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STORE AND SHOPPING CENTRE LOCATION AND SIZE: A REVIEW OF BRITISH RESEARCH AND PRACTICE

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INTRODUCTION

There are a number of ways in which a review can be organised, ranging from a chronological presentation of work done (with some evaluation) to a conceptual framework to which individual contributions can be attached; or on another axis, from commercial application as the prime focus to academic viewpoint. I have chosen to emphasise a particular conceptual framework as being the most effective basis for the argument in an attempt to lend coherence to this particular presentation (rather than to claim unique validity). This approach has the advantage that it is then relevant to any point on the commercial-academic spectrum and can be used to situate and appraise a variety of applications and research studies of each kind. The review is 'British' in the sense that much of the research described was carried out in Britain, but inevitably there are some antecedents and follow-up research in other countries to which it is also appropriate to refer.

It is also useful at the outset to emphasise that I have treated this paper as a review of ideas and practice and worked on the basis that the argument will be more readable if I do not also make it a detailed literature review at the same time. There are relatively few references cited in the text, therefore; but I have tried to compensate by providing an extensive bibliography on the relevant aspects of retailing.

The objective is to focus on either store or shopping centre location and size. On the whole, these are best treated as separate problems but, as we will see, it is possible in principle to link the

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two scales - though at the expense of raising difficult research problems. The discussion will be presented, therefore, in terms of retail facilities (or units) and most of the analyses can then be applied at either of the two scales.

It is only possible to understand location and size issues properly by relating possible sites to markets: that is, to demand at residential (or workplace) locations and the flows (which should also be related to transport costs) from origins to facilities. This basic underlying conceptualisation is shown in Figure 1. The principal agents in the system of interest are therefore consumers and retailers, and they are connected by expenditure flows. The retailers' operations will be influenced by relationships with a variety of other kinds of agents: manufacturers of goods, wholesalers, distributors and transport firms, developers, financiers and land owners. Town planners and transport planners will also be involved. We will focus on consumers and retailers, however - interpreting the latter as developers if we are working at the scale of 'centres' - but within a framework where explicit connections to the interests of other kinds of agents can be pursued. The system of interest will be referred to as the retail system, defined in an appropriate way for a particular study.

We then make a major distinction between analysis and application. The argument is that a good analytical framework is vital if any applied study is to be successful. We attempt to provide this framework with analysis based on modelling concepts. There are thus two major sections of the paper: the first is devoted to analysis and modelling; and the second to applications. This also helps us to keep a clear line of argument on the prior assumptions which have to be made in different types of study: 'pure' analysis, interpreting history and predicting development in terms of 'likely' behaviour of retailers; studies for one retailer against a set of assumptions about the likely behaviour of competitors; and so on. These are important distinctions which will be pursued when we review different kinds of application below.

We proceed, therefore, with two major sections on analysis and applications and then follow with some concluding comments, including a discussion about priority areas for further research and development.

ANALYSIS AND MODELLING

Preliminaries.

In any particular piece of analysis (or indeed application) it is necessary to define the system of interest, and especially the level of resolution at which it is viewed. We have argued that there are three main elements to a model: demand, flow and facility supply. We would expect demand to be related to per capita expenditures and to residential (say by zone i) (and possibly workplace) populations; and that these quantities should be disaggregated by type of good, say g, and person (or household) type, say m. We would expect the retail facilities to be characterised in relation to location (say j), goods available and (possibly type of shop, say h). This would imply that the flow terms were characterised by g, m and h and perhaps should also be related to transport costs by mode (say k). Note that each of these indices could in principle be a list. Thus, we might have $m = \underline{m}$ = (car ownership, social class, household structure).

The key variables thus defined are shown on Figure 2. Already, the flow array has five dimensions and there is in addition, transport mode k. Important judgements have to be made in any analysis or application on how much information is necessary and on how much can be feasibly handled - in the hope that both are compatible! In the following, we will simplify slightly, but still keep a good degree of realism, by dropping the store type category, h and transport mode, k - though noting how they can be added back if necessary (cf. Wilson, 1983, for the details). We also neglect trips made from workplaces, for simplicity of exposition, on the same basis.

We thus have demand characterised by E_i^{mg}, the flows by S_{ij}^{mg} and retail supply in terms of revenue, D_j^g and attractiveness, W_j^{mg}. We will show later how these supply variables are functions of an array of variables, X_{jk}^g, k = 1, 2, 3, ... which characterise actual supply - floorspace, goods stocked and so on.

This articulation of levels of disaggregation and a corresponding set of algebraic variables provides the beginnings of a conceptualisation for an analysis. (Note also that we have implicitly assumed the existence of appropriate residential and retail zoning systems. This is convenient for both practical (data) reasons and, as will become clear, for analytical reasons).

It can now be argued that any analytical approach can be stated and discussed in relation to these main arrays of variables. We first examine some traditional and approximate analyses in this light and then proceed to assemble the elements of a modelling approach.

Traditional and approximate analyses

In this subsection, we briefly review the approaches (and in some cases contemporary variants of them) which precede the existence of modern modelling techniques - dating from before the mid-sixties say. We also include some more recent approaches which can be seen as generating useful approximations for key variables in appropriate circumstances where the full detail and power of modelling is not necessary*.

It is useful in this context to distinguish the 'centre' and 'store' problems. The former has its traditional analytical roots in central place theory (Christaller, 1933, Losch, 1940) as exemplified in the work of someone like Berry (1967). There are useful notions of hierarchy and use of concepts like the 'range of a good', but essentially the theory is based on non-overlapping market areas and has a very rigid underlying geometry. It can be used to give an idea of structure at a broad scale, but in general can be considered outmoded by the types of model to be presented below.

At the store location scale, a variety of techniques are in common use, which range from the almost wholly intuitive to the beginnings of formal modelling. Simplest of all is a reliance on the experience of senior staff with no formal analysis. A close relative of this is the so-called parasitic method: allow larger stores to do the job for you and simply locate near to them. But we can then progress to a range of ideas which do involve some kind of formal analysis. Applebaum's analogue method is popular: evaluate a potential site by finding a similar site elsewhere with a similar shop, and build up a sales forecast

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* In the rest of this subsection, I rely heavily on material provided by Graham Clarke and I am most grateful for his help.

by comparison. Other methods involve calculating indices of some kind. Towsey (1972) cites Lichfield's 'index of shopping effectiveness', which essentially involves calculating per capita expenditure in a town divided by per capita expenditure for its region and using that as an indicator of site value. There is another which estimates 'retail saturation', and Bucklin's (1971) index which is, in effect, a rule of thumb for estimating market potential. Multiple regression models provide a means of estimating potential and taking advantage of more data. There has even been an attempt to make sense of a mound of data in the retail context using factor analysis (Davies, 1973). The most detailed of all the traditional analyses, however, is the painstaking identification and measurement of trade areas: estimating demand for each of a large number of small areas, and then allocating this to possible sites. A variety of rules have been used for this. In many cases, there is still an attempt - even with Converse's use of Reilly's (1929, 1931) gravity model to establish 'break points' (cf. Huff, 1964) - to delineate sharp market area boundaries.

The imperfections of any of these approaches can be readily seen simply by setting them against the algebraic framework established earlier for the description of a retail system. This made it clear that there should be three major elements of any analysis: demand, flow and supply (or attraction). The only acceptable contribution to contemporary methods from traditional analyses is the estimation of demand in some trade area analyses. The other methods do not make any detailed estimate of the market or when they do, they do not account for overlapping market areas. Again, none of the methods except trade area analysis, make any explicit estimate of flows. Some of the methods, the Lichfield index, for example, can be seen as representing approximate methods for measuring site attractiveness.

It does not need a detailed investigation to reveal the weaknesses of the non-modelling methods. The history of the alternative approach now spans more than 20 years. It is based on the flow models developed by Huff (1964), Harris (1964) and Lakshmanan and Hansen (1965). In that period, there has been a tremendous advance in technical capability associated with this kind of model - and with alternatives which can be reviewed within that framework. Perhaps because of the relative difficulty of implementing the models, their use is far from universal.

However, the rest of this narrative uses this approach as a foundation and demonstrates the technical capability which is now available.

The organisation of the rest of the argument.

The construction of flow models, with associated estimates of demand and attractiveness, are basic to further development and we consider this topic next. Additionally, it has now become possible to analyse the structure of whole retail systems and to provide important new insights on this basis. These ideas are presented in two sections, the first concerned with an updated comparative statics, the second a fully dynamic approach. We complete the section on analysis by showing how an integrated approach can be built up, taking advantage of the range of forecasts and insights which can be generated.

Flow models.

We briefly noted the early history of these models in the 1960's and that considerable development has taken place since then. Space is not available to give a detailed account of this history and so the presentation is focussed on a particular, if broad, formulation which is representative of the position which has now been reached.

We begin by presenting a model in very general terms which exhibits the main functional inter-relationships involved. We use the variables defined earlier, adding the vector notation $\underline{X}_j^g = \{X_{j1}^g, X_{j2}^g, \ldots\}$ of the components of supply for convenience.

$$e_i^{mg} = e_i^{mg}(e_i^{mgo}, \{\underline{X}_j^g\}, \{c_{ij}\}) \tag{1}$$

This functional relationship indicates that per capita expenditure at i is a function of some 'latent demand' estimate e_i^{mgo} together with the pattern of supply, $\{\underline{X}_j^g\}$, as perceived from i and mediated through the travel cost vector, $\{c_{ij}\}$.

Then, of course:

$$E_i^{mg} = e_i^{mg} \; P_i^m \tag{2}$$

Attractiveness can be written

$$W_j^{mg} = W_j^{mg}(\underline{X}_j^g, \underline{\alpha}_j^{mg}) \qquad (3)$$

where $\underline{\alpha}_j^{mg}$ is a vector of parameters, α_{jk}^{mg} being associated with X_{jk}^g, which measures the strength of each factor as a component of attractiveness for each income group. Travel impedance can be formally written as

$$f_{ij} = f(c_{ij}, \beta^{mg}) \qquad (4)$$

where β^{mg} is a parameter which measures ease of travel for the m-group for good g. f is a function which declines with c_{ij} to an extent determined by β^{mg}.

These elements can then be combined into a flow model as follows:

$$S_{ij}^{mg} = \frac{E_i^{mg} W_j^{mg} f_{ij}}{\sum_k W_k^{mg} f_{ik}} \qquad (5)$$

The denominator ensures that

$$\sum_j S_{ij}^{mg} = E_i^{mg} \qquad (6)$$

It also has the important effect of representing the effects of competition between retailers in the attraction of consumers - as a subtle combination of store/centre attractiveness and the travel cost function which relate these to distance from each residential zone.

The flow model can be used to predict revenue:

$$D_j^g = \sum_{im} S_{ij}^{mg} \qquad (7)$$

To complete the formal picture, we should also recognise that travel cost should itself be thought of as a generalised cost made up of a number of components:

$$c_{ij} = m_{ij} + at_{ij} + be_{ij} + p_i^{(1)} + p_j^{(2)} \qquad (8)$$

m_{ij} is the out-of-pocket money cost; t_{ij}, the travel time; e_{ij}, the 'excess time', e.g. spent waiting in bus queues; $p_i^{(1)}$, the origin costs; and $p_j^{(2)}$, the terminal costs, such as parking charges. Alternative functional forms may, of course, sometimes be appropriate.

To fix ideas, it is useful to present the model with specific functional forms for e_i^{mg}, W_j^{mg} and f_{ij}. Assume that e_i^{mg} is, in fact, constant. This is a reasonable assumption for an urban area with well-defined m-groups. (For a specification of a fully elastic demand model, see Wilson, 1985). Take

$$W_j^{mg} = (X_{j1}^g)^{\alpha_1^{mg}} (X_{j2}^g)^{\alpha_2^{mg}} \ldots \tag{9}$$

for a sequence of factors of attractiveness, and

$$f_{ij} = e^{-\beta^{mg} c_{ij}} \tag{10}$$

Then the flow model can be written

$$S_{ij}^{mg} = (e_i^{mg} P_i^m) \frac{\{(X_{j1}^g)^{\alpha_1^{mg}} (X_{j2}^g)^{\alpha_2^{mg}} \ldots\} e^{-\beta^{mg} c_{ij}}}{\sum_k \{(X_{k1}^g)^{\alpha_1^{mg}} (X_{k2}^g)^{\alpha_2^{mg}} \ldots\} e^{-\beta^{mg} c_{ik}}} \tag{11}$$

We now have a fully specified flow model. The X-factors are determined by retail management and planning - of all retailers in competition, or considered 'en masse' in centres. The transport system is reflected in the c_{ij}'s. e_i^{mg} and P_i^m can be determined from surveys and forecast in subsidiary models. The α and β parameters can be estimated. All terms on the right hand side of (11) are therefore known. Flows can be calculated; total revenues can be calculated from (7). There are, of course, subtleties in use, but we postpone a discussion of these until the section on applications.

Structural models and comparative statics.

We now pose a further question: at any time, is there potentially a stable equilibrium retail structure? To answer this, the analytical issue has to be posed in a certain way. We have to add hypotheses about retailer behaviour and then pursue the implications of competition along with all the other properties of demand, travel and the alternative patterns of supply. For ease of presentation, consider a single person type and a single good type, and assume that attractiveness can be measured through a single factor - floorspace (defined as W_j and appearing as an attractiveness function raised to the power α). The flow model then becomes

$$S_{ij} = \frac{E_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_k W_k^{\alpha} e^{-\beta c_{ik}}} \tag{12}$$

The complexities of the real world can be added again when the basic principles which lead to the new insights have been explained. Revenue attracted is

$$D_j = \sum_i S_{ij} = \sum_i \frac{E_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_k W_k^{\alpha} e^{-\beta c_{ik}}} \tag{13}$$

We now need to define the retailer's cost of supplying facilities in j, say C_j. We can assume this is a function of W_j for simplicity and that it refers to the same time period, say a year, as D_j:

$$C_j = C_j(W_j) \tag{14}$$

Then a simple hypothesis has to be added on retailer/developer behaviour which will help us to tackle the question as to whether there are stable patterns which are representative of various types of situation. It is this: if $D_j > C_j$, we expect W_j to grow; and vice versa. If there is an equilibrium, it occurs when

$$D_j = C_j \tag{15}$$

That is (using (13) and (14)), when

$$\sum_i \frac{E_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_k W_k^{\alpha} e^{-\beta c_{ik}}} = C_j(W_j) \tag{16}$$

If we make the even simpler assumption that cost is linear (and this turns out not to affect the character of the argument) with

$$C_j(W_j) = k_j W_j \tag{17}$$

for constants, k_j, then the simultaneous equations (16) become

$$\sum_i \frac{E_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_k W_k^{\alpha} e^{-\beta c_{ik}}} = k_j W_j \tag{18}$$

These equations are highly nonlinear: each term in the sum on the left hand side has a denominator which involves all the W_k's - in effect, because of the complexities of competition between retailers across space. Bu they can be solved numerically for the equilibrium pattern, $\{W_j\}$, and it is possible to manipulate them so as to gain considerable and important analytical insights (cf. Harris and Wilson, 1978). These can be summarised in the following points.

(i) There is, typically, a 'global' equilibrium for a given set of parameters and exogenous variables which has the greatest possible number of non zero W_j's for that situation and which can be interpreted as the pattern which maximises consumers' surplus.

(ii) There are many other stable equilibria which can be constructed by setting some of the non zero W_j's of the global solution to zero, or vice versa; and any of these are likely to occur in reality because real retailers will not necessarily locate their facilities precisely in accord with the model! However, each of these could be said to represent a <u>typical pattern</u>, say in terms of overall number and size of facilities, for that parameter set.

(iii) As parameters change - as they do, with shifting population distribution, new transport facilities, new α's or β's, and changing incomes - then it can be shown that even if these changes are slow and smooth, there can be <u>jumps</u> in the type of pattern of critical parameter values. The shift from corner shop food retailing to supermarkets is thought to be an example of this kind. (cf. Wilson and Oulton, 1983).

This all means that retailers and developers should be aware of these underlying structures both in relation to new and existing stores and centres. An example for an idealised grid, with an even distribution of population and ubiquitous and even transport access, is shown in Figure 3. These are alternative patterns for different α and β values. Clearly, higher α and lower β imply fewer, larger stores or centres. Figure 4 shows the importance of transport costs through the effect of emphasising cheaper travel to the centre. Figure 5 shows the effect of varying land prices, and Figure 6 a now realistic-looking structure derived by combining both of these additional features. Through this kind of fine-tuning, it is beginning to be possible to simulate a real system as shown for examples from Leeds in Figure 7. Finally, in a different way, the effects of jumps in pattern at critical parameter values are shown for a region of Nottingham in Figure 8.

It is now possible to add back all the necessary detail for a more realistic structural model. There are three aspects to this.

First, to shift to an appropriate level of disaggregation, re-introducing person types, m and types of good, g (and possibly store types, h). This would involve giving an account of the attractiveness function in terms of X-factors, and these should include terms which represent, for a good g, the proximity of stores selling other types of goods. This allows the inclusion of agglomeration effects in relation to consumers' scale economics and, together with other features, lays the foundations for this style of modelling functioning as a replacement for central place theory.

The second area of elaboration relates to the adjustment mechanism. In the example above, the basis of the mechanism was profitability, but only size of store or centre was adjusted. In reality, there would be some possibility of adjustment of prices of goods sold; and also a land rent distribution would evolve to reflect the comparative advantage of different locations. These mechanisms can be added to the comparative static structural model, but in this paper, we show how to include them in a full dynamic model - with the equilibrium solution as a by-product - in the next subsection below.

Thirdly, it is obviously necessary to refine the account of retailers costs, rather than simply assuming them to be proportional to floorspace. The different components would all have to be brought to a common time period - say a year - and would include land, floor-space (ie. buildings), labour, interest on capital, costs of goods for sale and costs of other inputs.

We will discuss in the next subsection but one the effects of combining all these elements into an integrated attack on the task of building an effective retail model system.

Dynamics.

For simplicity of exposition, we now revert to the aggregated example of the previous subsection. The equilibrium condition which generated the structural model arose from a hypothesis about directions of change in W_j relative to profitability $D_j - C_j$. It can be argued that retail systems will never in practice be in equilibrium because parameters and exogenous variables are continually changing - even though the trajectories will be influenced by underlying equilibria. It is therefore appropriate to write down a fully dynamic model. If $\dot{W}_j$ is the rate of change of W_j with respect to time, then a formal dynamic representation of the hypothesis we have been using is

$$\dot{W}_j = \varepsilon(D_j - C_j)\ F(W_j) \tag{19}$$

This obviously has the equilibrium condition

$$D_j = C_j \tag{20}$$

The factor $F(W_j)$ determines the form of the trajectory to equilibrium, particularly for small values of W_j, when $D_j - C_j$ may differ substantially from zero. Usually, it is taken as either 1 or W_j.

Again, these equations, either as differential equations or difference equations, can be solved numerically - but also there is a new analytical result which can be derived, building on the work of May (1976). This shows that the parameter ε (or, more precisely, εD_j) can be critically large, and that when these values are exceeded, periodic or even chaotic oscillatory behaviour sets in and equilibrium is impossible to achieve. This could be interpreted as retailers or developers 'over-reacting'.

It is at this point, again in relation to the simple example, that we can show how to introduce prices and rents - say p_j and r_j. Suppose on good sites, p_j's are decreased to attract more revenue but that land owners can increase r_j's. Then a term like p_j would appear as one of the X-terms in the attractiveness function, W_j, and r_jW_j would be a term in retailers' costs, C_j. An extended dynamic model can be written formally as

$$\dot{W}_j = \varepsilon_1(D_j - C_j)\ F_1(W_j) \tag{21}$$

$$\dot{p}_j = -\varepsilon_2(D_j - C_j)\ F_2(p_j) \tag{22}$$

$$\dot{r}_j = \varepsilon_3(D_j - C_j)\ F_3(r_j) \tag{23}$$

Experiments conducted with such a model show that realistic price and rent surfaces can be generated (cf. Wilson, 1985, Birkin and Wilson, 1985).

It should be noted that in this presentation of dynamics, it is still being assumed that consumer behaviour patterns are in equilibrium - so consumers are supposed to respond rapidly to any supply side changes. This is, on the whole, a reasonable approximation; but it is worth noting that a more complete dynamic model can be constructed which does not rely on this approximation using the master equation formulation (Haag and Wilson, 1986).

Alternative hypotheses and approaches.

It is worth remarking that many different derivations of the flow model presented here are available. These range from argument by analogy with gravity models via entropy maximising to random utility theory. Perhaps seven or eight distinct cases can now be identified. They are viewed in Macgill and Wilson (1979) and for most practical purposes, can be considered equivalent. However, there are also alternative models, such as Stouffer's (1940, 1960) intervening opportunities model. This seems to have lost popularity in recent years and, in any case, its main features can be captured with a variation of the cost function in a spatial interaction model (cf. Wilson, 1967, 1970).

This argument perhaps sounds complaisant. It is not intended to be because there are many important research issues which will be taken up in the concluding section. There are also continuing new developments to the basic model: Fotheringham's (1983-A, 1983-B, 1985-A) competing opportunities model falls into this category. It can be interpreted in the terminology of this paper as introducing a new kind of X-factor into the attractiveness function. He has also explored the effects of his innovation on the structural and dynamic models (Fotheringham, 1985-B).

It can also be the case that a shift to extremes of scale can demand a new modelling approach. Wrigley and Dunn (1984-A, 1984-B, 1984-C, 1985), for example, confront the problem of modelling brand choice within stores using longitudinal data and they use statistical (NBD and Dirichlet) models.

The central feature of the argument, however, is that the principles for retail modelling are well established, though in any particular study, a lot of detailed model design and fine-tuning need to be done.

Integrated analysis.

In this subsection, we summarise the steps to be taken to establish sound foundations for a modelling exercise. First, it is necessary to establish a level of resolution which is appropriate to the problem in hand. This will establish the sets of categories m and g, and the spatial units. Detailed decisions then need to be taken on (i) demand; (ii) attractiveness; (iii) retailers' costs; (iv) transport generalised costs. The flow model can then be run and the structural and dynamic models used to investigate the stability of overall retail structures at one time or at a sequence of points in time. This modelling framework will then provide the basis for a wide range of applications, and it is to these we now turn.

APPLICATIONS

Introduction.

There have been many applications of the range of ideas discussed above - but far more of the 'traditional' form than model-based. It is interesting to speculate at the outset on the reasons for this. These are no doubt many and varied, but the most important almost certainly relate to data availability and the effectiveness of the associated computer programmes: the data were often not available without large-scale special surveys and the computer programmes were not easy to use. To this, it might be added that experience was not available in relation to the fine-tuning of models. It can be argued now that the situation has changed quite fundamentally. The data are available commercially for many applications; and it is now possible to develop user-friendly computer programmes of the type to be described here. It should now be possible for the community to gain the necessary experience relatively rapidly. It is appropriate, therefore to proceed in this section on the basis that model-based applications will be the main feature of retail planning in the future.

At the end of the previous section, we summarised the steps to be taken as the foundation of a model-building exercise. We now focus on the uses to which such a model can be put. The argument proceeds in three steps. First, we discuss model outputs and performance indicators; secondly, we discuss the desirability of an interactive computer package for analysis and planning; and thirdly, we review the range of possible applications.

Outputs and performance indicators.

If the problem is one of store location from the retailer's point of view or centre location from the developer's point of view, then the most important output is probably the revenue attracted. The problem may also be looked at from the point of view of a town planner who may be interested not only in the efficiency of stores and centres, but also the effectiveness of delivery or access in relation to the residential population. This preliminary argument suggests there are two kinds of indicators, relating to facilities and residences; and an extensive list of indicators can be developed. First, we introduce some basic concepts first used in the field of health services planning.

Consider the variables for an aggregate retail model together with some additional variables as displayed on Figure 9. We can take $(S_{ij}/S_{i*})P_i$ as the proportion of P_i which is served by j and, hence, in relation to the flow matrix $\{S_{ij}\}$, we can define the <u>catchment population</u> of j as

$$\Pi_j = \sum_i \frac{S_{ij}}{S_{i*}} P_i \tag{24}$$

This leads to new indicators of facility efficiency such as $(D_j - C_j)/\Pi_j$, profits per head of catchment population.

But we can also do a similar calculation in reverse:

$$\hat{W}_i = \sum_j \frac{S_{ij}}{S_{*j}} W_j \tag{25}$$

can be taken as the notional square footage used by residents of i. Then $\hat{W}_i/P_i$ can be taken as a measure of effectiveness of delivery of retail services to a residential population in i.

Thus, while a retailer may be most interested in profitability and efficiency at his or her own site, the planner may be further interested in the equity of residential effectiveness indicators.

These new indicators can be combined with older ones such as the Hansen (1959) accessibility and concepts of market potential. Typical indicators to be considered can be summarised as follows:

<u>Residential zone</u>

* accessibility
* transport expenditure
* consumers' surplus

<u>Facility location</u>

* market potential
* cost per head of catchment population

* profit per head of catchment population
* revenue per head of catchment population
* price index
* rent index

This brief analysis shows that even when the focus is on retailers or developers alone, it is necessary to look at a set of indicators, and this means in turn that there is no simply-defined optimum to seek. This, therefore, suggests that the decision-maker or planner needs to be an integral part of the computer system and it is to this which we now turn.

An interactive analysis and planning system.

Software is now available which will accept data files, run any part (or all) of the model system described above, and then allow the user to re-run with on-line modifications to any of the inputs. For any run, any desired performance indicators can be selected for on-line output (with hard copy available if required).

This means that in any of the tasks of store or centre siting or sizing, or of performance appraisal, it is possible first to calibrate the models for the existing situation and then to make conditional forecasts by running the flow model for any selected site and reviewing the indicators. Experience shows that the identification of sites is relatively straightforward. It is possible to use the structural model interactively as a design tool: given everything except the W_j's, what would the equilibrium $\{W_j\}$ pattern look like? This test can also be carried out with some W_j's fixed at existing values. Further, it is possible to study the stability of any proposed plans by running the dynamic model (if necessary, one iteration at a time).

This is a reasonably complete description of the running of the system when it is being used by a town planner in relation to whole centres - but even then some kind of sensitivity testing will be needed to explore the consequences of alternative behaviour patterns of retailers. The situation may involve an even wider range of sensitivity testing when the system is being used by a single retailer or developer who has to take possible alternative responses of competitors into account. Ideally, a series of 'competition' scenarios should be developed, and each possible site location tested for each scenario (and with a series of sizes for each). Such a layout of model runs is shown in Figure 10. The interactive system could easily be used to organise a set of runs of this type. It is hoped, then, that at least one site shows itself as satisfactory against a range of indicators over a good range of scenarios. Such an example is shown on Figure 10 - location 2.

To conclude: it should be emphasised that the decision-maker at the computer terminal is an integral part of the system, and that human experience may be crucial both in interpreting the indicators and in devising the next plan to be tested. What the system offers is accurate predictions and associated sensitivity testing.

THE FUTURE

Research issues.

Introduction: Much research remains to be done, but this can mostly only be achieved by a wider range of experience: the testing of variations on the basic model. It has been argued that a good starting point has been achieved. In this section, therefore, we outline some of the issues which can be tackled either within university research or even in commercial applications from which lessons can be learned. We consider in turn: (i) variants of the basic flow model; (ii) issues associated with the structural and dynamic models; (iii) alternative models; and (iv) issues associated with applications.

The basic model: It may turn out to be important to experiment with other levels of disaggregation, and particularly to introduce store types explicitly. We have also mentioned the importance of developing elastic demand models, and this involves a new issue of defining a measure of 'perceived price' in a residential zone (see Wilson, 1983). More detail can be added to demand estimation using micro-simulation methods (Clarke, 1984). There will always be scope for explaining new terms in the attractiveness and generalised travel cost functions. A good research topic is to find a good measure of store quality (within a well-defined category).

Structural and dynamic models: There are a number of problems associated with the representation of retailer behaviour and particularly of competition. At one level, there is the difficult mathematical problem of handling the notion of a 'backcloth' in relation to a store or centre within which the whole set of competitors' locations is being changed and appraised simultaneously (cf. Wilson and Clarke, 1979). There is another problem associated with the present equilibrium model. It does, in a sense, assume a perfect market for retailer behaviour. In practice, there will be imperfections and there is the possibility of developing a new model with an entropy-dispersion term relating to the W_j's (cf. Wilson, 1985; Birkin and Wilson, 1985). Alternative hypotheses could also be considered for retailer behaviour; or, alternatively, to use the model in relation to a particular retailer to estimate size or pricing policy which would provide some degree of protection against competitors' responses. A further refinement along these lines involves using the dynamic model to test the effects of such policies in a time sequence, and extending the set of performance indicators to include a full related financial appraisal.

Further extensions are possible, for example by introducing more agents: we have already shown how to incorporate price indexes and land rents in this way. It would also be possible to include wage rates in appropriate circumstances.

Alternative models and extensions: In the argument so far, we have assumed the model-based analyses apply either to systems of stores or systems of centres. A more ambitious project involves combining the two scales so that it would be possible to predict centre distributions and store mixes within each centre. Research to date, however, suggests that there are difficult mathematical problems to be solved in achieving this step and, of course, there would then be very heavy data requirements.

A different kind of extension involves representing hierarchical structures. In one sense, the model system presented achieves this and thus replaces central place theory. This is because the range of structures across different goods' types will mimic central place systems though without any of the rigidities. However, within a g-type, there may still be some kind of hierarchy and it is useful to explore varients of the Nystuen and Dacey (1961) matrix analysis method for this, and the outcomes can be added to the set of performance indicators. An example of such a plot is shown in Figure 11.

Research issues in applications: Again, what is first needed is a wider range of experience with sets of performance indicators. However, it should be noted that batteries of performance indicators contain large numbers of numbers and are not always easy to analyse. Progress has been made for health care systems with the development of intelligent performance indicator programmes and it will be possible to apply these ideas in the retailing field.

Prospects for the future.

It has been argued that the model approach at the very least provides a conceptual framework for the analysis and planning of store or centre location and size. This facilitates the appraisal of other methods. However, the ease of availability of both data and software should make it feasible for model-based studies to become the norm rather than the exception in the future. An appropriate version of the basic flow model should always be available for forecasting sales and market penetration and we have seen that it is also possible to use structural and dynamic models to obtain different kinds of insights - particularly in relation to stability and competition and therefore risk analysis. All these analyses are most useful in a planning context if available through a user-friendly interactive system within which the decision-maker is an integral part of the system.

Although substantial research problems remain, as discussed above, sufficient progress has been made to engender confidence about future applications. Above all, further refinement will arise from a wider range of practical experience, and this is what we can now look forward to.

Acknowledgements.

Many of the ideas presented in this paper have been developed and discussed with colleagues in Leeds - particularly Mark Birkin, Graham Clarke and Martin Clarke - and I am most grateful for this support and help in a variety of respects.

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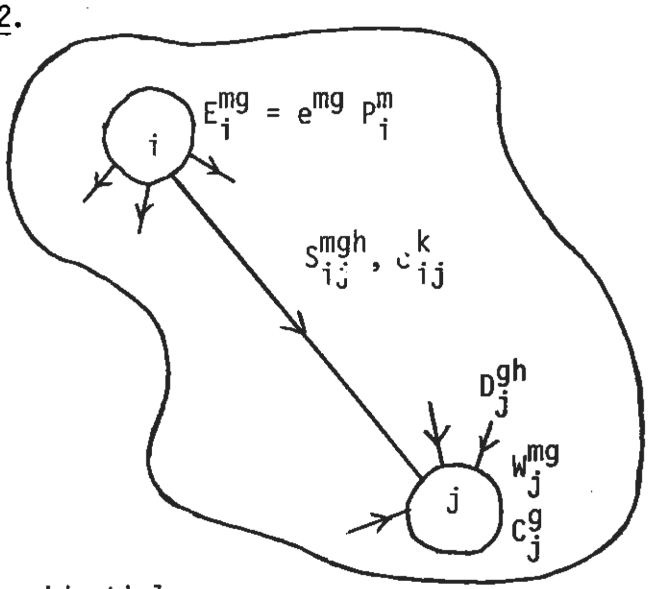
Figure 1.

demand by consumers ———— flows ———— supply of retail facilities

Figure 2.



i = residential zone

m = person/household type

g = type of good

j = retail facility zone

h = store type

k = transport mode

e^{mg} = per capita expenditure

P_i^m = residential population

E_i^{mg} = total demand

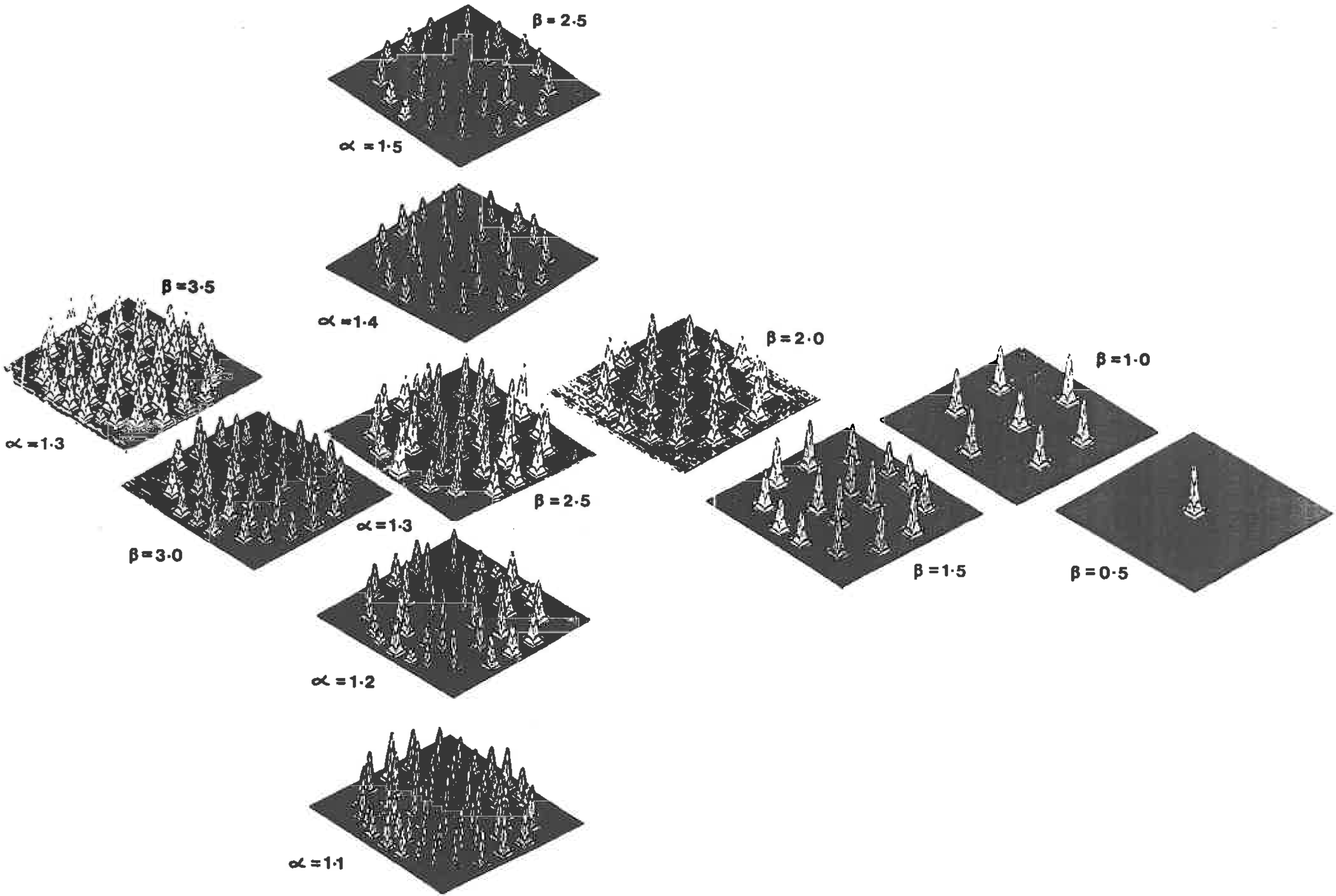
S_{ij}^{mgh} = flow

C_{ij}^k = transport cost

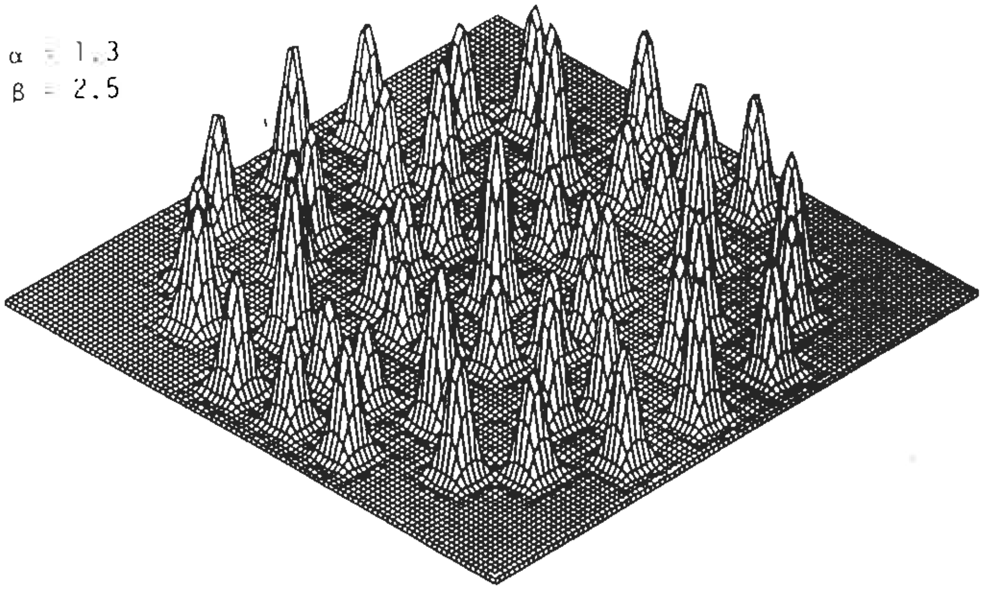
D_j^{gh} = revenue

W_j^{mg} = attractiveness of store/centre for consumers

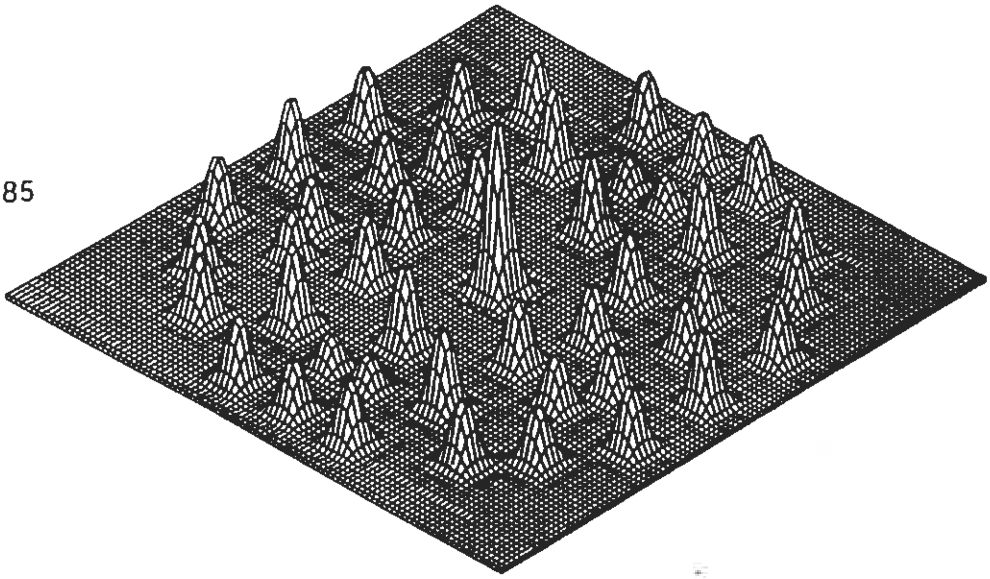
C_j^g = retailers' costs



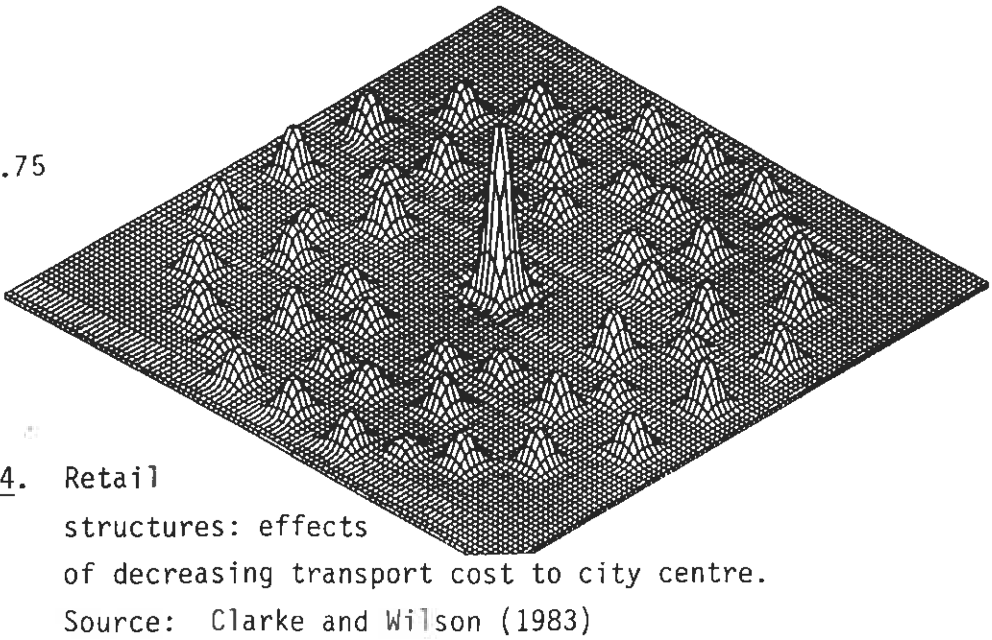
<u>Figure 3</u>. Alternative retail structures for varying α and β.
Source: Clarke and Wilson (1983)



(a) City centre trips 0.95 cheaper



(b) 0.85



(c) 0.75

Figure 4. Retail structures: effects of decreasing transport cost to city centre.
Source: Clarke and Wilson (1983)

Figure 5. Retail structures: effects of a land price surface
Source: Clarke and Wilson (1983)

$k_j \propto 1/c_{ij}$

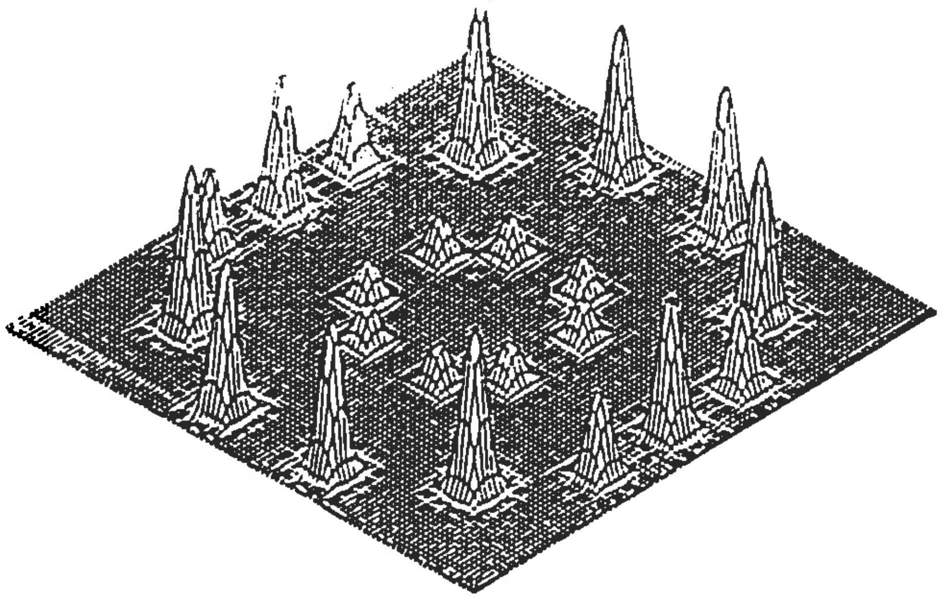
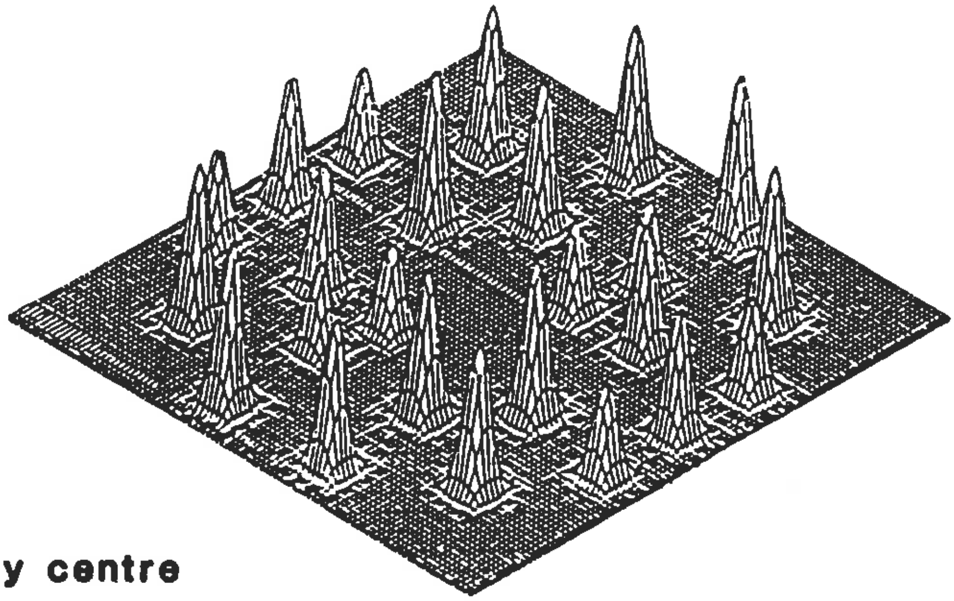
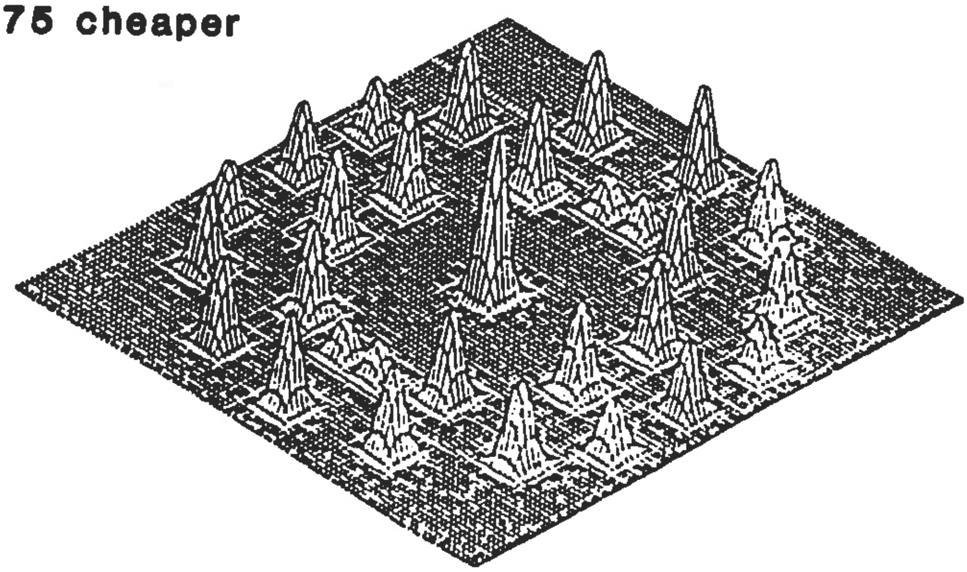


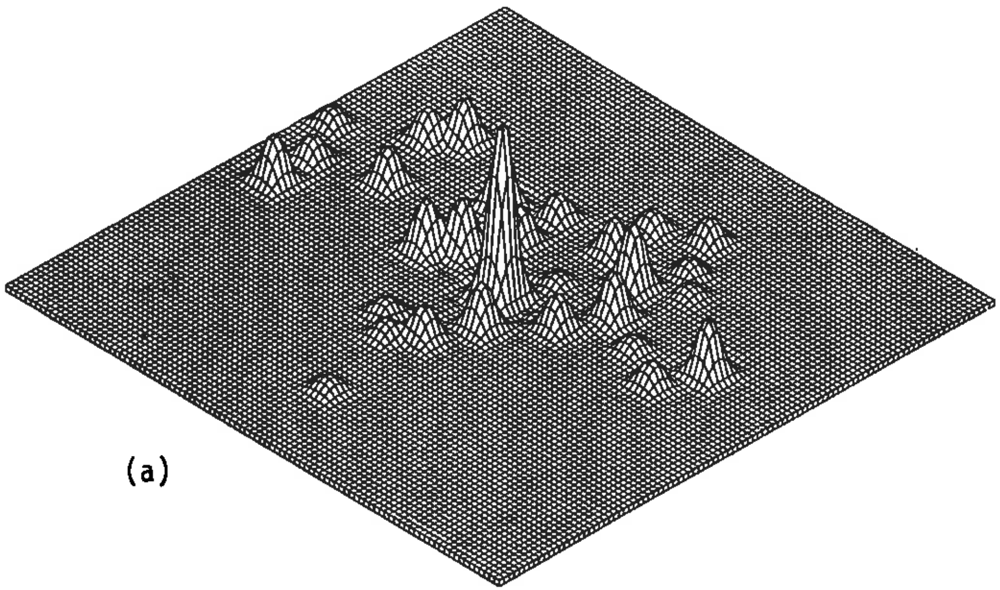
Figure 6. Retail structures: land prices and cheap travel to centre in combination
Source: Clarke and Wilson (1983)

$k_j \propto c_{ij}^{-0.5}$



$k_j \propto 1/c_{ij}$, city centre travel 0.75 cheaper




(a)

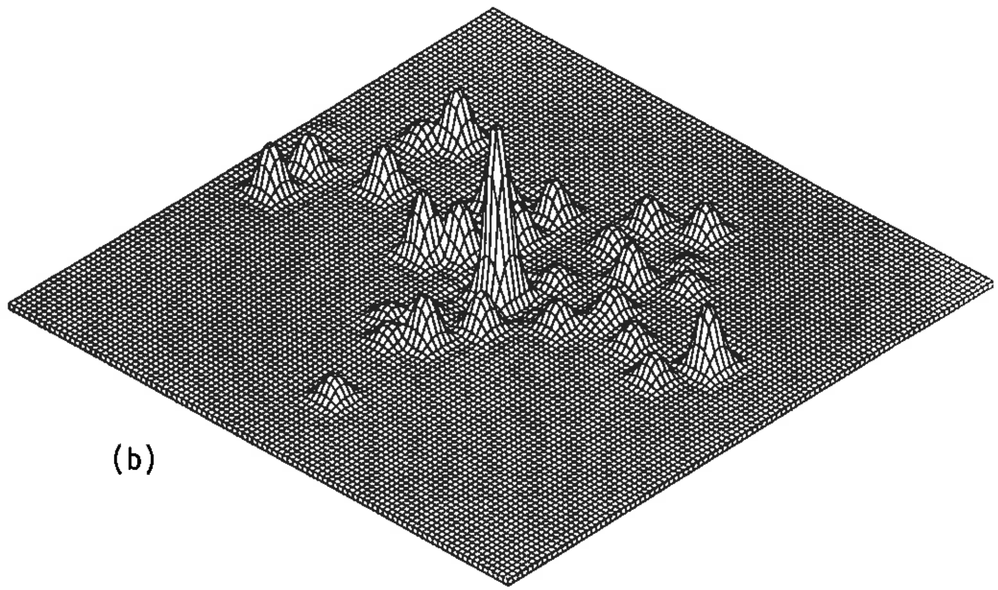
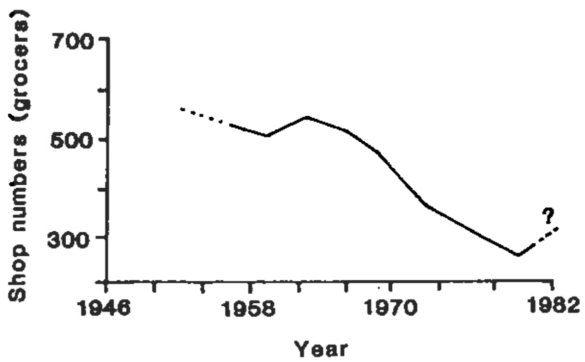

(b)

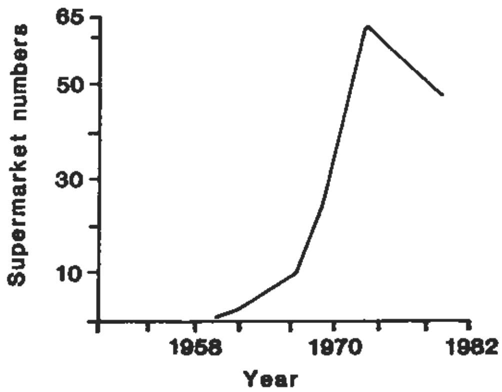
Figure 7. Leeds retail distribution: (a) Actual structure, 1961
(b) Structural model prediction, including land price variation

Source: G P Clarke (1986)

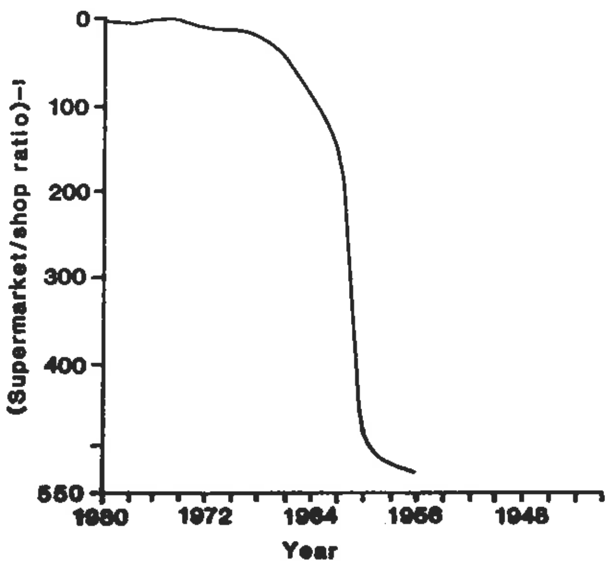
Figure 8. Food retailing in Nottingham



(a) Number of grocers in Nottingham



(b) Number of supermarkets



(c) An index of supermarket dominance

Source: Wilson and Oulton (1983)

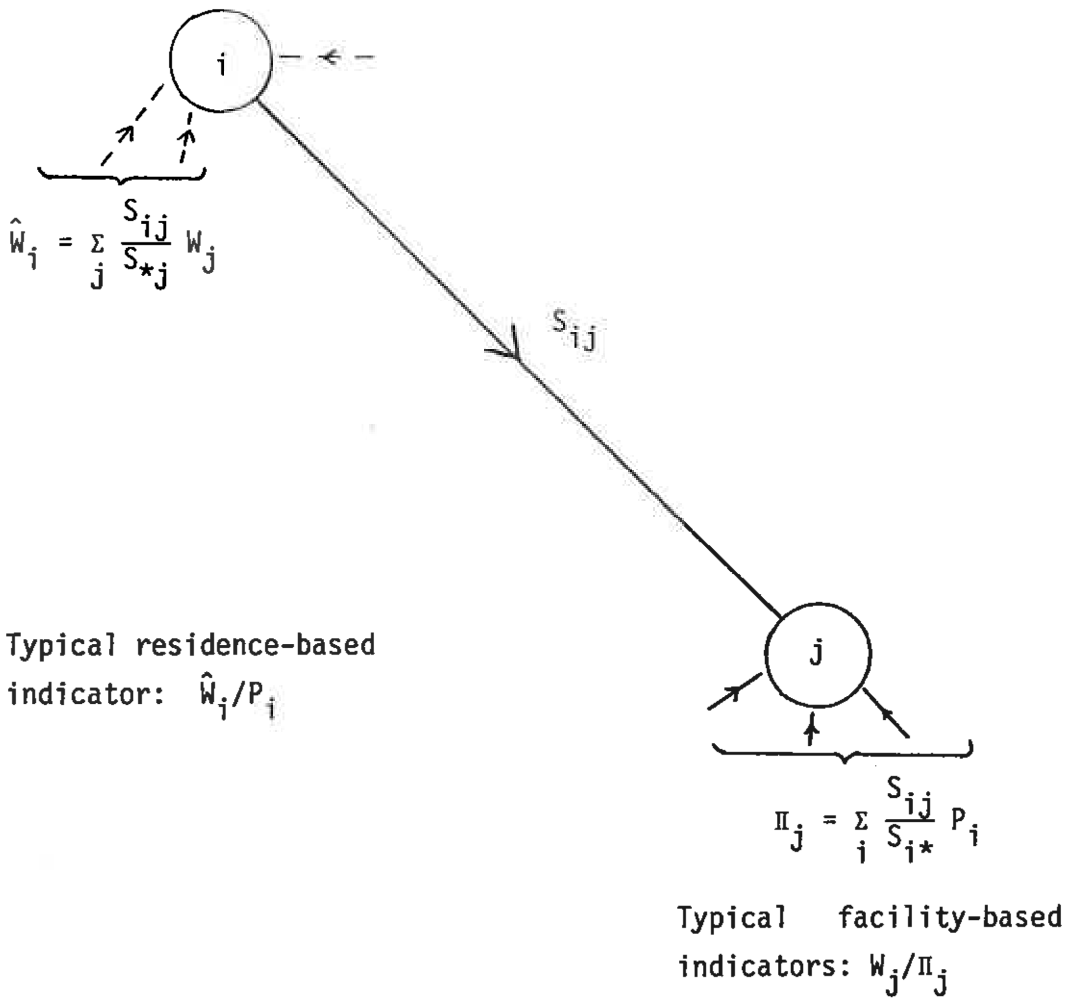


Figure 9. Residence- and facility-based performance indicators.

Figure 10. Hypothetical schedule of model runs for site location and size and sensitivity testing.

= model runs with 'acceptable' performance indicators. (Location 2, size 3 is thus relatively robust.)

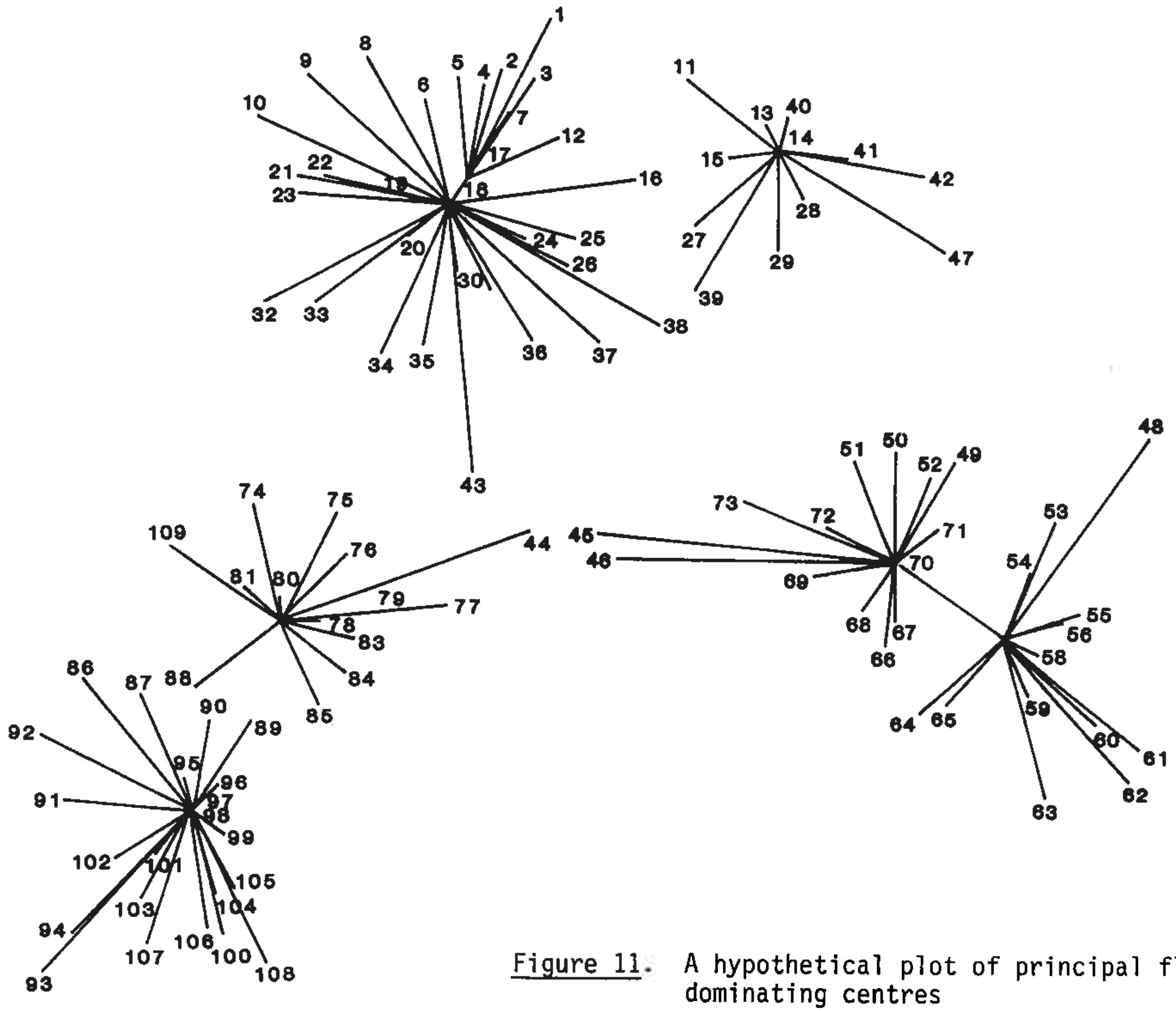


Figure 11. A hypothetical plot of principal flows to dominating centres

After Nystuen and Dacey (1961)

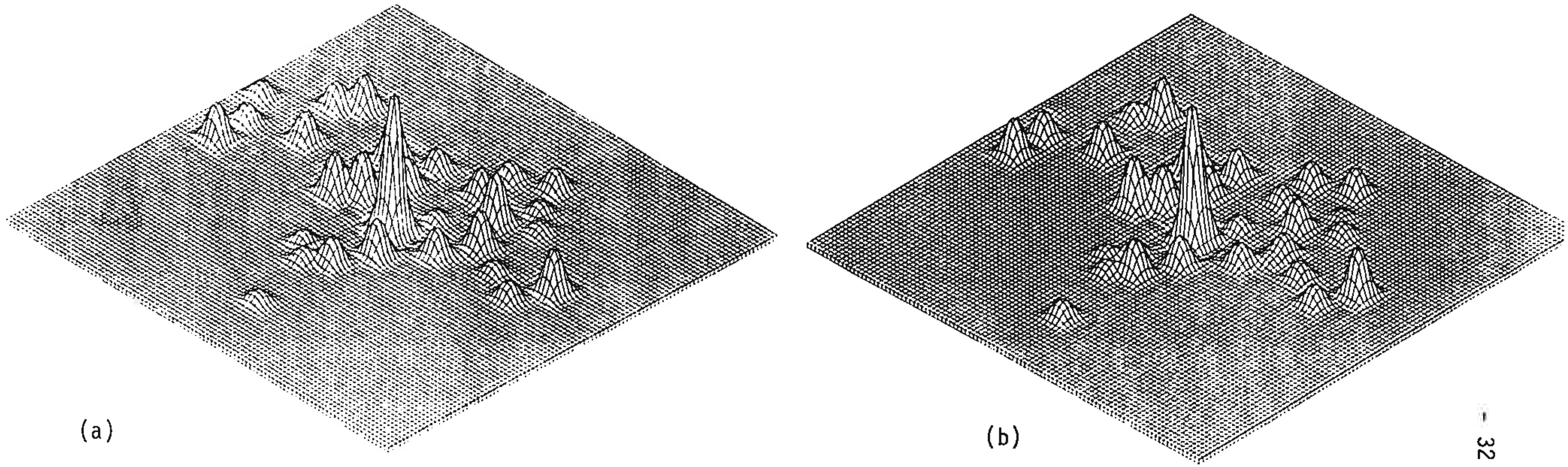
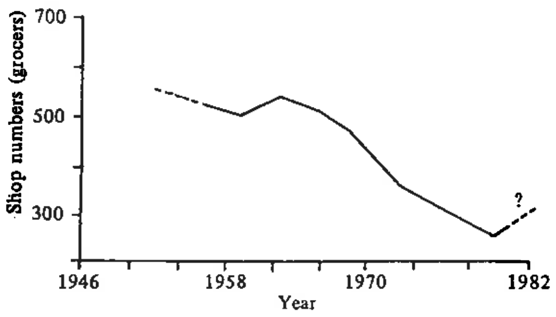


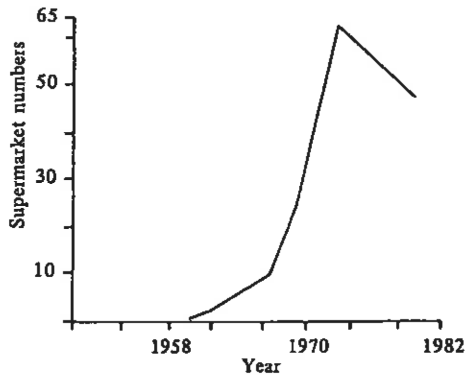
Figure 7. Leeds retail distribution:
(a) Actual structure, 1961
(b) Structural model prediction, including land price variation.

Source: G P Clarke (1986)

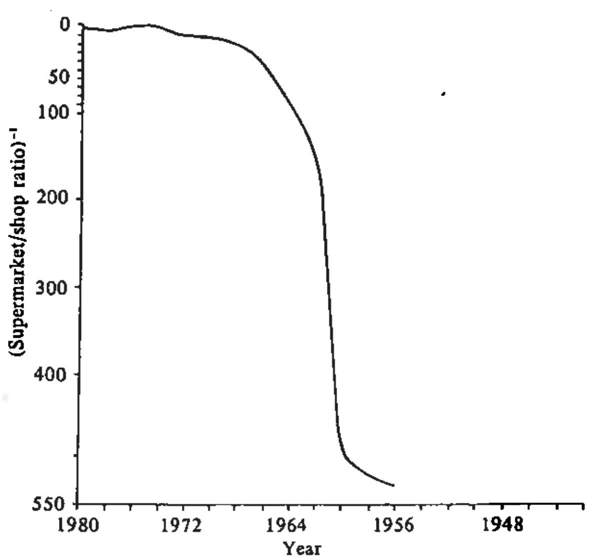
Figure 8. Food retailing in Nottingham.



(a) Number of grocers in Nottingham



(b) Number of supermarkets



(c) An index of supermarket dominance

Source: Wilson and Oulton (1983)

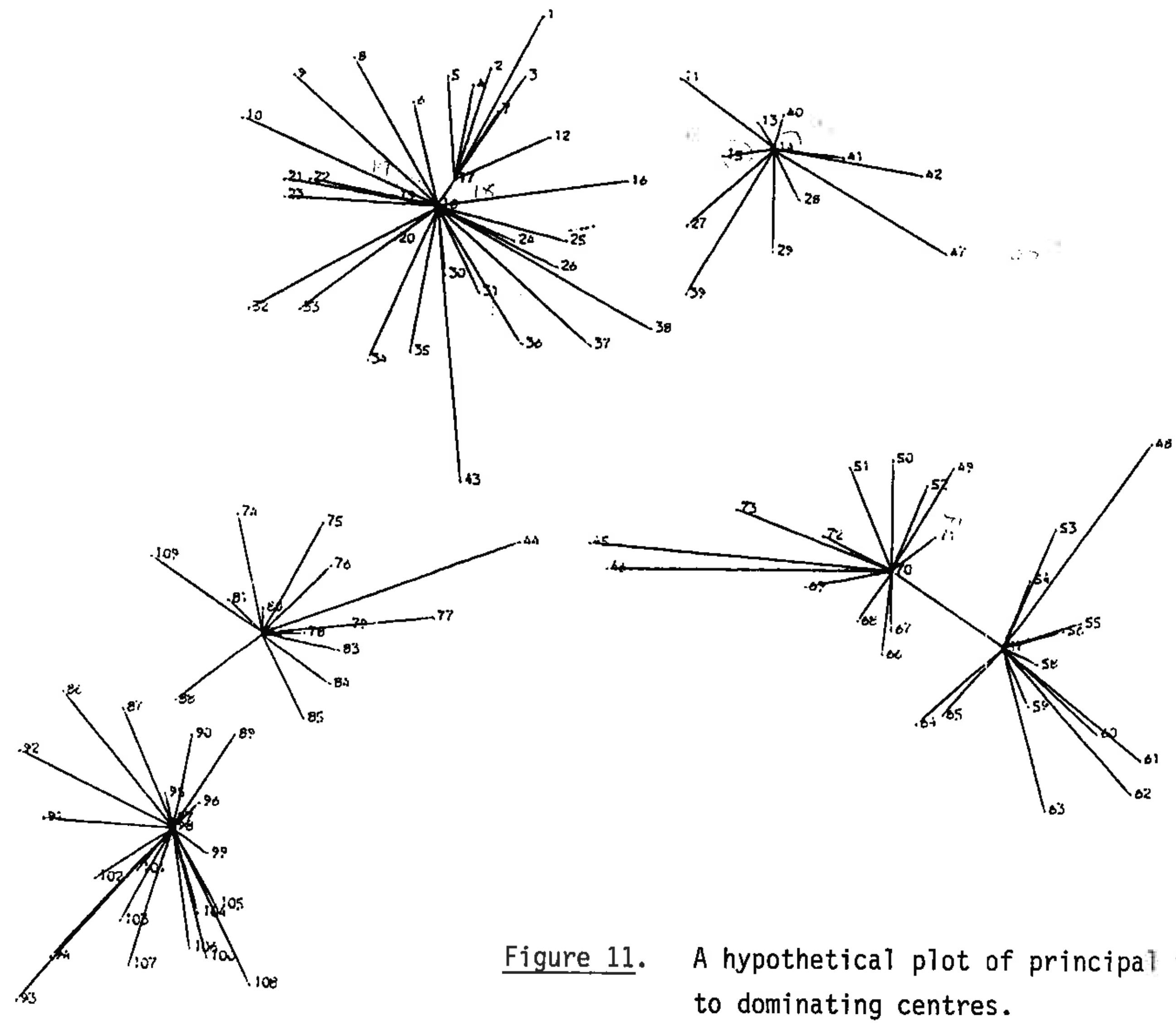
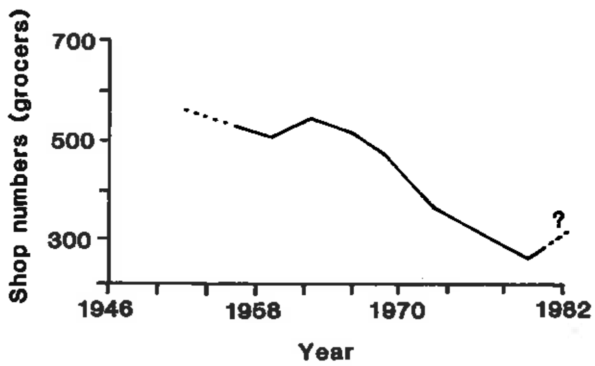
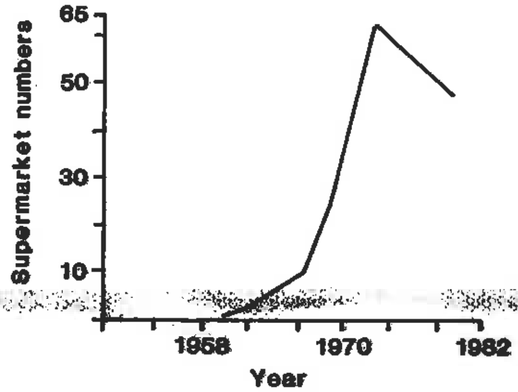
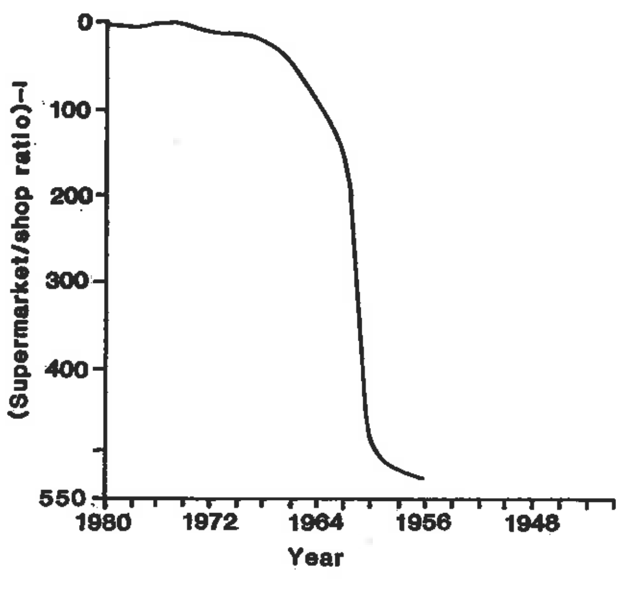


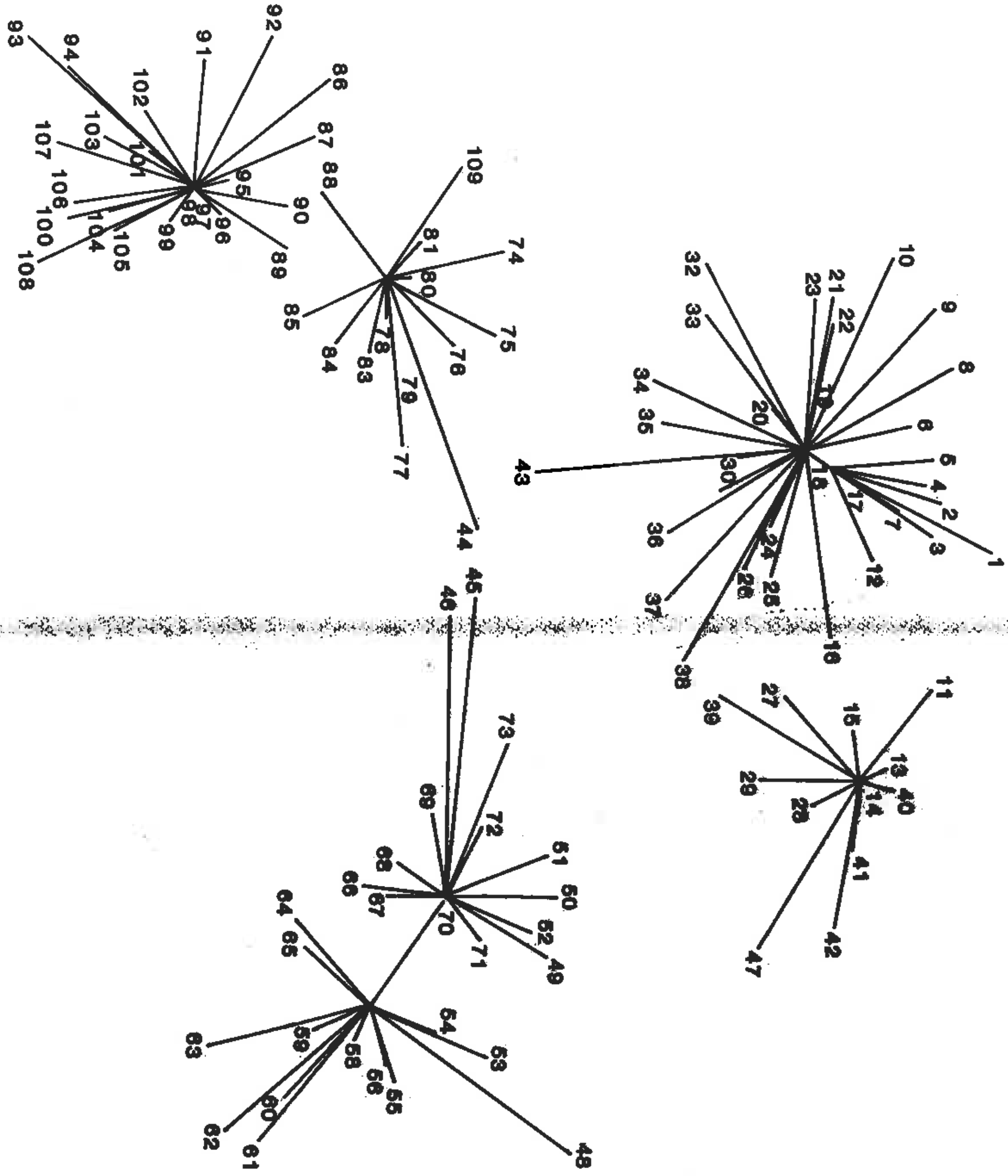
Figure 11. A hypothetical plot of principal flows to dominating centres.

After Nystuen and Dacey (1961).


Shop numbers (grocers)
700
500
300
1946
1958
1970
1982
?
Year


Supermarket numbers
65
50
30
10
1958
1970
1982
Year


(Supermarket/shop ratio)⁻¹
0
100
200
300
400
550
1980
1972
1964
1956
1948
Year



93
94
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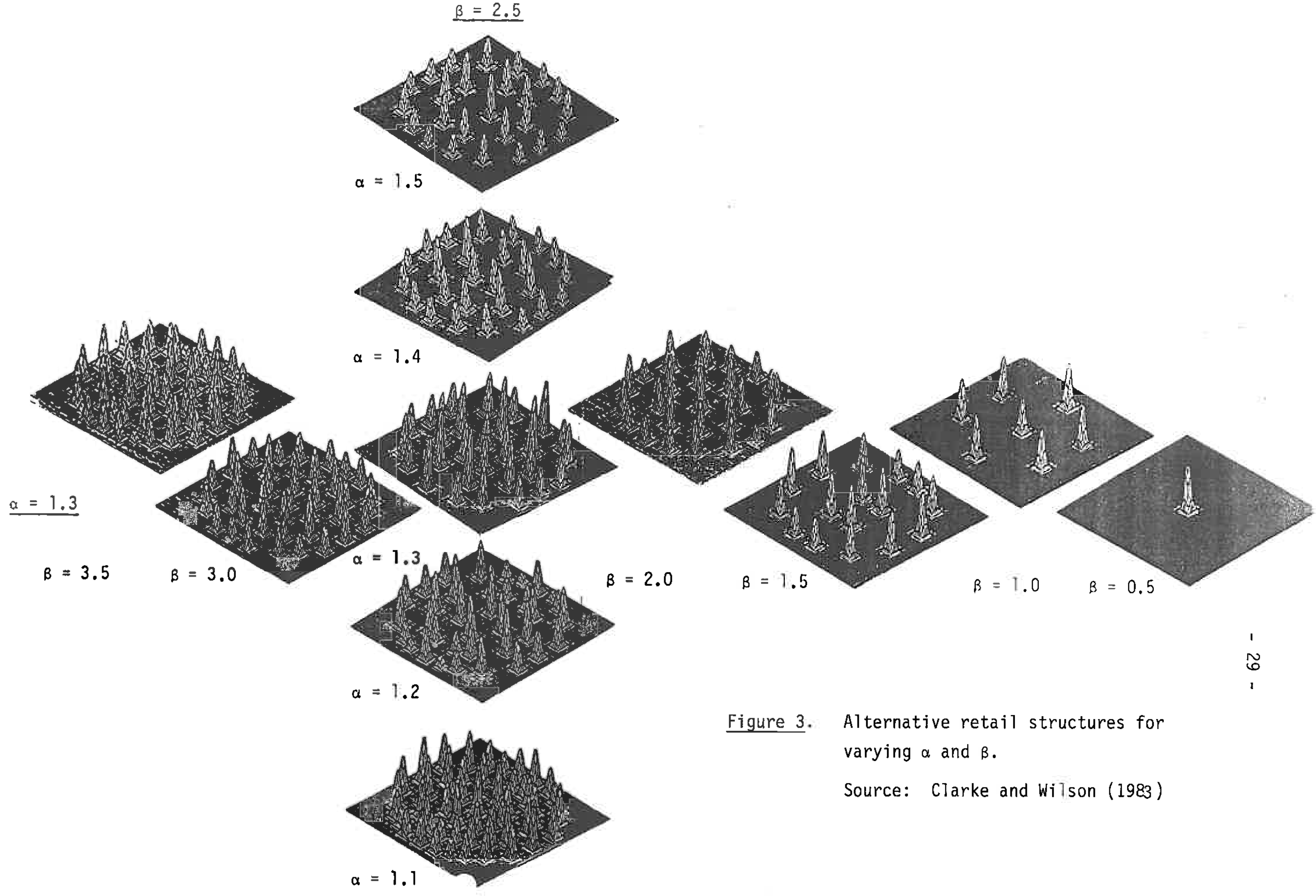


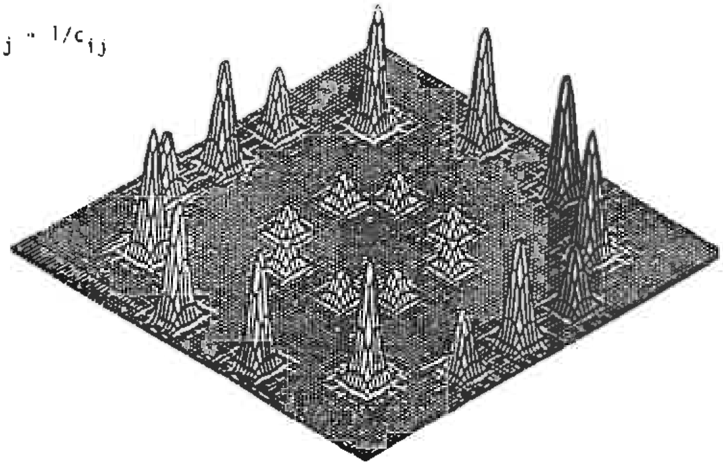
Figure 3. Alternative retail structures for varying α and β.

Source: Clarke and Wilson (1983)

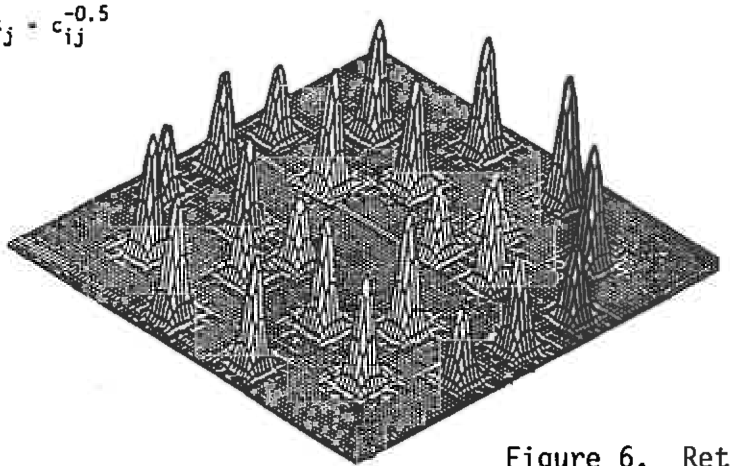
Figure 5. Retail structures: effects of a land price surface.

Source: Clarke and Wilson (1983)

$k_j = 1/c_{ij}$



$k_j = c_{ij}^{-0.5}$



$k_j = 1/c_{ij}$; city centre travel 0.75 cheaper

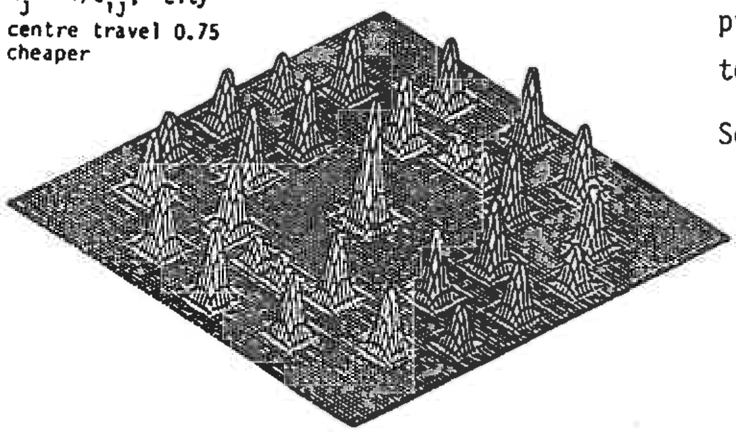


Figure 6. Retail structures: land prices and cheap travel to centre in combination.

Source: Clarke and Wilson (1983).