              CALL SPCOL(KOLA)
              CALL SCCOL(LOG)
              CALL MOVETO(IX+NUM/2,IY+IHT/2)
              CALL BFILL
              RETURN
              END

              SUBROUTINE FTABLE(STRING,FILE)
              CHARACTER*(*) STRING,FILE
              CHARACTER*16 ERROR
              INCLUDE 'AWEFUL.COM'
C......READ IN THE FLOOR TO LITTLE LINK TABLE. TRY TO OPEN 'FILE' IF
C......THE START IS NOT BLANK
              CALL OPENIT(STRING,FILE,1)
C......NOW READ LIMITS OF THE FLOOR TABLE INCLUDED IN THE FILE, AND
C......CHECK THEM WITH THE LIMITS IN THIS PROGRAM
  101         ERROR='READING LIMITS'
              READ(1,*,ERR=100,END=100)FMINX,FMINY,FMAXX,FMAXY
              IF(FMINX.LT.1.OR.FMINX.GT.FLOORX.OR.
     1           FMINY.LT.1.OR.FMINY.GT.FLOORY.OR.
     2           FMAXX.LT.1.OR.FMAXX.GT.FLOORX.OR.
     3           FMAXY.LT.1.OR.FMAXY.GT.FLOORY.OR.
     4           FMINX.GT.FMAXX.OR.FMINY.GT.FMAXY) THEN
                ERROR='FLOOR LIMITS'
                GOTO 100
              ENDIF
C......FETCH THE FLOOR TO LITTLE LINK GRID FROM FILE. NB: X IS STORED
C......AS THE FIRST SUBSCRIPT, Y AS THE SECOND, A BIT ODD BUT THERE
C......YOU HAVE IT.
              ERROR='FLOOR GRID VALUE'
              DO 102 I=FMINY,FMAXY
                READ(1,*,ERR=100,END=100)(FLOOR(I,J),J=FMINX,FMAXX)
  102         CONTINUE
              RETURN
C......READ ERROR, TRY AGAIN
  100         WRITE(8,200)ERROR
  200         FORMAT('  ERROR IN ',A)
              CALL WAITIT
              CLOSE(1)
              CALL OPENIT(STRING,' ',1)
              GOTO 101
              END

              SUBROUTINE GENERA(FLOR,LINE,CUST,GOND,VIEW,NUM,PROP)
              INTEGER FLOR,LINE,CUST,GOND,VIEW,NUM,PROP
              INTEGER PERC(256)
              INCLUDE 'AWEFUL.COM'
C......GENERAL DISPLAY OPTION, USING THE CHOICES FROM THE ARGUMENT LIST.
C......IF NUM IS -1 THEN GIVE THE TOTALS (IF TO BE PRINTED), IF +VE THEN
C......THE NUMBERS OF THE FLOOR PATCHES / GONDOLAS THEMSELVES. MEAINING
C......OF THE ARUMENTS CAN BE DERIVED FROM THE TERMS GIVEN AT THE START
C......OF 'ACTION'.
C
C......ZERO THE LUT SO THAT UPDATING IS NOT VISIBLE, AND RESET THE
C......SCREEN LIMITS. CLEAR THE SCREEN.
              CALL NULLUT
              CALL USEDSC
              CALL CLRCWP
C......DETERMINE WHETHER LINEWORK IS TO BE DRAWN ON THE FLOOR POLYGONS.
              IF(FLOR.EQ.1) THEN
                I=2
              ELSE
                I=0
              ENDIF
C......DETERMINE MAXIMUM FOR COMPLETION BAR, AND START THE BAR
              IF(GOND.EQ.0) THEN
                NTOT=LASTFL
              ELSE
                NTOT=POLMAX+OFFCOL
              ENDIF
              CALL BAR('PREPARING SHOP VIEW',NTOT,0)
C......OUTPUT THE FLOOR AND LINEWORK, THEN NUMBER THE FLOOR TILES,
```

```
C......THEN OUTPUT THE GONDOLAS AND NUMBER THE GONDOLAS.
            CALL POLGEN(OFFCOL+1,LASTFL,PHYFLR,I,NTOT)
            IF(LINE.EQ.1) THEN
              CALL POLGEN(POLMAX+OFFCOL+1,LINTOT+OFFCOL,PHYFLR,2,0)
            ENDIF
            IF(CUST.EQ.1) THEN
              CALL PERCEN(FLRTOT,PERC,OFFCOL+1,LASTFL,PROP)
              CALL NUMBER(OFFCOL+1,LASTFL,PERC,NUM,2)
            ENDIF
            IF(GOND.EQ.1) THEN
              CALL POLGEN(GONPOL+OFFCOL+1,POLMAX+OFFCOL,PHYGON,1,NTOT)
            ENDIF
            IF(VIEW.EQ.1) THEN
              CALL PERCEN(GONTOT,PERC,GONPOL+OFFCOL+1,POLMAX+OFFCOL,PROP)
              CALL NUMBER(GONPOL+OFFCOL+1,POLMAX+OFFCOL,PERC,NUM,1)
            ENDIF
C......DRAW THE LOGO
            CALL DRWRAT(ROWEND,COLEND)
C......SHUT DOWN THE BAR
            CALL BAR(' ',NTOT,-1)
C......SWITCH ON THE DISPLAY OF THE FLOOR AND THE GONDOLAS
            CALL WLUTM(254,1,LUT)
            RETURN
            END

            SUBROUTINE GETLIN(STRING,FILE,LMAX)
            CHARACTER*(*)STRING,FILE
            CHARACTER*16 ERROR
            INTEGER IX(100),IY(100)
            REAL XMIN,XMAX,YMIN,YMAX
            INCLUDE 'AWEFUL.COM'
C......FETCH A LINWORK FILE AND STORE IT INTO THE POLYGON STRUCTURE.
C......IF FILE START IS NOT BLANK IT IS THE FILE NAME TO TRY FIRST AS
C......THE ONE HOLDING THE DATA FILE REQUIRED.
C
C********************* OPEN A LINEWORK FILE ************************
C
C......FIRST RECORD IN FILE IS A SET OF 4 VALUES GIVING MINX,MAXX,
C......MINY, AND MAXY IN A NORMAL CARTESIAN SYSTEM. ALL FILES
C......SHOULD HAVE THE SAME VALUES FOR THE SAME SHOP - NO CLEVER
C......STUFF IS DONE TO SCALE DIFFERENT SYSTEM TO THE SAME RESULT!
C
C......POLYGON ENTRY LOOKS LIKE:
C......      RECORD 1:
C......         POLYGON NUMBER, NUMBER OF VERTICES, NUMBER OF SUBDIVISIONS
C...... RECORD 2:N+1
C......    X1 Y1  X2 Y2  X3 Y3  .. ..  .. ..
C......    .. ..  .. ..  .. ..  .. ..  .. ..
C......         .. ..  .. ..  .. ..  XN YN
C...... ORDER IS CLOCKWISE STARTING AT '1' END GOING TOWARDS MAXIMUM
C...... SUBDIVISION ON LONG SIDE. POLYGONS DO NOT CLOSE.
C
C......SET LIMIT FOR NUMBER OF POINTS IN A CLOSED POLYGON
            LIMIT=99
C......TRY TO OPEN 'FILE' IF THE START IS NOT BLANK
            CALL OPENIT(STRING,FILE,1)
C
C****************** READ AND SCALE LINWORK ********************
C
C......GET REGISTER MARK LOCATIONS, AND CALCULATE SCALINGS TO FIT
C......THE PLUTO GRAPHICS SCREEN
  101       ERROR='REG MARKS'
            READ(1,*,ERR=100,END=100)XMIN,XMAX,YMIN,YMAX
            SCALE=AMIN1(FLOAT(SCRENX-XOFSET)/(XMAX-XMIN),
     1                  FLOAT(SCRENY-YOFSET)/(YMAX-YMIN))
            DO 102 I=1,10000
C......GET DETAILS FOR POLYGON, CHECK POLYGON NUMBER OF VERTICES
              ERROR='POLY HEAD'
              READ(1,*,ERR=100,END=108)NUMP,NUMV,NUMS
              IF(NUMV.GT.LIMIT-1) THEN
                ERROR='POLY SIZE'
                GOTO 100
              ENDIF
              ERROR='POLY LIST'
C......ALL IS WELL, GET THE POLYGON COORDINATES.
              READ(1,*,ERR=100,END=100)(IX(J),IY(J),J=1,NUMV)
```

```
C......GO THROUGH AND SCALE ALL POINTS ON THE POLYGON TO SCREEN
C......COORDINATES, USING THE SCALINGS CALCULATED ABOVE. REMEMBER
C......THE MAXIMUM COORDINATES USED SO FAR.
              DO 103 J=1,NUMV
                IX(J)=(IX(J)-XMIN)*SCALE+XOFSET+0.5
                IY(J)=(YMAX-IY(J))*SCALE+YOFSET+0.5
  103         CONTINUE
              LMAX=LMAX+1
              IF(LMAX+OFFCOL.GT.LINMAX) THEN
                ERROR='DIMENSIONS'
                GOTO 100
              ENDIF
              CALL SAVLIN(LMAX+OFFCOL,IX,IY,NUMV,IXCEN,IYCEN)
  102       CONTINUE
  108       RETURN
C......READ ERROR, TRY AGAIN
  100       CALL LENGCH(ERROR,L)
            WRITE(8,200)ERROR(1:L)
  200       FORMAT('  ERROR IN ',A,' IN GETLIN')
            CALL WAITIT
            CLOSE(1)
            CALL OPENIT(STRING,' ',1)
            GOTO 101
            END

            SUBROUTINE GETPOL(STRING,FILE,POLMX)
            CHARACTER*(*)STRING,FILE
            INTEGER POLMX,LINE
            CHARACTER*16 ERROR
            INTEGER IX(100),IY(100),JX(5),JY(5),LOGBAS,KARRY,MOLD
            INTEGER*4 IXD,IYD
            REAL XMIN,XMAX,YMIN,YMAX
            INCLUDE 'AWEFUL.COM'
C......FETCH A POLYGON FILE, UPDATE THE POLYGON ARRAY TO HOLD THE
C......REFERENCE NUMBERS AND LOGICAL COLOURS. STRING HOLDS THE FILE
C......QUERY, POLMX IS THE MAXIMUM POLYGON NUMBER FOUND IN THIS
C......POLYGON SET, AND ACTS AS AN OFFSET TO THE POLYGON NUMBERS IN
C......THE NEXT FILE. IF FILE START IS NOT BLANK IT IS THE FILE NAME
C......TO TRY FIRST AS THE ONE HOLDING THE DATA FILE REQUIRED.
C
C********************** OPEN A POLYGON FILE *************************
C
C......FIRST RECORD IN FILE IS A SET OF 4 VALUES GIVING MINX,MAXX,
C......MINY, AND MAXY IN A NORMAL CARTESIAN SYSTEM. ALL FILES
C......SHOULD HAVE THE SAME VALUES FOR THE SAME SHOP - NO CLEVER
C......STUFF IS DONE TO SCALE DIFFERENT SYSTEM TO THE SAME RESULT!
C
C......POLYGON ENTRY LOOKS LIKE:
C......      RECORD 1:
C......         POLYGON NUMBER, NUMBER OF VERTICES, NUMBER OF SUBDIVISIONS
C...... RECORD 2:N+1
C......    X1 Y1  X2 Y2  X3 Y3  .. ..  .. ..
C......    .. ..  .. ..  .. ..  .. ..  .. ..
C......       .. ..  .. ..  .. ..  XN YN
C...... ORDER IS CLOCKWISE STARTING AT '1' END GOING TOWARDS MAXIMUM
C...... SUBDIVISION ON LONG SIDE. POLYGONS DO NOT CLOSE.
C
C......KARRY DETERMINES THE LARGEST POLYGON NUMBER, INCLUDING OFFSET
C......OF POLMX, THAT IS FOUND IN THIS FILE. SET TO THE OFFSET NOW
C......(POLMX), AND AT THE END POLMX IS SET TO ITS NEW VALUE.
            KARRY=POLMX
C......SET LIMIT FOR NUMBER OF POINTS IN A CLOSED POLYGON
            LIMIT=99
C......TRY TO OPEN 'FILE' IF THE START IS NOT BLANK
            CALL OPENIT(STRING,FILE,1)
C
C******************* READ AND SCALE A POLYGON *********************
C
C......GET REGISTER MARK LOCATIONS, AND CALCULATE SCALINGS TO FIT
C......THE PLUTO GRAPHICS SCREEN
  101       ERROR='REG MARKS'
            READ(1,*,ERR=100,END=100)XMIN,XMAX,YMIN,YMAX
            SCALE=AMIN1(FLOAT(SCRENX-XOFSET)/(XMAX-XMIN),
     1                  FLOAT(SCRENY-YOFSET)/(YMAX-YMIN))
            DO 102 I=1,10000
C......GET DETAILS FOR POLYGON, CHECK POLYGON NUMBER, AND VERTICES
```

```
              ERROR='POLY HEAD'
              READ(1,*,ERR=100,END=108)NUMP,NUMV,NUMS
              NUMP=NUMP+POLMX
              KARRY=MAX0(NUMP,KARRY)
              IF(NUMP.GT.LIMPOL) THEN
                ERROR='POLY NUMBER'
                GOTO 100
              ENDIF
              IF(NUMV.GT.LIMIT-1) THEN
                ERROR='POLY SIZE'
                GOTO 100
              ENDIF
C......CHECK THAT WE ARE DEALING WITH A RECTANGLE IF SUBDIVIDED
              IF(NUMS.GT.1.AND.NUMV.NE.4) THEN
                ERROR='POLY SHAPE'
                GOTO 100
              ENDIF
              ERROR='POLY LIST'
C......ALL IS WELL, GET THE POLYGON COORDINATES.
              READ(1,*,ERR=100,END=100)(IX(J),IY(J),J=1,NUMV)
C......GO THROUGH AND SCALE ALL POINTS ON THE POLYGON TO SCREEN
C......COORDINATES, USING THE SCALINGS CALCULATED ABOVE. REMEMBER
C......THE MAXIMUM COORDINATES USED SO FAR.
              DO 103 J=1,NUMV
                IX(J)=(IX(J)-XMIN)*SCALE+XOFSET+0.5
                IY(J)=(YMAX-IY(J))*SCALE+YOFSET+0.5
  103         CONTINUE
C
C*************** SUBDIVIDE AND STORE THE POLYGON *****************
C
C......ENTER THE POLYGON INTO THE POLYGON LIST IF IT IS NEW, KEEPING
C......DETAILS OF ITS POLYGON NUMBER, THEN INCREMENT TOTAL NUMBER OF
C......POLYGONS TO ALLOW FOR THE SUBDIVISION SET OF LOGICAL COLOURS
C......NEEDED.
              IF(TOTPOL+NUMS.GT.LOGMAX) THEN
                ERROR='NUMB COLRS'
                GOTO 100
              ELSE
C......GET BASE LOGICAL COLOUR FOR THIS POLYGON, REMEMBER IT IN POLNUM
C......AND ENTER THE MAXIMUM NUMBER OF SUBDIVISIONS ALLOWED IN POLCHK.
C......IF THIS AN ALREADY USED POLYGON NUMBER THEN WE DRAW IT JUST THE
C......SAME, BUT ALWAYS WITH ONLY ONE AREA, AND ONLY IN THE BASE LOGICAL
C......COLOUR ALREADY USED.
                IF(POLNUM(NUMP).EQ.0) THEN
C......A NEW FRESH POLYGON
                  LOGBAS=TOTPOL+1
                  POLNUM(NUMP)=LOGBAS
                  MOLD=0
                ELSE
C......A MULTIPLE GOLDEN OLDY POLYGON
                  LOGBAS=POLNUM(NUMP)
                  MOLD=1
                ENDIF
                IF(NUMV.EQ.4.AND.NUMS.NE.1) THEN
C......GO THROUGH AND SUBDIVIDE THE POLYGON INTO ITS SUBPOLYGONS,
C......DRAW EACH ONE, AND SET EACH TO THE APPROPRIATE BASE PHYSICAL
C......COLOUR IN THE INITIAL COMPLETE LUT.
                  POLCHK(LOGBAS)=NUMS
                  IXD=IX(2)-IX(1)
                  IYD=IY(2)-IY(1)
                  DO 104 J=1,NUMS
C......GET COORDINATES OF SUBDIVISION RECTANGLE
                    A=FLOAT(J-1)/FLOAT(NUMS)
                    JX(1)=IX(1)+IXD*A+0.5
                    JY(1)=IY(1)+IYD*A+0.5
                    JX(4)=IX(4)+IXD*A+0.5
                    JY(4)=IY(4)+IYD*A+0.5
                    JX(5)=JX(1)
                    JY(5)=JY(1)
                    A=FLOAT(J)/FLOAT(NUMS)
                    JX(2)=IX(1)+IXD*A+0.5
                    JY(2)=IY(1)+IYD*A+0.5
                    JX(3)=IX(4)+IXD*A+0.5
                    JY(3)=IY(4)+IYD*A+0.5
C......GET LOGICAL COLOUR FOR THIS POLYGON
                    L=LOGBAS+J-1
```

```
C......REMEMBER THE SCREEN COORDINATES FOR THIS SUBPOLYGON FOR USE
C......AGAIN WITHOUT REREADING THE FILE. GET CENTER OF GRAVITY AT THE
C......SAME TIME (IXCEN,IYCEN).
                       CALL SAVLIN(L,JX,JY,4,IXCEN,IYCEN)
  104                CONTINUE
C......UPDATE TOTAL OF POLYGON (AND LOGICAL COLOURS) NOW USED
                     IF(MOLD.EQ.0)TOTPOL=TOTPOL+NUMS
                   ELSE
C......NONRECTANGULAR POLYGON MUST ALWAYS HAVE NO SUBDIVISIONS, AND
C......PREFERABLY BE CONVEX AND NON-REENTRANT OR THE FILL LOCATION
C......MAY WELL FALL OUTSIDE THE POLYGON. SO GET LOGICAL COLOUR
C......FOR THIS POLYGON.
                     POLCHK(LOGBAS)=1
C......REMEMBER THE SCREEN COORDINATES FOR THIS SUBPOLYGON FOR USE
C......AGAIN WITHOUT REREADING THE FILE. GET CENTER OF GRAVITY AT THE
C......SAME TIME (IXCEN,IYCEN).
                     CALL SAVLIN(LOGBAS,IX,IY,NUMV,IXCEN,IYCEN)
C......UPDATE TOTAL OF POLYGON (AND LOGICAL COLOURS) NOW USED
                     IF(MOLD.EQ.0)TOTPOL=LOGBAS
                   ENDIF
                 ENDIF
  102          CONTINUE
  108          POLMX=KARRY
               RETURN
C......READ ERROR, TRY AGAIN
  100          CALL LENGCH(ERROR,L)
               WRITE(8,200)ERROR(1:L)
  200          FORMAT('  ERROR IN ',A,' IN GETPOL')
               CALL WAITIT
               CLOSE(1)
               CALL OPENIT(STRING,' ',1)
               GOTO 101
               END

          SUBROUTINE GZCNVU(USRCHR)
          CHARACTER*(*) USRCHR
C......CONVERT A CHARACTER STRING TO UPPER CASE
C......GET LENGTH OF CHARACTER VARIABLE USRCHR.
          LS=LEN(USRCHR)
C......CHECK AND ALTER IF NECESSARY
          DO 100 I=1,LS
          IVAL=ICHAR(USRCHR(I:I))
          IF(IVAL.GT.96.AND.IVAL.LT.123)USRCHR(I:I)=CHAR(IVAL-32)
  100     CONTINUE
          RETURN
          END

               SUBROUTINE INCPOL(COUNT,LOG,FYSIC,FYEMP,SINC)
               INTEGER COUNT,LOG,FYSIC(3),FYEMP(3)
               REAL SINC
               INCLUDE 'AWEFUL.COM'
C......MODIFY PHYSICAL COLOUR 'FYSIC' TO ALLOW FOR THE FREQUENCY
C......'COUNT' FOR LOGICAL POLYGON 'LOG'. THE INCREMENT TO USE FOR
C......A CHANGE IN FREQUENCY IS 'SINC'. REMEMBER THE NEW COLOUR IN
C......THE LUT STORAGE. IF THE COUNT IS ZERO THEN USE THE EMPTY
C......POLYGON COLOUR SUPPLIED IN FYEMP.
               IF(COUNT.EQ.0) THEN
                 DO 101 I=1,3
                   LUT(I,LOG)=FYEMP(I)
  101            CONTINUE
               ELSE
                 J=COUNT*SINC
                 IF(INVERT.EQ.1)J=255-J
                 DO 100 I=1,3
                   IF(FYSIC(I).EQ.0.AND.BLKWHT.EQ.-1) THEN
                     LUT(I,LOG)=0
                   ELSE
                     LUT(I,LOG)=MINO(FYSIC(I)+J,255)
                   ENDIF
  100            CONTINUE
               ENDIF
               RETURN
               END

          SUBROUTINE LENGCH(USRCHR,JS)
          CHARACTER*(*) USRCHR
```

```
C......RETURN THE NUMBER OF CHARACTERS (JS) HELD IN USRCHR BEFORE THE
C......RIGHTMOST BLANK.
C
C......GET LENGTH OF STRING
       IL=LEN(USRCHR)
C......FIND FIRST NON-BLANK CHARACTER (STARTING FROM THE RIGHT)
       DO 100 I=1,IL
       JS=IL-I+1
       IF(USRCHR(JS:JS).NE.' ')GOTO 101
  100  CONTINUE
C......SET NON-BLANK STRING LENGTH TO ZERO IN CASE NO CHARACTERS ARE
C......FOUND
       JS=0
C......POSITION OF LAST NON-BLANK CHARACTER IS NOW STORED IN JS
  101  RETURN
       END

            SUBROUTINE NEWANI
            INCLUDE 'AWEFUL.COM'
C......SET UP NEW CONDITIONS FOR A FRESH ANIMATION WITH DIFFERENT
C......DATA BUT USING THE PRESENTLY CHOSEN SHOP
C......SET THE LITTLE LINK CUSTOMER COUNT STORAGE ARRAY TO ZERO
            CALL SETDIM(FLRCNT,LOGMAX,0)
C......SET THE ACCUMULATION SPACE FOR LITTLE LINK PASSERS TO ZERO
            CALL SETDIM(FLRTOT,LOGMAX,0)
C......SET THE GONDOLA FREQUENCY COUNT LIST TO ZERO
            CALL SETDIM(GONTOT,LOGMAX,0)
C......SET THE GONDOLA LOOK COUNT LIST TO ZERO
            CALL SETDIM(GONCNT,LOGMAX,0)
C......SET THE PEOPLE ARRAY TO UNUSED
            CALL SETDIM(PEOPLE,CROWD,0)
C......SET UP THE CUSTOMER STACK, AND SET STACK LEVEL
            DO 102 I=1,CUSTOM
              STACK(I)=I
  102       CONTINUE
            QUICK=0
C......SET THE LIVING CUSTOMER LIST TO EMPTY
            CALL SETDIM(ALIVE,CITEMS*CUSTOM,0)
            RETURN
            END

            SUBROUTINE NULLUT
            INCLUDE 'AWEFUL.COM'
C......SET THE LUT IN THE GRAPHICS SCREEN TO ALL BLACK. THEN REGENERATE
C......THE LUT TO WHATEVER HAS BEEN DEMANDED.
C
C......SET UP INITIAL LUT USED FOR POLYGONS TO A DEFAULT OF ALL BLACK
C......AND SEND IT TO THE GRAPHICS BOARD
            CALL SETDIM(LUT,3*LOGMAX,0)
            CALL WLUTM(254,1,LUT)
            CALL SETCLR
            CALL PERCOL
            RETURN
            END

            SUBROUTINE NUMBER(IBEG,ISTO,TOT,NUM,KOL)
            INTEGER TOT(256)
            CHARACTER*4 WORD
            INCLUDE 'AWEFUL.COM'
C......WRITE THE POLYGON NUMBER IN EACH POLYGON HELD IN THE SYSTEM
C......BETWEEN IBEG AND ISTO. ALWAYS START NUMBERING AT NUM. KOL IS
C......THE COLOUR TO USE. IF NUM IS -1 THEN DRAW THE NUMBERS HELD IN
C......TOT (USUALLY GONDOLA OR FLOOR SIGHTING TOTALS) RATHER THAN
C......INCREMENT NUM. IBEG IS THEN THE ENTRY POINT TO TOT.
            CALL SFCOL(KOL)
C......ENSURE TRANSPARENT BACKGROUND IS USED FOR SYMBOL COPYING.
            CALL SSTYLE(136)
            J=NUM
            DO 100 I=IBEG,ISTO
              IF(NUM.EQ.-1)J=TOT(I)
              WRITE(WORD,200)J
  200         FORMAT(' ',I3)
              CALL WRITEP(POLCEN(1,I)-6,POLCEN(2,I)-7,WORD)
              J=J+1
  100       CONTINUE
C......RETURN STYLE TO DEFAULT
```

```
      CALL SSTYLE(128)
      RETURN
      END

      SUBROUTINE OFGOND(ID,GOND,SUB)
      INTEGER ID,GOND,SUB
      INTEGER BASE,LOG,LOGA,LOGB
      INCLUDE 'AWEFUL.COM'
C......REMOVE A LOOK, IF ONE HAS BEEN SET PREVIOUSLY FOR THIS PERSON
      LOC=PEOPLE(ID)
      LOGA=LOOKGN(1,LOC)
      LOGB=LOOKGN(2,LOC)
      IF(LOGA.GT.0) THEN
C......DECREMENT GONDOLA COUNT FOR ALL SECTIONS. DO NOT ALLOW THEM
C......TO CROSS ZERO. DIFFERENT ACTION DEPENDING ON WHETHER IT IS
C......ZERO (NOBODY LEFT IN LITTLE LINK) OR NOT.
        DO 103 J=LOGA,LOGB
          GONCNT(J)=MAX0(GONCNT(J)-1,0)
          IF(GONCNT(J).EQ.0) THEN
C......RETURN TO EMPTY GONDOLA STATE
            DO 102 I=1,3
              LUT(I,J)=PHYGON(I)
  102       CONTINUE
          ELSE
C......MODIFY PHYSICAL PERSON LOCATION COLOUR TO ALLOW FOR THE NUMBER
C......OF PEOPLE ON THAT LITTLE LINK. REMEMBER THE NEW COLOUR IN THE
C......LUT STORAGE.
            CALL INCPOL(GONCNT(J),J,PHYSEE,PHYGON,50.0)
          ENDIF
  103   CONTINUE
      ENDIF
      LOOKGN(1,LOC)=0
      RETURN
      END

      SUBROUTINE OFLINK(ID,FLX,FLY)
      INTEGER ID,FLX,FLY
      INTEGER ADD,LOG
      INCLUDE 'AWEFUL.COM'
C......MODIFY THE DISPLAY INTENSITY FOR THE FLOOR COUNT AT FLX,FLY.
C
C......GET LITTLE LINK NUMBER FROM FLOOR GRID INDEX ALLOWING FOR THE
C......FLOOR POLYGON OFFSET (IF ANY), AND CONVERT IT TO THE LOGICAL
C......COLOUR ASSOCIATED WITH THAT LITTLE LINK
      LOG=FLOOR(FLY,FLX)+FLUPOL
      LOG=POLNUM(LOG)
C......DECREMENT FLOOR COUNT FOR THAT LITTLE LINK. DO NOT ALLOW IT TO
C......CROSS THE ZERO. DIFFERENT ACTION DEPENDING ON WHETHER IT IS
C......ZERO (NOBODY LEFT IN LITTLE LINK) OR NOT.
      FLRCNT(LOG)=MAX0(FLRCNT(LOG)-1,0)
      IF(FLRCNT(LOG).EQ.0) THEN
C......RETURN TO EMPTY FLOOR STATE
        DO 101 I=1,3
          LUT(I,LOG)=PHYFLR(I)
  101   CONTINUE
      ELSE
C......MODIFY PHYSICAL PERSON LOCATION COLOUR TO ALLOW FOR THE NUMBER
C......OF PEOPLE ON THAT LITTLE LINK. REMEMBER THE NEW COLOUR IN THE
C......LUT STORAGE.
        CALL INCPOL(FLRCNT(LOG),LOG,PHYCUS,PHYFLR,50.0)
      ENDIF
      RETURN
      END

      SUBROUTINE ONGOND(ID,GOND,SUB)
      INTEGER ID,GOND,SUB
      INTEGER BASE,LOG,LOGA,LOGB,PUB,OLDG,OLDS
      INCLUDE 'AWEFUL.COM'
C......SWITCH ON A GONDOLA TO INDICATE A LOOK AST IT.
      BASE=POLNUM(GOND+GONPOL)
      IF(SUB.EQ.0) THEN
        LOGA=BASE
        LOGB=LOGA+POLCHK(BASE)-1
      ELSE
        PUB=SUB
  100   IF(PUB.GT.POLCHK(BASE)) THEN
```

```
C......SUBDIVISION ASKED FOR GREATER IN NUMBER THAN THAT AVAILABLE.
C......THIS CURE WORKS ONLY FOR COMPRESSIONS TO 1 SUBDIVISION, OR
C......FOR COMPRESSIONS INTO HALF THE NUMBER OF SUBDIVISIONS.
                  PUB=(PUB-1)/2+1
                  GOTO 100
                ENDIF
                LOGA=BASE+PUB-1
                LOGB=LOGA
              ENDIF
C......UPDATE THE POLYGON COLOURINGS,KEEPING TRACK OF TOTAL LOOKS
C......AND PRESENT LOOKS.
              DO 101 L=LOGA,LOGB
                GONTOT(L)=GONTOT(L)+1
                GONCNT(L)=GONCNT(L)+1
                CALL INCPOL(GONCNT(L),L,PHYSEE,PHYGON,50.0)
  101         CONTINUE
C......REMEMBER THE LOOK RANGE FOR THIS CUSTOMER
              LOC=PEOPLE(ID)
              LOOKGN(1,LOC)=LOGA
              LOOKGN(2,LOC)=LOGB
              RETURN
              END

              SUBROUTINE ONLINK(ID,FLX,FLY)
              INTEGER ID,FLX,FLY
              INTEGER ADD,LOG
              INCLUDE 'AWEFUL.COM'
C......MODIFY THE DISPLAY INTENSITY TO THE FLOOR COUNT AT FLX,FLY.
C
C......GET LITTLE LINK NUMBER FROM FLOOR GRID INDEX ALLOWING FOR THE
C......FLOOR POLYGON OFFSET (IF ANY), AND CONVERT IT TO THE LOGICAL
C......COLOUR ASSOCIATED WITH THAT LITTLE LINK
              LOG=FLOOR(FLY,FLX)+FLUPOL
              LOG=POLNUM(LOG)
C......INCREMENT FLOOR COUNT FOR THAT LITTLE LINK
              FLRCNT(LOG)=FLRCNT(LOG)+1
              FLRTOT(LOG)=FLRTOT(LOG)+1
C......MODIFY THE POLYGON DISPLAYED ON THE SCREEN FOR THE CHANGE IN
C......PEOPLE IN THE LITTLE LINK.
              CALL INCPOL(FLRCNT(LOG),LOG,PHYCUS,PHYFLR,50.0)
              RETURN
              END

              SUBROUTINE OPENIT(STRING,FILE,LUN)
              CHARACTER*(*) STRING,FILE
              CHARACTER*50 NAME
              CHARACTER*16 ERROR
         LOGICAL*4 HERE
C......TRY AND OPEN THE FILE SPECIFIED IN 'FILE'. IF THIS FAILS THEN
C......ASK USER FOR A FILE NAME, USING 'STRING' AS PART OF THE PROMPT.
C......IF THE FIRST CHARACTER OF 'FILE' IS BLANK THEN READ ONE IN
C......ANYWAY.
              NAME=' '
              CALL LENGCH(FILE,L)
              IF(L.NE.0) THEN
                NAME(1:L)=FILE(1:L)
              ELSE
                NAME(1:1)=' '
              ENDIF
  101         IF(NAME(1:1).EQ.' ') THEN
C......SET UP A WINDOW TO LIST FILE WITHIN, SAVE PRESENT CONTENTS.
                CALL TextWindow(1,1,80,25)
                CALL PushWindow
                MARK=1
C......GIVE A DIRECTORY LISTING OF THE APPROPRIATE TYPE OF FILE
                M=L-3
                CALL ERASE
                NAME='DIR *'//FILE(M:L)//' | MORE'
                CALL CMND(NAME)
C......GET FILE TO USE FROM USER
                CALL LENGCH(STRING,M)
                WRITE(8,201)STRING(1:M)
  201           FORMAT(' FILE NAME FOR ',A,': ',\)
                READ(8,200)NAME
  200           FORMAT(A)
              ELSE
```

```
C......INDICATE NO WINDOW HAS BEEN OPENED
              MARK=0
            ENDIF
C......CHECK STATUS OF FILE NAME FOR BEING ALREADY CREATED
        INQUIRE(FILE=NAME,EXIST=HERE)
        IF(HERE) THEN
              ERROR='FILE OPENING'
              OPEN(LUN,FILE=NAME,ERR=100)
            ELSE
              ERROR='FILE EXISTENCE'
              GOTO 100
            ENDIF
C......RETURN PREVIOUS WINDOW CONTENTS IF A NEW WINDOW HAS BEEN OPENED,
C......AND ENSURE WE ARE WORKING IN AN APPROPRIATE WINDOW FROM HERE ON.
            IF(MARK.EQ.1)CALL DIAMEN(1)
            RETURN
C......READ ERROR, TRY AGAIN
  100       WRITE(8,202)ERROR
  202       FORMAT(/,'  ERROR IN ',A)
            CALL WAITIT
            NAME(1:1)=' '
            GOTO 101
            END

            SUBROUTINE OTITLE(IX,IY,TITLE,KOL)
            CHARACTER*(*) TITLE
            INCLUDE 'AWEFUL.COM'
C......OUTPUT A TITLE LINE AT HEIGHT IY, CENTERED IN TERMS OF X, IN
C......COLOUR KOL.
C......BUT NOT YET!!!
            CALL LENGCH(TITLE,L)
            CALL SFCOL(KOL)
            CALL OUTCHR(IX,IY,TITLE,1,L)
            RETURN
            END

            SUBROUTINE OUTCHR(IX,IY,NAME,I,L)
            CHARACTER*(*) NAME
C......OUTPUT A CHARACTER STRING AT THE GIVEN X,Y POSITION
C
C......ENSURE A TRANSPARENT BACKGROUND IS USED FOR SYMBOL COPYING.
            CALL SSTYLE(136)
            CALL MOVETO(IX,IY)
            DO 101 J=I,L
              NUM=ICHAR(NAME(J:J))
              CALL PCHAR(NUM)
  101       CONTINUE
C......RETURN STYLE TO DEFAULT
            CALL SSTYLE(128)
            RETURN
            END

            SUBROUTINE PERCEN(DATA,PERC,IBEG,ISTO,PROP)
            INTEGER DATA(256),PERC(256),IBEG,ISTO,PROP
            REAL TOT
C......EITHER CALCULATE PERCENTAGES FROM THE DATA HELDS IN DATAB IF PROP
C......IS 1, OR SIMPLY COPY THE DATA FROM DATA INTO PERC TO MAINTAIN THE
C......ABSOLUTE VALUES IF PROP IS -1.
            IF(PROP.EQ.1) THEN
              TOT=0.
              DO 101 I=IBEG,ISTO
                TOT=TOT+DATA(I)
  101         CONTINUE
              DO 102 I=IBEG,ISTO
                PERC(I)=FLOAT(DATA(I))/TOT*100.+0.5
  102         CONTINUE
            ELSE
              DO 100 I=IBEG,ISTO
                PERC(I)=DATA(I)
  100         CONTINUE
            ENDIF
            RETURN
            END

            SUBROUTINE PERCOL
            INTEGER COLS(3),HI,LO
```

```
              INCLUDE 'AWEFUL.COM'
C......SET UP THE PERMANENT COLOURS. IF BLKWHT IS 1 THIS IS TO BE A B/W
C......LUT, IF -1 THEN IT IS TO BE A COLOUR ONE.
C
C......SET THE BOTTOM OFFCOL PERMANENT COLOURS (NOT USED IN PALETTE
C......CHANGING) TO THE DESIRED COLOURS.
              IF(BLKWHT.EQ.1) THEN
                HI=255
                LO=255
              ELSE
                HI=220
                LO=0
              ENDIF
              COLS(1)=HI
              COLS(2)=HI
              COLS(3)=LO
              L=0
              M=OFFCOL-1
              DO 100 I=1,M
                L=L+1
                DO 103 J=1,3
                  K=MOD(L,3)+1
                  LUT(J,I)=COLS(K)
                  L=L+1
  103           CONTINUE
  100         CONTINUE
C......THIS COLOUR (OFFCOL) IS ALWAYS GOING TO BE FULL WHITE - FOR
C......TITLING AND OTHER PURPOSES.
              LUT(1,OFFCOL)=255
              LUT(2,OFFCOL)=255
              LUT(3,OFFCOL)=255
              RETURN
              END

              SUBROUTINE POLGEN(IBEG,ISTO,PHYS,LINE,LIM)
              INTEGER LINE,PHYS(3),LIM
              INCLUDE 'AWEFUL.COM'
C......PLOT THE POLYGONS IBEG TO ISTO ON THE SCREEN, FILLING WITH
C......THE CHOSEN BASE PHYSICAL COLOUR AS WE GO. IF IBEG IS BEYOND
C......THE LAST FLOOR/GONDOLA POLYGON (POLMAX) THEN WE ARE DEALING
C......WITH LINEWORK AND MUST NOT FILL THE POLYGON! LINE INDICATES
C......WHETHER AN OUTLINE IS TO BE DRAWN AROUND THE POLYGONS OR IF
C......THEY EXIST, SUBPOLYGON PIECES. IF IT IS NON-ZERO THEN IT IS
C......THE LOGICAL COLOUR TO USE. IT IS SENSIBLE TO USE ONE OF THE
C......SET 1-OFFCOL WHICH ARE GUARANTEED TO BE PERMANENTLY VISIBLE
C......ONCE ANIMATION STARTS. LIM MARKS THE MAXIMUM FOR BAR DISPLAY.
C......IF LIM IS ZERO NO BAR CALLS ARE TO BE MADE FOR THIS CALL OF
C......POLGEN (USED FOR LINEWORK).
C
C......PICK UP EACH POLYGON IN TURN
              DO 100 LOG=IBEG,ISTO
                IB=SCNPOL(LOG-1)+1
                IS=SCNPOL(LOG)
                IF(LOG.LE.POLMAX+OFFCOL) THEN
C......THIS IS A FLOOR/GONDOLA POLYGON, SO SET THE COLOUR, DRAW THE
C......BOUNDARY, AND THEN FILL THE POLYGON.
                  CALL SCCOL(LOG)
                  CALL MOVETO(SCNCDS(1,IS),SCNCDS(2,IS))
                  DO 101 I=IB,IS
                    CALL LINETO(SCNCDS(1,I),SCNCDS(2,I))
                    ROWBEG=MIN0(ROWBEG,SCNCDS(2,I))
                    ROWEND=MAX0(ROWEND,SCNCDS(2,I))
                    COLBEG=MIN0(COLBEG,SCNCDS(1,I))
                    COLEND=MAX0(COLEND,SCNCDS(1,I))
  101             CONTINUE
                  CALL SPCOL(LOG)
                  CALL MOVETO(POLCEN(1,LOG),POLCEN(2,LOG))
                  CALL BFILL
C......ENSURE LUT KNOWS ABOUT THE PHYSICAL COLOUR TO USE FOR THIS
C......LOGICAL COLOUR
                  DO 103 K=1,3
                    LUT(K,LOG)=PHYS(K)
  103             CONTINUE
                ENDIF
C......FOR BOTH LINEWORK AND FOR FLOOR/GONDOLA POLYGONS WE CAN NOW PUT
C......A LINE AROUND THE SUBDIVISION IN THE DESIRED PERMANENT COLOUR
```

```
            IF(LINE.NE.0) THEN
              CALL SCCOL(LINE)
              CALL MOVETO(SCNCDS(1,IS),SCNCDS(2,IS))
              DO 102 I=IB,IS
                CALL LINETO(SCNCDS(1,I),SCNCDS(2,I))
 102          CONTINUE
            ENDIF
C......UPDATE THE COMPLETION BAR IF IT IS SWITCHED ON
            IF(LIM.GT.0)CALL BAR(' ',LIM,LOG)
 100      CONTINUE
          RETURN
          END

          SUBROUTINE PRINOF
C......WAIT UNTIL USER IS READY AND PROMT HIM TO SWITCH OFF PRINTER
          WRITE(8,200)
 200      FORMAT(' SWITCH THE PRINTER OFF (^P)?')
          CALL WAITIT
C......RETURN TO NORMAL INTERACTIVE WINDOW
          CALL DIAMEN(1)
          RETURN
          END

          SUBROUTINE PRINON
C......CLEAR THE SCREEN AND WAIT UNTIL USER IS READY
C
C......SET UP WINDOW TO USE
          CALL TextWindow(1,1,80,25)
          CALL PushWindow
          CALL ERASE
          WRITE(8,200)
 200      FORMAT(' SWITCH THE PRINTER ON (^P)?')
          CALL WAITIT
          RETURN
          END

          SUBROUTINE RECTAL(IX,IY,NUM,IHT,LOG,KOLA,KOLB,POL,CNT)
          INTEGER POL,CNT
          CHARACTER*10 WORD
C......DRAW A RECTANGLE, TLC IS IX,IY, WIDTH IS NUM, HEIGHT IS IHT,
C......THE LOGICAL COLOUR TO USE FOR FILLING IS LOG, AND THE OUTLINE
C......COLOUR IS KOLA. WRITE THE POLYGON NUMBER (POL) IN KOLA AND THE
C......COUNT (CNT) IN COLOUR KOLB.
          CALL FIRECT(IX,IY,NUM,IHT,KOLA,LOG)
          CALL SFCOL(KOLA)
          WRITE(WORD,200)POL
 200      FORMAT(' ',I3)
          CALL WRITEP(IX+NUM/4,IY+IHT/4,WORD)
          CALL SFCOL(KOLB)
          WRITE(WORD,200)CNT
          CALL WRITEP(IX+NUM/4,IY+IHT+IHT/4,WORD)
          RETURN
          END

          SUBROUTINE SAVLIN(LOG,JX,JY,NUMV,IXCEN,IYCEN)
          INTEGER JX(100),JY(100)
          INTEGER*4 IXC,IYC
          INCLUDE 'AWEFUL.COM'
C......SAVE THE POLYGON HELD IN JX AND JY INTO THE LINE STORE FOR LATER
C......USE. AT THE SAME TIME CALCULATE AND STORE THE CENTER OF GRAVITY
C......(IXCEN,IYCEN) OF THE POLYGON FOR USE OUTSIDE. THE LOGICAL COLOUR
C......(LOG) IS USED AS A TAG FOR THE POLYGON NUMBER, AND IS CONSISTENT
C......WITH USAGE IN GONTOT AND FLRTOT. NUMV IS THE NUMBER OF POLYGON
C......VERTICES.
          IBEG=SCNPOL(LOG-1)+1
          ISTO=IBEG+NUMV-1
          IF(ISTO.GT.CDSMAX) THEN
            WRITE(8,200)
 200        FORMAT(' ERROR IN DIMENSIONS IN SAVLIN')
            CALL WAITIT
            CALL InitScreen
            STOP
          ENDIF
          SCNPOL(LOG)=ISTO
          IXC=0
          IYC=0
```

```
      DO 100 I=IBEG,ISTO
        J=I-IBEG+1
        IXC=IXC+JX(J)
        IYC=IYC+JY(J)
        SCNCDS(1,I)=JX(J)
        SCNCDS(2,I)=JY(J)
100   CONTINUE
      IXCEN=FLOAT(IXC)/FLOAT(NUMV)+0.5
      IYCEN=FLOAT(IYC)/FLOAT(NUMV)+0.5
      POLCEN(1,LOG)=IXCEN
      POLCEN(2,LOG)=IYCEN
      RETURN
      END

      SUBROUTINE SETDIM(ARRAY,SIZE,VALUE)
      INTEGER ARRAY,SIZE,VALUE
      DIMENSION ARRAY(SIZE)
      DO 100 I=1,SIZE
        ARRAY(I)=VALUE
100   CONTINUE
      RETURN
      END

      SUBROUTINE SETCLR
      INTEGER HI,LO
      INCLUDE 'AWEFUL.COM'
C......SET COLOURS FOR ALL OBJECTS. IF BLKWHT IS -1 WE ARE IN COLOUR,
C......AND IF BLKWHT IS 1 WE ARE IN BLACK AND WHITE
      IF(BLKWHT.EQ.1) THEN
        HI=0
        LO=0
      ELSE
        HI=75
        LO=40
      ENDIF
C......SET PHYSICAL FLOOR COLOUR
      PHYFLR(1)=0
      PHYFLR(2)=0
      PHYFLR(3)=HI
C......SET PHYSICAL GONDOLA COLOUR
      PHYGON(1)=HI
      PHYGON(2)=0
      PHYGON(3)=HI
C......SET BASE PHYSICAL COLOUR FOR PEOPLE STANDING ON THE FLOOR
      PHYCUS(1)=LO
      PHYCUS(2)=LO
      PHYCUS(3)=LO
C......SET BASE PHYSICAL COLOUR FOR GONDOLA OBSERVATION COUNTS
      PHYSEE(1)=LO
      PHYSEE(2)=LO
      PHYSEE(3)=0
      RETURN
      END

      SUBROUTINE SETUP
      INTEGER COLS(3)
      INCLUDE 'AWEFUL.COM'
C......INITIALISE THE PROSPERO F77PC SCREEN SYSTEM READY FOR USE
      CALL InitScreen
      CALL ScreenUnit(8)
C......FIRE UP THE PLUTO GRAPHICS SCREEN, CLEAR THE WORKING PARTITION,
C......SET THE BACKGROUND COLOUR TO ZERO, AND THE TRANSPARENT COLOUR
C......TO ZERO AS WELL. THEN SET STYLE TO THE DEFAULT
      CALL PINIT
      CALL CLRCWP
      CALL SBCOL(0)
      CALL STCOL(0)
      CALL SSTYLE(128)
C......SET UP MAXIMUM LIMITS FOR ARRAYS AND THINGS, AS FOLLOWS:
C     CUSTOM - MAXIMUM NUMBER OF CUSTOMERS AT ONCE
C     CROWD  - MAXIMUM PERSON CODE POSSIBLE
C     FLOORX - MAXIMUM FLOOR GRID COORDINATE IN X
C     FLOORY - MAXIMUM FLOOR GRID COORDINATE IN Y
C     LIMPOL - MAXIMUM POLYGON NUMBER - FLOOR OR GONDOLA
C     LOGMAX - MAXIMUM LOGICAL COLOUR NUMBER TO BE USED FOR
C              PALETTE CHANGES IN THE SIMULATION
```

```
C           OFFCOL - STARTING LOGICAL COLOUR TO BE USED FOR PALETTE
C                    CHANGES DURING THE SIMULATION
C           CITEMS - MAXIMUM SIZE OF CUSTOMER DATA BASE ENTRY
C           CAMERA - MAXIMUM NUMBER OF CAMERAS IN ACTION
C           CDSMAX - MAXIMUM NUMBER OF POINTS THAT CAN BE HELD IN
C                    THE COORDINATE LINE STORE.
C           LINMAX - MAXIMUM LINEWORK NUMBER
C           BLKWHT - 1 INDICATES BLACK AND WHITE, -1 GIVES COLOUR OUTPUT.
C           INVERT - 1 GIVES INVERSION OF B/W ONLY, -1 GIVES NO INVERSION.
            CUSTOM=200
            CROWD=5000
            FLOORX=50
            FLOORY=20
            LIMPOL=500
            OFFCOL=3
            LOGMAX=256
            CITEMS=15
            CAMERA=10
            CDSMAX=5000
            LINMAX=400
            BLKWHT=-1
            INVERT=-1
C......SET SCREEN SIZE PARAMETERS
            SCRENX=1023
            SCRENY=767
            XOFSET=5
            YOFSET=5
            CALL SETCLR
            CALL PERCOL
C......SET POLYGONS TO UNUSED
            CALL SETDIM(POLNUM,LOGMAX,0)
C......SET GONDOLA CONTRACTIONS ARRAY TO ZERO
            CALL SETDIM(POLCHK,LOGMAX,0)
C......SET THE FLOOR TABLE
            CALL SETDIM(FLOOR,FLOORX*FLOORY,0)
C......SET THE SCREEN COORDINATE MARKER ARRAY TO ZERO
            CALL SETDIM(SCNPOL,LOGMAX,0)
C......SET THE NUMBER OF POLYGON COLOURS USED SO FAR TO THE PALETTE
C......CHANGING BASE COLOUR LESS 1.
            TOTPOL=OFFCOL
C......ENSURE USED SCREEN LIMITS ARE RESET
            CALL USEDSC
C......ENSURE THE LUT IS ALL BLACK
            CALL NULLUT
            RETURN
            END

            SUBROUTINE TIMEIT(LASTIM)
            INTEGER*4 LASTIM,IHOURS,MINS,ISECS,IHUNDS
            CALL TIME(IHOURS,MINS,ISECS,IHUNDS)
            LASTIM=IHUNDS+ISECS*100+MINS*6000+IHOURS*360000
            END

            SUBROUTINE UPGOND(ID,GOND,SUB)
            INTEGER ID,GOND,SUB
            INTEGER OLDG,OLDS
            INCLUDE 'AWEFUL.COM'
C......IF THE VALUE IN GOND IS NON-ZERO IT INDICATES THAT A GONDOLA
C......IS BEING LOOKED AT, AND SUB IS THE SUBDIVISION OF THE GONDOLA
C......THAT IS SPECIFICALLY BEING WATCHED.
C
C......SWITCH OFF THE LAST GONDOLA BEING LOOKED AT, UNLESS IT IS THE
C......ONE NOW BEING LOOKED AT, BUT BY ANOTHER PERSON.
            LOC=PEOPLE(ID)
            OLDG=LOOKGN(1,LOC)
            OLDS=LOOKGN(2,LOC)
            IF(GOND.NE.0) THEN
              IF(OLDG.NE.GOND)CALL OFGOND(ID,OLDG,OLDS)
              CALL ONGOND(ID,GOND,SUB)
            ELSE
              CALL OFGOND(ID,GOND,SUB)
            ENDIF
            RETURN
            END

            SUBROUTINE UPLINK(ID,KAMERA,FLX,FLY)
```

```
              INTEGER ID,KAMERA,FLX,FLY
              INCLUDE 'AWEFUL.COM'
C......UPDATE THE POSITION OF A PERSON IF THEY HAVE MOVED SINCE THEY
C......WERE LAST SEEN. THEY ARE ASSUMED TO BE ALIVE AT THE PRESENT.
C
C......GET LOCATION IN ALIVE LIST, SET CAMERA POSITION TO SEEN, AND
C......REMEMBER CAMERA POSITION
              LOC=PEOPLE(ID)
              ALIVE(KAMERA,LOC)=1
              ALIVE(CAMERA+2,LOC)=KAMERA
C......CHECK FOR SAME LOCATION AS BEFORE
              IF(FLX.NE.ALIVE(CAMERA+3,LOC).OR.
     1           FLY.NE.ALIVE(CAMERA+4,LOC)) THEN
C......DIFFERENT LOCATION, SO MOVE THE PERSON FROM OLD TO NEW
                CALL OFLINK(ID,ALIVE(CAMERA+3,LOC),ALIVE(CAMERA+4,LOC))
                CALL ONLINK(ID,FLX,FLY)
                ALIVE(CAMERA+3,LOC)=FLX
                ALIVE(CAMERA+4,LOC)=FLY
              ENDIF
              RETURN
              END

              SUBROUTINE USEDSC
              INCLUDE 'AWEFUL.COM'
C......SET SCREEN AREA USED TO OUTSIDE THE AREA, AS A MARKER THAT WE
C......NEED TO UPDATE THE ACTUAL USED LIMITS
              ROWBEG=30000
              COLBEG=ROWBEG
              ROWEND=-1
              COLEND=ROWEND
              RETURN
              END

              SUBROUTINE WAITIT
              CHARACTER*1 KAR
C......HANG ON UNTIL THE USER HAS READ A MESSAGE OF SOME SORT.
              WRITE(8,201)
  201         FORMAT('  PRESS <CR> WHEN READY: ',\)
              CALL BELL
              READ(8,200)KAR
  200         FORMAT(A)
              RETURN
              END

              SUBROUTINE WRITEP(IX,IY,NAME)
              CHARACTER*(*) NAME
              INTEGER*2 NUM
C......LEFT JUSTIFY THE CONTENTS OF NAME, AND SEND IT TO PLUTO AS AN
C......INTEGER STRING BEGINNING (TLC) AT IX,IY.
              CALL LENGCH(NAME,L)
              IF(L.NE.0) THEN
                I=1
  100           IF(NAME(I:I).EQ.' ') THEN
                  I=I+1
                  GOTO 100
                ELSE
                  CALL OUTCHR(IX,IY,NAME,I,L)
                ENDIF
              ENDIF
              RETURN
              END
```