Working Paper 247

ON THE DEVELOPMENT OF BEHAVIOURAL LOCATION MODELS FOR INDUSTRIAL AND HOUSING POLICY ANALYSIS

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CONTENTS

1. INTRODUCTION

Over the last ten years, land use, transportation and travel models have been subjected to many criticisms. These range from the political biases and ideological implications of their forecasting assumptions, through their questionable theoretical premises, to their lack of immediate practical relevance [76]. A number of these questions arise under the generic issue of model validity. This has too often been narrowly interpreted in terms of the goodness of statistical fit of model predictions to observed data, typically at the cross-section. The calls for simple, time-dependent, policy-sensitive and, above all, realistic, models of location and behaviour, have commonly been heard, although the conflicting nature of these requirements has not always been appreciated [61]. This paper focuses on the development of dynamic, behavioural location models for policy-oriented analysis.

Considerable progress over the last decade has been made in the development and application of travel models, which address data at the level of the individual [8; 27;79]. There is considerable expectation that these 'choice-based' models can be integrated with 'constraint-based' studies of individual activity patterns to predict aggregate travel flows for policy [11; 42; 43; 48; 57;]. In the case of land use modelling, and particularly that of industrial location, however, much less detailed and precise explanations of evolving spatial patterns are available from considerations of the decision-making of firms. Thus we would echo the call for increased theoretical and empirical study in this area [32].

At any time the aspirations of the modeller often exceed the information available and, consequently, from given information, unreasonable imputations are frequently made. On the other hand, as Putman has had cause to remark in his review of land use models [71], the more ambitious varieties of model do not always reach the stage of operation. It is in the detailed conceptualisation of the processes involved in generating patterns of locations that simplifications necessarily involved in model formation must, however, be assessed.

It is not the intention of this paper to develop specific new location models. Rather, we work towards a framework within which to assess some of the problems and possibilities of constructing theories of the required variety. We believe it is convenient, and indeed appropriate, to examine firms and households as decision-makers, in juxtaposition over time and space. Each is an evolving entity, whose location decisions are intimately connected with stages of development (such as life cycle stage in the household case). Also, it has long been recognised in the theoretical literature that location choices are associated with a derived demand for attributes attained through the performance of an activity or function at a particular place. It is thus to be expected that the locational aspects of sites for firms and households, over time, may assert themselves either directly through a 'proximity' influence, mediated by the transport system; or indirectly, through the established local supply side characteristics, for example, those associated with infrastructure development.

In the following sections, we shall focus on several aspects of the behaviour of households and firms which relate to their stages of development and locational behaviours. In particular, we wish to emphasize the importance of creating a conseptual framework within which the constraints, choices and time-dependent decision processes of spatial actors are made explicit. As a background to this development, we briefly first review some previous dynamic approaches to the intra-urban location modelling of households and manufacturing industry. We emphasize difficulties with the estimation of various elasticity parameters of traditional kinds for policy impact analysis. Finally, we shall note some of the problems associated with statistical inference in conjunction with 'snapshot moment' data.

2. PERSPECTIVES ON INTRA-URBAN LOCATION AND ALLOCATION MODELS

In the development of models of intra-urban residential and industrial location, interest centres on the twin concerns of how a system will develop in the absence of governmental interference (which we shall label 'natural' development), and how development will occur under alternative public policies or corporate investment strategies. Often it is the difference between these 'trajectories' which is of practical as well as theoretical interest.

Interfacing urban policies with modelling now seems to demand some, and often detailed, knowledge of the processes associated with urban development. This is necessary so such processes can be accommodated without undue political difficulty, and so that the effects of planned changes on relevant individuals, organisations and sections of society can be thoroughly assessed in both theory and practice, beforehand [12;13]. With few exceptions, early land use models exhibited an almost total disregard for the processes underpinning urban systems. The derived demands for housing and industrial space from intra-urban mobility was seldom reflected in their analytic expressions, for example. Traditionally, location models were constructed as appendages to employment and population projection models. Dynamics, growth potential or sequential location decisions were implicitly ignored as independent, exogenous characterisations of firms and households. For example, the majority of operational land use studies, and in particular those employing the Lowry strategy, involved simple allocation mechanisms of the form

$$E_j^k = E_*^k M_j^k \tag{1}$$

$$P_i = \eta \sum_j E_j M_{ji} \tag{2}$$

in which E_j^k denotes the total industrial employment in sector k to be alloted to zone j; and E_*^k, E_j are, respectively, the sectoral employment and zonal employment totals, respectively. P_i, the zonal population total, is related to the employment total through the inverse activity rate η. The share functions M_j^k and M_{ji} simply embody the characteristics of the location pattern at a particular time, and denote, respectively, the proportion of sector k employment to be allocated to zone j, and the share of employees who work in j and live in zone i.

Although ill-defined, the behavioural concept of 'attractiveness' has been central to such location modelling, however. Thus, with due regard to 'holding capacities', which were predetermined limits imposed by the supply of space/infrastructure, the allocation was deemed on the basis of previous behaviour, to be proportional to, or a function of, zonal attraction (typically expressed for S.I.C. groupings in terms of an accessibility score), existing demand and topological features.

For residential location, for example, the gravity form

$$M_{ji} = \frac{A_i e^{-\beta c_{ij}}}{\sum_i A_i e^{-\beta c_{ij}}} \tag{3}$$

is still frequently used for spatially allocating a prescribed population total. It is commonly remarked, though, that when A_i, the attractiveness factor, is taken to be proportional to the existing population - as is often the case - the mechanism which produced the current state of the system is internalised. The future development is then much the same as that existing at the base year, and any natural or planned dynamics are obscured.

With regard to residential location, more substantial, behaviourally-oriented, theoretical and practical developments have emerged since the mid-1960's. For example, an explicit recognition of the inertia and durability of the supply side of housing has led to consideration of stock adjustments in dynamic or quasi-dynamic formulations [47; 93]. In addition, more attention has been paid to market segmentation within dynamic accounting frameworks (as reviewed in [93]). Theoretically, the nature of competitive urban housing markets and submarkets have also received much attention. In particular, the analysis of variability in demand has been embraced in both entropy-maximising and choice-theoretic approaches [2; 55; 77; 87]. Yet the recent housing models for policy examination, such as those developed by the Urban Institute [21] and NBER [47; 49], have faithfully embodied the traditional economic paradigm in which price formation and comparative statics remain central to the theoretical structure.

The dynamic stock-flow framework of the 'mover-stayer' variety is now, nonetheless, a more-or-less common conception of the housing system [47; 93]. This has the general features shown in Figure 1. In the time slice, $(t,t+\Delta t)$, the allocation equations may be summarised in the bi-proportional form

$$\Delta T^{\alpha\beta} = \Delta D^{\alpha} . \Delta S^{\beta} . p^{\alpha\beta} \qquad (4)$$

in which $\Delta T^{\alpha\beta}$ represents the number of movers, out of a total ΔD^{α}, with characteristics $\underline{\alpha}$, which is associated with the supply state $\underline{\beta}$. ΔS^{β} is the total change in that supply category. The natural dynamics of the entities - firms and households - and that of the suppliers of stock, are

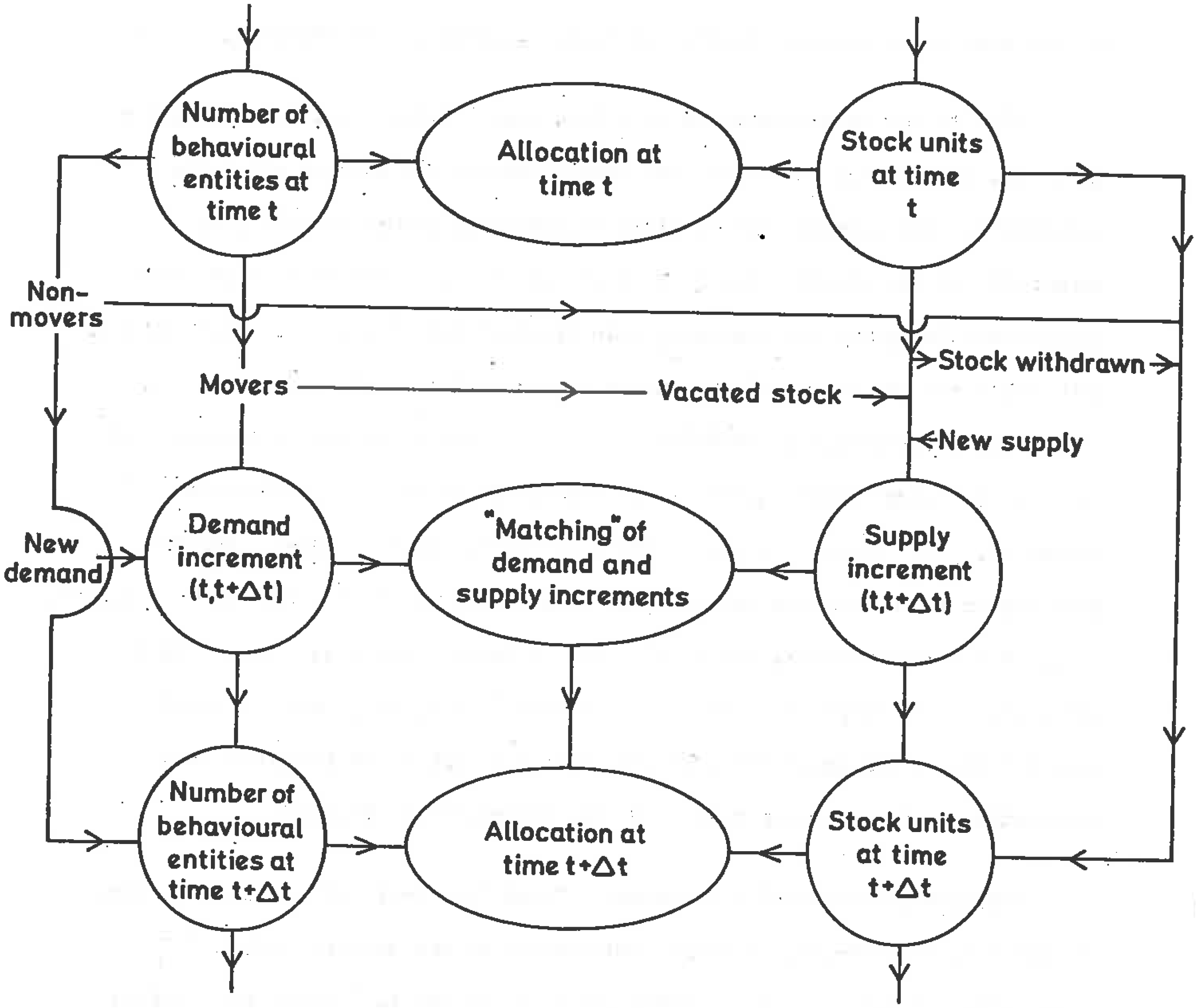


Figure 1: The stock-flow dynamical representation

reflected in equations for ΔD and ΔS, respectively. The rules of the 'market' are reflected in the association matrix, $p^{\alpha\beta}$, governing the allocation process.

This particular framework for analysis may of course be applied generally to urban markets [93], and in particular to industrial dynamics. Indeed, the discrete facility industrial location models of Rose [see 71] and Barlow and Smith [7] are attempts to allocate employment on essentially these lines. Here, the size distribution of firms is aged in a Markov process which incorporates birth-death transitions (see also [18; 19; 36; 46]). While a programming algorithm is used to assign new and locating firms to zones in the Rose model, Barlow and Smith employ a sequential proportionality procedure based on attraction factors, with land availability updating.

In recent papers, Byler and Gayle [14] and Williams *et al.* [89] have reviewed and developed vacancy chain models within a dynamic accounting framework which permit a generalisation of the conventional cross-sectional and dynamic disequilibrium models to accommodate the interdependency of moves in both the housing and labour systems. The basic model forms may also be applied to the industrial sector to examine the interaction of demand and supply. The generality of this dynamic disequilibrium framework should not distract attention from three specific, important and unresolved issues:

(1) the appropriate level of market segmentation - the definition of $\underline{\alpha}$ and $\underline{\beta}$ classes;

(2) the embodiment of theoretical statements concerned with dynamics and allocation;

(3) the appropriate context for location and policy variables.

In later sections we shall further examine some of these.

In addition, a stark reminder of the stringent requirements for policy analysis, and of the difficulty of using the stock-flow model for this, is given when we consider the time-dependent modification of a variable, $X \to X+\delta X$. The response of the system trajectory corresponding to equation (4) is given in general terms by

$$\delta(\Delta T^{\alpha\beta}) \approx \frac{\delta X}{X} (\varepsilon_D^{\alpha} + \varepsilon_s^{\beta} + \varepsilon_p^{\alpha\beta}) \Delta T^{\alpha\beta}$$

in which ε_D^{α}, ε_s^{β} and $\varepsilon_p^{\alpha\beta}$ represent the dynamic elasticity parameters associated with the creation of behavioural and supply units of characteristics $\underline{\alpha}$ and $\underline{\beta}$ respectively, and with the allocation function $p^{\alpha\beta}$. Thus,

$$\varepsilon_D^{\alpha} = \frac{X}{\Delta D^{\alpha}} \frac{\partial(\Delta D^{\alpha})}{\partial X}, \quad \text{etc.} \tag{6}$$

The issue of market segmentation must thus not only be viewed in the context of analysis of variance at the cross-section, but also with respect to changes in the segments and in their responses over time.

Because the supply, demand and allocation functions may all have different response properties to the change ∂X, the system, which is not in equilibrium, will, in general, be characterised by rather complex dynamics. Indeed, the response of a housing system to macro-economic pertubations is known to be intricate, and this is already reflected in the structure of well-known, aspatial, econometric models [4].

We now turn to an attempt to consider the variety of transitions open to the system. It should be recalled that the modifications to these transitions by a public or corporate policy is now a central focus of interest for the model builder. Attention centres first on the successive 'states' of modern urban firms, and the macro-scale variables affecting their transitions from one state to another (for example, rents and transport costs). The discussion is then extended to influences on the 'states' of residences (housing). The enquiry isolates, for future behavioural location modelling, the key conditions of industry and housing which need to be predicted for any one time, and over time. The influence of micro-scale variables (individual decision processes) at any particular time is considered in a further section. This approach permits the analysis of both the changing locations or supply of urban industry, employment and housing, and the responses of salient individuals and groups to them.

3. LOCATION AND THE DYNAMICS OF FIRMS AND HOUSEHOLDS IN CITIES

At the outset, we summarise features of the dynamics of firms, and, to a lesser extent, of households, which have received more empirical and theoretical attention. It is necessary to re-interpret these as general development processes, caused by specific macro-scale variables, in order to draw out the nature and causes of transitions between 'states' for time-dependent location modelling.

Firms

One picture which emerges from the study of the contemporary mobility of industrial firms is the progression of a successful firm through a series of stages, and a parallel spatial movement to serve markets the size of which are commensurate with the scale of operation. A not-untypical development pattern is depicted in the time-space diagram shown in Figure 2.

In manufacturing industry, six types of space-related developmental stages have been observed: births; transfers; the establishment of branch plants; extensions; ownership change; and closures [65].

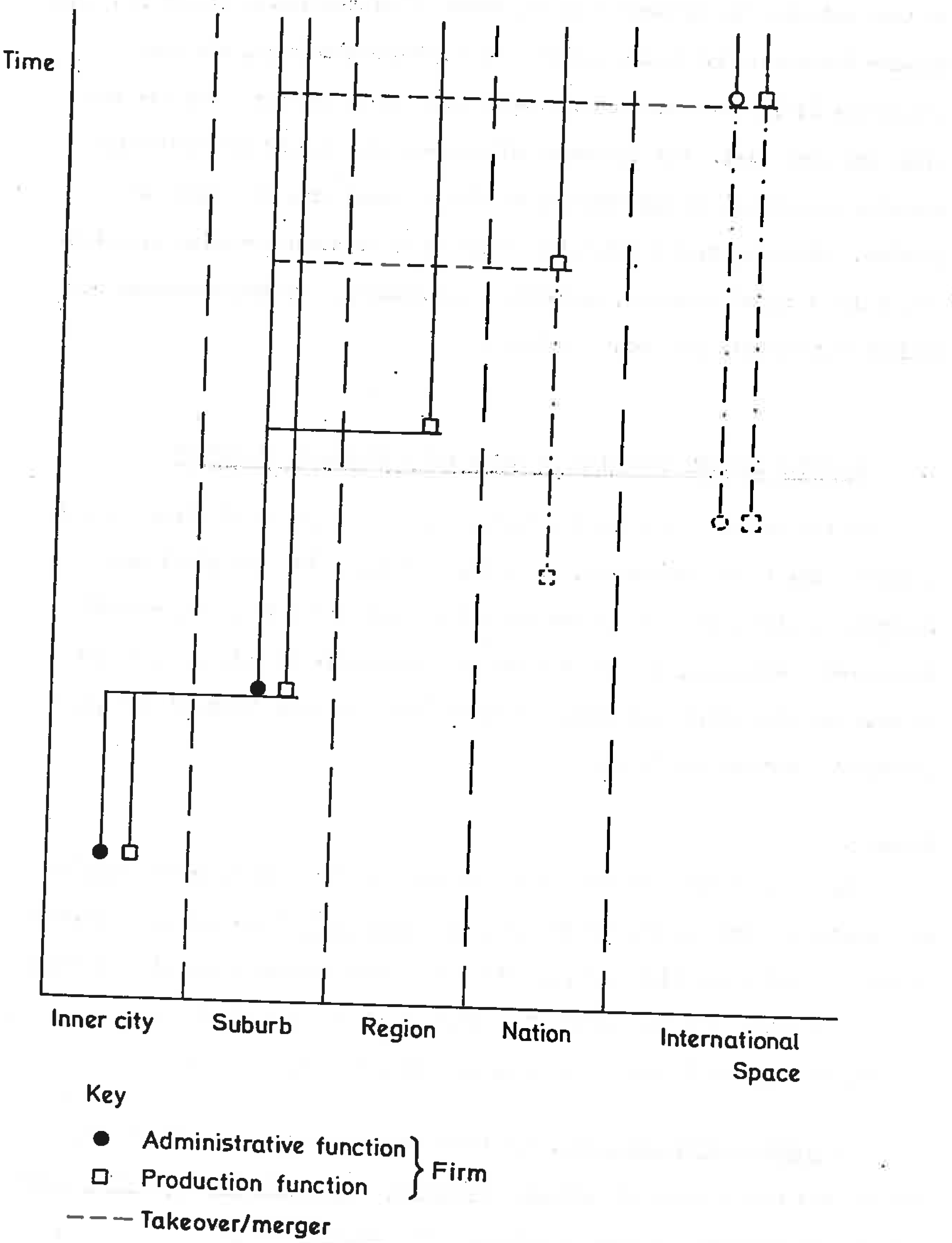


Figure 2 : An example of the space-time dynamics of an expanding firm
Based on diagrams by Erlandson (1975)

Births are predominantly of small, inner-city firms. These new firms suffer high rates of closure and there is therefore a high turnover. Over time, rates of creation seem to be declining so that new small firms are no longer the important component of employment they were. However, as is now increasingly observed, their 'seedbed' function may still be vital [24; 33].

Complete transfers generally involve young, small firms, with less than one hundred employees. Those firms which have high growth rates usually move as the result of unplannned production growth. A large contract might double production. Alternatively (and especially in inner cities), transfers are the result of externally-generated stressed (for instance: compulsory purchase orders, traffic congestion, high labour turnover, a change in insurance premium on the factory and so on) [15].

Establishment of branches is the prerogative of older, large firms. In a recent survey [65] it was found that 48 per cent of firms in the sample establishing branches were already multiplant in character and occurs mainly as a result of planned production growth to open up new markets (ie. expansion).

Extensions (in-situ expansion) are by far the most common industrial location-related decisions. Usually these are part of the production plans of large (and therefore often old) firms. Older, larger firms are able to find capital to purchase large amounts of land to expand on, and extension is therefore the most common way of meeting their space needs. The fundamental question in this case is therefore not where but when? [65].

Ownership change normally occurs as the result of diversification strategies by large firms, who can use a merger or takeover as a means of obtaining new branches without having to set them up. A takeover may often be a decision with spatial implications. Acquisition is usually the result of a need to diversify or integrate, and firms usually look only at specific areas, especially if interested in a particular regional market. Since takeover often leads to rationalisation, it can also imply closure decisions. In any rationalisation, peripheral factories are probably the first to be closed.

Closures are mostly carried out by old, large firms faced with declines in profitability, and a resultant need to diversify away from failing products. Often they are made in conjunction with plans to open other factories as part of a general rationalisation [64].

From the 1950's and 1960's, there has been little doubt that, in the British context at least, there was an increasing degree of industrial mobility, reflected not only in changes at existing sites, as above, but also in new site construction [38; 50; 94]. The variables influencing the rates of transition are, unfortunately, not as well-known. Some significant ones can be discerned, however, for modelling purposes.

Two important trends in particular are clear. One is that from the mid-1960's employment in factory production decreased due to higher productivity, automation and so on. Simultaneously there occurred a greater separation of non-production functions (ie. administration, research, etc.) from factory production functions. This was due to decline in the relative importance of transport costs, increased lightness of industrial product, automation and standardisation leading to a decreased demand for skills and therefore less need to exist in trained labour areas, and government policy [38; 50; 94].

At the same time, factory floorspace has been increasing so that land rent has become a far more significant factor in the costs of firms. This has encouraged the move of production (but not necessarily administration, research, etc. [37]) from inner-city sites especially. If firms in the inner city expand they are now often forced to relocate out, due to the high cost of inner-city land. In addition, branch plants in inner-city areas are often the first to be closed in any rationalisation scheme. They typically have obsolescent plant, and a limited site expansion horizon. Additionally, inner-city sites, which usually have high values, can often be sold to competing land uses, thus giving a boost to the company coffers. They may also be converted by companies to more profitable use, for instance to warehousing [75]. In addition, new industries are not attracted to inner-city sites because of the high redevelopment costs compared with 'green-field' sites.

In Table 1, we have assembled some results of various surveys giving additional causes of why firms move. (Further review material on locational aspects of inner-city firms in Britain, specifically in relation to the importance of transport problems, may be found in the recent paper by Patterson and May [70]). Although the figures are primarily given as illustrations, they do suggest that there are three predominant reasons for movement:

(1) expansion of output;

(2) site problems (through reorganisation of production or site congestion);

(3) labour shortage (usually of female labour).

It should be noted, however, that the continued trend to automation and product standardisation, as we have mentioned above, has reduced demand

TABLE 1

MAJOR REASONS GIVEN BY FIRMS RELOCATING OR OPENING A NEW PLANT

	% of Firms in Survey			
	A	B	C	D
Expansion of output	72	76	83	79
Inadequate existing premises	41	87)	50	
Site congestion	55	47)		
Labour shortage	25	23	40	56
Lease difficulty	9	32	5	–
I.D.C. difficulty	8)	41	12	–
Local Planning problems	17)		11	–
Too far from markets	–	–	19	11
Traffic congestion	8	–	–	–
Opportunity to purchase or rent premises .	–	–	20	–

Because of multiple responses the columns do not sum to 100%.

Source (A) ILAG Survey of 159 establishments with London origin 1964-67 (Part of (C)).

(B) New and Expanding Towns Survey of 53 <u>relocating</u> establishments with London origin 1970-75.

(C) House of Commons Expenditure Committee of 1973. All firms opening a new <u>plant</u> 1964-67 in areas not manufactured in previously.

(D) Northcott [66]. 82 firms <u>opening new factories</u> in special development areas 1973-76 (Choice of Location).

for labour with special skills [38; 59]. When combined with the general decrease in manufacturing employment, this leads to the prospect of smaller, semi-skilled work forces in future. It is possible to speculate, therefore, that labour availability will become a less important factor in future terms of industrial location, especially since, at present, demand for a particular labour force is restricted to a few industries (eg. female labour by the clothing industry).

Transport costs have noticeably decreased in importance relative to other costs as a prominent factor in industrial location, and, excluding certain particular industries (eg. transport firms), are usually reckoned at only four to five per cent of all manufacturing costs incurred. The building of the motorway system has eased the problems associated with transport costs, and it now seems probable that "the simple transport cost argument is not of major significance for most British manufacturing firms" [50, p. 214].

> "The inadequacy, or at least the incompleteness of traditional industrial location theory, certainly in its simpler form based on Weberian transport costs analysis" [94, p. 143]

is increasingly demonstrated, although it has been suggested [23] that such a theory may now come into play at a different scale, that of the world arena, rather than at regional or national scales.

There is little doubt that market accessibility is still an important factor in plant location [50]. However, the increase in plant size has increasingly meant

> "Concentration of production at one or a few locations serving perhaps the whole national market, in place of previous patterns of smaller factories, probably dispersed throughout the country in relation to particular regional markets." [50, p. 49-50].

Large firms have large markets and want to be central to these. Once again inner-city sites are unsuitable for this purpose.

In sum, the lessening of the importance of transport costs must have had some effects which are only now becoming fully apparent. One is that the importance of a suitable choice of location per se is diminished or becomes more heavily dependent on other factors. Another is the aforementioned centralising of production facilities.

It should be remarked that, in spite of the importance of the space requirements of firms, there is a paucity of information on this topic. See, however, the general paper by Norcliffe [64]; and [1; 30; 31] for a description of Swedish industrial space requirements.

A major deficiency in studies of industrial location is the attention given to the decisions and movements of industrial firms, as if they were completely independent entities [80]. Yet industrial mobility depends on spaces being available, be these newly created or met by other agents. Relatively little is published about the land market in older industrial properties, which is of course a function of rate of industrial mobility itself. There are three actors who determine the supply of new industrial space - landowners, developers and local and central government authorities [28; 29]. Landowners in Britain are perhaps of less importance than formerly, but still play their part. In particular, much land has been available from former nationalised industries which often have their own property companies [58]. The developers who build on industrial land are usually large building firms, since much capital is generally involved. Recently, though, the U.K. government has become involved in providing industrial space through the New Towns Program, industrial estates [5] and, lately, even, advanced factories. Local authorities, particularly since the

Inner Urban Area Bill, play a more directly entrepreneurial role in supply of industrial space, but it remains to be seen whether this option will be taken up by many local authorities.

The challenge for dynamic location modelling for policy is to link all these causal factors with the rates of transition of metropolitan industrial firms from one developmental and spatial state to another. Computer based micro-simulation models, making efficient use of the necessary large data bases, may prove useful in these investigations.

Households

In a number of ways the general progression through a series of states (which in the few discrete facility location models has been simulated by a Markov process) together with the matching (or mis-matching) of supply attributes to the changing needs of a behavioural unit parallels the much discussed family 'life-cycle' and 'housing-cycle' concepts [25; 26; 51; 62; 72; 73]. Indeed we may parallel the separate components of demand for, and supply of, infrastructure. This parallel between the systems should not however, be taken to extremes. It should be remembered that firms, unlike households, may be part of quite intricate organisational networks. Also, while the motive forces of firm dynamics are predominantly of an economic/financial nature those of the households are demographic, economic and, importantly, social.

In both the U.K. and the U.S.A., as other 'advanced' societies, the transitions of households between different 'states' occur within the frame-work of a multiple housing market. This is controlled to a varying degree by institutions determining tenure [63]. In the U.K., for example, a distinction can be made between four tenure-related 'states' (with the relevant institution in brackets): owner-occupied housing (building societies, clearing banks); public housing (local authorities); furnished rented housing (landlords); unfurnished rented housing (landlords).

Expansion of owner-occupation and the public sector, at the expense of the rented sector, have for many years been features of the British experience. It is also possible to discern now a growing fifth 'state', housing controlled by housing associations [39]. The institutions are themselves spatial actors whose pattern of lending can have either indirect spatial repercussions (through the type of person lent to), or direct spatial consequences (as in redlining by building societies [62]).

Such is the importance of the tenure factor that the

> "Patterns of association between dwelling and household characteristics are consistent with an interpretation of tenure as the <u>key factor affecting relationships</u>."
>
> [62, p. 28, our emphasis].

The tenure system thus seems the critical variable giving rise to particular patterns of demand and supply, and leading to the housing of different sections of the population [63]. Within each submarket there are also a series of constraints on entry [6]. In the case of owner-occupation, entry is crucially determined by income - usually at the particular age when the household is first formed [62] - and by the availability of a deposit. The principal constraint in the other main sector, that of public housing, is the allocation procedure in force in the area in which a council house is sought. It should be stressed that rather little is known about the dynamics of the local authority housing market [73], but that, in general, due to the lack of interauthority transfer arrangements, mobility tends to be much less than in the owner-occupied market. A recent survey [86] has shed considerable light on preferences and constraints in such systems. Such constraints are crucial elements in micro-level decision processes, and it is to a consideration of theses that we now turn.

4. DECISION CONTEXTS, CHOICE THEORIES AND MICROANALYSIS

In this section, we shall concentrate on some general aspects of those areas in which there appear to be shortcomings in current theoretical approaches. The process itself will be regarded as a matching of a (firms, households) and b (stock) vectors brought about by the choices, constraints and decisions of individual firms and households, and the 'rules of commodity exchange'.

It is of course possible to exhaustively classify the individual items of the vectors according to intrinsic characteristics or functions, as follows:

firms $\leftrightarrow$ (organisation/ownership; age; size; input requirements and market for inputs; production characteristics; market for outputs and output characteristics; financial aspects),

with corresponding elements for the household. For the stock, location, age, size, rent/cost, and tenure would be relevant aspects. The classifications can be made with respect to dominant factors in such attribute lists [71; 81]. Thus the early 'trade-off' residential location theories included the journey-to-work costs as an important determinant of spatial patterns; later to be modified to include accessibility factors relating to a range of family activities [52; 55].

In emphasizing individuals' attributes for the study of individual decision-making, it is crucial not to deny the existence and importance of their environments as salient factors, also. It is interesting in this context to consider the traditional economic paradigm based on rational choice:

> "The classical economically rational consumer will choose a residential location by weighting the attributes of each available alternative - accessibility of workplace, shopping and schools; quality of neighbrourhood life and the availability of public services; costs, including housing price, taxes, and travel costs; dwelling characteristics, such as age, number of rooms, type of appliances; and so forth - and picking the alternative which maximises utility. Housing prices and the supply of new dwelling units will adjust to reconcile consumer tastes with the existing housing stock at each point in time." [55, p. 75].

As Andersson [3] has recently commented in his consideration of structural and functional approaches to consumer theory:

> "My proposal for reformulating consumer theory is to <u>work inwards to the individual from his environment</u> and not outwards from the individual to this environment ... . A reasonable approach would be to see the problem as a question of generating economic and environmental constraints imposed upon the individual in his actual choice situation. It means that we have to describe the arena of the activity before we can start the discussion of economic behaviour of that arena ... . Some of the constraints are even so narrow that they are actually part of the human himself, his physical body, his knowledge and his own life history." [3, p. 35-6].

While these approaches are not necessarily as divergent as they first appear - choice theory of the random utility variety may be augmented by constraint relations generating market segments with a similar range of choice, for example; - it <u>is</u> the case that choice theory has tended to overemphasize the existence and role of choice at the expense of individuals' environmental constraints. These may be of an economic, physical and social nature.

That rational choice theories oversimplify the nature of decision contexts is now well-accepted [42; 45; 76]. More elaborate frameworks have been proposed which attempt to represent the way in which entities search for, acquire and processs information about their situations. In

Figures 3a and 3b we note two particular examples associated with residential and industrial location. These decision contexts form a dynamic framework within which we may pose the following set of enquiries:

(1) What induces a transition?

(2) How often are such decisions made?

(3) Is the decision actually made by the entity under the modeller's scrutiny or by some associated unit? (as, for example, with forced moves by household dependents in employment changes; the action of subsidiaries);

(4) How do different alternatives present themselves - what are the characteristics and extent of the search process?

(5) How is information about alternatives acquired? What information is deemed significant?

(6) Are the implications of a decision certain or uncertain?

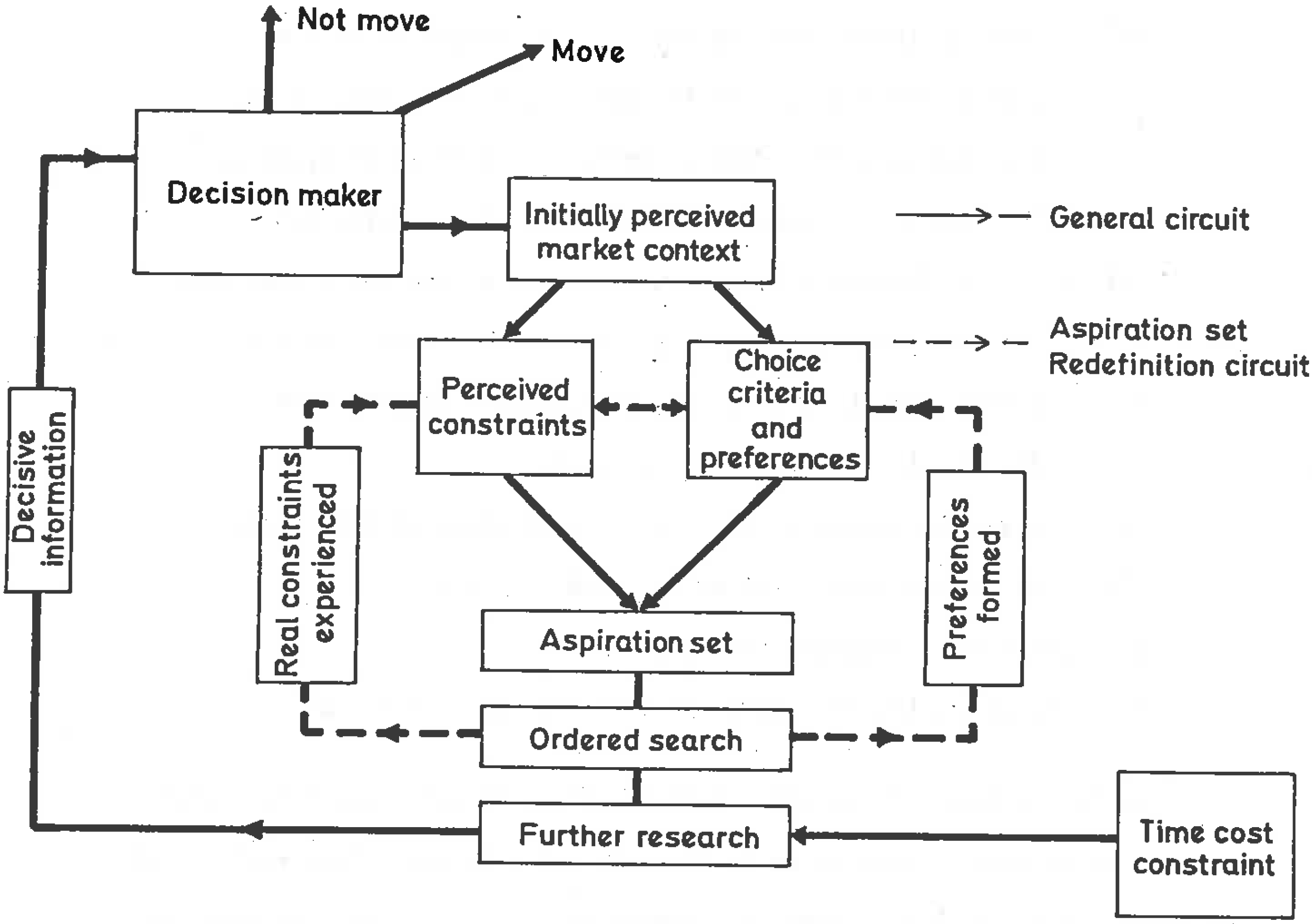
(7) What constraints exist on individual action?

(8) How is the decision actually made?

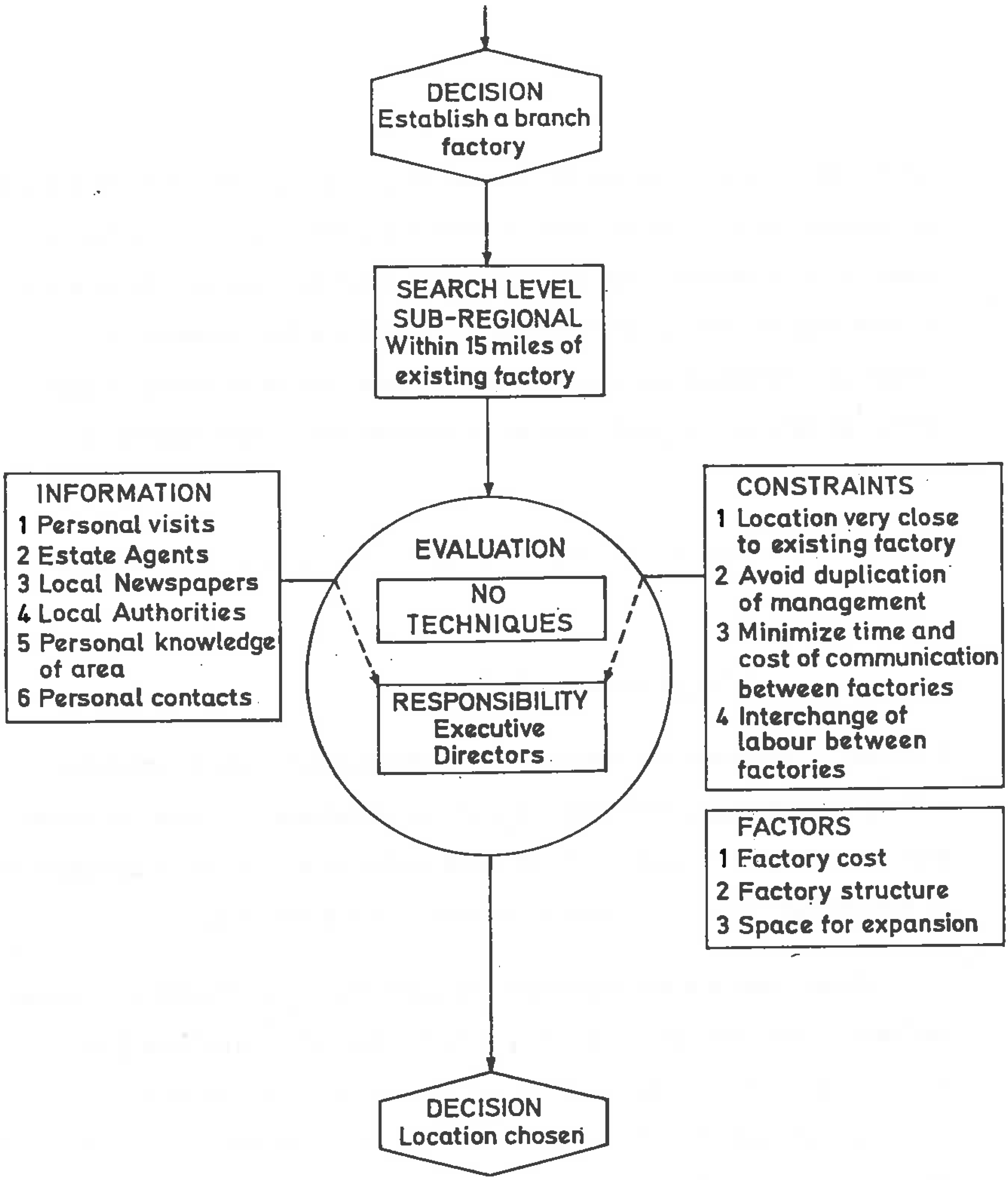
(9) How do policy variables enter the decision context?

It is a matter of empircial investigation to determine the answers to such questions. However, it is the role of a future behavioural theory to embed, at a particular level of resolution, what are considered to be relevant hypotheses about situational constraints in a representation - analytic or otherwise - which will guide individuals (or aggregates) through states of natural or constrained locational change (development).

Denoting the current association between a decision unit d and a stock element s, with respective attributes $\underline{a}$ and $\underline{b}$, as $d(\underline{a},\underline{b})s$, we therefore represent transitions in terms of different states of association,



3 (a.) Residential search and selection (from Maclenan, 1977)



3 (b.) Branch factory search and selection (from North,1974)

which will be induced either by changes in a and/or s. All transitions may be regarded as specific responses to triggers, which may be a policy in question or associated with the natural dynamics of d and s. It is self-evident that observable associations $\{d(\underline{a},\underline{b})s\}$ are the products of transitions occurring at some time in the past, and in observing cross-sectional data the implicit process of aggregation in time should be recognised.

Let us summarise the transition contexts at time t in terms of the following notation:

$$T_t\{d(\underline{a},\underline{b})s \rightarrow d(\underline{a}',\underline{b}')s' \mid \underline{A}(\underline{b})\}D$$

in which D represents the process of selection between the alternative actions considered A, from which $A_{s'}(\underline{b}')$ is selected. We would emphasize that the decision variables of different individuals may not be independent, as exemplified by congestion and clustering phenomena [7].

We now consider two important and much-criticised aspects of current rational choice theories: firstly, that the set of alternatives $\underline{A}$ is uniform and uniformly-known across the population in a given market segment, and, secondly, that D represents maximisation of a utility function defined on the attributes of the alternatives $\underline{A}$.

That different decision-makers differentially search available options and therefore acquire differential information about them is a feature of both residential and industrial location [20; 53; 82]. However, in the search for a new location, it is relatively easy to find common characteristics amongst some, though not all, firms. Thus the small, privately-owned firm seems to have an unsystematic search pattern which has as its main constraint the houses of key workers. Very rarely is the search radius over ten miles, and that distance can be seen as an absolute constraint.

Most small firms start life in a vacant building or share a parent's factory, and most are usually near to the same type of small firms, in order to gain linkage benefits. By contrast, large firms have a much larger search radius, usually for the simple reason that a suitable site cannot be found locally. (Most new branch plants are based within 50 miles of headquarters [38].) Even so, a distance of more than 100 miles is very unusual, and the larger the proposed move the greater the consideration given to not moving at all. Large firms are more likely to be tempted by Development Area subsidies. As a rule, they move, as we identified above, as a result of expansion and other often-quoted factors like labour force [38; 50]. It seems that scale is critical in the search process. Thus a multi-national may undertake a detailed examination of alternative countries in a search for a suitable location but, after this, it is interested in any site, within a large radius, which is vacant. By contrast firms limited to one city or region may make a more careful search. Search depends on the number of attributes being considered which a site must have to be considered as satisfactory. If a firm's requirements are demanding they can be potentially met by far fewer spaces; others whose attribute requirements are less demanding will have to consider far fewer alternatives.

For residential location, it is well known that the area of search generally varies with current location, the reason for movement and the information channels used. Life-cycle moves tend to be associated with very localised searches, while long distance searches usually accompany a change of job. Lyon and Wood [54] have recently suggested that, in practice, house buyers concentrate on only one or two variables in making a decision, perhaps using these as substitutes for a range of others; that they are often influenced by boredom in looking at houses; that they often do not take much time in deciding on a house; and, generally, that they do not engage in a 'rational' search and decision process.

Three specific constraints may be identified with the search process itself:

(1) Time - a much underestimated factor [34].

(2) Information - evidence from the U.S. [74] and the U.K. [44; 67] is that people predominantly use informal channels, particularly in local moves, although the proportions vary by tenure group and class. The inference must still be that families search areas with which they or contacts are familiar. In this context, it is of interest to note the current debate [69] on the existence of several relatively distinct housing markets over urban space.

(3) Location - leading on from this the initial location is obviously a heavy constraint on the areas searched.

The influence of these search constraints implies that 'choosing' a house inevitably involves a restricted and possibly small degree of choice. A corollary is that the constraints may be so great as to take a decision not to move. Of course such a decision can be made before the search is initiated. In either case such decisions can at least be partially revealed by households which adopt alternative, implicit location strategies - for instance, house improvement.

The different industrial and residential search strategies and inter-individual heterogeneity of information may perhaps be incorporated into random utility choice theory by using a probabilistic opportunity set generator [70]: that is, by treating $\underline{A}$ as a random variable, or by replacing the popular multinomial logit model by the dogit function [35], which is viewed as incorporating limited information [9]. However, it would appear that still more radical modifications may be in order. Previous work summarised in the decision scenarios of Figure 4, points to the incorporation of satisficing criteria into the decision mechanism. This is possibly in conjunction with a restricted 'trade-off' [42; 54; 56; 60; 65]. An elimination-by-aspects strategy [84], too, would especially seem to have a role to play in model development.

It should be appreciated that the preceding decision theory refers to the individual unit. Market segmentation, as always, must play an important role in the aggregation process. It is not the intention, nor would it be possible, to account for the totality of variation in observed patterns of individual behaviour at every scale of analysis. It is yet to be ascertained, however, how many factors are required to provide a 'realistic' representation of the decision process at any level. More information is clearly desirable to assess how policy variables, mediated by individuals' attributes, constraints and available alternatives, can influence the destiny of a system. This investigation should ideally be achieved by examining individuals' decision contexts and behaviours. However, this is extraordinarily expensive and difficult for requisite large samples, over time. Failing this, the modeller must rely on the interpretation of variability in observable patterns of behaviour at aggregate and disaggregate levels. We conclude by examining some of the pitfalls in this seemingly easier exercise. We also suggest computer-simulating modelling - checked against samples of available transportation, land use, household and other states for cities, at different time periods - as a practicable alternative.

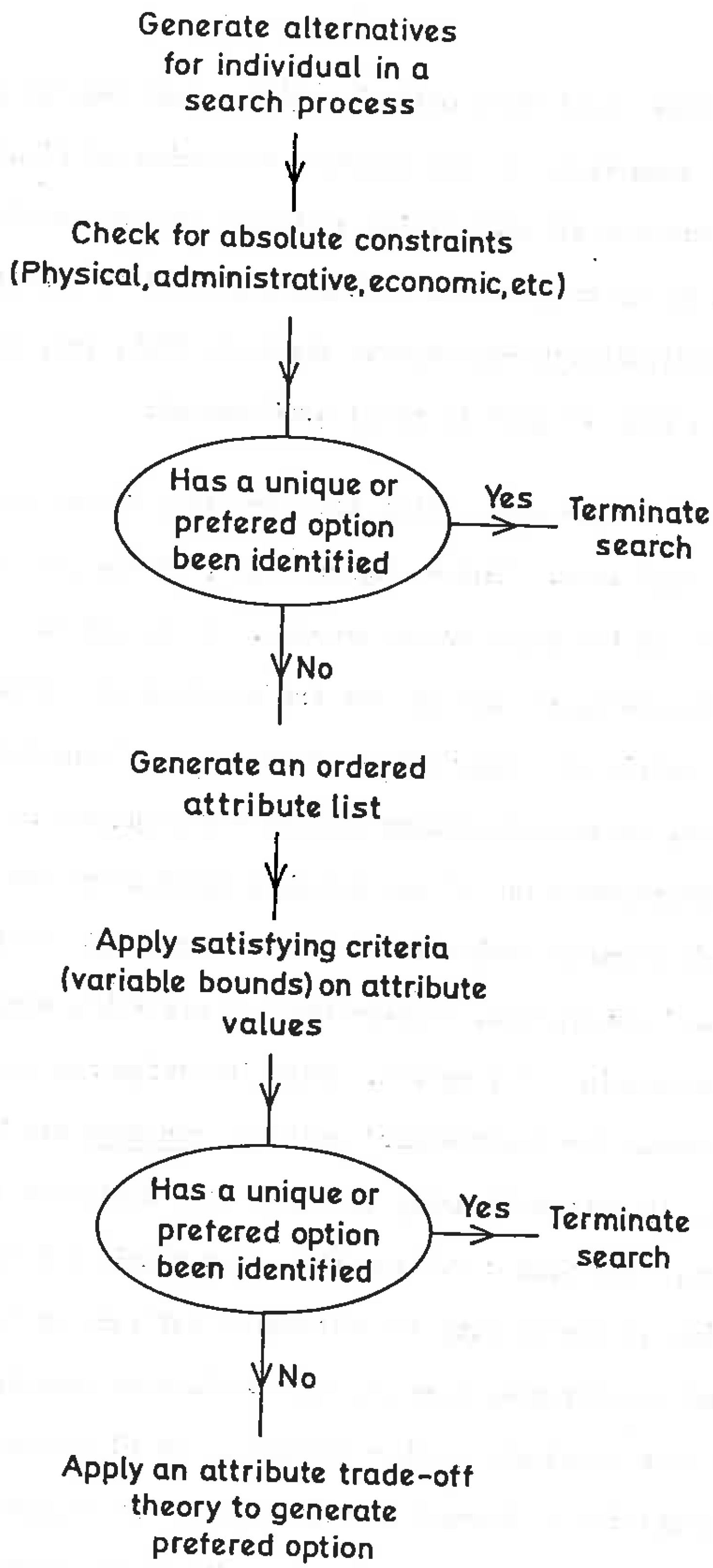


Figure 4: A possible structuring of theoretical enquiry for behavioural choice

5. OBSERVATION, INFERENCE AND MODEL DEVELOPMENT

In socio-economic systems, the responses to policy variables are very seldom observed directly, and elasticities to determine them *are* generally inferred from *observed* behaviour, typically at one or more cross-sections. Thus, at a 'snapshot' moment, we might be endowed with the information $\{d(\underline{a}',\underline{b}')s\}$ for a set of behavioural units in the system, in which $\underline{a}'$ and $\underline{b}'$ represent limited information on the attributes. For residential and, particularly, industrial, location, considerably less information is generally available. The modeller may have to be content with broad indicators of spatial patterns, and limited observations on households/firms, and on stock. In this final section, we discuss briefly two problems of inference for dynamic, behavioural location modelling which this state of affairs engenders: namely, the equifinality problem and the causation-correlation problem. Their severity refinforces the cause for carrying out the location modelling above by computer simulation; that is, by using models to generate artificial data. Such data may then be 'checked' to validate the model against samples of active data available for successive time periods. This provides 'large' numbers of 'goodness-of-fit'tests, all of which must 'succeed', to validate the model.

Ultimately, of course, a model must be judged *post hoc* through an examination of such discrepancies between its predicted and actual behaviours. However, as we have indicated, the current knowledge of a system falls short of that required for confident behavioural predictions using standard analytic modelling approaches. Many hypotheses are simply untestable with available observations (eg. utility or profit-maximisation). A resultant consequence for current enquiry is that alternative possible explanations or hypotheses, which are all apparently consistent with observed patterns appear. This equifinality problem can take several forms.

An excellent example of the equifianlity issue is available in the spatial interaction functions embedded in residential location models. Consider, for example, the interpretation of β in equation (3).

Directly from the model we may derive expressions relating to the role played by β:

(1) Dispersion characteristics

$$\frac{M_{ji}}{M_{ji'}} = \frac{A_i}{A_{i'}} e^{-\beta(c_{ji}-c_{ji'})}$$

(2) Moment characteristics

eg. mean value of cost $\langle c_{ij} \rangle = \frac{\text{constant}}{\beta}$

(3) Elasticity characteristics

$$\frac{\partial M_{ji}}{\partial c_{ji}} = -\beta M_{ji}(1-M_{ji})$$

$$\frac{\partial M_{ji}}{\partial c_{ji'}} = \beta M_{ji} M_{ji'} , \quad i \neq i'.$$

In these expressions, each manipulation on the model naturally involves the parameter β, which is often interpreted directly in terms of these manipulations, that is, as a dispersion or elasticity parameter. These interpretations are related to the <u>analytic</u> properties of the models and are totally independent of any underpinning <u>theory</u>. Note that (1) and (2) characterise a cross-sectional pattern, while (3) pertains to conditions of change, and is thus pertinent to a policy-testing context. The same parameter is involved in a <u>description</u> of variability <u>and</u> in an elasticity context, governing response.

It is widely known that the model form (2) may be generated from an embarassingly large number of different theoretical perspectives. Within each one of these perspectives, β will have a distinct interpretation which will correspond to a particular role played in the theory. Take, for example, the interpretations of the β parameter in the model, which is underpinned by the entropy-maximising, random utility-maximising and intervening opportunities theories:

(1) Entropy-maximising theory: $\beta = \dfrac{\partial S}{\partial C}$

S : entropy at most probable configuration of the system

C : total observed trip cost;

(2) Random utility-maximising theory: $\beta = \dfrac{\Pi}{\sqrt{6}\sigma}$

σ : common standard deviation of the utility distributions generating the model;

(3) Intervening opportunities theory: β related to the probability that an opportunity will be accepted in the search process.

In (1) no micro-behavioural assumptions are made whatsoever; the most likely pattern is generated subject to available knowledge. In (2) and (3), specific behavioural assumptions are made which cannot be verified on available information.

Here lies a fundamental problem. If a multiplicity of theories can be found to generate analytically a model of specific functional form which provides a good base year fit, does it matter that we cannot discriminate between them on the available evidence?

In one sense - a practical one - the question is non-consequential. The same functional expression is involved and therefore, naturally, identical forecasts will be generated from the different theoretical perspectives. However, as has been pointed out [76], the production of the particular functional form, for example (2), from various theoretical premises has become an end in itself, and not the <u>explanation</u> of the actual behaviour underpinning the statistical pattern. Since more realistic explanations can strongly be argued to advance both theory and policy, whatever the acceptable level of accuracy of the prediction, alternative methods to determine these seem desirable.

This debate is tainted with philosophical problems. However, an issue of immediate practical relevance is the generation, sometimes, from varying theoretical assumptions, of equally acceptable models. These may succeed on the basis of statistical goodness-of-fit criteria, but yield different, and sometimes distinctly different, predictions [87;90;91]. In this case, cross-sectional information is not only insufficient to discriminate between hypotheses. More worryingly, it is inadequate to identify <u>any</u> acceptable model, for theoretical or for policy purposes.

Another class of statistical problems associated with the equifinality issue is generally referred to as the correlation-causation 'syndrome' [10;16]. Though well-known, it is often overlooked in practice, but is acute in dynamic modelling using cross-sectional data. Here, we refer only to a few aspects involved in the inference of causal relations for purposes of the prediction or control of behaviours from an analysis-of-variance at the cross-section.

Many of the more obvious difficulties in generating behaviourally acceptable models with cross-sectional data arise from the lack of adequate market segmentation, and the interference of proxy variables, manifested in the multi-collinearity problem. In addition, in the case of residential and manufacturing systems, the evolution of the supply side is such that several characteristics of newly available options are often intimately associated (eg. site area, neighbourhood characteristics, transport related attributes). Unravelling the influence of individual factors is therefore particularly difficult using cross-sectional data.

'Transitions' themselves may also conspire to deceive with such data. In the evolving behavioural system, the combination of birth and death processes over space can easily be confused with relocation decisions unless such information is explicitly available. In this context, it is interesting to refer to absence of information at the cross-section on non-transitions too. As is frequently remarked, for many households and firms, the character of the houses and factories occupied are considerably different from the type of property they may have liked to occupy but did not [56; 73]. Predictions of 'stayers' must be included in dynamic modelling. Indeed, it may well be the case that for some families or firms, the feasible options are so few that the supply itself leads to the observed 'demand' at any particular time. It is increasingly recognised now that without a full recognition of constraints - financial, physical, personal, administrative - the notion of revealed preference is at best dubious. Constraints, alternatives and preferences (or non-preferences) cannot be inferred from cross-sectional data on behaviours, as modelling would require.

Finally, and most importantly - because the observation of statistical associations seldom reveals anything about the processes which have given rise to them - information gleaned at a 'snapshot' moment (eg. an inferred elasticity parameter) will often be extremely misleading. For example, the existence of an accessibility index in the industrial location models described in Section 2, allows, in principle, a forecast of the land use pattern following the impact of a new transport system. However, as we have stressed above, the transitions available to the behavioural units can involve complex organisational as well as locational changes. To neglect the existence of the 'internal degrees of freedom' is therefore to deny an essential feature of modern industrial development. This organisational dimension is currently being appreciated in the related fields of trip generation [42], and in commodity flow analysis, and should become increasingly important in employment and housing studies, too.

6. CONCLUSIONS

There is little doubt that traditional spatial interaction and location models may be elaborated to produce excellent statistical fits to observed location patterns and may indeed serve as trend forecasts. There is equally no guarantee whatsoever that such models would provide an adequate basis for dynamic or policy analyses and generating the kind of information which is of relevance to policy makers. Indeed, most industrial location models are not constructed on derived demand principles, and are extremely limited in the range of population responses, other side effects and policies they can therefore address.

We have sought to treat the location decisions of firms and households in the same general dynamic framework in which the demand for stock attributes, and thereby location, are strongly dependent on the stage of development. Although more complex in terms of functional and organisational detail, we feel that there is yet much to be gleaned by returning to a behavioural perspective of the firm for more detailed categorisation, as in micro-behavioural treatments of the housing market. Both for future theory and practice, the choices, constraints and decision contexts of actors at different scales seem essential for the understanding of 'natural' and 'controlled' processes.

As a general approach to dynamic model development which may accommodate the diversity between individual actors, interdependencies and interactions, together with a direct assualt on the aggregation problem we may appeal to micro-simulation, relevant applications of which have recently been reviewed by Orcutt *et al.* [68], Haveman and Hollenbeck [41], Clarke *et al.* [77] and Williams [88]. This procedure involves the manipulation of real and/or synthetic samples which are subjected to the various demographic, social and economic processes responsible for the transitions between states. Such a simulation procedure may also be adopted for resolution and aggregation of decision models such as have been described earlier and applications to this context are described by Williams and Ortuzar [90] and by Walker [85].

While the price paid for the micro-simulation approach would inevitably be the problems of practical implementation, we feel that such a path towards the qualitative and quantitative analysis of the complex forms of dynamics and adaptation to policy should be followed and would be rewarded. We feel it also inevitable that such micro-models will be increasingly reliant on the stated intention information to explore the potential changes to a system.

The theoretical concerns of behavioural 'process' modelling cut right across traditional disciplinary boundaries, taking routes in subjects as diverse as economics, behavioural geography, transport studies, operational research. The problems of generating realistic representations in dynamic policy-oriented location models - analytic <u>or</u> simulation - appear as great as their potentialities. The framework presented in this paper does not deny the existence of problems, such as the aggregation issue and the complexity of the choice process. It welcomes the possibility of their solution as integral to the process of model construction. This is in marked contrast to many established models which create an illusion of reality it is dangerous to perpetuate as the cridibility of their theoretical and methodological assumptions relating to response becomes increasingly undermined.

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ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support given by the S.S.R.C.