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COMBINING THEORETICAL AND EMPIRICAL RESEARCH IN RETAIL LOCATION ANALYSIS

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1. Introduction

The retail model has played two roles in regional science: as a rich test bed for innovation and the exploration of new theoretical concepts; and as a substantive applied field, of potential interest both to planners with development control and welfare functions and to retailers for performance evaluation or site appraisal. It is generally agreed, however, that theoretical development has run ahead of empirical testing and effective application. The purpose of this paper is to attempt to begin to redress the balance and to present the results of some empirically-based research.

In the next section (2), we summarise the progress which has been made with the theory - referring to G P Clarke and Wilson, 1986a for the detail. In section 3, we discuss the two main modes of application: geographical analysis and planning. We then take each of these modes in turn and in sections 4 and 5 match theory against empirical testing using data collected in Leeds. Concluding comments and a discussion of issues for future research are presented in section 6.

2. Theory and the retail model: a review of progress

In this section, we note the basic steps in theoretical development. For detail and references, the reader is referred to two more recent reviews (Wilson, 1986; G.P. Clarke and Wilson, 1986a).

(i) The basic flow model has now been available and in use for more than 20 years. The model can be presented as follows:

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$$S_{ij} = A_i e_i P_i W_j^{\alpha} e^{-\beta c_{ij}} \tag{1}$$

where

$$A_i = 1/\sum_k W_k e^{-\beta c_{ik}} \tag{2}$$

to ensure that

$$\sum_j S_{ij} = e_i P_i \tag{3}$$

S_{ij} is the flow of expenditure from residential zone i to shops (shopping centres or a store of a particular kind) in j; e_i is the per capita expenditure of residents of i; P_i, the population of i; W_j, a measure of the 'attractiveness' of j, usually measured via floorspace as a proxy; c_{ij}, a measure of travel distance or cost between i and j. α and β are parameters.

Principles for disaggregating the model have been established (including the incorporation of composite terms in attractiveness factors). Variants on the most common spatial interaction hypotheses are available - but each of the main components is well understood in principle and is a submodel in its own right: demand, attractiveness, generalised travel cost. There is a lot of empirical experience with the models, much of it unreported.

(ii) A significant advance was the possibility of modelling the evolution of physical structures, either in comparative static terms or with a full dynamic model.

Suppose, to fix ideas, that we work with the simpler model given by (1)-(3) and that retailers' costs, C_j, can be taken as a function of a lead variable such as floorspace, W_j:

$$C_j = C_j(W_j) \tag{4}$$

or more specifically for a simple illustration,

$$C_j = k_j W_j \tag{5}$$

The character of the argument is in no way dependent on the simplicity of this assumption.

A typical product of the flow model is revenue, D_j:

$$D_j = \sum_i S_{ij} \tag{6}$$

Thus, profit, Π_j at j is

$$\Pi_j = D_j - C_j \tag{7}$$

$$= D_j - k_j W_j \tag{8}$$

However, if 'normal' profits are included in retailers' costs, then the market will ensure that the Π_js are competed to zero and so the following equilibrium condition must hold:

$$D_j = k_j W_j \tag{9}$$

In full, substituting for D_j from (6) and S_{ij} from (1) and (2), this can be written

$$\sum_i \frac{e_i P_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_k W_k^{\alpha} e^{-\beta c_{ik}}} = k_j W_j \tag{10}$$

which are a set of nonlinear simultaneous equations in the W_js.

These equations can be solved numerically and also interpreted analytically. It turns out that there is the possibility or rapid structural change from one kind of equilibrium solution to another at critical parameter values. Empirical testing has been problematic because of the difficulties of assembling appropriate time-series data. This provides the focus of our contribution in section 4 below.

3. Modes of application

3.1 Geographical analysis

In the retailing and service area, the geographer's task can be seen as the explanation and interpretation of patterns of service supply in relation to demand and of corresponding evolutionary paths of change. It is clear that the models and concepts presented in section 2 should contribute substantially to this, but equally clear that the difficulty is one of assembling time-series data, especially on structures and particularly disaggregated. Commentators have noted both the promise and the difficulties in the past, but emphasised that judgements on the theory must in part await empirical confirmation. The task is made even more difficult by the nature of the theoretical insights themselves: multiple equilibria and disequilibrium dynamics do not make for easy interpretation of even good data. Nonetheless, we report the progress made in section 4 below.

3.2 Applications in forecasting and planning

It seems that retailers have been reluctant to use even the flow model for making revenue predictions as part of site evaluations. There is evidence that this situation is now changing, both because increasing competition makes more accurate forecasting important and because of retail flow expenditure data becoming commercially available with, for example, the LUPIN data (Beaumont, 1986). There is also the possibility that geographers have been slow to offer retail analysts a wider range of performance indicators which can be derived from model outputs and so here, we learn some lessons from the health field (c.f. M. Clarke and Wilson, 1984, 1985) and discuss how to improve the present situation. Some results using these ideas are presented for Leeds in section 5.

Before proceeding in this way, it is worth noting that there are two kinds of 'planning' application: those already mentioned which involve retailers in site evaluation; but planning authorities in local government are also interested in more effective processing of applications for planning permission and, more broadly, in appraising the welfare implications of existing or proposed structures of service provision.

This subdivision is reflected in the overall approach to performance indicators and the ways in which we can learn from the health field. There are two basic kinds of indicator: those which relate directly to service facilities and hence to efficiency or site evaluation; and those which relate to populations by zones of residence and hence on the effectiveness of provision for those populations. We present the argument by using the aggregate case as an example, though noting that disaggregation presents no conceptual problems.

First, we calculate the <u>catchment populations</u> of j-zones (whether centres or stores). This is

$$Q_j = \sum_i \frac{S_{ij}}{S_{i*}} P_i \tag{11}$$

It is a partition of residential populations into groups served by particular js, which can then be summed to give the catchment population of a j. But, conversely, we can define

$$Z_i = \sum_j \frac{S_{ij}}{S_{*j}} W_j \tag{12}$$

as the <u>effective supply of floorspace</u> to residents of i. The kinds of indicators which can be calculated can then be exemplified as follows:

<u>Efficiency</u>

* market potential of the site
* supply costs per head of catchment population
* profit per square foot
* profit per head of catchment population
* revenue per square foot
* revenue per head of catchment population
* price index
* rent index

<u>Effectiveness</u>

* accessibility
* transport expenditure
* consumers' surplus
* effective floorspace per head of residential population

These indicators can be calculated for each model run, to test existing structures or in 'what if' planning. It is easy to see how they can be used for impact analysis, deflection rates or residents' welfare. These calculations involve only the flow model. It is possible to use the structural or dynamical analyses to test the stability of configurations. This is obviously important for planners. It can be used by retailers to investigate how large their own stores should be to resist various levels (and locations) of competition. It could also be used by either planners or retailers as the basis of computing optimum configurations.

4. Tests of the structural model

4.1 Introduction

Much of the progress made in the theoretical work briefly described in section 2 has been made with the equilibrium version of the basic flow model presented in equations (1)-(3), and this forms the basis of the empirical experiments to be explored in this section. The two main objectives are to test the ability of the equilibrium model to reproduce the size and structure of the major retail centres in Leeds (which can largely be accomplished with contemporary data) and to analyse certain types of structural change over time, such as the introduction of new forms of grocery retailing.

4.2 Data

The study area chosen for the empirical work includes the whole of the Leeds C.B. and the additional Census wards of Pudsey, North and Horsforth to the west. The area has been divided into grid-squares (see figure 1) which means there are 729 (27x27) potential demand zones. Population totals for each zone have been worked out from the small area statistics of the Census of Population. For the most densely populated areas of the city a large number of enumeration districts (Eds) make up one grid zone. The population total is then simply calculated by summation.

Conversely, at the suburban fringe, one Ed may cover anything up to five grid zones or more. In this latter case the population allocated to each grid zone is carefully worked out from 'built-up' areas on the Census map. There are a large number of zones which are 'external' to the Leeds C.B. area, especially to the south-west and south-east, and these are given a very small demand to account for possible long-distance shoppers.

We can calculate zonal expenditure levels from the Family Expenditure Survey based on the expenditure levels given for the variety of socio-economic groups identified in the Census of Population. Clearly this gives a rich data set for the demand side, effectively an array of information on the location and spending power of a numer of different person types, n, for different types of good, g.

Aspects of retail change in Leeds since 1960 have been the concern of a much wider study (G.P. Clarke, 1986a), and data has been built up on some 30 or so shopping centres in Leeds, from a variety of different sources: data held by Leeds City Planning Department, GOAD shopping centre plans, classified trade, telephone and street directories and the author's own survey. Thus for general retailing in the city we have a 729x33 zonal matrix (for 1981) which can be extended where necessary to accommodate different types of good (i.e. for the work on performance indicators in section 5 we shall use a 729x39 system for grocery retailing). In order to make quick progress with the empirical work we are forced (for the time being) to use a very elementary Euclidean distance matrix for our measure of spatial impedance. Clearly one important task for future research is to work towards the kind of detailed cost functions specified in G.P. Clarke and Wilson (1986 a), Wilson (1983). To make this Euclidean distance matrix more realistic for urban travelling, distances to the city centre can be factored to reflect the fact that most major routes converge on the city and hence travel times to that city centre are generally quicker. Hence we take

$$C(j,365) = V \times \text{Euclidean distance} \tag{13}$$

where V takes a series of values less than one so that the city centre (zone 365) is favoured to varying degrees (M. Clarke and Wilson, 1983).

4.3 Parameter exploration

From the equilibrium model presented in section 2 and the additional parameter in equation (13) above, we can see that there are four main parameters of the model even in its standard, aggregate form. Each of these (as seen in the range of numerical experiments presented in M. Clarke and Wilson 1982, 1983; M. Clarke, 1985), along with variables such as $e_i P_i$ are all capable of producing structural change (which will be explored laterin section 4.4). For now we can simply note the nature of such parameter changes. The effects of β-variation are shown in figure 2a and α-variation in figure 2b. It can be seen that the higher the value of α the more concentrated facilities become (α traditionally representing scale economies) whilst the higher the value of β the more dispersed facilities become (β representing the ease or willingness of consumers to travel). The parameter k was described in section 2 as the unit cost of providing retail floorspace. When k is defined as a constant the solutions change very little, in a relative sense, as k itself is varied (though see G P Clarke, 1986b for analysis of k changes with 729 possible facility locations).

We can build in the effects of spatial variation of costs by replacing k with k_j and adding a suitable submodel of k_j. In figure 3, k_j is taken to be inversely proportional to the distance of the zone from the centre, reflecting the generalisation that facilities are cheaper to supply away from the city centre: note in this case how facilities at the suburban edge become more dominant. (We shall explore k_j values in more detail in section 4.4).

The parameter V was incorporated in equation (13) to reflect cheaper travel to the city centre, and it was noted that it should take a series of values of less than one. In figures 4a and 4b the effect of reducing V can be seen whilst figure 5a shows the actual spread of major retail facilities in Leeds in 1982. It can be seen that a value of 0.75 produces the right sort of scaling between the city centre and the largest suburban centres. (The city centre dominates for a variety of reasons but we shall use this value of V until we look in more detail at defining the attractiveness of centres in a more realistic fashion in section 4.4.) For this purpose, we took $\alpha=1$, $\beta=2$, $k_j=1$ for all j, but we refine these values later.

The fact that there are already four key parameters in the model makes any traditional calibration procedure very difficult indeed. As M. Clarke (1986) explains, this leads us to look more in the direction of sensitivity analysis rather than formal calibration where the emphasis then is much more on parameter exploration, the model-builder's experience with the parameter space of the models and analysis of the qualitative nature of the solutions as much as the quantitative. However we can still calibrate the flow model for α and β for example, and use these best fit values for experimentation in the equilibrium model. Ideally flow data on shopping trips is needed for this calibration procedure (which is becoming available on a large-scale through LUPIN - see Beaumont, 1986) but for now we simply use a 'minimum sum of squares' procedure based on known centre size against those predicted by the model, assuming a straightforward revenue/floorspace ratio. This certainly gives us some idea on the real parameter space of the model (i.e. α=1.00, β=2.15 and α=0.90, β=1.75 being the two best combinations) which is useful at this stage.

4.3 The aggregate model

Figure 5 shows the equilibrium solution for the two combinations of α and β(V=0.75, $k_j=1\ \forall_j$) using the aggregate model as well as the real world pattern for 1982. There are clearly some marked differences. In the equilibrium model the most 'attractive' centres in the system expand whilst the least attractive decline. This can be clearly seen in relation to the city centre in figure 5, for example, and the effect this has on surrounding centres nearby. We can see this process more clearly by stopping the iterative procedure after a certain number of steps and looking at the consequent allocation of facilities. This is shown in figure 6 for one set of calibrated values (α=1.00, β=2.15). If we start with one iteration, figure 6a, then we see all centres able to attract facilities although the size differentials are not great. After five iterations (figure 6b) the most 'attractive' centres are beginning to dominate, and after ten iterations the solution is fast approaching equilibrium.

The aggregate equilibrium solution is worth looking at more closely. It shows the 'optimal' location of facilities given contemporary population and expenditure patterns and the given values of the parameters. It shows a major focus of facilities at the city centre, with an inner ring of smaller suburban facilities flanked by an outer ring of much larger centres (a pattern increasingly apparent in the U.S.A. where less rigorous planning control has allowed such a pattern to develop). Clearly the affluent northern suburbs are especially attractive in the model, a fact borne out in real life by the number of planning applications for retail developments in this area, a theme we shall return to in section 5. We shall also see in section 5 that the equilibrium model is often most useful in assessing the impacts of new developments in terms of their longer-term ability to attract sufficient trade to expand and be profitable. This invokes the ideas of development possible/no development possible states introduced by Harris and Wilson (1978) and of structural stability which is examined in more detail in both sections 4.5 and 5.

4.4 Model refinement: components of attractiveness and spatial variation in costs

Although the aggregate model is important for identifying optimal locations for retail development it is clearly unable to replicate the real-world retail configuration of Leeds centres which may lie in non-optimal locations (usually because of their historical development within the city). An interesting research question then is how to make the smaller, less-optimal centres actually 'survive' in our equilibrium model. In the aggregate model facilities are located primarily in relation to the size of centres (W_j) and the distance centres are from areas of population (c_{ij}). Two particularly pertinent comments here are that consumers may shop at particular centres for other reasons than purely physical size (see the large literature on urban consumer behaviour for example) whilst retailers may locate in centres which are considerably cheaper than major suburban centres, where multiples gather and push-up rents and rates. Hence, to produce a more realistic spread of facilities we need to introduce spatially disaggregated costs and attractiveness terms. (Whilst we pursue this below for the Leeds study we should also note complementary work on issues such as spatially disaggregated cost terms using similar types of models to the ones addressed here: see Lombardo, 1986, and Fotheringham, 1985, for example.)

To determine the attractiveness of individual centres we can define (at least) four basic components: first, a measure of the variety of different functions or goods available at each centre. Clearly the more goods and services available the more attractive the centre becomes to the general shopper. This ties up with Fotheringham's notion of 'competing destinations' (Fotheringham, 1985) though we should note that we are concerned with shopping centres rather than individual stores. Second, we add a measure which might reflect the relative importance of a particular centre, in this case the number of key multiple retailers located in each centre. These two measures are 'objective' in the sense that they can be quantified relatively easily (the data coming from G.P. Clarke, 1986a). The third and fourth components are more 'subjective' in that although they can be measured in quantitative terms they are assigned values largely on the basis of the authors' knowledge of the centres involved. The third measure aims to capture the 'environmental' aspects of a particular centre by noting the presence of cafes and restaurants, the number of covered walkways, malls and precincts and the number of pedestrianised areas. All of these factors help to improve the safety and comfort of shopping. The last component of the attractiveness term could be labelled the 'transport factor' and includes the availability of car parking facilities (seen as particularly important by Timmermans, 1981) and the provision of local public transport facilities.

In these four measures we hope to have captured the average attributes of shopping centre attractiveness. Clearly if we were more concerned with individual goods then we would have to include prices and quality in far more detail, and indeed other variables which may be important for particular goods. (For groceries, for example, there may even be a case for adding a 'Sainsburys' or an 'ASDA' factor.)

Figure 7 shows the new equilibrium solution for the model with centre-specific attractiveness values (incorporated in the $W_j^{\alpha_j}$ term; see G.P. Clarke, 1986b for more details.) The advantage of such an approach is that important centres that are in close proximity to other centres can now become more dominant in the model with the refined attractiveness terms, in line with real-world sizes. (Such as Harehills and Harehills Lane to the east of the city centre: see Appendix for their locations.) Conversely, some of the centres in very attractive locations in a modelling sense, which are not very attractive sites in the real setting, can have the amount of facilities allocated reduced to a more realistic scale (Middleton to the far south and Holt Park to the far north for example).

However, as one might expect, some centres do even worse than before with the new attractiveness term added: namely the older inner-city and inner-suburban centres. Clearly one of the main reasons that facilities exist today in these kinds of centres is that it is relatively cheap to locate there, and certainly much cheaper than the larger, more attractive suburban and city centres.

Although we lack detailed information on the cost of locating in each centre an interesting research question is what kind of costs would the unattractive centres require in the models in order to offer a sufficiently high W_j to attract nearby consumers? Using a simple iterative scheme costs can be systematically reduced in these unattractive centres, and at the same time increased in the most attractive centres, in order to produce a pattern of W_js across the city which resembles the actual distribution of facilities. The set of k_js which reproduces the known pattern of facilities is shown, alongside the equilibrium model solution using these k_j values, in figure 8.

Clearly this final set of k_j values shows that some of the smallest real-world centres do still need to have relatively low values of k_j in order to attract facilities whilst some of the larger centres have much higher values to stop them becoming too dominant. These values would also make sense in terms of real costs in different centres. Rents for example are far lower in smaller, less attractive, centres and much higher in the city centre and larger suburban centres. However there are clearly some anomalies, all of which are explained by the relative isolation of such centres which forces the model to want to locate facilities in these regions: hence the very high k_j values which these centres attract to stop facilities being allocated. Middleton, to the southern edge of our spatial area, is one such example with a k_j value of over two.

In terms of retailing, apart from a few isolated parades, there is little development between the small Middleton centre and Beeston and Hunslet to the north. It is not surprising therefore that the models wish to allocate extra facilities to this area. It is also interesting to note that Leeds Planning Department had indeed been trying for some years to attract major retailers to this part of the city, though the retailers themselves have been generally keener on the northern edge of the city where potential demand and wealth is greater. Presto finally agreed to a new site close to the present Middleton District Centre and thus since 1982/83 (and our last retail survey) a new centre has indeed emerged in this area. We shall look in more detail at the performance of various parts of the city and the possible impacts of new locations in section 5.

In the last two sections we have attempted to model the existing configuration of retail centres using the type of equilibrium models set up by Harris and Wilson (1978). Our empirical case-study has shown that for real systems we need careful disaggregation of the basic model to reflect locational cost variations and the different attractiveness of individual centres.

Attention has focused primarily on the 1981 Census data and the known retail pattern of 1982. Clearly the next important empirical task is to look more closely at change over time in which new forms of retailing have emerged and in which new forms of parameter disaggregation will be required.

4.5 Examples of structural change

So far we have looked at the ways needed to extend the equilibrium model to represent more adequately retail centre size and location for the contemporary retail scene in Leeds. However, one of the themes of section 2 was that of structural stability; the way in which small changes in the parameters of the model may in particular circumstances lead to major structural changes in the system being modelled. This has been shown for a wide range of parameters in a number of different sub-systems (M Clarke and Wilson, 1983, 1985, Birkin and Wilson 1986a,b) and seen most strikingly for the patterns associated with a logistic attractiveness function in Clarke, Clarke and Wilson, 1986).

One such structural change in a retailing context has been the corner shop to supermarket transition in food retailing and this is a theme we pursue here by way of example. The grocery environment of the early 1960s was clearly dominated by the 'corner-shop' or small outlet within the new parades common in the outer suburbs. The arrival of the supermarket however, was to have profound effects on the ability of many small retailers to survive in the face of the increased competition. G.P. Clarke (1985) showed the dramatic decline of grocery retailers in North Leeds after 1955 whilst Wilson and Oulton (1983) plot the changing numbers of grocers and supermarkets in Nottingham (figure 9).

The speed of this change seems to have been caused through a number of factors. The abolition of resale price maintenance in 1964 extended the range of goods that multiple traders could buy in discount. The effect of this was not only cheaper operational costs for those retailers who could buy in bulk, but also cheaper prices to the customer. The independent retailer could simply not buy as cheaply and hence pass on savings to the shopper. These economies of scale in both buying and selling were thus crucial.

Consumer behaviour was also changing rapidly during the 1960s. More people than ever before were able to travel longer distances to enjoy the benefits of not only cheaper prices at supermarkets but also wider choice as stores got progressively larger. Alongside increasing car ownership levels came a large increase in the number of households able to purchase a refridgerator/freezer which in turn facilitated bulk buying of groceries on a weekly basis.

All of these advantages enjoyed by the supermarket in the 1960s were similarly enjoyed by the superstores in the 1970s, only on a far greater scale. (Most of the superstore operators themselves had grown from purely supermarket operators.). Very large firms could also enjoy a number of other benefits: the ability to pay far greater fixed costs for superstore developments (which would include land for car parking facilities), the ability to stock new lines of products alongside groceries, and the increasing ability to enjoy the benefits of mechanised distribution and handling facilities.

The changing retail grocery sector then provides the impetus for looking at new kinds of model forms. By the 1980s we are clearly left with three levels of operation: the corner shop, the supermarket and the superstore. Each of these has been particularly important at different points in time and each have very different trading characteristics. Thus fixed and operational costs, prices and the ease of travel for consumers are all important in explaining the changing market shares over time. We saw in section 2 that the standard flow model can be easily disaggregated into person type (m), good type (g), and it is possible to extend the arguments to shop type (h) (c.f. Wilson, 1983). Adding a price term explicitly into the model (c.f. Birkin and Wilson, 1985) then produces the following new model structure (ignoring the person type and type of good for ease of interpretation):

$$S_{ij}^h = A_i^h e_i P_i W_j^{\alpha^h} p_j^{-y^h} e^{-\beta^h c_{ij}} \qquad (14)$$

where

$$A_i^h = 1/\sum_{jh} W_j^{\alpha^h} p_j^{-y^h} e^{-\beta^h c_{ij}} \qquad (15)$$

to ensure that

$$\sum_{hj} S^h_{ij} = e_i P_i \tag{16}$$

with h=1 the corner shop, h=2 the supermarket and h=3 the superstore. The other variables are as listed before.

(N.B. Wilson, 1983, explores the possibility of modelling a number of goods associated with a particular h category, but we do not pursue this here.)

We should note that the balancing factor A^h_i ensures that the total amount of spending on groceries is distributed between the different store types. This means that the competition between locations and store types is explicitly modelled. To make the costs (C^h_j) more realistic we can divide the cost parameter into two main terms:

$$C^h_j = OC^h_j + PC^h_j \tag{17}$$

where C^h_j represents unit costs for store type h, OC^h_j represents unit occupancy costs for store type n and PC^h_j represents unit purchasing costs for store type h each per unit of floorspace. Occupancy costs are made up of rents, rates and power (McClelland, 1966): here we also add labour costs which are a similar kind of fixed cost (at one period of time). Purchasing costs are the costs involved in buying stock to retail. These two main types of cost are expressed in greater detail in McClelland (1966).

To make progress we begin with the situation of the mid 1960s and look at aspects of the corner shop to supermarket transition. (Population and expenditure data for 1966 is used here.) There are obviously now a large number of parameters to test but as Wilson (1981) suggests our intuition often tells us one parameter may have more influence on taking a particular system to criticality than others. Here then we briefly look at price and ease of travel variation whilst more details on all the parameters appears in G.P. Clarke (1986c). First, we specify a base set of values for h=1, the corner shop and h=2 the supermarket:

$P_j^{-\lambda 1}$	$= 1.00$	$P_j^{-\lambda 2}$	$= 1.00$	(price index)
OC_j^1	$= 1.00$	OC_j^2	$= 1.30$	(fixed costs)
PC_j^1	$= 1.00$	PC_j^2	$= 1.00$	(purchase costs)
β_j^1	$= 2.50$	β_j^2	$= 2.50$	(ease of travel)
α_j^1	$= 1.00$	α_j^2	$= 1.00$	(consumer scale economies)
V	$= 0.95$	V	$= 0.95$	(city centre factor)

The only difference between the two store types is thus the fixed costs which are set higher for the supermarket case. Running the model with this base set thus allocates all facilities to the corner-shop environment, since the supermarket has no advantages as yet.

In figure 10 we plot the effects of steadily decreasing the price index for the supermarket case (holding all other parameters constant). As we described above, the abolition of resale price maintenance meant that supermarkets were more able to offer discount prices on a far wider range of goods. Clearly, price reductions were a major incentive to shop at supermarkets. As price decreases in figure 10 we see the progressive development of a more supermarket dominated environment (note that the plots are scaled according to the largest values recorded in each figure).

Figure 11 shows the effects of steadily decreasing β, the ease of travel parameter. As the 1960s progressed it is clear that travel was becoming relatively more easy as levels of car ownership increased and many planned centres acquired new car parking facilities and improved local transport networks. As β decreases in figure 11 we again see a pattern change between the two levels of activity and a shift towards the supermarket case. The speed of transition for β-changes here is very rapid: a small change around β=2.43 produces the most dramatic shift in terms of the amount of facilities allocated between the two store types.

Whilst we have looked here at only two parameter changes the reality of the corner shop to supermarket transition was undoubtedly a combination of all these parameters although it may be argued that prices and ease of travel may well have led the way for the development of larger stores which in turn led to the cost-cutting efficiencies characteristic of today's operations. Data on the changing 'scale of costs' and prices is extremely difficult to obtain. Much of the literature on retail costs takes retailing activity generally, or gives comparisons between different types of good (i.e. Nooteboom, 1983, Tucker, 1975). It is much harder to locate studies which take account of different shop sizes for particular goods.

However, one valuable source which sheds some light on the different prices and costs of local grocers and supermarkets is the National Board for Prices and Income (NBPI)(1971). They were particularly concerned with prices, profits and costs in food distribution during the 1960s and we exploit much of this data in G.P. Clarke (1986c) and very briefly here.

Following the findings of the NBPI Report we can get some measure of the relative differences in the cost and prices terms between the two store types, and figure 12 is illustrative of the types of structure which emerge when these parameters are combined. It can be argued that figure 12 shows a reasonable approximation to the actual pattern of supermarket provision, certainly in terms of level of provision. We might expect that an element of 'fine tuning' between these parameter values would begin to get much closer to the Leeds set.

We can extend the argument in to the 1970s by adding the third store type, hypermarkets or superstores, and using 1971 Census and expenditure data for the demand side variables. Here we take the parameter values shown in figure 12 as a starting point for varying the parameters of the h=3, superstore category (with the addition of much higher fixed costs for the superstore category). For brevity we show in figure 13 one such parameter change for prices. Once again, steadily decreasing prices makes the superstore case become attractive enough to cause major structural change in the system as consumers switch trade in the models to take advantage of the cheaper prices.

There are many features of these sorts of models which are worthy of further study and more details appear in G.P.Clarke (1986-B). In particular it is interesting to see which set of parameters produce the right kind of distribution of expenditure between the three store types (Leeds City Council, 1984, suggests today's levels of expenditure are around 30% for the corner shop, 40% for the many supermarkets in local centres and 30% for hypermarkets and superstores) and where the optimal locations for hypermarket development would appear to be.

5. Planning and performance indicators

5.1 Introduction

An important argument of sections 2 and 3 was that apart from the testing of models in empirical contexts for the sake of verification of theory there is clearly a need to make the output of these models more relevant in an applied context, not only for the equilibrium models but also for the standard flow model described in section 2.

Encouragingly there has been some resurgence of interest in these sorts of model for retail planning. Penny and Broom (1986) discuss the use of such models to help decision-making in the store-location field whilst Mason and Meyer (1981) discuss similar approaches in a U.S. context. There is evidence too that retail planners are becoming increasingly interested in these types of analytical tools; at the very least they can do the same sorts of calculations that are presented by retailers at planning inquiries.

It seems the need for analytical methods, especially in fields such as store location research, will become especially crucial in the next few years as retail competition increases. A recent report by Donaldsons (see Chartered Surveyor Weekly, 1986) suggests that due to relaxed shop planning by many local authorities, existing superstores will soon be vulnerable to competition as further prime sites are released. Similarly Schiller (1986) predicts a third wave of out-of-town developments will have profound effects on the retail environment during the late 1980s. This will involve clothing and comparison goods in particular with firms such as Marks and Spencer, Habitat and Laura Ashley taking the lead. Although the Chartered Surveyor report indicates that planning controls may be easing in terms of out-of-town developments these recent trends surely place even greater need on detailed impact and accessibility studies from retail planners.

To examine the idea of more relevant model outputs we take up the discussion on retail performance indicators outlined in section 3, both facility-based (which are most likely to relate to the interests of commercial firms) and residence-based (more likely to relate most directly to retail planners). Any detailed study would produce a vast array of indicator data and we are forced to be selective here for illustration and ease of presentation.

5.2 The flow model

Although we have talked at great length about the utility of the equilibrium models, and their ability to say more about structural stability, there is scope for continuing to explore the basic flow model, especially for the purposes of system description and 'problem' identification. It remains one of the simplest and quickest tools for experimentation with a series of 'what if?' scenarios, especially if these can be incorporated within a more detailed information system/package which eases data handling, model implementation and inspection/interpretation of results (see Birkin and Wilson, 1986; Birkin and G P Clarke, 1985).

5.2.1 Facility-based indicators

Figure 14 shows a set of facility-based indicators for the 'best-fit' combinations of α,β (α=1.00, β=2.15), for all the major retail centres in Leeds based on the total retail demand in the 729 zones. The indicators are as listed on the figure. To give a firmer representation of the spatial dimension we also plot the revenue and revenue/floorspace indicators on each figure. The plots can be linked to the raw data through the key provided.

The revenues shown in figure 14 help to confirm the earlier results for the equilibrium model in terms of the most attractive sites. Apart from the city centre (zone 32 in figure 14) and the major suburban centres, we see the northern suburbs of the city attracting relatively large revenues as do the more isolated centres such as Bramley to the west (number 14) and Middleton to the south (number 31). All these centres consequently have relatively large catchment areas as they draw their trade from a wide geographical area.

Centres in Leeds that have large floorspace areas, yet only attract small revenues in the models consequently have small catchment areas and high rates for the floorspace/catchment area ratios. Clearly the indicators which say most about the prime locations, or potential investment areas, are those which have high revenue/floorspace ratios or high revenues/catchment areas. In figure 14, the northern suburbs and the Middleton area to the south are such examples.

In order to look at the effects of changing retail patterns on the flow model we can look again at the case of the new centre recently built at Middleton and discussed first in section 4.4. In figure 15 we can introduce the known floorspace size of the new Middleton centre and re-examine the resulting set of facility-based indicators. It is noticeable that the revenue attracted to the new centre is relatively high and has a marked impact in the reduction of revenue to nearby centres, notably the smaller, older Middleton centre, the Beestons and Hunslet. Consequently indicators such as revenue/floorspace for the older Middleton centre are also significantly reduced.

Whilst indicators based on aggregate retail patterns for all person types provide a useful description of the total system, retailers and planners are clearly also interested in the service provided to particular groups of consumers. On a welfare basis for example planners might ask how well are the unemployed or retired members of the community catered for, whilst retailers, on the basis of maximising profits, may be more interested in the location of the most affluent population and the centres they are most likely to retail at. Again we can use the simple flow model for illustration here and focus on three different consumer groups: the professional socio-economic class group, the retired and the unemployed. Similarly, rather than look at retailing as a whole we can look at a particular good, in this case grocery retailing.

Figures 16-18 show the facility-based indicators for each of these three person types. From figure 16 we can see how dominant the northern suburban centres become in attracting revenue from the highest socio-economic groups in the city: Holt Park, Sainsburys at Moortown, Moortown and Horsforth in particular. (See also the revenue/floorspace indicators.) Conversely, centres such as Hunslet to the south of the city centre, with a relatively large superstore present, can expect to attract very few of the most affluent consumers, a fact reflected in its low revenue indicator and high floorspace/catchment population indicator. Figure 17 shows the likely patronage of centres by the unemployed population of the city and clearly the pattern is very different. In this case the most attractive centres are Bramley, Crossgates, Hunslet and Harehills. The floorspace/catchment population indicators, conversely, show high values for the most affluent northern suburban centres which do not pick up as much trade from this client group. The revenue/floorspace indicator also shows that some of the smaller inner-area centres are relatively attractive for the unemployed groups: see the relatively high values in York Road, Harehills Lane, Harehills Lane (Shaftesbury Parade), Stanningley and especially Middleton.

The patterns for the retired population (figure 18) resemble more the aggregate consumer patterns although again the southern zones of the system seem particularly in need of extra provision to serve the local retired community.

5.2.2 Residence-based indicators

Although we can gain some insight into consumer welfare by examining the facility-based indicators we can also look explicitly at a set of residence-based indicators for the 729 demand zones. Figure 19 shows such a set of indicators for the flow model, based again on the 'best-fit' α,β combination. There are three particularly useful residence indicators. Figure 19a shows the per capita consumer surplus measure for residents in zone i to shopping centres in zone j (along with the algebraic form of the indicator). From the basic flow model we can suggest that $\frac{\alpha}{\beta}\log W_j$ represents the size benefits of shopping at centre j and c_{ij} the disutility of travel. Hence, the higher the consumer surplus value the greater are the benefits over the disutilities.

The second indicator (figure 19b) can be interpreted as a measure of effective provision as introduced in section 3. Again the higher the $\hat{W}_i$ term the greater the effective provision of retail goods for consumers in zone i. (Note again this is measured as effective provision per capita.) Figure 19d shows the third indicator, average transport 'costs' for residents in zone i: so the greater C_i, the more consumers have to 'pay' to obtain goods and services.

Figure 19 shows that the same kind of areas come out as being poorly serviced or provided for when the residential indicators are calculated for Leeds. Generally we see a worsening of provision levels as we extend away from the city centre and the more densely retailed inner suburban areas, although as the four indicators show there are clearly pockets of zones which fare relatively worse than surrounding areas, and conversely areas which do particularly well if close to the larger outer-suburban centres.

Gaps in the effective level of service provision should be clearly of most interest to the retail planner yet the retailer as well will be interested to know where such gaps exist. Clearly the residential indicators can be directly compared with the facility-based indicators to get a clearer overall picture of retail deficient areas and possible areas for investment.

Figure 20 shows the same set of residence-based indicators with the addition again of the extra shopping centre at Middleton. Comparing figures 19 and 20 shows how the various welfare measures increase in the southern sections of the city as the new centre provides extra facilities (yet note that even under this scenario the residents to the south of the city are still relatively worse-off compared with those in the northern and eastern suburbs).

5.2.3 Policy implications

Clearly the identification of these patterns and subsequent areas of under-provision are only the first stage in any analysis of effective provision. In all the work on performance indicators (i.e. G.P. Clarke and Wilson, 1986 a) we have been keen to stress that our approach should be investigative: that is when the model-based indicators suggest the existence of a problem then other means should also be used where appropriate to investigate further. In terms of shopping deficient areas planners may encourage a number of different responses - the addition of new stores or centres; changes to the transport system which would affect the indicators directly through the c_{ij} terms (this may be especially important for client groups such as the elderly or unemployed); the encouragement of mobile shops or facilities; or perhaps more grandly, the provision of facilities such as computer-based shopping where groups such as the elderly can use local facilities like libraries and community centres to order their groceries direct from participating superstores (see Davies, 1982; Davies and Edyvean, 1984; for a discussion of such a scheme in Gateshead).

5.3 The equilibrium model

We suggested in sections 4 and 5.1 that the equilibrium model may be particularly useful for assessing the impact of new centres both in terms of their likely ability to survive and be profitable and on the possible impacts on the trading patterns of other centres in the system. This again returns us to the idea of structural stability analysis. There are clearly many different impact analyses we could examine, especially for a city such as Leeds which is currently 'a northern battleground for shopping centre developers' (Pepinster, 1986). For illustration we have chosen four new hypothetical developments in very different locations across the city:

(i) between the areas of Moortown and Roundhay beyond the northern ring road of the city,

(ii) an area in Richmond to the south-west of the present York Road centre,

(iii) in Kirkstall, which lies between the present Kirkstall Road ribbon development and the district centre at Bramley,

(iv) an area to the west of Beeston Road, close to the southern ring road.

(See Appendix for their relative locations.)

Figure 21 shows the results of the equilibrium model without any of the new developments, whilst figure 22 shows the effects of including the new centres. The new centres have been given the same attractiveness values as similar recent shopping centre developments (such as Hunslet and Bramley), whilst costs have been allocated on an equivalent basis to nearby new locations

Of the four new locations it appears that Moortown is by far the most attractive of sites, followed by Kirkstall, Beeston West and Richmond. The centre at Moortown helps to cream off some of the high revenues previously going to Holt Park, Sainsbury's (Moortown), Roundhay and Moortown (centres 1-4). The Kirkstall centre does relatively well in an area of under-provision between Bramley and Headingley. (Figure 21 shows the high revenue,

revenue/floorspace indicators for Bramley, a centre which in real terms has proved very successful.) Our third centre at Beeston fares relatively well even though its immediate catchment population is not large, nor indeed the most affluent in Leeds. However, the local centres in competition are themselves rather small and unattractive and hence the new centre is able to deflect a sizeable revenue (compare figures 21 and 22). The final development at Richmond struggles to generate a high revenue. Although there are no major district centres nearby, the combined effect of a number of medium-sized centres and the considerable impact of the city centre provide too much competition to generate high revenues.

6. Concluding comments

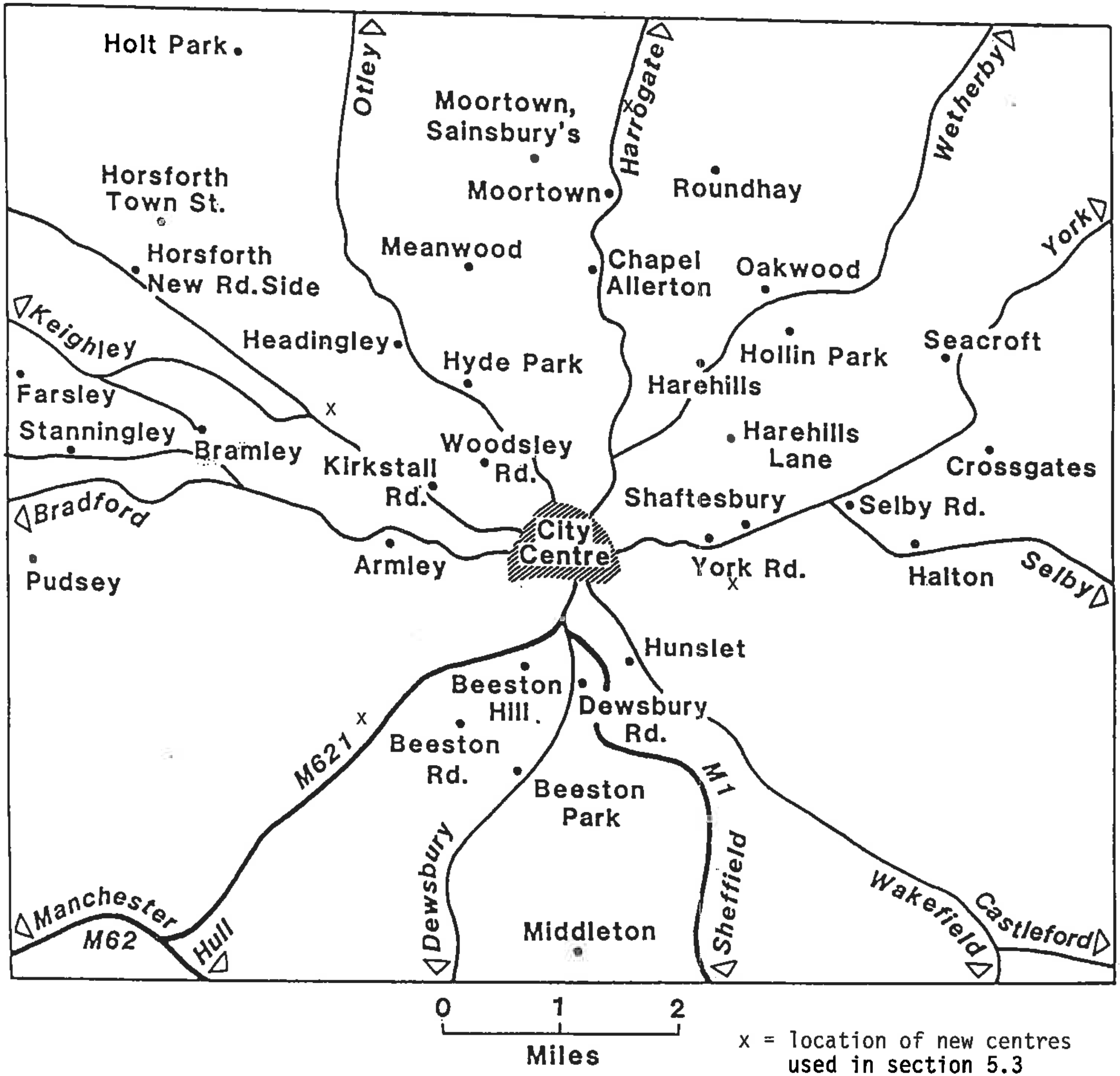
We hope we have shown that the wide range of theoretical developments related to retailing which have emerged in the last decade or so can be combined in useful and interesting ways. It is significant that a focus on the potential usefulness of the models itself leads to further theoretical developments - particularly those associated with performance indicators. The main conclusions to be drawn can be summarised as follows.
It is possible to calibrate and fine-tune the equilibrium model to reproduce existing structures in a plausible way. Further, when the extension is made to dynamics - as in the case of the grocery example above - again, actual trajectories can be broadly reproduced and there is evidence that key parameters achieve critical values beyond which the nature of the structure of provision changes. We have also demonstrated that the concept of 'performance indicators' makes the analysis more useful both to planners and retailers and that the equilibrium model makes a further contribution here in relation to stability analysis.

The tasks for further research mostly relate, initially at least, to the need for more and better data (though we should also note the possibility of expanding the dynamic models to predict price indexes and land rents (cf. Wilson, 1985, Birkin and Wilson, 1985); but the hunt for such data will be better informed because of the recent theoretical and empirical work already undertaken.

We have already noted the possible availability of improved demand and consumer flow data. The main needs here are for quantity - a wider range of case studies - and disaggregation - in relation to consumer types, types of goods purchased and types of store used. The main gaps relate to measures which can be used in constructing attractiveness functions and the elements of retailers' costs. Progress can be expected to be more rapid on the first of these as commercial secrecy is likely to constrain the second. More refined data will lead to more refined models and already some new and difficult theoretical issues are beginning to emerge: for example, what is the relationship between store use and centre use? How is the attractiveness of a centre related to the mix of particular stores which make it up?

Above all, what is needed is a wider range of examples of empirical work with a variety of models. Out of this experience will emerge another order of magnitude of improvement in both understanding and usefulness.

Appendix



The shopping centres of Leeds

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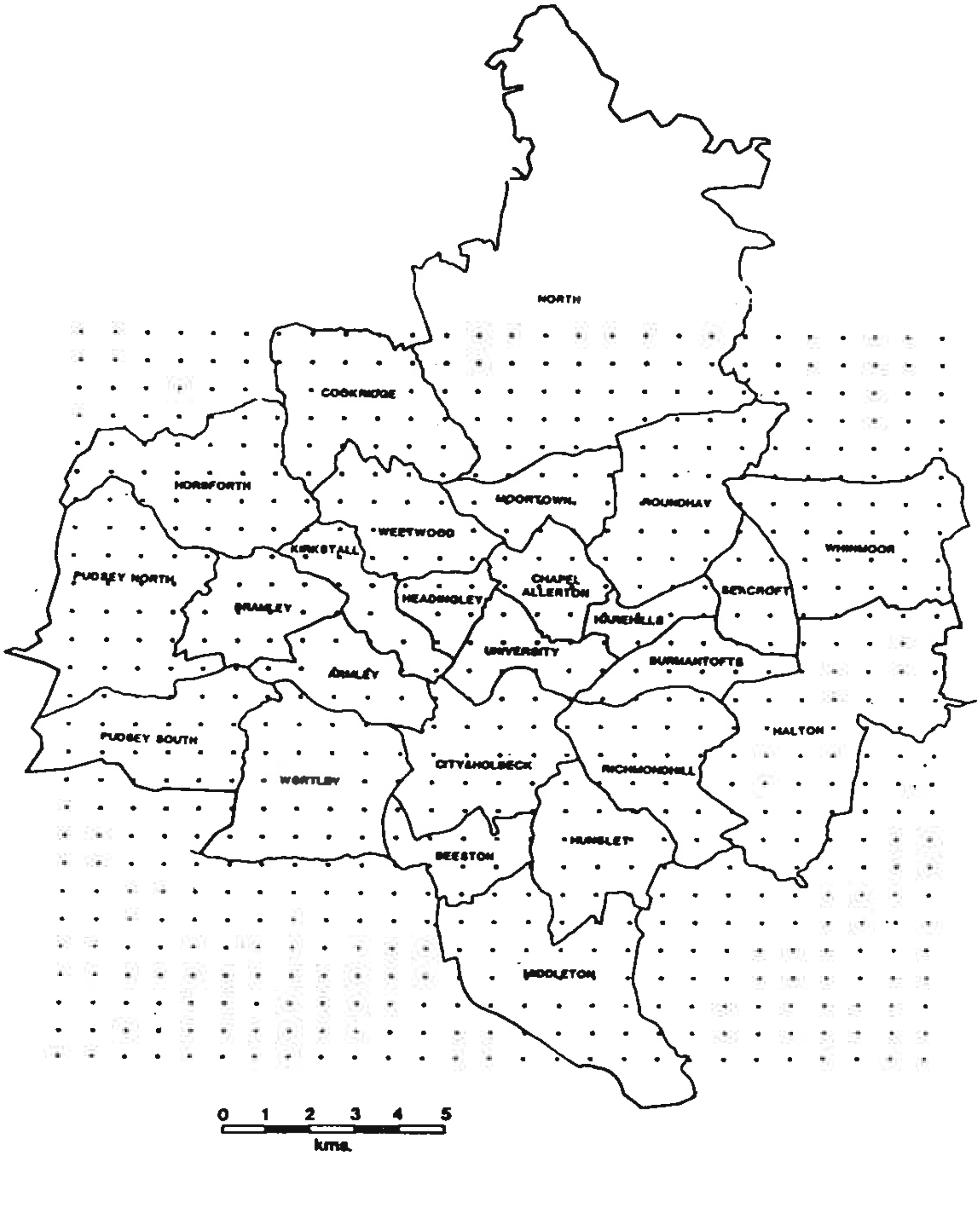


Figure 1 <u>729-zone system and Leeds Census wards</u>

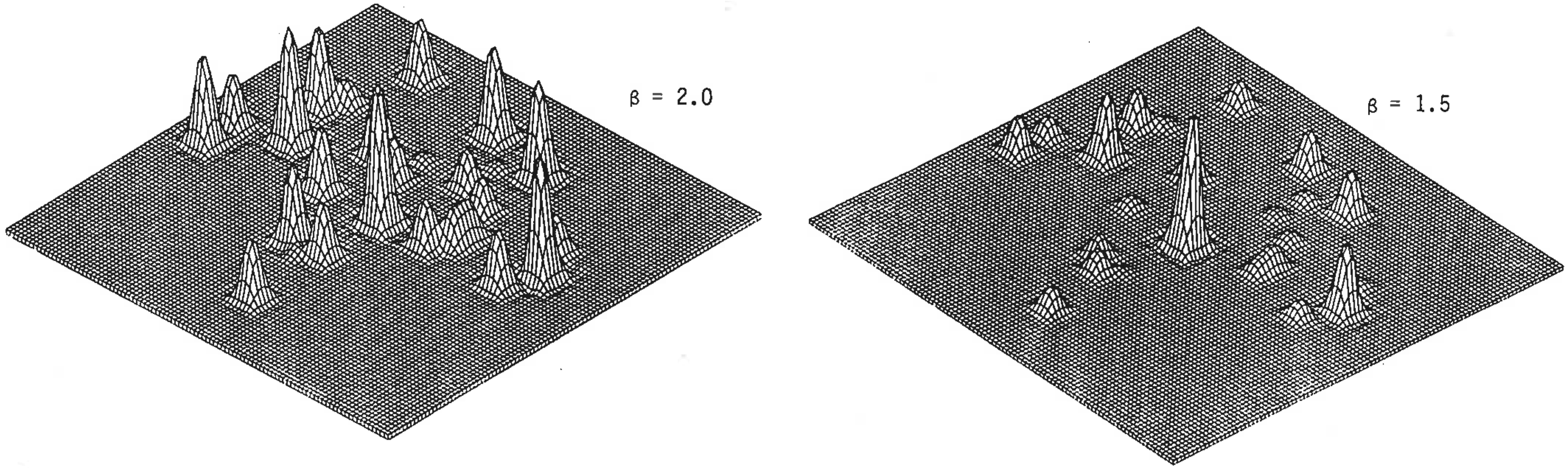


Figure 2a <u>β-variation for all retail centres</u>

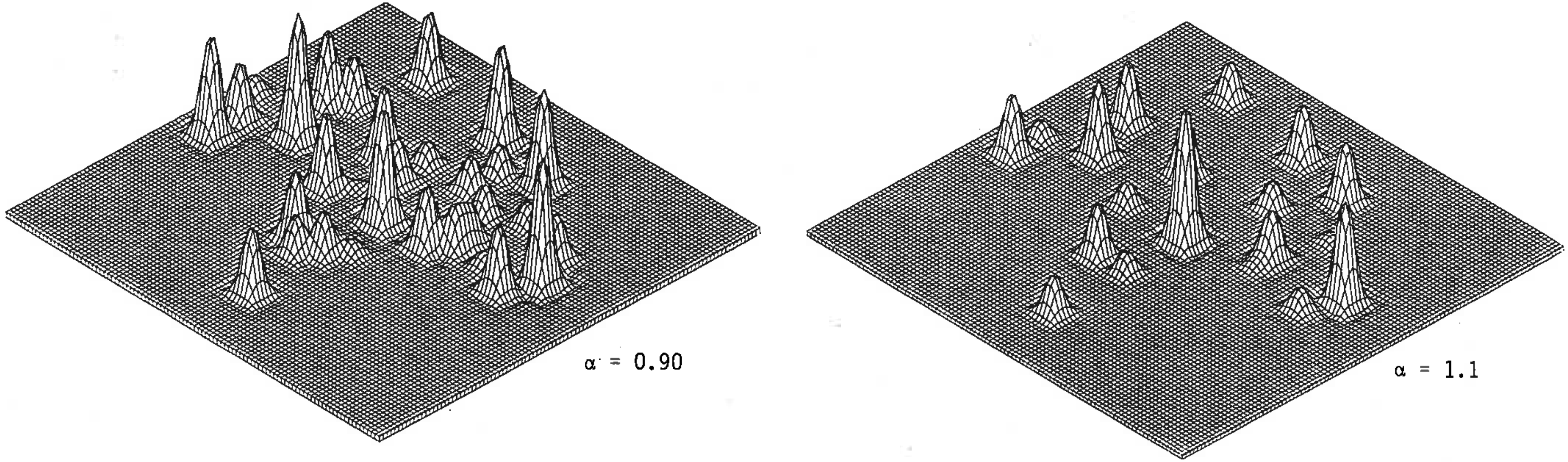
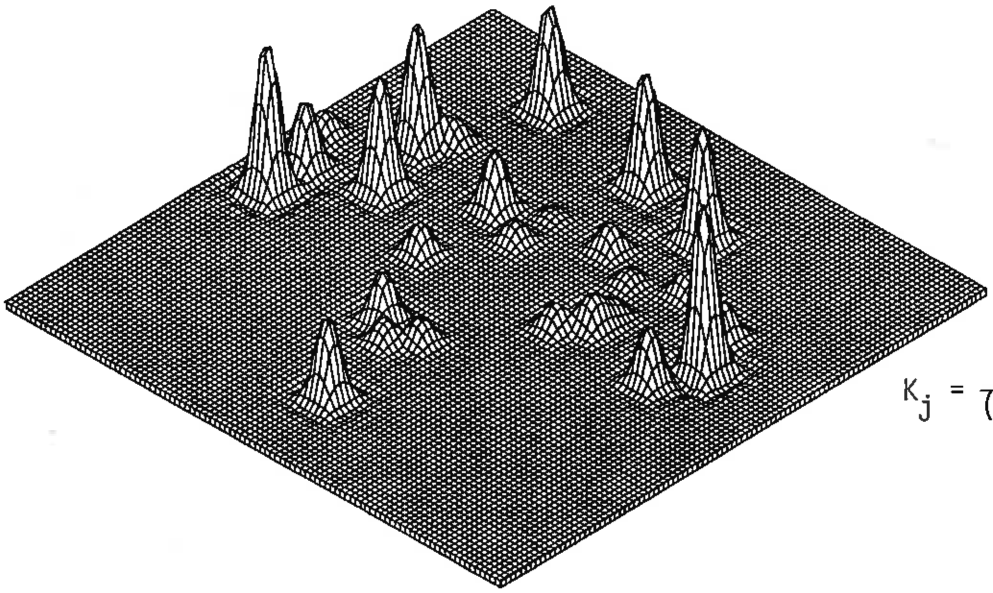


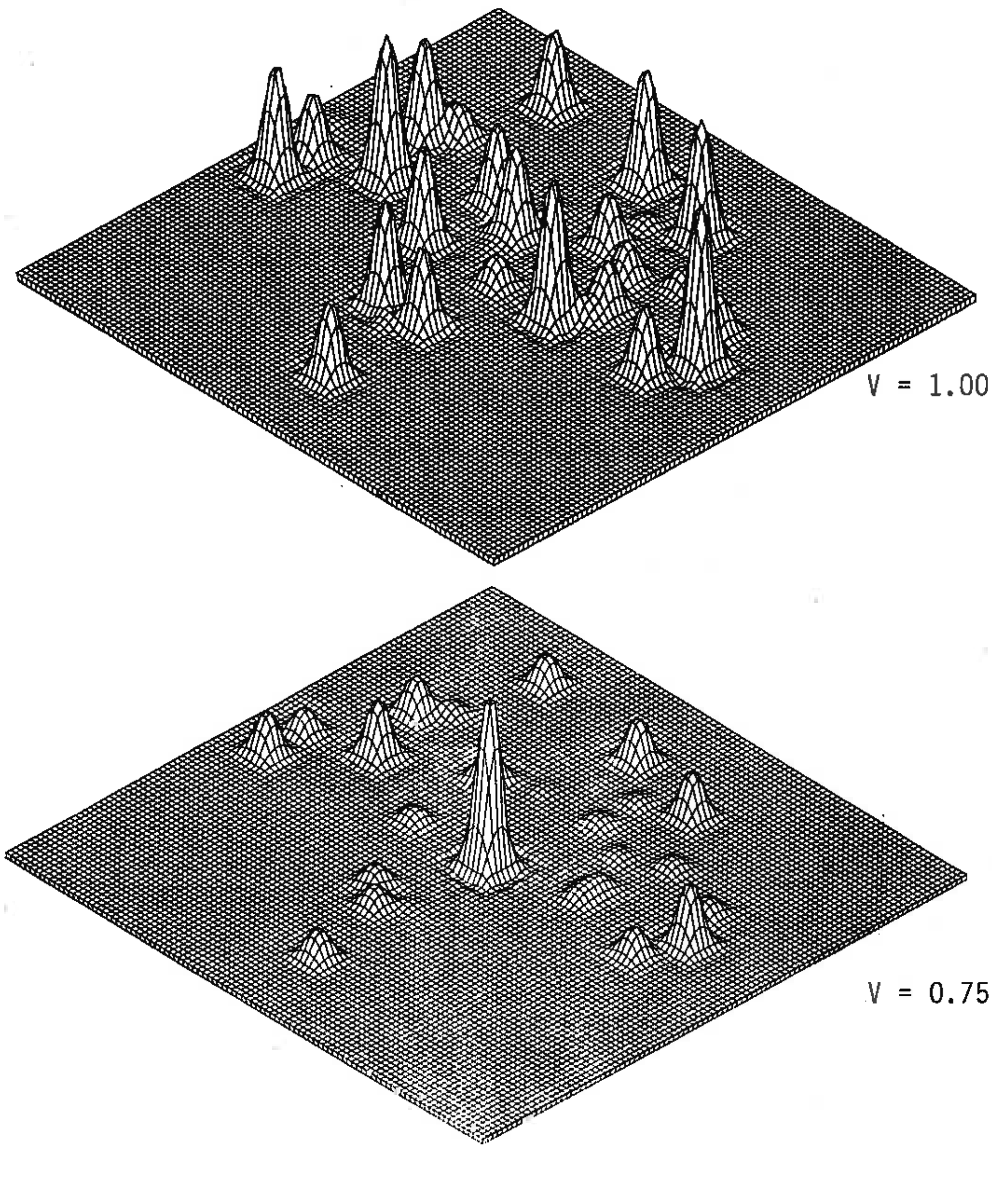
Figure 2b <u>α-variation for all retail centres</u>

Figure 3 Costs as a function of distance from centre



$K_j = \frac{1}{(C_j,365)}$

Figure 4 Effects of changing V



V = 1.00

V = 0.75

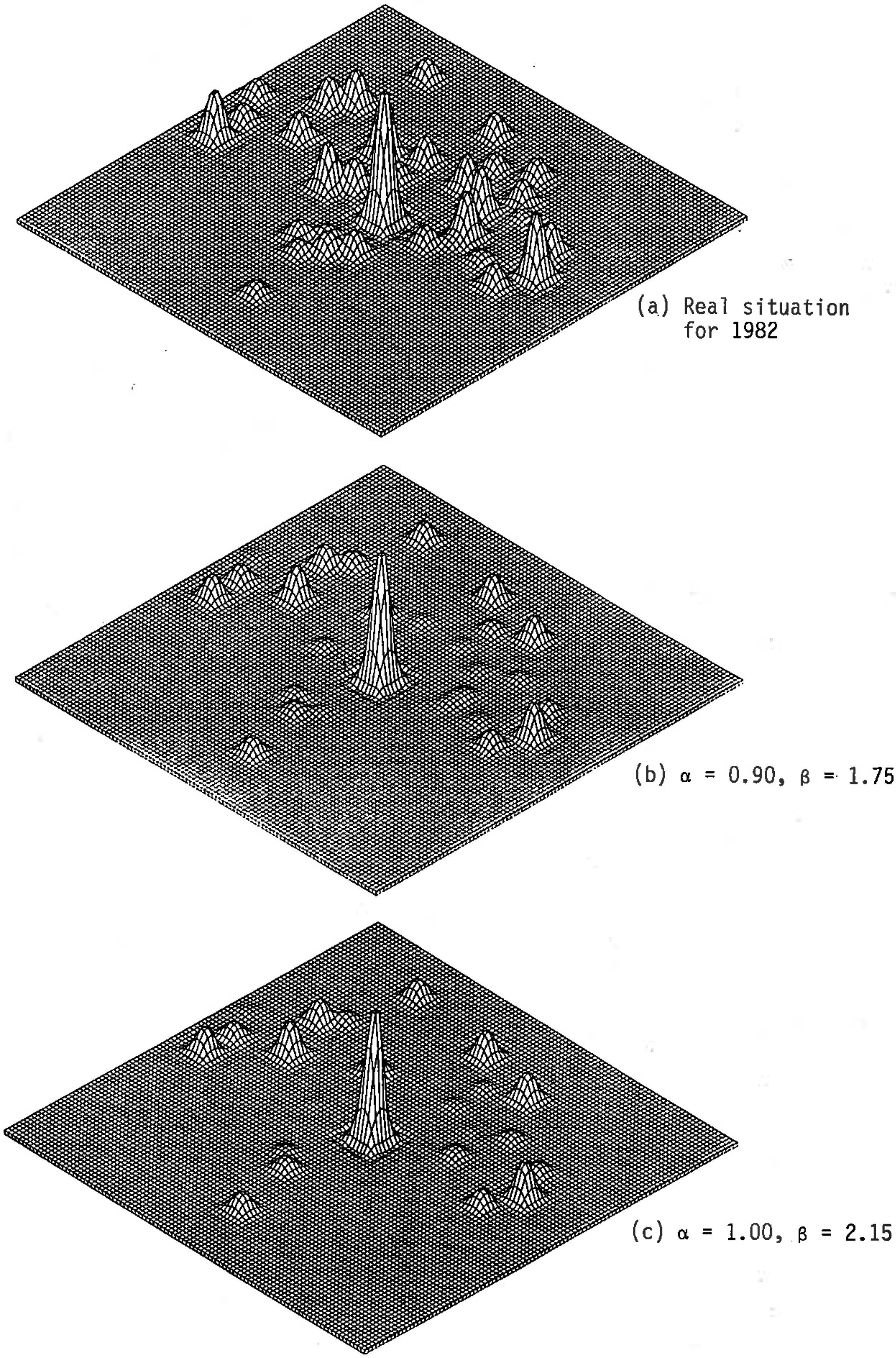


Figure 5 Equilibrium solutions for best-fit α, β values

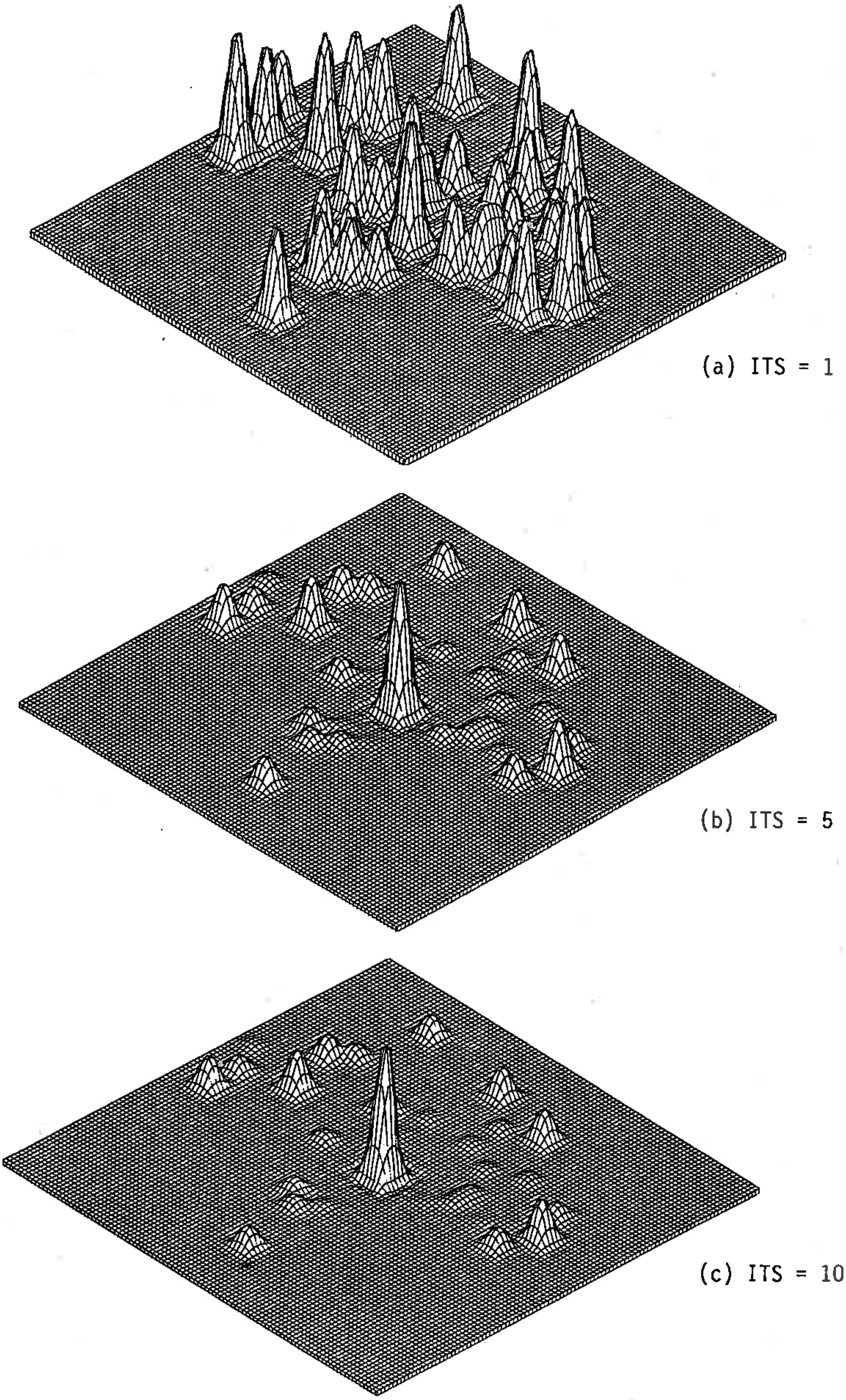


Figure 6 Model solutions after various iteration levels (ITS)

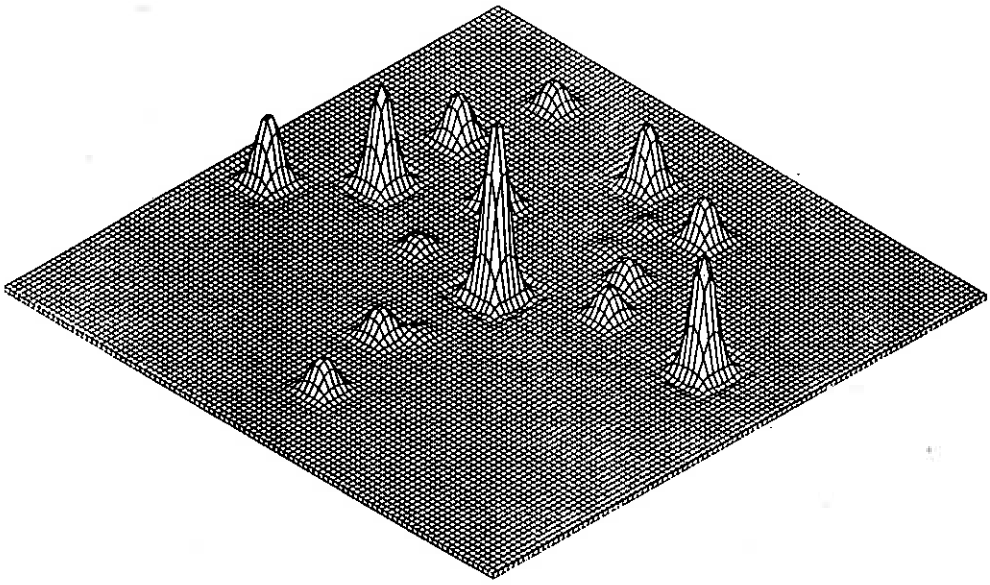
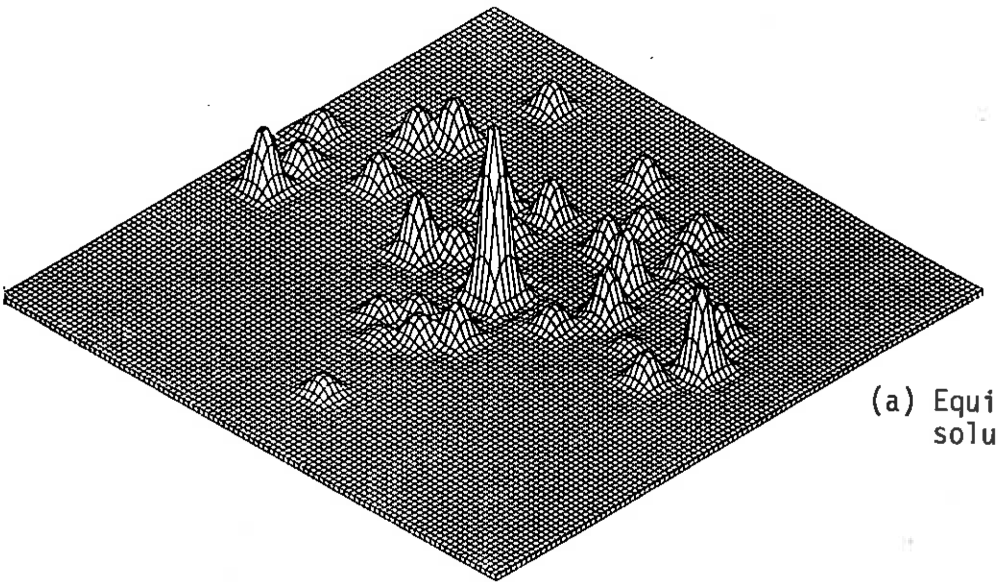
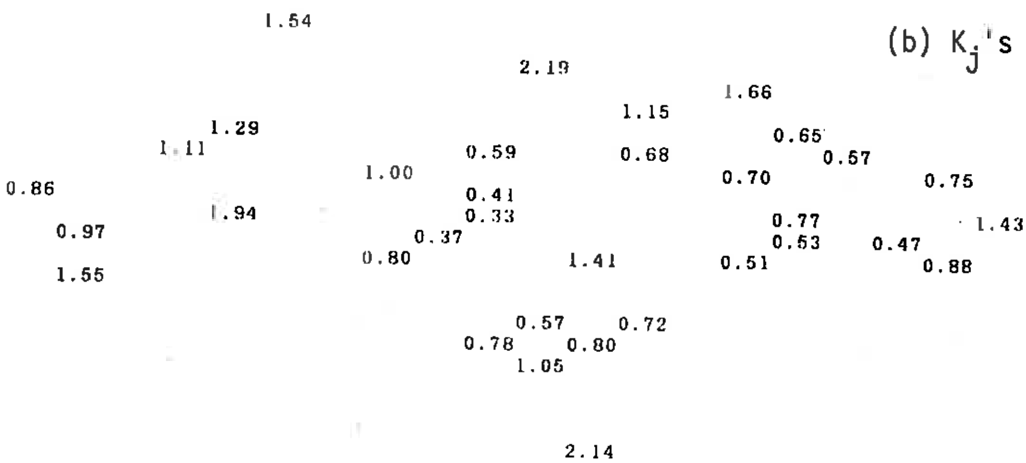


Figure 7 Equilibrium solution with new attractiveness term



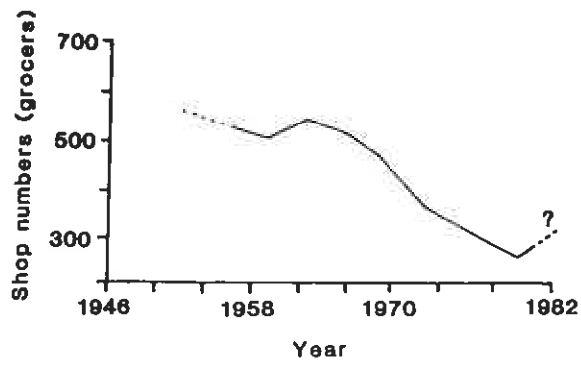
(a) Equilibrium solution



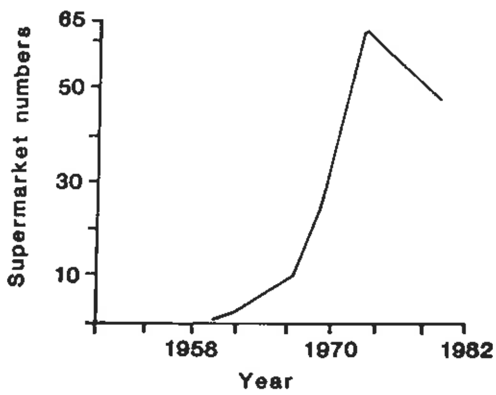
(b) K_j's

Figure 8 Equilibrium solution with attractiveness and cost terms

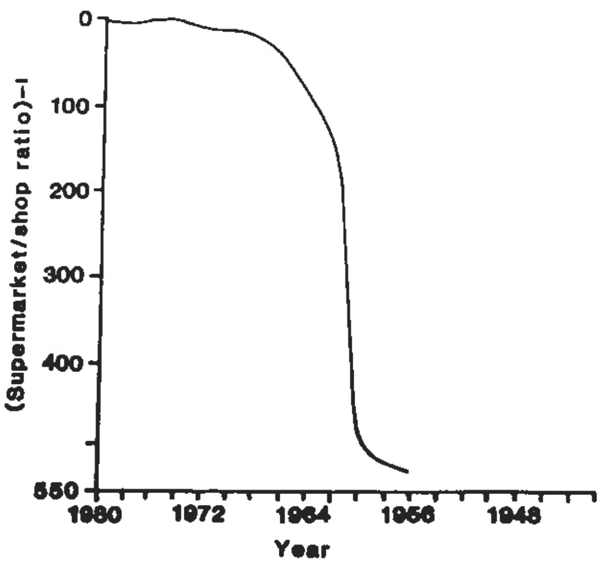
Figure 9   Food retailing in Nottingham



(a) Number of grocers in Nottingham



(b) Number of supermarkets



(c) An index of supermarket dominance

Source: Wilson and Oulton (1983)

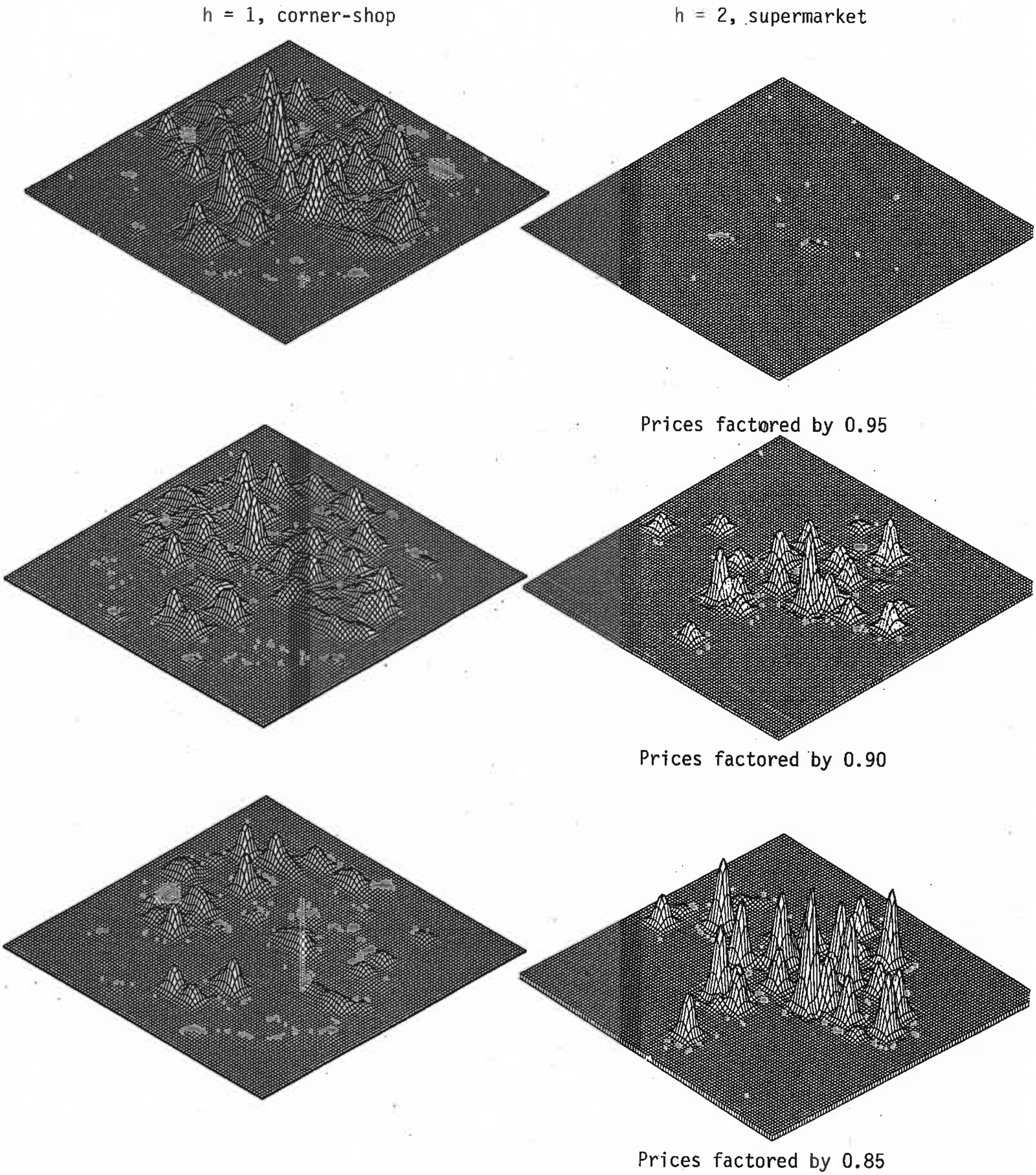


Figure 10 <u>Price index variation for two store types</u>

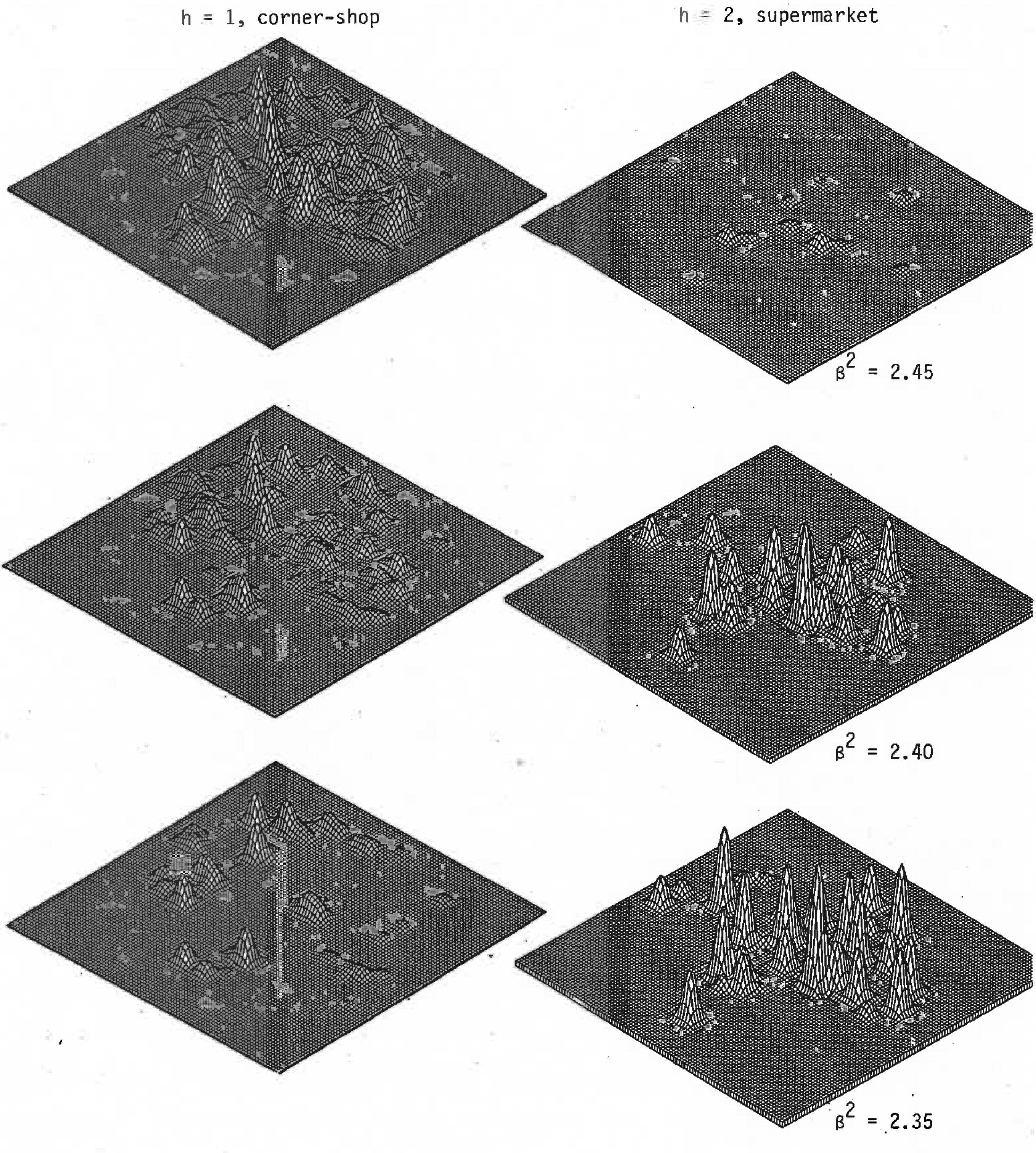
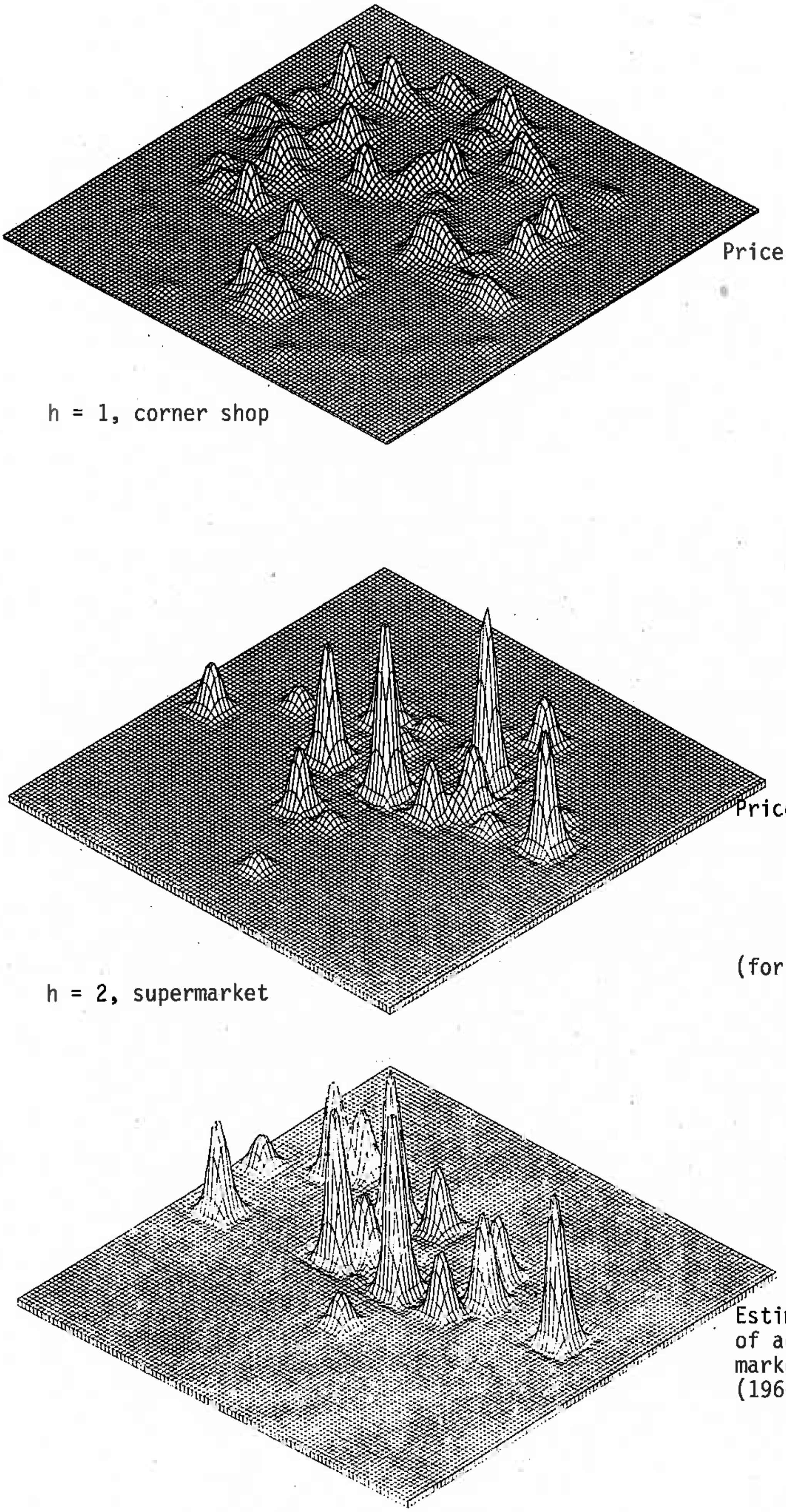


Figure 11 <u>β-variation for two store types</u>



Price index = 1.00
OC_j = 1.00
PC_j = 1.00
β = 2.50
α_j = 1.00 $\forall_j$

h = 1, corner shop

Price index = 0.94
OC_j = 1.70
PC_j = 0.80
β = 2.25
α_j = 1.02
(for larger centres only)

h = 2, supermarket

Estimated revenues of actual supermarkets in Leeds (1966)

Figure 12 Combined prices and costs

Parameter values

h = 1	h = 2	h = 3
Price index = 1.00	Price index = 0.90	Price index (as below)
β = 2.50	β = 2.25	β = 2.25
OC_j = 1.00	OC_j = 1.70	OC_j = 3.00
PC_j = 1.00	PC_j = 0.80	PC_j = 0.75
α_j = 1.00	α_j = 1.02	α_j = 1.02

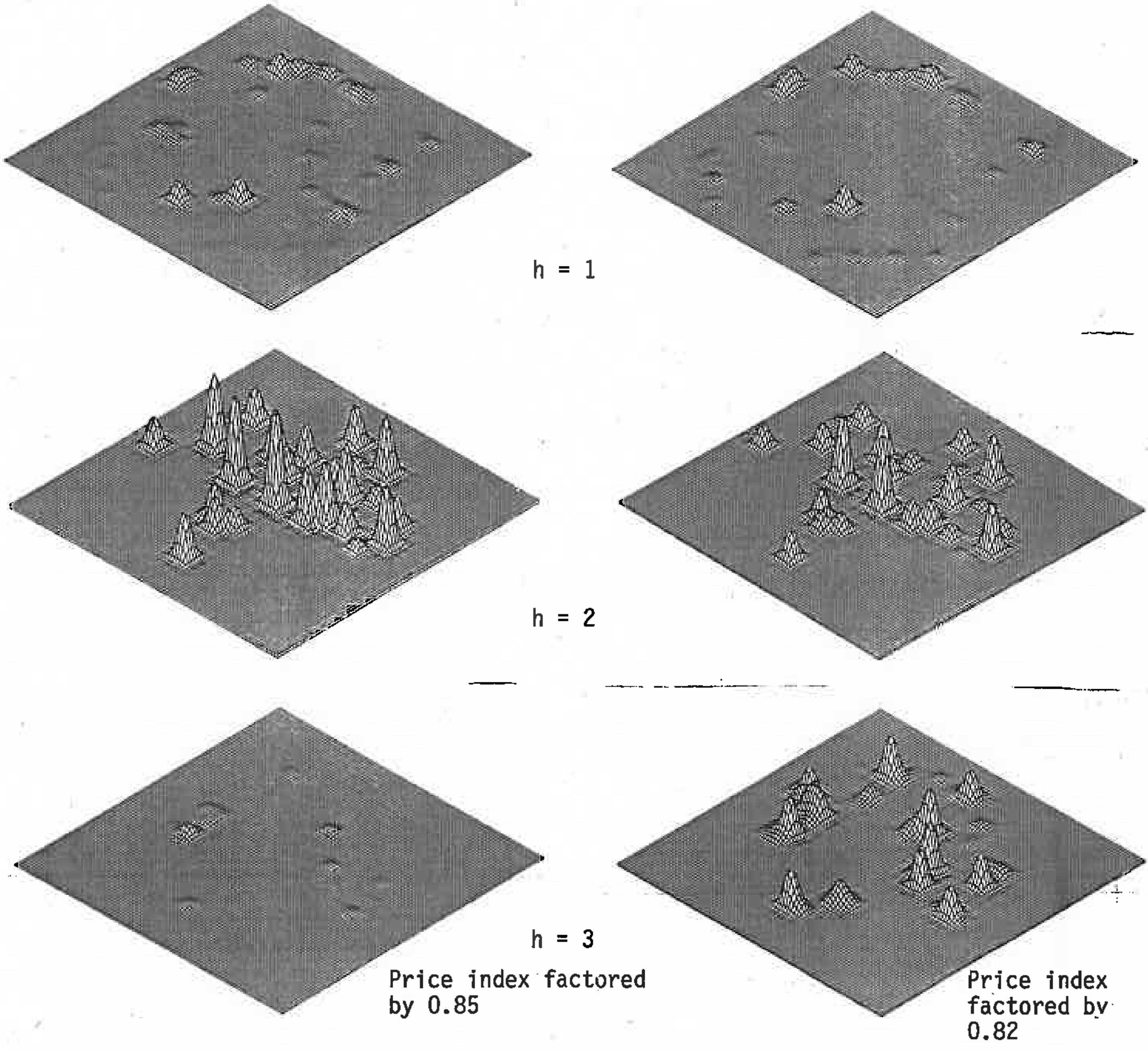


Figure 13 Price-index variation for 3 store-types

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

8022.05078 (1)	10524.3789	8180.50000	4483.27344	9239.27344	4201.33594	5412.14062-(7
1409.10449	11549.5547	6367.06250	6985.47266	4165.46094	3402.34546	10098.5430
8616.87109	17842.7461	5499.08984	1702.35522	2387.42041	1264.12549	1732.85327
3677.56592	6766.80469	15049.6836	10744.1797	4370.85937	2882.31250	5988.02734
4571.84766	3434.88428	7259.76562	24196.3281	8223.07031	3286.79468	

CATCHMENT POPULATION OF CENTRE J

10616.4141	13630.6836	10648.0195	5949.42969	12568.1992	5765.91016	7499.98828
1938.00757	15794.5586	8667.83984	9856.38281	5625.39062	4646.69922	14028.6797
12253.1367	23152.0312	7525.39844	2274.21216	3361.54224	1760.98389	2438.96704
5097.41406	8367.90625	20267.2969	15514.3555	6015.26172	4025.90796	8259.25000
6250.80859	4660.82422	9615.88672	33817.3672	11191.2812	4549.17969	

REVENUE PER CATCHMENT POPULATION

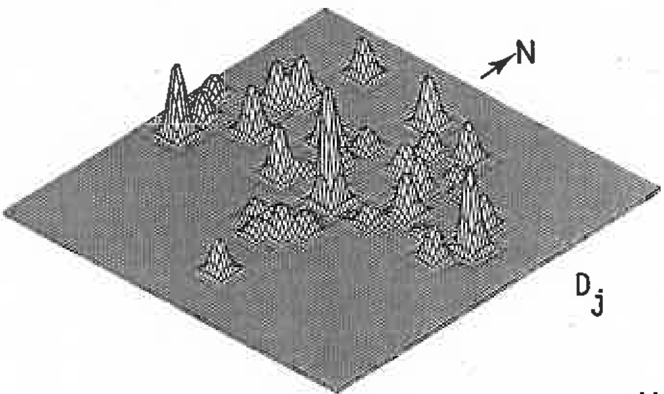
0.755627155	0.772109389	0.768264890	0.753563523	0.735131025	0.728650928	0.721619844
0.727089226	0.731236279	0.734561622	0.708725750	0.740474939	0.732206941	0.719849825
0.703237951	0.770677328	0.730737329	0.748547196	0.710215747	0.717851818	0.710486531
0.721457124	0.808661580	0.742559969	0.692531466	0.726628244	0.715940952	0.725008607
0.731400967	0.736969233	0.754976153	0.715499997	0.734774649	0.722502708	

FLOORSPACE PER CATCHMENT POPULATION

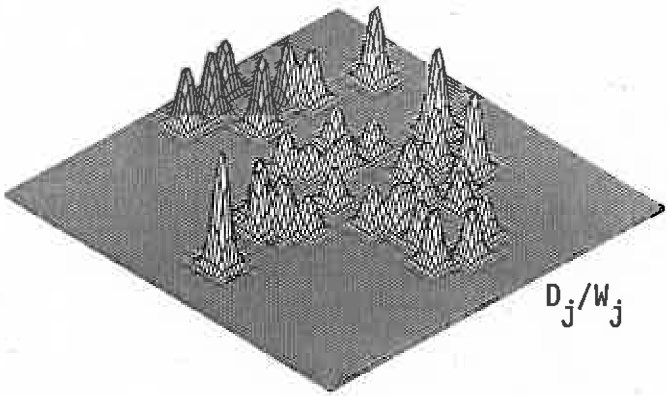
0.433291256	0.374155819	0.403830945	0.605099976	0.636527121	0.953882337	0.920001388
0.928788900	0.848393440	0.772972286	1.05515289	0.639955521	0.989950001	0.413438737
0.848762214	0.660849094	0.518244982	1.14325237	1.13043308	0.738223672	0.738017321
0.725858212	0.609471440	0.542746246	0.715466380	0.914340913	0.745173514	0.641704738
0.527931690	0.514930367	0.259986401	0.922602832	0.554002643	0.945225358	

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

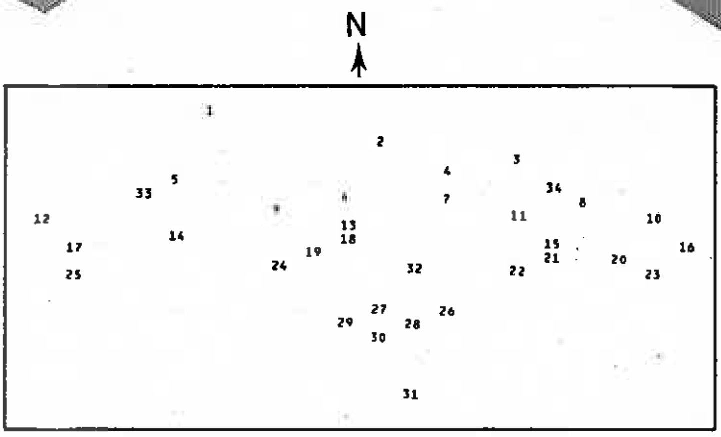
1.74392319	2.06360340	1.90244102	1.24535370	1.15490913	0.763879240	0.784368157
0.782835782	0.861907065	0.950307786	0.671680033	1.15707207	0.739640296	1.74112797
0.828545272	1.16619205	1.41002274	0.654751956	0.628268480	0.972404182	0.962696254
0.993936718	1.32682419	1.36815262	0.967944086	0.794701695	0.960770786	1.12981606
1.38540745	1.43120098	2.90390587	0.775523305	1.32630157	0.764370799	



D_j



D_j/W_j



Key to location of centres

Figure 14 Facility-based indicators for aggregate flow model

$\alpha = 1.00$, $\beta = 2.15$: all person types, all retail goods

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

8022.05078 (1)	10524.3789	8180.50000	4483.27344	9239.27344	4201.31641	5412.07812
1409.07251	11549.4141	6366.72266	6985.06641	4165.45312	3402.09888	10098.2344
8613.03906	17836.3633	5498.89453	1701.97754	2386.19800	1262.48706	1731.00903
3668.51733	6748.00781	15046.5625	10736.3477	4161.23828	2808.27588	5539.28516
4427.37891	3081.88403	4070.13745	24013.0195	8223.06641	3286.77124	4658.95312

CATCHMENT POPULATION OF CENTRE J

10616.4141	13630.6836	10648.0195	5949.42578	12568.1914	5765.88281	7499.91016
1937.98560	15794.3516	8667.64453	9856.02734	5625.38281	4646.41797	14028.3867
12250.2070	23148.6523	7525.26172	2273.74878	3360.03369	1759.99097	2437.57129
5089.51172	8357.94922	20265.2266	15505.0039	5760.67187	3929.26440	7671.55859
6064.09766	4190.73437	5408.01953	33611.3125	11191.2695	4549.16797	6051.31641

REVENUE PER CATCHMENT POPULATION

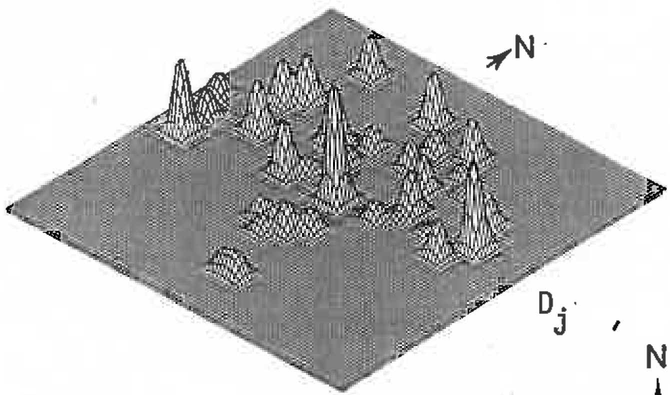
0.755627155	0.772109389	0.768264890	0.753564000	0.735131502	0.728650987	0.721619010
0.727081001	0.731236935	0.734538913	0.708710074	0.740474582	0.732198179	0.719842851
0.703093290	0.770514071	0.730724633	0.748533666	0.710170805	0.717325866	0.710136771
0.720799446	0.807375968	0.742481828	0.692444026	0.722352922	0.714707732	0.722054720
0.730096877	0.735404253	0.752611399	0.714432657	0.734775066	0.722499371	0.769907355

FLOORSPACE PER CATCHMENT POPULATION

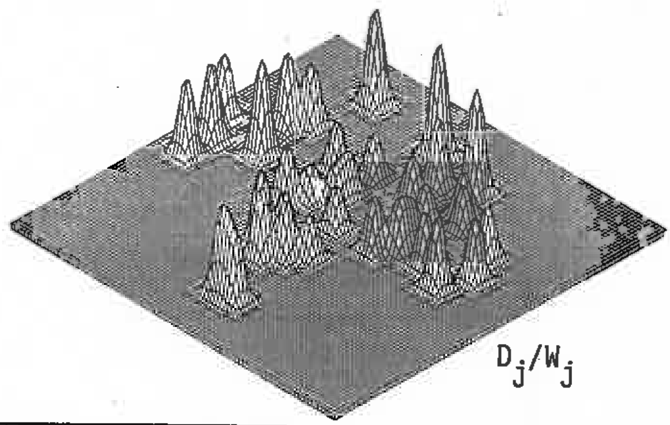
0.433291256	0.374155819	0.403830945	0.605100393	0.636527538	0.953886867	0.920010984
0.928799450	0.848404527	0.772989690	1.05519104	0.639956415	0.990009904	0.413447380
0.848965228	0.660945594	0.518254399	1.14348602	1.13094044	0.738640130	0.738439918
0.726985216	0.610197484	0.542801678	0.715897858	0.954749703	0.763501644	0.690863490
0.544186473	0.572691977	0.462276399	0.928258896	0.554003239	0.945227742	0.578386545

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

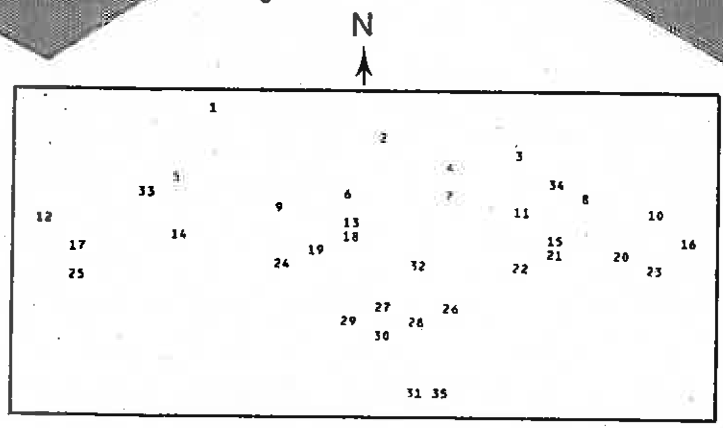
1.74392319	2.06360340	1.90244102	1.24535370	1.15490913	0.763875663	0.784359097
0.782818019	0.861896515	0.950257063	0.671640992	1.15707016	0.739586711	1.74107456
0.828176796	1.16577530	1.40997219	0.654606700	0.627946794	0.971143842	0.961671650
0.991491139	1.32313824	1.36786842	0.967238486	0.756588757	0.936091959	1.04514790
1.34162903	1.28411770	1.62805462	0.769648015	1.32630062	0.764365375	1.33112907



D_j



D_j/W_j



Key to location of centres

Figure 15 Facility-based indicators for aggregate flow model with the addition of a new centre at Middleton (no 35)

$\alpha = 1.00$, $\beta = 2.15$: all person types, all retail goods

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

1832.52905	(1) 4945.95703	521.106934	1111.25366	2171.12085	859.653564	562.254639 (
605.485596	1351.56543	284.783691	1091.21753	637.251709	40.7466888	1559.72949
337.996094	1431.85327	73.4465179	65.3666534	22.6915131	185.414749	45.8060760
141.166565	351.038086	677.086182	379.024902	752.247070	23.1161194	229.972397
502.203613	217.191574	202.551315	1750.43652	575.036133	1388.95947	1492.81812
941.100586	619.312988	560.734619				

CATCHMENT POPULATION OF CENTRE J

1843.04956	4960.26953	522.300537	1112.78882	2186.22974	865.605957	564.482178
612.012939	1356.43994	293.231201	1098.07935	639.006104	40.9796448	1572.34204
342.904297	1456.65796	73.9994812	65.8529510	22.9844971	189.294525	46.5213776
143.601654	356.615479	682.435303	385.196777	765.619629	23.4464722	233.563034
508.605469	220.642212	207.969376	1778.65674	577.600586	1397.13354	1504.05176
952.295654	625.133789	568.468750				

REVENUE PER CATCHMENT POPULATION

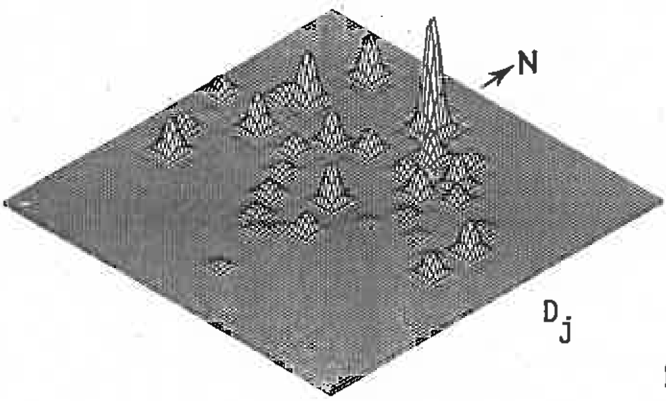
0.994291782	0.997114539	0.997714698	0.998620391	0.993089020	0.993123412	0.996053815
0.989334583	0.996406376	0.971191585	0.993751049	0.997254491	0.994315267	0.991978467
0.985686362	0.982971489	0.992527425	0.992615342	0.987252951	0.979503989	0.984624207
0.983042717	0.984360158	0.992161691	0.983977318	0.982533634	0.985910296	0.984626651
0.987412870	0.984360933	0.973947763	0.984133959	0.995560110	0.994149387	0.992531061
0.988244116	0.990688682	0.986394763				

FLOORSPACE PER CATCHMENT POPULATION

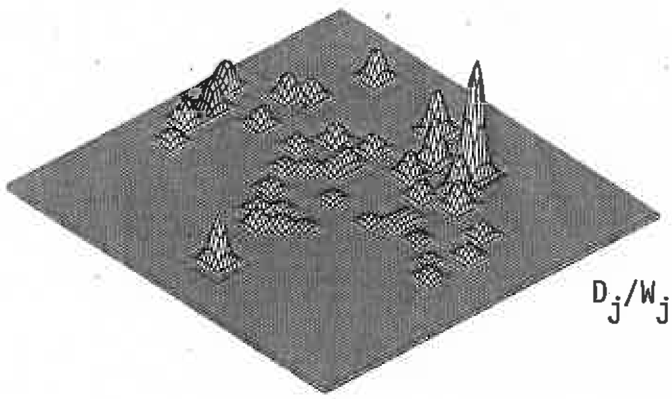
1.35644722	0.907208741	0.382921278	0.898643076	2.05833721	2.31051922	1.77153492
1.63395214	1.99050426	2.72822189	2.27670193	1.56492996	2.44023514	2.22597790
4.08277130	3.15791321	1.35136032	3.03706932	4.35075855	5.28277206	4.29909801
4.87459564	4.20621109	1.75840759	4.15372086	5.87759209	4.26503372	3.42519951
2.94924068	2.26611137	0.961679995	4.49777603	1.73129940	1.07362652	2.99191761
3.67532825	3.19931507	3.51822281				

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

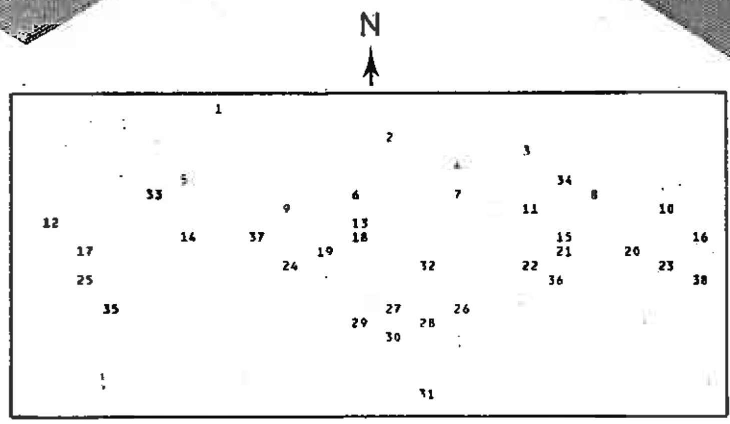
0.733011603	1.09910107	2.60553455	1.11125278	0.482471287	0.429826736	0.562254608
0.605485559	0.500579774	0.355979562	0.436486959	0.637251675	0.407466888	0.445636988
0.241425753	0.311272442	0.734465122	0.326833248	0.226915121	0.185414732	0.229030371
0.201666474	0.234025359	0.564238429	0.236890554	0.167165995	0.231161177	0.287465453
0.334802389	0.434383094	1.01275635	0.218804538	0.575036108	0.925972939	0.331737339
0.268885851	0.309656441	0.280367255				



D_j



D_j/W_j



Key to location of centres

Figure 16 Facility-based indicators for flow model using professional socio-economic group and grocery outlets

(α = 1.00, β = 2.15)

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

137.659393 (1)	250.363602	30.6395416	98.6865540	358.429199	247.865875	141.432785
124.976288	301.460205	133.034500	414.378418	146.036835	19.5800323	564.756104
322.664551	655.865723	19.3247681	34.5728607	12.6779175	175.919724	46.6416626
150.160889	158.017975	142.843994	203.405701	526.437988	12.3001623	124.983368
212.162323	95.6619568	216.708832	1335.26733	104.368210	141.631699	335.342529
202.379105	217.215775	247.612076				

CATCHMENT POPULATION OF CENTRE J

386.852051	703.907471	82.9156036	260.691162	928.416504	630.357178	358.667236
322.194092	766.414795	343.732910	1041.40527	368.841064	48.9995575	1427.42725
806.245605	1673.34619	49.1302032	86.5873718	32.0770874	442.658936	116.654007
376.356445	398.671875	370.071777	518.992920	1331.98584	31.2864838	318.003418
543.484375	246.668381	549.370361	3361.98389	268.257080	369.475098	869.865967
508.741211	554.935059	633.826172				

REVENUE PER CATCHMENT POPULATION

0.355845034	0.355676830	0.369526803	0.378557324	0.386065066	0.393214941	0.394328654
0.387891293	0.393338144	0.387028694	0.397903085	0.395934284	0.399596095	0.395646155
0.400206268	0.391948581	0.393337786	0.399282932	0.395232797	0.397415936	0.399829030
0.398985803	0.396360934	0.385989964	0.391923845	0.395227909	0.393146157	0.393025219
0.390374243	0.387816012	0.394467592	0.397166431	0.389060378	0.383332133	0.385510564
0.397803605	0.391425550	0.390662432				

FLOORSPACE PER CATCHMENT POPULATION

6.46241856	6.39288521	2.41209030	3.83595657	4.84696198	3.17280388	2.78809929
3.10371876	3.52289581	2.32738781	2.40060234	2.71119404	2.04083443	2.45196342
1.73644352	2.74898243	2.03540707	2.30980492	3.11748981	2.25907516	1.71447086
1.85993862	3.76249218	3.24261379	3.08289337	3.37841415	3.19626808	2.51569557
2.75996876	2.02701283	0.364053130	2.37954712	3.72776699	4.05981350	5.17321014
6.87972546	3.60402489	3.15543842				

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

0.550637543E-01	0.556363538E-01	0.153197706	0.986865163E-01	0.796508789E-01	0.123932898	0.141432762
0.124976277	0.111651897	0.166293085	0.165751338	0.146036804	0.195800304	0.161358833
0.230474651	0.142579496	0.193247676	0.172864258	0.126779139	0.175919712	0.233208299
0.214515507	0.105345309	0.119036615	0.127128541	0.116986215	0.123001575	0.156229198
0.141441524	0.191323876	1.08354378	0.166908383	0.104368210	0.944210887E-01	0.745205283E-
0.578226000E-01	0.108607829	0.123806000				

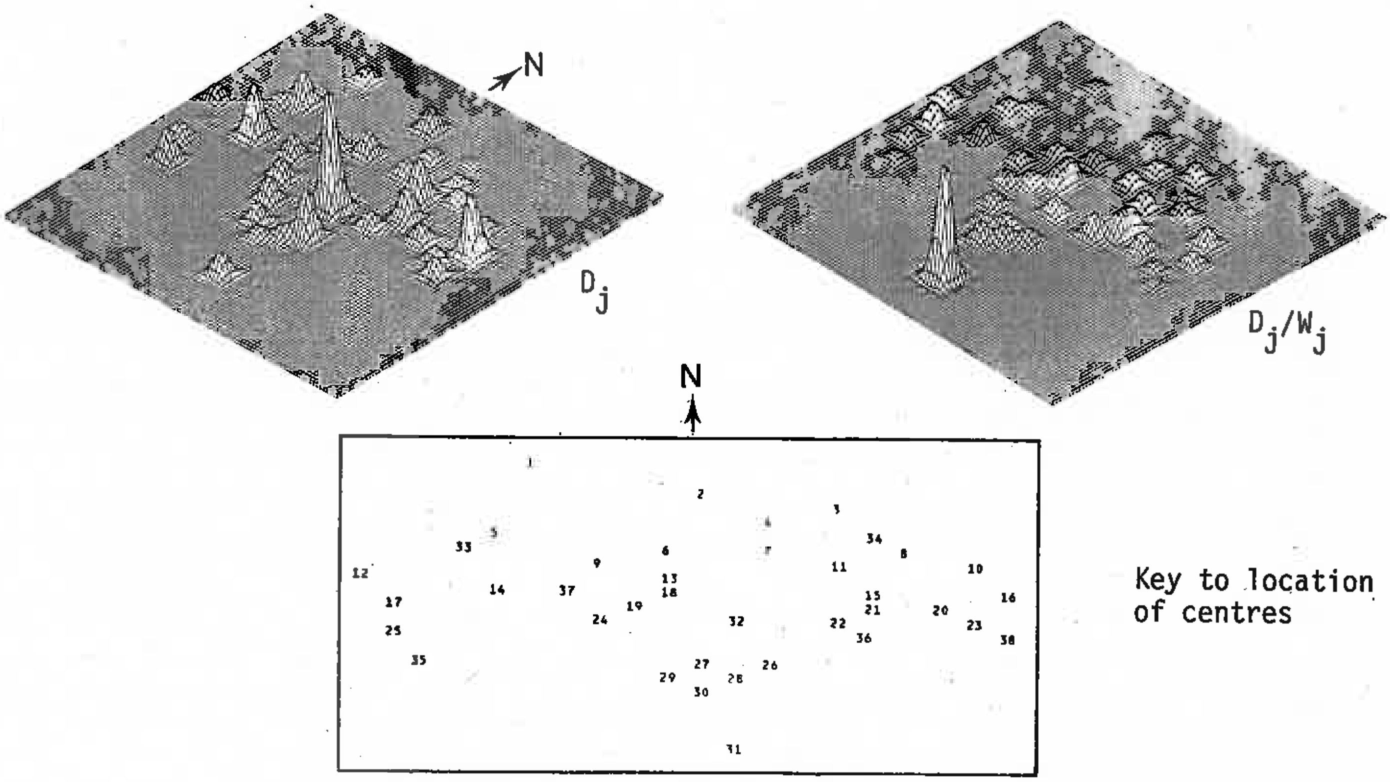


Figure 17 Facility-based indicators for flow model using unemployed persons and grocery outlets
(α = 1.00, β = 2.15)

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

636.415283 (1)	1354.65674	138.864960	382.333008	1085.12305	490.469482	287.165771
267.092529	739.830078	257.760010	586.732422	355.101074	28.0748749	1201.96826
428.845703	1232.65186	49.8740387	49.7806702	22.9761963	257.227783	68.1764679
244.429596	262.446533	428.149658	446.002197	989.501465	25.3582458	260.017090
495.115234	215.693741	311.751709	2222.71948	304.230225	432.509277	919.393555
473.372314	539.301270	570.567139				

CATCHMENT POPULATION OF CENTRE J

1473.42065	3128.04614	319.688965	875.480957	2482.89160	1124.18115	656.110596
613.670410	1685.28345	594.061523	1342.40161	805.468506	63.8335419	2734.75928
974.960449	2832.93433	113.303162	113.138504	52.3774567	589.099854	154.915359
554.914307	605.638428	976.199951	1016.73169	2260.13892	57.7333527	592.435547
1126.31543	491.989502	712.586182	5050.32422	692.357178	998.384277	2100.52295
1097.68018	1228.95117	1299.29395				

REVENUE PER CATCHMENT POPULATION

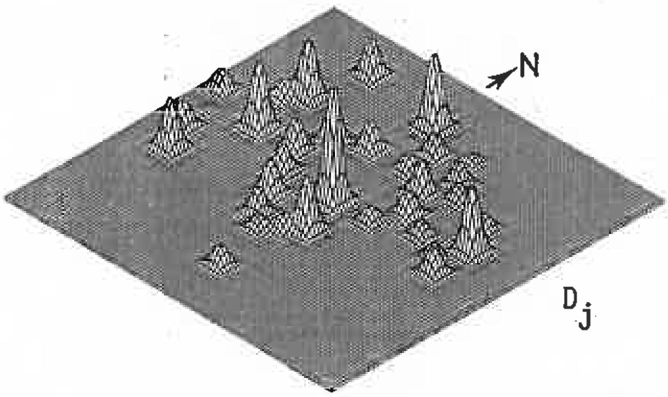
0.431930423	0.433067977	0.434375167	0.436711907	0.437040031	0.436290383	0.437678874
0.435237706	0.438994408	0.433894455	0.437076628	0.440862715	0.439813793	0.439515173
0.439859569	0.435114861	0.440182209	0.439997554	0.438665748	0.436645448	0.440088451
0.440481663	0.433338583	0.438588023	0.438662589	0.437805593	0.439230382	0.438895106
0.439588428	0.438411236	0.437493324	0.440114200	0.439412236	0.433209181	0.437697411
0.431247890	0.438830495	0.439136267				

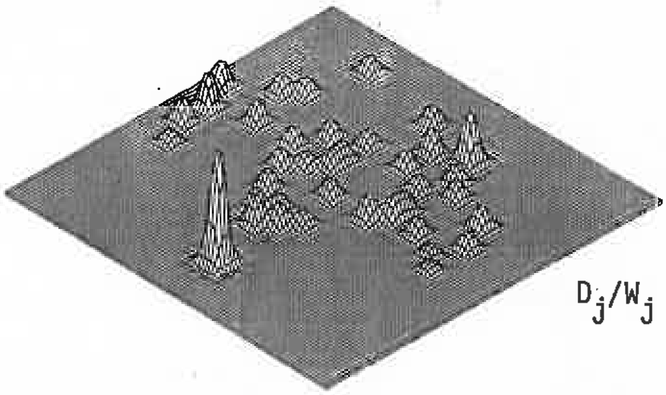
FLOORSPACE PER CATCHMENT POPULATION

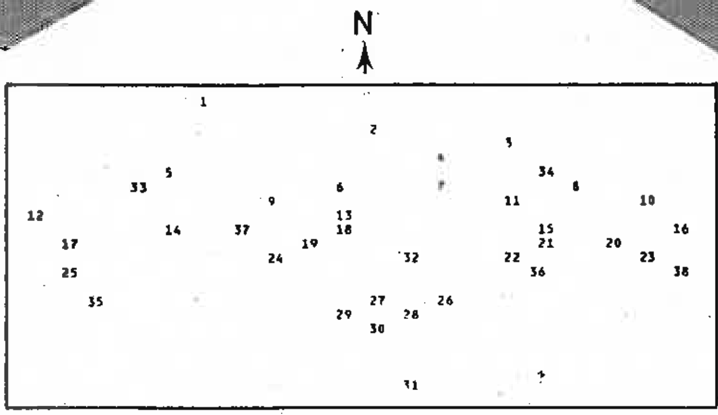
1.69673157	1.43859768	0.625608027	1.14222908	1.81240273	1.77907181	1.52413273
1.62953854	1.60210419	1.34666157	1.86233330	1.24151325	1.56657410	1.27981949
1.43595505	1.62375736	0.882587850	1.76774406	1.90921783	1.69750500	1.29102707
1.26145554	2.47672462	1.22925568	1.57366943	1.99102783	1.73210049	1.35035706
1.33177567	1.01628113	0.280667782	1.58405590	1.44434071	1.50242710	2.14232349
3.18854237	1.62740326	1.53929710				

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

0.254566073	0.301034808	0.694324791	0.382332981	0.241138399	0.245234728	0.287165761
0.267092526	0.274011135	0.322200000	0.234692931	0.355101049	0.280748725	0.343419492
0.306318343	0.267967761	0.498740375	0.248903334	0.229761958	0.257227778	0.340882301
0.349185109	0.174964309	0.356791377	0.278751373	0.219889164	0.253582418	0.325021327
0.330076814	0.431387424	1.55875778	0.277839899	0.304230213	0.288339496	0.204309642
0.135249197	0.269650578	0.285283566				







Key to location of centres

Figure 18 Facility-based indicators for flow model using retired persons and grocery outlets
(α = 1.00, β = 2.15)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	14.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	28.	27.	23.	19.	19.	21.	22.	21.	18.	16.	15.	14.	13.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	34.	31.	26.	21.	22.	26.	28.	26.	22.	20.	20.	19.	17.	13.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	27.	33.	33.	33.	26.	22.	25.	30.	33.	30.	25.	24.	25.	24.	21.	17.	13.	9.	0.	0.	0.	0.	0.
0.	0.	0.	22.	26.	30.	32.	29.	24.	21.	26.	32.	32.	31.	27.	28.	30.	28.	24.	19.	15.	13.	11.	10.	0.	0.	0.
0.	0.	0.	25.	28.	29.	28.	26.	22.	21.	24.	28.	31.	29.	29.	30.	30.	30.	26.	21.	18.	17.	16.	15.	0.	0.	0.
0.	0.	0.	29.	32.	34.	32.	27.	24.	25.	26.	26.	27.	29.	30.	30.	30.	30.	28.	24.	21.	22.	22.	20.	0.	0.	0.
0.	0.	27.	32.	35.	35.	34.	29.	29.	30.	30.	31.	29.	30.	32.	30.	31.	30.	30.	26.	25.	27.	27.	25.	22.	0.	0.
0.	25.	28.	33.	34.	35.	31.	29.	33.	36.	34.	32.	30.	31.	32.	33.	34.	32.	29.	27.	30.	33.	32.	29.	25.	22.	0.
0.	30.	28.	30.	32.	31.	28.	30.	36.	36.	35.	32.	30.	30.	32.	34.	34.	34.	29.	28.	32.	34.	35.	32.	29.	25.	0.
0.	30.	30.	28.	30.	31.	29.	29.	33.	35.	33.	32.	31.	30.	30.	32.	34.	34.	31.	28.	31.	36.	38.	36.	32.	27.	22.
0.	31.	31.	29.	31.	32.	31.	28.	30.	31.	32.	33.	34.	35.	34.	32.	34.	34.	33.	29.	31.	37.	38.	38.	33.	28.	23.
0.	32.	32.	31.	30.	32.	29.	28.	32.	34.	33.	34.	39.	42.	39.	34.	33.	34.	31.	28.	31.	35.	38.	36.	32.	27.	22.
30.	34.	36.	34.	29.	27.	26.	29.	35.	35.	35.	36.	41.	42.	42.	36.	32.	31.	28.	27.	31.	33.	34.	32.	29.	25.	20.
0.	37.	37.	37.	30.	25.	24.	28.	33.	35.	33.	35.	39.	42.	39.	35.	31.	28.	25.	24.	29.	32.	31.	28.	25.	22.	0.
0.	35.	37.	35.	30.	23.	21.	25.	28.	29.	30.	32.	34.	36.	35.	33.	29.	25.	22.	21.	24.	27.	26.	24.	21.	18.	0.
0.	31.	32.	31.	27.	21.	18.	20.	23.	25.	28.	31.	32.	34.	33.	32.	27.	23.	19.	18.	19.	21.	21.	20.	17.	14.	0.
0.	26.	27.	26.	23.	18.	15.	17.	20.	24.	28.	30.	32.	32.	33.	30.	26.	21.	17.	14.	14.	15.	16.	15.	13.	10.	0.
0.	22.	22.	21.	18.	14.	12.	14.	18.	22.	27.	30.	30.	31.	29.	26.	23.	19.	14.	11.	10.	10.	10.	10.	8.	6.	0.
0.	0.	17.	16.	13.	9.	8.	11.	15.	20.	23.	26.	28.	27.	25.	23.	19.	16.	12.	8.	6.	5.	5.	4.	3.	0.	0.
0.	0.	0.	10.	8.	5.	5.	9.	13.	16.	20.	22.	24.	24.	22.	20.	17.	13.	9.	5.	2.	1.	0.	-1.	0.	0.	0.
0.	0.	0.	5.	2.	1.	2.	6.	10.	14.	17.	21.	26.	28.	26.	21.	17.	12.	8.	3.	-1.	-3.	-5.	-6.	0.	0.	0.
0.	0.	0.	0.	-3.	-3.	-1.	3.	8.	12.	18.	24.	30.	30.	30.	24.	18.	13.	7.	2.	-2.	-6.	-9.	0.	0.	0.	0.
0.	0.	0.	0.	0.	-6.	-3.	2.	7.	12.	18.	23.	28.	31.	28.	24.	18.	13.	7.	2.	-3.	-8.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.	6.	11.	16.	21.	24.	26.	24.	21.	17.	12.	7.	1.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	4.	9.	13.	17.	20.	21.	20.	17.	14.	10.	5.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(a) Measure of consumers' surplus $CS_i = \sum_j S_{ij}(\alpha/\beta \log W_j - c_{ij})$

(b) Effective provision per capita (see text)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	6.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	6.	6.	6.	6.	5.	5.	6.	6.	6.	6.	7.	7.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	6.	6.	6.	5.	5.	5.	6.	6.	6.	7.	7.	7.	8.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	6.	6.	6.	6.	6.	6.	6.	5.	5.	6.	6.	7.	7.	7.	8.	8.	9.	10.	0.	0.	0.	0.	0.
0.	0.	0.	7.	7.	7.	6.	6.	7.	7.	6.	6.	6.	6.	7.	7.	7.	7.	8.	9.	10.	10.	10.	10.	0.	0.	0.
0.	0.	0.	8.	8.	8.	8.	8.	9.	9.	8.	7.	7.	7.	8.	8.	8.	8.	10.	10.	11.	10.	10.	10.	0.	0.	0.
0.	0.	0.	8.	8.	8.	8.	9.	10.	11.	11.	10.	10.	9.	10.	9.	10.	11.	11.	11.	11.	10.	10.	10.	0.	0.	0.
0.	0.	8.	8.	8.	8.	9.	10.	11.	12.	12.	12.	12.	11.	11.	12.	12.	12.	12.	12.	11.	11.	10.	10.	10.	0.	0.
0.	8.	8.	8.	8.	8.	9.	10.	11.	12.	12.	13.	13.	12.	13.	13.	14.	13.	13.	12.	11.	10.	10.	10.	9.	9.	0.
0.	8.	8.	8.	8.	8.	9.	10.	12.	12.	12.	13.	13.	13.	13.	14.	14.	14.	13.	12.	11.	10.	10.	9.	9.	9.	0.
0.	8.	8.	7.	7.	7.	8.	10.	12.	12.	13.	13.	13.	13.	13.	13.	13.	13.	12.	11.	10.	9.	9.	9.	9.	9.	9.
0.	8.	7.	7.	7.	7.	7.	10.	11.	12.	13.	13.	13.	13.	13.	13.	12.	12.	12.	11.	10.	9.	9.	9.	9.	9.	9.
0.	7.	7.	7.	7.	7.	8.	10.	11.	12.	13.	13.	13.	13.	13.	12.	12.	12.	11.	10.	9.	9.	9.	9.	9.	9.	9.
7.	7.	7.	7.	7.	7.	8.	10.	11.	12.	12.	13.	13.	13.	13.	12.	12.	11.	11.	10.	9.	8.	8.	8.	8.	8.	9.
0.	7.	7.	7.	7.	8.	9.	10.	11.	11.	12.	12.	13.	13.	13.	12.	12.	11.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	10.	11.	11.	11.	12.	12.	12.	12.	12.	12.	12.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	10.	10.	10.	10.	10.	11.	11.	12.	12.	12.	12.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	8.	8.	9.	10.	10.	9.	9.	9.	9.	10.	11.	11.	11.	11.	11.	10.	9.	9.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	9.	9.	9.	8.	8.	9.	9.	10.	11.	11.	11.	11.	11.	10.	9.	9.	8.	8.	8.	0.
0.	0.	7.	7.	8.	8.	9.	9.	9.	8.	8.	8.	8.	9.	9.	10.	10.	10.	11.	11.	10.	9.	9.	8.	8.	0.	0.
0.	0.	0.	7.	8.	8.	9.	9.	8.	8.	8.	7.	7.	7.	7.	8.	9.	9.	10.	10.	10.	10.	9.	9.	0.	0.	0.
0.	0.	0.	8.	8.	8.	8.	8.	8.	7.	7.	6.	5.	5.	5.	6.	6.	7.	8.	9.	9.	9.	9.	9.	0.	0.	0.
0.	0.	0.	0.	8.	8.	8.	7.	7.	6.	5.	4.	4.	4.	4.	4.	5.	6.	7.	8.	8.	9.	9.	0.	0.	0.	0.
0.	0.	0.	0.	0.	7.	7.	6.	6.	5.	4.	4.	4.	4.	4.	4.	4.	5.	5.	6.	7.	8.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	6.	5.	4.	4.	4.	4.	4.	4.	4.	4.	4.	5.	5.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	5.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(c) Average transport expenditure $C_i = (\sum_j S_{ij} C_{ij} / \sum_j S_{ij})$

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.	25.	27.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	11.	12.	16.	21.	21.	19.	18.	19.	21.	23.	24.	25.	27.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	8.	14.	19.	17.	14.	12.	14.	17.	19.	19.	20.	22.	26.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	12.	6.	6.	7.	13.	18.	15.	9.	7.	10.	14.	15.	14.	15.	18.	22.	27.	31.	0.	0.	0.	0.	0.
0.	0.	0.	18.	14.	10.	8.	10.	16.	19.	14.	8.	7.	8.	12.	11.	9.	11.	15.	20.	24.	27.	29.	31.	0.	0.	0.
0.	0.	0.	16.	13.	12.	12.	15.	19.	20.	16.	12.	9.	10.	10.	9.	9.	9.	14.	18.	22.	24.	25.	26.	0.	0.	0.
0.	0.	0.	12.	9.	7.	10.	15.	18.	17.	16.	14.	13.	11.	10.	10.	9.	9.	12.	16.	19.	19.	20.	22.	0.	0.	0.
0.	0.	14.	9.	6.	6.	8.	14.	14.	13.	12.	10.	12.	11.	9.	10.	10.	9.	9.	14.	15.	14.	15.	17.	21.	0.	0.
0.	14.	13.	8.	7.	6.	10.	13.	10.	7.	8.	10.	11.	10.	10.	9.	8.	9.	11.	13.	11.	8.	10.	14.	18.	22.	0.
0.	9.	11.	11.	9.	10.	13.	13.	8.	7.	7.	9.	12.	13.	10.	9.	8.	8.	12.	13.	9.	8.	8.	11.	15.	19.	0.
0.	8.	10.	12.	11.	9.	12.	14.	11.	8.	9.	10.	11.	14.	14.	11.	8.	8.	11.	14.	11.	7.	6.	8.	12.	17.	22.
0.	8.	9.	11.	9.	9.	10.	15.	13.	11.	10.	10.	10.	11.	12.	12.	9.	8.	9.	12.	12.	7.	6.	6.	11.	16.	21.
0.	9.	8.	9.	11.	9.	12.	14.	11.	8.	9.	9.	8.	6.	8.	11.	9.	8.	10.	12.	11.	8.	6.	8.	12.	17.	22.
12.	8.	6.	8.	12.	15.	16.	14.	8.	8.	8.	10.	6.	5.	6.	9.	11.	10.	13.	13.	10.	9.	8.	11.	15.	19.	23.
0.	6.	6.	6.	12.	17.	19.	15.	10.	8.	11.	11.	8.	6.	7.	10.	12.	14.	16.	16.	12.	9.	11.	14.	18.	22.	0.
0.	8.	6.	8.	13.	19.	21.	18.	15.	14.	14.	12.	10.	9.	9.	11.	15.	17.	20.	20.	16.	14.	15.	18.	21.	25.	0.
0.	12.	11.	12.	16.	22.	24.	22.	19.	17.	13.	10.	9.	8.	9.	10.	15.	20.	23.	24.	22.	20.	20.	22.	25.	28.	0.
0.	17.	16.	17.	20.	25.	28.	25.	22.	17.	11.	9.	7.	8.	8.	12.	16.	21.	25.	28.	27.	26.	25.	27.	29.	32.	0.
0.	21.	21.	22.	25.	29.	31.	28.	23.	17.	12.	9.	9.	8.	11.	14.	19.	23.	28.	31.	32.	31.	31.	32.	34.	36.	0.
0.	0.	26.	27.	30.	33.	33.	29.	24.	19.	15.	12.	11.	12.	14.	18.	21.	26.	30.	34.	36.	37.	37.	37.	38.	0.	0.
0.	0.	0.	33.	35.	37.	36.	31.	27.	22.	19.	16.	14.	14.	16.	19.	23.	27.	32.	36.	39.	41.	42.	42.	0.	0.	0.
0.	0.	0.	38.	40.	41.	38.	34.	29.	25.	20.	16.	11.	8.	11.	16.	22.	27.	32.	37.	42.	45.	47.	48.	0.	0.	0.
0.	0.	0.	0.	45.	44.	40.	35.	30.	25.	20.	13.	7.	6.	7.	13.	19.	25.	32.	37.	43.	47.	50.	0.	0.	0.	0.
0.	0.	0.	0.	0.	46.	42.	36.	31.	25.	19.	13.	8.	6.	8.	13.	18.	24.	31.	37.	43.	48.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	37.	31.	26.	21.	16.	12.	11.	12.	15.	20.	25.	31.	37.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	33.	28.	23.	19.	17.	16.	17.	19.	23.	27.	32.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	21.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 19 Set of residence-based indicators: aggregate flow model without new centre at Middleton

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0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	14.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	28.	27.	23.	19.	19.	21.	22.	21.	18.	16.	15.	14.	13.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	34.	31.	26.	21.	22.	26.	28.	26.	22.	20.	20.	19.	17.	13.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	27.	33.	33.	33.	26.	22.	25.	30.	33.	30.	25.	24.	25.	24.	21.	17.	13.	9.	0.	0.	0.	0.	0.
0.	0.	0.	22.	26.	30.	32.	29.	24.	21.	26.	32.	32.	31.	27.	28.	30.	28.	24.	19.	15.	13.	11.	10.	0.	0.	0.
0.	0.	0.	25.	28.	29.	28.	26.	22.	21.	24.	28.	31.	29.	29.	30.	30.	30.	26.	21.	18.	17.	16.	15.	0.	0.	0.
0.	0.	0.	29.	32.	34.	32.	27.	24.	25.	26.	26.	27.	29.	30.	30.	30.	30.	28.	24.	21.	22.	22.	20.	0.	0.	0.
0.	0.	27.	32.	35.	35.	34.	29.	29.	30.	30.	31.	29.	30.	32.	30.	31.	30.	30.	26.	25.	27.	27.	25.	22.	0.	0.
0.	25.	28.	33.	34.	35.	31.	29.	33.	36.	34.	32.	30.	31.	32.	33.	34.	32.	29.	27.	30.	33.	32.	29.	25.	22.	0.
0.	30.	28.	30.	32.	31.	28.	30.	36.	36.	35.	32.	30.	30.	32.	34.	34.	34.	29.	28.	32.	34.	35.	32.	29.	25.	0.
0.	30.	30.	28.	30.	31.	29.	29.	33.	35.	33.	32.	31.	30.	30.	32.	34.	34.	31.	28.	31.	36.	38.	36.	32.	27.	22.
0.	31.	31.	29.	31.	32.	31.	28.	30.	31.	32.	33.	34.	35.	34.	32.	34.	34.	33.	29.	31.	37.	38.	38.	33.	28.	23.
0.	32.	32.	31.	30.	32.	29.	28.	32.	34.	33.	34.	39.	42.	39.	34.	33.	34.	31.	28.	31.	35.	38.	36.	32.	27.	22.
30.	34.	36.	34.	29.	27.	26.	29.	35.	35.	35.	36.	41.	42.	42.	36.	32.	31.	28.	27.	31.	33.	34.	32.	29.	25.	20.
0.	37.	37.	37.	30.	25.	24.	28.	33.	35.	33.	35.	39.	42.	39.	35.	31.	28.	25.	24.	29.	32.	31.	28.	25.	22.	0.
0.	35.	37.	35.	30.	23.	21.	25.	28.	29.	30.	32.	34.	36.	35.	33.	29.	25.	22.	21.	24.	27.	26.	24.	21.	18.	0.
0.	31.	32.	31.	27.	21.	18.	20.	23.	25.	28.	31.	32.	34.	33.	32.	27.	23.	19.	18.	19.	21.	21.	20.	17.	14.	0.
0.	26.	27.	26.	23.	18.	15.	17.	20.	24.	28.	30.	32.	32.	33.	30.	25.	21.	17.	14.	14.	15.	16.	15.	13.	10.	0.
0.	22.	22.	21.	18.	14.	12.	14.	18.	22.	27.	30.	30.	31.	29.	26.	22.	18.	14.	11.	10.	10.	10.	10.	8.	6.	0.
0.	0.	17.	16.	13.	9.	8.	11.	15.	19.	23.	26.	28.	27.	25.	22.	19.	16.	12.	8.	6.	5.	5.	4.	3.	0.	0.
0.	0.	0.	10.	7.	5.	5.	8.	12.	16.	19.	22.	24.	25.	24.	23.	20.	16.	11.	7.	3.	1.	0.	-1.	0.	0.	0.
0.	0.	0.	5.	2.	0.	2.	6.	10.	13.	17.	22.	26.	29.	30.	28.	23.	18.	13.	8.	3.	-2.	-4.	-6.	0.	0.	0.
0.	0.	0.	0.	-3.	-3.	-1.	3.	8.	13.	18.	23.	29.	32.	32.	31.	26.	20.	15.	9.	3.	-2.	-6.	0.	0.	0.	0.
0.	0.	0.	0.	0.	-6.	-3.	2.	7.	12.	18.	23.	28.	31.	31.	29.	25.	20.	15.	9.	4.	-2.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	1.	6.	11.	16.	20.	24.	26.	27.	25.	22.	18.	13.	8.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	4.	9.	13.	17.	20.	21.	22.	21.	18.	15.	11.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(a) Measure of consumers' surplus $CS_i = \sum_j S_{ij}(\alpha/\beta \log W_j - c_{ij})$

(b) Effective provision per capita (see text)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	6.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	6.	6.	6.	6.	5.	5.	6.	6.	6.	6.	7.	7.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	6.	6.	6.	5.	5.	5.	6.	6.	6.	7.	7.	7.	8.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	6.	6.	6.	6.	6.	6.	6.	5.	5.	6.	6.	7.	7.	7.	8.	8.	9.	10.	0.	0.	0.	0.	0.
0.	0.	0.	7.	7.	7.	6.	6.	7.	7.	6.	6.	6.	6.	7.	7.	7.	7.	8.	9.	10.	10.	10.	10.	0.	0.	0.
0.	0.	0.	8.	8.	8.	8.	8.	9.	9.	8.	7.	7.	7.	8.	8.	8.	8.	10.	10.	11.	10.	10.	10.	0.	0.	0.
0.	0.	0.	8.	8.	8.	8.	9.	10.	11.	11.	10.	10.	9.	10.	9.	10.	11.	11.	11.	11.	10.	10.	10.	0.	0.	0.
0.	0.	8.	8.	8.	8.	9.	10.	11.	12.	12.	12.	12.	11.	11.	12.	12.	12.	12.	12.	11.	11.	10.	10.	10.	0.	0.
0.	8.	8.	8.	8.	8.	9.	10.	11.	12.	12.	13.	13.	12.	13.	13.	14.	13.	13.	12.	11.	10.	10.	10.	9.	9.	0.
0.	8.	8.	8.	8.	8.	9.	10.	12.	12.	12.	13.	13.	13.	13.	14.	14.	14.	13.	12.	11.	10.	10.	9.	9.	9.	0.
0.	8.	8.	7.	7.	7.	8.	10.	12.	12.	13.	13.	13.	13.	13.	13.	13.	13.	12.	11.	10.	9.	9.	9.	9.	9.	9.
0.	8.	7.	7.	7.	7.	7.	10.	11.	12.	13.	13.	13.	13.	13.	13.	12.	12.	12.	11.	10.	9.	9.	9.	9.	9.	9.
0.	7.	7.	7.	7.	7.	8.	10.	11.	12.	13.	13.	13.	13.	13.	12.	12.	12.	11.	10.	9.	9.	9.	9.	9.	9.	9.
7.	7.	7.	7.	7.	7.	8.	10.	11.	12.	12.	13.	13.	13.	13.	12.	12.	11.	11.	10.	9.	8.	8.	8.	8.	9.	9.
0.	7.	7.	7.	7.	8.	9.	10.	11.	11.	12.	12.	13.	13.	13.	12.	12.	11.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	10.	11.	11.	11.	12.	12.	12.	13.	12.	12.	12.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	10.	11.	10.	10.	10.	11.	11.	12.	12.	12.	12.	11.	10.	9.	8.	8.	8.	8.	8.	0.
0.	7.	7.	7.	8.	8.	9.	10.	10.	10.	9.	10.	10.	11.	11.	12.	12.	12.	11.	11.	9.	9.	8.	8.	8.	8.	0.
0.	7.	7.	7.	7.	8.	9.	9.	9.	9.	9.	9.	9.	10.	11.	11.	11.	11.	11.	11.	10.	9.	9.	8.	8.	8.	0.
0.	0.	7.	7.	8.	8.	9.	9.	9.	9.	9.	9.	9.	9.	10.	10.	10.	10.	11.	11.	10.	9.	9.	9.	8.	0.	0.
0.	0.	0.	7.	8.	8.	9.	9.	9.	9.	8.	8.	8.	8.	8.	8.	9.	9.	9.	10.	10.	9.	9.	9.	0.	0.	0.
0.	0.	0.	8.	8.	8.	9.	9.	8.	8.	8.	8.	7.	7.	7.	8.	8.	8.	8.	9.	9.	9.	9.	9.	0.	0.	0.
0.	0.	0.	0.	8.	8.	8.	8.	8.	8.	7.	7.	7.	7.	7.	7.	7.	7.	8.	8.	8.	9.	9.	0.	0.	0.	0.
0.	0.	0.	0.	0.	8.	8.	8.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	8.	8.	8.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	7.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(c) Average transport expenditure $C_i = (\sum_j S_{ij} C_{ij} / \sum_j S_{ij})$

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.	25.	27.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	11.	12.	16.	21.	21.	19.	18.	19.	21.	23.	24.	25.	27.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	6.	8.	14.	19.	17.	14.	12.	14.	17.	19.	19.	20.	22.	26.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	12.	6.	6.	7.	13.	18.	15.	9.	7.	10.	14.	15.	14.	15.	18.	22.	27.	31.	0.	0.	0.	0.	0.
0.	0.	0.	18.	14.	10.	8.	10.	16.	19.	14.	8.	7.	8.	12.	11.	9.	11.	15.	20.	24.	27.	29.	31.	0.	0.	0.
0.	0.	0.	16.	13.	12.	12.	15.	19.	20.	16.	12.	9.	10.	10.	9.	9.	9.	14.	18.	22.	24.	25.	26.	0.	0.	0.
0.	0.	0.	12.	9.	7.	10.	15.	18.	17.	16.	14.	13.	11.	10.	10.	9.	9.	12.	16.	19.	19.	20.	22.	0.	0.	0.
0.	0.	14.	9.	6.	6.	8.	14.	14.	13.	12.	10.	12.	11.	9.	10.	10.	9.	9.	14.	15.	14.	15.	17.	21.	0.	0.
0.	14.	13.	8.	7.	6.	10.	13.	10.	7.	8.	10.	11.	10.	10.	9.	8.	9.	11.	13.	11.	8.	10.	14.	18.	22.	0.
0.	9.	11.	11.	9.	10.	13.	13.	8.	7.	7.	9.	12.	13.	10.	9.	8.	8.	12.	13.	9.	8.	8.	11.	15.	19.	0.
0.	8.	10.	12.	11.	9.	12.	14.	11.	8.	9.	10.	11.	14.	14.	11.	8.	8.	11.	14.	11.	7.	6.	8.	12.	17.	22.
0.	8.	9.	11.	9.	9.	10.	15.	13.	11.	10.	10.	10.	11.	12.	12.	9.	8.	9.	12.	12.	7.	6.	6.	11.	16.	21.
0.	9.	8.	9.	11.	9.	12.	14.	11.	8.	9.	9.	8.	6.	8.	11.	9.	8.	10.	12.	11.	8.	6.	8.	12.	17.	22.
12.	8.	6.	8.	12.	15.	16.	14.	8.	8.	8.	10.	6.	5.	6.	9.	11.	10.	13.	13.	10.	9.	8.	11.	15.	19.	23.
0.	6.	6.	6.	12.	17.	19.	15.	10.	8.	11.	11.	8.	6.	7.	10.	12.	14.	16.	16.	12.	9.	11.	14.	18.	22.	0.
0.	8.	6.	8.	13.	19.	21.	18.	15.	14.	14.	12.	10.	9.	9.	12.	15.	17.	20.	20.	16.	14.	15.	18.	21.	25.	0.
0.	12.	11.	12.	16.	22.	24.	22.	19.	17.	13.	10.	9.	8.	9.	10.	15.	20.	23.	24.	22.	20.	20.	22.	25.	28.	0.
0.	17.	16.	17.	20.	25.	28.	26.	22.	17.	11.	9.	7.	8.	8.	12.	16.	21.	26.	28.	27.	26.	25.	27.	29.	32.	0.
0.	21.	21.	22.	25.	29.	31.	28.	23.	17.	12.	9.	9.	8.	11.	15.	19.	23.	28.	31.	32.	31.	31.	32.	34.	36.	0.
0.	0.	26.	27.	30.	33.	33.	29.	24.	20.	15.	12.	11.	12.	15.	17.	21.	25.	29.	33.	36.	37.	37.	37.	39.	0.	0.
0.	0.	0.	33.	35.	37.	36.	32.	27.	23.	19.	16.	14.	14.	14.	16.	19.	24.	28.	33.	38.	41.	42.	43.	0.	0.	0.
0.	0.	0.	38.	40.	41.	38.	34.	29.	25.	20.	16.	11.	8.	7.	10.	15.	20.	26.	32.	37.	42.	45.	47.	0.	0.	0.
0.	0.	0.	0.	45.	44.	40.	35.	30.	25.	20.	14.	8.	6.	5.	7.	12.	18.	24.	30.	36.	42.	47.	0.	0.	0.	0.
0.	0.	0.	0.	0.	46.	42.	36.	31.	25.	20.	14.	9.	6.	6.	8.	13.	18.	23.	29.	35.	41.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	37.	32.	26.	21.	17.	13.	11.	11.	12.	16.	20.	24.	30.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	33.	28.	24.	20.	17.	16.	16.	17.	19.	23.	27.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	21.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Figure 20 Set of residence-based indicators: aggregate flow model with new centre at Middleton

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

4880.03906 (1)	5205.92187	5097.42578	3064.15039	7581.69531	6935.60547	7600.07422 (
2878.58228	11084.6758	6685.43750	9926.05469	4025.95215	7354.32422	4570.67187
6091.33594	9277.42969	14766.7695	3981.96411	3104.45068	4200.69141	1247.54761
1646.26367	10432.1680	6202.07031	10783.2812	13435.8047	7870.84375	6221.86719
3100.57642	5624.07031	1028.41382	1167.52954	22259.2773	6381.43750	3040.58887

CATCHMENT POPULATION OF CENTRE J

9948.70703	14764.3437	11021.3008	4677.36719	13291.5625	5612.51953	7153.38672
2256.10767	15148.9961	6828.12891	9806.32031	4570.81250	4139.14844	9012.90625
16406.5391	10179.1992	27401.5352	5285.49609	1380.46924	2190.07129	820.005859
1232.46167	7397.60937	6821.82812	22524.6406	15501.6484	7834.65625	4940.27656
3431.97241	5983.90625	1466.59814	2337.95361	43802.6250	9624.77734	2740.36157

REVENUE PER CATCHMENT POPULATION

0.490519881	0.352600932	0.462506711	0.655101478	0.570414126	1.23573780	1.06244373
1.27590561	0.731710196	0.979102373	1.01220989	0.881938238	1.77677155	0.507125199
0.371274829	0.911410511	0.538902998	0.753375649	2.24883652	1.91806126	1.52138805
1.33575153	1.41020775	0.909150720	0.478732546	0.866733909	1.00461864	1.25942898
0.903438568	0.939866006	0.701223969	0.499390946	0.508172214	0.663021803	1.10955715

FLOORSPACE PER CATCHMENT POPULATION

0.462371538	0.345426798	0.390153527	0.769663751	0.501885557	0.979952037	0.964578032
0.797834216	0.884547055	0.981235037	1.06054020	0.770743847	1.11133957	0.383332009
0.353517532	1.02169132	0.558362842	0.737868249	1.98341713	1.73510265	1.58535385
1.46049118	0.590161529	0.747600138	0.488354027	0.716052830	0.702009082	0.607259572
1.54430103	0.551479220	1.63643932	1.06931114	0.712286055	0.644170702	1.56913567

REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

1.06087780	1.02076817	1.18544765	0.851152637	0.947711885	1.26101875	1.10145950
1.59921169	0.827214599	0.997826457	0.954428315	1.11831951	1.59876537	1.30590534
1.05023003	0.892060518	0.965148330	1.02101612	1.19401932	1.10544491	0.959651947
0.914590895	2.81950474	1.21609211	0.980298281	1.21043205	1.43106174	2.07395554
0.585014403	1.70426369	0.428505719	0.467011809	0.713438332	1.02926350	0.707113683

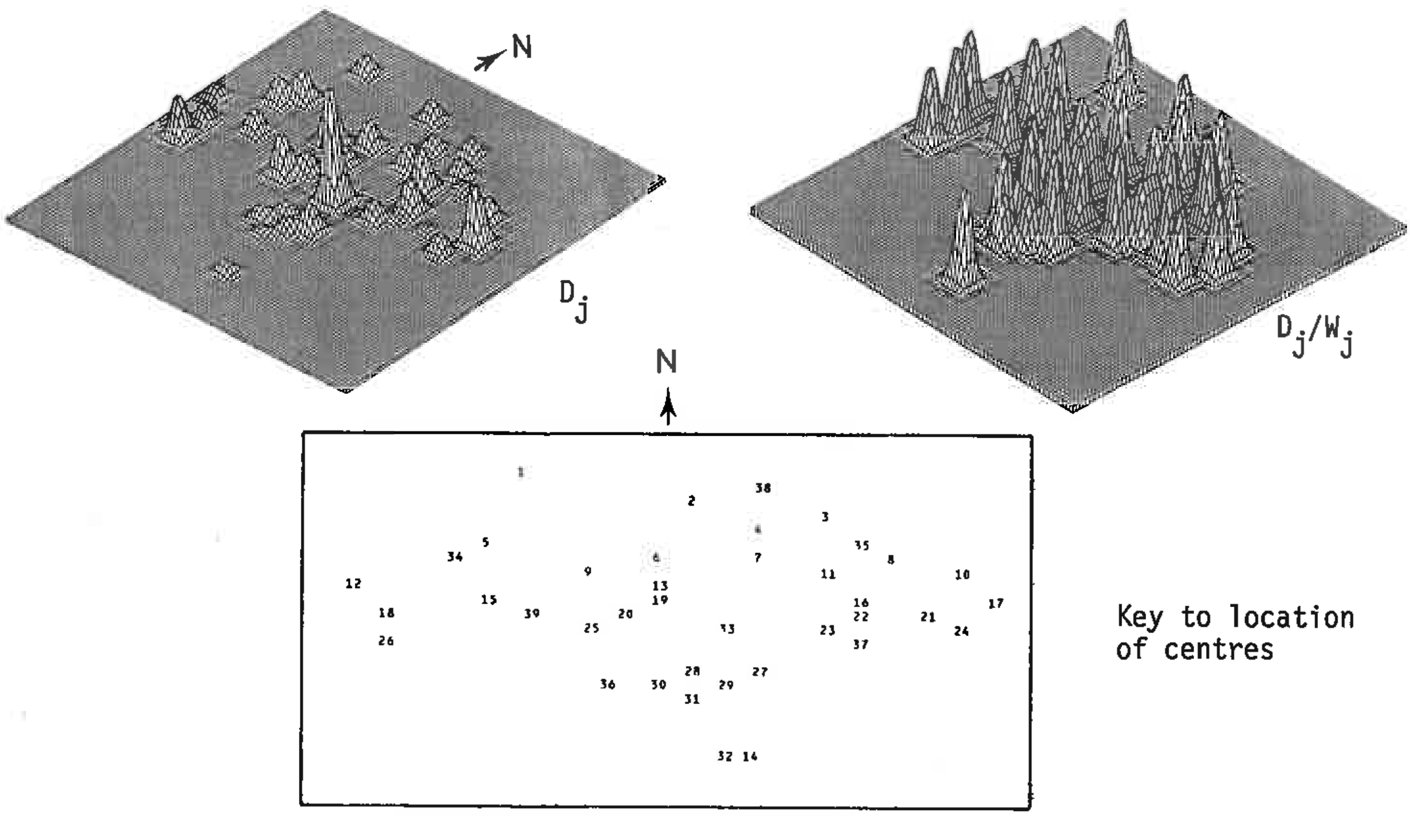


Figure 21 Facility-based indicators for equilibrium model with centre-specific attractiveness and cost terms

(1) represents number of centre

REVENUE ATTRACTED TO CENTRE J (D_j)

5194.39453 (1)	250.210403	1029.72876	1738.21973	7384.55469	9365.49219	8854.96094 (7
2420.31763	11054.7852	6516.32812	9448.19531	4017.68188	6706.42969	4582.80859
3392.22632	9611.94141	14911.5156	4844.78906	3368.15015	7133.68359	1002.25684
1422.96216	7695.62500	5832.69922	9769.23828	6347.35547	8085.20312	5096.93750
4261.73047	878.361572	899.151611	1104.74805	21718.8203	7165.64453	6058.48437
4915.52344	2129.79443	7375.29297	5540.50781			

CATCHMENT POPULATION OF CENTRE J

10580.5352	733.226562	2231.13330	2665.68408	12947.1328	7566.07422	8321.36328
1895.65479	15103.7656	6655.35547	9320.06250	4663.01953	3771.76343	9067.15625
9137.15625	10542.9648	27657.3359	6431.57031	1497.94873	3729.29175	658.109375
1064.57764	5454.07812	6410.50000	20426.3398	7369.44141	8062.77344	4063.44678
4729.49609	943.502197	1291.51196	2225.47632	42836.8047	10814.1250	5429.64844
9364.19531	2339.83301	19941.3516	9693.47656			

REVENUE PER CATCHMENT POPULATION

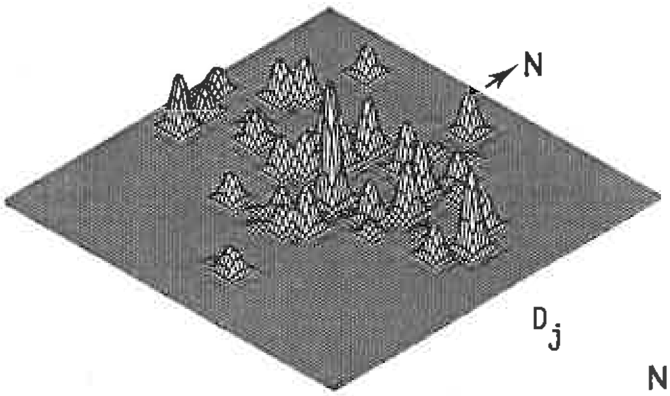
0.490938723	0.341245651	0.461527169	0.652072608	0.570362151	1.23782635	1.06412315
1.27677059	0.731922448	0.979110420	1.01374722	0.861605167	1.77806187	0.505429506
0.371256232	0.911692441	0.539152265	0.753282428	2.24850750	1.91287804	1.52293301
1.33664417	1.41098499	0.909866452	0.478266656	0.861307502	1.00278187	1.25433826
0.901096046	0.930958688	0.696200728	0.496409655	0.507013023	0.662618935	1.11581516
0.524927437	0.910233498	0.369849145	0.571570754			

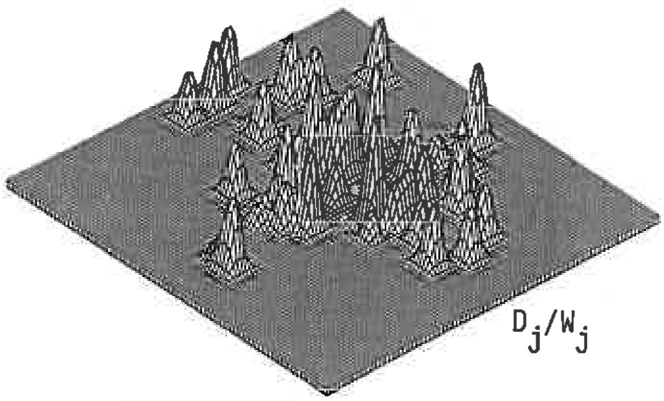
FLOORSPACE PER CATCHMENT POPULATION

0.434760571	6.95555782	1.92727089	1.35049725	0.617897391	0.726929128	0.829191029
0.949539959	0.887195945	1.00670719	1.11587143	0.772031903	1.21958828	0.386008561
0.634770751	0.986439764	0.553198576	0.606383741	1.73570633	1.01896000	1.97535515
1.69081116	0.678391397	0.795569718	0.538520336	1.50621986	0.682147384	0.738289475
1.12062645	3.49760628	1.85828686	1.12335491	0.728345633	0.573324203	0.791948140
0.533948660	2.13690376	0.250735223	0.515810788			

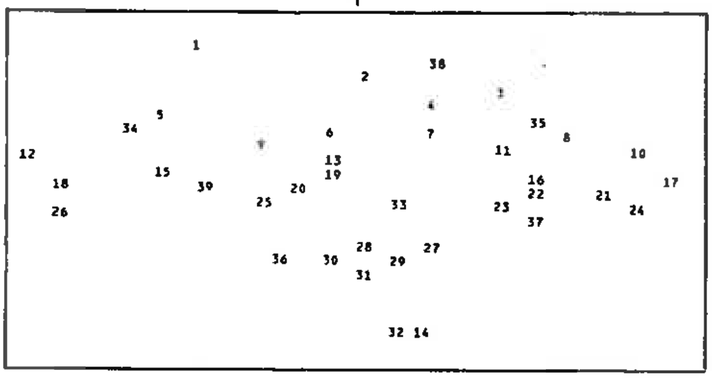
REVENUE PER SQ. FOOT OF FLOORSPACE (D_j/W_j)

1.12921619	0.490608625E-01	0.239471793	0.482838809	0.923069298	1.70281601	1.28332710
1.34462070	0.824983954	0.972586274	0.908480287	1.11602211	1.45791912	1.30937386
0.584866583	0.924225092	0.974608839	1.24225330	1.29544163	1.87728500	0.770966768
0.790534496	2.07989788	1.14366627	0.888112545	0.571833789	1.47003651	1.69897842
0.804100037	0.266170144	0.374646485	0.441899180	0.696116030	1.15574837	1.40894985
0.983104646	0.425958872	1.47505856	1.10810089			





N



Key for location of centres

Figure 22 Facility-based indicators for equilibrium model with centre-specific attractiveness and cost terms and the addition of four new retail centres