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PREFACE

This book is the direct result of the Second International Workshop on Strategic Planning held at the Delft University of Technology in April 1980. The workshop was initiated by the EURO Working group on Operations Research in Urban and Regional Planning and the Working group on Strategic Planning of the British Section of the Regional Science Association. Consequently, the meetings were attended by individuals with an often bewildering range of experience, concerns and disciplinary backgrounds—precisely those ingredients that are so useful for defining the full range of issues and possibilities of strategic planning.

The purpose of this book is to explore the conditions under which strategic planning takes place or might take place in practice. Special attention will also be devoted to issues of substantial research. Various methodological approaches will be considered and several practical planning processes are analysed. It will appear that the notion of 'strategic planning' conjures up many different meanings to the various authors. However, all of these meanings are robust enough to tolerate a concept in which strategic planning is seen as a set of activities to guide future decision-making. Therefore, strategic planning is not directly dealing with implementation problems. Obviously, this does not imply—as will be illustrated in this book—that implementation problems are denied or neglected.

This book is composed of five parts. Part I focuses on the theory and application of strategic planning. A general overview will be given of the major shifts that have occurred in the basic foundations and emphasis of this type of planning. Several regional planning processes in the United Kingdom and The Netherlands are discussed. It will be shown that the concept of strategic planning has no balanced—theoretically consistent—identity yet.

Part II is devoted to spatial theories and methods which could effectively contribute to an operational analysis of strategic planning problems. Several spatial interaction frameworks are treated and empirically illustrated.

In Part III some interesting simulation models will be discussed. As the field of urban and regional studies grows more complex, it is clear that these models offer great possibilities in situations where an understanding is needed of partial issues in relation to a comprehensive whole.

Simulation models can be used to gain an insight into possible future situations. However, there are also other ways to deal with the time to come. Part IV is devoted to three entirely different approaches to 'manage the future'.

Finally, in Part V attention is paid to the monitoring and review in strategic planning. Planning goals will change, and unexpected impacts trigger corrective actions that might result in progressively greater economic and political commitments to make further corrections if the initial ones are not successful. In order to come to an effective strategic planning it is necessary to develop a methodology which is able to cope with such subsequent induced decisions in an adequate way.

A large number of people cooperated to make the workshop and this book possible. I owe especially debt to Paul Drewe, Rudi Hamerslag and Albert Pols—professors at the Delft University of Technology—for chairing the meetings.
in a very stimulating way. I also owe great debt to Peter Batey and Bruno Dejon, who were of valuable assistance in coordinating the British and the German contributions, respectively.

It should be noted that a quick and relatively simple publication of the papers was preferred to a balanced edition which would have cost too much time to prepare. Some of the contributions need a rapid dissemination because it describes research which is still in progress. Therefore, I did not pay any attention to the heterogeneity of styles, grammar, levels of discourse, notations, and so forth. Purists will forgive me for not paying more attention to matters of editorial elegance.

Henk Voogd
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The concept of strategic planning originates from business planning, where it is often referred to as applying this kind of approach. Therefore, a comparison of the experiences in business planning and the ideas on strategic planning which emerge from physical planning is very interesting. This will be done by BLACKER, who is interested in his contribution to the methodology of strategic planning, and HUNTER, who examines the contribution of both. A comparison of RAUSCHER and HUNTER is then made to show the systematic methodology of strategic planning based on a broad, general, and comprehensive methodology. The methodology of strategic planning is organized together with a number of models, which are used to show the methodology. The methodology of strategic planning is organized together with a number of models, which are used to show the methodology.

PART I

THEORY AND PRACTICE OF STRATEGIC PLANNING
EDITORIAL INTRODUCTION

The concept of strategic planning originates from business planning, where already a long tradition exists in applying this kind of approach. Therefore, a comparison of the experiences in business planning and the ideas on strategic planning which emerge from physical planning is very interesting. This will be done by KREUKELS, who outlines in his contribution some striking correspondences and differences. A remarkable conclusion of Kreukels is that a systematic methodology of strategic planning based on commitment generation - organization together with analysis - did not crystallize out until now. Strategic planning needs a methodology that covers not only analysis but also bargaining, organization, consulting and so forth.

This conclusion is to some degree confirmed by BARRAS. In his paper he stresses the importance of supporting analysis as a means to inform planning through better understanding of how the key development processes in an area are operating and interacting. He argues that procedures of strategic planning must not become so protracted that the whole process suffers from excessive delay and inflexibility.

BRACKEN and HUME discuss in their contribution some interesting research with respect to the functioning of structure planning in Wales. One noticeable conclusion is that there has been almost no cross-fertilization of ideas and experiences between local authorities. Nevertheless, there exists in Wales a statutory requirement to consult with neighbouring authorities. The structure plans in Wales appear to be almost entirely professional's plans, in that the input from representatives of the people has been minimal. According to the authors a radical re-examination is required of the role and the power of the authority over the processes operating in its area. They argue that a mapping of the responsibilities of the various authorities might be an interesting new avenue to explore.

An intriguing planning approach is described by DEKKER, who outlines the ideas behind the preparation of the regional plan of Twente. This planning process bears several experimental features. Although the provincial government is legally authorized to establish a regional plan an organization has been set up in which various governmental and semi-governmental bodies of different levels are cooperating. Therefore, this approach is a good example of commitment planning, in which supporting analysis is seen as a function of the deliberation and bargaining process and not as a 'static' activity in the first phase of the plan-making process.
Εραστής Στρατής, Περιφέρεια Βορείου Ελλάδος

Είδος: Επιστολή

Διεύθυνση: Περιφέρεια Βορείου Ελλάδος

Ημερομηνία: 10/09/2023

Συνάντηση με τον Πρόεδρο της Περιφέρειας 

Η συνάντηση έγινε στις 10/09/2023 στο Προεδρικό Μέγαρο του Περιφερειακού Ελεγκτή, Περιφέρεια Βορείου Ελλάδος.

Περιέχει σημαντικά μονάδες για την επικοινωνία και την πληροφόρηση του κόσμου, σε συνδυασμό με την παρουσία των απεριόριστων διαδικτυακών μέσων.

Θα συνεχισθεί με τον Πρόεδρο της Περιφέρειας για τη συνεχή επικοινωνία και την πληροφόρηση του κόσμου.

Ευχάριστος για τη συνάντηση.

Θώμας Κωνσταντίνου

Βορειοελληνική Περιφέρεια
1. INTRODUCTION

At present a comparison of physical and business (corporate) planning offers a fruitful starting point for further developments in strategic planning more generally (Branch, 1966; Ackoff, 1970; Kreukels, 1978). If one considers strategic planning as a systemic mode of middle or long range planning (5-25 years), then business planning contains the most explicit and comprehensive framework for a methodological approach of this kind of planning. On the other hand physical planning is characterized by a well developed tradition of long range planning (10-25 years). But its methodological approach based on systems theory and rational decision theory and brought together in processplanning is deficient if one needs a planning methodology, that covers not only analysis but also bargaining, organization, consulting and so on (Kalba, 1974; Solesbury, 1974). Precisely these last themes are connected to analysis within the tradition of strategic planning in the business sector. In that tradition not only systems analysis and operations research, but also organization and management theory have been applied. Particularly this characteristic of strategic planning in the business sector makes an inventory of experiences there most interesting. Further methodological developments in middle or long range physical planning may be derived from that. This contribution starts with an introduction of the concept of strategic planning with particular reference to business planning. Here an attempt is made to bring out a nucleus of a theory and methodology of strategic planning. This is followed by a comparison of the origin and general developments of a middle/long range approach in the business sector and in physical planning. In the next part the development of a methodology of strategic planning within the business sector is described for two phases (1960-1970, 1970-1980) and confronted with experiences of processplanning in the field of physical planning in the same period. Then a prototype of strategic planning, which summarizes the methodological achievements in the business sector, is presented. Possible contributions of that prototype for a middle or long range approach in physical planning are indicated too. The conclusions at the end of this overview are directed to the prospects held by organization and management theory in general for further methodological developments in long range physical planning.

2. THE CONCEPT OF STRATEGIC PLANNING

In a general sense the concept of strategic planning is related to a differentiation of planning levels:

- **Strategic level**: long range, macro level, (inter) national scale,
- **Tactical level**: middle range, meso level, (sub) regional scale,

Strategic planning in this sense can be found in physical planning, for example within national and (sub) regional planning studies, the strategic choice method and in the literature about monitoring (Strategic Plan for the
Within the business sector there are a great number of near-synonyms for a middle/long range orientation in management: corporate strategy, business strategy, strategic planning, long term planning and corporate planning. As such this orientation distinguishes itself from one emphasizing operational problems (the daily management). The concept of strategy has been taken over in this context from the military sector in the fifties (Emery, Trist, 1965). Strategy is then defined as an attempt to guarantee the survival of the organization by a conscious confrontation with influences from within and from the environment of the organization. To that end one has to consider external and internal circumstances and changes in order to adopt a course of action (a strategy) that offers maximal guarantees for the survival of the whole. Strategy-assessment then is identical with choosing objectives and implementing these (Croon, 1973). Strategic Planning has been defined recently as the systemic preparation of decisions, regarding what services an organization shall render after a period of take-off (lead time), to which clients, in which regions and with which means this shall be implemented. These means may involve finances, personnel, machinery, procedures, organization-structures, training, etc. Within strategic planning the following elements have been distinguished: the chosen objectives ('what' strategies), the chosen instruments ('how' strategies), the chosen time horizon (based on lead times) (Snellen, 1975). This last definition is the basis for the subsequent analysis of strategic planning.

3. ORIGIN AND GENERAL DEVELOPMENTS IN BUSINESS AND PHYSICAL PLANNING

In the period 1958-1965 the business units became increasingly concerned with the environment and with each other. Also great and sudden shifts in production, markets and investments led to a situation of uncertainty and risk (Snellen, 1975). In this context middle to long range management became urgent. Here one has to locate the origin of strategic planning in the business sector. Ansoff (1964) emphasized the need to pay attention to strategic problems in addition to operational problems. A strategic approach was related to a general conception of behavioral patterns in organizations. Existing forms of planning: product, market and investment planning had to be integrated in a more inclusive approach: strategic planning. Generally speaking this means a shift from short term to middle or even long term management. Partial solutions within the organization should be brought together in a well integrated and consolidated course of action as a reply to uncertainty and risk in the near future. As such strategic planning may be considered as a supplement and extension of daily management. It is not surprising then, that short term objectives and capacities are closely related to long term perspectives in this approach. This means, that particular attention is paid to implementation and to a realistic planning horizon (middle range planning: 4/5 years).

Physical planning on the other hand has been characterized from its early days by a long term and comprehensive approach. Traditionally the attention for daily policy matters and activities and for implementation was marginal. Within the mode of process planning one sees gradually a reorientation to 1) a planning horizon, which is more in keeping with capacities of control and degrees of knowledge, 2) the necessary relations between middle/long range perspectives and short term policies and opportunities (growing attention for implementation, monitoring and the review of plans), and 3) partial programmes and plans as building blocks of long term plans.
In this sense the development of planning in the business sector and in the field of physical planning are in opposite directions. Due to their different starting points, however, physical and business planning have come closer together as a result of these converse developments. In the following scheme these diametric lines of progress in both fields are illustrated.

**Scheme 1. Developments of Planning in the Business sector and in Physical Planning.**

Given the convergence of developments in both of these fields of planning and given the specific attributes of business strategic planning it is worthwhile to profit from the achievements within the business sector for further methodological developments in middle/long range physical planning. In particular the experience in business planning with procedures for strategy formulation may be of use in physical planning. In these procedures specific attention is paid to relations between long term strategies and short term principal implementation schemes. Also, partial programmes are emphasized as building blocks for long term plans. More interestingly, the process of planformulation is based on an exchange between agencies, that constitute the daily practice of policies, management and activities within the organizations. To illustrate this methodological lesson from business strategic planning a more detailed description and a comparison with attributes of processplanning in physical planning is presented in the following part.

4. METHODOLOGICAL DEVELOPMENTS IN BUSINESS STRATEGIC PLANNING: A COMPARISON WITH PHYSICAL PLANNING

The first phase of business strategic planning could be located in the period 1960-1970. This phase was characterized by a goal formulation approach (Gilmore, Brandenburg, 1962; Stewart, Doscher, 1963; Ansoff, 1965). Also one finds here a problem solving variant. Then the planning process is divided in four steps: 1) Specification of Problems, 2) Formulation of Alternatives, 3) Evaluation of Alternatives with Criteria for Problem Solutions, 4) The Choice of the Solution and its Implementation (Ansoff, 1965).

In essence this is a decision-logical approach, which is also the base of processplanning in physical planning in the period between 1969-1975 (McLoughlin, 1969; Chadwick, 1971). Planning methodology was at that time primarily related to analysis. Planformulation was considered mainly as a rational processing of information with goal setting at the start and the plan at the
end. But there were also important differences between the first phase of business strategic planning and process planning in physical planning. In the business sector the first phase was characterized by a search process, related not only to externally defined objectives but also to internal capacities of the agencies within the organization. The approach was also selective in the formulation of strategies (formulation of strategic items). By these two characteristics strategic planning in the business sector is distinguished from process planning in physical planning. These characteristics may be considered as an anticipation of the second phase (1970-1980), in which the methodological features of business strategic planning are diverging even more from those of process planning in physical planning.

In the second phase (1970-1980) the planning process in business planning is considered as a gradual progress of formulating objectives to means and capacities. Here plan formulation is not based on fixed objectives or targets at the very first of the process. Rather plan formulation is considered as a goal-seeking and -finding process. Besides, and more importantly, planning methodology gets a broader character. Not only analysis is emphasized, but also bargaining, organization and so on are included in the methodology. This extension is expressed in the term: 'search processes', which are considered a combination of research and consultation. In other words, the goal-seeking process is interpreted no longer as a decision-logical procedure, but as a commitment generating process, resulting in a plan or strategy in the form of a commitment package. The relation between objectives, means, capacities and potentials is represented in combinations of 'what' and 'how' strategies throughout the whole phase of plan formulation and finally in the ultimate plan: strategy scheme + principal implementation scheme. This approach of relating perspectives to capacities is also manifest in the form of explorations. The search processes are not only oriented to information streams from the top-down, but also from the bottom-up and analysis and consultation is not only based on an inside-out but also outside-in orientation.

When comparing these methodological features with the formal methodology of process planning in physical planning, then some significant differences will be noted. Notwithstanding the attention to phasing, iteration and a more specific and partial use of quantitative methods, the methodology of process planning is until now primarily a decision-logical one. Yet a gradual change occurred in middle to long range physical planning (Kalba, 1974; Solesbury, 1974; Batey, 1977; Krueckeberg, 1978). This change is connected with a re-orientation from plan- to planning methods. Particularly empirical studies of planning practice stimulated this reorientation (Boyce, Day, McDonald, 1970; Friend, Power, Yewlett, 1974; see also Warren, Rose, Bergunder, 1974). In fact, the decision-logical approach is relativated, but a systemic methodology, based on commitment generation, organization together with analysis, did not crystallize out until now. In the following part an example of such a framework is presented in the form of a recent prototype of strategic planning in the business sector.

5. STRATEGIC PLANNING: A PROTOTYPE

In this part, first a process scheme is presented, which is based on the methodology of strategic planning in the business sector, as described by Snel- len (1975).
Scheme 2. Steps in Strategic Planning processes, taken from Snellen (1975).

<table>
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<tr>
<th>Step</th>
<th>Description</th>
<th>Process</th>
<th>Analysis + Consultation</th>
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<tr>
<td>1.</td>
<td>Assessment of the Existing Strategy</td>
<td>Product/Market + Means Strategy</td>
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<tr>
<td>2.</td>
<td>External Explorations (Search process (1): analysis + consultation)</td>
<td>Product/Market + Means Exploration Exploration of the Environment; opportunities/threats</td>
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<tr>
<td>3.</td>
<td>Internal Explorations (Search process (2): analysis + consultation)</td>
<td>Product/Market + Means Search Exploration of the Organization; Strengths/weaknesses</td>
<td></td>
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<tr>
<td>4.</td>
<td>Tentative Strategy</td>
<td>Preliminary + Preliminary Means Strategy</td>
<td></td>
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<tr>
<td>5.</td>
<td>Evaluation</td>
<td>Search Processes by means of existing and new criteria or business policy (internal/external)</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Definitive Strategy</td>
<td>Definitive + Definitive Means Strategy</td>
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Implementation

The remarks made by Snellen with each of these steps are repeated briefly here:

ad 1. **How is the existing strategy as to objectives and means assessed?**

An appropriate basis for formulating a new strategy would be absent if one had no understanding of the existing strategy.

ad 2. **What external developments will take place?**

Of concern here are developments which require a strategic response. Such developments need to be predicted. This may include not only input or output factors but may concern means as well. The latter is somewhat neglected in the literature (assessment of opportunities and threats).

ad 3. **Is the existing organization able to cope with the external developments?**

The evaluation of an external development as favorable or not can be made only against a backdrop of possible and probable developments in the organization itself (assessment of strengths and weaknesses).

ad 4. **What actions and reactions appear feasible and desirable?**

The previous steps may indicate that the present strategy should be continued or altered. In either case it appears helpful to translate a preliminary understanding into provisional strategies, regarding objectives and the main modes of implementation both (tentative strategies).
ad 5. What options as to the definitive strategy are acceptable?

In the course once more of several rounds of research and consultation some of the alternatives in the tentative strategies are eliminated and a final one is selected (the definitive 'what' and 'how' strategy).

This approach is characterized moreover by the following properties. In the first place in the search processes a significant emphasis is placed on contributions from the rank and file members of the organization rather than working only from the top down. The partial plans of the various divisions of the organization involved are attributed an important role in the process of strategy formulation (e.g. portfolio-balancing) (bottom up as well as top down approach). Furthermore during the search processes one attempts not only to project the expectations and perceptions of the organization but also to formulate the opportunities and limitations, defined by units in the environment of the organization (e.g. consumers' perspective, investors' analyses, etc.) (outside in as well as inside out approach). In the third place, the objectives are not taken solely and purely as the starting point and motivating force to strategy formulation but are considered to be outcomes of the process of research and consultation as well. The various participants will have committed themselves to these objectives gradually over the rounds of search processes (commitment packages as result of plan formulation). Finally, strategies regarding objectives and those regarding means are developed jointly from the outset (i.e. 'what' and 'how' strategies are related).

Generally the following comments can be made on this prototype of strategic planning, regarding a possible application in physical planning. First one should have in mind important differences between the fields of business planning and physical planning. By example:
1. physical planning as activity of the governmental system is characterized by interorganizational rather than intraorganizational relationships;
2. physical planning as activity of the governmental system functions in an administrative/political context;
3. the object of physical planning is diffuse and comprehensive when compared with that of business planning.

Secondly, in both of these traditions (strategic planning in the business sector and process planning in physical planning) the methodological elements for implementation policy itself in conformity with the chosen strategy are still not clearly profiled.

Given these comments the methodological traditions of strategic planning in the business sector can be of value for further developments of strategic planning in physical planning. In the following conclusions this statement is summarized.

6. CONCLUSIONS

The most important lesson of strategic planning in the business sector for the field of physical planning is the widening of planning methodology from analysis to consultation, organization and so on. In terms of further experiments this means a plea for use of organization and management theory, particularly the applied versions in the traditions of planning of change and organization development (Schein, 1969; Zaltman and Duncan, 1977; Zaltman, Duncan and Holbek, 1973; Rothman, 1974; Schmidt, 1976). Furthermore the approach of strategy formulation within organization and management theory is interesting (Mintzberg, 1979). In addition to the regional science and operations research tradition in physical planning this reorientation implies a linkage with social psychology, sociology, political and administrative
An impulse to this reorientation in more general terms is attempted by the author in his thesis (Kreukels, 1980).

REFERENCES

1. INTRODUCTION

This paper attempts to summarise some of the important lessons to be learned from the first ten years of Structure Planning in Britain. When introduced, this new planning system was hailed as a major conceptual and methodological advance, and its progress has been followed with considerable interest by planners throughout Europe. After ten years one cycle of planning has been completed, and sufficient experience has been gained for a review of progress to be worthwhile. It must be emphasised, however, that the system is still evolving, and that there are several differing views on its achievements and shortcomings so far. Furthermore, there is considerable uncertainty about how it may evolve in the future. Consequently, judgements made at this stage must inevitably be both subjective and interim in character.

The content of the paper is divided into five sections. Firstly, there is a brief discussion of how the operation of the previous planning system influenced the design of the 1968 and 1971 Town and Country Planning Acts. The next section indicates how the context for Structure Planning has changed since 1968, concentrating on internal procedural changes in local government and on external changes in economic conditions. There then follow two sections which describe the progress that has been made with Structure Plans in the last ten years, then summarise how the content of Plans has changed over this time. Having reviewed current progress, the final section then draws out some general lessons concerning the problems of implementing strategic planning systems.

2. THE AIDS OF THE REFORMED DEVELOPMENT PLANNING SYSTEM

The reasons for the major reform of British planning in 1968 can only properly be understood in relation to the operation of the former planning system, introduced in the immediate post-war period. The 1947 Town and Country Planning Act was a fundamental innovation, in that it combined a new system of land use planning with new powers for the public control of land use. Development plans were to take the form of a map, supplemented by a written statement of policy. The map was to show in precise detail the existing use of all land in an area, and the proposals of the local authority for its future development. The parallel powers of development control meant that planning approval had to be sought for any new development or change of use on a plot of land. These planning and development control powers of local authorities were the basis of the British planning system for the next twenty years. For a detailed review of the 1947 planning system and its operation see Hall et al (1973).

Two criticisms were increasingly made of this system during the 1950s and 1960s. Firstly, a great deal of work was necessary to produce the land use maps, so that they were slow to appear and, once produced, infrequently reviewed. In other words, the system was inflexible and slow. Secondly, the excessive detail in the plans about each plot of land obscured broader policy issues. In particular, there was not enough attention paid to the underlying
social and economic forces which determine land-use development - for example, the trends in labour and housing markets which affect where people live and work.

As a reaction to the perceived shortcomings of the current system, the planning literature of the 1960s began to emphasise the need for more comprehensive and strategic planning (see, for example, McLoughlin, 1969 and Friend and Jessop, 1969). The new ideas strongly influenced a whole series of special, innovative sub-regional planning studies during the 1960s, producing strategic development plans which acted as prototypes for subsequent Structure Plans. The increasingly critical attitude towards the established planning system was highlighted by an official government-sponsored enquiry which reported in 1965 (Planning Advisory Group, 1965). It was the recommendations of this Group which laid the foundations for the 1968 Town and Country Planning Act, proposing a reformed, two-tier system of development plans.

County Structure Plans, at the upper level, were intended to differ from the previous development plans in several ways. They were to be primarily written statements, rather than maps, which set out the issues and put forward policies concerning all aspects of a local area over the next fifteen years or so. Not only was a broad range of subjects to be included, but the plan was also to cover the relevant activities of all agencies in the area, including private companies, nationalised industries, central government and households, as well as those of the local authority itself. Plan proposals had to be supported by analysis and reasoned justification, and had to take account of the likely availability of resources. They had to be subjected both to public scrutiny and central government approval. Once approved, plan policies were to be continuously reviewed and updated.

The lower level Local Plans were intended to be closer to the pattern of the previous 1947 system. They were to elaborate the more detailed effects of broad Structure Plan development policies, either in terms of particular local areas or particular topics. It was not intended that these local plans be submitted to central government for approval, but they could only be finalised once the Structure Plan policies were approved. (For a more detailed discussion of the new development planning system see, for example, Solesbury, 1974).

This is the essence of the current development planning system in Britain. It is important to remember that, unlike the previous 1947 legislation, it was only a procedural and administrative reform. Though it widened the planning obligations of local authorities, no new powers to control development, or resources to invest in development, were made available. This has had an important influence on the way the system has evolved.

3. THE CHANGING CONTEXT

Before considering how this development planning system has operated in the last ten years, it is important to note that the context for Structure and Local Planning has changed radically since 1968. There are two aspects of this changing context. On one hand there has been a series of reforms of local government organisation and procedure which have inevitably affected the role of development plans. On the other hand, the changing economic situation has markedly affected the scope and content of plans.

Let us consider the organisational changes first. The 1974 reform of local government in Britain did not fundamentally affect the aims of the 1968 planning system, but it did complicate the division of planning functions between departments and between the two levels of local government (Counties and Districts). This has had repercussions for the preparation of Structure Plans. Thus, for example, it is the County Planning Department that prepares the Structure Plan, and future housing policies are an important component of the plan. Yet public housing policy is decided by a different department in
a different authority - that is, the Housing Department of the District Council. Similarly, while development control is primarily the responsibility of the District Planning Department, the County Planning Department must be consulted on strategic decisions.

In opposition to this fragmentation of powers and functions, there has been a growing trend towards more 'corporate' methods of working within local authorities (see, for example, Eddison, 1973). However, though often elaborate procedures have been developed in order to encourage more integrated decision-making, the practical results have been only modest. In particular, inter-departmental collaboration at the operational level has only been achieved for special projects or studies and has not provided the necessary general basis for effective strategic planning.

The other component of the changing context has been the economic situation. The first Structure Plans were prepared in the late 1960s and early 1970s, at a time of comparative economic growth when the predominant concern was the choice of areas to develop. With the economic crisis of the 1970s, attention has shifted away from the spatial allocation of growth to the problems of local unemployment, poor housing and the decline of the inner areas of major cities. Furthermore, throughout all sectors of local government activity, constraints on the availability of resources have become a dominant concern.

These changes in both the organisational and economic context of local government planning are clearly reflected in the changing relations between central and local government in Britain. In particular, central government has increasingly sought to restrict spending by local authorities, since this now constitutes one third of all public expenditure in Britain. In the past, central government has been able to exercise aggregate control over local authority spending, since it contributes over 60% of the necessary finance in the form of grants. Now it is developing more specific controls, particularly over local authority capital expenditure. The chosen method has been to introduce a series of sectoral programmes for different local authority departments, the most important being for Housing and Transport (Housing Investment Programmes and Transport Policies and Programmes). By requiring local authorities to produce investment programmes for, typically, a four year period, showing planned expenditure on a service in relation to stated policies, central government can control the allocation of grants and permissions for investment in each sector.

The implications of these new programmes for Structure Planning are profound. When they were introduced, Structure Plans were a unique medium-to long-term plan to guide the future development of an area. Now they are being surrounded by shorter-term investment plans covering some of the major topics of the Structure Plan such as housing and transport, but prepared independently by separate departments of local government. The future role of Structure Plans in relation to the new sectoral programmes is thus being called into question.

4. PROGRESS IN STRUCTURE PLANNING

It is a useful simplification to say that the changing focus of interest in the progress of the new development planning system has broadly followed different phases in the plan-making process itself. Thus in the late 1960s and early 1970s attention concentrated on the problems of plan preparation. Subsequently, attention shifted to the procedures for public participation and central government approval of plans. Now, the main concerns are the implementation and review of plans. This discussion will concentrate upon Structure Plans, since work on Local Plans is only now gathering momentum as most Structure Plans near completion.

In general, plan preparation has been a slow and very elaborate process.
Typically, large teams of planners were assembled to produce the first plans. They worked steadily through ambitious programmes of analysis covering all aspects of local development. They then implemented elaborate procedures for deciding objectives, generating strategies, evaluating alternatives and selecting the preferred plan strategy. The result of this comprehensive and systematic approach was that it was at least four and often more years before the first draft plans appeared. When they did appear, they were usually massive documents of several hundred pages, in which the major issues were buried among a mass of detail.

In an attempt to speed up plan preparation, central government modified its earlier advice, stressing the need for greater selectivity (Department of the Environment, 1974). While all plans should deal with the central issues of employment, housing and transport, other issues should only be included if they are of "key structural importance to the area concerned". More selectivity in the supporting analysis was also urged. These recommendations have, on the whole, been followed in the preparation of the more recent plans.

By this time, the first wave of plans had been published, and increasing attention was being paid to public participation, the examination in public and central government approval of plans. Various approaches to public participation have been tried, with most authorities adopting some form of procedure based on public meetings, or questionnaires, or a mixture of both. Despite their efforts there is a general feeling that public participation has been ineffectual (see, for example, Drake et al, 1975). Even where councils have made great efforts to test public opinion, they have found a widespread lack of interest. This is, however, understandable. It is the experience of British planning that the general public is most concerned about planning issues at two levels. At the most basic level, each person is very concerned as to whether redevelopment proposals affect their own property. On a broader level, local communities often become very hostile to major development projects that directly affect their area, for example a motorway route or a new airport. However Structure Plans do not, on the whole, affect the public at either level. Their policies are too broad to be seen to affect individual properties (that is the function of Local Plans) and they do not generally propose specific investment projects such as motorways or airports.

Once their plans were submitted for assessment, planners were able to shift the blame for delays on to central government. Delays in central government assessment procedures seem to a large extent to derive from uncertainty about the acceptable scope and content of a Structure Plan in the light of the original comprehensive specifications and the subsequent revised emphasis on selectivity. A rather conservative interpretation seems now to be prevailing which argues that, despite the broad socio-economic framework, Structure Plans essentially remain strategic land-use plans. Many of the policies that local authorities have included in their plans, for example measures to improve the local economy, are therefore considered to lie outside the scope of the plan, and central government is either ignoring them or requesting their removal.

This leads to the final phases of implementation and review. As more plans are being completed, the technical focus is switching to the development of information-based monitoring systems. Though progress in the actual construction of these systems remains slow, they should provide the basis for that 'continuous updating' of plan policies which is considered a vital component of the new system. It is the implementation of these policies that presents rather more serious problems (see Barras, 1978).

What in fact are the powers available to implement Structure Plan policies? The traditional planning instrument of development control is really more appropriate to the detailed implementation of Local Plans, and in any case is only a 'negative' control. Conversely, broader policies for
topics such as housing and transport can only be implemented by other departments of local government, particularly following the recent introduction of sectoral programmes. Though in theory the Structure Plan is a plan for the whole local authority, there is as yet little indication that these other departments are making serious efforts to help implement the policies set out in the Plan.

In summary, it must therefore be said that, despite increasing emphasis on selectivity, the preparation, discussion and approval of plans remains slow. Only by 1980 will all counties in England and Wales have submitted their first Structure Plan to central government, more than ten years after the system was first introduced, and so far only about half of these plans have been approved. Furthermore, delays have been occurring at each stage in the planning process. On balance, therefore, the first of the two main criticisms of the previous planning system, that it was inflexible and slow, has not yet been overcome by the reformed system.

5. THE CONTENT OF STRUCTURE PLANS

The second criticism of the old planning system was that it did not focus on the broader policy issues, and in particular that there was not enough attention paid to the underlying social and economic forces which determine physical development. In order to judge how effective Structure Planning has been in meeting this criticism, it is necessary to consider the content of the Plans produced so far, and how this content has changed over time. Here it is necessary to make a distinction between the quantitative analysis and forecasts in the separate 'Report of Survey', and the presentation of strategic policies for future development in the 'Written Statement' of the Plan.

Let us consider the supporting analysis first (for a more detailed review see Barras and Broadbent, 1979). It is clear that the style and content of most Reports of Survey have been strongly influenced by the initial advice published by central government, both as to the topics to be covered in plan preparation (Ministry of Housing and Local Government, 1970) and the analytical methods to be used (Department of the Environment, 1973). This advice suggested that the analysis should be structured according to a set of subject areas including 'population', 'employment', 'housing', 'transport', 'retailing', 'leisure' and 'the environment'. Nearly all Plans have adopted this format, building up often detailed, but separate, analyses of demographic trends, local employment structure, journey to work patterns, and so on. An elaborate early example of this approach was provided by the South Hampshire plan. The technical methods available to planners have tended to reinforce this fragmentation of analysis into component subjects, reflecting the fact that it is the linkages between different parts of the local economy which are least understood in current theory. This is why, for example, most plans do not adequately explore those crucial inter-relationships in the local labour and housing markets that determine migration behaviour and the match between demographic and employment structure.

Furthermore, the typical Report of Survey tends to concentrate on forecasting without adequate prior analysis of past trends or the current situation. To a limited extent, this reflects a reaction against the use of sophisticated mathematical techniques such as spatial interaction models, which most practising planners seem now to regard as providing insufficient information to warrant the costs of their application. However, the frequent lack of even simple statistical analysis, involving trends or cross-tabulations, suggests that the problem is more fundamental. It stems from a failure to recognise that the main requirement of the analysis is to inform policy-making by providing an understanding of the most important development processes operating in an area. No plan has yet presented a fully articulated
description of these underlying processes of economic and social development, though one or two of the more recent examples (e.g. Merseyside, Greater Manchester) are making serious attempts to do so.

We can now turn to the manner in which Plan policies are derived and presented. As already noted, the early plans were produced in a period of growth when the main concern was the most appropriate level and location of population and employment growth, and the provision of extra service and transport facilities, both to cater for this growth and to improve standards of provision. These policies were generated with respect to often complex and abstract hierarchies of social objectives which were essentially a product of the planners' imagination. Thus one plan talks about promoting 'the physical and mental health, and the spiritual, intellectual, moral and physical development and aesthetic awareness of each individual in the community'.

The abstraction was often worsened by the use of plan generation and evaluation techniques such as development potential analysis and goals achievement matrices which, unless very carefully used, tend to obscure the real choices under a mere formalism of weighted factor scores and combinatorial selection.

With economic recession, and the new emphasis of selectivity, plans have tended to focus around a smaller number of 'key issues'. East Sussex was one of the first authorities to base its plan on this approach. Since then, there has been a growing divergence between the plans for metropolitan areas in the North and Midlands, with predominant concerns such as inadequate housing, a narrow or declining employment base and decaying infrastructure, and those of the continuing 'growth' counties in the South East region outside London, which are still concerned with the containment and location of new development. These trends have led planners away from abstract objectives to a more realistic appraisal of concrete social and economic problems, and a greater awareness of the constraints imposed by limited public sector resources, particularly in the major metropolitan areas. The consequence is that recent Structure Plans show a considerable diversity in content, derived from very different local problems, whereas the early plans suffered from a misleading uniformity of approach and content derived largely from their abstraction and their inflexible adherence to central government advice on plan preparation.

It can thus be argued that Structure Plans are increasingly focussing on the key issues and problems in their local area, and effectively relating physical development to broader socio-economic trends. To this extent they are a great improvement over the previous system. What is still required, however, is greater integration of the analysis to assist integrated policy-making.

Two particular weaknesses also remain. Firstly, despite one of the original aims of the reform, there is still inadequate emphasis on the distributional effects of plan policies upon different social groups. This requires greater attention to questions such as types of housing tenure and the balance between public and private transport provision. Secondly, a more explicit link must be made between the availability of resources and plan policies. Typically most plans make some attempt to cost their final strategy, but do not consider finance as an initial constraint on policy-making. In some cases this has meant that once the final strategy, or set of alternative strategies, has been derived, subsequent costing shows them to be unrealistic in relation to the anticipated availability of public sector finance. More surprisingly, despite the origins of the British planning system in land use control, there has so far been little explicit attempt to analyse or quantify the availability of land as a strategic resource constraint in the Structure Plan.
6. THE MAIN LESSONS

The experience of the reformed development planning system in Britain in the past ten years provides several important lessons which should be of value to planners in other Western European countries who are concerned about the problems and possibilities of strategic planning. Five main lessons are worth summarising here:

(i) Plans which are designed to be strategic and integrated must still focus on the most important problems and issues particular to a given area, avoiding facile abstraction and a spurious, all-embracing comprehensiveness.

(ii) The main function of the supporting analysis is not to merely provide mechanistic forecasts of future trends, but rather to inform plan-making through better understanding of how the key development processes in an area are operating and interacting.

(iii) It is vital that the availability of key resources such as finance and land are recognised as potential constraints at each stage of plan-making, especially in the context of the current economic recession.

(iv) The procedures of strategic plan-making must not become so protracted that the whole process suffers from excessive delay and inflexibility.

(v) Public participation in strategic planning can only be made effective if the issues are specified in a concrete manner, and if the distributional effects of policies upon different social groups are highlighted.

As far as Structure Planning in Britain is concerned, the preceding review has indicated improvements in approach and method over the past ten years with regard to all of these lessons, except perhaps that concerning public participation. There remain, however, the more serious problems which derive from the inherent contradiction between the intended scope of a strategic development plan such as the Structure Plan, and the limitations of the powers and resources available for its implementation.

Within the local authority itself, the only direct powers available to planners are the control and regulation of land use and its development. These powers are clearly inadequate to implement a broad medium to long-term strategy for the overall development of an area. It is also necessary to coordinate the capital programmes of the main departments within the local authority such as Housing, Transport and Education, each of which has a vital role in local development. Such coordination to assist the implementation of a strategic development plan is very difficult to achieve when powers and resources are fragmented among many departments and even different levels of local government. It is made more difficult if the development plan is produced in isolation from shorter-term sectoral investment programmes, as has been happening in Britain in the last few years.

More fundamental are the problems caused by the relationship between the local authority and other agencies involved in development. On the one hand, there is the control which central government exercises over local authorities. In Britain, the current economic recession has seen central government use its financial control in such a way that local authorities are tending to become the subordinate agencies of national economic policy. In particular, the heaviest cuts in public expenditure have fallen on local authority capital programmes, severely damaging the prospects for implementing local development strategies. On the other hand, it is often not sufficiently recognised that many of the most important aspects of local development are determined by the actions of private sector companies over which the local authority has little control. Thus large property and construction companies directly dominate the physical development of housing and commercial and industrial building, while more indirectly the investment plans of manufacturing and service companies are crucial determinants of local economic development.
This contradiction between the ambitious scope of the reformed development planning system and the problems of implementation has contributed to the current reaction in Britain against the former ideals of strategic planning. Incrementalism and fragmentation are the outcome of the new 'realism' which has become intellectually fashionable, while at the practical level central government is retreating from the aims of the original 1968 legislation, reducing the Structure Plan to no more than a strategic land use plan. Yet the worsening effects of recession and the growing problems of urban decline make the need for integrated development planning at local level greater than ever, so that physical development can be planned within a framework of economic and social policy that takes account of the severe resource constraints now operating.

Despite the current reaction in Britain, it is essential to bear in mind two fundamental principles. The first is that, despite temporary fluctuations in political emphasis, strategic planning, at both central and local level, is increasing and will continue to increase. The second is that, as with any long-term tendency in society, the development of planning is a dialectical process. Just as the 1968 reform was a response to the perceived shortcomings of the 1947 system, so the next reform will be a response to the contradictions that have emerged with the implementation of Structure Planning. The task for central government legislators and local government planners is to ensure that the next stage is indeed an advance, that learns from the current experience, and not a temporary retreat born of expediency.

REFERENCES


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REFERENCES


1. INTRODUCTION

This paper discusses our recent work* which has involved a critical examination of Structure Planning practise in Wales. Although our concern is primarily with structure planning practice relating to population, employment, and other key activities, it was necessary at the outset to review more broadly the context for strategic planning. First, it was important to establish, as far as possible, the developments and pressures which led to the introduction of a new system of land use plans in Britain in 1968. Also, it was necessary to document the significant changes which have taken place since that date. The second context was that of the substantive environment within which Structure Planning was introduced in 1968. Here we identified two levels of concern. At the national level, social, economic, and political changes have taken place which have influenced sub-regional strategic planning. At the sub-national level, any consideration of strategic policy-making, particularly in a region such as Wales, had to be set in the context of the recent history of demographic and economic change.

Having established these contexts, the first task of the research was to delimit the scope and content of the Structure Plans. This was achieved by way of a descriptive analysis of the Plan documents, and this enabled us to assess the overall approach adopted by each planning authority. From this, the second task of the research examined the detailed methodological and analytical content of the Plans.

Plan documents in themselves, can only yield very partial clues as to the perceptions and attitudes which shaped their final form. A more complete analysis of the Plan-making and implementation processes was obtained in the third stage of our research by means of in-depth interviews of officers and members of the planning authorities. Problems inherent in this form of research were recognised, namely the dangers of post-hoc rationalisation; the difficulties of recall; the influence of subsequent experience, and so on. These problems were minimised by a thorough research design, tested by pilot trials, and a standardisation of approach. The interviews were conducted by two researchers which enabled a degree of quality control to be exercised over the interpretation of responses. These responses were fully recorded.

The fourth stage of the research is concerned with the policy content of the Welsh Structure Plans. The introduction of Structure Planning was a "policy innovation" (Solesbury, 1975) designed to achieve a more flexible system of planning. It is therefore surprising that little research has been conducted into the policy content of Structure Plans. Our research identified two crucial areas for analysis. First, the most basic concern is with the inter-county compatibility of the Structure Plan policies. This is of particular importance in Wales, where the last explicit regional planning statement was made in 1967.

* The research programme is funded by the Social Science Research Council.
(Welsh Office, 1967). Second, is the internal consistency of the Structure Plan strategy. A number of questions are pertinent: are the policies consistent with the analytical and forecasting work undertaken by the authority? Are the policies consistent with any statements of intent, or any ideological stance made clear by the authority? Finally, are the policies consistent with other policies in the Structure Plan strategy?

Thus the scope of the research project extends from a broad consideration of the contexts within which Structure Planning has been undertaken in Wales, through a more specific methodological analysis, to a consideration of Structure Plan policies themselves. Before discussing some detailed findings of the research, it will be helpful to briefly outline the development of Structure Planning in Britain, and the Welsh context.

2. STRUCTURE PLANNING IN BRITAIN

In May 1964, an advisory group was established by the then Ministry of Housing and Local Government "to assist in a general review of the planning system" (P.A.G., 1965). The existing planning system was at that time 17 years old and rapidly falling out of favour with both planners and the public alike. Planning procedures were characterised by interminable delays, while the planning system itself was criticised as being too rigid and narrow in perspective.

Society at large, however, was undergoing fundamental structural change at this time. In retrospect, the Sixties' decade stands out as a 'boom' period as indicated by the rise in the general standard of living. Between 1956 and 1969, the average weekly earnings of manual workers rose by 113 per cent. in the same period, prices rose by about 57 per cent (C.O.I., 1971). Increases in real income by over 50 per cent in fourteen years understandably raised expectations of continued prosperity in years to come. One manifestation of this post-war affluence was the growth in private transport which has profound planning implications. In 1969, £1,518 million was spent on the running costs of private cars and motor cycles (Patmore, 1972), but the scale of expenditure is less important in its implications than the sheer volume of traffic generated. In 1950 there were 2½ million cars on the roads of Britain. By 1970 this figure had increased to 12 million, and together with a rapid expansion of commercial traffic had a traumatic effect on the transport network, and particular stress was placed on outdated, and war-damaged town centres.

It was not long before these developments, and the post-war pressure for private development, subjected the planning system to unprecedented demands. The Ministry of Housing and Local Government was under heavy pressure with submissions of all kinds of plans requiring approval, as well as a backlog of appeals and the virtual breakdown of the review procedure (Bor, 1974). This inevitably produced delays, and urgent administrative changes were clearly required.

This was the context within which the Planning Advisory Group set about their review of the British planning system. In their report (1965), the central issue for criticism and recommendation was the Development Plan system. The 1947 Act plans, the P.A.G. claimed, had become increasingly rigid and unable to anticipate or guide change. They were too concerned with detail and did not consider the 'social and economic underpinnings' of the land use pattern. In conclusion, the P.A.G. did not see the existing system of development plans as a suitable vehicle for the future planning of Britain, which faced "a surge of physical development on a scale ... not previously seen" (P.A.G., 1965).

To overcome these difficulties, the P.A.G. recommended that plans should be devised in recognition of two distinct, but mutually interactive spheres of planning activity: at one level, issues can be identified which are of a strategic, or resource allocative nature. At a lower level planning issues concern the detail and the implementation of strategic decisions. Such a system, they
concluded, demanded two different types of plans, but which together would provide the flexibility and scope, and control and guidance required in a modern planning system.

The conclusions and recommendations of the Planning Advisory Group's report were incorporated in large measure into the Town and County Planning Act 1968 (re-enacted in 1971) and this legislation forms the basis of the current planning system. In accord with the Planning Advisory Group's recommendations, Structure Plans were devised as the principal strategic planning instrument, and local plans were intended as the vehicles for local implementation and control. The new Structure Plans were to be policy vehicles, and not the means for expressing physical development proposals. They were set to cover fifteen years, and in recognition that "planning is a continuous process" (Department of the Environment, 1979) planning authorities are required to monitor and review the implementation of the Plan. Structure Plans did, therefore, represent a considerable change in the style of British planning. The new planning framework "represented a substantial broadening of the scope and basis of statutory planning" (Dunlop, 1976).

The E.A.G. Report, and the subsequent new legislation sparked off a debate of considerable intensity which continues today. In the course of the last twelve years the planning system has been attacked frequently. Regan (1978), has described it as "a system with no friends", for "it appears to satisfy neither the planning professions, nor the lawyers, nor the public". More general criticism has accused Structure Plans of being too abstract, or too comprehensive and representing hopes rather than real possibilities. They are also said to be too detailed and complex, difficult to understand, and disguise issues rather than explain them clearly. They are also accused of being ambiguous in scope and content.

The whole future of Structure Plans is in fact called into doubt by Smart (1977) who considers that "P.A.G.'s concept has been significantly overtaken by events; it has become procedure bound, blurred, disorganised, and subject to competing priorities. There is a prima facie case for reviewing the structure planning system". This is clearly a singularly unhappy thought with which to greet the large number of long awaited newly approved Structure Plans. Yet, there can be little doubt that there is some truth in Smart's criticisms, for great changes have taken place in the planning environment since 1968.

On the planning administration side, the single most important development was the reorganisation of local government in 1974. This introduced a two-tier system of local administration which destroyed the P.A.G.'s basic assumption of a unitary system of local government. Under the new organisation, planning responsibilities were split nearly, if not sensibly, between county and district levels. Counties became the structure planning authorities, while Districts became mainly responsible for implementation and the control of development. Further although Structure Plans were a 'policy innovation', subsequently there has been a burgeoning of policy instruments in many other spheres of local government activity. These include Area Management Plans, Corporate Plans, Inner City Programmes, Transport Policies and Programmes, and Housing Investment Plans. Yet nowhere has the role of the Structure Plan within this panoply of policy instruments been clearly defined.

In terms of the social, economic and physical environments the "surge of physical development" anticipated by the P.A.G. failed to materialise. The essential question is, can a planning system born into conditions of economic growth, and based on the assumption of continued prosperity, cope with prolonged economic decline? Barra and Broadbent (1979) point out that Structure Plans are intended to influence the whole development of the local area, and yet the local authority has relatively little control, for example over economic activity. This issue is the crucial problem in Structure Planning. Confusion over the scope and effect of local authority powers in the planning environment permeates all parts of the Structure Planning process. As Drake et al. (1975) contend,
"most of the difficulties of concept or practice can be traced back to this central problem of uncertain scope and lack of power". Evidence from the present research supports this contention.

3. THE WELSH CONTEXT

The economic and demographic histories of any region are inextricably woven together, and Wales is no exception. Over the last two hundred years the requirements of industry have dominated and determined population movement. The rapid expansion of the iron, coal and steel industries, largely in South Wales led to the area becoming a 'boom area' in the British economy which produced an intense demand for labour. In the face of falling productivity in the coal industry, for example, gains in output were, for some time, only achieved by increasing the labour force (Humphries, 1972). Thus the net migration into Wales at the end of the nineteenth, and the beginning of the twentieth centuries was considerable: Thomas (1930) showed that between 1901-1911, Wales was absorbing migrants at a rate not much less than the United States (an annual rate of 4.5 per 1000 as against 6.3 per 1000 in the U.S.A.).

This movement then dramatically reversed. In the decade 1911-1921 some 90000 people left Wales, to be followed by almost 300000 between 1921 and 1931, mostly from the mining valleys of South Wales. The economic history of Wales, and particularly South Wales, is a classic example of a 'boom and bust' economy. However, it must be noted that the rural parts of Wales (Mid- and North-West Wales) exhibit population trends which appear to be quite unaffected by the violent fluctuations characteristic of the industrial areas. Until recently, Mid-Wales has exhibited the trends of out-migration characteristic of many rural areas in Western Europe, while North-West Wales is remarkable because of its lack of change and constant population level. This apparent stability may, however, be obscuring subtle but significant changes.

These are the main features in the demographic and economic history of Wales. The trends are long term and unrelenting. It is in this context that the recent experience in Structure Planning must be evaluated. Post-1974 Wales comprises eight counties each of which is a Structure Planning authority. Because of the sequential way in which Structure Planning was introduced in Britain, the pre-1974 reorganisation counties in the North West of Wales began their Structure Plans in 1971, some 3 years before the others. As a result the 'new' county of Gwynedd inherited three Structure Plans, whereas the remainder each prepared one. Eleven Structure Plans formed the basis of our research.

4. PROBLEMS AND ISSUES IN STRUCTURE PLANNING

Although government advice has, in recent years attempted to formalise the Structure Planning process, Structure Plans in general are far from standardised. While basic principles may be common - such as time-scale and procedure - there need be no uniformity of language or approach. Inter-county comparison and analysis of Plans is therefore by no means straightforward. In order to cope with the diversity in a systematic way, it was necessary to develop a clear analytical framework. By this means we were enabled to classify and expose the approaches to Structure Planning on the basis of perceived problems and issues on the part of the planning authorities. Accordingly the Plans were examined in the context of eleven 'components of analysis' which were designed to elicit from the documents the County Planning Authorities' attitudes to, and perceptions of, those issues in formulating their policies.

The study by Barras and Broadbent (1979) of twenty English Structure Plan Written Statements provided a useful guide in the formulation of the approach although they adopted only five components for classification. In our work the fewer number of Structure Plans under consideration allowed for a more
Wales: Administrative areas post-1974

West Glamorgan
Mid Glamorgan
South Glamorgan

County Boundary
District Boundary

0 10 20 30 40 Miles
0 10 20 30 40 Kms
detailed classification, and the requirements of the research project demanded that the framework differed from, and extended beyond that of Barras and Broadbent.

The analysis made clear that both the content and depth of treatment varies considerably from Plan to Plan. The only truly consistent feature common to all the Plans was the identification of key issues. Following government advice (DOE, 1974) counties identified those issues which they considered to be of key structural importance to their future. In all other areas, however, where government advice is noticeably less specific, there is considerable variety between the eight Plans. This variety can be summarised as follows. First, the explicit recognition of the importance of supra-county influences on the economic development of the areas is by no means common to each Plan. It is clear that Plans which are more recent, and those for areas suffering from de-industrialisation, are more willing to acknowledge such influences. On the other hand, all the Plans are willing to identify the underlying causes of their problems as being the run-down of traditional industries, the failure to replace lost jobs and so on. Second, the identification of 'problems' perceived by the authority is varied: this seems to indicate a lack of consensus as to what the Structure Plan should be concerned with. Thirdly, few Plans explicitly considered the effects of pre-Structure Plan local authority policies in any meaningful way. Finally, only four counties make any attempt to express clear spatial, or aspatial priorities for the allocation of resources over the Plan period. Two Plans express clearly spatial priorities and two express aspatial priorities.

Although it is difficult to specify the causal factors behind this diversity exactly, a priori a number of features would seem to be important. Firstly, the inherent diversity of Wales must, to some extent, to reflected in the Plan documents. Problems of the rural hinterland, such as prolonged depopulation and difficulties in service provision are different in nature, if not in cause, to the problems of industrial decline and urban dereliction. Thus, they may merit a different planning response. Secondly, because of the sequential way in which Structure Planning was introduced in England and Wales after the 1968 Act, not all the Plans were constructed over the same period. It might be expected, therefore, that some form of 'learning process' took place as more and more authorities grappled with their Structure Planning task. Indeed, central government advice to authorities has become more extensive since the early years of the 'first round' plans. However, as will be evident from a following discussion of our interview survey findings, evidence of any inter-county learning was not found among the Welsh authorities. Thirdly, the differing political perspectives of the county councils, and any changes of political orientation during the plan-making process might reasonably be expected to be reflected in the Plans. Planning is clearly a political process, involving the distribution of scarce resources, and nowhere is this more evident than in the strategic or allocative role performed by the Structure Plan. However, the political dimension of the plan-making process is difficult to identify from a study of the published documents. In fact, the documents imply that the planning process is objective and rational.

In addition to these three determining influences, a number of other 'lower level' variables appear to have influenced the approach of the Councils to Structure Planning. Firstly, differences in the interpretation of central government advice has given rise to differences in the Plans. Secondly, the content of the Plans has been determined by the requirements of the public participation programme. In particular, each county had to resolve the problem of how to present the Structure Plan in as straightforward a manner as possible, without undermining its credibility. Finally, certain areas of the authorities responsibilities can be recognised as being subject to influences which lie beyond the area of their control. In these circumstances, they clearly have to cope with the problem as to how such uncertainty can be treated within the
analysis and strategy, again without seriously undermining the credibility of their Plan. The decision as to whether to include or exclude extra-county influences is a difficult one, in terms of communicating uncertainty, but ultimately it must be a political decision.

The interview survey made it possible to test some of these a priori hypotheses and to provide information relating to the planning process in a way that the document survey alone could not. A number of features emerged clearly from this survey. First, while the debate about the form and content of the 'new' Structure Plans dominated the planning literature in the late sixties, and early seventies, many planners tackling the task 'on the ground' did not consider that their function had changed greatly with the passing of the 1968 Act. Indeed, we did not find any evidence that one source had particularly influenced planners' views as to their 'new' role. It was not until the publication of central government's circular in 1974 that planners acknowledge the benefit of government advice. In general, their views of government advice can be summarised by the consistent comment "too little, too late".

Secondly, the degree of contact between local authorities is very slight beyond the statutory requirement to consult with neighbouring authorities. We found no evidence that any great cross-fertilisation of ideas and experience took place. What appears to have had a much greater influence on the approach to and final shape of the Plan, was the professional experience of the personnel involved. Thus the use of, for example, AIDA or potential surface techniques seemed to depend much more on the 'fortuitous' presence of persons with those skills in the planning department rather than the perceived value inherent in such techniques.

Thirdly, the Structure Plans in Wales appear to be almost entirely professional's plans, in that the input from the elected members has been minimal. Members, in the main, have not grasped the essence of the Structure Plan, nor have they expressed a great deal of interest in it. This means as one planning officer put it, that Structure Plan issues may be passed by the Planning Committee "on the nod". Further, there appears to have been very little 'learning' experience among elected members during the preparation and approval of the Plans. In this sense, therefore it is difficult to say that the Welsh structure plans embody any explicit ideological commitments from the elected members. They are, indeed, "consensus documents".

Fourthly, public participation was grasped as a new opportunity for planners to involve the public especially among younger officers. For the first time, as required by the 1968 Act, planners had a statutory duty to consult with the public during the preparation of their Plans. In most cases planners considered this to be a useful experience, although how truly 'participative' the process has been is quite another matter. It is noticeable, for example, that in the identification of the key issues, in no case did public participation change the list drawn up by the planners, but merely added to it. This may simply mean, of course that the planners are well in tune with local feelings.

Finally, on the question of monitoring, we met with a varied response. In all cases, the importance of monitoring as an activity was acknowledged. However the preparation and allowance that planners have made for monitoring the implementation of the strategy is very diverse. Two authorities claimed that they began monitoring in effect when they began their Plans, while on the other hand two other, admittedly smaller, authorities have made no preparation as yet, and intend to await the results of the 1981 census! The attitude to monitoring held within a county clearly conditions their perception of data needs and analysis and this is now examined in greater detail.

5. ANALYSIS AND METHODOLOGY IN WELSH STRUCTURE PLANS

In contrast to the diversity which characterised the overall approach to Structure Planning in Wales, the approach to analysis and forecasting has been
remarkably similar. The forecasting of future levels of key activities has been a central concern in Structure Plan making, and time and resources have been spent in considerable quantities by Counties in producing these. The forecasting exercises themselves have been extensively written up in Structure Plan documents, and defended at the Examinations in Public. However, it is clear that in Wales, each County has undertaken approximately the same form of analysis of past trends, and even the same methodology and techniques by which they forecast future key activity levels. Other authors (Barras and Broadbent 1979; and Breheny and Roberts, 1979a, 1979b and 1979c) have identified similar features in English Structure Plans. Firstly, forecasts, in the main, have been undertaken on a strictly sectoral basis, using conventional techniques such as cohort survival and economic base models. These exercises formed a central part in the 'key issues' chapters in the Reports of Survey. Secondly, very little discussion is undertaken about the role of forecasting within the Structure Planning process, or the aims of the exercise, or indeed regarding the choices of specific forecasting techniques. In documents which purport to set down the development strategy in areas over a period of fifteen years, the lack of discussion about these issues is a matter of great concern.

The third common feature is the way in which sectoral forecasts have been related. In nearly all cases, the Structure Plans have identified the three key issues of concern as being population, employment and housing. This follows the advice contained in the government circular 98/74 (DOE, 1974). Forecast levels for these activities have been related in that the outputs of one forecasting exercise become the inputs for another, and in the same way feed into 'secondary' forecasting for other socio-economic factors. This can be described as a linear-deductive approach to planning forecasts, and is a common feature of the Welsh Plans. The leading activity which drives the whole system is population, and forecast levels, when modified by given economic activity rates, produce forecast labour supply figures. Similarly, by the application of headship rates, housing demand figures are obtained. In the same way, 'secondary' forecasts for recreation, shopping, education social services, and so on can be deduced. Among all the Welsh counties, only one - Gwent - attempted to improve on this linear sequence, by adding a 'policy' feedback loop, thereby revising estimates in the light of anticipated effects of plan implementation.

For this methodology to have such a widespread appeal, its attractions must be considerable. Indeed, there are advantages in the use of this approach. Basically, these are that it is a quick and cost effective way of generating forecasts. No highly specialised skills are required, and the data requirements can be tailored to suit data availability. Its disadvantages, however, are considerable. However, it must be born in mind that there are inherent problems in all forecasting. The aim, therefore, is to be continually eroding infinite uncertainty, and many of the disadvantages of traditional forecasting exercises may be common to all forms of forecasting. Firstly, linear-deductive forecasting is not, and cannot be, dynamic. It starts from a static base, and tries to predict the future of a dynamic system. Secondly, the quality of data which are commonly fed into the system is by no means uniform. Such data are generally derived from the census, or other such national sources, and thus reflect the type of data that are collected at this level, rather than that which is tailored to meet the needs of local area forecasting. Thirdly, as it has been used in Wales, the linear-deductive methodology is wasteful of resources. The planning authorities have undertaken almost identical forecasting exercises, using the same data, but with marginally different assumptions. Such work clearly could be more efficiently carried out by central government with some degree of local authority involvement.

Finally, the linear-deductive system in operation tends to be essentially supply based. Thus, population supply, labour supply, and household supply are the principal outputs from the system. What makes this unsatisfactory in prac-
tice, is that no planning authority in Wales has made any real attempt to quantify the demand side of the equation. Job supply is the major area of uncertainty. Whilst it must be recognised that estimation of this requires more resources and time, without it, the forecasting exercise is so partial and fraught with internal problems as to be almost meaningless.

The attitudes of the planners to forecasting was revealed in our attitude survey. It quickly became clear as the survey progressed, that many planners regard the Structure Plan forecasting exercise as a technical hurdle over which they had to jump. This was due particularly to reasons of professional satisfaction and the perceived requirement of the 'Examination in Public'. It is clear that among planning officers in Wales, plan and policy-making necessarily includes a substantial amount of technical and analytical verification. Forecasting, in particular, is seen as a rational technical process. This perception is due, we believe, to two factors. First, planning education in recent years has embraced quantitative analysis so fiercely that when planners leave the schools, if they don't know how to 'do it', at least they know they ought to do it. Secondly, as Regan (1978) has pointed out, planning as an activity comprises technical, legislative, and political elements, and the relative importance of each may change over time. Planning, however, in its quest for rationality, has over-emphasised the contribution of the technical and legislative inputs to the neglect of the political inputs. What appears to be required is a critical re-examination of the role of forecasting within a planning discipline which is not constantly striving for objectivity.

A matter of concern, however, which emerged from both the document and the interview survey was the issue of the relationship between the forecasting exercise and policy. It is assumed that the means by which forecasting "informs" policy is obvious and widely appreciated, for no county makes this link explicit. Other counties in England explain in some detail how they see this link: Tyne and Wear's Structure Plan is a good example though this may be exceptional. It is not evident that in Wales the planners have seriously considered the relationship.

6. THE POLICY DIMENSION

"Considering the future is always a combination of guesses and decisions in different mixtures according to the relationship between the phenomenon and the subject's power" (De Jouvenal, 1968). In a mixed economy such as Britain's, planners possess varying degrees of control over certain facets of the environment, whereas over other facets autonomous forces operate. The balance between the two will clearly vary depending on the nature of the planning intervention under discussion. It is our conclusion that this is a central area of planning concern, and that any discussion of the efficacy or efficiency of planning must focus upon the fundamental question of control.

In recognition of the partial nature of planners' control, forecasting can no longer be regarded simply as a unitary, linear process, since planning must reconcile its two components of "reactive adaption" and "predictive control". The forecasting of controlled events is clearly entirely different to that of uncontrolled events. This must be reflected in the planning process. Breheny and Roberts (1979a) have made the useful distinction between 'predictions' which refer to the former category, and 'projections' which refer to the latter.

In the Welsh Plans, no explicit consideration is given to this dichotomy. Forecasts are generated, and 'uncertainty' appears to be regarded as a type of residual which can be assumed away. Breheny and Roberts (1979a) also found that among their sample of thirteen English Structure Plans this attitude proved to be the rule rather than the exception.

The basic problem appears to be that planners, in general, do not fully understand exactly where in the local development process they can intervene, and to what effect. It is clear from our study that the analysis of past
trends commonly carried out by the authorities does not give them this information. Nor does this customary analysis provide the basis on which policy-orientated forecasts can be made. What is required is a radical re-examination of the role and the power of the authority over the processes operating in its area. Based on our experience of Welsh Structure Planning we would suggest that a new approach to the Structure Planning task might embrace four elements.

Firstly, a local authority must truthfully and critically evaluate the powers which it has at its disposal. Secondly, local authorities must set in motion public participation programmes which should help in the identification of issues and problems, and also assist in the political decision of exactly what degree of planning intervention is required. Third, local authorities should undertake rigorous analyses of their local economies. At present, this is a sadly neglected area, and as Parry Lewis (1973) recognised, "a great deal of forecasting is to be criticised on one simple but fundamentally important ground: it is not based on an understanding of the process or phenomenon that is the subject of the forecast".

Local authorities need to construct a representation of the local development processes operating within its area. A suitable basis may well be that provided by Barras and Broadbent (1979). It would then be possible, using the authority's own classification of its powers, and given the political decision as to how involved the authority ought to be, to map 'county responsibilities' on to this schema. We suggest that this could well take the form of a non-spatial 'key diagram' which would compliment the existing key diagram of the plans. The fourth requirement is that authorities should prepare their monitoring programmes in conjunction with their analyses and forecasting, and this requires a clearer evaluation of data needs and availability. We believe that in satisfying these requirements, a planning authority would be in a stronger position to make trend based projections and policy based forecasts, and to achieve a state of 'controlled' uncertainty. At least, the approach to analysis and forecasting would thereby be made explicit.

7. A CONCLUDING COMMENT

Since the preparation of the Welsh Structure Plans, the Welsh economy has undergone some important and far-reaching changes. Continued de-industrialisation, persistent unemployment, and considerable reductions in the levels of public expenditure have brought about circumstances to which the Plans badly relate. Conventional wisdom and traditional approaches to plan and policy making are quickly becoming redundant. The clear implication is that planners must either adapt their present attitudes and methods or be relegated to an increasingly marginal role in strategic affairs. Among British regions, Wales reveals the dilemma facing planning authorities all too clearly.

REFERENCES


1. INTRODUCTION

The preparation of a regional plan is a good example of strategic planning: a regional plan is a long term plan, which for its realisation depends on many fields of public administration.

Planning in public administration requires a decision structure and a decision procedure which are comprehensible for the parties involved: the politicians and the public. The number of parties and their involvement is increasing and therefore the demands for comprehensibility are getting stronger. On the other hand we are growing aware of the fact that the object of physical planning is highly complex: the number of issues to be dealt with is large, the relations between issues are numerous as well as the number of influences from other societal fields. A very important task for the planner is to reconcile the requirements of the parties involved and the notion of complexity.

In a planning process and the organisation structure in charge of that process two basic phenomena are to be seen, which at first sight are conflicting: analysis and integration. When looking more in detail both phenomena can be understood in the light of mastering complexity on one hand and making a comprehensible decision structure on the other. In this paper a description is given of the preparation of the regional plan of Twente by giving an idea of the planning process, the decision structure, the organisation structure and research activities. In all these four elements analytical and integrative aspects will be discussed.

The preparation of the regional plan of Twente has several experimental characteristics. While the provincial government is legally authorised to establish a regional physical plan an organisation has been set up in which governmental and semi-governmental bodies of different levels take part. The 21 municipalities of the region are working together in a regional governmental body. This regional body, which has an elected council, is the main partner of the province in the project. In this way the plan will have elements of a regional plan as well as elements of an intermunicipal structure plan.

The project started in 1978 and will end in 1983. From that moment the plan will enter the phase of permanent evaluation and revision.

2. A BRIEF DESCRIPTION OF THE REGION

The region of Twente (see Figure 1) is situated in Eastern Holland near the German border. The population amounts 550,000, of which 50% is living in the cities of Enschede (142,000), Hengelo (75,000), Almelo (64,000). The number of jobs is 178,000. The population increased by 19% in the last 15 years, the number of jobs decreased by 8% in the same period.

Urbanisation took place in the end of the last century and the first decades of this century mainly as a result of the development of the textile industry.
TWENTE

roads and railroads

- motorway (double lane)
- motorway (planned)
- intercity railroad
- motorway (single lane)
- railroad
The region is characterised by an attractive countryside and a high quality of the nature. Nevertheless tourism is not a very well developed feature of the region. The greater part of the camping sites is used by the inhabitants of the area for weekend recreation. Twente has quite good railway and waterway connections with different parts of the Netherlands and bad connections with Germany. Until recently the region was poorly linked to the national highway system.

The main problems in the regional development are:
- the poor economic perspectives of the region in relation to the population growth
- the growing geographic desequilibrium in employees and jobs
- the decrease of the quality of nature and landscape
- deficiencies in the physical situation concerning agricultural use
- urban sprawl accompanied by social segregation.

These problems are in general terms not specific for the region but have typical regional features when observed in detail.

3. THE PHASES IN THE PLANNING PROCESS

3.a. The main phases

There are three main phases to be distinguished:
- policy headlines
- minor policy issues
- policy measures.

The distinction between policy headlines and minor policy issues is caused by the notion that there are some decisions to be made concerning the spatial development of the region which are more important than other ones. To say this in another way: some decisions are more strategic than other ones. This implies a certain hierarchical order in decisions. It will be clear that decisions about the policy headlines give rise to constrains to decisions about minor policy issues. At the same time they present an important framework of evaluation of alternative options about minor issues. On the other hand decisions about minor policy issues can necessitate a revision of decisions about headlines. Policy measures are linked to both policy headlines and minor policy issues. In general several policy measures have to be taken to realise policy headlines, on the contrary do minor policy issues demand a relative limited effort. It has to be stressed however that the establishment of policy measures in space, time and quantity is better possible in relation to the minor issues than to the policy headlines. Policy headlines tend to be global. It has to be stressed that decisions about policy headlines need to be based upon knowledge about efforts. An important question from the political and methodological point of view is the identification of policy headlines. A preliminary remark has to be made: all issues that are dealt with in the planning process should be relevant to the spatial development of the region. Five criteria have been used to identify headlines and minor issues:

1. the geographical scale of the issue
2. the period concerned
3. the societal impact of the issue in terms of direct and indirect effects and number of people involved
4. the number and effort of policy measures which are related to the issue
5. the political evidence of the issue.
Policy headlines answer in general a combination of these criteria in the sense that they are related to superregional or regional issues, their societal impact is great, the effort in terms of policy measures is considerable and the political evidence is great.

Each phase ends with the publication of a discussion report which becomes subject of consultation and public participation. This reports are prepared by a project organisation (see also 7). The three discussion reports will be brought together in the legal regional plan.

3.b. Steps within phases

Within the main phases of the political headlines and minor policy issues several steps are to be taken:
1. identifying general goals
2. inventory of possible policy measures
3. identifying problems
4. inventory of explicit and implicit existing policies
5. identifying the decision space of the different issues, i.e. acceptable and feasible options for each single issue
6. drawing up of alternatives for highly interlinked issues and evaluation of the alternatives in the light of goals, existing policies and necessary policy measures.

The distinction between headlines and minor issues is to be seen in the steps 3, 4, 5 and 6. By the partition of the process in steps a highly analytical action takes place. Of all steps step 5 and 6 cause the greatest variety of information. In the case of the regional plan Twente for 50 issues about headlines 130 options are defined. The number of possible combinations of options is very large. Public and political discussion about such amounts of possibilities is hard if not impossible. This very fact asks immediately for integrative tools, i.e. feedback between different steps. Four integrative tools can be mentioned:
1. the identification of topics (planelements) to be dealt with in all steps
2. the search for interconnected decisions areas
3. evaluation techniques aimed at the elimination of options and combinations of options
4. measures in the field of organisation and procedures.

During step 6 the number of combinations of options is reduced greatly by distinguishing interconnected decision areas. It is expected that in the phase of minor policy issues the number of planelements to be combined in alternatives will be less than in the phase of policy headlines. This is due to the fact that policy headlines deal with global development principles with rather reticulated effects and minor policy issues tend to deal with more local and isolated topics.

Each step in the phase of policy headlines and minor policy issues ends with the publication of a planning report. The before mentioned discussion reports after each phase are compilations of several planning reports. The discussion reports about the policy headlines are based upon 7 planning reports.

4. THE ALTERNATIVES WITH RESPECT TO HEADLINES

4.a. Introduction

As an illustration of the approach in this section a description will be given of the content of the alternatives with respect to headlines.
ALTERNATIVES OF URBANISATION
dwellings and employment areas

O present
A,B,C,D additional 1977-2000

- 5000 dwellings (200 ha.)
- 50 ha. employment area
- central urban area
The main starting points are the problems of the region, which are described in section 2. To solve the problems different options for 50 issues/planelements were developed. In general one option can be defined as a trendprojection. As a result of an analysis of relations between planelements, fields could be defined within which the relations between planelements were quite strong: interconnected decision areas. For the headlines three areas were identified:
- population and regional economy
- urbanisation
- the rural area.
For these complex decision areas alternatives are developed by combining options. The number of alternatives for the decision areas varies from 3 to 5. The alternatives give a rather representative picture of the options. The alternatives are described in terms of policy measures to be taken to realise them.

The remaining planelements are to be seen in relation to the decision areas. For these planelements the options are given with a short comment. The planelements related to urbanisation are for instance: interregional roads, regional and urban transportation networks, waterways, airport, recreation in the urban area. The planelements related to the rural area are: forestry, outdoor recreation in the rural area, waste disposal, water supply, electricity supply and sand production.

It has to be stressed that the decision making process (see also 5) is not only directed to the choice between the alternatives as such but to the desirable and feasible mixture of elements of alternatives as well.

4.b. Population and regional economy

In relation to the main problems of section 2 the question is which population growth in combination with which economic development should be chosen. The options regarding the population growth are
- a net outmigration in the next 20 years
- a development according to natural growth; in this case there will be immigration from mediterranean countries and outmigration to other parts of Holland
- a net immigration.
The options regarding the economic development are
- continuation of the trend, i.e. a very slow growth of the number of jobs.
- a moderate economic development
- an acceleration of the economic development.

Both sets of options are combined in 5 acceptable and feasible alternatives. There has to be stressed that the trendprojections are a relative rapid growth of population and labour market (+ 12% from 1977 to 2000) and a stable number of jobs.

It will be clear that the balance between the development of the number of jobs and the development of the labour market is a very important criterium for evaluating the alternatives.

4.c. Urban development (see figure 2)

Starting from working propositions regarding the total number of people and jobs the alternatives of the urban development differ in the following properties:
- the split of population growth over the southern(S) and northern(N) part of the region
- the same for the growth of number and jobs
TWENTE
the rural area

- zone of dominant agricultural value
- zone of agricultural value and high value of nature and landscape
- zone of dominant value of nature and landscape
- zone of agricultural value and moderate value of nature and landscape
the degree of concentration of population and jobs in the highly urbanised area (central urban area) and the less urbanised area
- the boundaries of the central urban area.
Out of hundreds of possible combinations 4 alternatives have been selected which give a quite representative impression of the possibilities.

4.d. The rural area

The central question of the rural part of the region is how to reconcile the claims of the expanding agricultural economy on one hand and to maintain the quality of nature and the landscape on the other hand. As compared with the alternatives for population and the regional economy and urbanisation the alternatives for the rural area have direct links to policy instruments. These policy instruments are in the field of the preservation of nature and landscape, land consolidation and income measures of farmers. The main options for the agricultural economy are:
- a rapid development
- a moderate development
- a slow development.
The main options for the quality of nature and landscape are:
- the improvement of the quality
- the maintenance of the actual level
- the acceptance of a further decrease of the quality.
Dependent on the characteristics of zones both sets of options can be combined in alternatives. For this reason the whole area has been divided into 4 zones (see figure 3):
a. a zone with a dominant agricultural value
b. a zone of agricultural value and a moderate value in terms of landscape and nature
c. a zone of agricultural value with a high value in terms of nature and landscape
d. a zone with a dominant value of nature and landscape.
The alternatives have been established especially for the zone mentioned as b and c. For the other zones only single options are given.

4.e. The relations between alternatives

The distinction between three sets of alternatives has the advantage of telling three rather comprehensible stories. The disadvantage however is the risk of neglecting the cross influences between the different areas. For this reason there has been made a rough analysis of cross relations between the alternatives in terms of compatibility. The same applies to the planelements related to the alternatives. In this respect the general goals (step 1 in section 3.b.) have played an important role as terms of reference.

5. THE DECISION-MAKING PROCESS

The planning reports and discussion reports (see section 3 and 4) are prepared by a planning organisation. Until the moment that the discussion reports are given free for public participation, advice and consultation the process of preparation is quite systematic and rational. Differences in opinion between participants in the process are mostly translated in different options or built in in the more comprehensive alternatives. From that moment on the process is not surprise-free anymore.
A large amount of reactions upon the discussion reports will be given, which differ in thoroughness, scope and preferences. Local governments, agrarian pressure groups, environmental pressure groups, central government agencies, all react in their own way. New options and alternatives will be outlined partly as a step in a process of negotiations. The procedure takes about 1½ year before the final decision will be made by the provincial parliament. At the beginning there is a period of 6 months in which public participation and preliminary discussions in several advisory bodies take place. The role of the project organisation changes. Before the public decision making process the project organisation is a rather creative body in which old ideas are brushed up and new ideas are developed. Afterwards the role becomes more procedural, the main substantial task is the maintenance of consistency.

6. THE OUTPUT OF THE PROJECT

The outcome of the project will be:
- a set of decisions about the spatial development of different weight
- a set of decisions about policy measures of different weight
- a set of guidelines of different weight
- a set of procedures.

The set of decisions about the spatial development will be divided into three categories:
- essential decisions: essential decisions are policy headlines which highly influence the regional development in several ways
- important decisions: important decisions are policy headlines which influence the regional spatial development in several ways, or decisions about minor policy issues on regional scale
- indicative decisions: indicative decisions are decisions about minor policy issues which can be dealt with rather isolated; they are generally of local and or sectoral importance or deal with a preliminary preference.

The set of policy measures is divided into two categories, apart from the distinction between measures by the body which is legally responsible for the regional plan and those by other parties involved:
- necessary measures: these measures are bound to several essential and important decisions
- desirable measures: those measures are bound to rather isolated important and indicative decisions.

The guidelines need some further explanation. A particular characteristic of strategic planning is its relative abstract position to more operational planning. Operational planning in the field of physical planning is in general in the hands of local governments and sectoral agencies. The strategic plan is for its realisation rather dependent on local and sectoral planning results. Only a part of the realisation is coped with by the policy measures of the regional plan itself. Another part however will be visible in yet unforeseen or otherwise unknown events. To cope with this kind of uncertainty the guidelines play an important role. They provide a checklist for the responsible authority to check events when they are submitted to an approval or advisory procedure. In this way guidelines are to be seen as decisions, which are not defined in place and time.

The procedures are to be seen as the more procedural and organisational means of realisation, updating and reviewing of the regional plan.
The procedures show a strong relationship between the weight of the decision, measure or guideline and the character of the procedure. To change or add an essential decision necessitates the involvement of the highest authority on the provincial level, the consultation of authorities on other levels of public administration and advisory bodies and a thorough public participation procedure.

An indicative decision can be changed or added by a decision only based upon the advice of the physical planning agency.

7. THE ORGANISATION

The organisation which has been established for the project of the regional plan of Twente is experimental in character and of a complex structure. The organisation structure consists of a steering committee, a coordination group, a planning group and 5 research groups and a secretariat group (see diagram 1). The steering committee has politicians as members. In the other groups civil servants of the cooperating bodies take part.

There has been established an independent body to organise public participations in several stages of the process.
The organisation in diagram 1 is working according to a working program that has been approved by the provincial parliament.

The organisation structure, the procedures and other rules are a consequence of the underlying philosophy that a regional plan only can be successful when all parties involved can identify themselves with the results. There are two elements to be seen:
- the political element: a regional plan is an important tool of coordination between different levels of public administration, a regional plan is for its realisation dependent of national, provincial and local efforts
- the efficiency element: the preparation of a regional plan requires a lot of information and expertise that is quite disperse; by involving different agencies a lot of information and expertise is disclosed, sometimes however, at the price of communication problems.

3. RESEARCH

The preparation of a regional plan should be legally based upon research. There is a wide range of possibilities to be seen: a simple manipulation of statistical data, the interpretation of existing sources of research, a survey of a specific subject, research in depth concerning important issues. Within the framework of this paper the following remarks are important. People working in the research side of planning agencies tend to focus upon rather specific subjects (planelements), upon the present situation and tend to work at a quite disaggregate level. Results of research in the field of physical planning show a great variety in scope, methodology, validity, generality and forecasting power. For this reason research tends to be analytical and desintegrative rather than integrative. The cycle of a research project often exceeds the planning cycle. These phenomena make the adjustment of the different research activities and the planning process quite difficult.

In the preparation of the regional plan of Twente several measures have been taken to overcome these problems:
1. the work of the research groups is lead by some guidelines: research groups should deliver information about the past, about the long term trends, about problems in relation to the past and the trend, about possible alternative developments and about policy measures required for alternative developments
2. the results of the integrative work of the planning group is checked by the research groups in the light of the available expertise
3. during the planning process specific questions are posed by the planning group to the research group about white spots.

It must be understood that it will be difficult to measure the results of the planning process by standards of scientific work. It does not make sense to try to make a plan that answers scientific standards in absolute terms. The main question is whether it is possible to improve the scientific standard in a substantial way by further research in a justified amount.

9. CONCLUDING REMARKS

The project described in the previous sections is now half-way. The first discussion report has been published in December 1979. A public participation procedure takes place in which + 70 discussion groups give their comments and preferences concerning the alternatives and the planelements which are not built in in the alternatives.
At the same time a consultation procedure of different governmental bodies takes place. It is rather premature to evaluate the results reached so far systematically. Nevertheless a few impressions can be given.

The first impression concerns the degree of involvement of the participants in the project. Although the emphasis in the project lies at the provincial physical planning agency different parties play an active role in the established project organisation. Two elements are to be seen:

- the disclosure of available expertise
- the guarding of specific interests.

In comparison with the predecessor - the 1966 plan - the new regional plan will gain in terms of feasibility and lose in terms of innovating ideas. As the main criticism about the plan of 1966 was the lack of executive measures the experiences up till now are quite hopeful. As a result of the large amount of participants many bodies show signs of identification with the project. There is an atmosphere of cooperation in contrary to other policy fields where competition is the dominant feature. Consultation and persuasion are more important than legal powers. In this way the whole project has an integrative value.

The second impression is that desintegrative elements lie in wait, partly as a result of lack of information and structure. So explicit integrative mechanism need a lot of attention. These mechanism are visible in the following fields:

- the operational field of physical planning: the planning group
- the methodological field: the use of planning methods directed at giving structure to the object of planning and the process of the preparation of the plan
- the operational field of managing the organisation: the secretariat group and the use of management techniques
- the field of policy coordination: the coordination group and steering committee
- the procedural field: the design and use of clear decision making procedures within and outside the project organisation.

By and large one can say that every analytical act in the process demands an integrative counterweight. These counterweights can be seen as the strategic elements of the project, which derive their strategic significance from the fact that they are interlinked. It is very important that these elements are identified and taken into consideration in advance. The established organisation can better stick to the object of planning when tools are quite well developed.

To say it in other words: the planning of a planning process is of primordial significance.

The third impression concerns the object of planning. In regional physical planning the object is of a complex nature. When the period is limited within which the planning process should have its first round one has to choose between completeness and comprehensiveness on one hand and depth on the other. In practice a mixed strategy will be pursued: study in depth of the strategic elements of the plan and study in breadth of the less strategic elements. Special attention should be given to the strategic elements which are new and which are showing the greatest signs of erosion.

The final impression concerns the political side of the project. Physical planning in the Netherlands has changed from expert planning to political planning. This very fact causes new points of attention:

- the translation of expertise in the field of research and planning in political terms
- information in the direction of the rank and file of the political bodies in charge: the political parties and the public
- measures in the field of organisation which make the planning process interactive between planning agencies, political bodies and their rank and file.

This applies to the present stage of the project as to the operational and maintaining phase of the plan as well.

All these elements influence the professional role of the planner and cause a new specialism and new fields of research.
of research and planning was carried out. This research added a significant number of new insights to the field of planning. The results were compiled into a comprehensive report which was then presented to the planning committee. The report highlighted several areas for improvement and provided recommendations for the future. The committee subsequently adopted the recommendations and began implementing them in the planning process. This approach was successful in improving the efficiency and effectiveness of the planning process.
PART II

SPATIAL INTERACTION ANALYSIS
PART II

SPATIAL INTERACTION ANALYSIS
EDITORIAL INTRODUCTION

The next papers are dealing with the analysis of spatial interactions. Special attention will be devoted to modelling strategies. An interesting piece of research is presented by Pitfield, who did review the goodness-of-fit statistics for freight flow models. His investigation has established the presence of a consistent error in the underestimation of intrazonal flows. A new model is specified to overcome the bias in the predictions of freight flows. However, Pitfield notes that the expense of calibration is rather high, especially when the model is made more realistic by introducing multiple streams. He argues that future resources may best be devoted to the collection of more homogeneous freight flow data.

An important instrument in strategic planning might be transport pricing policy. Therefore, it is interesting to explore the effects of changes in transport prices on locational behaviour of firms or households. The contribution of Mackett is focused on the impact of rail fare increases on the spatial behaviour of the inhabitants of south-east England in general and London in particular. His paper outlines some of the behavioural responses to large transport cost increases and treats the information required to study these changes. In addition, a description is given of some of the techniques and ideas that are available for the analysis of the consequences of rail fare increases.

The paper of Cordey-Hayes and Varaprasad is also dealing with transport pricing in a very intriguing way. It outlines the development, calibration and policy testing of a strategic model for the exploration of the interaction between transport supply — including pricing policy and congestion — and the population redistribution process between a metropolitan area and its hinterland. Remarkable is that the authors focus on the dynamics of metropolitan change at a coarse geographic scale rather than the detailed spatial disaggregation and comparative static approach of most land use/transport models. Consequently, the model appears to be very appropriate for strategic policy analysis.

Urban and regional systems embody very complex structures of spatial interactions, which can be modelled in various ways. A serious theoretical contemplation about the possible improvements of interaction models can be considered as an essential step towards a better understanding of spatial behaviour. In the contribution of Dejon some specific cases of dynamic spatial interaction models will be treated. The author’s investigations are based on a graph theoretic approach of spatial structures. To describe the dynamic behaviour of certain spatial interaction systems Dejon proposes an implicit system of differential equations. He shows that it is possible to prove the global asymptotic stability of this mathematical system.
MULTI-STREAM FREIGHT DISTRIBUTION MODELS:  
A TREATMENT OF PRODUCT HETEROGENEITY

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Leicestershire, LE11 3TU, U.K.

1. INTRODUCTION

Recent research on the goodness-of-fit of freight distribution models in the United Kingdom has shown that a doubly-constrained gravity model with a negative power deterrence function provides predictions that are superior to those from a transportation problem. However, despite this relative superiority, the absolute goodness-of-fit is often poor, even though the models are calibrated so as to minimize the deviation between predicted and actual mean haul. In particular, in response to the above findings reported in Pitfield (1978a), Gordon (1979a) noted that there was a consistent underestimation of intrazonal flows as this was implied by the reported consistent overestimation of interzonal flows. A number of possible explanations for this bias were suggested but, as discussed in Pitfield (1979), none of these explanations appeared to be responsible for the errors.

Subsequent investigation of the parameters of the calibrated models and of the characteristics of the freight data have suggested the possibility that the distribution model, given the available data on freight flows, was misspecified and an alternative model form was selected in order to test this hypothesis.

The next section outlines the data used in the study and summarizes the initial goodness-of-fit result. Attention is then focussed on some possible explanations for the bias in the predicted distributions. The following section establishes the empirical basis for respesifying the model and this model, and some preliminary attempts to calibrate it, are described.

2. GOODNESS-OF-FIT OF FREIGHT DISTRIBUTION MODELS

a. The Freight Data

The data used in this research were produced by British Rail (1975a) as part of its long-range strategic-planning studies. Information is provided on internal freight flows between 134 zones for four modes: road, rail, coastal shipping, and pipeline. These flows may also be disaggregated into thirty commodity groups based on the CSTE classification (Economic Commission for Europe, 1965) and these are listed in Table 1.

The elements of this data and their derivation are described in more detail in Pitfield (1977; 1978b).
Table 1. British Rail Commodity Classification

To facilitate distribution modelling exercises, a matrix of interzonal separation was derived. Acting as a proxy for transport cost, a distance matrix was estimated from the road mileage between zonal centroids. Intra-zonal distance was based on an analysis of self-self road flows that involved summing the tonmileage of such flows and dividing by the total tonnage moved by road within each zone.

b. The gravity model: specification and calibration

The doubly-constrained gravity model was calibrated to produce predicted freight movements for most of the commodity groups shown in Table 1. The model is given by:

\[ T_{ij} = A_{ij} + B_{ij} + D_{ij} - \beta \]

where \( T_{ij} \) is the predicted flow between zones i and j;
\( O_{i} \) is the total flow originating in zone i,
\( \sum_{j=1}^{m} N_{ij} = D_j \) is the total flow terminating in zone \( j \),

\( \sum_{i=1}^{n} N_{ij} = D_j \) is the total flow between zone \( i \) and \( j \);

\( d_{ij} = \beta \) is a negative power deterrence function based on the \( n \times m \) distance matrix, where there are \( n \) origin zones and \( m \) termination zones;

\[
A_i = \left[ \sum_{j=1}^{m} B_j D_j d_{ij} \right]^{-1}
\]

\[
B_j = \left[ \sum_{i=1}^{n} A_i O_{ij} d_{ij} \right]^{-1}
\]

Equations (4) and (5) give the balancing factors that ensure that

\[
\sum_{j=1}^{m} T_{ij} = O_{i1} \quad \text{and} \quad \sum_{i=1}^{n} T_{ij} = D_j
\]

It was reported in Pitfield (1978a) that the fastest method of calibrating this model was Williams' (1976) acceleration of Hyman's (1969) method, which essentially involves searching for the value of the parameter \( \beta \) that minimizes

\[
\left| C_{\text{obs}} - \tilde{C}_k \right|
\]

where

- \( C_{\text{obs}} \) is the observed mean trip cost
- \( \tilde{C}_k \) is the predicted mean trip cost for the \( k \)'th estimate of the parameter \( \beta \).
For most of the commodity groups examined, equation (7) was less than 10^{-5}.

For each of the estimates of $\beta$ obtained as (7) converges towards an acceptable minimum, estimates of the balancing factors, shown in equations (4) and (5) are required. These values were found iteratively by setting initially all $B_j = 1$, solving for $A_i$ on this basis and then re-estimating $B_j$ and so on. This process was halted when the successive estimates for each balancing factor changed by less than $Z$, where $Z$ was allowed to vary between 10^{-1} and 10^{-3} so as to give more accurate estimates of $A_i$ and $B_j$ as the best $\beta$ value was approached.

\textbf{c. Goodness-of-fit: the statistics and the results}

The statistics that, both theoretically and empirically, have been established as amongst the more useful of the variety of means of assessing goodness-of-fit, are ad hoc in nature. The first of these is the standardized root mean square, which is root mean square divided by the mean cell entry in the actual flow matrix so as to make the resulting statistic comparable between models of different data matrices. This is given by

$$R_{MS}^2 = \left[ \frac{1}{nm} \sum_{i} \sum_{j} \frac{(T_{ij} - N_{ij})^2}{\sum_{i} \sum_{j} N_{ij}/nm} \right]^{\frac{1}{2}} \tag{8}$$

The second statistic is the index of dissimilarity (Timms, 1965) which varies between 0 and 100 and shows the percentage of predicted tonnage that would have to be reassigned between zone to replicate exactly the observed flows. This is given by

$$D = 50 \sum_{i} \sum_{j} \left[ \frac{T_{ij} - N_{ij}}{\sum_{i} \sum_{j} T_{ij}} \right] \tag{9}$$

The third and final statistic is the overall percentage error of prediction which is attributable to Mera (1971). This statistic indicates the error in the off-diagonal cells of the predicted freight flow matrix and is given by

$$PEP = 100 \left[ \frac{\sum_{i} \sum_{j} (T_{ij} - N_{ij})}{\sum_{i} \sum_{j} N_{ij}} \right] \tag{10}$$

It is necessary to assess goodness-of-fit as although it is a requirement of the calibration procedure that the parameter value is determined by the macrostate constraint (7), it is not a requirement of this process that the actual correspondence between the $T_{ij}$ and $N_{ij}$ matrices will be good.
Further, as there is no clear agreement on what is the best statistic to use to assess fit, it is appropriate to use a variety of indicators so that the assessment is not merely descriptive but may be instructive.

The values of these statistics are shown in Table 2 for twenty-eight commodities moved by road in 1972. Commodity group 4 is exclusively carried by rail and commodity group 5 is the least important commodity moved by road in terms of tonnage carried. It is clear from both the $R^2_\text{MS}$ and $D$ statistics that as well as the efficiency of the model varying between commodity groups, so the absolute level of fit is often poor. This is most clearly implied by the $D$ statistic.

<table>
<thead>
<tr>
<th>Commodity group</th>
<th>$R^2_\text{MS}$</th>
<th>$D$</th>
<th>$P_\text{EP}$</th>
<th>Commodity group</th>
<th>$R^2_\text{MS}$</th>
<th>$D$</th>
<th>$P_\text{EP}$</th>
</tr>
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<td>4.94</td>
<td>37.95</td>
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<td>30.54</td>
<td>18.95</td>
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<td>5.52</td>
<td>31.57</td>
<td>17.56</td>
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<td>9</td>
<td>5.01</td>
<td>41.82</td>
<td>18.43</td>
<td>24</td>
<td>7.46</td>
<td>49.05</td>
<td>23.60</td>
</tr>
<tr>
<td>10</td>
<td>5.15</td>
<td>37.09</td>
<td>43.26</td>
<td>25</td>
<td>7.41</td>
<td>40.42</td>
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<td>45.13</td>
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<td>12</td>
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<td>6.50</td>
<td>33.61</td>
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<tr>
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<td>40.51</td>
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<td>31.05</td>
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<td>6.73</td>
<td>42.18</td>
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<td>30</td>
<td>6.61</td>
<td>32.62</td>
<td>48.00</td>
</tr>
</tbody>
</table>

Table 2. Selected goodness-of-fit indicators for twenty-eight commodities moved by road, 1972.

Whereas the better modelled commodities are other earths and stones; coal and coke products; bricks and other building materials; flyash, waste and flasks and industrial sand/clays, the worst fits are found for furniture, textiles and shoes; alloys and non-ferrous metals; plastics gases, acids and bulk chemicals; and electrical equipment.

However, of particular interest to the main concern of this article is the $P_{EP}$ statistic. It was noted by Gordon (1979a) that for 26 of the 28 commodities, interzonal flows are overpredicted by an average of approximately 20% and as it is a requirement of the doubly-constrained model that $\Sigma \Sigma T_{ij} = \Sigma \Sigma N_{ij}$ so intrazonal flows are underestimated.
Indeed the degree of this error can be readily calculated, given data on the proportion of flows in the actual data that are intrazonal. For example, a 20% overprediction of interzonal, when these flows are 75% of the total, is matched by a 60% underprediction of self-self flows, whereas a similar overprediction when interzonal flows are 25% of the total, is echoed by a 6.6% underprediction of intrazonal flows. Table 3 shows the percentage of flows that are self-self and a statistic \( P_{EP} \) which gives the error on the diagonal cells of each commodity flow matrix. This has a mean of -16.10. It is the character of this error, as well as the overall fit indicated by \( R^2 \) and D that first suggested a requirement to improve model efficiency and second, suggested a possible route to this improvement.\(^*\)

### 3. POSSIBLE SOURCES OF BIAS IN PREDICTIONS

#### a. Error in the distance matrix

As the model is calibrated to reproduce mean logged length of haul, a consistent underprediction of flows for the shortest distance classes, that is the self-self flows which have a mean intrazonal distance of 12.41 miles, suggests that the estimates of self-self distance are biased in an upward direction. Further this bias is relative to the estimate of interzonal distance for which flows are consistently overpredicted.

<table>
<thead>
<tr>
<th>Commodity group</th>
<th>Percentage of self-self flows</th>
<th>Commodity group</th>
<th>Percentage of self-self flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>64.28</td>
<td>16</td>
<td>39.81</td>
</tr>
<tr>
<td>2</td>
<td>42.36</td>
<td>17</td>
<td>31.82</td>
</tr>
<tr>
<td>3</td>
<td>39.29</td>
<td>18</td>
<td>52.72</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>19</td>
<td>29.71</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>20</td>
<td>37.46</td>
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<tr>
<td>6</td>
<td>41.95</td>
<td>21</td>
<td>61.69</td>
</tr>
<tr>
<td>7</td>
<td>48.41</td>
<td>22</td>
<td>49.92</td>
</tr>
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<td>8</td>
<td>63.35</td>
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<td>50.83</td>
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<td>9</td>
<td>48.95</td>
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</tr>
<tr>
<td>15</td>
<td>61.69</td>
<td>30</td>
<td>72.30</td>
</tr>
</tbody>
</table>

Table 3. The percentage of self-self flows in the \( N_{ij} \) matrix, and the intrazonal error of prediction, for twenty-eight commodities moved by road, 1972.

\(^*\) These results could not be improved upon by using the transportation problem of linear programming. These results are reported fully in Pitfield (1978a).
However, it seems plausible that the estimates of interzonal distance are acceptable. These were derived by British Rail (1975a) in the course of selecting zonal centroids. As the majority of freight traffic travels by road, road flow data between each pair of zones was analysed and the average length of haul determined. This figure was then compared with road distances between towns in the pairs of areas and by this process a centroid was selected that was thought to best represent a location that could be viewed as the originating or terminating point within that zone for all flows. These centroids are detailed in Pitfield (1978a) and illustrated in Figure 1.
Similarly, the estimates of self-self distance also seem acceptable and not subject to an upward bias. These were estimated by examining all road freight flows within each area, calculating total ton-miles for such traffic and then dividing by total tons moved. The results of a comparison of a systematic sample of these estimates with those based on $\frac{2}{5}$ (zone area) is fully reported in Pitfield (1977). The mean error for this sample is an overestimate of 1.26 miles so there appears to be little evidence for a sufficiently large error in this part of the data input to the distribution model to explain the errors reported in the previous section. Besides, the estimates used in the model are more likely to reflect transport usage than those based on $\frac{2}{5}$ (zone area) $\frac{1}{2}$.

A final possibility, however, is that although distance is well estimated, it is a biased proxy for cost, overestimating cost for shorter flows. More research on the relationship between costs and distance is required before any judgement on this explanation is possible.

b. Misspecification of the deterrence function

The negative power deterrence function was used in the gravity model for two reasons. First, a priori, it was thought an appropriate specification as Wilson (1971) has suggested that such a function is appropriate to interregional long distance flows, whereas the negative exponential deterrence function is more appropriate to intraurban short distance flows. Second, marked differences in convergence speed were experienced if the progress of calibrating a model with $d_{ij}^{-\beta}$ as opposed to $\exp(-\beta d_{ij})$ were compared. The speed of model convergence is often an indicator of the ultimate goodness-of-fit of the model and even when $\exp(-\beta d_{ij})$ was used on a commodity flow matrix characterized by a low mean trip length, the speed of convergence was prohibitively slow.

The goodness-of-fit results reflect these expectations in the very few cases where the error in equation (7) reached acceptable limits when $\exp(-\beta d_{ij})$ was used. These fits are shown in Table 4 and a comparison with Table 2 confirms the superiority of the negative power deterrence function. It seems that the negative power deterrence function is more suitable than the negative exponential function.†

*) This approximates the first moment representing the mean length of trip in a circular zone with a uniform distribution of origins and destinations.

† The negative exponential function has a longer radius that a negative power function, which has itself been shown to lead to consistent errors in prediction.
Table 4. Goodness-of-fit indicators for three commodities moved by road, 1972 using the negative exponential deterrence function.

<table>
<thead>
<tr>
<th>Commodity group</th>
<th>R²</th>
<th>MS</th>
<th>D</th>
<th>P²</th>
<th>EP</th>
</tr>
</thead>
<tbody>
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<td>8.86</td>
<td>39.46</td>
<td>30.19</td>
<td></td>
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<tr>
<td>15</td>
<td>4.40</td>
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<td>55.74</td>
<td></td>
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</tr>
<tr>
<td>21</td>
<td>6.01</td>
<td>43.16</td>
<td>81.12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. MULTI-STREAM MODELS

a. Data deficiencies: product heterogeneity

An examination of the detailed definition of the commodity groups defined by British Rail (1975a) in terms of their CSTE components immediately demonstrates their potential heterogeneity. Different types of commodity, that move over different distances in response to different demands are grouped together and each of these components may well be subject to a different distance deterrence. Consequently, the estimated deterrence function may be an average of, if it were possible to do so, a number of correctly specified and calibrated functions.

Some information is available on the likely components of commodity freight flow matrices although much of it is fragmentary (British Rail, 1975b). For example, grain and cereal (commodity group 9) includes imported grain that moves over short distances in bulk from ports to mills; flour and offals that have long journeys to bakeries and feed mills; and barley for distilling that moves very long distances in excess of 200 miles. Milk fresh (commodity group 30) is dominated by short distance flows which, in turn, consist of doorstep deliveries from dairies to domestic consumers and collection from farms. Certainly all of the 21.8 million tons moving less than 15 miles and a proportion of the 7.7 million tons in the range 16-20 miles is of these types. The remainder and the longer distance flows are associated with concentrated movements between pasteurizing/bottling plants and bottle piles.

Similar information is available for sixteen of the thirty commodity groups, however for the groups with the largest error in intrazonal flow predictions there is generally not any additional information. One exception is meat and fish (commodity group 12) where it is known that the 31 million tons that moves under 25 miles includes most movements of livestock amongst farms, markets and slaughterhouses and of meat and fish from wholesalers to small retailers.
The 14.1 million tons moving over 26 miles includes traffic from slaughterhouse to processing factory, poultry farm to packing station, and thence to wholesale depots. Nevertheless, for every commodity it is possible to determine the distribution of movement across distance bands and this information is detailed in British Rail (1975a). The most notable feature of these data is the concentration on short distance movements and the abrupt decline of tonnage moved as distance increases. Table 5 shows the frequency distribution for miscellaneous (group 27), potatoes, fruit and vegetables (10), meat and fish (12) and steel (2).

<table>
<thead>
<tr>
<th>Distance (millions tons)</th>
<th>Commodity group 2 (millions tons)</th>
<th>Commodity group 10 (millions tons)</th>
<th>Commodity group 12 (millions tons)</th>
<th>Total (millions tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-25</td>
<td>23.2</td>
<td>38.1</td>
<td>31.0</td>
<td>109.0</td>
</tr>
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<td>26-50</td>
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<td>4.3</td>
<td>6.5</td>
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<td>2.5</td>
<td>1.8</td>
<td>7.0</td>
</tr>
<tr>
<td>76-100</td>
<td>3.8</td>
<td>1.7</td>
<td>1.4</td>
<td>6.9</td>
</tr>
<tr>
<td>101-150</td>
<td>4.1</td>
<td>2.8</td>
<td>2.2</td>
<td>8.1</td>
</tr>
<tr>
<td>151-200</td>
<td>1.9</td>
<td>0.8</td>
<td>0.9</td>
<td>3.6</td>
</tr>
<tr>
<td>201-250</td>
<td>1.0</td>
<td>0.6</td>
<td>0.6</td>
<td>2.2</td>
</tr>
<tr>
<td>251-300</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>&gt;301</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 5. Mileage gradation of tonnage for selected commodity groups, moved by road, 1972.

There is a prima facie case for data disaggregation for many of the groups so as to concentrate modelling efforts on more homogeneous sub-aggregates. However, the available data does not readily allow such disaggregation.

b. Estimates of the distance deterrence parameter: 'trade' and 'distributive' flows

Another indicator of heterogeneity is provided by the estimates of the $\beta$ parameter in the gravity model. These are shown in Table 6. The values of this table may be compared with estimates obtained in modelling a survey of consignments originating and terminating in industrial establishments on Severnside (Gordon, 1978). In this case a doubly-constrained gravity model was fitted using a similar calibration procedure to that earlier outlined. This gave a mean $\beta$ value across 43 commodity groups of 1.08 compared to a mean of 2.0 from Table 6. This difference is taken by Gordon and the author to represent the difference in character of the freight flow data. In the Severnside case, the movements are largely restricted to 'trade' flows whereas the national data is composed of 'trade' and 'distributive' flows, the latter accounting for a good part of the movements in the shorter mileage bands. That is, the flows of each commodity group are composed of a mixture of types of movement at different stages in the production distribution process (as the evidence of the previous section suggests) and each of these types of flow is likely to be subject to a different degree of impedance by distance. The first step in disaggregating flows by type is to distinguish shorter distance 'distributive' flows between, for example, wholesalers, stockholders and consumers from longer distance 'trade' flows between producers and consumers, with the expectation that the former are subject to a relatively higher distance impedance than
the latter (Gordon, 1976).

<table>
<thead>
<tr>
<th>Commodity group</th>
<th>$\beta$</th>
<th>Commodity group</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.65</td>
<td>16</td>
<td>1.50</td>
</tr>
<tr>
<td>2</td>
<td>1.39</td>
<td>17</td>
<td>1.20</td>
</tr>
<tr>
<td>3</td>
<td>1.26</td>
<td>18</td>
<td>1.99</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>19</td>
<td>1.28</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>20</td>
<td>2.31</td>
</tr>
<tr>
<td>6</td>
<td>1.46</td>
<td>21</td>
<td>2.55</td>
</tr>
<tr>
<td>7</td>
<td>1.87</td>
<td>22</td>
<td>2.00</td>
</tr>
<tr>
<td>8</td>
<td>2.81</td>
<td>23</td>
<td>2.29</td>
</tr>
<tr>
<td>9</td>
<td>1.91</td>
<td>24</td>
<td>1.55</td>
</tr>
<tr>
<td>10</td>
<td>2.29</td>
<td>25</td>
<td>1.82</td>
</tr>
<tr>
<td>11</td>
<td>2.08</td>
<td>26</td>
<td>1.74</td>
</tr>
<tr>
<td>12</td>
<td>2.18</td>
<td>27</td>
<td>2.17</td>
</tr>
<tr>
<td>13</td>
<td>2.22</td>
<td>28</td>
<td>1.77</td>
</tr>
<tr>
<td>14</td>
<td>2.16</td>
<td>29</td>
<td>1.57</td>
</tr>
<tr>
<td>15</td>
<td>2.78</td>
<td>30</td>
<td>2.87</td>
</tr>
</tbody>
</table>

Table 6. Estimates of distance exponents by commodity group.

Consequently, it can be concluded that an examination of $\beta$'s also suggests the need for more homogeneous flow data. As the collection of such data is enormously costly in both time and resources and there is insufficient information to systematically disaggregate the existing flow data into more homogeneous groups, a fresh modelling approach has been contemplated.

c. The specification of a 2-stream model: the parallel of migration models

It has been recognized for some time that the motivations behind personal migration movements may be broadly categorised as housing or employment (Harris and Clausen, 1967; Gordon, 1975; Hyman and Gleave, 1976; Gordon, 1979b). Longer distance moves commonly involve both a change of house location as well as a change in job. Shorter moves primarily involve a change of house with a given job. Moves of intermediate distance are likely to involve both types of motivation.

In the absence of survey data that identifies the motivations of migrants, attempts to model interregional migration flows have had to work with matrices of interregional movement composed of both types of move. However, it has been noted that the distance deterrence function that operates for different motivational groups is likely to differ, such that an aggregate model will be inefficient. Consequently, Gordon (1975; 1979b) has investigated the applicability of a 2-stream distribution model.

Beyond an experimentally determined cut-off distance, it is assumed that moves are primarily motivated by employment factors. This stream is modelled and then the residuals from this stream and those remaining moves below the cut-off distance are taken to represent housing moves and this second stream is modelled separately. Such models have been applied to British migration data with some success.
Clearly there is a parallel between the specification of housing and employment streams in migration and 'distributive' and 'trade' flows in freight movements. Consequently, to test for the existence of two streams of movement and to overcome the bias reported in the single stream model, a 2-stream model is specified for freight flows. This has the form

\[
T_{ij} = A_i^T B_j^T d_{ij} - \beta^T + A_i^D B_j^D d_{ij} - \beta^D
\]  

where the \( T \) and \( D \) superscripts refer to trade and distributive flows respectively. \( \beta^T \) is expected to be greater than \( \beta^D \) which is itself expected to be less than the composite deterrence function parameter \( \beta \), which has a shorter radius than either of the 2-stream functions.

d. Calibration: practice and possibilities

The procedure used to calibrate model (11) is to first specify a range of cut-off distance ranging in 25 mile bands up to 200 miles. For each cut-off distance, the cells of the matrix containing flows greater than this distance are identified and other cells taken as zero. The value of the \( \beta \) parameter and the balancing factors are then found by the usual methods for the entire matrix. This gives an estimate of the trade stream.

The residuals from this prediction compared to the actual flow data are then determined. This matrix, however, may contain negative flows to be estimated if the trade stream model overpredicts a cell entry. These negative flows are taken as zero and, after this adjustment, the resulting matrix represents distributive flows. \( \beta^D \), and the vectors \( A_i^D \) and \( B_j^D \) are then calculated giving the estimates of the distributive stream.

The trade and distributive stream estimates are then summed to give the \( T_{ij} \) matrix, which may, depending upon the presence of overprediction of the trade stream cells, result in more predicted movement than actual.

A potential modification to this procedure avoids the time consuming and costly experimental specification of cut-off distances. Although examining the results for a variety of cut-offs is instructive, if the concern is with fit, then the cut-off distance may be found iteratively. This, of course, assumes that the relationship between model fit and cut-off distance is well behaved.

e. Future research

Experiments in migration modelling have looked at the utility of multi-stream models, in particular introducing a third stream but have not found this change in specification useful. In freight models, however, there is a distinct possibility than an appropriate model for some commodities may be of a multi-stream form, so it may be necessary to both optimize the selection of cut-off distances and the number of streams. However, even the computer run time of a 2-stream model with experimentally varied cut-off distances is high and to proceed along this empirical path without further theoretical justification seems questionable. It may be preferable to concentrate resources on obtaining better data in the first place, so obviating the need to employ models of the sort described in this paper.
f. Preliminary results

The commodity flow prediction that are most affected by a bias in intra-zonal flow estimates are engineering products and machinery (commodity group 28), furniture, textiles and shoes (25) and other parcels and newspapers (29) and the largest divergence between the estimates of $\beta$ for trade flows alone (the Severnside study) and $\beta$ for combined trade and distributive flows are for furniture, textiles and shoes, and miscellaneous (27).

A further indication of the importance of distributive flows in the data is provided by the ratio of tonnage moved to tons produced. Unfortunately, these data are not available for commodity groups 24 to 29. However, where the figures are available this ratio is highest for meat and fish (12), potatoes, fruit and vegetables (10) and other foods and drinks (13) and these commodities are amongst those with the highest $P_{dp}$ statistics.

A first attempt was made, therefore, to calibrate the 2-stream model for these commodity groups with, so far, mixed results. Table 7 shows the parameter estimates for the streams for commodity group 27. It can be seen that $\beta^T$ is never significantly lower than $\beta$ obtained from the single stream 'misspecified' model and neither it is stable which suggests that the 2-stream model itself is a misspecification. Further, $\beta^D$ is always the maximal value allowed by the program which implies that the shorter distance distributive flows, as $\beta^D \rightarrow \infty$, are close to the transportation problem distance minimizing pattern. Finally, goodness-of-fit, as shown by the index of dissimilarity $D$, is always worse than the single stream model. Consequently, there is little point in pursuing the analysis of this result which could otherwise have enabled the identification of the magnitude of each stream and its spatial distribution; a comparative examination of the shadow prices and the products $A_i$, $O_i$ and $B_i$ $D_i$ as indicators of attractiveness for each stream; and an examination of the sensitivity of parameter values to variations in the cut-off distance.

<table>
<thead>
<tr>
<th>Cut-off Distance (miles)</th>
<th>Parameters</th>
<th>Goodness-of-fit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta^T$</td>
<td>$\beta^D$</td>
</tr>
<tr>
<td>0</td>
<td>2.208</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>2.053</td>
<td>20.0</td>
</tr>
<tr>
<td>50</td>
<td>2.100</td>
<td>20.0</td>
</tr>
<tr>
<td>75</td>
<td>2.246</td>
<td>20.0</td>
</tr>
<tr>
<td>100</td>
<td>2.424</td>
<td>20.0</td>
</tr>
<tr>
<td>125</td>
<td>2.130</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Table 7. 2-stream model results for commodity group 27

Neither does the initial evidence suggest that the results could be improved by the specification of a negative exponential function for either one or both of the streams.

More promising results, however, are provided by the preliminary examination of the two-stream model for commodity group 25 (furniture, textiles and shoes). For the cut-off distances examined, Table 8 shows that the $\beta^T$ parameter is consistently less than the
single stream model $\beta^T$ Further, $\beta^D$ is in excess of both $\beta$ and $\beta^T$ and in one case does not default to the maximum value of $\beta$ forced by the program.

<table>
<thead>
<tr>
<th>Cut-off distance (miles)</th>
<th>Parameters</th>
<th>Streams</th>
<th>Trade (1,000 tons)</th>
<th>Distributive (1,000 tons)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.876</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>55232</td>
</tr>
<tr>
<td>25</td>
<td>1.407</td>
<td>4.126</td>
<td>37139</td>
<td>21457</td>
<td>58596</td>
</tr>
<tr>
<td>50</td>
<td>1.329</td>
<td>20.000</td>
<td>36383</td>
<td>21783</td>
<td>58166</td>
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<tr>
<td>75</td>
<td>1.361</td>
<td>20.000</td>
<td>38520</td>
<td>22116</td>
<td>60636</td>
</tr>
</tbody>
</table>

Table 8. 2-stream model results for commodity group 25.

These parameter estimates yield estimates of the trade and distributive streams that, although in combination result in an overestimate of total movement, give some idea of the importance of the two streams with the distributive stream amounting to about 37% of the total movement. This still, however, appears to be an underestimate of the shorter flows if the mileage gradation (British Rail, 1975b) is examined. Further, the lower half of Table 8 shows goodness-of-fit indicators and these results, whilst demonstrating the improvement over the single stream model for the first two cut-off distances, still reveal an underestimation of intrazonal flows. As it is not possible to specify a higher value of $\beta^D$ than 20.0 and as this appears to be necessary for the higher cut-off distances, the next tasks are to experiment with cut-offs below 25 miles, particularly in view of the mean intrazonal distance, and to calibrate the model for a full range of higher cut-off distances in an effort to further reduce the underestimation of intrazonal short distance flows.

Note that for the zero cut-off distance, the model reported in this section performs somewhat superiorly, as far as goodness-of-fit is concerned, to the model calibration reviewed in Section 2. The $\beta$ values also differ. These variations are the product of slight differences in the calibration procedure.

* These indicators, except D, are not strictly comparable between each cut-off distance as the total predicted flows are not constant.
5. CONCLUSION

This article has reviewed goodness-of-fit statistics for British freight flow models and it has established the presence of a consistent error in the underestimation of intrazonal flows. Some possible causes of this error are examined but with the exception of the non-linear relationship between cost and its proxy, distance, all are dismissed.

A respecified model is then suggested on the basis of empirical observation of the nature of the data. This model is a potential means of overcoming the bias in the predictions, in the absence of a data collection initiative. However, it is noted that the expense of model calibration is high, especially when the model is made more realistic by introducing multiple streams and that despite the potential use of iterative procedures to speed calibration. It seems that future resources may best be devoted to the collection of more homogeneous freight flow data and this is so particularly in view of the mixed results of preliminary experiments in model calibration. Although in one experiment, the model is a distinct improvement on the single stream specification, there is still a tendency to underestimate the shorter flows.

6. REFERENCES


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THE IMPACT OF RAIL FARE INCREASES ON LOCATIONAL BEHAVIOUR

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1. INTRODUCTION

The effects of transport cost increases on the lifestyles of individuals and on the function and form of cities, is a field of growing interest. It is, however, often difficult to study the problems, because the increases are often marginal (in real terms), and may not be perceived fully by those concerned. The type of area that is most suitable for research in this field is one where the trips are long, so that fares increases are large in absolute amounts, where many trips are by public transport, so that the trip-makers pay their share of the cost of travel directly (that is, they do not divide their payment between overheads and running costs) and one where there have been large increases in travel costs in the past and there are expected to be even larger increases in the future. In Britain the example that best meets these criteria is long distance rail commuters to central London. A three year project to study the impact of rail fare increases on location and commuting decisions in London and south east England began in October 1979 at the Institute for Transport Studies at the University of Leeds. The project (described in Kirby, Mackett and Nash, 1979) contains two main elements: a survey of past location and related decisions, and the development of a range of models of different aspects of the processes. At this stage, the problems are being examined as part of the design processes for both the survey strategy and model definition. There have been several studies of the effects of transport costs on locational behaviour (for example, de Langen and Verster, 1979, Butler et al, 1969, and Brown 1975, but none of these have modelled the choice processes for individuals. However, there has been a great deal of modelling in a variety of fields that are very relevant, for example, of the residential location process, of migration, of the relationship between housing costs and transport costs and so on (see Mackett, 1979c). Most of these studies have been aggregate studies, with very few focussing on the behaviour of individuals. However, models of individual choice have been developed in the transport planning field over the past few years, and there is an excellent opportunity to draw together the two streams of ideas in this project to produce new, operational models. The objective of this paper is to outline some of the behavioural responses to large transport cost increases, both observed and potential, to discuss the information required to study these changes, and then to describe some of the techniques and ideas that are available for the analysis of these effects, some of which will be used in the current project. The recent changes in London and south east England are described in the next section of this paper. In section 3, the potential behavioural responses, the information required to study them and our survey strategy are discussed, and then in section 4, the analysis methods are examined. These ideas are still evolving, but in view of the topicality of the subject, and the stages that have been reached in the two design processes, it is an appropriate time to state our current thinking, so that others have an opportunity to contribute ideas and to learn from our work.
2. THE CHANGES IN SOUTH-EAST ENGLAND

Over the period 1961 to 1977 the cost of a monthly British Rail season ticket for a 30 mile journey rose by about 55% in real terms (SCLSERP, 1977). Over the same period, employment in central London fell by about 250,000 jobs, which was reflected in the loss of rail commuters. In fact, there was a differential decline between long and short distance commuters. Patronage on the inner suburban services has been declining since the early 1960s, while long distance trips reached a peak in 1973 and have been declining since, suggesting that the physical expansion of the London commuting belt has ceased. In fact, combining data from two sources (SCLSERP, 1977, British Railways Board, 1979) suggests that there are recent signs of a slight increase in the number of commuters into central London. Nonetheless, London is becoming relatively more dependent on long distance commuters. Such commuters are less able to switch modes since they have less choice of mode than those living nearer central London, who can travel by bus, underground, bicycle or even walk. British Rail's fare structure is such that it is cheaper to travel by rail than by car for trips from more than about 50 kilometres from central London, but cheaper by car (in petrol costs) for shorter journeys (assuming the rail traveller purchases a second class annual season ticket). However, the cost of commuting by rail from, say, Rugby is currently (March 1980) £957 per annum, which is a great deal of money which must be paid out of disposable income. Consequently, long distance commuters are liable to be very sensitive to large increases in rail fares, but may well switch location rather than mode, in which case, they are not likely to be attracted back to rail even if fares were to drop.

We cannot, at this stage, assess the extent to which the decline in commuting to, and employment in, central London has been due to the cost of travel. However there have been at least two other factors at work. Firstly, car ownership has been rising rapidly, and once a person has a car available for the journey to work it becomes much easier to cross-commute, that is to live in one town and work in another. There is evidence that this is happening, with the development of new employment centres around London, for example near Heathrow Airport (SCLSERP, 1977). There is an obvious problem of cause and effect here: did people purchase cars to enable them to travel to their new jobs outside central London, or did they start searching for new jobs having purchased a car? The second factor is the deliberate policy of decentralization from London which was encouraged by all governments from the mid-1940s up to the 1970s. Initially this meant building the New Towns about 45 kilometres from central London, partly to help post-war reconstruction, and partly as a result of the belief in deterministic planning at that time. The objective was to build self-contained towns, with little or no commuting to London, at the same time taking jobs and population away from London. In a fairly recent paper Thomas (1977) states that regional policy for south-east England was to develop 'counter-magnets' to London's growth and argues that this policy is reducing London's commuting problem, without actually defining it, but presumably regards the large numbers who commute as the problem. As well as the New Towns, there has been a general policy of dispersal from London. In fact, it has been argued elsewhere (Mackett, 1980b) that the two factors of the growth of car ownership and the deliberate policy of decentralization have lead to the 'inner-city crisis' of the late 1970s. The Government's response to the crisis has been the reversal of the previous policy of decentralization (House of Commons, 1977) but it is an open question whether this will have any significant effect on London. Many people have already found jobs outside central London and have bought their cars; there seems little incentive for them to move back to jobs in central London. The policy change may slow down the rate of decline, but seems unlikely to do more than that, in which case British Rail is going to require further subsidy on its commuting services into London.
Indeed, the document by the Standing Conference on London and South East Regional Planning (SCLSERP, 1977) was written in response to a suggestion by the Government that the London commuter services should cover their costs by 1981, on the grounds that these commuters earn salaries above the national average and so such subsidies are regressive. The response to this argument is that there are many lowly paid commuters, who would suffer seriously from the fares rise following the reduction in subsidy and that the central London economy would be affected adversely. The poorest London commuters live in north Kent and south Essex, many of whom bought their houses when travelling was much cheaper. If rail fares were increased significantly they would be faced with the choice of having to pay the extra cost or moving nearer to London and so incurring higher housing costs or a lower housing standard. There are two interesting points associated with these areas, firstly they have the highest proportions of commuters to central London and hence experienced less of a decline than other sectors, and secondly, commuters from these areas have the poorest quality service (British Railways Board, 1979). It is these areas where there is a shortage of jobs and significant dependence on London as a source of employment (SCLSERP 1977). Consequently, it is the people in these sectors who will suffer most if rail fares rise: they have fewer alternative local jobs, and so are more captive to British Rail, but, in addition, have the service most in need of improvement.

The extra cost of travel and housing in south-east England is ameliorated for many people by the payment of a London Weighting, which is designed to compensate for the extra cost of housing and travel for those working in London. A survey was carried out (Pay Board, 1974) to compare these costs for those working in London with the rest of the country. It was found that bank and assurance company employees who tend to receive assistance with housing costs spend less on housing than those in the public sector, and travel further to work. That is, they are spending part of the money they save on housing on travel, giving them a wider choice of residential locations. Williams (1978) has used these data for an analysis of the difference between the cost of travel time and the value of travel time, which has implications for this project.

The locational changes that have been going on in south-east England during the 1970s have been complex, and there are insufficient data for a comprehensive analysis of the underlying factors. In the next section some of the possible effects of rail fare increases on individuals will be considered.

3. BEHAVIOURAL RESPONSES

Let us suppose British Rail increases its fares substantially, so that a commuter is required to pay several hundred pounds extra per year. He or she is faced with a variety of alternatives. Firstly, the increase can be paid, but this may mean reducing savings, or general economy on other items. The commuter can switch mode, but for the long distance commuter, the only possible alternative may be car, and parking spaces in central London are both expensive and limited, and congestion on the road may make it impossible. It this is a feasible option some households might purchase a car (or be given one). The whole household can change its residential location, but a move towards London will mean an increase in housing expenditure or a drop in standards; in addition, the process of moving home is very expensive. The worker can change his or her workplace from central London to a more local job. Another alternative is to increase the householder's income by one or more members taking a part-time job, or a marginal worker entering the job market locally. However, if the commuter to central London is a marginal worker, he or she might cease being in employment. If the person concerned is not the head of the household he or she might decide to leave the household to set up a new home in London. If it is the head of household he or she might start renting a flat in London from which to travel to work on some days, or he or she could decide to travel...
to central London on fewer days each week, and work at home on the other days.

A wide range of possible responses have been mentioned above, and not all are applicable to every household, but several issues emerge from the discussion. Firstly, whilst only one member of the household may be affected directly all others could be included in the response. Secondly, although several of the possible responses described are not likely to be brought about solely by the fares increase, they might be triggered off or brought forward in time because of the fares rise. It will be important to establish the degree of sensitivity of the various responses to transport costs. There are other aspects of behaviour that are not sensitive to transport costs, but do, partially, affect the decision unit and its economic and social status at a particular point in time and so need to be represented in any dynamic analysis; the type of process being considered here are promotion at work, household formation and producing children. The analysis is made even more complex by the workings of the housing finance system in Britain. Because income tax relief is given on the interest payment on mortgages some people move home in order to reduce their tax liability. Other people enter the owner-occupation sector from the private rented sector, or living with others in order to gain this tax relief, and because house purchase is a very good and safe investment. This is related to another difficult issue - that of expectation, some decisions are made not on past or current costs but on the basis that a move of home would be a good future investment. For example, inflation has been at a fairly high level in Britain in recent years, and this has affected house prices. Consequently it is wise to invest money in a house which is an asset that will appreciate in value, yet with a reasonable expectation that there will not be a rise in the cost of the repayment of the loan.

It is clear from the discussion above that some complex data will be required to study the response to transport cost changes and other relevant processes in south-east England. Several survey strategies have been considered (Mackett, 1980a) and the following seems best able to meet our requirements within the resources available: a sample of firms in central London will be selected and an unstructured interview held with the management about their responses to rail fare increases, and to acquire their permission to survey their employees. All workers in the selected firms will be sent a fairly simple self-completion questionnaire on their recent locational behaviour, housing and transport cost concessions received and their household characteristics. At the end of the questionnaire they will be asked to indicate whether they would be willing to be interviewed. A selection will be made from those giving a positive answer, and those selected will be interviewed at home, so that other members of the household can supply information. Questions will be asked on the location decisions and the journey to work over the past ten years, plus information on changes in the composition and economic activity of the household over the same period. It will be clear from the above discussion that the information required is complex and it will need great skill to obtain it. In the next section some of the analytical methods to be used will be outlined, so that the detailed data requirements can be seen.

4. ANALYSIS AND FORECASTING OF THE RESPONSES

Several underlying themes emerge from the discussion above. Firstly, an axiom of the project is to increase understanding of the behavioural processes that underlie the responses to rail fare increases in south-east England. We do not intend to produce models that merely replicate the processes, rather we want to understand the choices that are available to people in a particular situation then to be able to represent the decisions that are made. This principle has underlain the work of Hagerstrand (1970) on space-time interdependencies, and the development of models of individual choice behaviour by Luce (1959) and others. However, we are also interested in the impact of the outcome of all the individual decisions that are made in response to the fare
increases. This means we need to be able to aggregate across the individual behavior in order to understand the overall impact of the changes, and because there are supply-side constraints, particularly in the housing market that can only be treated at a macro-level, but have important implications for individuals. See Drewe (1974) for discussion of some of the issues in aggregation in this field.

Many of the decision processes being examined here take place over a period of time, for example, the decision to move home. The process itself takes time, and so the response to a change may not occur for quite a long period. For these reasons time must be represented explicitly in the models. The final basic principle of the analytical methods of this study is the obvious need to relate the processes at work to transport cost changes. This will be no easy task, as there will always be a wide variety of processes at work, many of which are potentially sensitive to transport costs, but could be taking place for other reasons. It would be very easy to attribute incorrectly decisions to rises in rail fares, when they were quite irrelevant, and then to overestimate the future effects.

It is important in this work that we examine not only the effects of transport costs upon individual decisions, but also the interrelationships between different decisions. For example, Beesley and Dalvi (1974) and Weinberg (1979) have argued that the residential and employment location processes are inter-dependent, and should be modelled as such. Further empirical evidence has been supplied by Brown (1975). An analytical framework to describe mobility of residence and workplace has been devised by Verster and de Langen (1978) as part of a project investigating similar concepts to our project on south-east England.

Although the emphasis in this paper has been on the behavior of individuals, we are also interested in the relationship between the economic and demographic components of the urban system, in particular the relationship between the supply of jobs and the requirements of the economically active population. Models of these relationships have been developed by Madden, Baty and Worrall (1979) and Gordon and Ledent (1980); both models involve the integration of an input-output model with a demographic accounting framework.

A framework that is based upon some of the principles discussed above is shown in figure 1. The individuals in the study area at time $t$ form the population; they also form households of one or more persons. Many of the population are economically active and so if they have a job, are employed residents. When they make a journey to work they become the employment sector. As time passes by, the individuals can go through several processes. They can join others to form new households. These and existing households can produce further individuals. People can become economically active and so take jobs, others can cease to work and become economically inactive. Migration between houses and between workplaces can occur. At the end of the period at time $t+1$ the new levels of population, households, employed residents and employment can be enumerated. Survivors are those who have not changed their state over the time period. It will be appreciated these are some of the processes discussed in Section 3 above. It should be noted that no spatial labels have been attached to the variables. Space can be represented by using a zoning system and so considering the number of individuals in each zone, or by attaching a spatial label to each individual. The former method is that used in macro models the latter in micro-simulation models and related to work by Wilson and Pownall (1976) on efficient methods for representing urban systems. The processes over time can be represented in a variety of ways. For example, there are well established techniques for forecasting the population in a set of zones whereby various rates are applied to the existing population to find the number of survivors and births (see for example, Rees and Wilson, 1977). A similar method can be used for the employment process, with entry to the job market analogous with birth and retirement equivalent to death. Employment accounting is much more interesting than the demographic method because individuals can enter and leave the job market more than once in a lifetime, and so the employment accounts
Fig. 1. The urban accounting framework.
may be regarded as policy-sensitive. These concepts can be used at various levels of resolution and related to planning policy as shown by Mackett (1976).

An alternative to the use of models of the individual components would be a comprehensive model. Indeed the framework was conceived to underpin an operational macro-level integrated land use-transport model (Mackett, 1979a,b), which does not explicitly represent the spatial dynamics of population and employment change; in the model people are only represented when they survive in or move into a dwelling or job, at which point they are given a spatial location. If they do not survive over time they are, in effect, lost to the system. This is common to all such models, but the accounting framework would represent people explicitly as they change location and status. Conversely, the integrated land use-transport model includes some of the spatial and temporal processes in the accounting framework, and would be one way to make the various processes sensitive to changes in transport costs. Modifications to the model for use in the current project are described in Mackett (1979c).

As mentioned above, the framework in figure 1 could be used to represent individuals moving from one state to another over time. In the aggregate case, in which rates are applied to individuals we are, in effect, dealing with averages. Thus, for example, if we have a survival rate of 0.4 we are saying that 40% of the population survives from time t to time t+1. However, if we are dealing with individuals, that person either survives or does not, that is, the resulting value must be 0 or 1. The easiest method here is to regard the publicity of survival as 0.4 and then use random numbers to determine for each case whether the person actually does or not. The technique of using random numbers to simulate the outcome of a process is called the Monte Carlo method (see for example, Hammersley and Handscomb, 1964). As the population size grows, the closer the average will be to the aggregate value, but using the micro-approach means that we are considering individual behaviour, and can link the modelling very closely to the observations from the survey, rather than averaging over a wide range of observed behaviour on the assumption that the behaviour of one person compensates for that of another. This method of considering individuals has been termed 'micronimulation', and, in this case, the appropriate labels of location, economic activity, social status and so on, would be attached to each individual by means of the Wilson and Pownall (1976) technique. This method has been used to simulate a car-sharing scheme (Bonsall, 1979) and the interaction between the labour and housing markets (Clarke, Keys and Williams, 1979). A similar, but rather simpler, method has been used for urban growth by Mason (1977), but he used a deterministic method based on income levels rather than an element of randomness to determine the outcomes.

Over the past few years models of individual choice based upon the theories of Luce (1959) have been used in transport planning, particularly for modal split. More recently attention has turned to locational choice, for example McFadden (1978) and Louviere (1979) have considered the choice of residential location, Tardiff, Lam and Odell (1978) have a simple model of residential and employment location choices and Moss (1979) has developed models of the migration decision. All these models require testing and validation, but appear to offer very useful insights into locational choice processes.

There is a wide range of exciting techniques being developed in fields relevant to this project. This will be drawn upon in the development of new methods for examining the effect of transport costs on locational decisions. Furthermore, we shall be able to use the data from the survey for model calibration and testing, and so shall be able to make a useful contribution to the field.

5. CONCLUSIONS

In this study we are examining the impact of rail fare increases in London and south-east England. The supply of labour in central London is dropping and so the city is becoming more dependent on long-distance commuters who are likely to be very sensitive to large rail fare increases. Some of the commuters...
particularly to the east of London, have fairly low incomes and could suffer
greatly if fares increase because there are few alternative local jobs available.
However, all these trends have been determined from aggregate data and there is
a real need for an examination of the underlying behaviour that is bringing
about these changes. For this reason, we shall be undertaking a survey of the
behaviour of individuals over the past few years. These data will be used in
the development of a variety of models of the responses of individuals to increas­
es in rail fares. From this analysis we should then be able to understand
why the past changes have occurred, and make an assessment of likely future
changes.

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TRANSPORT PRICING POLICY AND METROPOLITAN POPULATION REDISTRIBUTION

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1. THE PROCESS OF METROPOLITAN RESTRUCTURING

In the last two decades there has been in Britain, as well as in other countries of the industrialised West, a major redistribution of population and employment from metropolitan conurbations to the surrounding regions. While there is disagreement among scholars as to whether the decentralisation process represents a continuation or a reversal of past trends (see, for example, Gordon, 1979), there is no doubt that it has given rise to many problems. These include the unemployment in, and the general rundown of, inner city areas, the erosion of their tax base, the loss of population and employment, and the subsequent and further decline and higher charges of public transport and other services.

While a small proportion of the restructuring is planned and officially assisted (in the case of both job and population relocation), most of the moves outward are generally spontaneous reactions to the changing urban environment (Department of the Environment, 1976a, 1976b; Dennis, 1978). These reactions are the result of a complex and dynamic interplay of many factors. The outward movement of the higher and middle income groups has been generally attributed to higher expectations of living standards, the low cost and relative mobility of private transport, the high cost of housing and the negative externalities of urban life, such as noise and congestion (Mills, 1975).

The movement of manufacturing and service jobs to areas peripheral to the conurbations is driven by the need for mature industry to expand, and to be free from urban congestion, as well as the need to remain near the dispersed labour market. It has been suggested, for example (Vernon, 1960), that as firms grow in cities, their need for scale economies becomes greater than the external economies that the conurbation provides. By leaving, however, they add to the city's decline by no longer providing the agglomeration economies necessary for newcomers. One result of the dispersal of manufacturing jobs is that unemployment in central city areas is higher than in the surrounding region, partly because of a mismatch between the skills required and those available among those remaining (Stone, 1978). It has also been hypothesised that vacancies in adjacent peripheral areas are not taken up by lower paid blue collar workers remaining in the inner areas because of the difficulty and cost of commuting by public transport to the dispersed jobs (Foreman-Peck and Grippolos, 1977).

The expansion of the metropolitan hinterland also results in longer commuting distances, and some orbital trip-making as against the traditional radial journeys to work (Department of the Environment, 1978). Thus, it emerges that the urban development process is a complex cyclic set of relationships, where events and processes are both cause as well as effect.

It has long been established in urban economics that there is to some extent a trade-off between 'location costs' and 'travel costs'. The well-established

1 This article is a summary of CTS Research Report (16).
The pattern of population deconcentration due to low 'travel costs' has been complicated by the sudden increases in fuel costs in the mid-1970s, which are likely to continue into the future. This has given the long-established evolutionary process of metropolitan growth a severe perturbation, and the question arises as to whether this impulse is likely to accentuate the outward movement, or have more complex results leading, for example, to a long-term reversal of trends.

Transport supply, including prices, is simultaneously the cause of the weakening of the urban centripetal forces, as well as the web that holds the conurbation and its commuting hinterland together. Transport supply policies can strengthen or weaken this relationship, and alter the interactive processes of population restructuring, employment decentralisation and changing accessibilities. Our understanding of these processes is generally qualitative and sometimes expressed in subjective terms, such as 'flight from blight' or 'inner city ghettos'. If strategic plans are to be made for the future of urban areas, and for the living and working patterns of future populations, our understanding of the underlying processes, and the implications for housing provision, urban renewal, job creation, transport planning and the provision of public services, have to be enhanced.

This then is the policy context of this paper. The study addresses itself to the effects of the changing structure of transport pricing in the population redistribution process. We are interested in exploring the possible direction and rates of change, the eventual constraints and the possible agendas for strategic policy action.

2. MODELLING STRATEGY

Almost all previous approaches to studying the land-use/transport interaction have been concerned with compiling large data inventories of trip making in terms of land-use and using derived empirical relationships to obtain highly specific transport output at a fine spatial scale. There has been little concern with the subsequent reciprocal interactions between transport supply and land-use, and of the impossibility of specifying detailed population and employment inputs for some decades ahead. In spite of their size and spatial complexity, existing models pay no attention to the underlying processes of change. There is room in the hierarchy of urban models for methods which focus on processes of change and development rather than on the relationship between structure and interaction at a fine spatial scale. This paper describes a study which attempts to begin to redress this imbalance. Our modelling style stems from both methodological considerations and from practical needs.

Thus, we consider the modelling strategy data inventory $\rightarrow$ empirical relationships $\rightarrow$ forecast to be generally of limited value and inappropriate when dealing with dynamic systems. However, whilst attempting to adopt a structuralist viewpoint it is important to recognise that there is an extremely poor theoretical understanding of the processes involved in the dynamics of metropolitan restructuring. The system outlined in the last section is characterised by an immense array of interacting variables, conflicting objectives and competing policies that cannot be understood from any single theoretical perspective. The modelling framework adopted in this study in no way attempts to represent this complexity, for we consider that such an attempt would produce models almost as intricate and incomprehensible as the real world. They would founder on unending data problems but, more importantly, the complex technical detail would hide an essentially simple set of structural assumptions.

Our modelling objective is to clarify issues that are likely to be most
critical in the future given our theoretical framework. The modelling style adopted in the present paper is also influenced by practical policy requirements. The spatial complexity and cost of existing urban transport/land-use models effectively limits the number of policy alternatives tests to three or four, so the limited selection of alternatives becomes of critical importance. Yet there is a need for a broad-brush approach to investigate the effects of a wide variety of policies quickly and inexpensively. The approach (of strategic planning) can be used to narrow the field of policy alternatives for more detailed investigation and evaluation.

The pointers are, therefore, to a spatially coarse, dynamic, process-oriented model for strategic analysis of the possible time trajectories of the effects of alternative policies. Such a model will enable the testing of a wide range of alternative transport pricing policies from which a better understanding of their long-term implications can be gained. The kinds of questions which could be addressed are of the following nature: what would be the effect on intrametropolitan migration patterns of an increase in rail fares caused by the removal of subsidies? Would the dispersal of office employment from the centre have an effect on long-distance commuting? Will population loss from the city decrease with the increasing cost of petrol, and what effect would this have on modal split and congestion? The next section outlines the development and application of a strategic model based on logistic growth theory to study the dynamics of population redistribution and commuting in the South-East of England.

3. DEVELOPMENT OF AN INTERACTIVE SPATIAL MODEL OF POPULATION DYNAMICS

(a) Overview

In the model outlined here, the spatial dynamics of a region's population are represented by a set of differential equations which describe the rates of change of population of each of three functionally defined spatial sub-divisions namely an urban core, a metropolitan commuting hinterland and the remainder of the planning region. Taken together, these equations provide a continuous description of the urban processes through time that result in the redistribution of the urban and regional population. These population movements lead in turn to changes in the intensity of commuting to the metropolis, which are also written as differential equations. Thus, the model is of changing metropolitan relationships as well as of population movement.

Essentially, the model is based upon a logistic function as a primary descriptor of growth and this is modified by secondary growth inhibiting terms which alter the shape of the growth curve and the point of long-term equilibrium. It builds on the logistic framework developed by Glaister (1976) by incorporating the essential notions of space and commuting. Demographic considerations are included, and the time scale is brought into line with that of conventional planning models. This enables Glaister's abstract model to be calibrated for a specific region, and for policy tests at a strategic level to be carried out.

There are ten differential equations in all, describing the rates of change of ten urban variables; as an integrated set, they form a dynamic simulation model of metropolitan change driven by changes in transport pricing policy and congestion. Given a complete set of initial conditions, it is possible to explore the way urban processes work (as hypothesised) to produce intraregional population movement and changes in the regional linkages to the metropolis area. This then allows us to investigate the reaction of the system to various pricing policies or to trends outside the control of the planner, such as rising fuel costs and fares. A block diagram of the interactions at every instant in time is given in Diagram 1.
The region is divided into three functional areas noted above and defined in Section (b). The central equations of flow (equations 1, 2 and 3) describe the rate of change according to mode of the economically active population of the central urban area, zone 1. The size of the population of this zone acts as an attractive force on the economically active population of the rest of the region to reside and work in zone 1. This represents the sum of the agglomeration benefits of urban living. Simultaneously, the travel and congestion cost within the urban zone causes some of the working population within it to migrate to other parts of the region. These urban externalities affect bus, automobile and subway users differently. It can also be seen that the instantaneous modal split fractions \( \pi_k \) operate only on those who have to make the modal choice, namely the in-migrants. The modal mix at any point in time is, therefore, not brought about by a complete reallocation among modes at every point in time, but through marginal changes in the modal quantities.

\[
\begin{align*}
\frac{db}{dt} &= \sigma_1 w_1 (w_2 + w_3) \pi_b - \gamma_b c_b b \\
\frac{da}{dt} &= \sigma_1 w_1 (w_2 + w_3) \pi_a - \gamma_a c_a a
\end{align*}
\]
where \( b \), \( a \) and \( u \) are the numbers of bus, automobile and underground users for work trips within the urban area, \( w_i \) are the populations of zone \( i \) and \( c_k \) are the generalised costs of the trip by mode \( k \), including congestion cost. The first term represents the logistic growth of a mode, while the second term is the growth inhibiting term caused by high travel costs. \( \eta_k \) are the instantaneous modal fractions operating on the new city migrants.

\[
\sigma_1 = \frac{g_1}{g_1 + g_2 + g_3}
\]

where \( g \) denotes the zonal job distribution.

The flow of economically active persons between zone 1 and the rest of the region is converted to population flows by the application of an appropriate activity rate. This is necessary because the forces of intra-metropolitan migration in the model, in both directions, act primarily on workers and trip makers, and not on the general population. The changes in the modal composition of work trips is translated to population flow in and out of zone 1 through the application of the appropriate activity rates. Thus

\[
dw_1 /dt = \sigma_1 w_1 (w_2 + w_3) /q_2 - (\gamma_b c_b b + \gamma_a c_a a + \gamma_u c_u u) /d_1
\]

where \( q_1 \) is the activity rate of outmigrants from zone 1, and \( q_2 \) is the activity rate of immigrants to zone 1, such that in general \( q_2 > q_1 \).

Since the system is considered as essentially closed, the change in the population of zone 1 of the region is made up by corresponding changes in the population of zones 2 and 3. If there is a net inward migration to zone 1, the increase is drawn from zones 2 and 3, and if there is a net out-flow of population from zone 1, there is a corresponding increase in the population of the two non-central zones (equations 6 and 7). The model is, therefore, concerned with the spatial dynamics of the city-region population.

The change in the population of zone 1 is assigned to zones 2 and 3 according to their existing populations, and a cost of move deterrent function (equation 8). Migration between zones 2 and 3 is modelled as a function of the attraction potential of zone 2 to zone 3 residents, and the disbenefits accruing on zone 2 residents as a result of the increasing population of their zone.

\[
dw_2 /dt = -\rho dw_1 /dt + \sigma_2 w_2 w - \sigma_3 w_2^2
\]

\[
dw_3 /dt = -(1 - \rho) dw_1 /dt - \sigma_2 w_2 w + \sigma_3 w_2^2
\]

where \( \rho \) is the proportion of the change in \( w \) that is attributable to the change in \( w_1 \), given by

\[
\rho = \frac{w_2 \cdot \exp(-\phi_1 g_{21})}{w_2 \cdot \exp(-\phi_1 g_{21}) + w_3 \cdot \exp(-\phi_3 g_{31})}
\]

where \( c_{g_{21}} \) and \( c_{g_{31}} \) are the generalised cost of travel from zones 2 and 3 to
zone 1, weighted by modal proportions.

The changes in the commuting flow to zone 1 from zones 2 and 3 are also expressed as differential equations for each mode (equations 11 to 14). Since, of those who migrate from zone 1 to live in zones 2 or 3 (or vice versa), a certain proportion \( s_k \) will keep their jobs in the conurbation and commute daily by car or rail from their new location. It is reasonable to postulate that this proportion is a function of the relative costs of travelling to their old jobs in the conurbation and of travelling to a new job near their new residential location. Let this proportion be \( s_2 \) for zone 2 and \( s_3 \) for zone 3. It is thus postulated that

\[
k_2 \cdot \exp(-\phi \cdot c_{21}) \\
\frac{c_2}{\exp(-\phi \cdot c_{21}) + \exp(-\phi \cdot c_{22})}
\]

\[
k_3 \cdot \exp(-\phi \cdot c_{31}) \\
\frac{c_3}{\exp(-\phi \cdot c_{31}) + \exp(-\phi \cdot c_{33})}
\]

where \( c_{ij} \) are the generalised mode-weighted cost of a work trip from \( i \) to \( j \).

In addition, existing commuters may decide to withdraw from the commuting population in response to the cost of commuting. Thus, the total changes in number of rail \((r_{ij})\) and car \((a_{ij})\) commuters from zones 2 and 3 to zone 1 are given in the equations

\[
dr_{21}/dt = -c_2 \cdot \rho \cdot dw_{1}/dt \cdot \pi_{21} - \eta_r \cdot c_{21} \\
da_{21}/dt = -c_2 \cdot \rho \cdot dw_{1}/dt \cdot \pi_{a21} - \eta_a \cdot c_{21}
\]

\[
dr_{31}/dt = -c_3 (1 - \rho) \cdot dw_{1}/dt \cdot \pi_{21} - \eta_r \cdot c_{31} \\
da_{31}/dt = -c_3 (1 - \rho) \cdot dw_{1}/dt \cdot \pi_{31} - \eta_a \cdot c_{31}
\]

where \( \eta_r, \eta_a \) are the constant price elasticities of travel for rail and car trips, \( c_{kij} \) are the generalised cost of the \( i-j \) trip by mode \( k \), and \( \pi_{kij} \) are the instantaneous modal proportions. The generalised costs for each mode in zone 1 are assumed to have two components: a generalised congestion-free cost component \( c_{nc} \) and a congestion cost component (details of their computation are given in the full paper).

Although the model is of a closed system at the regional level, for calibration it is necessary to account for the movement of persons to and from areas outside the region. These are input exogenously into the model on the basis of official projections. The effects of these movements on model variables, such as work trips, are, however, included. Annual births and deaths are also accounted for in the model. The full system of equations is given in Cordey-Hayes and Varaprasad (1980).
The model was calibrated for the south-east standard region of Britain. Zone 1 was composed of the Greater London conurbation, zone 2 was the Outer Metropolitan Area (OMA), and zone 3 was the Outer South-East (OSE). The model was simulated with initial values of endogenous variables pertaining to a base year; in the present study, the base year used was 1961, the earliest year for which a complete data set could be estimated. As the simulation progressed, the values of all exogenous variables such as transport costs, job supply and wage levels, were up-dated to reflect the changing circumstances. In addition, annual age-specific fertility and mortality rates from 1961 were also input in each simulation 'year', and annual migration movements of people between the parts of the south-east region and areas external to it were estimated and accounted for in each year. This was necessary because the models simulated only intra-regional movement, and external movement had to be taken into account exogenously.

Values of endogenous variables such as the population of each zone, the number of work trips by mode in the conurbation, and the modal split of the long-distance commuting trips from the outer zones to the central zone are output at the beginning of each simulation 'year'. The output at five-year intervals were compared with the available data for 1966 and 1971. In the case of population only, the 1976 figures were also used for the calibration as travel data after 1971 were not available. Values of model parameters were then estimated so as to achieve an approximate fit of the output values with the actual observed values at these points in time, while maintaining any constraints of inequality and relativity that operated on the parameters.

Using this methodology, calibration was achieved over a 15-year period (1961 to 1976) for the population variables, and a ten-year period (1961 to 1971) for work trip variables. The values of the endogenous variables in the models (population and work trips) were tested for approximate agreement with the observed population and work trip figures for 1966, 1971 and 1976 (population only). Thus, four time frames (including the initial point) were used to calibrate the model with respect to population, and three for the work trip figures.

Having calibrated the model so that it describes not abstract processes, but real processes in a specific geographical area, it was possible to observe the trajectories of model variables in response to specific transport and urban strategies. A range of policy tests were devised to observe the time paths of the endogenous variables under the effect of different policy initiatives. In real terms, these policies, or strategies, could either be initiated by planners, or be imposed on the system by external forces out of the control of these policy-makers. Thus, we can explore the effects of these policies on the rate of population decentralisation and the changing urban-regional commuting linkages in the south-east by varying the values of the exogenous variables that are input into the model at periodic intervals. The main exogenous variables that can be manipulated in this way are the real direct costs of the various modes, real income, the distribution of jobs, and fertility rates.

In these policy experiments, the model is run until 1991. As in the calibration procedure, values of exogenous variables are read in at each simulation year to reflect the changing urban environment in which the processes take place. The indices of real wages, bus, tube and rail fares, motoring costs, parking charges, job supply and distribution, fertility, mortality and migration rates were projected according to different economic and demographic scenarios. These constituted the possible exogenous settings within which the intra-
regional household relocation process will take place.

A range of policy tests were devised, reflecting a variety of such conditions. These were simulated by inputting in each simulation 'year' the values of the exogenous variables appropriate to the policy that is intended to be simulated. It can be seen that a large number of combinations of policies can be simulated. For example, high transport costs can be combined with declining real incomes and continuing job decentralisation. Different rates of cost increases may be associated for different modes.

A range of seven test runs were selected. These are summarised in Table 1 and include the testing of individual policies as well as combinations of these.

### TABLE 1: Summary of Policy Runs

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Description</th>
<th>POLICY VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>'Do Nothing' Policy, existing trend extrapolated</td>
<td>Real Wages: 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>2</td>
<td>Increase in motoring and public transport costs take place</td>
<td>Motoring Cost: 0 +1 +1 +1 +1 0 0</td>
</tr>
<tr>
<td>3</td>
<td>Motoring costs increasing at a higher rate, public transport at level 1</td>
<td>Bus Fare: +2 +1 +1 +1 0 0</td>
</tr>
<tr>
<td>4</td>
<td>Mode costs at level 1, with an increase in the job supply in zone 1</td>
<td>Tube Fare: +1 +1 +1 +1 0 0</td>
</tr>
<tr>
<td>5</td>
<td>All mode costs at level 2, with a dropping real income due to inflation</td>
<td>Rail Fare: +2 +2 +2 +2 0 0</td>
</tr>
<tr>
<td>6</td>
<td>'Do Nothing' Policy with a 'high' fertility projection</td>
<td>Job Supply: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>7</td>
<td>'Do Nothing' Policy with a 'low' fertility projection</td>
<td>Housing Stock: 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

Key: -1 A decreasing projection
     0 Existing trend extrapolated
     +1 Increasing projection (1st level)
     +2 Increasing projection (2nd level)

H 'High' fertility projection
M 'Middle' fertility projection
L 'Low' fertility projection

(a) Results of Policy Tests

These are shown in Figures 1 to 6, showing the trajectories up to 1991 of population levels and modal choice in GL under different 'strategies'. These reflect the basic assumption that increasing travel cost and congestion is a disincentive to urban living. Thus, strategies 1, 2, 3, 4 and 5 result in decreasing levels of GL population. Run 4, which assumes a slower decline of job supply in GL results in a higher population than the comparative do-nothing run, run 2.

The figures for the population levels of OMA and OSE are in the reverse order to that of GL. It is interesting to note, however, that the population predicted by the model for the Outer South-East is generally higher than official projections. This suggests that there is probably a wave of migration from the OSE to those counties just outside the South-East Standard Region, which shows up in the model as an increase in OSE population.

The results also show a continuing increase in commuting flows from the OMA and OSE into GL as the population decentralisation process accelerates. Regardless
of which set of policies is operative, the increase in the number of commuters is very nearly the same. It would, therefore, appear that the price elasticity of commuting in the model, in the form of the cost deterrence factors $\eta_1$ and $\eta_2$, is too small. These factors were estimated in the calibration procedure to fit commuting data for the period 1961 to 1971 when there was a large increase in commuting at low cost. The result is that as travel costs increased, the effect on commuting flows and modal split was minimal. If possible, these values and those of other parameters, should be determined by direct measurement rather than estimated calibration.

4. CONCLUSIONS

This paper has outlined the development, calibration and policy testing of a strategic model for the exploration of the interaction between transport supply (including pricing policy and congestion) on the population redistribution process between a metropolitan area and its hinterland. The style of modelling is innovative in that it focusses on the dynamics of metropolitan change at a coarse geographic scale rather than the detailed spatial disaggregation and comparative static approach of most land use/transport models. It has been consciously designed for strategic policy analysis.

The development of the model thus far has demonstrated its potential for policy analysis, but further work is required to refine the accuracy of a number of key variables, in particular the price elasticity of commuting. These refinements are currently in progress.

A second model, based on kinetic theory and time oriented accounting frameworks, has been developed in parallel with the logistic model described in this paper and calibrated and tested on the same area. This alternative model has house vacancies, travel costs and congestion as the key concepts in defining the relative attractiveness of zones. Comparison of the results of the two approaches is given in Varaprasad (1979).

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Stone, P A (1979). The implications for the conurbations of population changes, Regional Studies, 12, 95-123.
FIGURE 1
Projected population of Greater London

FIGURE 2
Projected population of Outer Metropolitan Area

FIGURE 3
Projected population of Outer South-East
FIGURE 4
Projected number of car users in Greater London

FIGURE 5
Projected number of bus users in Greater London

FIGURE 6
Projected number of tube users in Greater London
Dejon (to appear) proposes an implicit system of differential equations to describe the dynamic behaviour of some spatial interaction systems. Implicitness of the equations proposed means that the time derivative $f'(t)$ of the state vector $f(t)$ of the interaction system, at any time $t$ of interest, has to be calculated as a function of $f(t)$ by solving some algebraic system of equations. In network theory techniques are made available for achieving that. In this paper, we are going to expound the nodal analysis technique, exemplified on some specific examples of dynamic spatial interaction networks. The simplest of the examples chosen is such that a fully explicit system of differential equations $f'(t)=F(f(t))$, $F$ a known vector function, is obtained which allows for ready interpretation of the dynamics of the spatial interaction process. This then leads to an asymptotic stability statement (ascertaining for the specific case at hand what could be proven, by a more general method, for the whole class of implicit systems of differential equations proposed by Dejon (to appear)).

The graph theoretic structure of the spatial interaction systems here under study will be of the type of Fig. 1, i.e. of almost bipartite type (see also Fig. 1 in Dejon (to appear)). For the static part of the spatial interaction system we will assume throughout a production-constrained model, i.e. current sources of fixed strengths $O_i$ in arcs $(oi)$, $i \in P$. (The notations used in this paper are the same as in Dejon (to appear).) Let us recall that $N$ denotes the set of nodes and $A$ the set of arcs of the network. Nodes are designated by Latin letters $i,j,k,l$ or by $0$, arcs by Greek letters $\alpha, \beta$ or by ordered pairs $(ij)$, indicating that the directed arc $(ij)$ points from $i$ to $j$. For general network theoretic terminology see also Iri (1969).

![Fig. 1. Type of graphs primarily considered](image)

The specific nature of the arc characteristics $t_{ik}(. \cdot)$ and $t_{ij}(. \cdot)$ will not be of relevance in the sequel. To fix, however, ideas and to explicit the nodal analysis technique in a static situation first, let us assume, for a moment,
that

\[ t_{ij}(f_{ij}) = \ln \frac{f_{ij}}{a_{ij}}, \quad a_{ij} > 0 \text{ some exogenous variable,} \quad (1) \]

for all \( i \in P, \ j \in J, \) and

\[ t_{jo}(f_{jo}) = 0 \quad (2) \]

for all \( j \in J. \)

A feasible current \( f := (f_{ij})_{i \in A} \) in the network constitutes a static equilibrium flow iff there exist (static) equilibrium potentials \( p_i, \ i \in N, \) such that

\[ p_i - p_j = t_{ij}(f_{ij}) = \ln \frac{f_{ij}}{a_{ij}}, \quad i \in P, \ j \in J, \quad (3) \]

\[ p_j - p_0 = t_{jo}(f_{jo}) = 0, \quad j \in J. \quad (4) \]

This implies

\[ f_{ij} = e^{p_i - p_0} \cdot a_{ij}, \quad i \in P, \ j \in J. \quad (5) \]

\( p_0 \) could have been chosen equal to zero from the outset without changing anything essential. With \( p_0 = 0, \ p_i \) or rather \( e^{p_i} \) is obtained via Kirchhoff's nodal condition at any node \( i \in P:\)

\[ 0_i = \sum_{j \in J} f_{ij} = e^{p_i} \sum_{j \in J} a_{ij}, \quad (6) \]

which yields

\[ e^{p_i} = \frac{0_i}{\sum_{j \in J} a_{ij}}. \quad (7) \]

Inserting this in (5) one obtains the static equilibrium flow values

\[ f_{ij} = 0_i \frac{a_{ij}}{\sum_{l \in J} a_{il}}, \quad i \in P, \ j \in J. \quad (8) \]

With special expressions for \( a_{ij}, \) like e.g.

\[ a_{ij} = e^{-3c_{ij}} \quad \text{or} \quad a_{ij} = w_j e^{-3c_{ij}}, \quad (9) \]

(8) is known as production-constrained gravity formula (see, e.g., Wilson (1974)).

2. EXPLICITLY OBTAINABLE DYNAMIC POTENTIALS

Dejon (to appear) suggests to obtain – for appropriate spatial interaction systems – the time rate of change vector \( \dot{f}(t) \) as equilibrium flow vector in a network \( (N, A, A_0, \ \hat{\ell}(\cdot)) \) with the following specifications: (a) \( A_0 \) is the set of all arcs \( a \in A \) with current sources, i.e., in this paper, all arcs \( (oi), \ i \in P. \ A \setminus A_0 \) are the remaining arcs. (b) \( \hat{\ell}(\cdot) \) stands for the dynamic arc characteristics.
\( \hat{t}_\alpha(\tau), \alpha \in \mathbb{A} \setminus \mathbb{A}_0 \), which are supposed to be of the form
\[
\hat{t}_\alpha(f(\tau)) = \hat{t}_\alpha(f'_\alpha(\tau)) + t_\alpha(f'_\alpha(\tau)). \tag{10}
\]
The \( \hat{t}_\alpha(\cdot) \) are (in the most general case set-valued) functions to be chosen, depending on the spatial interaction system under study. Throughout this paper, except for the last example in Section 3, we will assume
\[
\hat{t}_\alpha(f) = \frac{1}{G_\alpha} f'_\alpha,
\]
\[0 < G_\alpha \leq + \infty \text{ some constant.}
\]
The specific assumption to be made in this section is that
\[
G_\alpha = + \infty \text{ or } \frac{1}{G_\alpha} = 0 \text{ for all } \alpha = (\mathbb{J}), \mathbb{J} \in \mathbb{J}.
\]
At time \( \tau \), dynamic equilibrium prevails iff there exist "dynamic" potentials \( \hat{p}_j, j \in \mathbb{N} \), (which may vary with time) such that
\[
\hat{p}_j - \hat{p}_o = \hat{t}_{ij}(\hat{f}_{ij}(\tau)) = \frac{1}{G_{ij}} (\hat{f}_{ij}(\tau) + t_{ij}(f_{ij}(\tau))), \tag{13}
\]
\[
\hat{p}_j - \hat{p}_o = \hat{t}_{ij}(\tau) = t_{ij}(f_{ij}(\tau)), \tag{14}
\]
with \( \hat{p}_o \) chosen equal to zero. Omitting the time variable \( \tau \), this is equivalent to
\[
\hat{f}_{ij} = G_{ij} [\hat{p}_i - \hat{t}_{ij}(f_{ij}) - t_{ij}(f_{ij})]. \tag{15}
\]
As \( \hat{f} \) is supposed to be a current in \( (N, \mathbb{A} \setminus \mathbb{A}_0) \), Kirchhoff's nodal condition at any node \( i \in \mathbb{P} \) reads:
\[
0 = \sum_{j \in \mathbb{J}} \hat{f}_{ij} = \hat{p}_i \sum_{j \in \mathbb{J}} G_{ij} - \sum_{j \in \mathbb{J}} G_{ij} [t_{ij}(f_{ij}) + t_{ij}(f_{ij})], \tag{16}
\]
or equivalently
\[
\hat{p}_i = \sum_{j \in \mathbb{J}} G_{ij} [t_{ij}(f_{ij}) + t_{ij}(f_{ij})] / \sum_{j \in \mathbb{J}} G_{ij}. \tag{17}
\]
Inserting this in (15) one obtains
\[
\hat{f}_{ij} = -G_{ij} [t_{ij}(f_{ij}) + t_{ij}(f_{ij})] / \sum_{i \in \mathbb{P}} G_{ij}. \tag{18}
\]
which is a system of explicit differential equations for the unknown functions \( f_{ij}(\cdot) \).

Time-independent constants \( f^{*\mathbb{P}}_{ij} \), satisfying \( \hat{p}_i = \sum_{j \in \mathbb{J}} f^{*\mathbb{P}}_{ij} \), form a stationary solution of (18) iff they put the right hand side of (18) equal to zero for all \( i \in \mathbb{P}, j \in \mathbb{J} \). This is equivalent to saying that, for each \( i \in \mathbb{P} \), the various sums \( t_{ij}(f^{*\mathbb{P}}_{ij}) + t_{ij}(f^{*\mathbb{P}}_{ij}) \), \( j \in \mathbb{J} \), are all equal to their weighted average, say \( p_i \) (see (17)):
\[
t_{ij}(f^{*\mathbb{P}}_{ij}) + t_{ij}(f^{*\mathbb{P}}_{ij}) = \hat{p}_i, \quad i \in \mathbb{P}. \tag{19}
\]
Setting $\hat{p}_i := t_\alpha (f_i^{st})$ and $\hat{p}_0 := 0$, one concludes from (19) that any stationary solution of (18) is a static equilibrium flow in the network under study in this section. (Cf. equations (3) ff.) As, from (18), the converse is also seen to hold, we may resume: The stationary solutions of the dynamic equations (18) are the same as the static equilibrium flows, in the networks under study in this section.

We are now going to prove global asymptotic stability of the system of differential equations (18), using an elementary technique that does not work in the general case, but will do under the assumption that the static part $t_\alpha(.)$ of the arc characteristics is as given by (1) and (2). This is somewhat more restrictive than required by the technique of proof, yet covers the cases of all production-constrained gravity models. Let then $f_i^{st}$ designate the stationary solution (the explicit expression of which is provided by (7)). Global asymptotic stability means that for any solution $f(\cdot)$ of (18) the limit relationship

$$f_\alpha (\tau) + f_i^{st} \quad \text{as } \tau \to \infty$$

holds for all $\alpha \in A$.

We accomplish the stability analysis by examining the intervals $T_i(\tau)$, defined, for each $i \in P$, as the respectively smallest interval that contains all the numbers $t_{ij}(f_{ij}(\tau))$, $j \in J$. Equations (18) will be shown to imply that these intervals $T_i(\tau)$ keep shrinking as time elapses, provided they do not happen to be already reduced to a single point. If this occurs for $T_i(\tau)$, say, all $t_{ij}(f_{ij}(\tau))$, $j \in J$, are the same, and therefore equal their weighted average $\hat{p}_i$ (cf. (17)) which - by (18) - implies $f_{ij}(\tau) = 0$ for all $j \in J$. The flow values $f_{ij}(\tau)$ turn out to be stationary already.

For non-degenerate interval $T_i(\tau)$, let

$$L_i(\tau) = t_{ij} (f_{ij} (\tau)) - t_{ij} (f_{ij} (\tau))$$

be its length, under an appropriate choice of $j_0, j_1 \in J$. Its time derivative satisfies

$$\dot{L}_i (\tau) = \frac{f_{ij} (\tau)}{f_{ij} (\tau)} \dot{f}_{ij} (\tau) - \frac{f_{ij} (\tau)}{f_{ij} (\tau)} \dot{f}_{ij} (\tau)$$

$$\leq \min_{j \in J} (f_{ij} (\tau)) - \frac{f_{ij} (\tau)}{f_{ij} (\tau)} \leq \min_{j \in J} (f_{ij} (\tau))$$

As the $G_{ij}$ are all larger than zero, one concludes from inequality (22), which holds at any time $\tau$, that $L_i(\tau) < 0$ as $\tau \to \infty$. Therefore, and because of the fact that the upper limit of $T_i(\tau)$ decreases permanently while the lower limit increases, $T_i(\tau)$ shrinks to a limit point, say $p_i$. That implies that for all $j \in J$

$$\ln \frac{f_{ij} (\tau)}{a_{ij}} \to p_i \quad \text{as } \tau \to \infty,$$

or equivalently

$$f_{ij} (\tau) \to e^{a_{ij} p_i} = f_i^{st} \quad \text{as } \tau \to \infty.$$
Equations (18) also provide some easy information about possible oscillatory behaviour of the solutions $f_{ij}(.)$. The derivative $\frac{d}{dt} f_{ij}(.)$ of $f_{ij}(.)$ undergoes a change of sign whenever $t_{ij}(f_{ij}(.) + t_{ij}(f_{ij}(.)))$ passes through the weighted average $\beta_i$ (cf. (17)), either from above to below or in the reverse direction. If there are only two nodes in $J$, this cannot happen. The more involved case of three or more nodes is not going to be considered here.

After that much information about the qualitative behaviour of the solutions of the differential equations (18), what about the chances that these equations model some actual spatial interaction system reasonably well?

Beforehand, let us point to the obvious: Equations (18) do not take care of exogenously generated time rates of change $\hat{f}_{ij}(.)$ of the system. Dejon (1979) distinguishes between such exogenously generated time rates of change, say $\hat{f}_{ij}(.)$, and endogenously generated ones, say $\hat{f}_{ij}^{en}(.)$, while the total time rate of change is

$$\dot{f}_{ij}(.) = \hat{f}_{ij}(.) + \hat{f}_{ij}^{en}(.)$$

(25)

and equations (18) are modified to read

$$\dot{f}_{ij}^{en} = -G_{ij}(t_{ij}(f_{ij}(.) + t_{ij}(f_{ij}(.))) \frac{\sum_{\leq J} G_{11} t_{10}(f_{10}(.) + t_{11}(f_{11}(.)))}{\leq J} G_{11}.$$  

(26)

Another possible objection against the equations proposed is the absence of time lags. There is, however, one obvious way at least of accounting for them; see Dejon (to appear).

A certainly more serious objection is that equations (18) or (26) allow only for push-pull effects in modelling dynamics. Cordey-Hayes and Gleave (1974), however, observe that migration between labor market areas exhibits positive correlation between gross out-migration and gross in-migration and conclude that this "imposes significant reservations on push-pull approaches to migration". The two authors postulate and substantiate the existence of some intrinsic attractiveness of city regions that controls gross in-migration and gross out-migration per capita. This poses a challenge to develop a network theory based dynamic spatial interaction model incorporating intrinsic attractiveness as well as push-pull, hopefully with a possibility of strengthening or weakening one of these effects relative to the other one at the modeller's discretion.

From empirical evidence on intra-urban residential mobility, as reviewed by Quigley and Weinberg (1974), the author is inclined to favour an attempt at pure push-pull modelling of intra-urban migration. Even if intrinsic attractiveness effects will have to be taken into account, too, it appears to be a worthwhile exercise to study the workings of network theory based pure push-pull models beforehand.

3. IMPLICITLY DEFINED DYNAMIC POTENTIALS

We are going to abandon assumption (12) (i.e., $G_{jo} = +\infty$ for all $j \in J$) which meant that "resistance" in the spatial interaction system to changes of its state vector $f(\tau)$, at any time $\tau$, was concentrated in arcs $(ij)$, $i \in P$, $j \in J$. Admitting such resistance also in arcs $(jo)$, $j \in J$, we assume

$$\dot{f}_{jo}(f_{jo}(\tau)) = \frac{1}{G_{jo}} \dot{f}_{jo}(\tau) + t_{jo}(f_{jo}(\tau)).$$  

(27)

(As we shall deal in the sequel of this paper with endogenously generated time rates of change only, we ease notation by no longer using superscripts $en$ or $ex$.) The dynamic equilibrium conditions now take the form
\[
\dot{p}_i - \dot{p}_j = \frac{1}{G_{ij}} \dot{t}_{ij}(f_{ij}), \quad \forall i \in E, j \in J, (28)
\]
\[
\dot{p}_j - \dot{p}_o = \frac{1}{G_{jo}} \dot{t}_{jo}(f_{jo}), \quad \forall j \in J, (29)
\]
with \( \dot{p}_o \) to be chosen equal to zero; cf. equations (13) and (14). Solving with respect to \( \dot{t}_{ij} \) and \( \dot{t}_{jo} \), one obtains
\[
\dot{t}_{ij} = G_{ij} [\dot{p}_i - \dot{p}_j - t_{ij}(f_{ij})], \quad \forall i \in E, j \in J, (30)
\]
\[
\dot{t}_{jo} = G_{jo} [\dot{p}_j - t_{jo}(f_{jo})], \quad j \in J, (31)
\]
Kirchhoff's nodal conditions at nodes \( i \in E \) and nodes \( j \in J \) provide linear equations from which to calculate the dynamic equilibrium potentials \( \dot{p}_i \) and \( \dot{p}_j \):
\[
0 = \dot{p}_i \sum_{j \in J} G_{ij} = \dot{p}_j \sum_{i \in E} G_{ij} \left[ \dot{p}_i - t_{ij}(f_{ij}) \right], \quad i \in E, j \in J, (32)
\]
\[
\sum_{i \in E} G_{ij} [\dot{p}_i - t_{ij}(f_{ij})] - \dot{p}_j \sum_{i \in E} G_{ij} = G_{jo} \left[ \dot{p}_j - t_{jo}(f_{jo}) \right], \quad j \in J, (33)
\]
or equivalently
\[
\dot{p}_i = \frac{\sum_{j \in J} G_{ij} [\dot{p}_i - t_{ij}(f_{ij})]}{\sum_{j \in J} G_{ij}}, \quad i \in E, j \in J, (34)
\]
\[
\dot{p}_j = \frac{\sum_{i \in E} G_{ij} [\dot{p}_i - t_{ij}(f_{ij})]}{G_{jo} \sum_{i \in E} G_{ij}}, \quad j \in J, (35)
\]
Depending on the size of this system, the equations may be solved by a direct method, Gauss elimination for example, or by some iterative procedure. The conceptually simplest one would be fixed-point iteration as suggested by the fixed-point form of equations (34), (35). That would be the analogue to calculating balancing factors (or equivalently static equilibrium potentials) for doubly constrained gravity models by Furness' iteration; cf. Dejon (1978). With values for \( \dot{p}_i \) and \( \dot{p}_j \) from (34) and (35), equations (30) and (31) furnish the desired time derivatives \( \dot{t}_{ij} \) and \( \dot{t}_{jo} \). The headline of this section refers to the fact that equations (34) and (35) require some numerical procedure for obtaining the dynamic potentials \( \dot{p}_i \) and \( \dot{p}_j \).

So far we only considered equations for net nodal time rates of change, namely \( \dot{t}_{ij} \) and \( \dot{t}_{jo} \). To study net directional time rates of change, we work with an extended graph of the type of Fig. 2; cf. also Fig. 2 in Dejon (to appear).
There is a one-to-one correspondence between nodes $j \in J$ and nodes $k \in K$, indicated by an arrow $(jk)$ in Fig. 2. This connecting arrow says that node $j$ and node $k$ represent the same "zone" of the spatial interaction system. Correspondingly, $f_{jk}$ is the net rate of change in "zone" $j$ (= "zone" $k$) of the spatial activity under study, whose level in "zone" $j$ is measured by $\hat{f}_{jk}$. Net directional time rates of change, say $\hat{f}_{kk'}$, will be obtained as flows in arcs $(kk')$, $k,k' \in K$. The extended graph possesses exactly one arc per pair of nodes $k,k' \in K$. $f_{kk'}(t) > 0$ means that, at time $t$, a net amount $f_{kk'}(t)$ of spatial activity is being endogenously relocated, per unit of time, from "zone" $k'$ to "zone" $k$. If $f_{kk'}(t)$ is negative, net relocation takes place from "zone" $k$ to "zone" $k'$.

On the newly introduced arcs $(kk')$ we assume a dynamic arc characteristic of the form

$$
\frac{\hat{f}_{kk'}}{G_{kk'}} \in \text{a sense measures resistance of the spatial interaction system to relocation of spatial activity between "zones" $k$ and $k'$. This resistance is, by the chosen form of equations (36), tacitly assumed to be independent of the direction in which net relocation occurs, be it from $k'$ to $k$ or from $k$ to $k'$.}
$$

Dynamic equilibrium now means that there exist dynamic potentials $\hat{p}_i$, $\hat{p}_j$ and $\hat{p}_k$ such that

$$
\hat{f}_{ij} = G_{ij}[\hat{p}_i - \hat{p}_j + \tau_{ij}(f_{ij})], \quad i \in P, \quad j \in J, \quad (37)
$$

$$
\hat{f}_{jk} = G_{jk}[\hat{p}_j - \hat{p}_k + \tau_{jk}(f_{jk})], \quad j \in J, \quad k \in K, \quad (38)
$$

$$
\hat{f}_{kk'} = G_{kk'}[\hat{p}_k - \hat{p}_{k'}] \quad \text{resp.} \quad \hat{f}_{k'k} = G_{kk'}[\hat{p}_{k'} - \hat{p}_k], \quad k,k' \in K. \quad (39)
$$

The dynamic potentials obtain as solutions to a system of linear equations that represent Kirchhoff's nodal conditions:

$$
\hat{p}_i = \sum_{j \in J} G_{ij} \left[ \hat{p}_i + \tau_{ij}(f_{ij}) \right] / \sum_{j \in J} G_{ij}, \quad i \in P, \quad (40)
$$

$$
\hat{p}_j = \sum_{i \in P} G_{ij} \left[ \hat{p}_i - \hat{p}_j + \tau_{ij}(f_{ij}) \right] / \sum_{i \in P} G_{ij}, \quad j \in J, \quad (41)
$$

$$
\hat{p}_k = \sum_{k' \in K} G_{kk'} \left[ \hat{p}_k - \hat{p}_{k'} + \tau_{kk'}(f_{kk'}) \right] / \sum_{k' \in K} G_{kk'}, \quad k \in K. \quad (42)
$$

In equations (41) and (42), $j$ and $k$ represent a same "zone", i.e. $(jk)$ is an arc of the extended network.

Again we have this feature that the dynamic potentials have to be calculated from Kirchhoff's nodal conditions by some numerical procedure.

The dynamic arc characteristics $\hat{f}_a(\tau)$ used so far were all linear with respect to $f_a(\tau)$. This made them convenient to handle algebraically. In particular we were able to express the $\hat{f}_a(\tau)$ explicitly as functions of $\hat{p}_a(\alpha)$ and $\hat{p}_s(\alpha)$, if $\alpha(\alpha)$ designates the node at which arc $\alpha$ starts and $\epsilon(\alpha)$ the node at which it ends; see equation (15), equations (30) and (31), and equations (37) - (39).

This feature will still be preserved, at the expense however of lengthy expressions for $f_a(\tau)$, if one works with the following type of dynamic arc characteristics:

$$
\hat{f}_a(f_a(\alpha)) = \hat{f}_a(f_a(\alpha)) + \tau_a(f_a(\alpha)) \quad (43)
$$
with

\[
\begin{cases}
    \frac{1}{G_\alpha} \dot{f}_\alpha + \Lambda_\alpha & \text{for } \dot{f}_\alpha > 0 \\
    \text{interval } [-\lambda_\alpha, \Lambda_\alpha] & \text{for } \dot{f}_\alpha = 0 \\
    \frac{1}{G_\alpha} \dot{f}_\alpha - \lambda_\alpha & \text{for } \dot{f}_\alpha < 0.
\end{cases}
\] 

(44)

This type of characteristic is designed to model effects like transaction costs, moving costs, lack of perfect information on behalf of potential movers, that may all be observed in intra-urban migration (see e.g. Quigley and Weinberg (1977)) and presumably also in other migration phenomena. Cf. Dejon (to appear; equations (8) and (16)) for the type of equations (44).

Solving (44) for \( \dot{f}_\alpha \) yields

\[
\dot{f}_\alpha = \begin{cases}
    G_\alpha [\hat{t}_\alpha - \tau_\alpha (f_\alpha) - \Lambda_\alpha] & \text{for } \hat{t}_\alpha > \tau_\alpha (f_\alpha) + \Lambda_\alpha \\
    G_\alpha [\hat{t}_\alpha - \tau_\alpha (f_\alpha) + \Lambda_\alpha] & \text{for } \hat{t}_\alpha < \tau_\alpha (f_\alpha) - \Lambda_\alpha \\
    0 & \text{else},
\end{cases}
\]

(45)

where

\[ \hat{t}_\alpha = \hat{p}_a(\alpha) - \hat{p}_e(\alpha) \] and \( \alpha = (a(\alpha), e(\alpha)) \).

If we write symbolically

\[
\dot{f}_\alpha = \hat{t}_\alpha^{-1} (\hat{p}_a(\alpha), \hat{p}_e(\alpha); \tau_\alpha (f_\alpha)),
\]

(46)

we can express Kirchhoff's nodal condition at any node \( l \in N \) by

\[
0 = \sum_{a \in A \setminus \Lambda_\alpha} d_{a1} \hat{t}_\alpha^{-1} (\hat{p}_a(\alpha), \hat{p}_e(\alpha); \tau_\alpha (f_\alpha)),
\]

(47)

where

\[
d_{a1} = \begin{cases}
    +1 & \text{if } 1 = a(\alpha) \\
    -1 & \text{if } 1 = e(\alpha) \\
    0 & \text{else}
\end{cases}
\]

(48)

Formulation (47) of Kirchhoff's nodal conditions holds for any type of dynamic arc characteristics \( t_\alpha(\cdot) \) that possess uniquely defined inverses \( t_\alpha^{-1}(\cdot) \). Similarly to further above, the dynamic equilibrium potentials \( \hat{p}_l, l \in N \), are then calculated from Kirchhoff's nodal conditions by some appropriate, possibly iterative numerical procedure. The potential \( \hat{p}_l \), at some arbitrarily chosen "reference node" 1' may be set equal to zero without hindering solvability of equations (47). After insertion of the dynamic equilibrium potentials in (46), one obtains \( f_\alpha(\tau) \). This process has to be repeated for each point in time at which time derivatives are wanted.

4. CONCLUDING REMARKS

Linearity of dynamic arc characteristics \( t_\alpha(\cdot) \) with respect to \( f_\alpha(\tau) \) provides for algebraically simple expressions of the \( f_\alpha(\tau) \) as functions of the dynamic equilibrium potentials \( \hat{p}_l, l \in N \). In general, these have to be calculated by some numerical procedure from Kirchhoff's nodal conditions. In the simplest cases, however, they are easily obtained in closed form, and explicit first-order differential equations result for the state variables \( f_\alpha \); (cf. equations...
If the static part of the model constitutes a production-constrained gravity model, the dynamic equations (18) allow for ready discussion of some qualitative properties of their solutions. Linearity of dynamic arc characteristics with respect to $f_\alpha$ being algebraically convenient, one may still have to resort to other types of arc characteristics, depending on the application on hand. A first hint at another possible choice of characteristics is provided in (44). In modelling gross directional rates of change – as opposed to the net directional or zonal rates considered so far – one will presumably have to extend the class of models studied such as to cover effects of the type observed by Cordey-Hayes and Gleave (1974) in inter-regional migration. But even then, with network theory at the formal base of the models, nodal analysis as exemplified in the foregoing examples, will still be a basic tool to use.

REFERENCES


Formulation (4.7) of Kirchhoff's model equations holds for any type of dynamic characteristics (4.1) that possess uniquely defined potential $E_{d}$ (4.1). Similarly to (2.7), the dynamic equilibrium potentials $p_{j}^{*}$, $w_{j}^{*}$, are then calculated from Kirchhoff's model conditions (4.1) at appropriate, possibly iterative numerical procedure. The potential $E_{d}$ at each arbitrarily chosen "reference node" $i'$ may be, for equal to zero without violating solvability of equation (4.7). After insertion of the dynamic equilibrium potentials in (4.6), one obtains (4.7). This process has to be repeated for each point in time at which time derivatives are wanted.

4. **Continuous Derivatives**

Linearity of dynamics and characteristics (4.1) with respect to $E_{d}(i)$ provides for a priori simple solutions of the type (4.1) as functions of the dynamic equilibrium potentials $p_{j}$, $w_{j}$. In general, these have to be calculated by some numerical procedure from Kirchhoff's model equations. In the simplest cases, however, they may easily obtained in closed form, and explicit first order differential equations result for the state variables $q_{j}$ as well as equations

\[ \frac{dq_{j}}{dt} = f_{j}(q_{j}, p_{j}, w_{j}) \]
PART III

SIMULATION MODELLING
PART III
SIMULATION MODELLING
EDITORIAL INTRODUCTION

In the early seventies interesting research took place at the German Battelle Institute with respect to the development of a large urban simulation model - called POLIS. The first outcomes looked very promising and an enrichment of the German planning-toolbox seemed to be the result. However, the planning practitioners in Germany did show the same lack of enthusiasm to apply this (or any other) simulation model as anywhere else in the world. The major reasons for this reserved attitude are explained in the paper of RUPPERT and AGNEW. The authors argue that it is necessary to start an intensive discussion on the practical role which urban simulation models can play and what future model extensions and improvements are desirable. They contribute to this discussion by elaborating some recent major additions and modifications to POLIS and by expressing their viewpoint with respect to possible applications and forms of urban simulation in the next decade.

Simulation modelling is also advocated in the paper of CLARKE, KEYS and WILLIAMS. The authors assert that it is desirable to consider in more detail the characteristics or attributes of households, firms, etc. as a basis for the analysis and explanation of spatial phenomena. They argue that a micro-simulation approach might be very appropriate to deal with the high degree of heterogeneity in a population and they motivate this position with several examples. It is concluded that macro and micro-analytical approaches can co-exist and should be seen as complementary.

The relevance of a micro-simulation approach is illustrated by WEGENER, who outlines in his paper an interesting simulation model of the Dortmund housing market. The major component of this model is an intrazonal migration model. Migration is in this case defined as a change of location of a household encompassing a change of residence. This change depends to a large degree on the housing satisfaction. Wegener concludes quite rightly that it is an enormous task to calculate these satisfaction values in a consistent way, but he is convinced that this variable cannot be excluded, because it is necessary to incorporate the variety of housing needs and tastes into a housing market model.
INTRODUCTION

If it has been remarkably quiet in the last 5 years on the German urban simulation model front, then this has been for two reasons. Firstly, many problem areas for which model builders in the early 70's were seeking solutions have since been resolved without the use of complex simulation models. These problem areas included the following:

- the spread of suburbia
- the main locations of residential building activity
- coordination of land-use and transport planning
- location of public facilities
- ramifications of public facility location decisions

The second point is that the data base for urban simulation models is out of date. In most cities, if at all, only part of the essential data of the 1970 national census is updated, namely, population, work place, building and housing. The availability of new census data in 1981 will undoubtedly initiate considerable activity in the revision of urban structure plans and it is at least worth while to consider if urban simulation models can play a greater role in this decade's planning process than they did in the last, especially in forecasting changes in land-use at the sub-regional level. The increased digitalisation of land-use data will obviate the necessity for costly and time consuming data collection. This alone was sufficient to determine a would-be user.

For the reasons outlined above, it appears appropriate to initiate now an intensive discussion - before the new data is available - on the practical role which urban simulation models can play and what future model extensions and improvements are desirable.

A look over the fence at the experience of neighbouring countries as well as presenting German models for criticism to an international forum is, if not essential then certainly desirable. Consequently this paper presents the major additions and modifications to POLIS since the publication year of the POLIS handbook (Battelle 1973) and discusses some of the latest results obtained in the last round of calibration runs. A guarded viewpoint of possible applications and forms of urban simulation in the 90's is sketched out. To complete the picture, a brief outline of the last simulation run in Köln is given (Battelle 1979).
The structure of the POLIS model is illustrated in figure 1. Since this diagram is more or less self-explanatory, no detailed description is given in the present paper.

IMPORTANT MODEL MODIFICATIONS BEFORE 1975

The first important change in this second development phase of the POLIS model was the introduction of a different method to calculate zonal indices of attractiveness for the allocation sub-models. Instead of calculating zonal attractiveness (e.g. for housing or office use) from secondary statistical characteristics, special goal hierarchies for each land-use type are used to establish attractiveness. Each partial goal (e.g. green area per inhabitant) is weighted and the characteristics (e.g. ratio of green to total zone area) are transformed by a utility function to give a value of utility for each goal of the hierarchy.

This modification of the model was carried out because attempts to calibrate the model by regression analysis almost always led to unsatisfactory results. Either variables, important to the town planner, were not significant or even entered the regression equation with the wrong (i.e. implausible) sign.

The second important change was organisational in nature, namely, the state of each zone (ca. 100) of the city or region being investigated is documented on the file HISTAT (historical status). This storing of the status data was originally developed so that the city development status at the end of each simulation period could be analysed using different sets of goal hierarchies (e.g. from the viewpoint of various social groups). But this modification has proved invaluable for comprehensive information possibilities (up to 240 zonal characteristics per period) which it supplies and has now become the main data base for preparing the output of results. Thus the information of the "standard output" is supplemented, and in many cases replaced, by an individual dialogue method allowing zonal changes to be presented cartographically.

MODEL MODIFICATIONS SINCE 1975

The first development phase of the model was completed in 1972, with application to the cities of Köln and Wien, and the second phase in 1975, with application to Darmstadt. The second phase was then followed by a series of improvements to the model - this time applied to Karlsruhe and once again Köln - to answer special problems and but also to improve the user environment and reduce computer time.

The most important improvements are as follows:

- a new updating model for population by age and socioeconomic grouping,
- extension of the HISTAT analysis programme,
- the introduction of a mechanism to correct partial attractiveness externally at each simulation phase of the model.

Initially the POLIS model performed a very simple updating of the population and age structure. At the beginning of each simulation period the age structure was updated by the "Cohort-Survival-Procedure" taking account of the age-specific death rate of the total population and the age-specific fertility rate of women.
If net migration to the zone under consideration was positive (caused by residential building activity), the new population was assumed to have a special (predominance of young families) age structure, constant for the whole city. On the other hand if net migration to the zone was negative then the age structure of the outgoing population was assumed to be the same as the population remaining in the zone. This leads, of course, to increasingly false age structures for the city as a whole. The socio-economic structure of the population reproduces, more or less, the initial simulation period.

In the extended version of the simulation model the subroutine FORTE (update of population) is replaced by an improved FORTE (update of population by age structure and sex) and a new subroutine FORTSO (update of socio-economic structure of the population). The subroutine FORTE retains the updating of the zonal population with help of the Cohort-Survival-Procedure but is extended by two improvements:

- The exclusion of the student population from the Cohort-Survival-Procedure so that the age and sex structure of the students is given exogenously.
- A more differentiated consideration of the changes of the zonal age structure caused by inner city migration.

The foundation of this new migration model is derived from an investigation in Bonn (Böhm et al 1975) which shows that the age structure of the outgoing population can be determined from the existing age structure of the zone under consideration. The model no longer operates with a constant inward and outward migratory age structure but with several zone-type-specific age structures (2 categories for inward and 3 for outward migration).

The second important extension of the simulation model lies not so much in content but more in the presentation of the results. This is based on the efficiency of the service programme which uses the HISTAT data file.

The first stage in this development was a simple service programme which made it possible to tabulate the changes of zonal characteristics. Either changes in one planning alternative (e.g. the change in zonal population between 1980-1985) or the difference of two planning alternatives for one period (e.g. innercity population of planning alternative A against planning alternative B in 1990) can be tabulated.

This service programme was then extended to include two important functions:

- the cartographical output of any zonal characteristic at each time period and
- the graphical representation of the tabular output described above.

The third important extension is a man-machine interface allowing the planner to manually change certain parameters during a simulation. Soon after the inclusion of the cartographical facilities in the HISTAT service programme it was used to display the zonal attractiveness at the disaggregated level of partial goals. Study of these maps revealed several implausible evaluations of zonal attractiveness, e.g. the level of green area or parkland. Thus the zonal (secondary statistics) characteristics were either insufficient to describe the zonal situation, gave too little weight to qualitative aspects or the zones were simply too large, i.e. too heterogeneous. In many cases, a planner with local knowledge could immediately give plausible reasons for correcting the partial attractiveness. This led to the introduction of the possibility of making external corrections to attractiveness. This correction possibility is
Fig. 1a. Urban simulation model POLIS (simplified flow diagram)
input

land-use in ha at
begin of simulation
period

change of land-use
by land-use plan

change of the floor
space/land-use ratio

forecast of properties
and areas ripe for re-
development

population and
employment develop-
ment for the whole
region

development of
living-room
aspirations per person
and floor space per
employee

ordered list of the 7 land-
use types by market power

behavioural parameter
for land-use specific
allocation decisions

parameter for
natural population
changes

specific migratory
structures for different
zonal categories

total development
of workforce
work places
educational activities

simulation step

zonal building
land reserves
incl. areas for
demolition and
change of land-use

forecast of expected
(private) building
activity

distribution of expected
(private) building activity
to individual zones accord-
ing to building reserve
land and zonal attractive-
ment.

update of building stock

update of
land-use balance

update of employment
by branch

update of population
by age, sex and socio-
economic structure

intervention of the
model if Infrastructure
deficient

land-use demand
for intervention
measures

last period
simulated

summary of the
individual periods

output

status table of
building stock

status table of
land-use

status table of
employment

status table of
population

protocol of the
change between
period p to p+1

documentation of zonal characteristics on the
HISTAT file

time series for
development of land-
use and transport

Fig. 1b.
deliberately organised so that changes can only be made at the level of partial measures of attractiveness (30-40 different characteristics) and not at the level of the seven land-use specific attractiveness indices thereby reducing the possibility of arbitrarily changing or even cooking the simulation results.

Further, less decisive model improvements were carried out in the third development stage which include:

- the possibility of using perceived journey times in the calculation of accessibility and in the calculation of relative journey times for the modal-split model, i.e. weighting factors are applied to especially time-consuming parts of a journey such as interchange time,

- the possibility of anticipating accessibility improvements, improvements resulting from, for instance, traffic planning measures and thereby increasing the attractiveness of one or more zones,

- an improved housing occupancy model which takes better account of the existing structure of housing, i.e. a more zone-specific calculation of change of dwelling place caused by increased aspirations for living space and

- a cleaner structure of the demolition and change of land-use submodels.

RECENT CALIBRATION RESULTS

In a separate study on the subject of development quality and development effect of transport systems, (Ruppert et al 1977), existing models were recalibrated. An important result of this study was that the allocation model for each specific use (housing) was modified so that, for instance, in the case of the house construction distribution model α in the following equation took the value 2.0 instead of the value of 1.0 assumed in earlier model applications

\[ \frac{WRZ_i}{SWRB} = \frac{WRK_i \times ATR_{iw}^\alpha}{\sum_j (WRK_j \times ATR_{jw}^\alpha)} \]

where

- \( WRZ_i \) = growth in residential area in zone i

- \( SWRB \) = total demand for residential area in the time period under consideration

- \( WRK_i \) = capacity of zone i for new dwelling units

- \( ATR_{iw} \) = attractiveness of zone i for residential use

The latest calibration in Köln (Battelle 1979) show that the influence of attractiveness should be increased even further with an \( \alpha \) of 2.5 in order to model the activity of single family dwelling units more accurately but at the same time reducing the weight of accessibility in the attractiveness index from 60% to 40%.
In addition to a description of the improved calibration of the allocation models, the last POLIS report documents how a shortened calibration procedure of the transport model can be made from existing results of modelling work from transportation studies.

THE LATEST SIMULATION IN KÖLN

The latest simulation runs on Köln were designed to identify the range of possible future changes of land-use in Köln. Two alternative forecasts of regional population and employment were applied together with different assumptions on the future development of aspirations for living floor space since the rise in demand for living rooms per person and floor space per employee has been the main driving force behind the expansion of the city into its hinterland. Thus two alternative development possibilities were compared with each other:

- The maximum development alternative (MAX-EV) assumes only a slight reduction in the overall population which sinks from 1.315 mill to 1.227 mill, a rise in the number of workplaces from 0.636 mill to 0.647 mill and an increase in the demand for living rooms (inclusive of kitchen) per person from 1.32 to 1.96.

- The minimum development alternative (MIN-EV) assumes a greater loss in population which sinks to 1.241 mill. Instead of an increased number of work places, a fall to 0.622 mill is assumed. Finally, it is assumed that the aspirations for increased living rooms per person of the maximum case cannot be achieved and only 1.82 rooms per person are realised\(^1\).

Figures 2 and 3 show some typical results of the POLIS simulation exercise in Köln. As is to be expected, more people remain in the innercity in the minimum alternative where an overproportional number of people move into the hinterland in the maximum alternative - especially in the attractive east and south west hinterlands (differences are shown in absolute numbers). Turning now to the workplaces, gains in the minimum alternative are mostly in the area around the industrial complex of Leverkusen in the north east and in the new town of Chorweiler to the north of Köln - this as a consequence of positive planning initiatives. In contrast there are percentage losses, in some cases over 15%, on the border of the innercity and in the traditional industrial areas of the hinterland, Dormagen, Bergisch-Gladbach and Wesseling.

It must be added that these global simulation runs did not, as hoped, initiate further, more detailed runs - mainly for the reasons already discussed, namely, the out-of-date data base and the fact that the planning office of Köln have developed their own method for integrated resource and activity planning without using computing tools.

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\(^1\) In retrospect, both the high (1.96) and low (1.82) goals for rooms per person appear high. Planners in Köln would now use figures of 1.8 and 1.7.
Fig. 2. Comparison of the two alternatives at 1990: left the positive population difference of the minimum minus the maximum case and right vice versa at 1990.

Fig. 3. Percentage workplace gain (left) and loss (right) for the minimum case between 1970-1990.
At the moment there is apparently little demand for the forecasting of land-use changes in the commuter belts. Other town planning problem areas such as re-development, reducing the negative impacts of (road) traffic and improving the visual appearance of residential areas are receiving most attention. It is quite possible that this state of affairs will not change after the national census data becomes available in 1981. On the other hand the rapid deterioration of the housing situation in the conurbations of West Germany is indicative of a failure in forecasting and strategic planning.

Just as it is clear that merely chasing urban development trends will not, per se, lead to desirable urban land-use structures, it is also certain that many of the so-called "goal forecasts" (planning targets which increase in standard over time) will not be met, since neither the means nor the planning techniques are available for their achievement. Turning again to the example of housing construction, it is not sufficient, in a situation where the number of house completions is sinking, to welcome the halt in the flight from the innercity and the reduced rate of urban sprawl and then to be surprised one day that changes in residential life-styles and aspirations necessitate an increase in house construction (after the construction industry has collapsed). Forecasting of trends is, as always, the essential first step in the planning process which is, per se, normative.

This does not imply that urban simulation models are merely improved mechanisms for preparing trend forecasts. By building allocation decision rules into the model to represent specific zonal building activity goals, the urban simulation model can replace formulas for building activity allocation. Not that such formulas should be abandoned, indeed each method has its own strengths and weaknesses and it is certainly prudent to check and modify the results of one model against another.

In addition to such corrections to the simulation process to take account of present day planning praxis, two further model extensions appear to us imperative.

- Decreasing the typical size of zone area (leading to an increased number of zones), but not however, in the transport section of the model structure. (Especially in the application to Köln, the land-use structure of most zones was too heterogeneous.)

- Building into the model the possibility of grouping zones with similar land-use/population/employment structures together (perhaps using cluster analysis) both for making input changes and for the output of results. Especially in the interpretation of results, grouping zones spatially, i.e. innercity zones or suburban zones, has been arbitrary and not often helpful.

It is now clear to the model builders involved with the design and application of computer supported decision aids that strategic decisions are also just decisions and that their development of town planning tools makes up only a small part of the complex town planners toolbox. But it would be a mistake if the initial disappointments caused by the failure of complex urban simulation models to fulfill all of their builders' ambitious objectives led to their total disuse. This is especially true today - more than 10 years after their first development - when considerable advances have been achieved in the fields of computerisation of the necessary data bases and both enormous improvements in computer hardware and software, especially in the area of interactive programming. In addition an increasing number of people, without special programming expertise or knowledge of computers are familiar with the use and with the output of
computers both in the office and at home. Computers are no longer holy cows which only the initiated dared to approach.

And there is the old question which is often posed again but from a new aspect, namely, the degree to which urban structure and transport network planning can be coordinated. One of the earlier aspects was minimising the negative impacts of traffic on environmental areas. Increasing concern over the long-term supply of liquid fuels poses the question again from the point of view of energy conservation. Models like POLIS could help to map the limits to energy conservation which could be achieved in urban transport and help in formulating guidelines for physical planning authorities.

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1. INTRODUCTION

In this paper we discuss the potential for the application of micro-simulation to the analysis of socio-economic and public policy issues through a series of examples drawn from urban and regional planning. Although the general approach is not new and indeed dates back to the study of household dynamics by Orcutt and his colleagues in the late 1950s (Orcutt et al., 1961) the number of such applications, particularly those involving a spatial dimension, is to our knowledge very small, and spread sparcely across several fields (see the overview by Clarke, Keys and Williams, 1980).

The approach was originally motivated by a desire to consider in more detail the characteristics or attributes of individuals (or households, firms, etc.) as a basis for the analysis and explanation of particular socio-economic phenomena. An explicit recognition of the high degree of heterogeneity in a population when each member is characterized by the values of several attributes, and the requirement to confront the aggregation problem directly, prompted a consideration of an efficient representation of the state of a system (Orcutt et al., 1961; Wilson and Pownall, 1916; Kain et al., 1977). It became apparent that the computational listing and manipulation - list processing - of samples of micro-units (individuals, households, etc.) multiply classified by the various demographic, social, economic, and activity attributes relevant to a particular context, was highly preferable to the manipulation of a large and typically very scarce occupation number matrix. The elements of the latter are the numbers of individuals cross classified by the various attribute levels of interest. That is, if the values \( x_i = \{x_{i1}, \ldots, x_{iM}\} \) of \( M \) attributes are associated with each of \( N \) individuals \( (i = 1, \ldots, N) \) in a population \( P \), then the storage of the \( NM \) elements associated with the \( N \) vectors \( \{x_1, \ldots, x_N, \ldots, x_N\} \) will typically be very much smaller than the number of elements in the \( M \) occupation number matrix. This quantity is given by \( \prod_{\mu=1}^{M} a_{\mu}^N \) where \( a_{\mu}^N \) is the number of classes associated with the \( \mu \)th attribute. Recent work (Wilson and Pownall, 1916; Clarke, Keys and Williams, 1980) has emphasised that micro-level interdependency, or more formally the structure of correlation in the joint distribution of attributes \( p(x) \) over the population, is a crucial determinant of the efficiency and advantage of the 'list processing' method.

Within this micro-level representation, models representing the statics or dynamics of the population \( P \) are embedded. Applications of micro-simulation combine a number of methodological features which tend to become intertwined in the discussion of a particular problem, so that different applications tend to appear idiosyncratic. While they may be mutually influential, the processes of: model specification; estimation; solution; and aggregation, should be clearly distinguished, and a general discussion of these may be found in Clarke, Keys
and Williams (1980). Although we shall attempt to draw out some methodological features in the following discussion, our main intention in this paper is to emphasize, through a series of examples, the motivation for the approach. For this reason we have selected specific and developing areas in our own and related work at Leeds. They include applications in the analysis of: the transportation policies; housing expenditure and finance; public sector housing allocation and dynamics; local authority service provision; and the interaction of certain economic and demographic processes. These will now be discussed in turn.

2. THE AGGREGATION OF TRANSPORTATION MODELS ESTIMATED AT THE MICRO-LEVEL

Although pioneering work on the specification and estimation of travel choice models using individual data took place in the early 1960s (Warner, 1962) it was not until the early 1970s, in the United States, that an effective challenge to "aggregate" travel forecasting methods materialized. This challenge was aided considerably by the emerging requirements to assess a broader range of policies for which conventional methods were not designed.

The initial claims of the so called "second generation" of models were considerable, and included: their increased policy sensitivity; their data efficiency; a lack of aggregation bias in the estimation of elasticity parameters; and the ease with which behavioural postulates could be interfaced directly with a representation of consumer choice. There was a related and important motivation involved, namely that the development of an appropriately specified micro-model based on behavioural principles would prove to be practically transferable in both space and time. This major prize would result not only in the rapid and economical development of travel response forecasts, but also in an increased confidence in model results.

Although it is now recognised that some of the original claims associated with "disaggregate behavioural" models were exaggerated and the difficulties of their application to general policy analyses understated, the micro-analytical framework has stimulated a number of theoretical innovations, and allowed several important problems of forecasting to be confronted (see, for example, the review by Williams, 1980). Not the least of the benefits was a far greater appreciation and understanding of the problems of aggregation itself.

This process may be summarized very simply in terms of the relationship between a probabilistic choice relationship \( P(A_j | X_i) \) estimated with micro-data, and the aggregate quantity \( N(A_j | X_I) \)

\[
N(A_j | X_I) = \sum_{A_j \in A_j} \sum_{X_i \in X_I} P(A_j | X_i \theta) \tag{1}
\]

in which

- \( P(A_j | X_i \theta) \) is the probability that an individual \( i \) with a vector of characteristics \( X_i \) will select an alternative (transportation mode, location, etc.) \( A_j \),
- \( N(A_j | X_I) \) is the number of individuals in the population \( P \) with characteristics falling into the class \( X_I \) who select an alternative belonging to the class \( A_j \),
- \( \sum_{X_i \in X_I} \) denotes summation over all individuals \( i \) who have characteristics \( X \) which fall in the range of the attributes specified by \( X_I \),
- \( \sum_{A_j \in A_j} \) denotes summation over all alternatives \( A_j \) belonging to the set of alternatives \( A_j \).
The vector of characteristics $\mathbf{x}$ in a mode choice context would contain variables relating to an individual and the associated household, and location variables in terms of which transport level of service variables of competing alternatives - substitutes - could be determined. The model $P(A_j | x, \theta)$ would typically be of multinomial logit form, in which the parameters $\theta$ are estimated from revealed preferences.

We shall rewrite this equation for aggregate demand in terms of the distribution of the independent variables $\mathbf{x}$ over the population $P$, such that

$$N(A_j | x_1^T) = \sum_{i \in A_j} S \cdot P(A_j | x, \theta) N(x, \theta)$$

with

$$N(x, \theta)$$

denoting the number distribution of the attribute vector $\mathbf{x}$ over the population $P$ of size $N$ in terms of which the density function $\rho(\mathbf{x})$ will be defined by

$$\rho(\mathbf{x}) = N(\mathbf{x}) / N.$$ 

denotes general summation (summation \( \Sigma \) over discrete variables and integration over continuous variables).

The process of producing aggregate outputs consists then of estimating the parameters $\theta$ of the micro-model from stated or revealed preferences, and "weighting" each contribution within the relevant aggregate class according to $\rho(\mathbf{x})$. We have assumed here that the alternatives $A_j$ are discrete. It is straightforward to present necessary modifications for continuously distributed options, although we shall not pursue this issue here.

There are many approaches to the evaluation of the aggregation process embodied in Equations (1) and (2), and Koppleman (1976) and Koppleman and Ben-Akiva (1977) have catalogued a taxonomy of different procedures with varying information requirements. The challenge is one of designing a method which is both accurate and computationally efficient.

One approach is that of direct numerical integration by Monte Carlo simulation in which a (typically parametric) density function $\rho^*(\mathbf{x}, \theta)$ is synthesised, or obtained directly from observations, and a random sample $P^*$ of size $N^*$ taken from it in order to perform the necessary summation

$$N(A_j | x_1^T) \sim \alpha \cdot \sum_{i \in P^*} \sum_{A_j \in A_j} P(A_j | x_1^T, \theta).$$

In this expression $\Sigma$ denotes summation over individuals in the sample $P^*$ and $i \in P^*$

$\alpha$ is a scaling factor relating $P^*$ to $P$. The accuracy of this method depends on the accuracy with which the density function is synthesized and the numerical evaluation performed.

This process of forming a random sample and aggregating micro-relations by Monte Carlo simulation is a general strategy and should not be associated exclusively with travel demand modelling. An example of its use in the latter is given in a car pooling model developed by Peter Bonsall in the Institute for Transport Studies at Leeds. Details of the study may be found in Bonsall (1979). Here we shall comment briefly on one of its components in so far as it relates to the aggregation process.

The nature of the transport policy to be assessed makes it desirable to examine car sharing as a process in which the mutual decisions of driver and passenger determine whether a "match" will or will not be made. It is known
that a potentially large number of demographic, social and activity variables of driver and passenger attributes will determine whether individuals, having applied to a pooling scheme, will in fact share a ride. In Bonsall's model the demand (passenger) and supply (driver) sides are confronted in a matching process, in which individuals, randomly drawn from synthesised populations $P_1$ and $P_2$ respectively determine the benefit of match. The total number of effective matches may be written

$$N(\text{share ride}) = \sum_{i \in P_1^*} \sum_{j \in P_2^*} P(\text{share ride} | x_i^1, x_j^2)$$

in which $P(\text{share ride} | x_i^1, x_j^2)$ is the probability that a driver $i$ with attribute $x_i^1$ drawn from a population $P_1^*(x^1)$ will share a ride with a passenger with attributes $x_j^2$ drawn from a population $P_2^*(x^2)$.

The probability is actually expressed in terms of a random utility function, estimated by stated preferences, and the outcome of the matching algorithm which is designed to take account of "competition" due to potential mis-match of supply and demand, is at the individual level a 1 or 0 according to the success or failure of a match.

This micro-level matching of lists is not uncommon to micro-simulation applications in which it is necessary to examine the interaction between demand for and supply of a commodity. We shall meet it once again in a housing example to which we now turn.

3. HOUSING MODELS AND MICRO-CONSIDERATIONS

In the development of housing models through the 1960s and 1970s there has existed a clear divide between aggregate econometric studies estimated with time series data, and typically applied at the national level, and those studies of stratified housing markets applied at the metropolitan/urban level and estimated at the cross section. The former have been used to analyse and explore the dynamics of demand, supply, prices, and mortgage institution behaviour as a function of macro-economic and demographic variables, while the latter of which the models developed at the Urban Institute, Washington (deLeeuw and Struyk, 1976), the National Bureau of Economic Research (N.B.E.R.: Ingram et al., 1972; Kain et al., 1977) and in Stockholm (Holm et al., 1978) are among the more prominent, concentrate on the problems of allocation and the general equilibrium (or disequilibrium) between demand and supply.

In spite of the large number of theoretical and empirical investigations on the housing systems, there do not exist, as far as the authors are aware, at the local or national level models which embrace the full dimensions of variability in expenditure, and incorporate an adequate recognition of:

(i) the nature of housing as an asset,
(ii) the effects of control and metering on allocation and dynamics of the institutions of tenure and finance.

These are fundamental and contentious issues and it would be quite wrong to be over critical of the state-of-the-art. However, we would suggest that in theoretical developments, particularly in the treatment of space and tenure, the conventional paradigm of information theory and random utility theory, particularly as used in transportation studies, have been too closely adhered to. Of course, models should be 'context dependent' but it is not always possible or necessary to attempt a causal approach. The changing emphasis in activity-travel demand research to reflect behavioural constraints in quantitative analyses does not however appear to be forthcoming in housing model
research, although there is a considerable and growing literature on the
general role of housing organization in social stratification.

Because institutional arrangements in housing systems are very specific to
individual countries, we shall limit our comments now to a British setting
which is characterised by large public and owner occupier sectors, and a
decreasing private rented sector. Their relative sizes (and the importance of
Housing Associations) vary considerably over the country. It is one of the
peculiar and important features of the housing system in Britain that indivi­
duals who live in very similar houses (for example in adjacent semi-detached
properties) can have very different housing expenditures, while because of
local rent pooling arrangements and cross subsidisation in the public sector,
households who live in rather different properties can have very similar (or
identical) rents. While the problems of: asset accumulation, the effects of
the large reserve purchasing power of exchange buyers, differential subsid­
isation; the sensitivity of household expenditure to the movement of macro­
economic variables and taxation policies are widely recognized; these features
have yet to be captured in a "causal" model of a national or local housing
system. In the technical papers of the recent Housing Policy Review (H.P.R.,
1977), for example, in which the issues of equity and subsidy were discussed
at some length, sketch calculations were directed at the subsidy to houses (ie.
stock in different tenures) over a nominal sixty year period (see also the
discussion by Webster, 1978).

We feel that there is a logical, and arguably pressing, need to attempt to
quantify the flows of money in the housing system between the relevant 'spatial
actors' and in particular: central and local government, building societies
and individual households, in order to bring out clearly the changes over time,
and under different policies, of the variability in expenditure between house­
holds
(i) over space (both intra- and inter-regional),
(ii) who are 'first time' and 'exchange' buyers,
(iii) between and within different tenures,
(iv) with different socio-economic and demographic characteristics.
This is the principal motivation for a micro-simulation study.

A model is currently under construction to draw out the above dimensions
of variability, with particular reference to the subsidy issue. In order to do
this it is necessary to generate a population \( P^* (\mathbf{y}) \) of households with attrib­
ute list \( \mathbf{y} \) which is given for the \( j \)th household by

\[
\mathbf{y}_j = \{ x_{j1}, x_{j2}, \ldots, x_{jn_j}; x^*_j \} \tag{5}
\]

in which \( x_{j\mu} \) is the vector of attributes for the \( \mu \)th member of an \( n_j \) membered
household. \( x^*_j \) refers to specifically household attributes. \( x^*_{j\mu} \)
includes demo­
graphic and economic characteristics of individual members, while \( x^*_j \)
includes household summaries, housing characteristics (house type, tenure, age, etc.)
and financial characteristics, including details of a mortgage, if held. By
storing the price of a house when bought, it is straightforward to embed the
notion of assett accumulation.

It would clearly be desirable to have micro-level housing information for
different parts of the country in different years in order to provide accurate
bases on which to construct populations \( P^* (\mathbf{y}) \). Because of data limitations,
and this is obviously why more progress has not been made in the examination
of micro-level housing behaviour, we have been content to synthesise \( P^* (\mathbf{y}) \) from
secondary data sources (that is from the conditional and marginal distributions
of the various attribute values in \( \mathbf{y} \)).
Having constructed these populations in a base year we can subject members to the interval (e.g. life cycle and economic) and external (fiscal and monetary) changes, to which each is subject, and modify attribute values accordingly.

Essentially this operation may be seen in terms of the solution of a set of differential equations, which govern the demographic and economic dynamics of the system, by means of Monte Carlo simulation. The relative values of a random number and the probability that an event will occur (e.g. the formation of a household) will determine whether a transition between individual micro-states is actually made.

We are resisting the temptation to attempt to build a very complex "behavioural" model because of data restrictions, and are settling for a sensitivity analysis of the time dependent behaviour of the population $P^t(\chi)$ under the various processes of interest

$$P^t(\chi) + P^t+\Delta(\chi)$$

In particular we are not here attempting to model details of the interaction between supply and demand, but are allowing prices (and rents) and other macro-parameters to be "imposed" on the system. It is then straightforward to extract from the updated list of individual households information on both current and past expenditure on the one hand, and the streams of costs and benefits flowing between spatial actors on the other.

We wish to conclude this section with reference to the dynamics and allocation in the public sector, which is also the subject of a modelling effort.

Underpinning the whole micro-representation is a very fundamental theoretical question, namely: how does an individual or household come to be associated with a particular set of attributes - that is, what dynamical processes are responsible for the structure of correlation between the attributes of individuals in the population $P^t(\chi)$? A very particular but important case in point is the association between household characteristics and house type attributes including tenure. In both the private and public sectors, the probability of a match between particular attributes on the demand and supply side at the micro-level is powerfully determined by constraints imposed by the institutions of tenure.

We are currently attempting to examine within the micro-simulation framework the interaction between supply and demand, in order to draw out a number of particular features of the housing system namely: the interaction between the public and private sectors; captivity effects, both within the public sector and in its queues; and the variation of allocation policies (e.g. between different local authorities).

It is difficult to document and account for the various transitions of households - again using Monte Carlo simulation to solve equations for household formation dissolution. In the housing system and in the labour market the external movers caused by households leaving the sector, and the new supply triggers a series of internal moves which must be accommodated in much the same way as an input-output system. The solution algorithm for this model thus combines the processes of transitions directly with an allocation policy. The public sector, in many ways operates as a multi-line queueing system with preemptive priorities. Priority rankings and decisions are sensitive to a number of attributes of individual households and associated houses "released" in any time interval. The list processing approach is particularly amenable to the high information requirements of the allocation. At the moment we are, again due to data restrictions formulating the problem of allocation and dynamics as a "game" in which the preference structures and constraints of both potential tenant and housing manager interact in a "multi-criterion" matching process. That potential tenants do show discrimination is evidenced by the co-existence and often proximity of highly sought after and vacant stock in the public sector.
4. LOCAL AUTHORITY SERVICE PROVISION.

The state, both at a national and local level, provides a wide range of services, such as education, health care, social services and benefit packages that are consumed by a large and heterogeneous client group. The field of service provision has given rise to a number of policy related issues that fall into several related categories. Amongst these are: determining existing and forecasting the future need for services; the allocation of finite resources between sectors and individuals (determining priorities); monitoring the efficiency, effectiveness and equity of service provision; and questions pertaining to ways of financing the cost of this provision. Current policies also demand that the effects of cuts in levels of provision can be assessed. With local authorities often being the largest single employer in an area, the role that the authority plays in the local economy is also an important topic.

Determining the need (or perceived demand) for services is a key aspect of planning in a local authority. In areas of social, economic and demographic change and where considerable capital investment is required over a number of years (eg. schools, hospitals, housing, transport, infrastructure) then there is a strong incentive for producing detailed and, as far as possible, reliable forecasts of future need. A suitably specified micro-simulation model that produces detailed cross-classified information pertaining to a number of socio-economic attributes deemed appropriate by the policy analyst should be of considerable use. Planners may be interested in changes in the number of individuals with certain types of attributes between given time intervals. For example, to provide appropriate care for the elderly it is necessary to have detailed information on individual characteristics. Formally we can determine this number in the following way

\[ N_{1,2,3} = \bigcap_{i=1}^{N} N_{1,2,3} \]

where \( N_{1,2,3} \) contains all individuals having attributes \( \mu_1, \mu_2, \mu_3 \). This is determined by establishing the intersection, \( \bigcap \), of all individuals, \( i=1, \ldots, N \) with attributes \( \mu_1, \mu_2, \mu_3 \). The policy analyst may thus be interested in \( N_{1,2,3} \), \( N_{1,2,3} \), \( N_{1,2,3} \), \( G_{t} \), and \( G_{t+T} \) for a suitable time period \( T \). The updating of the files of households and individuals may be performed in the manner outlined in Section 3. Used in conjunction with appropriate macro-models, that say produced aggregate forecasts of migration, changes in the demand for labour, and so on, micro-models have a wide potential application for producing forecasts and monitoring progress. Housing issues have been discussed above, but obvious applications exist in social services, where a large number of attributes of individuals are of interest, such as the elderly with respect to health care facilities, and in economic support for the unemployed, where there is often a mismatch between the skills and qualifications required by employers and those obtained by individuals.

The provision of services is traditionally based on the assumption of need rather than the ability to pay. It is therefore an interesting research question to assess how much of an income redistribution between individuals of different incomes is being effected by service provision. This needs not only consideration of what services individuals receive, and how much they are valued by individuals, but also how much individuals contribute to the financing of these services, through property taxes, income tax, charges and...
so on. Traditional concern has focussed on income band groups, where all those individuals or households whose income lies between two points are considered together (for example, Nicholson, 1964). This is clearly unsatisfactory, as very disparate groups under aggregation lie in the same class. For example pensioners, young single persons, unemployed persons with several children may all fall into the same income group, yet the service consumption pattern of their household will clearly differ (see Webb and Sieve, 1971). A micro-simulation approach affords a way of surmounting this difficulty by considering the basic micro-units, individuals and households. The approach involves an extension of the attribute list, \( \mathcal{W} \), to incorporate variables relating to service consumption, transfer payments and contributions to financing this, such as domestic rates, and other taxes. Aggregation in a variety of ways is then possible, and alternative aggregation schemes compared. If there is to be change in levels of service provision it is important that the effects of these changes can be assessed. Using the approach outlined in this paper it is possible to determine what these changes are and what type of individuals gain or suffer from these changes. Two models are currently being developed at Leeds relating to these issues. The first is concerned with assessing the impact of reductions in public sector employment. It is clear that if the person made redundant does not find employment then the burden to the state in welfare payments may approach the savings made by making that person redundant. Whether the person finds employment will depend on his or her attributes and also the type of vacancies existing in the local labour market, which will vary from region to region.

The second model being developed is concerned with fiscal interactions between individuals/households and the local authority. Equity issues are of interest here (between individuals, over time, and between authorities) as well as examining the impact of alternative local government finance schemes.

In many cases we do not have primary data sources, and we resort to the synthetic population generation methods outlined earlier. Clearly for detailed policy analysis in a local authority primary data may be deemed essential and this would necessitate a survey being undertaken. Orcutt et al (1976) suggests however that the size of the sample in such a survey need not necessarily be very large and hence prohibitive to the adoption of this method.

5. THE EFFECT OF DEMOGRAPHIC AND SOCIO-ECONOMIC FACTORS ON INCOME DISTRIBUTION

The previous modelling efforts discussed in this paper have been concerned with a partial analysis of the system of socio-economic variables in a given urban area or region. An implicit assumption in the making of a partial analysis is that any effects between the part of the system which is modelled and that which is not can be ignored for the purpose of analysing the problem at hand. The problem of how to close the system being modelled, that is which parts to omit from the modelling exercise, is dependent upon the relative strength of the interactions between the modelled and non-modelled parts of the system. It is also dependent upon the types of policy impact to be analysed using the model.

In order to illustrate the way in which these factors determine model specification an outline of a dynamic model of income distribution at the micro-level is presented. In particular our concern lies with the processes which give rise to this distribution over time and the impact upon it of various labour market policies and the role of the state.

Household income is derived from various sources. For the majority of households income is primarily earned by certain members of that household or is derived by benefits received from government. For a smaller proportion of households this is supplemented, to a greater or lesser degree, by unearned income from investments. In order to understand more fully the process by
which different incomes are received by different households it is necessary
to consider then the flows of the money through the system. In particular it is
of interest to investigate the transfer from rich to poor of money by means of
the tax system, and the costs and benefits received via the local authority by
different households (as described in the previous section). The need to con-
sider benefits received and monies paid to the National Exchequer automatic-
ally forces one to consider the different expenditure of households on
commodities such as transport, housing and consumer goods, the taxation on
which helps Central Government raise the money to pay for benefits. This may
be done by a macro-economic model if this were all that was of concern. How­
ever the way in which different households spend and receive money is depend­
ent upon their activity in the labour market, their position in the housing
market and other factors such as the age and number of individuals in the
household. These factors also affect the income of money from various sources:
benefits, wages and non-monetary income via services. By considering the
system as a set of micro-level units, households and individuals, the decisions
and processes underlying the flows of money may be explicitly incorporated into
the model. Further when these are present the impact of different policies
upon the income distribution, may be examined.

It can be seen from this discussion that many processes are involved in a
complete model of income distribution. These spread over the whole socio­
economic system and include effects peculiar to the demographic, labour market,
housing market and transportation sub-systems. These do not act independently
to determine the money flows but interact in different ways, particularly
through the household budget. Decisions made in the labour market, concerning
say a change of job of an individual, may affect the residential location of
the household of which he is a member. This will then affect the transportation
characteristics of that household and also the expenditure on items such as
energy, food etc. due to a changed income. There is, therefore, a variety of
interactions present in the system which require consideration. Those which
are of sufficient importance, on their own accord or because they cause other
effects, should be included in a model. A model built on the basis of micro­
level representation has the potential to incorporate the richness and wealth
of interaction found in the real world. The ability of a model to include all
interactions is limited by data availability, but the micro-simulation approach
at least allows all possible interactions, in theory, to be included.

It is the lack of micro-data at the urban level which constrains the type
of model which can currently be implemented. It is possible to build, as
described in Section three, a model of the housing market in which transitions
and allocations are explicitly considered. A model of the labour market can be
conceived along similar lines and linked with the housing market model to
provide a central basis for an income-expenditure model. Demographic changes
may also be considered in the framework of Monte Carlo simulation and these
can again then be linked with labour and housing market transitions by
individuals and households. Housing costs and wages provides only part of the
household budget and transfers between household and its members and central and
local government, as a function of labour, housing and demographic character­
istics, need to be included. A model such as this based at the micro-level
allows the variability and uncertainty present in the system to be included in
the model and also more aggregate outputs, such as total levels of transfers
paid, to be obtained for different classes of households, individuals and
spatial areas.
6. CONCLUSION

In developing the micro-simulation models outlined in this paper we have confronted a number of important questions, both of a theoretical and practical nature. Issues of aggregation are seen as of central importance to model building particularly in attempting to embed both micro- and macro-models into a coherent hierarchical framework for policy analysis. The combination of several modelling techniques in approaches to problem solving is particularly desirable. We must view the problem at hand and attempt to solve it in the most efficient way and not assume that any one technique holds a monopoly over others.

On a practical level the information requirements of the type of models described above are often seen as problematic. We recognise the paucity of longitudinal micro-data does constrain the model builder, as it has and continues to do in our own work. However, the list processing representation presents an excellent way of organizing information in a consistent and comprehensive manner. The organization of official information in this way may well be a necessary precondition of the full potential of the micro approach in to be realised.

Our own attempts to develop the approach are modest in scope, but we believe that if certain types of policy related questions are to be fully confronted much more research needs to be directed towards the design and construction of models using a micro-level representation.

REFERENCES


INTRODUCTION

It was decided to focus attention on the gypsy region, involving the London borough of Haringey. Haringey is a London borough with a total population of 272,000 people. The housing market model described in this paper was constructed from real estate transactions on the market. Real estate transactions are not only an indicator of the housing market but also an indicator of household mobility. In this model, household mobility is defined as moving from one house to another, which may be either within the same borough or to another borough. The housing market model is a macroeconomic model of choice behavior that allows for uncertainty and nonmonetary income restrictions.

II. MODEL: OVERVIEW

The housing market is the place where households try to satisfy their housing needs. With individuals trying to make a profit from renting housing investments. Housing investments, housing ownership decisions are not part of the housing market, but are affected by the tenant and ownership decisions. Households are in a housing market, housing market, having to compete with other kinds of land use. Household income and household size are the principal factors of the housing market model. The design of the model was based on the following hypothesis about their behavior:

- The housing demand is location dependent, mainly on the position in its life stage and its income.
- The satisfaction of a household with its housing situation can be represented by a utility function with the dimensions housing size and quality, neighborhood quality, location, and income level.
5. CONCLUSION

In developing the micro-simulation models described above, we have encountered some difficulties. In particular, the process of logical micro-simulation requires a great deal of detail and care to ensure its accuracy and reliability. However, the case presented here demonstrates that the small- scale system simulation presents an excellent opportunity of testing the impact of policies that affect the urban system. This simulation, which employs the small- scale urban systems model and the computer- based micro-simulation approach, provides a means to predict the effects of policy changes and to evaluate the potential benefits of alternative strategies.

On a practical level, the information requirements of the type and amount described above are often seen as problematic. In some cases, the precision of logical micro- simulation presents a particular challenge. The small- scale system simulation, however, provides an excellent opportunity to make our case. However, the lack of available data on the small-scale system simulation presents a particular challenge. The availability of the potential of the small-scale simulation is limited by its availability.

Our own efforts in testing the approach are limited in scope, but we believe that if certain key or policy-related questions can be fully confronted with more research needed to be directed towards the design and construction of models using a micro-scale representation.

REFERENCES


1. INTRODUCTION

The work on the simulation model of the Dortmund housing market is part of a larger research project conducted at the Institute of Urban and Regional Planning of the University of Dortmund within the Sonderforschungsbereich 26 Raumordnung und Raumwirtschaft, Münster, of the Deutsche Forschungsgemeinschaft. This ongoing project is aimed at the investigation of the relationships between economic, i.e. sectoral and technological, change, locational choice, mobility, and land use in urban regions. For this purpose, a spatially disaggregate dynamic simulation model of regional development was designed to simulate:

- location decisions of industry, residential developers, and households,
- the resulting migration and commuting patterns,
- the land use development, and
- the impacts of public programs and policies in the fields of regional development, housing, and infrastructure.

It was decided to use the urban region of Dortmund as a study region, including Dortmund (pop. 630,000) and 19 neighbouring communities with a total population of 2.4 million (cf. Schönebeck, Wegener, 1978).

The intraregional migration component of this model is the housing market model described in this paper. The decision to model intraregional migrations as transactions on the regional housing market was based on the evidence established by many surveys that household mobility within urban regions, unlike long-distance mobility, is almost exclusively determined by housing considerations, i.e. by the changing housing needs of households during their life cycle. Accordingly, the housing market model developed is a microanalytic model of choice behaviour of households and landlords subject to economic and noneconomic choice restrictions.

2. MODEL HYPOTHESES

The housing market is the place where households trying to satisfy their housing needs interact with landlords trying to make a profit from earlier housing investments. Following this narrow definition, housing investment decisions are not part of the housing market, but are effected on the land and construction market, which is separate, but closely related to it. On the land and construction market housing has to compete with other kinds of land use.

Households and landlords are thus the principal actors of the housing market model. The design of the model was based on the following hypotheses about their behaviour:

- The housing demand of a household depends mainly on its position in its life cycle and its income.
- The satisfaction of a household with its housing situation can be represented by a utility function with the dimensions housing size and quality, neighbourhood quality, location, and housing cost.
The willingness of a household to move is related to its dissatisfaction with its housing situation. A household willing to move actually does move if it finds a dwelling that gives it significantly more satisfaction than its present one.

After a number of unsuccessful attempts to find a dwelling a household reduces its demand or abandons the idea of a move.

Households have only limited information of the housing market; this limitation is related to their education and income.

There are on the housing market local as well as social submarkets which are separated by economic and noneconomic barriers.

Supply on the housing market is highly inelastic: There is practically no price adjustment in short market periods; quantity adjustment is delayed by long construction times.

In general, the housing market, although strongly regulated, fails to satisfy the housing needs of all groups of the population; instead, it tends to reinforce the spatial segregation of social groups.

3. MODEL STRUCTURE

Changes to the household and housing stock of an urban region can be caused by time (aging), migration, public programs, or private construction. In the simulation model these four kinds of changes are executed in four separate submodels. The last two of them deal with changes of land use and the building stock, i.e., with the land and construction market. They will not be treated in this paper. The first two contain the housing market model. They will be described in the following two sections.

a. The Aging Submodel

In the housing market model changes of households and housing of the model region, excluding public programs and private construction, are simulated over a number of discrete time intervals or periods.

The model region consists of the labour market region of Dortmund including Dortmund itself with its ten urban districts plus ten neighbouring communities, as well as of nine residential communities outside of the labour market region. Thus the model region is subdivided into 29 zones.

The population of each zone is represented in the model as a distribution of households classified by

- nationality (native, foreign),
- age of head (16-29, 30-59, 60+ years),
- income (none, low, medium, high),
- size (1, 2, 3, 4, 5+ persons).

Similarly, housing of each zone is represented as a distribution of dwellings classified by

- type of building (single-family, multi-family),
- tenure (owner-occupied, rented, public),
- quality (very low, low, medium, high),
- size (1, 2, 3, 4, 5+ rooms).

All changes of population and housing during the simulation are computed for these 120 household types and 120 housing types. However, these household and housing types are collapsed to about 30 household and housing types for use in the occupancy matrix.

The occupancy matrix $R$ of a zone represents the association of households with housing in the zone. Each element of the matrix contains the number of households of a certain type occupying a dwelling of a certain type, the total matrix contains all households occupying a dwelling or all dwellings occupied by a household (Fig. 1).
In addition, there exist for each zone a vector \( H \) of households currently without a dwelling and a vector \( D \) of dwellings currently without a household, i.e. vacant. \( H \) should contain zeros at the outset of each simulation period, but in \( D \) there may be vacant dwellings left over from previous periods.

All changes occurring to households and housing of a zone during a simulation period can be represented by movements into or out of or within the \( R \) matrix and the \( H \) and \( D \) vectors.

In the first, the **aging** submodel all changes of households and dwellings are computed which are assumed to result from biological, technological, or long-term socioeconomic trends originating outside of the model, i.e. which in the model are merely time-dependent. For households this includes demographic changes of household status in the life cycle such as birth, aging, death, marriage, and divorce, and all new or dissolved households resulting from these changes, as well as change of nationality or income. On the housing side it includes deterioration and certain types of rehabilitation and demolition. However, all changes of housing occupancy connected with migration decisions are left to the subsequent **migration** submodel.

In reality, both kinds of changes are mostly based on individual decisions and occur in a continuous stream of closely interrelated events. However, it is much more convenient to model them separately, each with a different type of model. Of course, that means that feedback between both kinds of changes is ignored, but that seems to be alright as housing decisions are assumed to depend on household status and income, and not conversely. The aging submodel therefore updates or "ages" households and dwellings by one simulation period without moving them relative to each other. This is accomplished by a Markov model with dynamic transition rates.

A transition rate is defined as the probability that a household or dwelling of a certain type changes to another type during the simulation period. The transition rates are computed as follows: The time-dependent changes to be simulated are interpreted as events occurring to a household or dwelling with a certain probability in a unit of time. These basic event probabilities and their expected future development are exogenously determined. Fifteen basic event probabilities have been identified for each of the three household age groups:

1. change of nationality,
2. aging,
3. marriage,
4. birth, native,
5. birth, foreign,
6. relative joins household,
7. death,
8. death of child,
9 marriage of child,
10 new household of child,
11 divorce,
12 rise of income,
13 decrease of income,
14 retirement,
15 new job,
and three for the four housing quality groups:
1 deterioration,
2 rehabilitation,
3 demolition.

Not all household events occur to every household. Some are applicable only to singles, some only to families, some only to adults, some only to children. The demographic event probabilities are checked against regionwide population projections and corrected if necessary. Some household events are followed by housing events, and vice versa: where a household dissolves, a dwelling is vacated, and where a nonvacant dwelling is demolished, a household is left without dwelling. The housing events contain only those changes of the housing stock which can be expected to occur under normal conditions in any housing area, i.e. a normal rate of deterioration, maintenance, rehabilitation, and demolition. More rehabilitation and demolition may occur later in the private construction sub-model: rehabilitation as a response of housing investors to the demand situation observed on the housing market, demolition where housing has to make way for industrial or commercial land uses. In addition, rehabilitation and demolition may occur in the course of public construction programs in the public programs sub-model.

The basic event probabilities are then aggregated to transition rates $P$ for households and $Q$ for dwellings using the disaggregate (120-type) household and housing distributions of each zone. Most events are independent of each other and can be aggregated multiplicatively; but some exclude others, i.e. are the complement of each other. Multiplication of the occupancy matrix $R$ with the transition rate matrices $P$ and $Q$ yields the occupancy matrix aged by one simulation period (Fig. 2). This implies the assumption that all households of a certain type share the same transition rates, no matter in which dwelling they live, and vice versa.

![Fig. 2. Aging of households and housing of a zone.](image-url)
Special provisions are necessary for events which modify the total number of households or dwellings of a zone. Such events are birth, marriage, marriage of child, divorce, death, new household of child, or demolition of a dwelling. Some of these events create a household without dwelling or a vacant dwelling, i.e. require a change in the H or D vectors. Moreover, also households without dwelling get older and vacant dwellings deteriorate or may be rehabilitated or be torn down, i.e. the H and D vectors themselves have to be aged.

b. The Migration Submodel

In the second, the migration submodel intraregional migration decisions of households are simulated. Migration is defined as a change of location of a household encompassing a change of residence. Consequently, the intraregional migration model is the actual housing market model.

When the migration submodel is entered, the following situation exists: All households and dwellings of all zones have been aged by one simulation period, i.e. now have the time label of the end of the current simulation period. However, no household has yet moved to another dwelling. That is to say: All households have proceeded in their life cycle - they have become older, children may have been born, the family income may have increased - , but their dwellings are still the same or even have deteriorated. Moreover, the expectations of the households with respect to size, quality, and location of housing generally will have increased. It may be assumed that many households which were quite content with their housing situation at the end of the last simulation period now are dissatisfied with it and are willing to improve it. These households are the potential movers of the current market period. They are contained in the R matrix of each zone. Besides, there are households without dwellings contained in the H vector of each zone consisting of newly founded households looking for a dwelling and of households which unvoluntarily had to vacate their dwelling for various reasons. It is assumed that these households must get a dwelling during this market period.

In addition, there are two exogenously specified vectors of households: the vector H' containing households migrating into the region from elsewhere during the simulation period, and the vector H'' containing households migrating out of the region. Both vectors have been aged already by another part of the model not discussed here in order to make them compatible with the households aged in the aging submodel. Immigrant households are treated just like households without dwelling, except that they do not come from a particular zone. Outmigrant households are of interest because they vacate a dwelling.

On the housing side the situation is simpler. A dwelling can either be occupied or be vacant. In the first case it is contained in the R matrix, in the second case in the D vector of its zone. At the outset of the market period the D vector contains vacant dwellings left over from previous periods plus dwellings vacated by dissolved households during the current period. In addition, newly constructed dwellings which were begun in earlier periods may now have been completed and are entered into the D vector.

The R matrix and the H and D vectors of each zone, plus the H' and H'' vectors are a complete representation of households and housing at the outset of the market simulation. Of these the H vectors of the zones and the H' vector clearly represent housing demand, and the D vectors of the zones and the H'' vector clearly represent the supply side. The R matrices of the zones represent some of both because of the linkage between housing supply and housing demand by vacant dwellings being put on the market with each move. But which of the households in the R matrices will actually move during the market period is not known at this moment.

Fig. 3 illustrates this configuration. Unlike in the aging submodel, now the information of all zones has to be available simultaneously. Therefore, by the additional zonal dimension, the R matrix becomes three-dimensional, and the
Hand D vectors become two-dimensional matrices. In all vectors and matrices the collapsed or aggregate household and housing structure with about 30 types each is used.

The satisfaction of a household with its housing situation is represented in the model by a multidimensional preference function containing the dimensions housing size and quality, neighbourhood quality, location, and housing cost. Two of these four dimensions are themselves multiattribute:

- **Housing size and quality** is composed of the attributes defining a housing type: type of building, tenure, quality, size.
- **Neighbourhood quality** is composed of attributes selected or aggregated from state variables of the zones. There are some 300 state variables from the fields of population, employment, buildings, public facilities, transportation, and land use maintained and kept available on a file. In addition, accessibility measures indicating the location of the zone to the work places and to retail, education, and recreation facilities in other zones have been computed and are also kept on the file.

Evaluation and aggregation of the attributes is performed with the help of an additive multiattribute utility theory (MAUT) model. The general form of the utility function specified by this model is
where $A_{in}$ is the attractiveness of evaluation object $i$ for activity $n$, $a_{im}$ is the attribute $m$ of that evaluation object, and $w_{mn}$ and $v_{mn}$ are importance weights and value or utility functions, respectively, of attribute $m$ as seen by actor type $n$. In the housing market model the actors are households, and the evaluation objects are dwellings or zones. Dwelling attributes are the attributes defining a housing type. Zonal attributes can be indicators for amenities supplied in the zones themselves or accessibility measures:

$$a_{im} = f_m(s_{ik})$$

(2a)

$$a_{im} = \frac{\sum_j s_{jk}/f_m(c_{ij})}{\sum_j s_{jk}/f_m(c_{ij})}$$

(2b)

where $f_m(s_{ik})$ is a generation function specifying how to calculate $a_{im}$ from variables $s_{ik}$ of the zones, and $f_m(c_{ij})$ is a transformation of travel times or cost between zones $i$ and $j$.

Obviously, there are as many preference systems as there are household types, as the household types have different housing needs depending on their size, position in their life cycle, and income. The preference systems of household types therefore differ in their attributes, utility functions, and weights. Moreover, the preference systems change in time, as aspiration levels rise and new priorities come into sight, and these changes are different for different household types. The model allows to specify different attributes, utility functions, and weights for different household types and different points in time.

The remaining two dimensions of housing satisfaction have only one attribute. The location dimension is represented by the attribute "job accessibility". A typical utility function of job accessibility looks like that in Fig. 4, left side. The explicit consideration of job accessibility in the model takes account of the fact that it is the most important location variable and perhaps the only one which really restricts the choice of a housing location. The second single-attribute dimension is housing cost. Its only attribute is rent or housing price plus housing operating cost in relation to (percent of) rent paying ability. Its utility function looks like that in Fig. 4, right side.

![Fig. 4. Sample utility functions of job accessibility and housing cost.](image)

For use in the housing market simulation the four dimensions of housing satisfaction are computed in advance and stored in two matrices: For each combination of household type, dwelling type, and zone, i.e. for each element of the three-dimensional occupancy matrix $R$, an index of housing satisfaction $U_{mki}$ is
calculated as a weighted aggregate of the four dimensions. Obviously, in this index only a general measure of job accessibility like that in (2b) can be included. Therefore an additional location measure is calculated for each pair of zones:

$$W_{ij} = \sum_{j} \frac{T_{ij}}{T_{ji}} v(c_{ji'})$$  \hspace{1cm} (3)

where $T_{ij}$ are home-to-job trips from $i$ to $j$, $T_{ji'}$ are job-to-home trips from $j$ to $i'$, and $v(c_{ji'})$ is the utility function of job accessibility. That is, $W_{ij}$ expresses the attractiveness of zone $i'$ as a new housing location with respect to job accessibility for a household now living in zone $i$ whose head has a job in zone $j$. The measure $W_{ij}$ is called the migration distance between $i$ and $i'$.

With the matrices $R$, $H$, $D$, $U$, and $W$, and the two vectors $H'$ and $H''$ all necessary information is available to enter the housing market simulation, i.e. the simulation of the market clearing process.

This simulation presents several methodological problems. First, it is not known at this time which households of the $R$ matrix will eventually decide to move as that certainly depends on the housing supply offered to them on the market. The housing supply, however, is only partly known because the major part of it consists of dwellings released by moving households during the market process, i.e. depends on just those decisions which are yet unknown. That is to say, the housing market, unlike many other markets, represents a complicated system of chain exchanges. Second, the level of information of the market actors about the housing market is generally low. That is, households inspect only a relatively small section of the market before making or not making a decision. Third, during a short market period the housing market is inelastic, and there is no real bidding process: A dwelling put on the market will not be given to the household bidding highest for it, but the landlord will select a household following a "first come, first served" rule or following other criteria, some of them noneconomic.

The simulation technique selected to deal with these problems is the Monte Carlo technique. It is based on the notion that the total market process can be sufficiently approximated by simulating a representative sample of individual market transactions. To achieve this, the model consists of a sequence of random selection operations by which hypothetical market transactions are generated. The random selection process is controlled by probability distributions which insure that only likely transactions are selected.

This stochastic kind of simulation has many advantages. Like no other technique it makes it possible to consider simultaneously objective and subjective, economic and noneconomic determinants of the individual decision situation of migrating and nonmigrating households, as well as their restricted information and choice on the housing market. In addition, the technique makes it easy to incorporate psychological hypotheses about the behaviour of households following successful or unsuccessful search experiences. In particular, it makes it possible to model the choice households make between intraregional migration and commuting. Probably the most important advantage of the technique, however, is that it solves the problem of modelling chain exchanges on the housing market in a simple and straightforward manner.

The basic unit of the Monte Carlo simulation is the market transaction. A market transaction is any successfully completed operation by which a migration occurs, i.e. a household moves into or out of a dwelling or both. There are two ways to start a market transaction: A household decides to look for a dwelling
"dwelling wanted"), or a landlord decides to offer a dwelling ("dwelling for rent/sale"). In either case the transaction may result in different kinds of migration: The household may be leaving the region ("outmigration") or entering it ("inmigration"), or currently be without dwelling ("new household/forced move"), or occupying one ("move"). For the landlord offering a dwelling only the last three migration types are of interest.

The model starts by selecting a transaction type and a migration type. It is assumed that "dwelling wanted" and "dwelling for rent/sale" are equally likely to occur. The migration type is selected in proportion to the number of migrations to be completed of each type, i.e. the totals of $H$, $H'$, and $H$ for the first three migration types, respectively. For the fourth or "move" type a tentative estimate of the number of moves as a portion of the $R$ matrix must be provided.

Once the transaction type and the migration type have been determined, the remaining parameters of the transaction are selected. A transaction has been completely defined if the following six parameters are known:

- $m$ household type
- $k$ old housing type
- $i$ old zone
- $j$ zone of job
- $k'$ new housing type
- $i'$ new zone

A move, for instance, is the migration of a household of type $m$ which occupies a dwelling of type $k$ in zone $i$ and whose head works in zone $j$, into a dwelling of type $k'$ in zone $i'$. Not all six parameters are required for all migration types: Obviously, no $k$ can be specified for households without dwelling, nor can $k$ and $i$ for inmigrant households, but it is assumed that inmigrant households have a job in $j$ already. Of outmigrant households only $m$, $k$, and $i$ are of interest.

The sequence of selection steps performed for each combination of transaction type and migration type is shown in Fig. 5. In each step one additional parameter is determined until the transaction has been completely defined. The following example illustrates this: In the case of a household considering a move ("dwelling wanted"/"move"), first the household by type, zone, and dwelling type is selected with

$$P_{k|i} = \frac{R_{mk}}{(100-U_{mk})^a} / \sum_k R_{mk} (100-U_{mk})^a$$

being the probability of dwelling type $k$ to be selected if household type $m$ and zone $i$ are already known, which is to say that households which are dissatisfied with their housing situation are selected more often than others. In the next two steps it is asked in which zone $j$ the head of the household might have his job and how this may restrict the choice of a new housing zone. With the help of the migration distance defined in (3) these two selection steps can be collapsed into one with

$$P_{i'|mki} = \frac{\sum_i D_{k'i'} W_{ii'}}{\sum_i \sum_k D_{k'i'} W_{ii'}}$$

being the probability of zone $i'$ to be selected as a new housing zone where $m$, $k$, and $i$ are given and zone $j$ assumed to be the work place zone of the household head. In the final selection step the household attempts to find a dwelling in zone $i'$ with

$$P_{k'|mk{i'}} = \frac{D_{k'i'} U_{mk'i'}}{\sum_k D_{k'i'} U_{mk'i'}}$$

being the probability of dwelling type $k'$ to be selected if all other parameters are given.
<table>
<thead>
<tr>
<th></th>
<th>dwelling wanted</th>
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<td>immigration</td>
<td>new household</td>
<td>move</td>
<td>immigration</td>
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<tr>
<td></td>
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<td>forced move</td>
<td></td>
<td>dwelling of type k'</td>
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<td></td>
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<td>living in zone i'</td>
<td></td>
<td>in zone i' offered to</td>
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<tr>
<td></td>
<td>in dwelling of type k</td>
<td>in dwelling of type k</td>
<td></td>
<td>household of type m</td>
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<tr>
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<td>working in zone j</td>
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<tr>
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<td>looks in zone i'</td>
<td></td>
<td>living in zone i</td>
</tr>
<tr>
<td></td>
<td>for dwelling of type k'</td>
<td>for dwelling of type k'</td>
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<td>in dwelling of type k</td>
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<tr>
<td></td>
<td>old dwelling</td>
<td></td>
<td></td>
<td>old dwelling</td>
</tr>
</tbody>
</table>

transaction completed

Fig. 5. Market transactions in the housing market model.
Once the transaction has been completely defined, the migration decision is made. This is no question for outmigrant households, they do migrate. All other households compare their present housing situation with the situation they would gain if they accepted the transaction. It is assumed that they accept if they can significantly improve their housing situation. The definition of what is considered a significant improvement has to be determined by calibration. The measure of improvement is the difference between the satisfaction received by the present dwelling and the satisfaction expected from the dwelling offered.

If there is a significant improvement, the household accepts. In this case all necessary changes in \( R, H, H', H'' \), and \( D \) are performed. Dwellings vacated with a move or an outmigration immediately reappear in the \( D \) matrix and are released again to the market.

If there is no improvement, the household declines. If the transaction type was "dwelling wanted", the household makes another try to find a dwelling, and with each attempt it accepts a lesser improvement. After a number of unsuccessful attempts the household abandons the idea of a move. If the transaction type was "dwelling for rent/sale", the landlord tries to find another household, but he does not reduce the rent during the market period. If a dwelling type in a zone has been declined by all household types, it is taken out of the market for this market period.

After successful or unsuccessful completion of a transaction the next transaction is selected. The market process comes to an end when there are no more households considering a move. It is assumed that this is the case when a certain number of transactions have been rejected. This number has to be determined by calibration to match the number of migrations produced by the model with the number of migrations observed in the region.

4. MODEL DATA AND CALIBRATION

The main data sources for the housing market model are tapes of the 1968 housing census and the 1970 census especially prepared for this project by the City of Dortmund. They are the basis for establishing the disaggregate (120-type) distributions of households and housing and of the occupancy matrix of each zone. The model results are checked against spatially disaggregate population and housing data of the year 1977 also made available by the City of Dortmund.

The base year household distributions of the ten districts of Dortmund were retrieved from the census tapes containing individual data. However, for the 19 neighbouring communities, for which such tapes were not available, estimates based on one-dimensional distributions taken from statistical tables had to be made. A special estimation technique was developed to substitute the income information not contained in the census data. By this technique each household is associated with one of the four income groups depending on the employment status and completed education of its head, both which informations were available on the tapes (cf. Gnud, Vannahme, 1980).

Base year data of the housing stock were taken from the 1968 housing census. As with the household data, tapes containing information on a dwelling-by-dwelling basis were available for Dortmund, while some estimation of distributions had to be made for the neighbouring communities. All information needed to establish the 120-type housing distribution for each zone was contained on the tapes. However, the quality attribute had to be estimated as an aggregate of a number of dwelling attributes.

Establishing the base year occupancy matrix presented a special problem. The 1968 housing census contained detailed housing information, but only very limited information about households. The 1970 census contained detailed household, but no housing information. The problem was to match both kinds of census, although they were 18 months apart in time. The problem was solved by first generating for each zone a household-housing matrix from the 1968 data and then "blowing it up" to match the 1970 household distribution.
The major problems of model calibration, besides estimation of numerous demographic, technical, and monetary parameters, are connected with the basic event probabilities for the aging submodel and the index of housing satisfaction used in the migration submodel.

The basic event probabilities are partly linked to empirically well-established demographic parameters and can be checked against exogenous population projections. Much more difficult is the estimation of probabilities for events like "new household of child", "rise of income", "decrease of income", "retirement", or "new job", for which only few data on the basis of household types exist. However, the only alternative to their approximation to one's best judgment would be to ignore them, which is no real alternative in a model based so much on household decisions.

Even more crucial is the estimation of the preference functions used to calculate the index of housing satisfaction for the migration submodel. There can be no doubt that the calibration of hundreds of utility functions and weights even for a past period of time, let alone their extrapolation into the future, heavily overtaxes the available data. But again, not to include them in the model would mean to ignore the essential variety of housing needs and tastes, which certainly would be the worse alternative.

Besides, this kind of model parameters has one great advantage: Their meaning can be communicated to everyone in everyday language, which makes them amenable to discussion and judgment. Consequently, formal estimation techniques in a strict statistical sense play only a minor role in the calibration of the preference functions, instead, many of the functions are determined by judgment, inferences, analogies, and careful checking of plausibility. The empirical foundations of this informal way of model calibration include the numerous surveys of regional and urban housing markets conducted in recent years which contain a wealth of material on migration motives and housing preferences.

ACKNOWLEDGMENTS

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REFERENCES


PART IV

MANAGING THE FUTURE
The major problems of model calibration, namely calibration of some unknown parameters, are connected with the basic problem of calibrating the data. Demographic data, like birth rates, death rates, and migration rates, are problematic. The lack of complete and accurate data makes calibration difficult. The problem is further compounded by the fact that the data are collected on a yearly basis, which is not sufficient to capture the effects of migration and other demographic changes.

The calibration process involves estimating the parameters of a model that best fit the observed data. This is done by minimizing the difference between the model predictions and the observed data. The parameters are estimated using statistical techniques, such as maximum likelihood estimation.

The calibration process is an iterative one, and it often requires several iterations to achieve a satisfactory fit. The calibration is performed on a regional basis, and the results are then aggregated to the national level. The calibrated model is then used to make projections for future periods.

ACKNOWLEDGMENTS

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Strategic planning is focused on future situations of urban and regional systems. There are several ways to manage the time to come. In the next contributions an illustration is given of three entirely different approaches to deal with the future. It should be noted that these approaches can co-exist. Therefore, they might be seen as complementary.

Effective strategic planning requires an adequate knowledge of the dynamics of the spatial system. In their interesting paper BATEY and MADDEN outline a forecasting framework which allows demographic and economic models to be integrated in a consistent manner. This is achieved by incorporating a conventional Leontief input-output model within an activity-commodity framework in which demographic-economic interaction is represented explicitly. It is illustrated that the inverse matrix derived in solving the activity-commodity framework provides a new series of income, employment and production multipliers, as well as offering fresh insights into the effects of population change upon the economy. The complete forecasting framework has been applied to Merseyside, a metropolitan county in North West England.

The forecasting approach of Batey and Madden provides useful information and knowledge of the dynamics of socio-economic activities in an area. Knowledge in itself is not sufficient, however. A planner needs also tools to transform this knowledge into operational planning proposals. One possible way to do this is by using a scenario approach to come to alternative future prospects and by evaluating the resulting alternatives by means of an appropriate evaluation method. This is illustrated by KITSCHE LOJENGA and VOOGD, who are dealing with some strategic planning aspects of energy-policy in The Netherlands. They start with a brief overview of the present Dutch energy situation and the prospects for the future. Subsequently, policy alternatives are set up and elaborated with respect to the supply of (natural) gas. Since these alternatives have a rather qualitative nature, they will be evaluated by means of an ordinal geometric multi-criteria evaluation procedure.

The advantage of a multi-criteria evaluation approach is that diverging policy viewpoints and conflicting priorities can be taken into account explicitly. Another way to treat conflicting viewpoints is by means of multi-objective optimisation theory. This is illustrated in an interesting contribution of HAFKAMP and NIKKAMP. Their paper outlines a conceptual framework for analyzing choice problems in a broader social setting. The aim is to find compromise solutions for choice conflicts, for instance with regard to conflicting options such as environmental protection and economic growth. The authors argue that such a compromise may be achieved by means of an interactive approach based on a learning strategy and on a stepwise provision of information on the range of feasible efficient solutions. The empirical application of the model shows that this approach is a promising new avenue to explore.
1. INTRODUCTION

A problem that is frequently encountered in forecasting exercises involving the modelling of demographic and economic systems concerns the interactions between the (usually) separate economic and demographic models. We have pointed to this problem elsewhere (Madden and Batey, 1980a), and have reviewed some particular suites of models in which authors have identified what may be inconsistencies in these interactions, and have made attempts to link together separate models to achieve a comprehensive demographic-economic forecast (see, for example, Fullerton and Prescott, 1975; Schinnar, 1976 or Breheny and Roberts, 1978). It is convenient to denote these linkages as interface I, the effect that the economy has on population, and interface II, the effect that population has on the economy.

Interface I is usually dealt with through some set of relationships that involve migration. Changes in elements of the economy such as the unemployment rate, or growth in particular sectors of industry, are supposed to directly or indirectly affect the net or the in- and out-migration rates which increase or attenuate the natural growth (or decline) in the population. These relationships are most often quantified using multiple regression analysis, with varying degrees of sophistication of both method and choice of independent and dependent variables. Our aim in this paper is not to investigate this interface: we take it for our purposes as one that is relatively trouble-free conceptually.

Interface II, however, has a particularly interesting problem associated with it. Our perception of this problem has been structured by the method by which interface II is usually handled in demographic-economic forecasting: a demographic model produces population forecasts which are fed into the final demand vector of an input-output model as consumption. This consumption then produces changes in the gross outputs of the industrial sectors represented in the model, which are combined with changes caused by other factors (such as exports) to represent overall changes in the economy. The problem is that in order to obtain a consumption vector from a population we have to know (or make some assumption about) unemployment, which is a determining factor in level of consumption. Unemployed people or households have less income than employed ones, and consume less. If we assume an economically active subset of a population, apply an arbitrary unemployment rate to that subset and derive a consumption vector, we can obtain gross output figures for industries. These gross outputs will imply a certain labour demand, which can be compared with labour supply (the economically active subset) to obtain an unemployment rate. This rate will be equal to the original assumed rate only by chance. It is clear that there is an inconsistency here which is rarely noted.

We have described in another paper (Madden & Batey, 1980a) how, in the context of an input-output model, attempts to overcome this problem (e.g. by incorporating households into the Leontief inverse, or by setting up a supply-led model) fail, and describe in some detail (Madden, Batey & Worrall, 1980)
an iterative technique based on Miernyk's (1967) Type III income multiplier which overcomes the problem. The essence of this technique is that an increase (or decrease) in population is assumed initially to be unemployed. The change in consumption caused by this population increment, if we assume it for the moment to be positive, causes a number of jobs to be created. We may assume that these jobs are taken by some of the unemployed increment. This causes a further positive increment in consumption which creates more jobs. This process appears in practice to converge fairly rapidly, arriving at an equilibrium which determines the employment status of the population increment. This process works equally for negative increments, and may in general be combined with other changes in final demand to cover all possible combinations of economic and demographic effects.

We can also demonstrate a simultaneous approach to achieving this equilibrium, which is valid for all combinations under conditions of less than full employment, and for positive increments under conditions of full employment. We can develop this approach further, and bring in a potentially greater diversity, if we move towards incorporating our input-output model into an activity-commodity framework.

2. ACTIVITY ANALYSIS AND THE INTEGRATION OF FORECASTING

Activity-commodity frameworks provide one means of overcoming the problem of integrating forecasts in strategic planning (Barras & Broadbent, 1975). Drawing upon the concepts of activity analysis from economics (Chenery & Clark, 1959), these frameworks offer a general approach to the systematic representation of urban systems. An urban system is characterised as a series of inter-related activities each producing and consuming one or more commodities.

The activities chosen to represent the system are grouped in matrix form, as shown in Figure 1. Associated with each activity is an activity level, measuring the extent to which that activity is utilised. Any input or output may be selected as a unit of measurement, but usually the output of the principal commodity produced by an activity will be most appropriate. Coefficients are formed by using the activity level to divide the different entries in an activity vector, a negative coefficient indicating the consumption of an activity by a commodity, and a positive coefficient the production of a commodity by an activity. Completing the framework is a vector of constraints. This enables us to place restrictions upon the level of consumption and production of commodities in the framework, as well as providing the means by which exogenous inputs may be entered into the framework.

Fig. 1. A Schematic Activity-Commodity Framework

\[
\begin{bmatrix}
    a_{11} & a_{12} & \ldots & a_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{m1} & a_{m2} & \ldots & a_{mn}
\end{bmatrix}
\begin{bmatrix}
    x_1 \\
    x_2 \\
    \vdots \\
    x_n
\end{bmatrix}
= 
\begin{bmatrix}
    b_1 \\
    b_2 \\
    \vdots \\
    b_m
\end{bmatrix}
\]

\(A\) (Coefficients Matrix) \(x\) (Activity Levels) \(b\) (Constraints)

where \(n\) = number of activities
\(m\) = number of commodities
In developing a forecasting framework, our main interest lies in the case where the number of activities is equal to the number of commodities (i.e., where $n = m$, in Figure 1). The activity–commodity framework in these circumstances gives a determinate solution and thus can be used predictively. We shall now examine how this type of framework can be used in order to extend a conventional Leontief input–output model.

We start by embedding the simplest form of input–output model within an activity–commodity framework. By rearranging the basic expression for such a model, we obtain: $(I - A)x = d$. This expression meets the essential requirements of an activity–commodity framework: a matrix of coefficients ($(I - A)$, the Leontief matrix); activity levels ($x$, the vector of gross output); and constraints ($d$, the vector of final demand). We assume that industrial sectors can be regarded as both industrial activities (columns) and industrial commodities (rows).

This framework can be extended to incorporate labour demand and household consumption by adding further activities and commodities. We incorporate 'households' both as a commodity (whose activity level is specified exogenously via the constraint term) and as an activity. The household activity vector 'consumes' various industrial commodities.

The inclusion of labour demand requires the addition of two new commodities, labour-at-home and labour-at-work. The labour-at-work row contains negative labour demand coefficients relating 'consumption' of workers by industries to gross outputs, and equating this to journey-to-work, an activity which 'consumes' labour-at-home to 'produce' labour-at-work. A distinction can be made between two types of unemployed person: heads of households and others. Following this we can define two types of economically active households: households with an employed head and households with an unemployed head. To this we add a third type of household: the economically inactive, giving a total of three household activity vectors in the framework. Unemployment is now represented explicitly: there are two activities concerned specifically with unemployment - of heads and 'non-heads' of households. In defining new commodities, we again distinguish between active and inactive households; we also include unemployed non-heads of household. The system is completed by setting the constraint on labour-at-home to represent net commuting minus labour supply, thus eliminating the need to make fixed assumptions about the number of workers per household for each household type.

The framework is shown in Figure 2. It automatically adjusts the weighting given to the various household activities in order to be consistent with the activity levels for unemployment. Given an exogenous input of active and inactive households, the framework calculates the split between employed and unemployed heads, in a manner which ensures that labour demand, unemployment and household consumption are mutually consistent.

This consistent version of the framework can itself be extended in a variety of different directions. In Figure 3 we present a more elaborate framework, embodying a number of important refinements. It is this framework which forms the basis of the empirical work outlined later in this paper. The new framework identifies workers according to their social (occupational) class. In Figure 3 we distinguish between manual and non-manual workers, and so the matching of labour supply and demand is carried out separately for these different types of worker. In principle, of course, there is no limit (other than data availability) to the number of types of worker that can be identified.

The most significant change represented by Figure 3 concerns the integration of several elements of a demographic model within the framework. Until now we have assumed that demographic inputs are prepared outside the framework, by applying headship rates and economic activity rates to the age-sex cohorts from a population projection model. In the framework shown in Figure 3, these calculations are performed internally. Instead of providing inputs of households and economically active persons, we are now able to enter the results of
**Fig. 2: A Consistent Demographic-Economic Forecasting Framework**

**ACTIVITIES**

<table>
<thead>
<tr>
<th>Industrial Activities</th>
<th>Journey to Work</th>
<th>Unemployed</th>
<th>Non-Heads</th>
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<tr>
<td>Labour at Work</td>
<td>Labour Demand</td>
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<td>+1</td>
</tr>
<tr>
<td>Unemployed Non-Heads</td>
<td></td>
<td>+1</td>
<td>-ve</td>
</tr>
<tr>
<td>Labour at Home</td>
<td></td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>Active Households</td>
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<tr>
<td>Inactive Households</td>
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**Coefficients Matrix**

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<tr>
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**Labour Demand -ve**

**Coefficients Matrix**

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<table>
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<table>
<thead>
<tr>
<th>Unemployed Non-Heads</th>
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<table>
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<th>Net Commuting minus Labour supply</th>
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<td>Households by Type</td>
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<tr>
<td>Inactive Households</td>
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**Activity Constraints**

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Fig. 3: The Operational Consistent Forecasting Framework

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<th>Industrial Activities</th>
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<th>Inactive Heads</th>
<th>Disaggregated Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs</td>
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<td>-1</td>
<td>-ve</td>
<td>+1</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>Workers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Unemployed</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-Heads</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Active</td>
<td>+1</td>
<td>-1</td>
<td>-ve</td>
<td>+1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td>0</td>
<td>0</td>
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<td>Headship</td>
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</tr>
<tr>
<td>Boom Activity Rates</td>
<td>+ve</td>
<td>+ve</td>
<td>+ve</td>
<td>+ve</td>
<td>+ve</td>
<td>+ve</td>
</tr>
<tr>
<td>Disaggregated Population</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>

Coefficients Matrix:

<table>
<thead>
<tr>
<th>Gross Output</th>
<th>Final Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs</td>
<td>0</td>
</tr>
<tr>
<td>Workers</td>
<td>0</td>
</tr>
<tr>
<td>Unemployed</td>
<td>0</td>
</tr>
<tr>
<td>Non-Heads</td>
<td>0</td>
</tr>
<tr>
<td>Active</td>
<td>+1</td>
</tr>
<tr>
<td>Household</td>
<td>0</td>
</tr>
<tr>
<td>Headship</td>
<td>0</td>
</tr>
<tr>
<td>Boom Activity Rates</td>
<td>+ve</td>
</tr>
</tbody>
</table>

Activity Levels

<table>
<thead>
<tr>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaggregated Population</td>
</tr>
<tr>
<td>Disaggregated Population</td>
</tr>
</tbody>
</table>
a population projection directly, via the constraints terms.

In this section we have described some of the possible extensions of an input-output model using activity-commodity frameworks. We have developed a procedure which ensures consistency between inputs and outputs and have shown that there is considerable scope for disaggregating several of the elements in the framework. Elsewhere (Madden and Batey, 1980a; 1980b), we suggest a further extension of the framework to include explicit representation of earned income, social security and household expenditure. However, though interesting in conceptual terms, this development of the framework has yet to be made operational with real world data.

3. THE DEVELOPMENT OF CONSISTENT MULTIPLIERS

We may usefully inspect some of the characteristics of activity-commodity frameworks with regard to their type and solution-method. The traditional framework (with activities \( n \) # commodities \( m \)) must be solved by linear programming; inspection of the dual variables is then a possibility. A non-zero dual variable indicates firstly that the constraint it refers to is binding (i.e. is involved in the l.p. solution) and secondly shows the amount by which the value of the objective function will increase if that binding constraint is relaxed by unity. These dual variables are known variously as opportunity costs or shadow prices, and their value as indicators of objective function response to constraint relaxation limited to small relaxations.

When \( n = m \), the determinate system, we have a set of \( n \) simultaneous equations in \( n \) variables. A convenient solution-method is to invert the matrix of variable coefficients, and post-multiply by the constraints vector. The inverse of the coefficients matrix then contains what are equivalent to a complete set of dual variables for all possible single variable objective functions, with of course no non-binding constraints, since all variables and equations play a part in the solution. Each \( ij \) entry in this inverse represents the effect that a unit relaxation of constraint \( j \) will have on variable \( i \). Each row represents one set of dual variables for a single variable objective function. Since all constraints are binding, technically we can, assuming all the relationships in the framework to be constant under all conditions, rely on the inverse entries' holding for large-scale changes in the constraints.

We can also develop interesting parallels between our coefficients matrix inverse and a Leontief \((I-A)\) inverse. Incorporated in our coefficients matrix we have a Leontief matrix as we explained in the previous section: when we invert, we automatically invert the embedded Leontief, and it is possible to discern in the inverse those entries which are directly comparable to a Leontief inverse. What is important is the nature of these entries. A simple, household-exogenous input-output model provides an inverse which can be used for, amongst other things, the derivation of multipliers each representing the ratio of direct and indirect household income to direct household income for each industrial sector. These are known as Type I income multipliers. An enhancement of the input-output model to include households produces Type II income multipliers the ratios of direct, indirect and induced income to direct income (see, for example, Richardson, 1972 for an explanation of this). However, these Type II multipliers are defective in the way in which households are treated, as being identical to industries. Thus positive increments in final demand in industrial sectors produce increases in income and consumption of households, which in the model are treated in money terms but in the real world are reflected in the creation of new jobs and the filling of these vacancies with people. Similarly, negative increments create negative income changes, which in the real world mean redundancies. The Type II multiplier ignores the reality that people made redundant do not stop consuming, and that those taking up employment are likely to have been consuming (from income from social security) before entering employment.

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If we take the industrial entries in our activity-commodity inverse, however, and create multipliers from them, we automatically ensure that real-world interactions between employment and unemployment are taken account of. We designate these multipliers Type IV, to distinguish them from previously identified types: their distinguishing properties are that they represent the ratios of direct, indirect and induced income to direct income, and further treat households as being different in their behaviour from industries. We would expect Type IV multipliers to be smaller than comparable Type II multipliers, as the changes in consumption in a consistent framework as a household moves from one employment state to another are incremental rather than absolute. Whereas Type II models treat changes in income and consumption of households as being directly related to each other, the consistent framework recognizes that, say, decreases in wages to labour do not mean identical decreases in household consumption. As household income falls, or is removed completely by redundancy, households do not necessarily spend correspondingly less, or disappear altogether from the system. In reality, social security takes the place of income from employment. Consumption is affected in different ways, depending on whether income from employment has ceased entirely or merely been reduced. In the first case, consumption will be based exclusively on income derived from social security, while in the second case falling wages will be 'topped up' by the addition of a certain amount of social security, maintaining consumption at a higher level than would otherwise be possible.

We can expect similar differences between the activity-commodity framework production multipliers, and those obtained from conventional input-output models. The production multiplier for a sector i is obtained by summing all industrial entries in column i of an inverse. This multiplier represents total requirements of industries to meet a unit increase in final demand in sector i. Multipliers that are derived from a consistent framework will be smaller than those from a household endogenous model, again as long as consumption from income is greater than consumption from social security.

Employment multipliers may be obtained by inspecting the journey-to-work rows in the inverse of the coefficients matrix. Entries against industrial sectors in these rows indicate the effect upon labour demand of a unit change in final demand for a given sector. Entries against demographic variables in the same rows provide evidence of the employment generation potential of the various elements of population, at the individual and household levels of aggregation.

Other cell entries in the inverse yield further information. It is evident that entries in the industrial sector cells of any of the population columns indicate changes in industrial activity that result from unit changes in population levels. Using these entries we can compare the effects on different industries of combinations of changes, modelling the effects of, for example, possible migration changes. Similar investigations can be made of other entries in the inverse: it is important, however, to be careful of entries relating to constraints that have a zero value. The 'commodities' that these rows relate to are all endogenous to the framework: while it is not incorrect to read their inverse entries as the effects that would be caused by unit increases in their constraint values, care must be taken in interpreting what the unit entry in the constraints vector implied here actually means. For example, an increase of one in the inactive household constraint would mean hypothesising an inactive household which was not associated with the population in the framework, and which 'in-commuted' to consume.

As well as gaining information about the demographic-economic system from the inverse entries, we can use the activity-commodity framework as a powerful forecasting tool. Forecasts can be obtained easily by post-multiplying the inverse by a proposed future constraints vector, and reading off the resulting state of the system from the activity level vector. In the next section we describe an empirical study using an operationalised activity-commodity framework.

* See Miernyk (1967) for a description of the Type III multiplier
4. A CONSISTENT FORECASTING FRAMEWORK FOR MERSEYSIDE

Our forecasting framework has been applied to Merseyside, a metropolitan county in North West England. Merseyside's initial prosperity was based on its port function, but over the last fifty years the local economy has been in decline, as the port's significance has diminished. This decline has accelerated in the last ten years and the area now faces severe unemployment problems, together with a high rate of net out-migration. A framework in which the close inter-relations between demographic and economic change are recognised is likely therefore to be of considerable value in the examination of strategic planning issues and policies for Merseyside County.

The Merseyside framework is similar in general terms to that illustrated in Figure 3. Inter-industry transactions are represented in a Leontief (I-A) matrix in which fifteen industrial activities and commodities are specified. Here we have made use of data assembled in a non-survey input-output study of Merseyside with a base year of 1970 (de Kanter and Morrison, 1978). Elsewhere in the framework we have relied upon data from published sources, including the 1971 Census of Population (for population, household composition and economic activity data), the Family Expenditure Survey (household consumption) and the Annual Census of Employment (employment data). In defining labour demand and labour supply, we have distinguished between manual and non-manual workers and in disaggregating population we have identified twelve categories of people: males, married females and single, widowed or divorced females divided according to four age groups. The complete framework consists of 38 simultaneous equations which we solve by inverting the matrix of coefficients.

Table 1 presents a selection of demographic-economic multipliers extracted from the inverse. Three types of multiplier are illustrated for each of the fifteen industrial sectors and for certain of the demographic categories. Of particular interest are the employment multipliers which show the effect on labour demand of changing final demand by 1, and the income multipliers, which enable comparisons to be made between conventional Type II multipliers and the

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Population*</td>
<td>1657100</td>
<td>1581000</td>
<td>1506400</td>
<td>1518000</td>
<td>1517000</td>
<td>1581000</td>
</tr>
<tr>
<td>Employment</td>
<td>699569</td>
<td>697082</td>
<td>696539</td>
<td>696601</td>
<td>696801</td>
<td>665647</td>
</tr>
<tr>
<td>Econ. Active</td>
<td>746516</td>
<td>713313</td>
<td>715920</td>
<td>717832</td>
<td>721782</td>
<td>56135</td>
</tr>
<tr>
<td>Unemployment</td>
<td>47947</td>
<td>24700</td>
<td>16774</td>
<td>19219</td>
<td>21031</td>
<td>56135</td>
</tr>
<tr>
<td>Unemp. Rate %</td>
<td>6.42</td>
<td>3.42</td>
<td>2.35</td>
<td>2.68</td>
<td>2.92</td>
<td>7.77</td>
</tr>
</tbody>
</table>

* Source of population projections: Merseyside County Council (1978)

Table 2: Forecasts of Population, Employment and Unemployment in Merseyside Metropolitan County 1971-1981
<table>
<thead>
<tr>
<th>Industrial Sector/ Demographic Category</th>
<th>Multiplier</th>
<th>Multiplier</th>
<th>Multiplier</th>
<th>Multiplier</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Production</td>
<td>Employment</td>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-Manual</td>
<td>Manual</td>
<td>Type II</td>
<td>Type IV</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1.343</td>
<td>0.00011</td>
<td>0.00013</td>
<td>1.724</td>
<td>1.568</td>
</tr>
<tr>
<td>Oils &amp; Fats</td>
<td>1.506</td>
<td>0.00006</td>
<td>0.00009</td>
<td>2.529</td>
<td>2.043</td>
</tr>
<tr>
<td>Food</td>
<td>1.516</td>
<td>0.00009</td>
<td>0.00018</td>
<td>1.913</td>
<td>1.635</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.589</td>
<td>0.00010</td>
<td>0.00031</td>
<td>1.755</td>
<td>1.523</td>
</tr>
<tr>
<td>Chemicals</td>
<td>1.558</td>
<td>0.00011</td>
<td>0.00024</td>
<td>1.806</td>
<td>1.517</td>
</tr>
<tr>
<td>Paper</td>
<td>1.407</td>
<td>0.00010</td>
<td>0.00017</td>
<td>1.630</td>
<td>1.387</td>
</tr>
<tr>
<td>Engineering</td>
<td>1.517</td>
<td>0.00012</td>
<td>0.00024</td>
<td>1.683</td>
<td>1.371</td>
</tr>
<tr>
<td>Vehicles</td>
<td>1.443</td>
<td>0.00016</td>
<td>0.00018</td>
<td>1.662</td>
<td>1.406</td>
</tr>
<tr>
<td>Construction</td>
<td>1.124</td>
<td>0.00003</td>
<td>0.00004</td>
<td>1.507</td>
<td>1.086</td>
</tr>
<tr>
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<td>1.519</td>
<td>0.00013</td>
<td>0.00032</td>
<td>1.852</td>
<td>2.065</td>
</tr>
<tr>
<td>Transport</td>
<td>1.542</td>
<td>0.00008</td>
<td>0.00024</td>
<td>1.844</td>
<td>1.539</td>
</tr>
<tr>
<td>Port</td>
<td>1.385</td>
<td>0.00014</td>
<td>0.00024</td>
<td>1.628</td>
<td>1.322</td>
</tr>
<tr>
<td>Distribution</td>
<td>1.313</td>
<td>0.00015</td>
<td>0.00008</td>
<td>1.703</td>
<td>1.532</td>
</tr>
<tr>
<td>Miscellaneous Services</td>
<td>1.202</td>
<td>0.00007</td>
<td>0.00005</td>
<td>1.538</td>
<td>1.134</td>
</tr>
<tr>
<td>Public Admin.</td>
<td>2.441</td>
<td>0.00029</td>
<td>0.00023</td>
<td>2.929</td>
<td>2.424</td>
</tr>
</tbody>
</table>

| Active Households nm                   | 2724.7     | 0.242      | 0.175      | -          | -          |
| Active Households m                    | 2317.5     | 0.214      | 0.152      | -          | -          |
| Inactive Households n                  | 1187.3     | 0.108      | 0.079      | -          | -          |
| Males U30                              | 133.6      | 0.012      | 0.008      | -          | -          |
| Males 30-44                            | 1238.2     | 0.112      | 0.079      | -          | -          |
| Males 45-64                            | 1361.5     | 0.123      | 0.087      | -          | -          |
| Males 65+                              | 935.8      | 0.085      | 0.061      | -          | -          |
consistent Type IV multipliers proposed earlier in this paper. We note that
the ratio Type IV/Type II is not constant as is the Type I/Type II ratio; this
because of the different income/consumption relations between the multipliers.

Table 1 also allows us to examine the effects of demographic change upon
the local economy. In the lower section of the table we can see what happens
if there are unit changes in some of the demographic variables. The loss of a
manual active household, for example, will result in a deduction of £2310 from
overall gross output. We can also determine the employment generation effects
of various types of demographic change, by examining the employment multipliers.

We have used the operational framework to obtain forecasts of population,
employment and unemployment in Merseyside over a ten year period. The results
of this exercise appear in Table 2. The table shows what happens when a number
of different population projections are input to the framework, in one case
holding final demand at its 1971 level, and in the other, reducing final demand
in all sectors by five per cent. Although the results do not purport to be
realistic forecasts, they nevertheless illustrate some of the ways in which
the framework can be used in a strategic planning context.

5. CONCLUSIONS

In this paper we have presented a forecasting framework which allows demo­
graphic and economic models to be integrated in a consistent manner. This has
been achieved by incorporating a conventional Leontief input-output model within
an activity-commodity framework in which demographic-economic interaction is
represented explicitly. We have shown that the inverse matrix derived in solv­
ing the activity-commodity framework provides a new series of income, employ­
ment and production multipliers which overcome the inconsistencies found in conven­
tional multipliers, as well as offering fresh insights into the effects of pop­
ulation change upon the economy. Our empirical study of Merseyside, although
capable of further development and refinement, suggests that the framework may
have considerable potential as a forecasting tool in strategic planning.

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### 2. EXISTING AND FUTURE ENERGY SITUATION OF THE NETHERLANDS

The Dutch energy situation at the present time is described as rather favorable. In comparison to many other countries, the level of dependency of energy-producing exporting countries for the Netherlands is relatively small. This situation is mainly a result of the production of a vast amount of natural gas in the southern part of Holland and in the North part of the North Sea. In the past twenty years, the Dutch answer has been: look under your own nose, look for gas and oil. In which the Dutch rule of 'that has been everything in the Netherlands is correct. The first natural gas field to be developed in the Netherlands was founded in 1959. Since then, the production of natural gas has significantly increased, and it is now an important source of energy.

The important and increasing influence of natural gas in the Netherlands can also be seen by the rapidly increasing consumption of natural gas since the beginning of the sixties. In 1965, when the production of North Sea gas started, the Netherlands was import dependent on natural gas. However, the production of natural gas has since then been steadily increasing, and in 1972, the Netherlands was already a net exporter of natural gas. This development has had a significant impact on the energy policy of the Netherlands, as it has reduced the dependency on imported energy sources.
In this paper we have presented a forecasting methodology which allows demographically and socio-economically significant factors to be integrated into a model. This has been achieved by incorporating a conventional market research activity in model-building. The methodology is based on the following assumptions: 1. The model can be represented by a set of linear equations. 2. The model will provide a basis for strategic planning. 3. The model can accommodate changes in the economy. 4. The model will be able to forecast the effects of changes in the economy. 5. The model will be able to forecast the effects of changes in the economy.

REFERENCES

[References listed in the document are omitted for brevity.]
STRATEGIC PLANNING OF ENERGY IN THE NETHERLANDS

Frans Kutsch Lojenga
Henk Voogd

Delft University of Technology, The Netherlands,
Faculty of Civil Engineering

1. INTRODUCTION

Since the oil crisis of 1973 it is a widely accepted fact that energy is a rather scarce raw material. A large number of papers, conferences, discussions etc. has stimulated the growing awareness that energy-supply in the present form cannot hold infinite. Nowadays, the use of fossile energy plays such a dominant role in our society, that many governments find this a reason to participate actively in energy planning for the short-term and long-term future. Not only in western countries the energy-case is a matter of continuing attention, but even more in developing countries a sufficient supply of energy now and in the near future is a matter of life. In putting it the economic way: energy supply is a "conditio sine qua non" for economic growth.

With constantly rising energy prices, a limited supply, and uneven spatially spread sources of energy, the margins for an energy-policy are fairly small. However, each government has to give concrete form to questions of a responsible energy policy within the framework of its plans for economic development.

This paper deals with the strategic planning aspects of energy-policy in The Netherlands. Therefore, in the next section we will give a brief overview of the present Dutch energy situation and the prospects for the future (up to the year 2000). Subsequently, policy alternatives are set up and worked out with respect to the supply of (natural) gas in The Netherlands. Since these alternatives have a rather qualitative nature, they will be evaluated by means of an ordinal geometric evaluation procedure. Therefore, this paper also includes a brief discussion of this type of evaluation. In addition, this approach will be applied to the energy-policy alternatives in order to draw some conclusions about the desired direction for the future energy-policy in The Netherlands.

2. PRESENT AND FUTURE ENERGY SITUATION IN THE NETHERLANDS

The Dutch energy situation at the moment might be described as rather favourable. In comparison to many other countries, the rate of dependency of energy-producing/exporting countries for The Netherlands is relatively small. This situation is mainly a result of the possession of a vast amount of natural gas in the northern part of Holland and in the Dutch part of the North Sea. In the past twenty years the Dutch economy has turned its basis from coal and oil to gas and oil, in which the former role of coal has been overtaken now by natural gas. This process, however, is not only restricted to The Netherlands. At the beginning of the sixties in Western Europe the share of natural gas in total primary energy consumption was hardly 2 %, but by 1978 this share has risen to about 15 %. In some other countries this share of natural gas in total primary energy consumption is even higher; for instance in the United States this share amounted in the seventies to more than 30 %. In The Netherlands this percentage was already 51 % in 1978 (see Scheme 1.1).

The important and increasing influence of natural gas in The Netherlands can also been shown by the rapidly increasing production of natural gas since the beginning of the sixties, in which since 1973 also the production of North Sea gas plays a moderate role (see Figure 1.1).
1. Shares of different forms of energy in the total primary energy consumption (in %) in The Netherlands.

<table>
<thead>
<tr>
<th>Year</th>
<th>Natural Gas</th>
<th>Oil</th>
<th>Coal</th>
<th>Nuclear Energy</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>1.2</td>
<td>48.1</td>
<td>50.4</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>1965</td>
<td>4.1</td>
<td>65.5</td>
<td>30.0</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>31.6</td>
<td>58.2</td>
<td>10.0</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>52.6</td>
<td>40.3</td>
<td>5.0</td>
<td>1.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

100.0 % 100.0 % 100.0 % 100.0 %

Source: Tielemans (1979)

Prognoses of the future development of gas-consumption are based on the assumption that it will not increase any more and that the relative share in The Netherlands will decrease to about 40 % by 1985. This assumption includes selectivity in the gas-policy (which means among others no new export contracts and prudence in new contracts with large industries), no extension of nuclear energy and an economic growth rate of about 2-3 % per year. This prospect implies that the provision of energy in The Netherlands for the years 1980-1990 will be rather unstable, which on its turn puts a pressure on the production of (natural) gas.

Because of this reason, the stock of natural gas in The Netherlands has a threefold function with respect to the provision of energy (Dept. of Economic Affairs, 1979):

a) a balance function (during periods of a peak in gasconsumption);
b) a crisis function (during periods of a substantial shortage of other forms of energy);
c) a strategic function (for the future generations in an uncertain future).
On the worldlist with the richest natural gas countries, The Netherlands comes in the 8th place, far behind the Sovjet-Union, Iran and the United States, but ahead of countries like Nigeria, Kuwait and Libya. On a world scale The Netherlands is the largest natural gas-exporter, and on a Western European scale the largest producers of gas. In spite of these impressive facts, the Dutch energy situation should be judged as vulnerable. Possible social-economic implications in a worst case situation should therefore not be underestimated.

In the following the necessity of a strategic planning concept will be clarified by several arguments concerning the fact that the world's largest natural gas-exporter imports already for some years gas from the Norwegian part of the North Sea and is about to import from Algeria too (to begin with in 1983 in the form of LNG; Liquefied Natural Gas). For an impression about the different problems of the Dutch LNG-imports see Kutsch Lojenga and Schut (1979).

At the moment the production of natural gas (Groningen + North Sea) amounts up to 160 mld m3 per year. By 1985 this amount will be decreased to 145 mld m3 and to at least 50 mld m3 per year in 2000. This exhaustion of the Dutch gas-reserves - from which at least about 550 mld m3 has to be delivered to foreign customers in the EEC - is about to happen in the same period that Middle East oilproducers will diminish their production considerably: 5 million barrels per day in 1985 and 10 million barrels per day in 1990. These shrinking oil productions added to an uncertain future of nuclear energy force the Western European countries (The Netherlands included) to import more and more gas and coal.

An energy-policy is in fact a long-term policy, which is caused by the wide integration of the use of specific forms of energy with the socio-economic activities (see Molag, 1979 and Tieleman, 1979). A second reason for this long-term aspect is the very long periods that are needed for preparation and development of new sources of energy and for realisation of new import contracts. Therefore, the policy should not only focus on the amounts of gas, but also on the term in which these amounts of energy are available (see De Vries and Kommandeur, 1974).

LNG-contracts for instance are such forward contracts, covering normally a period of about 20 years. Because of the still rising oil prices, new perspectives open up for natural gas production, enlargement of LNG-contracts, and last but not least for a moderate return to the use of coal in order to produce gas from it via a gasification-process. The choice between import of LNG or import via pipelines depends on several arguments, insofar the Dutch situation with respect to Algerian gas is concerned. The costs of pipelines over long distances are much higher that the costs of a LNG-transport-chain. A second reason in favour of LNG is the desired future position in the LNG-market with producers on much greater distance. In the third place LNG-import has a positive effect on the Dutch employment situation, especially in Oost-Groningen and the Botlek-area.

Weighing such criteria, an energy-policy therefore should be devoted to reach the largest possible diversity and flexibility, an increase in efficiency of energy-uses and a stabilisation of energy-prices in order to maintain a sufficient supply of energy. Demand and supply should be kept together in the long run.

In the next section these narrow margins of policy will be translated into some future scenario's. In addition, these scenario's will be evaluated against a set of relevant criteria.
3. ALTERNATIVE FUTURE SCENARIO'S

In the previous sections a description has been given of the present situation with regard to the supply and demand of (natural) gas in The Netherlands. This section will be devoted to a discussion of some scenario's with respect to possible future prospects. From an actual point of view it is likely to suggest that these scenario's could be based on (combinations of) at least four different components.

These components are:
A) The use of the existing natural gas fields in The Netherlands;
B) The import of LNG from other countries;
C) The import of natural gas from other countries via pipelines;
D) The production of gas from coal.

It is easy to see that each scenario must contain the first component. Because of some long-term contracts the Dutch government is obliged to supply some other European countries also in the near future with (rather inexpensive!) natural gas. The other components need not necessarily be a part of a scenario or might have a different share in the total supply.

For reasons of surveyability we will restrict our attention only to the components of a scenario. This implies that the amount of gas created by each component will not be taken into explicit consideration, since this would result in very inexact and uncertain information.

The various scenario's are described in scheme 3.1. If a particular component is included in a scenario this will mean that this component has a share of at least 10% in the total demand of natural gas on year basis.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>COMPONENTS</th>
<th>GLOBAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Intensive use of Dutch natural gas; development of new sources of energy.</td>
</tr>
<tr>
<td>2</td>
<td>AB</td>
<td>Dutch natural gas plus LNG from various countries all over the world. (mainly Algeria, Nigeria, Norway)</td>
</tr>
<tr>
<td>3</td>
<td>AC</td>
<td>Dutch natural gas plus natural gas via pipelines from other countries in or near Europe (e.g. Soviet-Union).</td>
</tr>
<tr>
<td>4</td>
<td>AD</td>
<td>Dutch natural gas plus gas from imported coal from all over the world.</td>
</tr>
<tr>
<td>5</td>
<td>ABC</td>
<td>Dutch natural gas plus LNG plus foreign natural gas by pipelines.</td>
</tr>
<tr>
<td>6</td>
<td>ABD</td>
<td>Dutch natural gas plus LNG plus gas from coal.</td>
</tr>
<tr>
<td>7</td>
<td>ACD</td>
<td>Dutch natural gas plus foreign natural gas by pipelines plus gas from coal.</td>
</tr>
<tr>
<td>8</td>
<td>ABCD</td>
<td>Minimum use of Dutch natural gas, LNG plus foreign natural gas plus gas from coal.</td>
</tr>
</tbody>
</table>

Scheme 3.1. Future scenario's for the supply of (natural) gas in The Netherlands.
The following criteria are used to evaluate the eight scenario's from scheme 3.1:

I - The final price of gas for consumers.
II - The number of new jobs created (directly or indirectly) by a scenario.
III - The realisation potentials from a political point of view.
IV - The probability that a disaster might occur.
V - The consequences of a possible disaster.
VI - The environmental damage.
VII - The quality of the buffer and balance function.
VIII - The flexibility with respect to the producers of the energy source.
IX - The realisation potentials from a technical point of view.
X - The time of exhaustion of gas energy.

Given the "fuzzy" nature of the scenario's, it is no surprise that the above-mentioned criteria can not be assessed on a cardinal ('metric') scale. Therefore, the various characteristics of the scenario's are only assessed via qualitative ('ordinal') scores. These are included in the effectiveness matrix of scheme 3.2. Evidently, the number of crosses symbolizes the quality of a scenario, i.e. the more crosses, the better.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<td>xxx</td>
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<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
</tr>
<tr>
<td>II</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>III</td>
<td>x</td>
<td>x</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
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<tr>
<td>IV</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
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<td>x</td>
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<td>V</td>
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<td>x</td>
<td>xx</td>
<td>xxx</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>VI</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>VII</td>
<td>x</td>
<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>VIII</td>
<td>x</td>
<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>IX</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>X</td>
<td>x</td>
<td>xxx</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
<td>xxx</td>
</tr>
</tbody>
</table>

Scheme 3.2. The Effectiveness Matrix

It is easy to see from scheme 3.2. that a final judgment heavily depends on the priorities attached to the various criteria. For this reason the following three alternative "weight" sets, each corresponding to a particular policy "vision", are used (scheme 3.3).

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
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<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>economic vision</td>
<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xxx</td>
<td>x</td>
<td>xxx</td>
</tr>
<tr>
<td>technical vision</td>
<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>xxx</td>
<td>x</td>
<td>xxx</td>
</tr>
</tbody>
</table>

Scheme 3.3. Some Alternative Sets of Priorities

The data presented in scheme 3.2 and 3.3 have been used as inputs for an ordinal geometric evaluation procedure to draw more quantitative inferences about the desired ranking of the various scenario's. The technical details of this geometric evaluation procedure will be outlined in the next section.
In this section an evaluation procedure is outlined, which is able to treat qualitative effectiveness rankings and criterion weights in a theoretical consistent way, without violating the ordinal characteristics of the imputed data. This procedure is called "ordinal geometric evaluation" (see Nijkamp, 1979; Nijkamp and Voogd, 1979; Van Setten and Voogd, 1978; Voogd, 1979).

An ordinal geometric evaluation procedure consists of two stages. In the first stage two metric (cardinal) matrices \( X \) and \( Y \) are extracted from the ordinal effectiveness matrix \( E \), which implies a representation of the alternatives and the ideal points of the criteria as points in a multi-dimensional space of a few dimensions. Matrix \( X \) is of order \( I \times P \) and contains the co-ordinates \( x_{pi} \) of alternative \( i \) and dimension \( p (p = 1, \ldots , P) \). Matrix \( Y \) is of order \( J \times P \) and contains the co-ordinates of the ideal points \( y_{pj} \) of the criteria. An ideal point can be interpreted as the "ideal value" of a criterion (see Coombs, 1950; Voogd, 1980).

It is easy to see that more ordinal conditions are available via the effectiveness scores than geometric co-ordinates \( x_{pi} \) and \( y_{pj} \) are necessary. Because such abundant information involves many degrees of freedom, it is possible to transfer these ordinal \( e_{ij} \)-scores into metric \( x_{pi} \) and \( y_{pj} \)-scores. This concerns a minimization problem, which can be formally denoted for a geometric space with a fixed number of dimensions \( P \) as:

\[
\min \phi = f(\hat{D} - \hat{D}) \\
\text{subject to:} \\
\hat{D} = E \\
D = g(Y, X)
\]

where:
- \( D \) = rectangular matrix (of order \( J \times I \)) of (unknown) geometric distances \( d_{ij} \) between criterion point \( j \) and choice possibility \( i \).
- \( E \) = rectangular matrix (of order \( J \times I \)) of (known) effectiveness scores \( e_{ij} \).
- \( D \) = rectangular matrix (of order \( J \times I \)) of (unknown) order-isomorph values \( \bar{d}_{ij} \), which have the same ranking as the imputed rankings \( \bar{e}_{ij} \) (denoted by the monotonicity symbol \( \bar{m} \)).
- \( g(Y, X) \) = geometric distance function.

It is aimed at a representation of the choice possibilities and criterion points in a geometric space of minimum dimensionality, i.e. \( P \) should be kept as small as possible. The auxiliary matrix \( D \) is used to do arithmetic operations with the qualitative information of matrix \( E \). Matrix \( D \) can be determined by means of a monotone regression procedure (see Kruskal, 1965, 1971) or a rank image procedure (see Guttman, 1968).

Model (1) can be specified as follows:
\[
\min \sum_{j=1}^{J} \sum_{i=1}^{n_j} (d_{ji} - \hat{d}_{ji})^2 
\]

subject to:
\[
d_{ji} = \left\{ \sum_{p=1}^{P} (|y_{jp} - x_{ip}|)^c \right\}^{1/c} \quad (c \geq 1)
\]
\[
n_j = \{ \sum_{i=1}^{I} (\hat{d}_{ji} - \bar{d}_j)^2 \}^{-1}
\]
\[
\bar{d}_j = \frac{\sum_{i=1}^{I} \hat{d}_{ji}}{I}
\]

Although the algorithmic aspects of this model would qualify for scrutiny, we will restrict our attention in this paper to the model itself. See, for a more profound consideration of the algorithmic features, Voogd (1978), Van Setten & Voogd (1978).

By means of (2) we are able to find optimal co-ordinate values $X$ and $Y$. To evaluate the taxonomy of alternatives, embodied by matrix $X$, we need a point of reference, i.e. an "ideal choice possibility". The co-ordinates of the ideal choice possibility can be formulated as a function of the weights of the various criteria ($w_j$) and the co-ordinates $y_{jp}$ of the criterion points. It is assumed that the more important a certain criterion is, the smaller the distance will be between that particular criterion point and the "ideal choice possibility". Therefore, $y_p$ can now be seen as a co-ordinate which minimizes the following function:

\[
\min \psi = \sum_{j=1}^{J} w_j (y_p - y_{jp})
\]

If we assume that the criterion weights add up to unity, i.e.

\[
\sum_{j=1}^{J} w_j = 1
\]

then

\[
\gamma_p = \sum_{j=1}^{J} w_j y_{jp}
\]

The preference score of choice possibility $i$ can now be calculated by means of a Minkowski distance metric

\[
\delta_i = \left\{ \sum_{p=1}^{P} (|x_{ip} - \gamma_p |)^c \right\}^{1/c} \quad (c \geq 1)
\]

Any value of $c \geq 1$ may be chosen, provided that the same value is used in model (2).
In (5) it is assumed that the criterion weights have metric properties. However, in practice they can mostly only be made explicit on an ordinal scale. This means that there is no sufficient information for a precise calculation of the co-ordinates of the ideal choice possibility. Hence, the only way left is to consider the area in the geometric space in which this reference point could be situated. This area is defined by the extreme values of the weights, which are in accordance with the rankings which reflect the importance of the criteria. Suppose we have three criteria for which the following hypothesis is valid: \( w_1 \geq w_2 \geq w_3 \).

Because condition (4) holds, the following extreme weight sets can now be distinguished: \((1,0,0)\), \((\frac{1}{3}, \frac{1}{3}, \frac{1}{3})\) and \((\frac{1}{3}, \frac{1}{3}, \frac{1}{3})\). For each extreme weight vector we can proceed now analogously as in (5) and (6). A combined interpretation of the results of the various extreme weights enables us then to come to a final judgement with respect to the choice possibilities.

5. EVALUATION OF THE VARIOUS GAS SCENARIO'S

The ordinal geometric evaluation method has been applied to the data of Scheme 3.2 and 3.3. It appeared that an almost perfect goodness-of-fit was possible by using a two dimensional geometric space (i.e. \( p = 2 \) and \( \phi = .0003 \)). The resulting preference scores (cf. formula (6)) are included in Table 5.1.

<table>
<thead>
<tr>
<th>ALTERNATIVE SCENARIO'S</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVIRONMENTAL VISION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme interpretation</td>
<td>.166</td>
<td>.325</td>
<td>.733</td>
<td>.733</td>
<td>.927</td>
<td>1.180</td>
<td>.925</td>
<td>1.178</td>
</tr>
<tr>
<td>Moderate interpretation</td>
<td>.431</td>
<td>.784</td>
<td>.784</td>
<td>.740</td>
<td>1.089</td>
<td>1.090</td>
<td>1.089</td>
<td>1.174</td>
</tr>
<tr>
<td>ECONOMIC VISION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme interpretation</td>
<td>1.299</td>
<td>.361</td>
<td>1.299</td>
<td>.341</td>
<td>.818</td>
<td>.325</td>
<td>.362</td>
<td>.341</td>
</tr>
<tr>
<td>Moderate interpretation</td>
<td>1.469</td>
<td>.344</td>
<td>1.421</td>
<td>.300</td>
<td>.675</td>
<td>.192</td>
<td>.742</td>
<td>.299</td>
</tr>
<tr>
<td>TECHNICAL VISION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme interpretation</td>
<td>1.115</td>
<td>.883</td>
<td>1.191</td>
<td>.881</td>
<td>.578</td>
<td>.526</td>
<td>.881</td>
<td>.477</td>
</tr>
<tr>
<td>Moderate interpretation</td>
<td>.983</td>
<td>.589</td>
<td>1.338</td>
<td>.621</td>
<td>.622</td>
<td>.552</td>
<td>.623</td>
<td>.567</td>
</tr>
<tr>
<td>Neutral interpretation</td>
<td>1.210</td>
<td>.987</td>
<td>1.341</td>
<td>.547</td>
<td>.992</td>
<td>.455</td>
<td>.752</td>
<td>.548</td>
</tr>
</tbody>
</table>

Table 5.1. The evaluation results

The lower a preference score is, the better a scenario is with respect to the interpretation of the vision concerned. In Scheme 3.3 three ordinal "levels" are being distinguished. This implies that there are only three extreme weight sets by which a solution can be defined. Evidently, one extreme weight set is the same for all visions: i.e. all criteria have then equal weights. This is called a "neutral interpretation". A "moderate interpretation" neglects less important criteria, whereas the "extreme interpretation" only considers the most important criteria.
Table 5.1 shows that from an environmental point of view scenario 1 will be the most attractive strategy. It must be noted that in case of a moderate interpretation scenario 4 is the second-best alternative, although it does not differ very much from scenario 2 and 3 in this respect. Evidently, scenario 8 is the less attractive scenario from an environmental viewpoint.

Scenario 6 appears to be very preferable from an economic point of view. However, the preference score for this alternative is very close to the preference scores of scenario's 2, 4 and 8. This means that these strategies are almost equally attractive.

Scenario 8 has the lowest preference scores for the technical vision. Consequently, this strategy must be considered as the most attractive alternative, which is especially caused by the high effectiveness rankings for criteria VII, VIII and X. Alternative 2 also has a very low score for the moderate interpretation although the scores for the neutral interpretation clearly show that scenario 8 is ultimately better.

In conclusion we might say that scenario's 2, 4, 6 and 8 appear to be the best strategies from a technical-economic point of view.

6. CONCLUSION

The qualitative evaluation procedure applied in this paper can be regarded as a useful tool for strategic planning problems, dealing with "soft" data. The evaluation shows that scenario 8 should be regarded as the most preferable solution from an economic and technical point of view; however, not from an environmental point of view. Nevertheless, considering the strategic aspects this solution is logically the best one. The economic and technical aspects of this energy strategy are rather good manageable and in that way also the environmental aspect.

The policy of the Dutch government - c.q. the "Gasunie" - corresponds to the description of alternative 8. This means that the actual strategy of the Gasunie fits well in the solution of our evaluation, i.e. a gas production from as many sources as possible in order to maintain in the future a sufficient supply at reasonable prices.

7. REFERENCES


1. INTRODUCTION

The aim of the present paper is to provide a conceptual framework for analyzing choice problems in a broader social setting (especially with regard to conflicting options such as environmental protection and economic growth). This framework is based on multi-objective optimization theory, and it attempts to find compromise solutions for choice conflicts. Such a compromise may be achieved by means of an interactive approach based on a learning strategy and on a stepwise provision of information on the range of feasible efficient solutions. In the present study the method of displaced ideals will be used as an operational tool for economic-environmental policy-making.

The use of the above-mentioned multi-objective choice model will be illustrated by means of a spatial economic-environmental model for two regions in the Netherlands. The conflicts and compromises between environmental and economic options will be exposed on the basis of this integrated model.

2. MULTIDIMENSIONAL WELFARE PROFILES

The socio-economic and environmental health of a region or place in a spatial system can hardly be represented in a meaningful manner by means of a single indicator. Welfare is essentially a multidimensional variable which has to be reflected via a series of indicators that make up the health of a region or place (see for a plea for the multi-dimensionality principle also Nijkamp [1979][1980]).

Such a multidimensional view of the quality of life is also inherent in the social indicator movement and the environmental impact movement. This multidimensional approach is based on a vector profile representation of all elements characterizing the socio-economic and environmental welfare of a region or place (cf. Paelinck and Nijkamp [1976]). Such a vector profile \( \mathbf{v} \) can be divided into subprofiles representing main categories of relevant socio-economic and environmental indicators such as \( \mathbf{v}_E \) (economic subprofile encompassing \textit{inter alia} production, investments and income), \( \mathbf{v}_S \) (social subprofile encompassing \textit{inter alia} (un)employment, distribution of income and accessibility to public facilities), \( \mathbf{v}_M \) (environmental subprofile encompassing \textit{inter alia} pollution, quantity of natural areas and congestion). It is clear that these subprofiles are only illustrative examples and by no means exhaustive.

Furthermore, one may construct such an operational profile for each region or place within a spatial system. Given a spatial system composed of \( R \) regions \( r = 1, \ldots, R \), the multidimensionality state of this spatial system can be represented by means of the following state matrix \( \mathbf{V} \) (cf. also Hafkamp and Nijkamp [1979]):
Each row of (2.1) is a multiregional cross-section of one welfare component, whereas each column represents a regional welfare profile. The elements of $V$ may be measured in metric as well as in non-metric units. In the present study, however, the assumption is made that $V$ includes only metric information. For non-metric information, adjusted methods (such as multidimensional scaling techniques; see Nijkamp [1979]) have to be employed.

The intertemporal evolution of a system of regions can be represented by a three-dimensional spatiotemporal block including the time dimension $t$ ($t=0, \ldots, T$) (see Fig. 1).

![Fig. 1. A spatiotemporal welfare block](image)

The information incorporated in (2.1) or in Fig. 1, can be used to measure discrepancies between spatial welfare profiles. A prerequisite for such a measurement is, however, a standardization of the elements of the welfare profile, so that they are transformed into comparable units. For the moment, the assumption will be made that a linear unweighted transformation is meaningful to obtain standardized variables ranging between 0 and 1. Then a useful standardization is (provided the profile elements are benefit criteria):

$$
\tilde{w}_{ir} = \frac{w_{ir} - v_{\min}}{v_{\max} - v_{\min}}
$$

where $w_{ir}$ is the $i$th element of region $r$, and where $v_{\max}$ and $v_{\min}$ are defined as:

$$
\begin{align*}
\max_i v_{ir} &= v_{\max} \\
\min_i v_{ir} &= v_{\min}
\end{align*}
$$

and:

$$
\begin{align*}
\max_r v_{ir} &= v_{max} \\
\min_r v_{ir} &= v_{min}
\end{align*}
$$
On the basis of (2.2) one may calculate the unweighted interregional discrepancy between any pair of regions \( r \) and \( r' \) by means of the following general Minkowski \( p \)-metric:

\[
d_{rr'} = \left( \sum_{i=1}^{L} (w_{ir} - w_{ir'})^p \right)^{1/p}, \quad p \geq 1.
\]  

(2.5)

Clearly, the elements of this metric may be provided with specific weights depending on political priorities. This problem of political priorities will be discussed in the next section which is devoted to multi-objective policy models.

3. INTERACTIVE MULTIDIMENSIONAL MODELS FOR COMPROMISE POLICY-MAKING

In Section 2 a systematic framework for representing spatial welfare profiles has been developed. So far, no attention has been paid to political priorities, welfare choices or optimising behaviour.

It is obvious that policy-makers and planners will usually base their decisions on a multiplicity of criteria (efficiency criteria, equity criteria, social criteria, environmental criteria and so forth). Hence, beside a careful examination of the set of feasible solutions, decision-makers have to evaluate the various alternative solutions. The existence of multiple decision criteria, the limited availability of information, the uncertainty about the set of feasible alternatives and the slow institutional procedures of decision and planning strategies preclude usually a straightforward application of traditional optimality principles.

In this paper the problem of multiple decision criteria will be tackled by introducing the following elements in a political evaluation procedure:

- **the presence of multiple objective functions**: for each element of the welfare profile described in Section 2 a corresponding objective function will be assumed. For example, one may assume maximization of production and minimization of pollution. A further analysis of these problems requires the application of some principles from multi-objective decision theory (see among others Cochrane and Zeleny [1973], Van Delft and Nijkamp [1977], Fandel [1972], Keeney and Raiffa [1976], Nijkamp [1977] and Rietveld [1980]).

- **the presence of an interactive choice procedure**: due to uncertainty and limited information the choice-making process is a learning procedure. This implies that information about the set of feasible alternatives is provided in a stepwise way to the decision-makers, so that they may formulate certain priorities or desires regarding the outcome of the decision procedure. The latter information is used to truncate the set of feasible solutions and to specify some trial solutions which may again be judged by the decision-makers. This procedure can be repeated until finally a (convergent) compromise solution can be identified, which is deemed to be satisfactory by the decision-makers.

In the context of decision models, a multi-dimensional view of welfare leads to a plea for multi-objective optimization models, in which multiple (conflicting) objective functions are to be optimized simultaneously. The reasons for the existence of multiple objective functions may be: the presence of non-commensurable objectives, the presence of different interest groupings or the presence of spatial spill-over effects. The use of multi-objective optimization theory takes for granted that the various decision criteria cannot be made commensurate in some way or another.
In general, a multi-objective optimization model may be formalized as:

\[
\max_{x \in K} w(x)
\]

(3.1)

where \( w(x) \) is a \((I \times 1)\) vector of objective functions, \( x \) a \((J \times 1)\) vector of decision variables and \( K \) a feasible area.

There is a large set of methods to analyze and solve these types of decision models. A central role in multi-objective optimization theory is played by the concept of a Pareto solution (non-inferior, efficient or non-dominated solution). A Pareto solution reflects the common feature of multi-objective optimization models that the value of the one objective function cannot be improved without affecting the values of the remaining objective functions and vice versa. Such a solution demonstrates the conflicting nature of these models: any feasible point that is not dominated by other points can be regarded as a Pareto solution.

In formal terms, a Pareto solution can be defined as follows: a Pareto solution is a vector \( x^* \) for which no other feasible solution vector \( x \) does exist such that:

\[
\begin{align*}
    w(x) &> w(x^*) \\
    w_i(x) &> w_i(x^*) \quad \text{for at least one } i
\end{align*}
\]

(3.2)

It has been proved among others by Geoffrion [1968] and Kuhn and Tucker [1968], that a feasible solution is a Pareto solution \( x^* \), if and only if a vector of weights \( \lambda \) does exist (with \( \sum \lambda = 1 \) and \( \lambda > 0 \)), such that \( x^* \) is the optimal solution of the following uni-dimensional program:

\[
\max_{x \in K} \lambda^T w(x)
\]

(3.3)

By means of a parametrisation of \( \lambda \) the set of Pareto solutions may, in principle, be determined, although in practice the algorithms for determining this set appear to be rather time-consuming (see Zeleny [1974]). Since the vector \( \lambda \) is a set of weights associated with each Pareto solution, it plays an important role in determining an ultimate equilibrium or compromise solution of a multi-objective model, particularly because any good solution of a multi-objective decision model should be a Pareto solution.

A figurative representation of the set of Pareto solutions (the efficiency frontier) is contained in Fig. 2, based on 2 objective functions.

Fig. 2. A functional space with the efficiency frontier of 2 objectives.
A closer examination of Fig. 2 leads to the conclusion that only the points on the edge between A and B are relevant Pareto points, because (1) all interior points are dominated by the points on the edge, (2) all points on the edges CA and DB are dominated by point A and B, respectively, and (3) no point on the edge AB dominates any other point on this edge.

Point B of Fig. 2 can be regarded as the ideal point, which may be used as a reference point for evaluating the points on the efficiency frontier. One may assume that the ultimate equilibrium (compromise) solution is that point which has a minimum discrepancy with respect to the ideal point P. This minimum discrepancy can again be measured by means of a Minkowski metric. This gives rise to the following compromise model (cf. also 2.5):

\[
\min \Psi = \left\{ \frac{1}{p} \sum_{i=1}^{I} (1 - \omega_i)^p \right\}^{1/p}
\]

\[
\omega_i = \frac{v_i(x) - \min_{i} v_i}{\max_{j} v_j - \min_{i} v_i}
\]

\[\times \in K\]

The solution of this compromise model can be calculated by applying nonlinear programming techniques. When \(p=1\) or \(p=2\), (3.4) can be directly solved by means of linear and quadratic programming algorithms, respectively. The solutions of (3.4) will be indicated as \(\omega_i\) (\(i=1, \ldots, I\)).

In many decision procedures, however, this first compromise will not be regarded as the final equilibrium solution, so that a certain interactive learning procedure has to be developed in order to reach in a series of steps such a final solution. Thus the provisional solution obtained by means of (3.4) has to be presented to the decision-maker as a trial solution which has to be judged by him. The decision-maker has to indicate which objective functions are to be improved and which ones give already satisfactory results.

Let us denote the set of objective functions which are judged to be unsatisfactory by \(S\), so that the decision-maker's preferences can be taken into account by specifying the following constraint:

\[
\omega_i(x) \geq \tilde{\omega}_i(x) \quad \forall i \in S
\]

In consequence, the following model has to be solved during the next stage:

\[
\max \bar{\omega}_i(x) \quad \forall i \in S
\]

\[
\omega_i(x) > \tilde{\omega}_i(x) \quad \forall i \in S
\]

Given this adjusted multi-objective programming model, a new ideal point \(P_1\) can be calculated in a way analogous to the first phase. Clearly, this displacement of the ideal point is due to condition (3.5). After the calculation of the new ideal point, a new compromise solution can be determined by means of (3.4) etc., until a final satisfactory compromise is attained. The various successive steps are briefly represented in Fig. 3. It has to be emphasized that the minimum distance procedure is an unweighted procedure; during a set of iterative steps a compromise is attained. Therefore, the interactive learning character of this procedure is essential in order to prevent a policy-maker.
from taking biased decisions on the basis of a single-step choice algorithm.

**specify multi-objective decision problem**

| ↓ | calculate ideal welfare profile |
| ↓ | calculate compromise solutions |
| ↓ | identify non-satisfactory solutions |
| ↓ | impose achievement constraints |
| ↓ | ultimate compromise solution |

**Fig. 3.** Representation of an interactive multi-objective decision procedure.

Clearly, a consistent decision-maker would reach the same compromise on the basis of alternative methods (such as game methods).

This method of *displaced ideals* originally developed by Zeleny [1976] can be regarded as one of the most practicable interactive multi-objective decision techniques. This procedure implies that instead of the optimizer concept a 'satisficer' concept is used, so that the ultimate compromise result complies with certain achievement levels specified by the decision-maker (cf. also Simon [1957]). Such compromise policy models are extremely important for environmental policy problems in which usually a certain compromise between diverging priorities (for example, maximum employment, minimum pollution and minimum depletion of natural resources) has to be found. In the following section, a spatial-environmental model will be developed by means of which the above-mentioned compromise notions will be illustrated.

4. **ILLUSTRATION OF THE INTERACTIVE COMPROMISE MODEL**

In this section an empirical illustration of the interactive compromise procedure will be given by using a multi-regional input-output model together with a pollution-emission and a pollution-diffusion model. The model is based on data collected and elaborated by Coupé [1976]; in another context an analogous model has been used by Hafkamp and Nijkamp [1979]. This model contains two regions, the Dutch provinces Groningen (G) and South-Holland (S). These regions are assumed to be linked in three different ways, viz. through the production technology (input-output flows), the pollution (diffusion of waste) and the labour market (commuting and/or migration).

For the sake of illustration and ease of representation the production system has been aggregated to two sectors: a non-polluting sector (1) containing the "service"-sectors and other tertiary sectors, and a polluting sector (2) containing among others industrial sectors. The objective functions, mentioned in Section 3, are assumed to be:

\[
\omega_1 = y_1^G + y_2^G + y_1^S + y_2^S \\
\omega_2 = l_1^G + l_2^G + l_1^S + l_2^S \\
\omega_3 = \max_{r=G,S} \{0.65 z_{1r}^T + 0.65 z_{2r}^P + 0.75 z_{3r}^P\}
\]

\(r=G,S\)
\( \omega_n \) denotes objective \( n (n=1,2,3) \); \( y^r_i \) and \( z^r_j \) denote value added of sector \( i \) in region \( r \), employment of sector \( i \) in region \( r \) and concentration of pollution of kind \( j \) in region \( r \), respectively. \( \omega_1 \) in (4.1) can be regarded as a traditional welfare measure, viz. value added in all sectors and regions; \( \omega_2 \) in (4.2), denoting a social welfare aspect, represents total employment over all sectors and regions; \( \omega_3 \), a measure for environmental quality, indicates total weighted concentration of pollution in the region where the environmental conditions are worst (i.e. the region with the highest weighted concentration, measured in \( \mu g/m^3 \) at the centre of the region). The weights are taken from a recent report of the Institute for Environmental Studies [1978]. The latter approach implied that concentrations of pollution in the industrial province South-Holland are taken as an indicator of environmental quality. Emission coefficients of all kinds of pollution are higher in this area; the production volume of the polluting sector is approximately seven times higher than that of the corresponding sector in Groningen. The pollutants distinguished here are: particles, \( SO_2 \) and \( NO_x \).

In general the question may be posed, whether it is better to take some (weighted) average of the regional concentrations of pollution in both regions or the maximum. Due to the extreme difference in size of the two regions, it was judged to be more appropriate to use here the maximum of both regions.

The following equations reflect the relationships between the variables in the model and the constraints on the system.

\[ r^r_i = c^r_i \cdot x^r_i; \quad r = G, S; \quad i = 1, 2; \quad (4.4) \]

\( c^r_i \) are value added coefficients, while \( x^r_i \) are regional and sectoral production volumes. In this model, production variables are treated as decision variables.

The following input-output constraints are assumed:

\[ (I - A^r) \cdot x^r \geq f^r; \quad r = G, S; \quad (4.5) \]

In equation (4.5) the \( (2x2) \) matrix \( [I - A^r] \) is the technological (input-output) matrix of region \( r \); the regional final demand \( f^r (E_{G}, E_{S}) \) is a known vector.

The employment equation is:

\[ l^r_i = \lambda^r_i \cdot x^r_i; \quad r = G, S; \quad i = 1, 2; \quad (4.6) \]

\[ l^r_i \geq E^r_i; \quad r = G, S; \quad i = 1, 2; \quad (4.7) \]

where the \( \lambda^r_i \)'s are regional sectoral employment coefficients.

Next, a series of side-conditions is imposed. In equation (4.7) regional sectoral employment is fixed above a given minimum. The presence of commuting is introduced via equations (4.8), where regional employment is allowed to attract commuters from the other region; \( E' \) is the given labour demand in region \( r \).

\[ \sum_{i=1}^{2} l^r_i \leq E^r + 0.1 E'^r; \quad (r, r') = (G, S), (S, G); \quad (4.8) \]
Total employment is restricted by means of (4.9) to the total available number of man-years:

$$\sum_{i=1}^{2} (1_i^G + 1_i^S) \leq E^G + E^S$$  \hspace{1cm} (4.9)

Emission of pollution of category $j$ as a result from production in sector 2 in any region is given in (4.10):

$$p^r_j = \pi^r_j \cdot x^r_2 \quad r = G,S; \quad j = 1,2,3$$  \hspace{1cm} (4.10)

Matrices $H^{rr'}$ link emission and immission of pollution in equations (4.11).

$$H^{rr'} \cdot p^r + H^{r'r} \cdot p^{r'} \leq \bar{z}^r \quad (r,r') = (G,S), (S,G);$$  \hspace{1cm} (4.11)

$H^{rr'}$ is a diagonal (3x3) diffusion matrix, while $\bar{z}^r$ and $p^r$ and $p^{r'} \in R^3$. $\bar{z}^r_p$ is a vector of regional concentration standards. During the first stage of the procedure $\bar{z}^r_p$ will be set on an infinitely high level (reflecting "no standards"), but during the procedure the standards may be assigned more realistic values.

5. SIMULATION OF AN INTERACTIVE COMPROMISE PROCEDURE

The data used are contained in Table 1; substitution of (4.6) into (4.7), (4.8) into (4.9), and (4.10) into (4.11) leads to a more condensed specification.

As a first step in the compromise procedure the first three equations will, in turn, be maximized and minimized respectively. In this way an ideal welfare profile can be derived; for the purpose of standardizing the objective variables, a "worst" profile can be identified as well.

The results of this first run for the initial year (1966) are contained in Table 2. The maximization of value added appears to reflect to a certain extent the real situation of 1955, except for an overestimation of commuting. It should be noted, however, that the simulation aspect of the model has to be kept in mind (see also Hafkamp and Nijkamp [1980]).

Production and employment coefficients in Table 1 show that production in region $S$ is more efficient than in region $G$. As a result of this, the maximization of value added leads to commuting from region $G$ to region $S$. In region $G$ only a minimum employment is realized.

Value added and pollution are at (nearly) optimal levels in the first compromise solution (see Table 2). Therefore, the required minimum employment in region $G$ is shifted to 155,000 man-years (i.e. 95% of the man-years available in region).

In the second run (see Table 3) a slight shift in the employment takes place. Due to the new minimum level of employment in region $G$, the compromise solution finally shows a slight increase in value added as well as in employment. The increase in pollution can be neglected here (from 2.086 to 2.094 and from 4.115 to 4.118, respectively).
\[
\begin{bmatrix}
0.7265 & 0.5117 \\
0.8993 & -0.1985
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.7553 & 0.5988 \\
0.9051 & 0.1218
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.6590 & 0.3820 \\
0.8993 & -0.1985
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.6030 & 0.3230 \\
0.8993 & -0.1985
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.0650 & 0.0672 \\
0.6590 & 0.3820
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.3620 & 0.4048 \\
0.6590 & 0.3820
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.162700 \\
0.8993 & -0.1985
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.941100 \\
0.8993 & -0.1985
\end{bmatrix}
\]
\[
\begin{bmatrix}
0.7000 & 1.0800 \\
0.6590 & 0.3820
\end{bmatrix}
\]
\[
\begin{bmatrix}
4.6800 & 7.1980 \\
0.6590 & 0.3820
\end{bmatrix}
\]
\[
\begin{bmatrix}
1.4385 & 8.7956 & 5.2729 \\
0.6590 & 0.3820
\end{bmatrix}
\]
\[
\begin{bmatrix}
1.7903 & 9.3193 & 4.8926 \\
0.6590 & 0.3820
\end{bmatrix}
\]

Table 1. Data for the simulation model of Groningen and South-Holland (1966) (employment is measured in millions of man-years, final demand is measured in billions of Dutch guilders (1960)).

<table>
<thead>
<tr>
<th>run no. 1</th>
<th>calculation of ideal welfare profile</th>
<th>optimization of</th>
<th>value added</th>
<th>employment</th>
<th>conc. of poll.</th>
<th>compromise</th>
</tr>
</thead>
<tbody>
<tr>
<td>region</td>
<td>G S G S G S G S G S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>value added</td>
<td>1.920 14.950</td>
<td>1.870 14.320</td>
<td>1.870 13.735</td>
<td>1.870 14.320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>employment</td>
<td>0.155 0.949</td>
<td>0.155 0.949</td>
<td>0.146 0.949</td>
<td>0.146 0.949</td>
<td></td>
<td></td>
</tr>
<tr>
<td>conc. of poll.</td>
<td>2.645 5.186</td>
<td>2.094 4.118</td>
<td>2.086 4.118</td>
<td>2.086 4.118</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Calculation of ideal welfare profile and compromise solutions for first run in interactive compromise procedure.

<table>
<thead>
<tr>
<th>run no. 2</th>
<th>calculation of ideal welfare profile</th>
<th>optimization of</th>
<th>value added</th>
<th>employment</th>
<th>conc. of poll.</th>
<th>compromise</th>
</tr>
</thead>
<tbody>
<tr>
<td>region</td>
<td>G S G S G S G S G S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>value added</td>
<td>1.920 14.950</td>
<td>1.870 14.320</td>
<td>1.870 13.630</td>
<td>1.870 14.320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>employment</td>
<td>0.155 0.949</td>
<td>0.155 0.949</td>
<td>0.155 0.949</td>
<td>0.155 0.949</td>
<td></td>
<td></td>
</tr>
<tr>
<td>conc. of poll.</td>
<td>2.647 5.184</td>
<td>2.094 4.118</td>
<td>2.094 4.118</td>
<td>2.094 4.118</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Calculation of ideal welfare profile and compromise solutions for second run in interactive compromise procedure.

Next a third run is carried out (see Table 4), not because any one of the objectives has an unsatisfactory value, but because the compromise solution of round 2 indicates too large intersectoral changes. In order to fulfill requirements as to value added, employment and pollution, the activities in (the polluting) sector 2 appear to decrease to a level exactly fulfilling the final demand conditions. In addition, a highly unlikely change in employment from sec-
tor 2 to sector 1 appears to occur. Therefore, some new constraints on employment in sectors 1 and 2 in region G and S are added, so that at least 90% of the original employment is guaranteed per sector.

run no. 3

<table>
<thead>
<tr>
<th>calculation of ideal welfare profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>optimization of</td>
</tr>
<tr>
<td>region</td>
</tr>
<tr>
<td>value added</td>
</tr>
<tr>
<td>employment</td>
</tr>
<tr>
<td>conc. of poll.</td>
</tr>
<tr>
<td>G</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>value added</td>
</tr>
<tr>
<td>employment</td>
</tr>
<tr>
<td>conc. of poll.</td>
</tr>
</tbody>
</table>

Table 4. Calculation of ideal welfare profile and compromise solutions for third run in interactive compromise procedure.

In the compromise solution, this assumption leads to a higher concentration of pollution via a higher employment and a higher production in (the polluting) sector 2. It also appears that the concentration of pollution in region S is still less than 90% of what it would be under optimization of total value added. It should be noted, however, that the concentration of pollution in region S remains approximately twice as high as in region G. Within the context of the present model with its fixed technology (fixed coefficients), such a large difference cannot easily be eliminated. Finally, value added and employment appear to reach more than 95% of their ideal values.

6. CONCLUDING REMARKS

The interactive compromise procedure exposed in Section 3 and based on the welfare profiles of Section 2 is a most promising technique for decision-making, especially for problems where sometimes conflicting objectives of a different dimension are to be guided to an optimum (or compromise).

The advantage over traditional types of analysis, like Cost-Benefit-Analysis and some types of Multi-Criteria-Analysis lies in the fact that it is not necessary to determine trade-offs (or shadow prices of different objectives). The recursive procedure, based on the "satisficer-principle", can be regarded as more realistic than the approaches emerging from the traditional "maximizer-principle".

In the empirical part in Sections 4 and 5 an attempt was made to simulate the decision process of (a group of) regional decision-makers, who have to identify an ideal compromise in the area of feasible solutions. Two aspects were neglected here for the time being.

First, the roles of different groups in society were hardly taken into account. It would be interesting to simulate a similar process with a decision-maker for each objective in each region, for example industrial interest groups for value added, labour unions for employment, environmental pressure groups for environmental quality, etc. This then requires a further elaboration of the steps "identify non-satisfactory solutions" and "impose achievement constraints" in Figure 3.

Secondly, there is the problem of implementation. In the procedure sketched in Section 5, certain optima are calculated. The ways for an economy to reach those optima are not given, so that a next step may be to extend the analysis with public instruments such as charges, standards, inducing shifts in consumer demand, change of infrastructural facilities, technology, etc. Clearly such a model should be a more extensive dynamic model.
The construction of such a dynamic model is fraught with many difficulties due to a severe lack of reliable data. Alternatively, one might also employ the previous static model as a frame of reference for future policies. The interactive nature of this policy model ensures a permanent feedback from policy-makers and vice versa, so that also changes in policy priorities, conflicting options and changes in external conditions can be taken into account in any time period the model is being used. In a dynamic society, decisions which are fixed definitively are less likely to occur, so that models have to play a role in an ongoing policy process. In this respect, the policy model used should leave room for taking account of alternative policy strategies and scenarios. The present interactive procedure may be regarded as an important vehicle for rationalising decision and policy processes.

The present paper may be seen as a cautious and tentative step on the path of building models where the designer does not merely prescribe a solution, but supports the decision-maker in determining all relevant consequences of the decisions he takes.

REFERENCES


PART V

MONITORING AND REVIEW
It has been long recognised that an essential part of any planning exercise is the ability to monitor the plan's progress. The concept of monitoring can be defined as a continuous analysis aimed at discovering and measuring significant deviations from a plan or policy. The problems around the monitoring of structure plans in England are extensively discussed in the paper of FRANCIS. He starts his paper by looking at the causes of the growing uncertainty against which the monitoring of structure plans is now taking place. He argues that techniques of monitoring should be established which will ensure that structure plans can be adapted to provide a realistic basis for the decisions which must be taken. These techniques must be able to cope with uncertainty. Francis asserts that the information base for strategic monitoring must be far more than a passive exercise in the collection and neat arrangement of numbers which are vaguely thought to be relevant. An identification of key issues is seen as important. An elaboration of the organisational consequences finishes this interesting contribution.

The paper of SCHEURWATER and MASSER concentrates on an information analysis system which can be used to monitor spatial developments in The Netherlands. They devote special attention to user requirements because the nucleus of an information storage and retrieval system already exists in the continuous population registers that are maintained by the local authorities. This paper contains the findings of the first phases of a large research project undertaken by the authors for the Dutch National Physical Planning Agency. Therefore, the task of implementation of the information analysis system is still in progress. However, the ultimate results seem very promising since the system can be used as a general framework for analysis of spatial data and as a means of integrating material from other sources that is required for monitoring purposes.

Another way of looking at monitoring is by studying plan implementation empirically, in the hope of learning something about the process and about what may be done to improve plan performance. This has been done by ALTERMAN, who did analyse by means of a multidimensional scaling technique the degree of implementation of a plan for the Krayot area in Israel. This empirical research is framed in a review of the various types of monitoring in relation to the context of statutory land use planning.

An interesting demographic monitoring system is discussed by GORDIJN and HEIDA. The nucleus of their system is a multi-regional demographic model. In addition, the practical aspects of demographic monitoring are treated. Special attention is devoted to the various steps within a monitoring procedure.

The last paper, written by VOOGD, concentrates on the monitoring of environmental objectives. An elaboration is given of the basic principles and major implementation problems of environmental monitoring. Some first ideas are given of an environmental model which is able to cope with the spatial characteristics and the cumulation of detrimental effects. This model offers also interesting possibilities to include synergistic effects. It is asserted that this environmental monitoring approach may be a meaningful addition to the conventional environmental impact statement methodology, although a lot of extra research is still needed to make this approach operational.
1. INTRODUCTION

Monitoring establishes what is happening now and may happen in the future. It then compares these trends against existing policies and hence determines what needs to be done. The monitoring process involves the identification of key issues and the answering of three questions - 'Are policies effective in achieving objectives?', 'Have policies resulted in unintended consequences?' and 'Are the assumptions and objectives of current policies still relevant?'

These three themes of targets, achievements and assumptions are common to monitoring of many activities - from the output of a production line to national strategic plans. Monitoring a structure plan is not an unique achievement. It draws upon established techniques and upon previous experience within land use planning. Indeed, the monitoring system developed for a structure plan is often a re-organisation and justification of what was already being done. It is also something which is both broad and diffuse. Monitoring draws upon information from many other agencies, especially those responsible for implementing development, and also gives guidance to these other agencies, providing the forecasts of the number and distribution of future population, dwellings and employment which underly the forward planning of their services.

Monitoring structure plans has, therefore, many tentacles. It also needs a central focus which is meshed into the existing decision making process. This paper looks in turn at the three elements that go to make up this central core: the organisation and analysis of information, the identification of key issues and the decision-making process. First, however, it looks at the causes of the growing uncertainty against which the monitoring of structure plans is now taking place. The conclusion returns to this theme, considering how the monitoring process itself, as it has developed over the last few years, will need to be adapted to give clearer guidance as to which policies to pursue in the 1980s.

2. UNCERTAINTY

The current development planning system, including Structure Plans, was initiated by the 1968 Town and Country Planning Act. The comprehensive long term land use strategies required from Local Authorities were accompanied, in the early and mid 1970s, by a series of medium term policy plans produced by local public authorities at the behest of central government - for instance Housing Investment Programmes and Strategies, Transport Policy and Plans and comprehensive development plans for water, social services and health. Although these plans have a shorter time horizon than the structure plan (between 3 and 10 years compared with the 10 to 20 years of the structure plan) and often involve annual submissions of capital expenditure, many aspects of their preparation and monitoring need to be dovetailed into the proposals of the structure plan as they provide, in part, the means by which the structure plan is implemented.
This inter-locking framework of policy plans for locally provided services stemmed from the increasing emphasis, in the 1960s, upon public services and investment. It was also influenced by the development, at much the same time, of new techniques of holding and analysing data, defining systems and forecasting. Ten years ago, long term master plans were in vogue, produced against the implicit premise that it was possible to forecast, if not control, reality. Now there is uncertainty as to the ability even to plan a few months ahead. There are several reasons for this reaction. Many of the assumptions in the early structure plans have already been proved wrong or unrealistic. Major demographic changes, especially the continued fall in the birth rate, were unforeseen. Inflation, and public expenditure cut-backs upon capital projects, have brought into question the realism of implementing structure plan proposals, especially those including large scale investment by public or private sources on new infrastructure, for instance on drainage or new roads. There have also been changes in attitudes. It is too simplistic to say that this represents a move from growth to no growth. But the implications, as well as the practicality, of proposals for major projects are increasingly questioned, especially if these projects involve comprehensive redevelopment or new roads. There have also been frequent shifts in central government policy and attitudes concerning regional development, inner cities and powers of land acquisition and assembly over the last five years. Finally, the effects of current trends upon living and working patterns is unknown. In the 1980s Britain will have the largest labour force it has ever had, due to the 1960s "baby bulge" and high female economic activity, and fewer people coming up to retirement age. The potential for change due to microelectronics is enormous, but what will be the reality given current investment levels and attitudes? Will we see a vast reduction in the numbers of people working in manufacturing, analogous to the change from an agrarian to an industrial society in earlier centuries? Can a growth in services or leisure employment compensate, or will the effects of modern technology be even greater upon the service sector itself, especially upon the need for office workers and floorspace?

"The plan is dead - long live continuous monitoring and review" is now frequently heard. Yet this is unrealistic. Techniques of monitoring must be established which will ensure that structure plans can be adapted to provide a realistic basis for the decisions which must be taken now. The aim of monitoring must be to ensure that uncertainty is, if not reduced, at least acknowledged. In Hampshire, as elsewhere, the approach has involved the collection, processing and presentation of relevant information to highlight issues of importance to strategic monitoring and the interpretation of this information in the light of existing planning policies. These two aspects - information and interpretation - are now considered in turn.

3. INFORMATION

To reduce uncertainty, the information base for strategic monitoring must be far more than a passive exercise in the collection and neat arrangement of numbers easily available on these current trends which are vaguely thought to be relevant. It includes selection, analysis and a systematic search for verbal information. Changes in projections and Member's views are as much part of the information base for strategic monitoring as are current trends in the birth rate.

a. Qualitative Information

The verbal information needed includes both hard (for instance policies approved, commitments made, events that have occurred) and soft (for instance information on emerging policies, proposals under consideration, assessments
of a problem, public attitudes towards certain issues). The information can be acquired from a wide variety of sources - published reports, internal papers, the press, personal contacts, committee minutes and so on. Its organisation and retrieval is, in practice, very time consuming and much more difficult than is the case for numeric information.

As part of the information base, the monitoring system needs to give opportunities for interested groups (other statutory bodies, local interest groups, local authorities) to raise issues and for prospective changes in policies to be aired and submitted for debate. In Hampshire the monitoring process includes arrangements to consult various groups (for instance house builders on land availability, industrialists and trade unionists on economic prospects) and lists are kept of the appropriate bodies to whom preliminary issues, information and final reports should be submitted. The implications of changes in central government policy, especially towards public expenditure and regional policy, are carefully studied and the conclusions summarised.

b. Data and Data Systems

Although such verbal information is a vital aspect of the information base for monitoring, most effort throughout the 1970s has been expended upon data - its capture, organisation and linkage - and upon a modelling framework to allow understanding of current relationships and projections of future trends. In Hampshire, for example, a comprehensive monitoring data base has been established which enables analysis of trends, the linkage of data and the revision of several sets of forecasts and projections. Appendix I lists the major sources of data which are held as computer files, analysed by regularly produced standard reports, general software ("in house" and SPSS) and computer mapping. The Appendix also gives the major projections and forecasts which are updated using these, and other, sources of monitored data and notes the links established between these files in a direct data transfer. The areal levels at which the transfer takes place and the compatibility (or rather lack of compatibility) between many of the areas is also described. A recent paper (Gould & Francis, 1979) expands upon many of the sources and models used in Hampshire. It should be noted that, in Hampshire, much of the monitoring and revision of forecasts has, in practice, a wider relevance than the monitoring of strategic policies and the level of detail reflects these wider needs.

How has this concept of "core" data and modelling systems helped to reduce uncertainty? First, it gives fuller information on current trends and the ability to relate trends together, although we have still some way to go before the full potential of all the sources, especially the more detailed, is realised for monitoring at the strategic level. Second, the projection models themselves give explanatory power. Models can be used to explain linkages and effects of change upon a system, thereby calling attention to those aspects of a forecast which are particularly affected by uncertainty. Models can also be used in combination to further bound the areas of uncertainty. An example of this is the use of long term employment and population projection models together to estimate job related migration. The effects of different trends in individual industrial sectors upon labour demand can be clearly shown, as can the effects of previous changes in the birth rate upon the local supply of labour - the difference between demand and supply of labour being the need for job-related migration. In contrast, the use of a population forecast which relies on migration trends derived from one or two observations over short time periods is more an act of faith than an explanation. Small area population forecasts have also been used in conjunction with the long term projections as an aid to the policy planners. The former provides an estimate of the population and potential housing stock likely to arise from existing residential
commitments and these can be assessed against the projections of population and housing need provided by the latter.

This data base in Hampshire has grown gradually, and consists of computer systems which are linked only when necessary and then at an areal level relevant to the user. This approach is different from the comprehensive management information systems, which provide strategic planning information as a by product of administrative systems and have been developed in several metropolitan authorities (for instance LAMIS at Leeds or the National Gazetteer Pilot Study at Tyne and Wear). Inevitably the data held reflect the availability of information. But the extent to which existing sources have been supplemented by surveys, and the ways in which the data are selected, organised and analysed, also reflects experience gained from monitoring. The selection has been determined by the policies in the structure plans, the issues which seem important in the political process and the data needs of other agencies, including those responsible for the implementation of development.

4. IDENTIFICATION OF THE KEY ISSUES

Development plans put forward policies to guide future development during the plan period and make specific proposals, primarily relating to the use of land for different types of development. The assessments which justify the policies and proposals depend upon assumptions concerning current and future trends and needs. They also depend upon the relationships assumed by the models used to describe, or predict, changes in the urban system. The monitoring of these assumptions provides the first basis for early warning of plain failure. But what are the key assumptions in the plan? In the nearly one million words of the South Hampshire Structure Plan and its supporting documents are contained many hundreds of explicit assumptions, from the number of acres of cemeteries required per 1000 persons in 1991 to future trends in industrial and residential density. Intrinsically the latter aspects are more important than the former, and assumptions of trends in residential density or industrial and office floorspace per worker are evidently much the more critical to land use allocation. Regular analysis of the information system outlined in Appendix I goes some way to showing how far the assumptions in the plan are being borne out in practice and the proposals implemented. Inevitably, some aspects are not able to be directly monitored on a continuous basis, especially those for which census data was used to establish relationships (for instance journey to work patterns or regression estimating models). Indirect evidence for changes in these relationships may, however, become evident from routine monitoring. Thus the monitoring of the population via biennial population canvases (Enhanced Electoral Registration - see Appendix I) showed that the equations assumed in the small area population forecasting model between the structure of net migration and the existing dwelling stock and derived from 1971 Census data, were now out of date. In this case, partial correction was possible, even though the detailed census data was lacking to re-calibrate the model completely. Very often, however, such findings give rise to further work on methodology or to data collection via specific surveys. The time scale of such studies often lie outside an annual monitoring cycle, although, as in this example, the routine analysis of existing data may help to give warnings of the emergence of a problem.

However, too much emphasis upon data and the plan means that there is a tendency to forget that planning policies are not the result of purely technical analyses. Policies are proposed, adopted and revised via political processes. In implementation, the policies remain subject to pressures, both supportive and hostile, that arise out of politics. Thus a general scan of data series and intelligence may suggest issues of importance, but policy changes or new
policies can be determined only via decisions taken as part of the political process.

Thus issues arise from the plan, routine analysis of captured data and from general awareness of areas of political concern and of the changing values of society. The identification of some of the issues for this year's monitoring cycle in Hampshire illustrate this interplay. Thus the first issue, the implications to the policies and proposals in the structure plans of revised long term projections of population and dwelling need, arises from the incorporation of new survey information, data on other monitored trends and revised employment projections in the existing model which link changes in employment and population. The relative economic performance of the area, and the diversification of its industrial base, will also be reviewed in the light of the increasingly gloomy national reports on economic prospects over the next year and the possible effects of recent advances in technology upon employment growth. This latter topic has received attention in previous monitoring reports and this year attention will focus upon the likely effect of micro-electronics and word processing upon the demand for office floor-space. The whole area of the impact of the 'technological revolution' upon patterns of living and working is evidently important to long term considerations of land release. The more dramatic possible effects of 'the chip' are also regularly raised at public enquiries and are a key issue in many Members' eyes - and it pays to be forewarned, if not forearmed. A number of other issues, for instance the environmental impact of new roads and delays in decisions by central government, arise from specific local problems which have caused public controversy over the last year and which affect the continued viability of the implementation of proposals in the structure plans.

In order to give the necessary guidance to decision takers on these issues, that is to aim to reduce uncertainty, many aspects of these issues have had to be analysed in depth in order to understand their nature, to predict ramifications on other policy areas and to judge the consequences of possible alternative actions. An example is continuing work on the effectiveness of existing planning policies in rural areas and the implementation of policies of restraining further dwelling and employment growth to that arising from the local population. These are general problems which prompted the development of the rural settlement file (see Appendix I). This year's monitoring cycle will be looking particularly at the effects of recent changes in government housing policy - especially the rights of local authority tenants to buy their dwelling and the curtailment of the council home building programme. Even when housing policy has been effective in dealing in aggregate with the overall need, the needs of particular groups of residents have often been frustrated. One group of the population often affected has been the population living in smaller villages relatively remote from employment centres. Housing, together with employment opportunities, public transport provision and rural services (school, shops, post office) influences the social mix and continued viability of many rural areas. Restrictive planning policies towards new industry or housing growth, especially in smaller settlements, may have, to some extent, contributed to a loss of services and population and hence made other local government investment for instance in schools or public transport, no longer viable. Sale of council housing in rural areas is likely to lead to fewer relets available in the villages to meet local housing needs. Housing restraint policies in rural areas, and the purchasing power of the rising number of retired in-migrants, have created high house prices. There is thus a danger that sections of the rural population - especially young families - will no longer be able to live in these areas: leading to further population loss, service decline and greater difficulty in implementing policies of
of restricting residential and industrial land release to needs arising from local residents.

5. THE ORGANISATION OF MONITORING

The analysis of such an interrelated problem is an active, not a passive, exercise and must lead to action within the existing organisational structure. Very often within a Planning Department monitoring is seen in two parts. First is the diagnostic - what is happening now and may happen in the future. Second is the prescriptive - what needs to be done. There are three ways in which the two parts can be integrated, namely:

i. both parts of the process are carried out by the planning team.

ii. the collection of information and raising of some preliminary issues is done by a separate section (for instance the Research and Intelligence Group). Interpretation, analysis, consultation and reporting is done by the planning team.

iii. a separate group is set up to work on the whole monitoring process as its main function.

This organisational aspect is one in which considerable differences are evident between local planning authorities, reflecting their differing approaches to strategic monitoring. The integrated approach (i), where the same people monitor and produce the plan, ensures familiarity with the aims, objectives and points of emphasis in the plan. Monitoring is likely to be digestible. At the other extreme, separate monitoring group (iii) may be more objective and likely to question basic premises. But such a unit may be remote and out of touch with political and practical problems and can give rise to internal discord. The second approach (ii) has the danger that the Research and Intelligence Group wallows in a sea of data, with the collection and organisation of the data taking up most of the time and even being seen eventually as the aim of the section - data organised for its own sake.

The approach in Hampshire lies somewhere between 'ii' and 'iii' and is focussed upon an annual monitoring cycle in which the Research and Intelligence Group produce Information Reports and is responsible for the production of the final report, whilst the area plan teams comment upon the effect of the new information upon the policies and proposals in each of the four Structure Plans. Many reports on single topics are, of course, produced outside this framework by both the Research and Intelligence Group and the planning teams whilst initial work on the key issues frequently throws up the need for further research not possible in the time scale.

6. CONCLUSIONS

We need new ways of looking at the structure planning process and at the world to adapt this framework to deal with the uncertainties of the 1980s. It has been argued that the structure planners of the 1970s, like the Russian acmeists, tried to make the world stand still long enough for them to catch a likeness of it (King, 1979). The emphasis was upon techniques, the future and comprehensiveness rather than upon key issues and ease of monitoring.

Within Hampshire, these criticisms could be levelled at the South Hampshire Structure Plan, although the preparation of the other three structure plans in the county was integrated within the monitoring framework as it emerged after 1974. Currently, the South Hampshire Structure Plan is being
reviewed in order to roll the horizon date forward to 1996 and this review is being undertaken in phase with the annual monitoring cycle. However, there are problems. Structure Plan review, unlike monitoring, is a statutory process including formal consultation and public participation. Central government sees a need to distinguish between monitoring and review: the central aim of monitoring being seen as deciding whether to alter, or not to alter, the development plan. However, emphasis upon an existing statutory plan may lead monitoring to be too concerned with justifying the plan or merely monitoring changes in assumptions already in the plan. Monitoring should be looking for new issues and spelling out the consequences of failure. To maintain public credibility, the results of monitoring must be seen to be clearly and rapidly reflected in changes in policy made by the review process.

To do this, a more flexible approach is required. Monitoring a structure plan does not need to be comprehensive to be effective, and the review of the plan needs to concentrate upon the key issues to be intellectually manageable. The review must allow for monitoring to continually reassess both old and new issues and for a future that appears a great deal more uncertain now than it did a few years ago. Expression of this future in terms of projections of population, dwellings and jobs is still required, but they need to be related to more general 'scenarios' which explore the practical limits of future change within which the land use plan needs to be formulated. Emphasis will need to be laid upon creating room for manoeuvre by ensuring that decisions on complex large scale developments do not close options for the future and that maximum use is made of opportunities given by existing commitments. This emphasis upon land availability is emphasised, in Hampshire, by the annual production of land availability schedules, based on the Land Development Progress System (see Appendix I) and by the recent establishment of a separate land availability unit.

The policies and proposals in the structure plan must also be seen to be able to be monitored given available information and resources. In Hampshire, most of the basic data and modelling systems required already exist. However, it seems a law of monitoring* that the larger and more comprehensive is the data system, not only the greater the staff resources for its upkeep but also the less use is made of the information at a strategic level. This has certainly been true of the Land Development Progress System and small area population forecasts (see Appendix I). Here recent changes in computer software will help, with the development of user-orientated file handling and command languages.

In the longer term, falling unit costs of computer time and new word processing software will enable the establishment of retrieval systems for non-quantified information whilst dynamic simulation will enable the user to explore relationships without the need for the present, rather monolithic, models. These changes should enable information to be more readily obtainable, and greater flexibility in the ways in which data is extracted, related and presented - enabling monitoring to respond more rapidly to the unexpected and immediate.

* The other laws are that, if the trend is interesting the data is probably wrong, and new sources or data are likely to increase uncertainty.
Finally, one other dimension of monitoring will need to be tackled - the effectiveness of the structure plan process itself. The structure plan is but one of the many activities of the Local Authority, and resources directed to monitoring and reviewing the plan need to be viewed against their contribution to the corporate policies of the County Council as a whole. Structure planners will need to be able to produce evidence that expenditure on monitoring and reviewing the plan is more effective than on retaining x posts for teachers or social workers. The act of faith of the late 1960s and early 1970s that such plans are a good thing may no longer be adequate - unless planners can prove that structure plans, by effective monitoring, can really be made to work.

REFERENCES


This paper also draws upon unpublished papers presented to the P.T.R.C. seminars on "Monitoring Development Plans".

The views in this paper are those of the author, and do not necessarily represent those of Hampshire County Council.
APPENDIX I: DATA SYSTEMS RELEVANT TO STRATEGIC MONITORING IN HAMPSHIRE

a. Computer Data Systems

<table>
<thead>
<tr>
<th>Minimum Areal Unit</th>
<th>Frequency of Update</th>
<th>Source</th>
<th>Use in Strategic Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTERNAL BASIC DATA SYSTEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Development Progress System (LDPS)</td>
<td>site; grid ref; ED</td>
<td>continuous</td>
<td>District planning authorities</td>
</tr>
<tr>
<td>Enhanced Electoral Registration (EER)</td>
<td>ward</td>
<td>biennial</td>
<td>Joint County-District survey</td>
</tr>
<tr>
<td>Mineral Sites</td>
<td>site; grid ref.</td>
<td>annual survey</td>
<td></td>
</tr>
<tr>
<td>Archaeological sites</td>
<td>site; grid ref.</td>
<td>continuous survey</td>
<td></td>
</tr>
<tr>
<td>One-off surveys (eg. employers; general household; rural transport; house condition)</td>
<td>various</td>
<td>- survey</td>
<td></td>
</tr>
<tr>
<td>Rural Settlements</td>
<td>settlement</td>
<td>as necessary EER; LDPS; 71 Census; survey</td>
<td></td>
</tr>
</tbody>
</table>

**EXTERNAL BASIC DATA SYSTEMS**

<table>
<thead>
<tr>
<th>Source</th>
<th>Use in Strategic Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971 base and relationships; long term trends</td>
<td></td>
</tr>
<tr>
<td>Central Government</td>
<td></td>
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<tr>
<td>ED</td>
<td>10 years</td>
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</tbody>
</table>
### Forecasts and Projections

<table>
<thead>
<tr>
<th>Minimum Areal Unit</th>
<th>Frequency of Update</th>
<th>Source</th>
<th>Use in Strategic Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Census of Employment (ACE)</td>
<td>annual (but 4 years out of date)</td>
<td>Central Government</td>
<td>size and structure of employment</td>
</tr>
<tr>
<td>Unemployment and Vacancies</td>
<td>monthly</td>
<td>Central Government</td>
<td>trends in number and structure of the unemployed and vacancies</td>
</tr>
<tr>
<td>Agricultural Census</td>
<td>annual (but 3 years out of date)</td>
<td>Central Government</td>
<td>trends in rural land use; employment in agriculture; viability of agriculture</td>
</tr>
</tbody>
</table>

**Small Area Population Forecasts**

<table>
<thead>
<tr>
<th>ED</th>
<th>annual</th>
<th>LDPS; EER; surveys; other</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPA (and sub-areas controlled to SPA)</td>
<td>necessary</td>
<td>ACE; 1971 Census; survey; other</td>
</tr>
<tr>
<td>SPA (and Districts and sub-areas controlled to SPA)</td>
<td>necessary</td>
<td>EER; surveys; 1971 Census; employment projections; other</td>
</tr>
</tbody>
</table>

**Notes:**

- Numerous small data sets, many held and analysed on computer, are excluded - for instance trends in births and deaths or land use and derelict land surveys.
- Ed enumeration district; SPA structure plan area.
b. Linkage of Computer Data Systems

[Diagram showing data linkage between various systems and surveys, labeled with abbreviations like ED, SPA, and S.]

- Direct computer data transfer
- Other links

( ) level at which data is transferred
- ED Census Enumeration District
- SPA Structure Plan Area
- S Settlement
c. Areal Units used in Data Systems

<table>
<thead>
<tr>
<th>Areal Unit</th>
<th>Number in county</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Structure Plan Areas</td>
<td>4</td>
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<tr>
<td>Districts</td>
<td>13</td>
<td>&quot;Second tier&quot; planning authorities</td>
</tr>
<tr>
<td>Local Office Areas</td>
<td>20</td>
<td>Employment and unemployment statistics</td>
</tr>
<tr>
<td>Structure Plan Sub-Areas</td>
<td>50</td>
<td>Sub-areas used for presenting structure plan policies</td>
</tr>
<tr>
<td>Rural settlements</td>
<td>300</td>
<td>Used for 'rural settlement' file</td>
</tr>
<tr>
<td>Wards and Parishes</td>
<td>350</td>
<td>Civil electoral units (370 in 1971)</td>
</tr>
<tr>
<td>Work trip zones</td>
<td>630</td>
<td>Used for employment and work trip information from 1971 Census and for employment monitoring</td>
</tr>
<tr>
<td>Enumeration districts</td>
<td>3,000</td>
<td>1971 Census minimum areal unit</td>
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d. Comparability between Areal Units

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<td></td>
<td>Local Office Areas</td>
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<td>Wards &amp; parishes</td>
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<td>Sub-areas</td>
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<td>Rural settlements</td>
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<tr>
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<td>1971 Census EDs</td>
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<td>1981 Census EDs</td>
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* boundaries co-incident
+ boundaries effectively co-incident
NO no direct relationship.
1. INTRODUCTION

1.1. The nature of strategic monitoring

Monitoring as an activity differs from the traditional process of review in a number of important ways. It is concerned with the continuous reassessment of aspects of planning policies rather than with the periodic comprehensive re-evaluation that is implicit in the review process. Because it is essentially continuous in nature the organisation of monitoring activities is largely dependent on the timing of events within a planning agency and also on the ability to process new information as it becomes available to the planning agency. In contrast the process of review can be seen as an independent activity within a planning agency involving its own cycle of data collection, analysis and interpretation.

The nature of monitoring varies according to the level at which it takes place. At the implementation level, where a high degree of control over the planned situation can be assumed and where external changes are of only limited interest, the role of monitoring is essentially to ensure that implementation takes place according to plan. At the intermediate, or management control, level (Anthony 1965), where there is a fairly high level of control and a clearly demarcated field of interest, monitoring is largely concerned with the identification of deviations from planned targets and checking the reliability of the forecasts upon which the planned outcomes are dependent. In contrast strategic monitoring is concerned with the anticipation of possible future developments and the initiation of new policy in response to current situations in a dynamic, imperfectly understood, and imperfectly controlled environment which encompasses an unlimited number of potential fields of interest and decision areas. The information that is required in order to carry out this task at the strategic level is unlimited and special attention must be given to the development of an efficient means of information selection in terms of particular tasks. Following their study of strategic monitoring requirements in the North West Region of Britain, Wedgewood Oppenheim et al (1975) have suggested that a mixed scanning approach should be adopted to deal with the problem of information selection. This combines the routine processing of quantitative information in depth with a more general examination of qualitative information covering a wide range of fields with possible implications for planning policy. The main features of their mixed scanning model are set out in Figure 1. From this it can be seen that three types of control activity are required in order to maximise the return of information handling activities and balance the
FIGURE 1 The mixed-scanning model of strategic monitoring activities (adapted from Wedgewood Oppenheim et al, 1975, Fig. 5, p. 23)

- Information flows
- Selection control
degree of effort that is put into the processing of quantitative data as against the investigation of new sources of possible interest. In the first place there is a need for control over data selection which is mainly influenced by information flows from the findings of the qualitative analyses and the evaluation of particular policy issues. Secondly there is the need for control over the analyses that are to be carried out in respect of the incoming information. This is influenced by information flows from both the routine processing of quantitative data and the continuous scanning of general trends as well as the results of more detailed qualitative studies and policy analysis.

Over and above these two control activities, Figure 1 indicates that there is a need for an overall control system to govern the allocation of resources that are devoted to the collection of qualitative as against quantitative information and the amount of time that must be given to information collection as against its analysis and interpretation. Perhaps the most important feature of the mixed scanning model is the emphasis that is given to the selective analysis of information in the framework of the ongoing activities of planning agencies. However the model does not make a clear enough distinction between the activities that are associated with the storage and retrieval of the information that is made available to the system and those associated with the analysis and presentation of this information to policy-makers. Nor does it take into account the fact that there may be important variations between different groups of policy-makers even within the same agency in terms of their monitoring requirements. The authors are currently engaged on a project in the Netherlands which seeks to overcome some of these deficiencies by the development of an information analysis system for strategic monitoring purposes. This project takes account of the experience that has been built up by systems analysts in the development of data base management systems which explicitly separate user requirements from the information storage and retrieval functions of computer based systems (see, for example, Tsichritzis and Lochovsky (1977) and Figure 2).

This paper presents the findings of the first stages of this research. It sets out the basic requirements that are imposed by monitoring activities and discusses the design issues that must be taken into account in the establishment of the information analysis system. Also, some first impressions of the implementation and use in practices of the system are discussed. Although, in some measure, the paper can be regarded as a report on work in progress, it is felt that the findings raise a number of questions which are of general interest to a wide variety of people concerned in policy analysis because of the emphasis that is given to user requirements in this case.

1.2. An information analysis system for monitoring spatial planning in the Netherlands

In the last few years a series of important studies have been carried out by the National Physical Planning Agency (Rijks Planologische Dienst) of the Dutch government in connection with the formulation of strategic spatial planning policies at the national level. These concern the growth and distribution of population and housing together with related topics such as the distribution of employment, services and recreational facilities (RPD 1974) and special attention has been paid to the consequences of different urbanisation trends (RPD 1976) and the needs of rural areas (RPD 1977). Collectively these studies form the Third Report on spatial planning for the Netherlands. The approach that has been adopted to the preparation of
FIGURE 2 The concept of an information analysis system
the Third Report differs significantly from that which was adopted in previous Reports. Whereas previous Reports were concerned mainly with the formulation of proposals to achieve the objectives of controlling the outward expansion of the Randstad and ensuring a better balance of development between this region and other parts of the country, the Third Report is concerned much more with the processes of planning and the need for better instruments and organisational structures to realise these goals. The success of such an approach depends, to a large extent, on the effectiveness of the policy analysis and the monitoring activities that are carried out by the National Physical Planning Agency. With this in mind a number of special working groups have been set up within the National Physical Planning Agency to identify priorities and to develop procedures for this purpose (RPD 1979).

The work of these groups has drawn attention to the importance of population change as an indicator of developments in a wide range of policy fields. The significance of population-indices in monitoring activities is further strengthened by the availability of information that arises in this case because of the existence of a continuous population registration system in the Netherlands (van den Brekel, 1977). This system is based on the use of personal cards for every individual in the country. These record, amongst other items, the place and date of birth, the place and date of marriage, all subsequent places of residence, and, eventually, the place and date of death of the individual. The advantages of register sources from the monitoring point of view are considerable. The constitute a continuous source of information about population change at the local authority level and material collected in this way can be processed quickly and published annually so that regular time series can easily be established. This data can be seen as the nucleus of an information storage and retrieval system already in existence in the Netherlands. It is therefore possible to concentrate attention on information analysis activities and user requirements in this research project.

The development and implementation of the information analysis system will take place in two main phases over a two year period. The first phase involves the implementation of the basic information analysis system and its testing in the cycle of monitoring activities that will be carried out by the National Physical Planning Agency during the first half of 1980. The experience that is gained in this phase will be taken account of in the planning of the second phase which will last until the middle of 1981. During this phase the capacity of the basic information analysis system will be extended and the computer software that has been developed for this purpose will be transferred to the National Physical Planning Agency in such a way that the information analysis system can be operated, maintained and updated by them on completion of the research project.

2. MONITORING REQUIREMENTS

2.1. Timing of monitoring activities

The monitoring activities that are envisaged in connection with the planning proposals of the Third Report are both continuous and cyclical in nature. They are continuous in the sense that monitoring takes place throughout the planning process and they are cyclical in that many of the activities that are involved must be related to particular events in the programme of the relevant planning agency. The monitoring system that is being set up by the National Physical Planning Agency involves certain activities which are carried out each year and the findings of these activities are incorporated
in the statement that is made by the Minister of Housing and Physical Planning to the Dutch Parliament at the beginning of the parliamentary year each autumn.

This implies that, for these activities, the basic task of data collection and processing must be completed by the beginning of February in any particular year so that the policy analyses can be carried out between February and May leaving the period between May and September free in order to prepare the Minister's statement. These deadlines also provide useful targets for the longer term monitoring activities that are being carried out alongside the more routine tasks of policy analysis and review.

2.2. Levels of policy statement

Three levels of generalisation can be distinguished in relation to monitoring activities connected with the proposals contained in the Third Report. These correspond broadly with the strategic, the impact and the implementation monitoring categories that have been identified in some other studies (see, for example, Wedgewood Oppenheim et al., 1975). At the highest level of generalisation the key decision areas in the Third Report are presented in a number of general goals and problem areas. The task of monitoring in this respect is to check whether these goals are still supported by existing norms and values and whether there have been any changes in the priorities that are attached to the solution of particular problems. At this level it is also important to identify new goals and emerging problems which may result in the redefinition of policy fields in overall terms and affect the scope of activity at lower levels of generalisation. At the second level of generalisation a number of policy guidelines must be developed as part of the overall strategy for achieving broad goals. Monitoring at this level is concerned essentially with the evaluation of these guidelines in terms of the overall strategy. This should also take account of implementation questions and their consequences on current planning practice. In many cases these guidelines can be represented in general quantitative terms. The third level of generalisation consists of a series of targets and programme statements which are specified in precise quantitative terms. This is the most concrete level of statement in the Third Report and forms the basis for the evaluation of the progress that has been achieved in the implementation of specific schemes at the local level. Inherent to the level of generalisation of the monitoring categories, the information analysis system concentrates on the last two levels.

2.3. The needs of related activities

The monitoring requirements of activities related to planning must also be taken into account in the development of the information analysis system. Of particular importance in this respect is the evaluation of the instruments and procedures that are used for control and implementation purposes. Special attention must be given to these questions in the design of monitoring systems because of the emphasis that has been given by the Dutch Parliament to the need to assess the cost-effectiveness of particular instruments in terms of their implications for the allocation of resources.

At the same time attention must also be given to the preparation of spatial policies at the provincial and local levels in that provision must be made for evaluating and reviewing plans made at these levels in the development of a monitoring system at the national level. Alongside its spatial planning activities the Dutch government has also produced a number of planning proposals and strategies for particular
sectors and particular attention has been given to public investment in the housing, transport, public utilities and recreation fields. These strategies must also be regularly evaluated and monitored in terms of their spatial implications.

3. SYSTEM DESIGN CRITERIA

3.1. The needs of users

The information analysis system will be mainly used by planners and policy-makers who have only a very limited knowledge of computers and computer software. Consequently the system must be designed in such a way that it can be operated by users who have only a minimum of technical knowledge. Because of this special attention must be given to the development of a simple command language. In this command language a basic instruction will be provided for many elements of the analysis of information for planning purposes. In this way an analysis with the aid of the system will be similar in terminology and content to the same analysis performed without the computer. This enables users to perform any scheme of analysis they specify in an efficient way. The command language will also provide facilities to get an overview of the possible options for further processing and analysis at any stage in the process. Although the system as described will be as self contained as possible, it will be backed up by substantial documentation and a thorough explanation of the methodology that is incorporated.

In the system development phase it must be borne in mind that the way in which the results of an analysis are made available to policy-makers has a great influence on the use that is made of them. For this reason special attention must be given to presentation techniques and the development of methods for summarising and synthesising complex statistical tables. With this in mind, recent developments in the field of computer mapping and computer graphics should be exploited in the development of the information analysis system so that, wherever possible, the results are presented in visual form to the user.

3.2. Flexibility and consistency in data handling

The amount of detail that is potentially required by users is a fundamental design issue in the development of information analysis systems. Although data is collected by the local authorities and assembled at the Central Bureau of Statistics on the individual level, users are not permitted to have access to information at this level of aggregation because of privacy considerations. Even if a compromise could be found which protects the privacy of the individual, the costs that would be involved in data handling are likely to be far greater than the benefits that might arise from access to records at this level of detail.

As the tasks of data collection are handled at the local authority level it is best to operate in the first place at this level of spatial detail. This brings with it problems in that local authorities in the Netherlands vary in terms of population size from less than one thousand in some cases
up to three-quarters of a million in cases such as Amsterdam. Because of this there are serious differences with respect to the level of spatial detail that is available from local authority population register sources and special consideration must be given to ways in which the smaller local authorities can be combined for data presentation purposes so that some of the most extreme differences are eliminated. In the case of small local authorities demographic information is automatically available at a very fine degree of spatial detail. In the case of the larger authorities information is supplied to the Central Bureau of Statistics only for the authority as a whole. The authorities themselves often process it to a finer level of spatial detail for their own use but this varies in scope and content from one authority to another. Proposals have been made for the development of a standard referencing system based on 500 by 500 metre grid squares to overcome these problems, but relatively little information is available so far on this basis with respect to population change.

A major task in the development of an information analysis system will be to guarantee consistency and comparability in the data as far as this is possible. This means that special attention must be given to the integration of material that is drawn from sources other than the population registers. The problem of consistency also arises where there are changes in boundaries and definitions over time and records must be organised in such a way that they can be re-aggregated with as little difficulty as possible.

3.3. Methods and Techniques

Three main types of information analysis can be identified. These deal with retrospective analysis, prospective analysis and analysis for side-effects respectively. Retrospective analysis involves the comparison of observed developments with the expectations of planners and policy-makers. Prospective analysis deals with the anticipated consequences of observed trends for the future. This seeks to identify new and expected tendencies as well as to clarify the implications of these developments in terms of existing planning goals. The analysis of side-effects is concerned with repercussions of deviations between expected or preferred developments either on other regions or on other policy fields.

In a large number of cases standard routines can be developed for all three of these types of analysis in the light of the requirements that have been specified by the users. These routines will consist of a series of instructions concerning the variables to be selected, the degree of aggregation that is desired, the types of analysis that are to be carried out, the way in which the results are to be presented to the user and the frequency with which the task is to be carried out.

In addition, a wide variety of methods and techniques must be incorporated in the information analysis system so that users can carry out more detailed studies if they wish to deepen their insight into the processes of population change. These include not only standard statistical techniques such as correlation and regression analysis but also mathematical models of spatial demography. (Baxter and Williams, 1978; Masser, 1978; Willekens and Rogers, 1978). These models can serve three roles within this analytical framework:
1. As a formal accounting framework for data collection and presentation.
2. As a tool for more detailed and systematic analysis of a particular data set. This role is illustrated and described with reference to a worked example in Masser and Scheurwater (1976).
3. As a means of interpolation and disaggregation where detailed or up to date data is not available.

It must be emphasised that the information analysis system as set out above is concerned essentially with the treatment of quantitative information. Consequently it refers only to the activities that are described in the middle and right-hand columns of Figure 1 and attention must also be given to the specification of tasks with respect to the treatment of qualitative information.

3.4. Description of the basic components of the information analysis system

The basic system will consist of five main components (Figure 3):

1. The data access modules that specify the information that is required from the data base,
2. The aggregation procedures that are required to group this information into the classes that are required by the user,
3. The statistical methods and techniques that are needed to carry out the analyses,
4. The summary measures which are required to present the results of the analysis in a condensed form,
5. The presentation techniques that control the form of the output of the results to the users.

The main objective of the current phase is to establish the basic framework of the information analysis system and to test it in operational conditions.

For this purpose, the information analysis system as sketched in Figure 3 has been developed in a version that is primarily directed to the most urgent needs of the National Physical Planning Agency in relation to the monitoring of the urban development processes. The experience that is gained in information processing and analysis in this phase will be the basis for modifications and extensions of the information analysis system in subsequent phases of the research.

It is therefore felt to be essential, to receive maximal feedback of the users of the information and a special questionnaire has been developed to accompany each information flow to make sure that this feedback is generated. The feedback that is essential for the development of the system is concerned with the policy areas, the priorities, the usage and the presentation of the information. Based on information about these issues it is hoped to be able to set priorities for the next phase of development and to gain insight in items as: which variables are the key variables, what level of detail of information is required and what level of prior analysis is regarded most useful.
FIGURE 3 The main components of the information analysis system
Apart from the structuring of the information analysis system in the next phase, based on the above mentioned feedback, the capacity of the system will be expanded by the incorporation of new data sets and by the inclusion of a wider range of statistical methods and techniques related to multi-regional demography. The second phase will also include the transfer of the information analysis system to the National Physical Planning Agency in such a way that it can be operated, maintained and updated by them on the completion of the research project.

4. CONCLUSIONS

Some of the main issues that are involved in the development of an information analysis system have been discussed in this paper in the context of a research project that is being carried out by the authors in the Netherlands. Because the nucleus of an information storage and retrieval system already exists in the continuous population registers that are maintained by the local authorities in this case it is possible to give much more attention to user requirements and to work towards the implementation of an information analysis system which can be used for monitoring purposes. This is of special importance to policy-makers because of the significance that is attached to monitoring activities in connection with the implementation of the policies that are contained in the Third Note. The present study is essentially concerned with making much better use of existing information sources than has previously been the case. It is necessarily confined to demographic processes because of the existence of a continuous population register system but it might be argued that the information analysis system developed in this framework can also provide a useful means of integrating material from other sources that is required for monitoring purposes.

It must be emphasised that only the preliminary phase of this research project has been completed and that the task of implementation of the system is still in progress. The practical value of the system under development is, however, potentially considerable, as it can be used as a general framework for analysis of spatial data. By its incorporation within the Dutch National Physical Planning Agency a national wide information basis is provided which can not only serve the Agency as a continuous and consistent source, but also develop into a reference system for provincial planning agencies and a basis for research scientists that are concerned with spatial development processes.

5. REFERENCES

Masser, I. (1978), Planning and migration research, Working paper 9, Institute for urban and regional planning, University of Utrecht, The Netherlands.
This paper summarises the main findings of the first stages of a research project which has been commissioned from the authors by the Dutch National Physical Planning Agency (Rijksplanologische Dienst). It should be emphasised that the views and opinions that are presented in this paper are those of the authors alone and that they do not necessarily represent those of the National Physical Planning Agency. A more detailed discussion of the points raised in this paper is available for Dutch speaking readers in Scheurwater (1979).
A METHOD FOR MONITORING LAND USE PLANNING IMPLEMENTATION:
A CASE STUDY OF AN ISRAELI STATUTORY PLAN

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1. INTRODUCTION

This paper is concerned with the improvement of implementation of urban planning. Specifically, it focuses on "traditional" statutory land use planning, which, despite the criticism meted at it (justified as that criticism may be) is still the predominant style of mandatory regulative planning in many western countries - including Holland, Israel and even the U.K. (in the latter local plans still have an overwhelming mark, despite the introduction of structure plans (Healey, 1979)).

The purpose of the present paper is twofold: First, the paper aims to study plan implementation empirically, in the hope of learning something about the process and about what may be done to improve plan performance. For this purpose, a method of measuring and analysing degree of implementation in the case-study is proposed and applied. Second, this paper is concerned with the improvement of monitoring techniques. It is hoped that the method proposed for measuring degree of implementation could be applied as a useful approach to the monitoring of planning decisions. In order to set the stage for the second objective, the paper begins with a brief review of the various types of monitoring in relation to the process planning approach in the context of statutory land use planning.

2. PROCESS PLANNING, STATUTORY PLANNING AND MONITORING

Few planners today would question the view that planning ought to be regarded as an on-going process, rather than being concerned with the production of end-state plans prepared on a one-shot basis (Robinson, 1965; Bolan, 1967; Perin, 1967; Faludi, 1973).

However, the process view of planning is only a canopy-concept, under which one may find a variety of approaches. At one extreme, the process view of planning has served as a justification for the virtual abandonment of the plan-making function altogether, in favor of a fluid approach to incremental policymaking (see for example Rondinelli, 1973). However, even if one has much sympathy for this view, one must realize that it cannot be applicable to all types of planning. Such a notable exception is statutory land use planning, which is mandatory in most western countries. Being a regular government function which impinges on private property, economic wellbeing, mobility, etc., statutory plans are expected to introduce a measure of reliability and predictability into the relationship between government and the various private and public operating bodies. One would thus expect that plans would constitute a responsible, well thought-out statement of policy which is expected to be relatively stable and to be effective in guiding on-going decisions in the 'public interest'.

Can the process view of planning be reconciled with the statutory plan-making function? This reconciliation is not easy, but attempts have been made. Once can probably cite the British shift away from the more rigid development plans to the more broad-stroked structure plans, as one attempt at this reconciliation. This has probably also been one of the
more influential attempts and has been recommended in other countries as well (for Israel, see Alterman, 1980a). Yet, one may note in passing, structure planning has not been devoid of criticism and some have noted (McAuslan, 1975:55) that it lacks the attributes of predictability and commitment which, as we noted above, are expected to be attached to statutory plans.

The growing attention devoted in recent years to the concept of monitoring and to the development of suitable monitoring techniques (Haynes, 1973; Harris & Scott, 1974) can also be viewed as part of the effort to reconcile plan-making with the need for a flexible process approach. Significant advances have been made in this area, especially in England and notably in the realm of statutory structure planning (Rose, 1978).

Growing experience in the construction and application of monitoring systems has led to the need for better conceptualization. It has been recognized that monitoring is not a monolithic concept, implying a uniform approach to the input of information. Wedgewood-Oppenheim et al (1976) distinguish between three types of monitoring: implementation monitoring, which is concerned with feedback information on the degree to which the plan in question is being implemented in accordance with its policies; impact monitoring, which is concerned with the evaluation of the effect of implementation with a view to possibly adjusting the means so as to achieve the stated goals better; and strategic monitoring, which is based on feed-forward information and is used for on-going policymaking where there is no plan in the traditional sense.

It is clear that statutory planning can benefit greatly from the first two types of monitoring. Implementation monitoring is necessary if the planning authority is to obtain some feedback on the extent to which the plan is being implemented. This type of monitoring would enable the planning authority to assure that the approved plan is implemented, thus strengthening the statutory plan's function of predictability and reliability. However, this type of monitoring on its own does not enable the adjustment of planning policy so as to meet new needs or to set new goals through a careful process of decision-making. For this, one would need to set up impact monitoring. Furthermore, it is proposed that planning bodies required to make on-going decisions about plan effectuation, would do well to adopt an additional type of monitoring, what we term self-consciousness monitoring. This type of monitoring is intended to focus inwards, and supply information to the decision-making body on its own pattern of decisions, the underlying assumptions and trends, the relationship with the plan, etc. (Alterman, 1975:164-168).

The method of measuring on-going planning decisions described in this case-study may be viewed as an approach to implementation monitoring and with proper supplements, to impact monitoring as well. At the same time, this method, with the addition of the statistical model, can also be utilized as a method of self-consciousness monitoring.

3. THE ISRAELI STATUTORY PLANNING SYSTEM

Local plans in Israel, as required by the Planning and Building Law 1965\(^1\), are intended to be the major regulative tool for directing and moulding urban development. The Law makes a distinction between outline (master) and detailed plans. An outline plan is akin to a traditional British development plan\(^2\), and is in many respects like the Dutch "bestemmingsplan" (Faludi & Hamnett, 1977), usually specifying permitted land uses in particular zones and covering the entire municipal area.
Detailed plans, on the other hand, designate land uses and site layout more specifically and reflect ongoing decisions. These plans are usually initiated by private or public developers. Normally, in order for a building permit to be issued, the detailed plan submitted earlier must accord with the outline plan—or else an amendment must be approved. The decision-making is carried out according to a two-tier system, whereby the decisions of the local planning commission must be approved by the district planning commission. This legally-required procedure has served as a source of data for the purpose of measuring the degree to which the outline plan in the case-study has been effectuated over the years.

In many respects the case-study selected, the outline plan for the Krayot area, a satellite town conurbation on the Mediterranean coast north of Haifa (see Figure 1), meets the requirements almost ideally. The present total population of about eighty six thousand is that of a medium size city by Israeli standards; yet it is not so big as to be unmanageable for the research purposes. The Krayot is a conurbation of three municipalities: Yam, Motzkin, and Bialik, which have been designated to fall under one joint local planning commission. The differences among these towns in terms of the mixed socioeconomic characteristics of the population and the varied types of housing, constructed by both the public sector and the private sector, enrich the case-study by providing what is almost a microcosm of Israeli society.

The outline plan is not too old, yet provides a long enough period for testing (since 1964). It is in the rigid style of conventional land use planning still predominant in Israel, specifying, in addition to the main road network and the land uses generally permitted in the various areas, the maximum permitted densities as measured by floor-area ratios (FAR) and often the maximum permitted building heights (see Figure 2). Yet at the same time it represents one of the better efforts of Israeli town planning of its time. Its roots lie in a plan prepared for the area in the 1930s by the British planner Sir Charles Abercrombie. The general lines of this plan were followed in the late 1950s by a planning consultant who undertook a comprehensive planning study considered very advanced for its time (Baruth 1958). Although the official version of the plan was prepared much more conventionally by another consulting architect, some of the initial influences seem to have seeped through.

![Figure 1. Regional location of Krayot](image)
At the time of the plan's preparation, the Krayot was a suburban area with low- to medium-density housing (0.5 to 0.75 FAR). The plan as finally approved contained two widely differing proposals: for the areas which at the time were not yet build up, it proposed residential density of 0.87 to 1.0 FAR, a density regarded as quite high at the time; while for the areas which were already built up, it proposed to maintain the existing suburban character and low densities.

All in all, then, the plan, which recognized market pressures by enabling greater densities, also placed a clear limit on densities, and accommodated these differentially. Furthermore, although higher densities were allowed in new areas, these were probably lower than what would have occurred in an unfettered market situation. The plan thus was intended to be a mechanism for controlling and directing development. This study attempts to measure to what extent it in fact fulfilled this function.

We assume the case-study to be quite representative of the majority of outline plans in Israel, and although we cannot of course generalize our conclusions to all urban areas, we wish to draw some preliminary conclusions pertaining to desirable planning approaches that could have improved chances of implementation in our case-plan and could do likewise in other cases. The method developed may be applied generally to the construction of a monitoring system.
4. THE MEASURE OF DEGREE OF EFFECTUATION

Our operational measure of effectuation, which could also serve as a method for implementation monitoring, is obtained by means of a comparison of the land use and development specifications of the outline plan with all the detailed or amendment plans submitted in the period 1964-1974. This comparison is carried out by the division of the area into a uniform grid of cells (one hectare each)*, and the registration of accordances and deviations by area for each category of land-use specifications. This yielded a matrix of "transitions" from the outline plan to the detailed plans by land use categories. The diagonal registers accordances (see Figure 3).

Figure 3. Schematic matrix of transformations in planned land uses (matrix LUSE_i)

\[
\begin{array}{c|c|c|c|c}
 & j = 1 & j = 2 & j = 3 & j = n \\
\hline
\text{From} & \text{To} & \text{From} & \text{To} & \text{From} & \text{To} & \text{From} & \text{To} \\
\hline
i = 1 & & & & & & & \\
i = 2 & & & & & & & \\
i = 3 & & & & & & & \\
i = n & & & & & & & \\
\end{array}
\]

The measure proposed does not purport to measure what actually happens on the ground, since, due to time-lag and other technical problems, this would be difficult indeed. Furthermore, this method does not register illegal building. However, although illegal construction is by no means rare in Israel (Alexander, Alterman, Law Yone, 1979), it usually pertains to small-scale private extensions; the larger transgressions are usually approved after-the-fact. It is believed that the method proposed, which registers planning-administrative decisions, thus provides a suitable method for measuring the degree of plan effectuation. We termed the measure ACCORDANCE.

5. TRANSITION MATRIX OF LAND USES

Table 1 shows Matrix LUSE - the transition in planned land uses from the outline plan, to the aggregate of detailed plans (1964-1974). The units are percentages of total area in dunams** for each land use category - i.e., the measure here is unweighted, every type of change being regarded as equal to any other type of change. An attempt at weighting will be presented later.

* One hectare = 10 dunams = approx. 2.5 acres.

** 1 dunam = 1000 sq. meters = 0.25 acre (approximately).
Table 1. Matrix LUSE—transitions in planned land uses from outline plan to detailed plans as % of total area in each land use category

<table>
<thead>
<tr>
<th>Detailed plans</th>
<th>OPEN SPACE</th>
<th>ROADS -50%</th>
<th>ROADS -75%</th>
<th>ROADS -87%</th>
<th>ROADS -100%</th>
<th>RES.</th>
<th>PUB. BLDG</th>
<th>COMM.</th>
<th>LT. INDUS</th>
<th>INDUS.</th>
<th>TOTAL AREA (in dunams)</th>
<th>TOTAL PCT</th>
</tr>
</thead>
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<td>OPEN SPACE</td>
<td>56.7</td>
<td>0.8</td>
<td>2.0</td>
<td>5.3</td>
<td>17.0</td>
<td>0.2</td>
<td>2.5</td>
<td>6.4</td>
<td>1.3</td>
<td>5.9</td>
<td>1.8</td>
<td>393</td>
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<tr>
<td>ROADS</td>
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<td>91.3</td>
<td>1.7</td>
<td>0.4</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>35.7</td>
<td>24.7</td>
<td>16.7</td>
<td>0.2</td>
<td>0.2</td>
<td>22.5</td>
<td>395</td>
</tr>
<tr>
<td>RES. -75%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.3</td>
<td>64.1</td>
<td>15.3</td>
<td>0.8</td>
<td>2.8</td>
<td>0.1</td>
<td>715</td>
</tr>
<tr>
<td>RES. -87%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td>1.7</td>
<td>1.2</td>
<td>1835</td>
</tr>
<tr>
<td>RES. -100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RES. HI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.0</td>
<td>62.3</td>
<td>18.2</td>
<td>6.5</td>
<td></td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>PUB. BLDGS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>COMM.</td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>134</td>
</tr>
<tr>
<td>LT. INDUS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>INDUS.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FUTURE</td>
<td>10.4</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>452</td>
</tr>
<tr>
<td>AREA</td>
<td>376</td>
<td>221</td>
<td>243</td>
<td>926</td>
<td>1317</td>
<td>161</td>
<td>856</td>
<td>200</td>
<td>90</td>
<td>712</td>
<td>402</td>
<td>5504</td>
</tr>
<tr>
<td>TOTAL PCT</td>
<td>6.8</td>
<td>4.4</td>
<td>4.1</td>
<td>16.8</td>
<td>23.9</td>
<td>2.9</td>
<td>15.6</td>
<td>3.6</td>
<td>1.6</td>
<td>12.9</td>
<td>7.3</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The categories are those appearing in the outline plans, as best interpreted. Those needing further definition are defined below:

- **RES. -50%**: Residential, up to 50% floor-area ratio, 2-3 floors.
- **RES. -75%**: Residential, up to 75% FAR, 3-4 floors.
- **RES. -100%**: Residential, up to 100% FAR, 3-4 floors.
- **RES. -87%**: Residential, up to 87% FAR, calculated for large projects with no height limit.
- **RES. HI**: Permits higher density residential, with no density or height limitations.
- **PUB. BLDGS.**: Public buildings, such as school, community centers, synagogues.
- **COMM.**: Commercial areas.
- **LT. INDUS.**: Light Industrial; not operationally distinct from INDUS.
- **FUTURE**: To be planned in the future; no designation at present.

*FAR = floor area ratio.

**Accordance**—same land use **Accordance**—transition to lesser but permitted use.
Before turning to the analysis of the patterns emerging from the matrix as a whole, it may be worthwhile to dwell on some of the highlights in the data, noting the trends that have occurred in the urban system.

5.1. Degree of implementation

The overall degree of accordance is 66% of the area (if we exclude the FUTURE category, the number declines somewhat to 63%). It may thus be said that during the 11-year period covered by the present study, about two-thirds of the Krayot area that has fallen under some detailed plan has followed the outline plan.3

5.2. Accordance by Land-Use Categories

The pattern of degree of accordance by land use may be of interest, and is as follows (extracted from Table 1):

Table 2. Accordances (in pct. of area in each land use category)

<table>
<thead>
<tr>
<th>Land Use</th>
<th>OPEN SPACE</th>
<th>ROADS</th>
<th>RES.</th>
<th>RES.</th>
<th>RES.</th>
<th>RES.</th>
<th>RES.</th>
<th>PUB.</th>
<th>COMM.</th>
<th>LT.</th>
<th>INDUS.</th>
<th>INDUS.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-50%+</td>
<td>-75%+</td>
<td>-87%+</td>
<td>-100%+</td>
<td>Hi. BLDGS.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>57%</td>
<td>91</td>
<td>36</td>
<td>74</td>
<td>78</td>
<td>64</td>
<td>93</td>
<td>52</td>
<td>60</td>
<td>74</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

+These denote a percentile version of the Floor-Area-Ratio.

Among the various intensities of residential use we find a general trend that where the larger the floor-area ratio permitted, the greater is the degree of accordance with the outline plan. The only exception is RES-100%, and that may be due partially to problems of interpreting the intentions of the plan regarding number of floors permitted once land assembly has been undertaken.

Among the non-residential uses we find that the two public uses--OPEN SPACE and PUB. BLDGS.--have had the greatest encroachment (despite public land ownership). These land uses have been transformed into uses with higher direct economic returns. The category of ROADS has very high accordance, indicating the importance the decision-makers seemed to have attributed to the roads demarcated by the outline plan. Finally, the three categories indicating economic activity (LT. INDUS, INDUS, and COMM.) have intermediate accordance, with COMM. being the lower of the three.

5.3. The Pattern of Transitions in Residential Land Use

If we aggregate all the residential land uses, it may be observed that the overwhelming proportion of areas designated as residential (of one intensity or another), have remained in that use category—as much as 93%. Residential land-use as a whole is also the major recipient of transformations from non-residential categories.

In all categories excepting ROADS and COMM., most changes are to residential land uses. In the case of roads and commercial uses, residential is the second-largest recipient. It is thus apparent that,
contrary to the recommendation of the plan, there is an increasing allo-
cation of land for residential uses in the Krayot. These findings seem to
indicate that the Krayot--which had been planned as a self-sufficient town
with its own industrial area and services--is increasingly becoming
"suburbanized", being drawn under the influence of Haifa. The outline
plan apparently did not predict these trends and is now finding it
difficult to contain the pressures for change.

A large portion of the total transitions that have occurred through
the years have been due to conversion to higher-density residential use.
RES.-HI has absorbed as much as 24.6% of the area that has undergone any
change. This is not surprising if we note, on the one hand, that housing
in Israel is a lucrative investment and, on the other hand, that in the
last decade, there has been increasing acceptance of high-rise apartment
blocks (which constitute 30% of the RES.-HI category). Generally, the
higher the intensity of the original residential category, the more often
is it changed to a higher intensity yet; this is especially notable regard-
ing RES.-85% and RES.-100%. Among the non-residential uses, PUB.BLDGS.
has changed to RES.HI most often, with all the implications this substi-
tution is likely to have had for the amount and quality of public services.
Another public use category, OPEN SPACE, has shown few transformations to
RES.HI but has rather tended to change to residential use of middle density
or to light industry and public buildings.

What is the meaning of these patterns? First, they point to the need
on the part of the decision-makers to clarify or redefine goals. If the
goals of the initial plan are still regarded as tenable, then better
controls ought to be devised for those land uses that tend to be trans-
formed into more lucrative uses. For example, the district planning
commissions could adopt a policy whereby every case of requested reduc-
tion in public areas would undergo a special procedure of scrutiny,
beyond that required by the Planning and Building Law. Alternatively,
once the decision-makers have become aware of their own pattern of
decision-making, they might wish to redefine goals, and then to intro-
duce a new policy (amended plan) regarding the more susceptible land uses.

6. THE PATTERN OF CHANGES IN LAND-USE MARGINAL TOTALS

6.1. The Coefficient of Dissimilarity

Although our measure of effectuation pertains to localized land
uses where both the 'origin' and the 'destination' of each cell in the
matrix are known, it may be of interest to see to what extent the supply
of each land-use area has changed within the urban region as a whole, dis-
regarding location. This can be achieved by looking at the marginal totals
of Table I. A measure has been proposed for comparing two percentage
distributions, called the Coefficient of Dissimilarity.$

Applied to the present problem, it would read:

$$\text{DISSIM.} = \frac{\sum_{i,j=1}^{n} |LUSE_i - LUSE_j|}{2} = 26, \quad \text{when } i = j$$

where LUSEi and LUSEj are the total area in land use categories i and
j, respectively.

Cumulation of the absolute percent differences in the marginal
distributions yields DISSIM = 26.$ The converse is (100 - 26) = 74,
which is higher than the degree of accordance. This means that if we disregard location of the land use in question but consider its existence anywhere in the city as implementation of the outline plan, then the degree of effectuation aggregated over time is quite high, higher yet (as may be expected) than if we require the land use to locate in the specific place as designated.

6.2. Description of the Changes in Marginal Totals

The coefficient of dissimilarity shows the tendency for detailed planning to maintain the approximate total area assigned in the outline plan for each land use, providing it anywhere else in the urban area. However, there are variations among land use types.

A comparison of the marginal totals in Table 1 shows that there has been very little decline in the total area of planned OPEN SPACE. That is, while there has definitely been encroachment on the areas specifically designated as open space in the outline plan (with an accordance of only 57%), this does not register in the land use totals, since other areas have been provided instead. Such additions do not necessarily fulfill the same open-space function: for example, a stadium and an agricultural-school farm are part of the additional area, without having appeared in the outline plan; while open space in areas conceived originally as "green paths" from the seashore inward, have declined. By using the location-specific measurement in most of our analysis, we have adhered to the plan's terms-of-reference and have avoided the evaluative question of deciding whether the function envisioned for open space is being fulfilled despite the transformations.

The area planned for ROADS has remained strikingly the same. There has been a general adherence to the routes of main roads demarcated in the outline plan, with very few additions (and only some small detours).

The two categories often regarded as 'amenities'--PUB. BLDGS. and COMM.--have both increased, possibly reflecting the rise in the standard of living and the concomitant change in accepted norms for planning public facilities. At the same time, it should be remembered that both these categories have a relatively low degree of location-specific ACCORDANCE, indicating that some of the area initially in these two categories has yielded to development pressures and has been transformed into other uses.

The conclusion to be drawn for better planning is that the outline plan's stipulations have not made it possible to think of public services in quantitative and normative terms (after all they depend on sizes and types of populations as well as generally changing styles) while leaving specific locational decisions to the detailed planning stage. Because the traditional approach which had been adopted could apparently not avoid arbitrariness in specific locations, many deviations have occurred even though the total quantities of land allocated have remained surprisingly similar.

The two types of industrial use show opposite trends. While LT. INDUS. has increased significantly, INDUS. has declined. Because the distinction between the two is not made clear in the plan, it is perhaps more meaningful to add the two together, noting that there has been almost no change in the joint area.

The discussion will now return to the full transition matrix.
7. SMALLEST SPACE ANALYSIS OF LAND USE TRANSITIONS

7.1. Introduction to SSA-1

The description up to now has pointed to some of the relationships, without attempting to comprehend the full matrix all at once. That would have been a difficult task to accomplish unaided. But on the basis of the full matrix transition data, we would have liked to obtain answers to questions such as: which land-use categories have a strong 'affinity' (in terms of likelihood of transition) for other particular land uses? Do they tend to cluster into groups? Is there some underlying structure? SSA may help us to obtain some of the answers.

The various versions of Smallest Space Analysis proposed by Louis Guttman, are a set of techniques that may help to provide answers to these questions. The techniques attempt to fit the data into a Euclidean space of minimum dimensions (hopefully two or three so that they can be visually comprehended), while yet maintaining as best as possible the monotonicity condition which, in the case of SSA-I version, is:

\[
\text{distance } (a,b) < \text{distance } (c,d) \text{ whenever } \text{corr. (a,b)} > \text{corr. (c,d)}.\]

The SSA-I version is applicable to square, symmetric matrices---i.e., the two halves split by the diagonal are the same. As inputs it may take correlations, distances, percentage distributions, or raw frequencies. The rank-order comparison among the entries is undertaken over the matrix as a whole.

A second version, SSA-II, is applicable to asymmetric matrices, i.e., the two halves of the matrix are not the same (although it must be square in this case too). That is, where \( \Pr (a|b) \neq \Pr (b|a) \), the monotonicity condition is:

\[
\text{distance } (a,b) < \text{distance } (b,c) \text{ whenever } \Pr (a|b) > \Pr (b|c).\]

The rank-order comparison whereby the distances are calculated is undertaken not over the whole matrix, but rather within each row or column separately. The algorithm attempts to map the best arrangement of points in the minimum number of dimensions, so as to maintain the rank-order of each row as best as possible. In both methods, only off-diagonal elements enter the computation.

Both SSA-I and SSA-II will be applied, serving different purposes suited to their differing attributes. SSA-I will be used to describe the structure of the land-use transition matrix; SSA-II will be applied to derive weights for the various transformations.

7.2. SSA-I Analysis of the Matrix LUSE

The SSA-I technique is suitable for describing the LUSE transition matrix in raw form since it compares each cell entry with all other cells, applying the rank-order criterion over the whole matrix. Because the technique applies to symmetrical matrices, it has been necessary to 'fold' the raw transition matrix over the diagonal, summing every pair of opposite cells into a single cell. The matrix used here
was not the row percentages described in Table 1, but rather the raw numbers matrix (or, equivalently, the percentages of the grand total).

The SSA-I solution is reproduced in Figure 4 for the 2-D space. The measure of goodness of fit, the Coefficient of Alienation, is 0.19, which is satisfactory. For the 3-D solution, it is 0.11, considered to be a good fit. It so happens that the 3-D solution maintains the basic structure of the 2-D case, only adding further refinement to it, to be described below. The 3-D solution is reproduced in Figure 4.

From the 2-D solution, we may learn something about the underlying policy of trends of land use transitions. A division down the center of the space may be observed, separating the land use categories along the RESIDENTIAL-NON-RESIDENTIAL dimension (excepting LT. INDUS. which falls in the residential 'region'). The mapping also shows a tendency for low-density residential uses to cluster separately, 'away' from the higher-density residential uses. OPEN SPACE and PUB. BLDGS. are located close to each other, as are INDUS. and COMM. This means that, on the one hand, residential uses generally show 'affinity' for each other in terms of likelihood of substitution more than for non-residential uses, and, on the other hand, that there are differences within the two major land-use types, with clustering by density or intensity of use.

This general split is maintained in the 3-D solution, but an added dimension appears: the 'affinity' of INDUS., LT. INDUS. and COMM. for higher-density residential (RES.-100% and RES.HI), and the affinity of OPEN SPACE and PUB. BLDGS. for low-density residential (RES.-75% and RES.-50%). The ROADS category tends toward separation (because of the scarcity of any transitions) in both the 2-D and the 3-D solutions.

It is interesting that even though the problem at hand pertains to substitution of one land use for another, rather than location side-by-side, the pattern emerging from the SSA analysis of planned land-use transitions strongly reminds one of the traditional notions of land-use planning regarding proximity in location, notions that have guided planners for decades and have only in recent years been questioned. These notions have been based on assumed 'compatibility' between uses, having their origins in conceptions about assumed nuisances and economic effects. On the North American planning scene, these concepts have through several decades received legal expression in court decisions about the legitimacy of planning or zoning and have been extensively documented (see Delafons, 1969; Heyman, 1970; Mandelker, 1970; Adler, 1971; Siegan, 1972). Siegan

**Figure 4. SSA-I two-space solution to distribution of planned land-use transitions**

![SSA-I two-space solution to distribution of planned land-use transitions](image-url)
has attempted to show that even when zoning regulations are not used, the underlying economic and life-style factors are so strong that they tend to reproduce a similar pattern of land use. On the basis of these concepts, traditional planning has for many years tended to separate residential from most non-residential use; and, if location of residents near a commercial or industrial area cannot be avoided, to further isolate the various densities of residential use from each other, permitting the higher-density uses to locate in proximity to certain non-residential uses. 12

It would appear that the decision-makers and planners have perceived deviation from the outline plan in terms of accepted and somewhat old-fashioned concepts about desirable and undesirable contiguity of land-uses. They have tended to permit deviations more often and in greater amounts where the distance, so to speak, from one to the other in terms of desirability of contiguity in location has been smaller. It is likely that this tendency reflects the decision-makers' unarticulated feeling that if the outline plan has designated the original land use as it has, it has done so on the basis of these very concepts of "good" planning, and that they ought to be adhered to as much as possible. Thus, it seems that the original plan still had some trace of influence on the decisions--even though these decisions were in fact about deviations from the plan.
8. SSA-II APPLICATION TO THE PROBLEM OF WEIGHTING LAND USE TRANSITIONS

8.1. The Dilemma of Assigning Weights

To this point, it has been assumed that a unit of change in planned land-use from X to Y has the same weight as a unit of change from Y to Z; and that transition from X to Y has the same weight as transition from Y to X, the land units each receiving a weight of 1.

However, it may be contended that not all changes are equivalent, whether in terms of the underlying motivations for the transition, or in terms of their urban impact. For example, deviation from planned open space to industry may not be of the same weight (by whatever criteria) as deviation from open space to residential use, and, furthermore, a change from planned open space to industry is not equivalent to a change from industry to open space.

Unfortunately, the solution to the weighting question is not easy. Although several methods of ranking come to mind—such as by land value, traffic generation or amenity—they would all require the introduction of external and possibly arbitrary assumptions to be used to study other people's reasoning. To avoid the role of judge of others' decisions (even if it be a judge armed with information), we decided to focus on the aggregate of decisions about land-use changes made by the appropriate local planning bodies, and to attempt to draw out the set of weights that may underlie these decisions, without subjecting them to any further evaluation. After all, the decision-makers were acquainted with local conditions at each point in time, better than a researcher who has to reconstruct the situation.

One may assume that by looking at the macro scale of the decisions (i.e., all detailed plans together), whatever regularity might exist is likely to emerge from the analysis. The derived set of weights could then be projected back to each individual case of decision-making regarding each detailed plan. The rationale underlying this procedure is analogous to the comparison of some local pattern (such as dwelling density) with some average, macro datum which serves as a standard (such as the equivalent national figure).

8.2. The SSA-II Solution to Land-Use Transitions

The SSA-II method is more suited than SSA-I to the problem of assigning weights because rather than comparing the rank-order of transformations over the whole matrix, it compares the rank-order within every row. That is, the solution tries to find the optimal arrangement of the points in minimum dimensions, putting together the distributions for each land-use. When looking at the relationship of any given point to the others, one is in fact looking from the 'point of view' of each land-use. It is important to adopt this point of view because some land-uses require large areas, while others need only small bits of area; and a transition is not a-priori of less importance just because it pertains to a small area. Another advantage of SSA-II for this problem is that it operates not on the 'folded' semi-matrix, but on the entire asymmetrical LUSE matrix, attempting to find the pattern that takes into account changes from X to Y and from Y to X separately.

The solution with 11 land-use categories (excluding FUTURE) yields an acceptable goodness-of-fit for the 2-D solution (Coefficient of Alienation of 0.14). The 2-D mapping is reproduced in Figure 6.
The weights were obtained thus: each land-use category serving as the
starting point in turn, the shortest linear distances were drawn between
it and all other points; these distances were ranked ordinally, in each
case separately, the shortest receiving a score of 1 and the longest a
score of 5, intermediate distances being ranked at possible increments
of 0.5 (see example in Figure 6).13 This procedure produced a set of
rank-ordered scores for each land-use category of the outline plan in
combination with each detailed-plan category. The weights served as multi-
pliers for the land-area percentage in each cell of matrix LUSE for every
detailed plan. A new variable, called SSAW, was constructed so as to be
equivalent to the reciprocal of ACCORDANCE.

8.3. Sensitivity to Weighting

The sensitivity to the new weights has been checked by comparing
the degree of ACCORDANCE with SSAW for all cases of detailed plans sub-
mitted for approval. The correlation between SSAW and ACCORDANCE is as
high as 0.87. The similarity in the results leads to the conclusion
that the macro-level of the decisions (which underlies the SSAW measure)
and each micro case, generally do not differ too much. Thus, the obser-
vations made in the unweighted analysis still hold. Nevertheless, the
theoretical problem of weighting does exist, and weights could make a
difference. Further analysis of other possible methods is beyond the
present work, but is undoubtedly desirable.
9. IMPLICATIONS OF THE FINDINGS FOR PLANNING

With reservation due to the fact that we have analysed only one case-study, we have drawn the following preliminary conclusions.

The (master) outline plan in our case-study is a conventional land-use plan consisting of a land-use map and an attached set of definitions and regulations regarding permitted uses, heights, floor area ratios, plus some special controls.

This type of planning has in recent years been the target of criticism (Perin, 1967; Rondinelli, 1973; Kaplan, 1973:104-105), and is widely regarded as having poor chances of implementation. This opinion draws support from the numerous variations, exceptions and deviations often cited (Ross, 1972; Kramsowiecki, 1970; Siegan, 1972:13-16; Delafons, 1969:24).

There are ample reasons for this criticism. The traditional style of land-use planning is said to be static, end-state oriented, insensitive to ongoing changes in the urban system, as well as narrowly physical and devoid of substantive and clear policy statements that could guide policy in a more relevant fashion (Branch, 1971; Perin, 1967). It is therefore no wonder that the process planning approach has gained wide acceptance. This general approach has tried many and differing suggestions, from the call to strengthen short- and middle-range planning (Branch, 1971; Robinson, 1965), through the calls for greater flexibility in planning style (PAG, 1965; Alterman, 1980a), up to an almost complete denial of the use of plan-making along with a view that the planner's role is to be an advisor for urban affairs and crisis-management (Friedmann, 1971; Rondinelli, 1973). All these approaches depend to some extent on monitoring of one type or the other.

Although the plan was quite conventional in size and lacked a monitoring system, we nevertheless found 63% accordance in the area which had undergone detailed (site) planning. From the analysis of the mutual relationships among land use changes, we found signs that seem to point to a desire on the part of the decision-makers not to deviate too "far" from the land use in the master plan, in a manner analogous to accepted conceptions about compatibilities of contiguous land uses. Paradoxically, although some of these conceptions are regarded as outdated today, the decision-makers seem to hold them, hoping thereby to render the deviations they have in fact approved, somehow less "offensive". Thus, despite its many shortcomings, there is no doubt that the plan has had a significant impact in shaping development.

At the same time, we also found many deviations. By analysing the patterns these present, we hoped to provide information which could shed light on desirable planning approaches that could reduce deviations.

Clearly, the plan has not been able to cope with the changes in the urban system, in residential, commercial open-space and other uses.

From our findings, some conclusions could be drawn about desirable approaches to flexibility in land-use planning. The master plan, it so happened, embodied two differing approaches. On the one hand, there were areas which were planned in a very detailed fashion, stating the development rights for virtually every lot of land. On the other hand, there were wide areas (especially those not yet built up) where the plan...
indicated only overall permitted density, allowing service and amenity uses to locate anywhere in the area, without pre-designation. However, although in the latter case flexibility in location was ensured, the problem was that the plan lacked any quantitative or qualitative specification of norms or amounts of service area, and of the desired locational policy (in programmatic rather than geographic terms).

Both these approaches turned out to be deficient in the light of our findings regarding degree of effectuation. In areas where the first approach was adopted, we found many digressions in the location of specific commercial or public uses, a fact which probably reflects changes in concepts about the desirable distribution of services. In areas where the second approach was applied, we found a somewhat higher degree of accordance, but nevertheless discovered many deviations in the overall permitted density which, due to the lack of norms and locational policies about public services, would leave the decision-maker without any indication about the implications of these changes for the quantity and quality of public services.

One may conclude at this point that, where the land-use planner deems it important that the plan should have long-range effect, he/she should attempt to identify those specifications whose determination at present is crucial for regulating future development. These should be worded in general terms without being location-specific, thereby opting for 'foot-loose' policy specifications so long as precise geographic location seems arbitrary. This is not to say that more specific policies are unnecessary; on the contrary, they are of much importance, but for the shorter-range, and usually for plans covering less than the total urban area. Our findings thus point out in the direction of the strategic planning or 'mixed scanning' (Etzioni, 1967) approach. They also seem to lend justification to changes in style of planning and land-use control such as have been introduced in Britain in the 1968 Town and Country Planning Act, where a shift has occurred from the conventional development plan to the structure plan (Heap, 1969:41-43), or to the trends in the U.S. calling for greater flexibility in zoning through approaches such as 'floating' zones (Heyman, 1970; Delafons, 1969:53-54; Woodbury, 1975).

But a more flexible, a more strategic plan, is not enough to answer the need for continuous planning. Alongside substantive flexibility in the plan, the need for ongoing evaluation, review and updating would be necessary. Several approaches to continuous planning may be cited (Altermann, 1980b).

One approach to continuous planning requires periodic updating through a short-range plan. This type of approach has been adopted by the recent American Model Land Development Code (Section 3-105), which requires the preparation of a Land Development Report for a range of 1 to 5 years, without which the long-range plan is not in force. However, some may consider this approach too rigid and perhaps arbitrary.

Other, more flexible approaches to continuous plan review depend heavily on the input of information from a well-constructed monitoring system. At the beginning of this paper, we drew the distinction between several types of monitoring. It is believed that the method described in this case-study could serve as a basis not only for implementation...
monitoring, but with proper supplements enabling evaluation of the impact of decisions, also for impact monitoring. Furthermore, we noted above that an additional type of monitoring should also find recognition - what we called 'self-consciousness monitoring', enabling decision-makers to monitor their decisions, and to become aware of their underlying assumptions. This type of monitoring is, we believe, especially important where statutory regulative planning is concerned, that is, where we would wish the decision-makers to be especially aware of the cumulative effect of their decisions, vis-a-vis the statement of approved public policy embodied in the plan. The method proposed here enables not only the measurement of degree of implementation, but, because it is based on the decisions made rather than on intervention on the ground, it can also (with the aid of the appropriate statistical models) point out the trends in decision-making, as well as some of the underlying assumptions.

FOOTNOTES

1. The Law was the offspring of the Town Planning Ordinance of 1936. Although some significant changes were made in the new law, especially with respect to national land-use planning, for the present purposes the two laws could be regarded as more or less the same. For a description of planning law in Israel, see Gouldman (1966), Strong (1971) and Katin and Virshubsky (1975).

2. For a description of the British Development Plan see, for example, Reynolds (1965) and Keeble (1969):37-45. Through the 1936 Ordinance Israel has imported the basic concepts and procedures of British town planning. The new Israeli Law of 1965 still bears marked resemblance to the 1947 British Town and Country Planning Act (Clarke, 1949); for a comparison with more recent legal changes see Telling (1977): 52-58. For a statement of the recent approach to urban planning, see Solesbury (1974):125-135; and Sharpe (1975).

3. In order to test whether the accordance between the outline plan and the detailed plans might be due to chance rather than the influence of the plan, we calculated the statistical correlation between the area allocated to each land use in each detailed plan and the parallel area in the relevant section of the outline plan, and found that for almost all the uses the correlation was over 0.45 and was statistically significant at the 0.001 level and better.

4. In the case of INDUS., we regard transformation to LT. INDUS. as a permitted lower intensity, especially because the planning administrators did not seem to make meaningful distinctions between the two categories, often placing the latter in areas designated for the former without specifying the substantive difference.


6. Here the category FUTURE has been excluded in order to maintain the symmetry—but this makes little difference.

7. See for example the exposition in Milton Bloombaum (1970); many and varied examples of the application of SSA-I and II are available, e.g., Mortimer (1974), Laumann and Guttman (1966, for SSA-II), Elizur (1970) and Guttman et al (1967).
When searching for a suitable method for the present purposes, we scanned literature on social mobility, having found that the nature of the problem has many aspects similar to our own: frequent presentation in the form of a transition matrix; distinction between mobile (deviations) and immobile (accordances); and an inherent rank-order among the occupational or educational categories. This area has also been a subject of many attempts at methodological innovations, from which we hoped to benefit. We found there the use of the Coefficient of Dissimilarity and SSA, both of which have also been applied in the present work (see Blau and Duncan, 1967).

8. This criterion applies to data of "similarities". For data based on "dissimilarities" the signs of inequality are reversed.

9. For a mathematical presentation of the method where algorithms are derived, see Guttman (1968) and Lingoes and Guttman (1967).

10. In other words, we had to make the assumption that changes from $x$ to $y$ and from $y$ to $x$ are in some way comparable. Although this assumption is not always reasonable, we feel the method would still be useful, since it provides some answers about the underlying relationship between land uses, a relationship that is not dependent on direction of transition.

11. The decision-rules are fluid, depending on the extent to which an added dimension substantially improves the solution. See Bloombam (1970). Coefficients as high as 0.21 are sometimes still considered acceptable by researchers associated with Guttman (e.g., 1973 book by E. Katz - "Israel's Leisure Culture", in Hebrew).

12. For an example of how some of these concepts have found expression in land-use planning and urban design, see Keeble (1969):214; 222-224.

13. Because of the monotonicity condition, the SSA should be interpreted from an ordinal, rather than an interval point of view.

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1. INTRODUCTION

This paper is a result of a research project undertaken by the research centre for physical planning TNO (PSC-TNO). The aim of the study was to develop a regional demographic model and a monitoring system for such a model. The project was started in 1977 within the framework of the National Demographic Research Program. The National Physical Planning Agency co-sponsored the project.

In this paper emphasis is laid on methodological issues in the developments of a monitoring system for a forecasting model. The features of the multi-regional demographic model will only be briefly described (section 2). In section 3 the necessity of monitoring is treated with the principle and meaning of forecasting as basis. Next monitoring is further elaborated in terms of its functional performance. In section 5 is described what demands monitoring makes on the formulation of forecasting models. The practical aspects of a monitoring system and its use in the planning context are then treated before the concluding remarks.

2. SHORT DESCRIPTION OF THE DEMOGRAPHIC MODEL

Briefly, the multi-regional demographic model has the following features:

- a cohort survival model, with disaggregation into one-year age groups, sex and forty regions;
- hierarchy with respect to the results of the national model of the Central Bureau of Statistics (CBS);
- births calculated using age-specific fertility rates which take regional differences into account;
- age- and sex-specific death rates without regional differences;
- a provisional submodel to forecast the in- and outmigration of the regions. Immigration forecasts are based on the observed (age- and sex-specific) structural immigration rates in the past and on the observed relation between housing production in a region and its volume of immigration. So mover-pools are created. The filling of these mover-pools is based on the observed structural shares (again age- and sex-specific) of the regions in these mover-pools in the past;
- regional foreign migration is calculated by breaking down the (CBS-forecasted) in- and outmigration by age and sex over the regions.

Compared to traditional demographic forecasting models an important extension was given by an attempt to prepare the forecasts as probability distributions. The parameters are treated probabilistic. Problems encountered with this approach were both practical and theoretical.
A practical problem consisted of the necessity to run the model many times with random numbers in order to generate a probability distribution. The main theoretical problem is the correlation between deviations in time (autocorrelation), space and between subsequent age-groups. This problem is still unsolved.

3. MONITORING A FORECASTING MODEL

"The only thing we can be sure of regarding forecasts is that they are wrong". This somewhat provocative statement can be defended as far as "traditional" forecasting is concerned.

What determines accuracy in forecasting and what are the sources of error? Jan Hoem (1973) and Keyfitz (1977) sum up six sources:

1. Estimation and registration errors
2. Pure randomness
3. Random vital rates (for example due to mild winters)
4. Unincorporated gradual changes
5. Gross shifts in mean vital rates (for example a medical breakthrough)
6. Serious model mis-specification (for example the neglect of (foreign) migration)

The amount of uncertainty caused by the first three sources can be estimated in principle by using statistical techniques. The impact of sources four and five cannot be quantified ex-ante. For both the time of occurrence and the amount of change cannot be foreseen. These sources of deviation require that one keeps a close watch over the actual developments by means of a monitoring system.

The error-source last named can be traced in advance by considering whether the model is able to reproduce the population development for a known period.

We draw two conclusions on the ground of the above arguments. The first is that a population forecast should never be given as a point estimate, but must be formulated as a probability distribution. In this paper we do not elaborate on this further. The interested reader is referred to the work of Passel (1976), Schwader (1973) and Sykes (1966). The second conclusion is this, Because of the lack of knowledge about the future and the need to detect unforeseen changes as early as possible, it is necessary to monitor the actual development closely.

4. THE FUNCTIONS OF A MONITORING SYSTEM

A monitoring system is defined as a system for the (semi) continuous evaluation of the (population) forecast in the light of the actual (demographic) development; for the analysis of the observed deviations therefrom and for testing the impact for the forecast.

The functions of a monitoring system include:

a) signaling: systematic data collection and the comparison of the actual with the forecasted development (testing);

b) analysis and evaluation of the collected information: to determine and evaluate the consequences of the differences between forecasted and actual development;

c) reporting the results to the users; and in some cases advising of the measures to be undertaken.
In a wider context also the amelioration of the monitoring system (monitoring the monitoring) can be seen as a part of the monitoring system.

5. DEMANDS UPON THE FORECASTING MODEL

During the study it turned out that the effective and efficient functioning of a monitoring system makes some methodological claims upon the forecasting model.

First of all the purpose of the forecast should be known. If the user is interested in the number of people in the age-groups 65 and over in the year 2000, then monitoring of birth-rates is not necessary. If one million people difference is within the policy margins of the user, a simple monitoring system can suffice. Demands concerning the user are defined as follows:

(1) The purpose for which the forecasting model is (or has to be) developed has to be explicitly stated, regarding:
- the (partial) populations at issue;
- the relevant points in time; and
- the required accuracy of the forecast, considering the relevant populations and points in time (policy-margins).

The second demand is somewhat obvious, but necessary:
(2) The model-structure and the hypothesis underlying the model must be explicitly stated.

The third demand is not trivial but almost always not satisfied:
(3) The statistical properties of the model parameters must be made explicit in terms of their probability distribution. We illustrate this demand with an example:
Suppose the population at risk is 100,000 and the death-rate is .000401, then the model stipulates that there will be 40.1 deaths. Apart from its impossibility, would the hypothesis be falsified if you observe an actual number of 35? It is more realistic (see also section 3) to treat the death rate as a binomial parameter, so that the forecast becomes a probability distribution. In that case realizations between 30 and 50 have a common probability of 90 percent.

The fourth demand is especially important for the efficient functioning of the monitoring system:
(4) Through sensitivity-analysis the effects of changes in parameters should be studied. The sensitivity of the forecast with respect to a given parameter and the statistical properties of that parameter are used to determine the critical parameters of the model. These are the parameters which should receive the most attention in the monitoring system.

The activities called for by these four demands are closely related to the work to be done to develop the forecasting model. Hence it is recommended to incorporate the monitoring-aspects in the preparation of the forecast. Our own experience is that through the explicit formulation of hypotheses, the specification of statistical properties etc. there is a positive influence on the quality of the forecasting model.
An example of the monitoring of some model parameters
regional fertility ratio's

Analysis of data showed important differences in age specific fertility rates between the forty regions. These differences were expressed in the ratio between the Total Fertility Rate (TFR_r) for the region r and the Total Fertility Rate of the Netherlands as a whole (TFR_N). Thus we define the Regional Fertility Ratio's (RFR_r) as:

\[ RFR_r = \frac{TFR_r}{TFR_N} \]  

(1)

Statistical analysis of the data of the last five years show no convergence nor divergence of these ratio's. For this reason and because no theoretical arguments run to the contrary, the ratio's were held constant in the forecasting period.

Of course the regional fertility ratio's showed some spread around their means. From this a measure of the standard-deviation was calculated. A forecast of the regional fertility ratio's was thus obtained. In applying the monitoring system for the year 1975 this forecast was confronted with the actual regional fertility rates as shown in figure 3.

The solid line represents the expectation; the dashed lines mark the 95% confidence-interval. Although the RFR_r of two regions fell outside the confidence-interval, the hypothesis of stable regional fertility ratio's could not be rejected. Hence the forecast was not revised on this part of the model.

*Fig. 1. Forecasted and observed values of the regional fertility ratio's for the forty regions*
6. PRACTICAL ASPECTS OF THE MONITORING SYSTEM

First of all an information system has to be developed. An excellent example is described in the preceding paper by Scheurwater and Masser. In fact our monitoring system can be plugged in their system without difficulty.

Secondly a program has to be written by which actual parameters such as birth- and death-rates are calculated from the data supplied by the information system. This program can be seen as a kind of dual model of the forecasting model.

Thirdly routines have to be developed for confronting the actual parameters with the forecasted ones and their statistical margins (testing). Major deviations have to be analysed.

A fourth step is to perform impact-analysis. One of them is to repeat the forecast, starting at the moment of monitoring using the then observed population-volumes and maintaining the original hypothesis about the parameters.

\[\text{DATA SYSTEM} \rightarrow \text{CALCULATION OF ACTUAL PARAMETERS} \rightarrow \text{CONFRONTATION OF ACTUAL AND FORECASTED VALUES} \rightarrow \text{RESULTS} \]

\[\text{IMPACT-ANALYSIS} \rightarrow \text{POSSIBLE ANALYSIS OF TREND-DEVIATIONS ETC.} \rightarrow \text{USER INFORMATION ABOUT CHANGED POLICY-MARGINS ETC.} \rightarrow \text{REPORT} \rightarrow \text{USER} \]

\[\text{REVISE FORECAST?} \rightarrow \text{REVISE HYPOTHESES IF NECESSARY} \rightarrow \text{RENEW THE FORECAST} \rightarrow \text{REPORT} \rightarrow \text{USER} \]

Fig. 2. The main components of the monitoring process

On the basis of the information gathered in this way a decision has to be made whether to maintain the original forecast or to renew the forecast. In case gradual changes or gross shifts in vital rates are detected (see error sources 4 and 5 in section 3), further analyses have to be performed. Now
hypothesis concerning the parameters may be the result. The impact of the new hypotheses on the forecast has to be analysed. Before taking the decision whether or not to renew the forecast it is advisable to consult the user. The requirements could possibly have changed.

For efficient functioning it is advisable to use the system stepwise, from crude to refined. For non-critical parameters one can stick to the crude level in case only minor deviations are detected. Care should be taken concerning the possibility of compensating errors in critical variables.

The last phase of the monitoring process is to report to the user. Here too it is advisable to use a stepwise approach. First the main developments and a general conclusion about the performance of the model. Second a closer look on those components which are causing trouble and an insight in the possible consequences for the forecast. Depending on the particular wishes of the user, more detailed data can be supplied or an advice given. The user should not be supplied with too much data.

As mentioned before, the functioning of the monitoring system itself should be evaluated periodically.

7. USE IN A PLANNING CONTEXT.

Only in pure Demography are population forecasts a goal in itself. Usually population forecasts are used as a vital information in a planning process. In principle each different planning-purpose poses different demands on the population forecasts. Among others:

1. the geographical units in the specific planning area;
2. the specific population-categories one is interested in;
3. the time-periods and the time-horizon;
4. the required accuracy of the forecast; and
5. the frequency and level of detail of monitoring.

In section 5 these user-requirements were discussed. Here the last two are briefly further elaborated. Not for every purpose a forecast has to be as accurate as possible. It is a matter of efficiency to balance the quality of the population forecast with the required accuracy in relation to other elements in the planning-process. For example if the planning-purpose is directed to the energy-supply in the year 2000 a rather crude model of the total population will suffice. On the other hand for the planning of services for basic-education in a city, a detailed model is needed. Likewise the monitoring-effort put in the population monitoring must be balanced and paced with the other elements in the planning-process. In figure 3 the position in process-planning of the population forecast and the associated monitoring-system are shown. It seems redundant to remark that we see planning not as planning for an end-state but as process-planning.

Organisationally we think that a monitoring-team should consist of:

- the user of the results of the forecast to provide the information about (changing) policy-margins etc. The involvement of the user in the team leads to a higher level of understanding if the forecast has to be revised "again". Also this involvement will lead to a better (more justified) use of the forecast;
- the supplier of the data for an adequate data-supply. This provides also an insight into the quality of the data;
- the operators of the forecasting model.
8. CONCLUSION

In this paper we described our experiences with the development of a monitoring system for population forecasts. We think that most of the findings are also applicable to the monitoring of other forecasts. The development of a monitoring system appeared to be desirable and very well possible. It is our opinion that such an investment, when integrated in a process-planning context, will prove to be profitable in terms of forecasting-quality and policy-usefulness.

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I. INTRODUCTION

It is well-known that the existence of a plan does not guarantee that its objectives will be fulfilled. Many additional legislations and accompanying controls are needed. Planners can play an active role in supporting these additional activities, for instance by assessing and evaluating new developments in the plan area and by periodically updating the plan content. The so-called monitoring phase in a planning process is therefore receiving an increasing attention (see, inter alia, Barnes, 1976; Haynes, 1974; Hedgwood-Oppenheim et al, 1975).

In this article a methodical framework will be developed to monitor a regional plan with respect to its environmental objectives. This monitoring framework is especially based on a growing concern for the environmental situation in the northern part of the Netherlands, called the Waddensea region (see Bastemeijer and Voogd, 1979). Recently a new plan has been developed, which is based on the goal to maintain the high environmental and ecological qualities of the Waddensea. This means that this plan embodies some wishful thinking, which lays a heavy burden on the Dutch legislation. At present this legislation is capable of refusing those activities that do not meet certain environmental standards. However, these standards are only dealing with primary effects. The spatial distribution of effects, synergistic effects and the cumulation of effects are not taken into consideration. This might imply a further deterioration of one of Europe's most unique natural environments, unless in short term a thorough refinement of the various legal standards is achieved.

This article concentrates on the key issues that are essential for such a refinement. In the next section an elaboration is given of the basic principles of an environmental monitoring model. This framework will be formally worked out in section 3. It will be shown that environmental modelling is hampered by several implementation problems. This is discussed in section 4. With these implementation problems in mind a new monitoring model will be outlined in section 5. The postscript of this article is devoted to some final remarks and conclusions.

2. ENVIRONMENTAL MONITORING

An environmental monitoring model has to give a systematic representation of the relations between the various socio-economic activities and the environmental-ecological system. This model must especially be capable to trace the potential damage to an area's air, water, land and ecological resources caused by a change in the human activity pattern. Such an improved monitoring capability is needed to provide planners responsible for the approval of new activities with a clearer understanding of the environmental consequences.

The main question to be answered by an environmental monitoring model can be formulated as follows: to what extent will a proposed change in the human activity pattern affect the quality of the various "nature" groups? In other words, what are the environmental consequences of, for instance, the introduction of a new activity or the extension (i.e. increase) of existing activities? A comparison of these consequences and a priori formulated standards should enable the decision-making agency to reject or accept a proposal under consideration.
The basic principles of an environmental monitoring model are intuitively not so difficult to grasp. Suppose there are a number of human activities in a certain area (e.g. fishing, industries, shipping, recreation). Each activity will raise to some extent a number of effects, which together might have several impacts on the environment (e.g. air pollution, noise, water pollution). The various nature groups are also interrelated by means of a complex system of ecological links. The presence of certain species of birds, for example, will depend on the presence of certain species of fish. As is well-known, the human activities show similar relationships, whereas some activities will also be influenced by the quality of certain nature groups. For instance, fishermen need fish to perform their profession. To some degree the success or failure of some activities will also be based on the impacts generated by other activities. For example, some recreational activities will not welcome an increase of water pollution. The various interrelations can be visualized as follow: see Figure 1.

Figure 1. A Global Illustration of the Interrelations between Human Activities and Nature

Figure 1 shows that an environmental monitoring model has to cope with a rather complex system of cause-effect relationships. In the next section will be discussed how these relations might be made explicit.

3. A FORMAL EXPLORATION

In order to take into account spatial differences in environmental impacts the study-region should be divided into a number of homogeneous zones \( z (z=1,2,\ldots,Z) \). The first step in each monitoring procedure is to make an inventory of the actual human activities in the area. Suppose each activity \( k (k=1,2,\ldots,K) \) can be expressed in a number of "units" (e.g. labourers, productivity, boats, etc.). This implies that a following activity-matrix \( A \) (of order \( K \times Z \)) must
be constructed:

\[
A = \begin{bmatrix}
  a_{11} & \cdots & a_{1z} & \cdots & a_{1Z} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  a_{k1} & \cdots & a_{kz} & \cdots & a_{kZ} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  a_{K1} & \cdots & a_{Kz} & \cdots & a_{KZ}
\end{bmatrix}
\]  

(3.1)

where \( a_{kj} \) denotes the number of "units" of activity \( k \) in zone \( z \). On the other hand there should also be insight in the environmental qualities of the area concerned. This means that another matrix, to be called a nature matrix, \( B \) (of order \( N \times Z \)) should be created:

\[
B = \begin{bmatrix}
  b_{11} & \cdots & b_{1z} & \cdots & b_{1Z} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  b_{n1} & \cdots & b_{nz} & \cdots & b_{nZ} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  b_{N1} & \cdots & b_{NZ} & \cdots & b_{NZ}
\end{bmatrix}
\]  

(3.2)

Its elements \( b_{nj} \) represent a quality indication with respect to nature group \( n (n=1,2,\ldots,N) \) and zone \( z \). As is outlined in the preceding section, the elements of \( A \) and \( B \) might influence each other by the impacts \( i (i=1,2,\ldots,I) \) that are generated by the various activities. These impacts are also zonedependent and can be denoted as \( c_{iz} \). Together they form an impact matrix \( C \):

\[
C = \begin{bmatrix}
  c_{11} & \cdots & c_{1z} & \cdots & c_{1Z} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  c_{i1} & \cdots & c_{iz} & \cdots & c_{iZ} \\
  \vdots & \ddots & \vdots & \ddots & \vdots \\
  c_{I1} & \cdots & c_{IZ} & \cdots & c_{IZ}
\end{bmatrix}
\]  

(3.3)

Evidently, the impact matrix is strongly time-dependent. This will influence the spatial distribution of the impacts and its higher-order effects. In impact and forecasting research this is usually taken into consideration by means of a linear model (see, among others, Cliff and Ord, 1975; Nijkamp, 1976 and Haggett et al., 1977). An example of such a model can be represented mathematically by the following matrix equation:

\[
v_{t+1} = v_{t} + w_{t+1}
\]

where:

\[
v = \begin{bmatrix} v_{t} \end{bmatrix} \]

(3.4)

\( v_{t} \) = a column vector (of order \( Rx1 \)) of forecasted levels \( v_{r} \) of each variable \( r (r,r' = 1,2,\ldots,R) \) at time \( t+1 \) (\( t = 0,1,2,\ldots \))
\( Q_t \) is a cross-impact matrix (of order RxR) of causal interrelations \( q_{rr'} \) among the various variables at time \( t \).

\( w_{t+1} \) is a column vector (of order Rx1) of primary impacts \( w_{r} \) expected at time \( t+1 \) as a consequence of proposed new land use activities scheduled for that time.

It is easy to see that in case no new activities are taken into consideration model (3.4) then changes into:

\[
Q_t \cdot v_t = w_{t+1}
\]

In order to substitute the information embodied by (3.1)-(3.2) and (3.3) into (3.5) a new matrix \( V \) must be created:

\[
V = \begin{bmatrix}
A

B

C
\end{bmatrix}
\]

Because zonal interrelations should also be taken into account, we have to rewrite matrix \( V \) as a vector \( v \) of order \( R \times 1 \), where \( R = (K + N + I) \cdot Z \).

This implies that instead of (3.6), we will use:

\[
v' = \begin{bmatrix}
v_1

v_2

v_3

\vdots

v_{t-1}

v_{t+1}

\vdots

v_{t'+1}

\vdots

v_R
\end{bmatrix}
\]

Consequently the cross-impact matrix \( Q \) has now the following structure:

\[
Q = \begin{bmatrix}
q_{11} & \cdots & q_{1r'} & q_{1r'+1} & \cdots & q_{1r} & \cdots & q_{1R}

\vdots

q_{r'1} & \cdots & q_{r'r'} & q_{r'r'+1} & \cdots & q_{r'r} & \cdots & q_{r'R}

q_{r'+11} & \cdots & q_{r'r'+1} & q_{r'r'+1+1} & \cdots & q_{r'r'+1} & \cdots & q_{r'+1R}

\vdots

q_{R1} & \cdots & q_{Rr'} & q_{Rr'+1} & \cdots & q_{Rr} & \cdots & q_{RR}
\end{bmatrix}
\]
where each \( q \) equals the quantity of change in the \( r \)-th element caused by a unit change one time-interval earlier in the level of the \( r' \)-th element. Or:

\[
q_{rr'}^t \bigg|_{t+1} = \frac{\Delta v_r \big|_{t+1}}{\Delta v_{r'} \big|_t}
\]

where \( v_r \big|_{t+1} \) is the level of the \( r \)-th element (i.e. activity, impact or nature group in a particular zone) at time \( t+1 \), and \( v_{r'} \big|_t \) is the level of the \( r' \)-th element at time \( t \).

By substituting (3.7) and (3.8) into (3.4) or (3.5) and by applying the model for various time periods \( t (t=1,2,\ldots,T) \) the possible consequences of a proposed activity can be monitored. This activity must be rejected if the model results do not meet the a priori formulated standards with respect to the \( v_r \) values.

4. SOME IMPLEMENTATION PROBLEMS

A more extensive treatment of the foregoing linear model in relation to an environmental impact assessment can be found in, inter alia, Antonini et al, 1974 and Schlesinger & Daetz, 1975. The implementation of this model will be hampered by several problems. In this section the main difficulties of model (3.4) and (3.5) are outlined and discussed. It will be shown that another modelling concept is necessary in order to arrive at an operational environmental monitoring tool. Such a new approach must be able to take into explicit account qualitative information and special characteristics of the impacts. The following arguments in favor of this conclusion can be given:

a) Assessment problems

In model (3.4) or (3.5) is assumed that the elements of \( v \) and \( Q \) can be measured on a metric (i.e. ratio) scale. Many variables undoubtedly will meet this condition. However, especially the environmental variables can often not be assessed on a ratio scale. Mostly only an ordinal scale can be used, which means that common arithmetic procedures are not allowed. This implies that the nature component - what is supposed to be the "hard-core" of the model - will be treated in a theoretically inconsistent way.

b) Partial versus integral modelling

An environmental monitoring model is supposed to be a partial model, i.e. a model that mainly focusses on the interrelations between human activities and nature. The cross-impact matrix \( Q \), however, assumes that all interrelations are taken into consideration. In other words, in stead of a partial model actually an integral model will be developed. This can be illustrated by clarifying the various blocks of matrix \( Q \) (see formula (3.8)):

\[
Q = \begin{bmatrix}
\text{INTER-} & \text{ACTIVITY-} & \text{ACTIVITY-} \\
\text{ACTIVITY-} & \text{NATURE-} & \text{IMPACT} \\
\text{EFFECTS I} & \text{EFFECTS II} & \text{EFFECTS III} \\
\text{NATURE-} & \text{INTER-} & \text{NATURE-} \\
\text{ACTIVITY-} & \text{IMPACT} \\
\text{EFFECTS IV} & \text{EFFECTS V} & \text{EFFECTS VI} \\
\text{IMPACT-} & \text{IMPACT-} & \text{INTER-} \\
\text{ACTIVITY-} & \text{NATURE-} & \text{IMPACT} \\
\text{EFFECTS VII} & \text{EFFECTS VIII} & \text{EFFECTS IX}
\end{bmatrix}
\]
Evidently, in an environmental monitoring model attention should be mainly concentrated on the blocks III and VIII. By paying equal attention to the other blocks not only an enormous amount of data should be collected (which included assessment problems!) but also an untraceable amount of additional measurement and modelling errors are introduced. The result is that in stead of the expected increase of accuracy a very "uncertain" outcome will result without almost any practical value.

c) The aggregation problem

The linear model operates as specified in equation (3.4) or equation (4.2) below:

\[ \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_R \end{bmatrix}_{t+1} = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{1R} \\ q_{21} & q_{22} & \cdots & q_{2R} \\ \vdots & \vdots & \ddots & \vdots \\ q_{R1} & q_{R2} & \cdots & q_{RR} \end{bmatrix}_t \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_R \end{bmatrix}_t + \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_R \end{bmatrix}_{t+1} \] (4.2)

Each constituent equation of (4.2) is a linear expression such as:

\[ v_{1t+1} = q_{11t} v_{1t} + q_{12t} v_{2t} + \cdots + q_{1Rt} v_{Rt} + w_{1t+1} \] (4.3)

The linearity of the coefficients \( q_{\cdot\cdot\cdot\cdot} \) as is assumed in equation (3.9) is debatable since in some cases non-linear coefficients are more appropriate. However, this refinement can reasonably be incorporated. Equation (3.9) can for instance be altered such that the elements \( q_{\cdot\cdot\cdot\cdot} \) depend on the level of the elements \( v_{\cdot\cdot\cdot\cdot} \) itself without structural change of the model.

The key problem in applying (4.2) lies in the linearity of the combining terms (i.e. the addition). There are several elements \( v_{\cdot\cdot\cdot\cdot} \) for which a simple addition of the values is incorrect. For example, if the difference in noise-levels from two separate sources is larger than 10 dBA the aggregated noise-level equals the highest noise-level. If the difference is smaller than 10 dBA the aggregated level will be the highest noise-level plus 3 dBA minus one-third of the difference between the two sources. In other words: the aggregation is often much more complicated than in (4.2) is assumed. Ideally, an unique function for each element \( v_{\cdot\cdot\cdot\cdot} \) should be used to combine simultaneous influences from cross-impacts of several elements, i.e.:

\[ v_{t+1} = f_r(v_1, \ldots, v_R, w) \] (4.4)

However, in this case another monitoring model have to be developed since model (4.2) is now not valid anymore.

d) The time decomposition problem

In model (3.4) is assumed that a time-unit \( t \) has been specified. Also a time horizon \( T (t=1,2,\ldots,T) \) must be postulated. This is the latest time \( t \) for which the environmental system is to be monitored. It is obvious that the values for both the time-unit and the time-horizon are rather arbitrary. Nevertheless, this choice will affect the model results. For example, if a small time interval duration is used probably a more accurate description of the fluctuations in interrelations can be given (e.g. seasonal influences can be captured). However, since this will result in an increase of the number of iterations to arrive at time \( T \), the decrease of measurement errors might at the same time cause an increase of the output "uncertainty" due to the addition of errors from the modelling procedure. On the other hand, a large time interval is less appropriate since this undoubtedly will increase the amount of errors in the cross-impact matrix \( Q \).
5. TOWARDS A SIMPLIFIED ENVIRONMENTAL MONITORING MODEL

In this section a framework will be developed to come to a new environmental monitoring model, which is able to overcome most of the problems mentioned in the preceding section. The first step is to construct an activity matrix $A$ (cf. formula (3.1)) and a nature matrix $B$ (cf. formula (3.2)). Also the impact matrix $C$ (formula (3.3)) is used, although its elements will be assessed in a completely different way compared to the procedure described in section 3. This will be elaborated below.

It is assumed that each activity $k$ ($k=1,2,\ldots,K$) will produce some effects on the environment (e.g. noise, discharge of toxic metals, air pollutants). These effects $e$ ($e=1,2,\ldots,E$) can be integrated into a consequence matrix $H$ (of order $K \times E$) where:

$$H = \begin{bmatrix} h_{11} & \cdots & h_{1e} & \cdots & h_{1E} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ h_{k1} & \cdots & h_{ke} & \cdots & h_{kE} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ h_{K1} & \cdots & h_{KE} & \cdots & h_{KE} \end{bmatrix}$$ (5.1)

Its elements $h_{ke}$ represent the amount of effect $e$ that one unit activity $k$ will generate in a certain period. A combination of the consequence matrix (formula (5.1)) and the activity matrix (formula (3.1)) will give an idea of the total amount of effect $e$ that is produced in zone $z$. Of course, in that case the specific addition rules of the various effects should be taken into account. The resulting scores $p_{ez}$ can be included in an effect-production matrix $P$ (of order $E \times Z$) with the following structure:

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1z} & \cdots & p_{1Z} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{ez} & \cdots & p_{ez} & \cdots & p_{ez} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{E1} & \cdots & p_{EZ} & \cdots & p_{EZ} \end{bmatrix}$$ (5.2)

Matrix $P$ contains the primary effects produced in a certain period and in a certain zone by various human activities. For reasons described in the preceding section we do not want to elaborate all possible cause-effect relationships. For an approval or rejection of a new activity it is sufficient to consider only the changes in the pattern of impacts in relation to the environmental qualities embodied by the nature matrix. Therefore it is necessary to determine the spatial distribution of the effects included in matrix $P$. Suppose that an effect $e$ is produced in zone $z'$ in the quantity $p_{ez'}$. This might affect zone $z$ to a degree $\delta_{ez}$ which is defined as:

$$\delta_{ez} = f_e(p_{ez'}, d_{zz'})$$ (5.3)

where:

- $d_{zz'}$ = the distance between zone $z$ and zone $z'$
- $f_e$ = the distribution function for effect $e$

It is assumed that the strength of an effect will decrease the farther it is removed from the source. Some well-known examples are noise and most air
pollutants. However, there are also effects which tend to accumulate (e.g. some toxic metals). For these effects must be assumed - since the time-element is not explicitly treated in this approach - that

$$\delta_{ez'} = p_{ez'}$$ \hspace{1cm} (5.4)

This seems a very reasonable assumption, because the use of (5.4) will undoubtedly result in a disapproval of the proposed activity, unless certain measures can be undertaken to remove that particular effect.

Evidently, zone z may not only be influenced by effect e of zone z' but also by the same effect from other zones. Together these influences, determined by (5.3) or (5.4), will create a total external effect $\xi_{ez}$, which is an effect-specific function $g_e$ of the various influences:

$$\xi_{ez} = g_e(\delta_{e_1}, \delta_{e_2}, \delta_{e_3}, \ldots, \delta_{ez'}, \ldots, \delta_{ez}) \quad (z' \neq z)$$ \hspace{1cm} (5.5)

It is easy to see that for some effects (e.g. the number of recreants) a single additive function is sufficient, i.e.:

$$\xi_{ez} = \delta_{e_1} + \delta_{e_2} + \delta_{e_3} + \ldots + \delta_{ez}, + \ldots + \delta_{ez} \quad (z' \neq z)$$ \hspace{1cm} (5.6)

For each zone a total effect score $\varepsilon_{ez}$ can now be calculated:

$$\varepsilon_{ez} = g_e(\delta_{ez'}, p_{ez})$$ \hspace{1cm} (5.7)

For reasons of convenience will for this moment be assumed that the impact categories i (i=1,2, ..., I) are similar to the effect categories e (e=1,2, ..., E), i.e. I = E. (It should be noted that this assumption is not strictly necessary and it is not always valid, e.g. in case of synergistic effects). The elements of the impact matrix C are now known, i.e. $c_{ez} = \varepsilon_{ez}$.

The appraisal of the impacts depends on their consequences for the various nature groups and on the environmental quality in a particular zone. The consequences can be globally summarized in an influence matrix $X$ (of order $I \times N$) where:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{11} & x_{12} & \cdots & x_{1N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{11} & x_{12} & \cdots & x_{1N} \end{bmatrix}$$ \hspace{1cm} (5.8)

The elements $x_{in}$ represent a qualitative (i.e. ordinal) impression of the degree in which impact $i$ might affect nature group $n$. In other words: matrix $X$ only contains ranking information.

The quality of the various nature groups in a particular zone is already given by the nature matrix $B$ (cf. formula (3.2)). Its elements $b_{nz}$ can for instance be assessed on a seven-points scale (e.g. with the semantic differential method). By means of a comparison of nature matrix B and impact matrix C a new matrix can be constructed, which is called a conflict matrix $Y$. This matrix is of order $(I \times N) \times Z$ and its elements $y_{inz}$ represent the degree of conflict between impact $i$ and nature group $n$ in zone $z$. The structure of $Y$ is as follow:
where:

\[ y_{inz} = f(b_{nz}, c_{iz}) \]  \hspace{1cm} (5.10)

Since the shape of function (5.10) is rather arbitrary, it is desirable to use only the global (i.e. ordinal) characteristics of the \( y_{inz} \)-scores.

In fact, matrix \( Y \) and \( X \) embody a multicriteria evaluation problem (see, among others, Nijkamp, 1977 and Voogd, 1980). The zones represent the choice-possibilities, whereas the various impact-nature group combinations can be considered as the criteria. The elements of \( X \) can be seen as the criterion weights. This implies that we are now able to calculate an overall conflict score for each zone. Given the ordinal nature of matrix \( X \) and \( Y \) the use of a qualitative multicriteria method is recommended. A practical method to treat large evaluation problems is the numerical interpretation method (see e.g. Voogd, 1980). Suppose for notation convenience that the various impact-nature (i.e.: \( i \) versus \( n \)) combinations are represented by the index \( j \) \((j, j'=1, 2, \ldots, J)\) where \( J = N \times Z \). The first step is then to formulate for each pair of zones \((z, z')\) a \( J \times J \) matrix \( U_{zz'}^{ij} \) with elements \( u_{zz'}^{ij} \), where:

\[
U_{zz'}^{ij} = \begin{cases} 
1 & \text{if } y_{jz} > y_{jz'} \text{ and } x_{j} > x_{j'}, \\
0 & \text{if } y_{jz} = y_{jz'} \text{ and } y_{jz} = y_{jz'} \text{ and } x_{j} = x_{j'}, \\
\text{otherwise} & \text{in all other cases}
\end{cases}
\]  \hspace{1cm} (5.11)

The various matrices \( U_{zz'}^{ij} \) can be integrated into a new matrix \( M \) (of order \( Z \times Z \)) with elements \( m_{zz'} \), where:

\[
m_{zz'} = \sum_{j} \sum_{j'} u_{zz'}^{ij} \]  \hspace{1cm} (5.12)

The overall conflict score \( \gamma_z \) for zone \( z \) can now be defined as:

\[
\gamma_z = \sum_{z'} m_{zz'} 
\]  \hspace{1cm} (5.13)

Obviously, zone \( z \) is more affected by the human activities as \( \gamma_z \) is higher.
6. POSTSCRIPT

The environmental model elaborated in the preceding section has on purpose a very simple structure since more sophisticated "dynamic" models appear to be rather useless due to the poor availability and quality of data in planning practice. Therefore is in this article an approach advocated, which enables the planner to evaluate a proposed activity in the light of all other activities in the area without the necessity to construct numerous time-series. Because qualitative information can be very easily incorporated it can be concluded that this approach offers a very good starting-point to come to a straightforward and meaningful monitoring tool.

The methodological framework developed in this article might also be of valuable assistance in the formulation of so-called Environmental Impact Statements regarding specific projects. So far, these statements are often characterized by an insufficient treatment of the spatial distribution of the various effects. Besides, the existence of other activities then the one under consideration is mostly neglected, which means that a cumulation of effects from different sources will not be noticed. The approach mentioned in the preceding section might therefore be a very meaningful addition to the conventional environmental impact statement methodology.

It should be stressed that this article is not intended to present a fully operational and tested procedure. A lot of interdisciplinary research is still needed to reach such a stage. In order to prevent further damage to the few valuable areas with a high environmental quality, it is to be hoped that this research indeed takes place.

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