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THE IIASA PROJECT ON URBAN AND REGIONAL SYSTEMS: A STATUS REPORT

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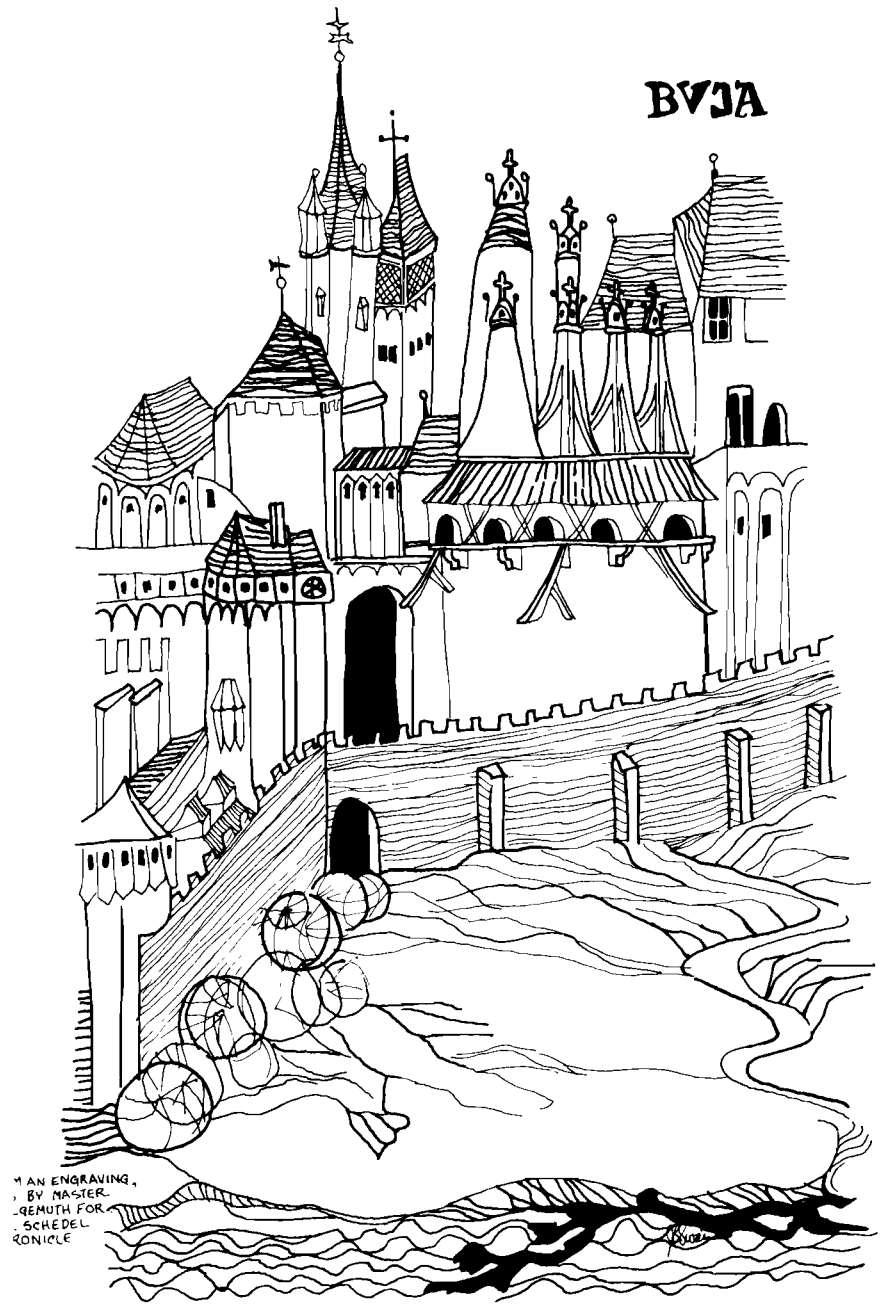

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FOREWORD

The IIASA Project on Urban and Regional Systems commenced early in 1974 with an initial emphasis on policy issues involved in national settlement systems. By year's end, when we hosted an international conference on the topic, more than half the group was working on one or another aspect of settlement systems, considered from the point of view of a national-level decision maker.

Other members of the group are working on urban emergency services and automated traffic guidance systems, with the intention of providing, early in 1976, volumes which could guide practitioners through the latest in the state of these arcane arts.

Emerging concerns, as we near mid-1975, are in the areas of resource-conserving and resilient approaches to urban design, and in the comparative performance of large urban regions. Throughout, close cooperation with other projects has been maintained on such subjects as power facility siting, regional development, and standards for environmental management.

* * *

Besides the listed contributors, a number of people have helped in getting this status report into print. Elizabeth Ann Drew typed and retyped the original pieces. Julie B. Swain played critic at rehearsals of our verbal presentation, and contributed the drawings that grace these pages. As always, the staff of Pups & Dogs, as the IIASA Department of Publications and Documentation is locally known, functioned in their usual smooth, well-oiled manner in turning a typescript into the present volume. To all, our sincere thanks.

H.S.
Laxenburg,
May, 1975.

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THE IIASA PROJECT ON URBAN AND REGIONAL SYSTEMS

Harry Swain

On March 10, 1975, the scholars of this Project presented the first formal accounting of themselves to their colleagues assembled in the new Wodak Conference Center at Schloss Laxenburg. For three hours we held forth about our first year in business; after lunch, we spent a further two hours answering the detailed questions of our colleagues. The experience of preparing and presenting this Status Report was a surprisingly valuable one, perhaps not so much to others as to ourselves. Being forced once again to argue one's position from first principles for an interested but lay and even skeptical audience has salutary effects on the dynamics of the group doing the presenting.

Who Reads Status Reports?

One of the first questions we had to face in the preparation of this printed version of our Report was, for whom are we writing? We decided to take the somewhat unorthodox step of trying to communicate directly, without intermediaries and with the minimum of jargon, not to fellow scientists or urban researchers (though they are welcome too) but to the experts in science policy and the management of international scientific programs in IIASA's national member organizations, and their governmental supporters. In a sense, we are trying to reach through the insulating layers of advisors with a reasonably readable Report that will allow our real sponsors to form their own ideas about the content and merit of the urban and regional work going on at IIASA. In doing so we recognize our amateurishness at this specialized kind of communication; we realize the substantial possibility of displeasing all our potential audiences at once. Still, we strongly believe in the usefulness of communication across all the normal

boundaries -- national, disciplinary, and in the present case, vocational also. So be warned, Gentle Reader this is not the standard sort of research report. It is meant to be journalistic, even occasionally breezy in tone. It is meant to be read. Those insatiable folk who want the full depth of technical detail are referred to those drier and more respectable publications noted in the bibliography.

What we really want to do in this Report is to get across some of the flavour of our work: where we're going, where we've been, and why we chose the route. Threaded throughout will be commentary on the consequences of the answers to those ultimately unscientific and subjective questions for the nature and style of our work here at IIASA.

A Little History

Each of the IIASA Projects commenced with a planning conference, where experts from all the member nations pondered what might usefully be done with the Council's broad mandate within the institutional and resource constraints of the infant organization. The urban conference was held in midsummer of 1973, under the chairmanship of Michel Rousselot, with the participation of the Director, Howard Raiffa, and the scientist who later became IIASA's second Deputy Director, Wolf Haefele. Some forty experts debated how to give substance to the Council's expressed desire to include urban problems among those important to advanced societies of varying economic systems. The deliberations of that conference are recorded elsewhere in stunning detail [23], and it is unfair to the welter of ideas presented at that conference to claim any far-reaching consensus. Yet at least two ideas were mentioned in one form or another by enough conferees to support a claim of near-universal approbation. These ideas are embodied in our present research program under the headings *national settlement systems* and *municipal systems*. A third, added later, grew out of the healthy interproject ferment that was, and is, one of the reasons for IIASA's existence. For want of a better name, this third concern is listed in our planning documents as *resource-conserving urban design*. Figure 1 attempts to locate these concerns in terms of spatial scale and the "universal-global" dimension so frequently used in Institute documents. The first and lengthier half of this Report, then, is devoted to a description, by those most closely involved, of work which has gone on here on the first of those topics. Of the 68 scientific man-months spent by this Project in its short life, some 45 have been devoted to work on national settlement systems and strategies.

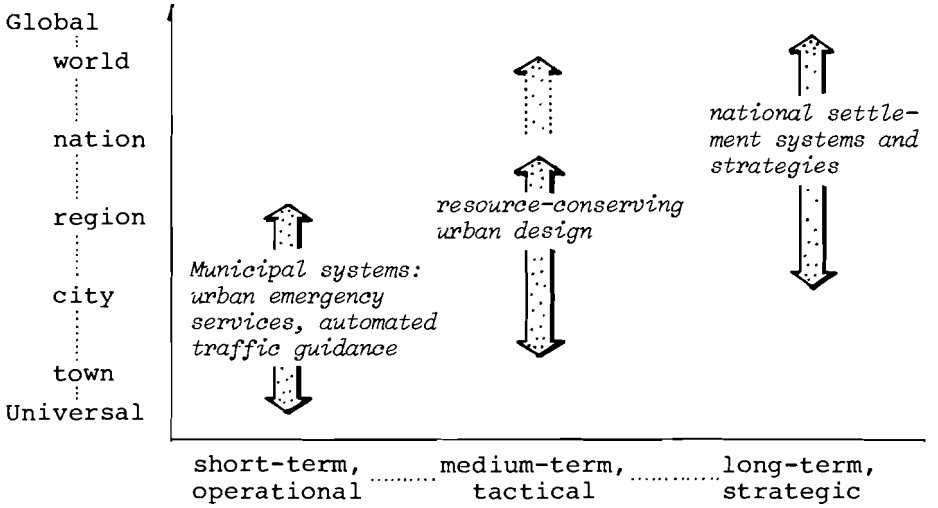

Figure 1: Current Concerns of the Urban Project

What is a Settlement System and Why is it Important?

Like any really interesting concept, this one is susceptible of many differing definitions. But the central notion has to do with *the spatial distribution of population and human activities over a nation's territory.* Examples of actions taken by governments to influence these distributions are legion. France, the USSR, and Great Britain have all tried for many years to control the growth of their capital cities; Sweden, France, Canada, Hungary and Poland all bias state expenditures and operating modes in favour of relatively underdeveloped regions. Often programs undertaken for other reasons have strong spatial impacts -- US housing and transportation policies come to mind -- even though they are not cast within the framework of an explicit overarching urban policy [17, 32]. Even there, the demand for a conscious policy has grown remarkably in the last five years[29]. Whether called urban growth policy, distribution of productive forces, regional policy, or a program for new towns and growth centers, all are included in the general concept of a settlement system.

So far, so good; but why is such an immense subject suitable for pursuit in a small international institute? We feel there are two parts to a reasonable answer. First, this is an area where practice far outstrips theory. Aca-

demics and disciplinary scientists have not found this a rewarding field, by and large; at a rough guess, governments have spent perhaps three orders of magnitude more on space technology and two on single diseases than they have on studying the human occupance of the earth. Somewhat paradoxically, the same governments have spent vast sums in trying to "manage" the distributional aspects of population and the location of economic and other activities, normally without spending even 0.1 percent on simple post facto program evaluation. While this anomalous situation is bound to change, it will take time. In the interim, this is classically the kind of situation where a small but competent group might make some substantial contributions: the problems are dominantly theoretical and methodological, and there is not very much competition around the world.

A second reason for wanting to pursue work on settlement systems here at IIASA is that it is likely to benefit considerably from international comparative study. Persons of theoretical bent who have experience with the strikingly different mechanisms used to accomplish the same ends in the various IIASA member nations are likely to learn a lot from each other -- and to advance the state of the art faster.

A word on the nature of the problems, as we see them. In conceptual or theoretical terms, there is a real problem in making the connection between broad social and economic goals, and the kinds of spatial objectives that are claimed to flow from them. By what standard -- better, by how comprehensive a standard -- is it "good" for Paris to be bigger or smaller? Should the Russians or the Canadians attempt to develop large permanent settlements in their Arctic regions? Should the USA move the poor people of Appalachia to urban job opportunities, or encourage firms to build plants in Appalachia? What are the *criteria* for such decisions, and what are appropriate *measures* on those criteria? (It must be noted that criteria may be discussed independently of subsequent value weightings.) The analysis of hierarchies of social objectives is admittedly difficult, but some useful work may yet be done in a careful comparative analysis of objective trees, embedded as they are in particular political systems. It turns out that, in this field, they are surprisingly universal, and that the key to the problem is a spatial theory of society adequate to the task of connecting those near-universal objectives and the programs or policies usually adopted to attain them. Now a general spatial theory of society is a tall order indeed; but as we hope to show in the following pages, there are tactics for going at the problem that skirt some of the more formidable difficulties.

At a somewhat less elevated level are the problems of program evaluation. Suppose, in some mythical nation, the Council of State has decided that it wishes to maximize the rate of growth in per capita income (a second-order goal, possibly coming right after some statement of welfare maximization) by encouraging rapid urbanization in the medium-sized cities away from the capital (the third-order, or spatial, objective). If in the paragraph above we were asking what logic guided the Council of State from income growth to encouraging the growth of medium-sized cities, we now assume a satisfactory answer to that question and ask the next: what instruments of policy may best be trained on the accomplishment of that spatial objective? Answers will have two components, one referring to general human behaviour and one to the specific features of history and circumstance in our mythical country. These are not entirely separable; the "preinstitutional" behaviour of social systems, in Tjalling Koopmans' useful word, cannot be completely comprehended outside its context. But in terms of relative weight, we intend to lay most stress on the universal parts for the next year or two. I am getting ahead of my tale -- but after some careful homework, we might have a capability to play the role of secondary consultant to a government. I will return to that idea later.

Planning Systems

To start with the area of least relative weight, we felt we had to bring our knowledge of the national planning systems in the centrally planned economies up to the levels of familiarity we had with Western ones. Two members of our group had held senior managerial positions in the national urban planning mechanisms of Canada and Australia, and in general, there was a broadly diffused knowledge of how things were done in countries with similar political and economic systems. But the Western-language literature of quality on Eastern European urban policy is remarkable for its skimpiness. We therefore initiated two activities: inhouse, our Soviet colleagues prepared two review papers, one on the Soviet planning system for the distribution of population and other productive forces [16], and one on the analytic techniques, models and methods used by Soviet planners in drawing up schemes to meet the general objectives [25]. This work is summarized in the immediately following sections of this Report. Externally, we asked some of the Eastern European contributors to our December, 1974, *Conference on National Settlement Systems and Strategies* to write about the objectives, policies, programs, and organizational mechanisms in use in their countries. A number of such studies will be published shortly in a special conference proceedings

volume [27]; we proudly report that six of ten cases and two special bibliographies refer to practice in Eastern European countries.

While we will not make any major efforts to compile inventories of national policies and programs -- others, for example the UN and OECD offices as well as private scholars such as Hansen [13], Goddard [7], Friedly [11] and Sant [24] are doing that quite well -- we shall surely remain interested in monitoring that literature, and in publishing bibliographies and commentaries from time to time as a contribution to the agency role of IIASA. Some fruits of this activity will be apparent in the two other conference proceedings volumes [28, 30]. We will also remain in contact with research groups elsewhere who make this their prime concern: for example, Ross MacKinnon will have attended the *IULA Congress on Urbanization*, including the preparatory meetings for Habitat, in Teheran by the time this Report is printed.

A more ambitious and worthwhile extension of this sort of policy analysis would be the generation of methods for the logical appraisal of goal systems for consistency, feasibility, equity, efficiency, and other normal tests. The end product would be an interrogative module which would allow a great deal of the really relevant information about the weight and worth of potential policies to be garnered from structured conversations with national policy makers and their technical aides. Whether or not we are actually able to do something along these lines is simply a matter of resources.

Migration

Within the broad field of settlement system policy, research priorities can be identified by the "differential malleability" [6] of components. This is to say that there are parts of the system that are more or less susceptible to manipulation, and parts that are either uncontrollable in principle, or inordinately difficult or expensive to influence. In the field of settlement systems, interregional migration is one of the very few population processes over which governments may exert influence in non-coercive ways. By way of contrast, birth and death are much less amenable to policy initiatives and the time required to achieve results is very long.

There are two key kinds of migration in urbanization, interregional and international. Both may be substantial contributors to urban growth [cf. 17] but international migration is a process so completely controllable by national

governments as to be of little research interest. New World countries receiving Southern European migrants, or Western European nations balancing economic growth against the social costs of hosting large communities of "guest workers", are dealing with rather special subsets of the urban growth problem, ones which we will continue to pass over in favour of the relevant national institutions. Likewise, intracity migration or residential change is a special subfield with its own modes of analysis, and is not crucial to understanding the process of urbanization.

Interregional migration patterns appear to be affected by a variety of factors which are partly in government control -- supply of jobs, information about distant opportunities, supply of many kinds of socio-cultural and economic infrastructure -- and these patterns have substantial similarities regardless of economic mechanism. For example, migration probabilities appear to vary with the same characteristics of origins and destinations, and with the same elements of life cycle and life style, in the USSR as in the USA, in France as in Iran, though of course the coefficients vary quite a bit. Furthermore, the existing predictive models can be relatively easily improved, and conversely, the feasibility of various urban growth and population distribution policies can be examined. These interesting subjects, constituting the methodological nub of a policy research module in the area of national settlement systems, are explored below by Cordey-Hayes and MacKinnon. We anticipate a continuation of work on what might be called the migration module through mid-1976, under the direction of Andrei Rogers; the focus in this second stage effort will be the integration of demographic and econometric approaches to migration.

Other Modules

Our approach should be a little clearer now. Within the broad context of strategies for the spatial distribution of population, we are encouraging carefully selected research scholars to put on paper the best of policy-evaluative modelling tactics for each of a selection of malleable entry points into the urban system. This at once gives us criteria for recruitment and a way of efficiently making use of our short terms at IIASA, all within a continuing and cumulative research context. For each of the major components, which so far are concerned with analysis of objectives and with interregional migration, we are constructing methodological modules which may be calibrated, easily modified, and applied in a wide variety of real policy research situations.

Following these two, there are several other modules that might usefully be constructed; the order will depend on IIASA's financial resources and the availability of appropriate expertise. High on our list of priorities are the *locational behaviour of firms* and the *provision of transportation and communication infrastructures*. As for the first of these, the locational preferences of firms and enterprises, particularly large ones with specialized components, are important in both socialist and market economies. The objectives and hence behaviour of firms are not perfectly isomorphic with the interests of society or individuals under any economic system. Sensitive and efficient guidance by governments will depend on a sufficiently subtle understanding of enterprise motivation. Recent French and British work on multinational firms, and the presence of an Organizations project at IIASA containing considerable expertise on Eastern European economic planning, give some hope that the time is ripe for an initiative in this area by the Urban project.

Communication systems, including transport, have enormous impact on spatial behaviour. An obvious example is the US Interstate Highway System. Ostensibly undertaken for simple trade and defense reasons, it has had large and not entirely anticipated impacts on the prosperity and growth of many places. In India, breakdowns in internal transportation systems for imported grains and other foodstuffs are exacerbating the already appalling problems of Calcutta, Madras and Bombay, as hungry rural populations move farther up the supply lines [21]. At the other end of the scale of economic development, pricing policies for long-distance data transmission are likely to have decisive effects on the localization of quaternary activities, the most dynamic sector of post-industrial societies [2]. Strong threads of commonality run through all these domains, and a logical continuation of our work in 1976 and beyond would be the construction of robust models for analyzing the settlement system impacts of alternative investment policies for major interregional circulation systems.

What About Applications?

A legitimate question at this point is, all very well, but how does all this work get applied? An appreciation of the realities of IIASA is fundamental to reasoned planning here. International organizations and research institutes, and IIASA is both of these, are hardly ever given genuine power to even plan, much less execute, important projects. Something as vital to national interests as a population distribution policy would never be delegated to outsiders, no matter how technically competent.

On the other hand, within every national government concerned about the development of its settlement system, there will be two different kinds of actor in the policy planning process: the political-level decision makers (call them *arbiters*), and their technical policy-analytic staffs. The most we can hope to do is play a sort of secondary consulting role for those arbiters, acting through their staffs. We can invent, document, and package a useful series of analytic instruments, and we can directly or indirectly train others in their calibration and use. We could even undertake partial analyses, in close collaboration with national authorities. Likewise, we should be in a position to advise on the adequacy of methods currently in use. These three possibilities constitute the limits of our institutional ambitions; but we believe that their achievement, with present resources and under present organizational constraints, would be a truly major one.

It is this imagined market that dictates the nature of our product: analytic modules for asking "What If?" questions about possible policy alternatives. These modules must be amenable to the demands of a real policy research context; above all, they must be capable of producing useful information from poor data in a timely fashion. They must do so in the hands of ordinary mortals, not just Nobel Prize winners. Their workings must be reasonably transparent and their outputs readily communicable to the arbiters who must apply the necessary value weightings. (One of the nicest things about Tobler's work is the way in which vast amounts of data can be reduced to robust and easily communicated information; the fact that his techniques are applicable to a wide variety of spatial processes renders them especially valuable.) Since breadth rather than depth is crucial in policy research, simple models giving a little information about many attributes are preferred to complex ones giving (usually spurious) three-digit accuracy about only a small fraction of the arbiter's domain of concern. For all these reasons, we are concentrating on building what in light moments we call *robust, quick-and-dirty, policy-testing models*.

A second kind of clientele (another route to the first) is fortuitously becoming available to us in June, 1976, when *Habitat, the UN Conference on Human Settlements*, will take place in Vancouver. Though there appear to be serious organizational and bureaucratic problems in the preparatory machinery, we cannot let the world's first conference-exposition in the field of our concern pass unremarked. Using Habitat as a benchmark, we will prepare as much of our work as can be put into the UN framework for whatever the international exposure is worth, and in turn expect to learn much about the problems and prospects facing urban students all over the globe.

STRATEGY FOR THE DISTRIBUTION OF PRODUCTIVE FORCES IN THE SOVIET UNION

Oleg Kudinov

In the 1974 Urban Project research program [26], a study of national settlement policies was envisaged. In the Soviet Union, policy for the spatial distribution of population and settlements is determined by the strategy for distribution of productive forces, though naturally there are feedbacks in the process of their elaboration. It was thus decided to analyze them together. I shall present here some of the highlights of this work, inviting interested readers to refer to the detailed reports [16].

Principles of Planning

Let me begin by reviewing the main planning principles in the USSR. Soviet economic planning has two main branches: industrial and spatial (Figure 2). The aggregation of industrial plans is the familiar national economic development plan, while that of regional plans is the general scheme for the distribution of productive forces. In this context, "productive forces" refers to the working population, together with its tools, factories, and supporting economic infrastructures. There are economic development plans for three horizons. Current plans are for a single year, there are the familiar five-year plans, and there are long-term plans with horizons of fifteen to twenty years. The basic form of national economic management is the five-year plan, in which only major targets are outlined on an annual basis. The long-term plans ensure continuity of the five-year plans and establish priorities for resolving major economic problems as they arise. Figure 3 places spatial and industrial planning side by side and emphasizes the importance of planning from the center, even though there are both temporal and spatial feedbacks.

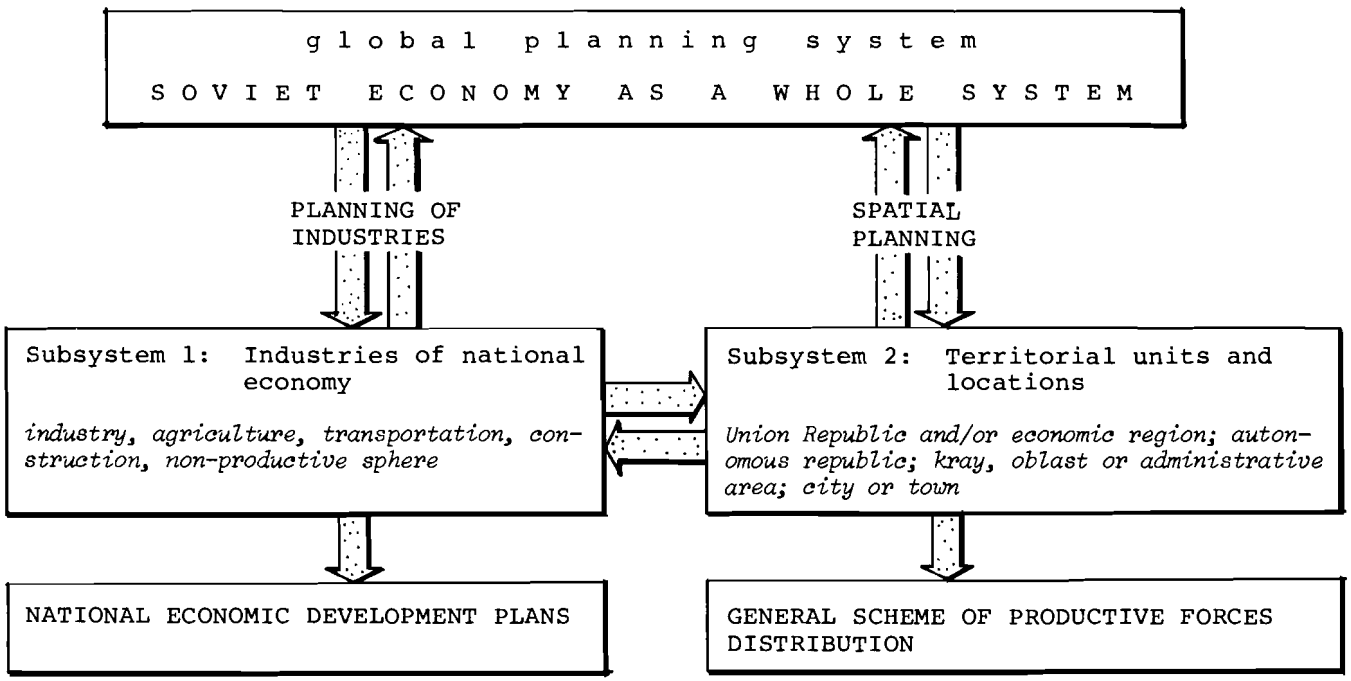

Figure 2: System of National Economic Planning in the USSR

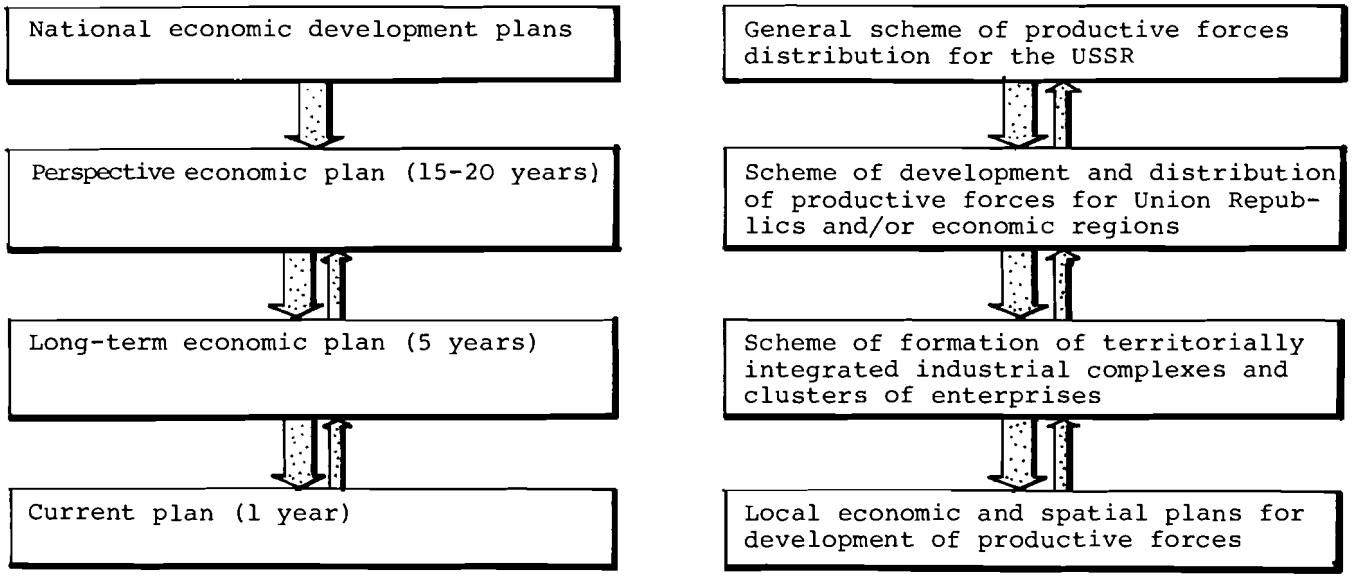

Figure 3: Hierarchies in Time and Space: Economic and Spatial Plans in the USSR

Strategy of Distribution of Productive Forces

Planning the spatial distribution of productive forces is of particular importance in the Soviet Union, with its vast territory and exceptionally diversified economic-geographic conditions. Such planning is decisive in ensuring efficient utilization of the country's material and manpower resources.

Localization of productive forces is intended to support the creation of a material and technical basis for development. It is understood, however, that rates of economic development and improvement of living standards is directly dependent on a rational distribution of production.

One of the characteristic features of the USSR is its highly uneven distribution of population, raw materials, and energy resources. Material and energy resources in the European part of the USSR are severely depleted as a result of intensive exploitation. The Asian part is very rich in natural resources: it holds half of the national reserves of natural gas, two-fifths of the oil, and half the wood, plus vast reserves of hydropower and other major raw materials. The European part has two-thirds of the population but only 13.5 percent of all energy resources. That is why accelerated development of the Asian part of the USSR continues to be the chief trend in the redistribution of productive forces.

Distribution planning is based on the following main principles:

1. Bringing production into the closest possible proximity to the sources of raw materials, fuel, power, and labour forces, and to the users of finished products;

2. More even distribution of the productive forces over the country's territory in order to achieve specialization and harmonious economic development of the Union Republics and economic regions.

The distribution of productive forces in the USSR is planned at the level of Union Republics and major economic areas. The list of such areas divides the country's territory into major economic complexes uniting a number of adjacent territories and regions or Union Republics; at present, there are nineteen such areas. Distribution of productive forces is tackled by the General Scheme of Productive Forces Distribution.

This Scheme is the scientific basis for rational distribution for a distant future. It determines optimal

territorial proportions of national economic development to ensure increased effectiveness of public production, and is a basic document for evolving the General Scheme of Population Distribution. To some extent the two Schemes influence each other.

Policies of Population Distribution

The General Scheme of Population Distribution of the USSR is a document of state significance and the most important forecast for developing a rational network of urban and rural settlements and systems of population distribution. This is done in coordination with forecasts for the development and distribution of the productive forces; on this basis, the principal stages of improving the existing settlement network are outlined.

The policy for improving the population distribution and settlement net work sets the following tasks:

1. Acceleration of development of towns and settlements in the Eastern regions, along with provision for a more evenly balanced population distribution between the European and Asian parts of the country;

2. Efficient restraints on the growth of large cities in developed regions, together with formation of new, large towns as centres of developing industrial complexes in Siberia, Kazakhstan and Central Asia;

3. Intensive development of small and medium-sized towns having favourable growth conditions; and

4. Creation of equal economic, social and cultural opportunities for urban and rural populations.

The formation of settlement systems is to be founded on:

1. Successive development of industrial complexes based on large cities and agglomerations;

2. Organization of a unified transportation system, and of systems of public and economic facilities; and

3. Realization of measures for environmental preservation and improvement.

In the General Scheme of Population Distribution, the following hierarchy of settlement systems has been proposed (Figure 4):

1. Global settlement system with the centre in Moscow;

2. Regional settlement systems; the centre of each system is a city with a population of about one to three million inhabitants;

3. Large grouped settlement systems; the centre of each system is a city with a population ranging from five-hundred thousand to one million inhabitants.

4. Middle-sized settlement systems; the centre of each system is a city with a population of one-hundred to five-hundred thousand inhabitants.

5. Small grouped settlement system; the centre of each system is a town with a population ranging from ten to one-hundred thousand inhabitants.

The efficiency of group settlement systems within the framework of the national economy is determined by several factors:

1. Joint utilization of an economic base and its infrastructure;

2. Diminished concentration of industrial enterprises in large towns and agglomerations;

3. Wider choice of job opportunities near residences;

4. Convenient access to service centres and facilities of different levels;

5. Wide range of recreational areas;

6. Favourable conditions for nature preservation and improvement of the environment.

Within the next fifteen to twenty years, it is envisaged to organize twenty-seven group settlement systems on the basis of the most important and largest towns of the country, and fifteen group settlement systems in new developing regions, mostly in the East. Later, it will be practicable to lay the foundations for another forty to fifty group settlement systems.

The General Scheme of Population Distribution will serve as the basis for:

1. Regional schemes of population distribution in all Union Republics and economic regions;

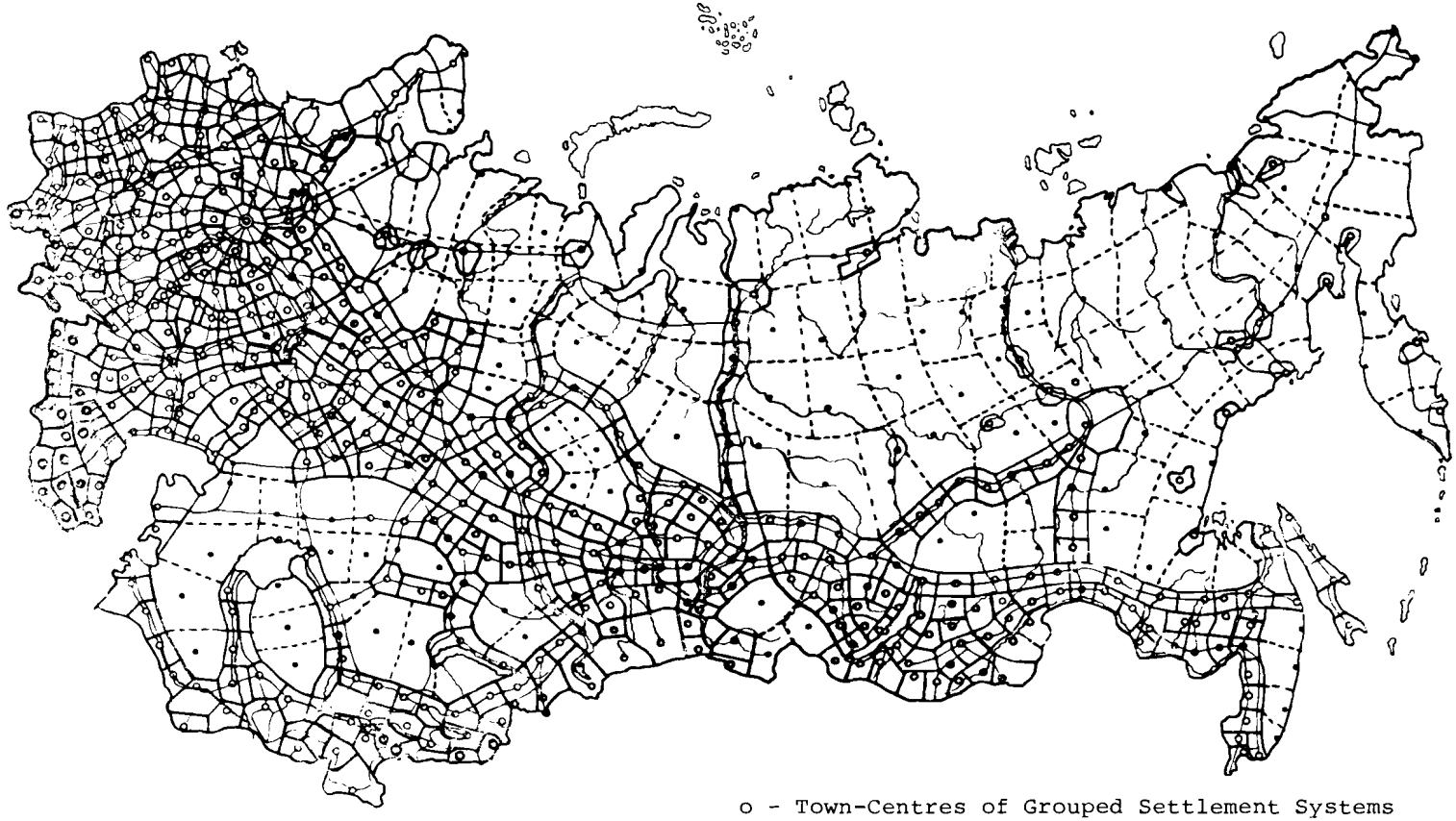

Figure 4: The Principal Scheme of Grouped Settlement Systems Development

2. Regional schemes of development and location of health resorts, recreation and tourism areas, nature parks and preserved zones;

3. Comprehensive regional planning schemes and projects for developing and newly developed areas of the USSR.

At present this methodology is being applied in a number of socialist countries; we are hoping that some components can be used in nonsocialist countries for goals of their economic and social development.

METHODOLOGIES FOR SETTLEMENT POLICY ANALYSIS

Valery Sokolov*

The goal of this presentation is to describe the progress made in two research directions of the Urban Project in 1974. The first refers to studies in national settlement policy formulation, while the second is concerned with methodological studies in designing complex models, of which urban system models are typical examples.

National Settlement Policies

These studies were aimed at collecting descriptive and normative models aiding formulation of national settlement policy in different countries, both West and East, with the final purpose of identifying through comparative studies those models of general concern that may be used irrespective of the political and social structure of a society. On the other hand we were interested in specifying those properties of the models which represent particular urban processes pertinent to specific countries.

The group involved in the studies includes O. Kudinov and H. Swain (descriptive models), and R. MacKinnon, M. Cordey-Hayes, and V. Sokolov (normative models). My special concern was surveying models which aid formulation of national settlement policies (NSP) in the USSR.

It is well known that the basis of socio-economic progress in the USSR is the principle of planned development in all sectors of life. One of the major streams of state planning activity is aimed at management of the national settlement system, which is closely related to the general problem of state economic development and increasing the welfare of the population.

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* *(Editor's note: Dr. Sokolov divides his time between the Urban, Survey, and Methodology projects. Since his basic home is here and since the other projects have not as yet produced status reports, we welcome the chance to demonstrate how, in the person of a single scholar, the concerns of many IIASA projects interpenetrate each other. --HS)*

The strategic instrument underlying NSP management in the USSR is the General Scheme of Population Distribution, while the tactical or operational instrument is the Regional Planning Principle. They define the scale, the rate and the direction of urban systems development, and determine the basic state and management variables, the trajectories of development, and the distribution of resources.

These instruments must be reinforced with many data concerning interaction of the urban area with an environment, evaluation of the efficiency of urban area usage, social issues, etc. These data are obtained through application of a wide variety of models representing specific processes and combinations of processes. The models form a hierarchical structure providing successive aggregation of data from lower to more complex levels.

The survey that has been prepared is not all-encompassing, but rather a collection of models related to three specific issues: population, evaluation of states of settlement systems, and facility allocation.

The first group is represented by models:

- of population growth;
- of static balances;
- of dynamic balances;
- of socio-demographic forecasts;
- of migration.

Several linear and non-linear approaches to the description of population growth are exemplified. The most widely used models are those for stationary and stable populations. The concept of homogeneous and differentiated populations is illustrated, and that of a socio-demographic group is applied, as a basis for the design of a working model.

The general approach to building static balances is described, and the standard compact form for these balances is given. The dynamic socio-demographic balance is a combination of the static balance with trend models. The dynamic model includes: the matrix of socio-demographic balance; balance equations; dynamic equations for the endogenous, exogenous and structural groups; the matrix of damping coefficients; the matrix of indices of elasticity; dynamic equations for the indices of elasticity. The modelling is illustrated with an interactive algorithm giving the sequence of socio-demographic balances of forecast. Each of these balances is compared with the real situation, and the results of comparisons are used to improve the model.

The approaches to socio-demographic forecasts are illustrated with the linear extrapolation of dynamic series. Although the importance of long-term forecasts is not in doubt, operational preference is given to short-term forecasts as their accuracy is much higher. According to some sources the root mean square deviation is calculated from real values is often in the limits of $\pm 3,48$. The survey shows good fits of forecast and real data. Two different approaches to migration models are considered. A common one treats the migration as a stationary Markov process, the transition coefficients being defined experimentally. The purpose of such models is to define the pattern of population distribution by a given time, so these models are part of the dynamic demographic models. Another approach is based on gravitation or attraction principles.

The ideas of potential and attractiveness were further developed in representing the distribution of population in existing settlement systems through forming a potential field for a given settlement or settlement system. The potential of a settlement field at a given point is defined as the sum of the populations at every other point divided by their distances from the given point.

Another use of potential field was demonstrated. Calculating the values of a potential field at different points leads to obtaining potential maps of territories, which is a useful pre-analytic test for solving industry and settlement allocation problems.

The models for evaluating settlement states are illustrated with an example where the potential economic development is used as the criterion.

Thus the problem formulation is as follows: given the description of alternative settlement states, which in a general case may be incomplete, and the describing vector for a specific settlement, find the state of the settlement. The solution uses expert technique for measuring the describing vectors, and a pattern recognition approach for classifying a specific vector with a particular state.

To generate the alternative for regional planning, mathematical programming models are widely used. They are well illustrated with several examples.

A typical objective function accounts for the types, functions, and relative weights of system components (urban settlements and related regions) with due regard for reconstruction of existing structures. Problems of service and amenity allocation are often tackled in the same way.

For example, integer programming models are used for evaluating basic parameters of a service network, e.g. the rational number of population for each service element, capacity and service range of elements, optimal allocation pattern, etc.

More sophisticated models, not only for urban areas but also for rural territories with long distances between settlements, are also illustrated.

To help in selecting alternatives for regional planning or allocation of service facilities, the concepts of efficiency and integral performance are introduced, through application of the consumer cost, which depends on service capacity and quality, and the reduced total cost (public expenditure for manufacture and use of a product). The final part of the survey presents an approach to solving a regionalization problem.

Tentative studies made with M. Cordey-Hayes showed that there is a great deal of similarity in models used in Western and Eastern countries, especially in population models.

Methodological Studies

The analysis of the principles underlying several complex urban models showed that though many of the macro-properties of the real system are well known, existing models rarely display these properties. Thus in trying to overcome the difficulties we have arrived at gaming simulation methodology (GSM) as one approach potentially to deal with this problem.

A gaming model is an interactive decision-making instrument based on a close interaction of normative and descriptive elements. The former represent the experience of systems analysts in formal modelling, while the latter introduce value judgments. Thus the implementation of a gaming model requires strong involvement by elements (people and organizations) used to working with incomplete, unreliable, or absent data and having broad experience of real systems. This means introducing an additional channel between model and real system, in contrast to the standard approach where the only channel is through the system analyst. The problem of data collection and process identification thus becomes much easier, and the necessity for introducing special measuring units into real systems is eliminated. Their functions are performed by those elements of the real systems which are incorporated in the model structure. Gaming studies will be detailed in the Methodology Project status report.

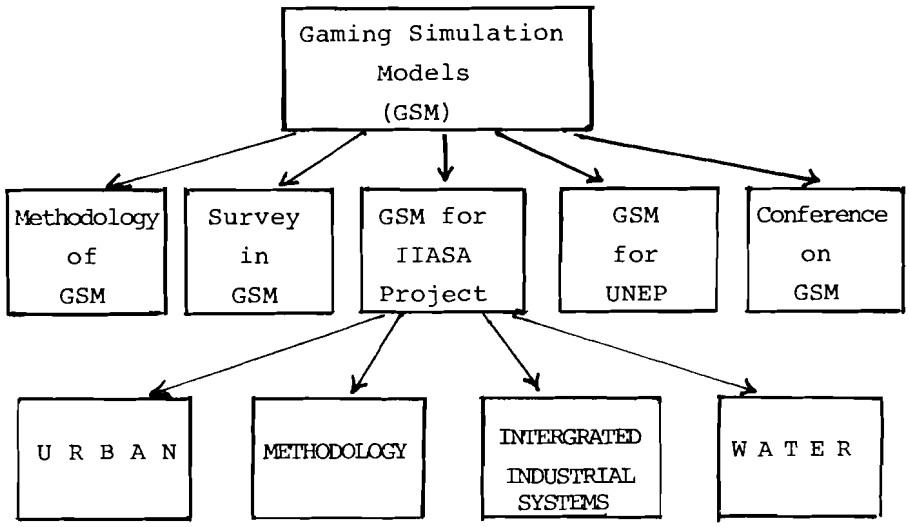


Figure 5.

A large bibliography on gaming models has been collected, and surveys on the methodology of gaming model application are in preparation.

Promising results have been obtained in elaborating a gaming model for allocation of vital resources shared by several countries. This model may be used to solve regional development problems and also manage water and other resources. Hopefully, the model will be experimentally verified by the summer of 1975.

Organizational Activity

The results of organizational activity may be summarized as follows:

- An intraproject group for gaming studies at IIASA includes I. Belyaev, R. Levien, B. Mazel, V. Sokolov, and I. Zimin;
- Links with UNEP have been established, and proposals for joint studies in regional development prepared;
- Links with the GSM group at the Institute for Control Sciences, Moscow, are well established. A conference on GSM is being planned for autumn 1975 in Alma-Ata (USSR) in collaboration with this group.

Plans for 1975

We plan to relate national settlement policy activity with gaming models for regional development through using GSM methodology to improve existing NSP models. Another collaborative effort is the relation of the resource management gaming model to resource-conserving urbanism, which is currently attracting attention. We are also planning further developments in gaming models and their application for conflict resolution at different levels.

NORMATIVE APPROACHES TO MIGRATION MODELLING

Ross D. MacKinnon

Introduction

In surveying the literature on migration models, many of which claim policy relevance, it is somewhat surprising to find only a handful of attempts to study these systems using optimization or goal-seeking methods. This is surprising for two reasons. First, national urban planners are allegedly behaving purposefully: they are attempting to achieve certain objectives, even if some of these are stated imprecisely and perhaps not at all. Secondly, the failure to adopt a normative approach is disappointing since a rather wide array of powerful techniques is available to solve such problems.

One of the reasons for this underutilization is that optimization methods require a mathematical statement of objectives in the form of a function to be maximized or minimized. Such requirements are certainly unrealistic. However, optimization models can be used not only in the narrow sense of providing accurate optimal solutions to planning problems, but also in a broader heuristic framework: suggesting general properties of planning procedures; indicating the feasibility, approximate costs and other implications of various hypothetical goals; demonstrating where the most promising areas of research or action are in the system -- that is, where the planning agencies have the most leverage to move the system towards the goals. A context in which the model and the modeller interact closely with the arbiter or his staff is envisaged, perhaps within one of the gaming simulation frameworks proposed by Valery Sokolov.

In addition to planning objectives not being precisely specified, the behaviour of the system is not well known. In large part, the theory of national settlement systems is either elegant and irrelevant, or rather primitive. Detailed data are seldom available and their collection is costly and time consuming. The estimation of large models is also costly in time and money, and in addition requires large numbers of highly skilled technical people. In spite of these research problems, many governments consider that actions must be taken without delay.

In view of these "supply" and "demand" considerations, typical of research in real policy contexts, it is clear that there is a need for aggregate models which presume neither an unrealistically large data base nor strong theory -- nor yet unlimited technical and human resources. The models I propose are aggregate, in the sense that few variables and few relationships are included explicitly, although they should be designed to allow the incorporation of new data and theory as they become available.

The models substitute a spatial and time dependence for detailed multivariate analysis. Thus they are disaggregated in space and time. But because of their aggregate nature in terms of variables and relationships, the policy instruments in these models are imperfectly specified. Only broad areas of concern may be indicated; for example, which regions or cities should be stimulated or between which cities should migration be encouraged, rather than how such stimulation and encouragement can actually be achieved.

A variety of models have been formulated. Some of them are described in MacKinnon [18]. The simplest models take the form outlined diagramatically in Figure 6.

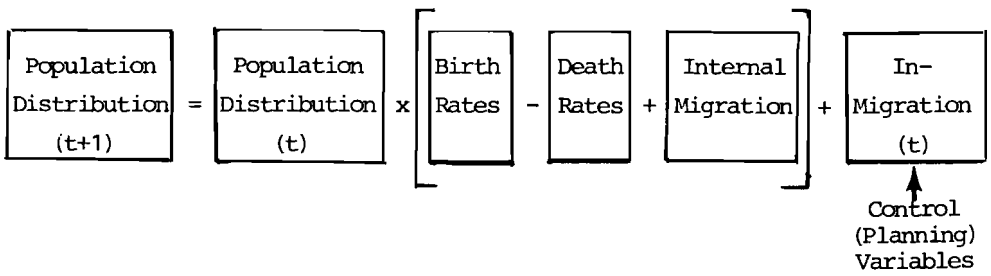


Figure 6: Simplest Migration Control Model

Population distributions change as a result of differential birth and death rates*, internal migration, and new migrants from outside the system, either foreigners or rural-urban migrants. It is assumed that initial choice of location of new entrants to the urban system can be influenced -- in the extreme case controlled. It is also assumed that for some, perhaps all, of the cities, there are desired population trajectories, such as those shown in Figure 7.

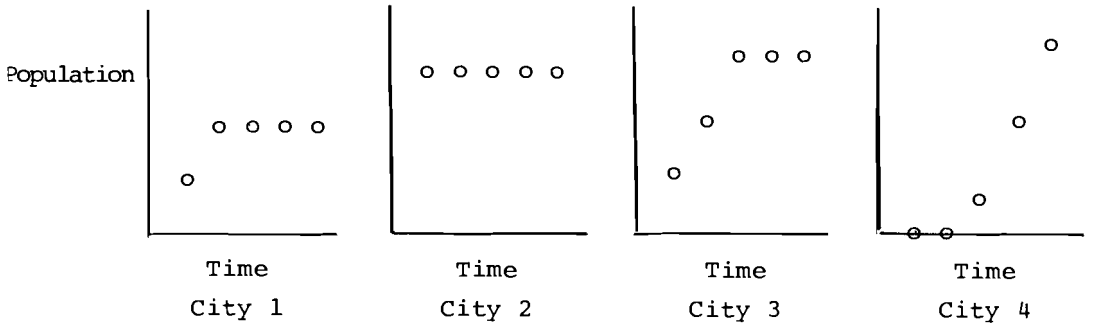


Figure 7: Illustrative Examples of Population Distribution Goals

The question which the model attempts to answer is: what sequence of controls should be placed on the system in order to minimize the discrepancy between desired and predicted population distribution? Some predictions regarding the total number of migrants into the system may further constrain the actions. Also the effort (inducements) required to make people move to the "correct" locations should be taken into account.

The form of this model can vary considerably, but a numerical application to the Canadian urban system is currently being run using a non-linear programming algorithm developed by Yuri Evtushenko [9].

*In empirical work carried out thus far, birth and death rates have not been included. These purely demographic aspects will receive a greater emphasis when Andrei Rogers joins the Urban Project in the Summer of 1975.

It is envisaged that extensive sensitivity analysis would be desirable to explore the policy space; thus the model would be run many times to demonstrate the response of plans and goal attainment levels to changes in a variety of assumptions. The first category of questions relates to how closely the set of goals can be approximated: what population trajectories are the most difficult to attain; which are precisely attainable? How sensitive is the discrepancy between goal and predicted population (taken both as a whole and for individual cities) to changes in the degree of allowable effort?

The second class of outputs which such models can provide relates to the nature of implied controls. Is a massive shift in in-migration behaviour implied? Are the internal dynamics of the system used extensively? Do these dynamics promote or inhibit goal attainment? What is the temporal and spatial pattern of controls -- highly concentrated or spread thinly over the system? Is there a large area of discretion as to what controls can be applied to yield the same basic result, i.e. how flat is the criterion function?

Other outputs relate to the sensitivity of the results (actions and goal attainment) to changes in internal migration propensities. The migration rates used in the model are only estimates, and even if accurate are undoubtedly unstable. How different are the implied actions if migration propensities change?

The second variant of this model assumes that the internal migration rates themselves are either fully or partially controllable although the costs of changing them varies from one city pair to another. Similar sorts of questions can be put to this perhaps more realistic model.

Both of these models, while pointing to promising directions of action, do not indicate what the precise form of these actions should be. That is, the explicit policy variables are not specified (e.g. increase the information about some cities, job opportunities, amenities, to residents in other cities; subsidize moves between critical pairs of cities; increase the number of opportunities at some cities).

One attempt to make the policy instruments somewhat more explicit is represented by a model which links the migration model to dynamics in the job market by means of introducing the concept of job vacancy chains. Described in more detail in the next section, the basic idea is that job vacancies, arising for a variety of reasons, when filled

may create other job vacancies so that a chain of consequences can be traced throughout the urban system. The initiation of these vacancy chains is partially controllable; for example subsidizing the creation of new jobs or encouraging early retirement. This set of models attempts to determine the spatial and temporal patterns of new job vacancies which are likely to result in desired future population patterns.

The approaches outlined above are all in the process of being applied to actual urban systems -- Canada, Austria, and hopefully an Eastern European country. In the light of this experience, the models will almost certainly be modified extensively.

One of the benefits of this aggregate modelling approach is that it clearly identifies areas where more research is needed. How can population distribution goals be elicited? How important are population distributions compared to other characteristics of the urban system? These and other goal-related questions should be the subject of quite extensive research on urban policy analysis.

The second broad area in which research is needed is in the identification of the determinants of migration. The results of work by Martyn Cordey-Hayes [3] are invaluable in this regard. In addition, however, the advantage of aggregate modelling is that the subjective judgments of experienced planners can be used. The models in their most aggregate form do not presume to tell the policy-makers exactly how to control the system. There is a large unique component in migration behaviour, as is evidenced by the rather poor fits obtained by most regression models and the ambiguous and contradictory results obtained with similar models in different locations. As more formal, transferable knowledge of such systems is obtained, some or all of the migration rates can be made functions of specific causal variables, some of them controllable.

A third attractive area of research is linking migration models to other locational processes which affect and are affected by changing population distributions. Two examples are some capital investment problems and the spatial diffusion of information and innovations.

In conclusion, this part of the national settlement systems project has been concerned with the development and application of simple aggregate models of the normative type. These, while making more modest promises than more disaggregate models, are believed to be a more accurate reflection of the current state of knowledge about such systems.

DYNAMICS OF MULTI-REGIONAL POPULATION SYSTEMS

Martyn Cordey-Hayes

Area of Interest and Motivation

The general area of interest of this section is the dynamic interrelationship of regional inequalities in opportunities, migration, and the differential growth of cities, with particular reference to developed countries in which migration movements are interurban rather than rural-to-urban.

I am interested in this area for two reasons, of which one is substantive and the other methodological. The substantive motivation stems from the view that problems of declining regions, metropolitan expansion and general population growth should be tackled jointly as part of the same policy. However, a major obstacle is that we have a very poor understanding of the interactions among cities or regions. We have a modest analytical understanding of the structure of individual cities but know little of the interdependence among them. Thus one aim of this research is to contribute to an improvement in understanding of the above relationships. Initially migration is taken as a focus because it is an important sector for policy implementation, and also because it is of key analytical significance.

The second motivation for interest in this general area is a methodological one. It stems from the view that urban model builders have over the last decade failed in two important aspects (even within their own terms of reference). They (we) have failed to test the hypotheses that go into the models, and have generally behaved as engineers skilled in design and construction rather than as scientists building theories and testing hypotheses.

Secondly, they (we) have built complex models without first considering whether simpler models may not be more appropriate or effective. These two failures mean that, even after a great deal of hard work, the models have contributed little either to policy or to an improvement of understanding. In the work considered here we try to avoid these failings by considering a hierarchical family of models of varying degrees of approximation and by testing the hypotheses upon which they are structured.

The System Considered

National settlement policy is concerned with the distribution and interaction of population and economic activity over space and through time. Conceptually the system of interest can be considered a multi-regional demographic subsystem interacting with a multi-regional economic subsystem as illustrated in Figure 8. About the only existing theory that considers this integrated demographic-economic multi-regional system is basically an economic one, in which it is argued that migration is a strong equilibrating mechanism for imbalances in the supply and demand for labour among regions. We are interested in considering the feasibility of building dynamic models of the above system, and in testing the adequacy of migration theory for this key linkage.

Very little analytic work has been carried out on this integrated system, and only a few multi-regional studies have been made on the independent economic and demographic subsystems. Table 1 and 2 aim to illustrate the inadequacies of these independent models. Table 1 compares the different equilibrium population predictions for three regions of the United States based on two different demographic models [10]. It can be seen that the linear model leads in the long term to about a ten percent shift of population from East to West, whilst the non-linear model gives an East-West shift of twice this, with the combined gains from the East and South regions making the West by far the dominant region. The only difference between the two demographic models is related to the migration movements between regions. It demonstrates that long-term forecasts of the distribution of population in a multi-regional system are extremely sensitive to assumptions made concerning inter-regional migration. Similar inadequacies are observed by comparing population projections derived from independent demographic and economic models constructed for the same region Rogers and Walz have pointed out that a dynamic input and output model analysis of the economy of West Virginia [19] predicts a substantial growth in employment for the region

during the period 1965-75, whilst a demographic projection for the same period gives a substantial decrease in population.

	PROPORTION OF TOTAL POPULATION		
	EAST	SOUTH	WEST
U.S. 1960	0.52	0.34	0.14
EQUILIBRIUM (LINEAR MODEL)	0.40	0.31	0.29
EQUILIBRIUM (NON-LINEAR MODEL)	0.29	0.22	0.49

Table 1.

	1965	1975
1. INDEPENDENT POPULATION PROJECTION:		
TOTAL POPULATION	1,812,000	1,751,000
2. INDEPENDENT ECONOMIC PROJECTION:		
TOTAL GROSS OUTPUT*	19.8	30.5
GROSS STATE PRODUCT*	4.6	6.9
TOTAL POPULATION	1,812,000	2,035,000
TOTAL EMPLOYMENT	477,600	563,000
LABOUR FORCE PARTICIPATION RATE	47.8%	52.2%
UNEMPLOYMENT RATE	6.8%	4.3%
3. CONSISTENT PROJECTION:		
TOTAL POPULATION	1,812,000	1,730,000
TOTAL GROSS OUTPUT*	19.8	28.6

*Billions of dollars in 1965 Prices.

One strategy to overcome these inadequacies is to link a multi-regional demographic model with an input-output model [22]. This leads to a large complex model in which there are a number of untested hypotheses, which therefore is likely to have the failings noted in the first part of this note. We have thus adopted a different strategy, described below.

Research Strategy

Our research strategy aims to be a structured learning process based upon the following three steps:

1. Construct an accounting matrix to describe recent migration movements in summary form, and use it in simple probabilistic models to assess the tendencies (and the problems) inherent in the current system;

2. Interpret (the transition parameters) in terms of hypothesized causal variables;

3. Using these tested hypotheses, construct dynamic models and conduct policy experiments to explore and evaluate the effectiveness of various policies aimed at achieving stated goals.

This research strategy and the results derived from it are described in detail in [3, 12].

Hypothesis Testing

Consider the traditional economic theory of migration summarized in the flow diagram below:

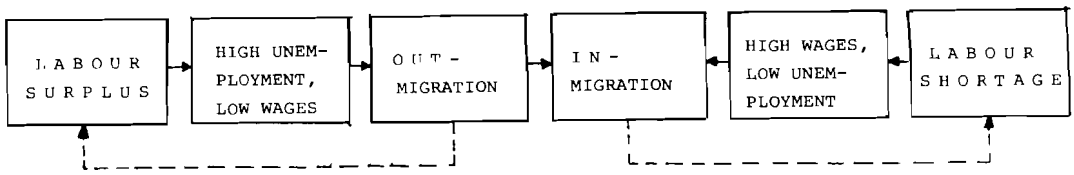


Figure 8: The Chain of Causality Implied in the Economic Theory of Migration.

The theory is based on a "push-pull" phenomenon stating that out-migration is motivated by poor employment conditions (low wages, high unemployment) and migrants are differentially attracted to areas with high wages and low unemployment. Such a process is self-equilibrating since out-migration reduces the labour surplus and in-migration reduces the labour shortages. The basic hypotheses of this theory are that in-migration is directly related to the economic attractiveness of an area, and that out-migration is inversely proportional to in-migration. That is, an economically prosperous area has large in-migration and low out-migration.

A great amount of research was carried out on migration in the late 1960's. The general conclusion was that in-migration could be interpreted in terms of concepts relating to economic attractiveness, but several researchers concluded that out-migration is independent of the economic characteristics of the generating area. Thus there are two rival hypotheses on the relationship between the directional components of migration, namely the economic hypothesis that in- and out-migration is independent of the economic characteristics of the area.

We have tested these hypotheses on migration data for England and Wales, France, Italy and West Germany, and in each case have found that neither is correct. Our most detailed work has been on the city regions of England and Wales, and the arguments that follow are mainly derived from that analysis. For England and Wales a strong direct (positive) correlation between per capita rates of in-migration and out-migration was observed. That is, areas with the highest rates of in-migration also had the highest out-migration. Declining regions were observed to have the lowest out-migration per capita and minimal in-migration; decline should therefore be associated with low in-migration rather than with high out-migration.

This direct correlation between per capita in-migration and out-migration has been explained partly in terms of a selective concentration of mobile population in attractive areas. That is, attractive areas accumulate large numbers of young and mobile people who are more likely to move on again than the remainder of the population who have established strong ties in the area. The least mobile are the unemployed in unattractive regions. Currently a theory which looks upon interurban migration as an extension of the local labour market is being developed and tested; it is outlined in Figure 8. There the probability of out-migration is hypothesized to depend on the local employment conditions,

the differential mobility of individuals within the region, and their knowledge/information of opportunities outside their own region.

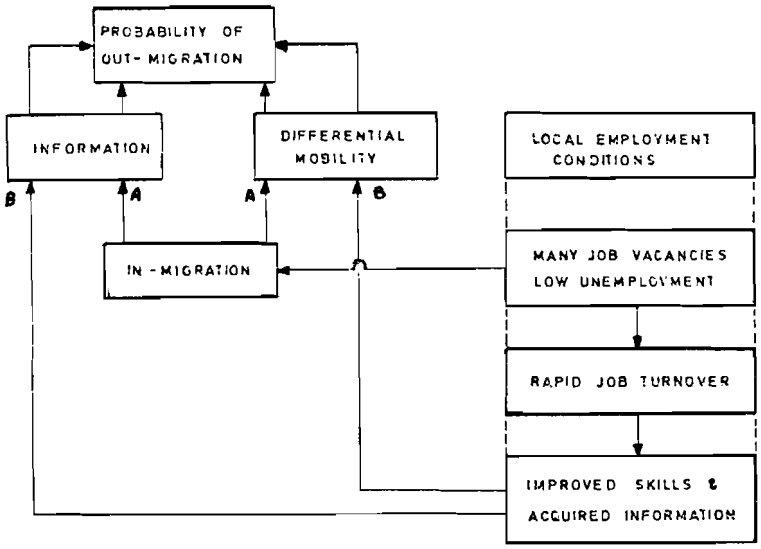


Figure 9: Positive Feedback Effects Relating Out-Migration to In-Migration.

This theory has been explained in detail in a recent conference paper, and all we note here is that there are two fundamental components. One is the selective concentration of mobile population mentioned above, and the other is based on a presumed relationship between occupational mobility and geographic mobility: conditions that favour voluntary local labour market turnover (a large number of vacancies) are also those that bring about occupational mobility and give a better knowledge of spatially more extensive labour markets. Both of these increase the likelihood of inter-urban migration, as indicated by the positive feedback arrows in Figure 9. Conversely low vacancies and high unemployment lead to a static labour market with few people changing jobs. This low turnover results in individuals not having the opportunity to enter a learning process; there

is little occupational mobility and low out-migration. These arguments recast interurban migration in a way that has important implications for both research and policy, and some of these are outlined in the papers cited above.

It is of interest to compare Figures 8 and 9 for the "standard economic theory" and the "mobility theory" sketched previously. The former is based on a deterministic chain of monocausality and is static. The latter has many feedback loops giving multicausality and is dynamic; it also uses concepts derived from demography, geography and sociology as well as economics. It is perhaps a useful illustration of the systems analytic approach as distinct from a single-discipline theory.

Nonetheless, when this multicausal theory is used as the basis for a systems model one ends up with a large complex model that has some of the characteristics previously mentioned as failings. The only consolation is that the hypotheses in the model have been tested and were derived from a structured learning process. However, in parallel with this theory-building a number of simpler models have been constructed (as part of the research strategy outlined above) and these are described below.

A Family of Models of National Settlement Systems

Technically the family of models corresponds to a set of differential equations with different simplifying assumptions generating varying degrees of approximation. This family is summarized below; as we move down, the models become more complex and require more data inputs.

1. Static

Uses only data on total in- and out-migrants to produce an estimate of long-term equilibrium population distributions.

2. Kinematic

Same data as above, but interpolates between current and equilibrium populations.

3. Markov Style

(a) Uses full migration flow matrix to produce population distribution over time;

(b) As above, but also allows feedback effects due to changes in population size.

4. Dynamic

Considers changes in transition parameters due to

(a) Demographic changes;

(b) Economic changes.

Each of the above models is operational and has been used to analyze the dynamics of the multi-regional population systems for the four countries mentioned earlier. This analysis is being extended to other countries, and preliminary hypothetical policy experiments are being conducted.

SPATIAL INTERACTION: EXTRACTING MEANING FROM MASSES OF DATA

Waldo R. Tobler

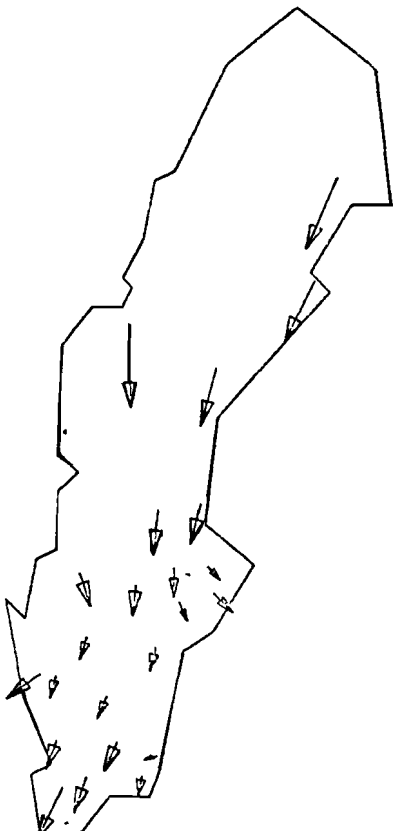
The literature on migration is extremely large, but at the same time rather disappointing and even frustrating. Most of the models are of the push-pull, economic-motivation type, and are stated in the form of single equations in which migration is the dependent variable. In practice a wide variety of particular equations is used, all of which tend to be judged statistically significant for highly particular sets of data. The reader comes away from this literature without a clear idea of the processes underlying human migrations, and without a clear statement of variables amenable to control by policy. These models are thus inherently less satisfying than those under development by Martyn Cordey-Hayes, which include feedback effects.

Given this unsatisfactory state of the art, I have taken a more intensive look at migration *data*, to see whether these perhaps have structural attributes which might be studied in a more fundamental way. Migration data for these purposes are accounting tables, showing the number of people who move from each region to every other region in a particular time period. The tables are square in format. It is worth remarking that only in recent decades have such tables become available on a regional basis. The size of the table varies widely, depending on the spatial resolution: the finer the geographical resolution the larger the table. Temporal resolution also varies. Japan has data for forty regions (a 40-by-40 table) every month, and has had these for more than a decade. Some countries do not publish the entire inter-regional migration table, but only the row and column totals, which of course masks many of the interesting details.

Since migrations are not the same in both directions, the tables are asymmetric, and thus there are regions of accumulation (net immigration) and regions of depletion (net emigration). The degree of asymmetry of migration tables is often surprisingly low, even though large numbers of people are actually moving. This means that a great deal of migration may take place without much accumulation or depletion. Here, one of the shortcomings of push-pull models of migration becomes clear. If these theories were really true, the tables would have to be completely asymmetric since nobody would move away from an economically attractive area. It is now natural to attempt to separate the migration tables into their symmetric and asymmetric parts, and to model these separately. Most models try, within a single framework, to study both parts. I have concentrated my effort on looking at the asymmetric part, removing the generally dominant symmetric part and treating it for these purposes as a type of statistical background.

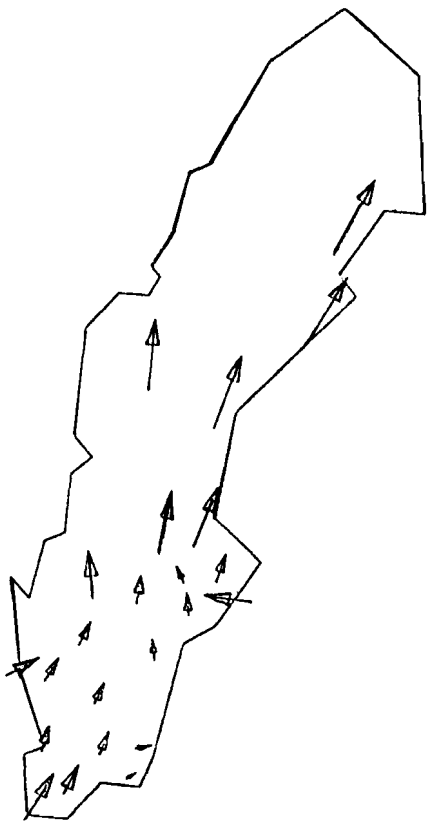
A mathematical analysis of the migration models has suggested that a useful measure of migration flows is the *relative net migration*, and that a convenient description of the entire pattern of flows is obtained by mapping the field of vectors derived from these relative net migration values. Quite a number of examples have been computed, only one of which, Figure 10, is shown here. In each case the migration table was decomposed into a flow field, shown for convenience as a pattern on a map. These simple descriptive maps summarize facts about migration patterns in a very satisfactory way -- patterns which can otherwise be appreciated only after laborious study of the original tables. Since the entire procedure represented in Figure 10 has been automated, results are available very quickly given only a good computer and the data. This is a real advantage. Take for example the migration table for the counties of the United States: this 3200-by-3200 table, containing about 10^7 numbers, would be humanly incomprehensible. The computer technique reported here renders the pattern comprehensible, even to a lay observer.

This does not yet explain migration, nor allow one to control it, although understanding is a necessary first step in the latter endeavour. However, some early results suggest that it may be possible to use the maps of migration fields in an analytical manner. The basic idea is that one may be able to work backwards from the field of vectors to obtain a forcing function -- crudely, the reason why the people moved. This method of working from the empirical migration tables backwards to the motivation is to be contrasted with the usual deductive method in which hypotheses developed *a priori* are tested. I must note, though, that



*Sweden, 1961-1966**

Asymmetry of Migration



*Sweden, 1963-1966**

Asymmetry of Migration which were assisted by governmental stipends.

Figure 10 :

*The two maps are not drawn to the same scale

the work described here still needs to be put on a firmer analytical basis. In particular, the assumptions required to infer a motivation for migration from the vector fields need clarification, and specification of the domain of validity is required.

Migration is an important type of geographical interaction, but only one of the types studied to date by geographers which are relevant to policy analysis for human settlement systems. It is natural, for example, to extend the present work to more general kinds of flow tables. Inter-regional commodity flow tables are now becoming available in the context of inter-regional input-output analysis in both East and West. Migration tables can of course be examined within this same context; alternatively, input-output tables can be examined by the methods developed for migration tables. Some work has been done along these lines here. Another interesting class of geographic interaction tables which is slowly becoming available relates to communication: numbers of telephone calls between regions, frequency of business contacts between regions, and so forth. If the conjectures about the importance of quaternary activities for post-industrial patterns of human settlement can be demonstrated, analysis of these flows of information will take on great import for its own sake; at the very least, there is now good evidence that information fields are crucial to migration decisions. I intend to continue the analysis of these flow tables.

MUNICIPAL SYSTEMS

Harry Swain

Figure 1 (p.3) mentioned work other than that related directly to settlement strategies at national or regional levels. Work on those topics is dangerous in the sense that the problem is enormously complex and there is a good chance that, with the best will in the world, we will not achieve anything new or noteworthy. So in all candour, it was with insurance against disaster as well as with the wishes of the national member organizations in mind that we decided to encourage work on selected aspects of municipal systems. The problems here may be homely but, as you will shortly learn, they are crucial to the quality of daily life in the metropolis and amenable to the application of a number of systems analytic techniques.

There are of course many specialized institutions which have concerned themselves with these kinds of problems. Our approach was therefore to select a small number of crucial areas where, with the help of collaborating institutions, we could synthesize and disseminate the best of the world's experience. In the case of *urban emergency services*, we welcome in the person of Dr. Ed Blum a connection with the recent research and applications of the New York City RAND Institute. The other current area is *automated traffic guidance systems:* Prof. Dr. Horst Strobel of the Hochschule für Verkehrswesen "Friedrich List" commutes between Laxenburg and Dresden, through the courtesy of the Academy of Sciences of the DDR.

The future of work on municipal systems at IIASA is undecided. Certainly we will go on to complete the work in progress described on the following pages. The question of a follow-on depends on the reception accorded the present work by our national member organizations, possibilities for application, availability of personnel, and the nature of other opportunities for using IIASA's modest resources that happen to be on the table when the decision has to be taken. Unlike many other organizations, our flexibility is our good fortune.

URBAN EMERGENCY SERVICES

Edward H. Blum

Introduction

Though its managers throughout the world face common basic problems, local government has often been among the last to benefit from innovations in technology, planning, and managerial methods. Our work in urban emergency services is directed toward overcoming that lag, by making accessible and applicable recent, significant advances in planning and providing these services.

As yet, this progress is only partly documented, and what documentation exists is widely scattered through esoteric journals and fugitive reports. Drawing on our experience in having developed and applied some of these advances, we are now synthesizing key results, strengthening the foundations with further research and writing down the product in book form for use by progressive managers and analysts around the world.

Importance and Motivation

Our work focuses on urban emergency services -- primarily emergency medical services, fire protection, and to a lesser extent, police emergency services. Four major reasons motivate this choice:

1. Worldwide, expenditures on these services and the remaining human and physical opportunity costs of the social ills they attempt to treat amount roughly to the equivalent of $100,000,000,000 per year. The potential savings in scarce resources from even small improvements are thus quite large.

2. Perhaps more than most others, the services directly intervene in matters of life and death; improvements in them can immediately save people's lives. Moreover, improving the "physical insurance" they provide can enhance people's feelings of security and well-being and thus better the intangible quality of life.

3. The technologies and management problems involved appear remarkably universal -- that is to say, quite similar even across major differences in cultures and economic systems. Results therefore promise to apply to services in many countries.

4. Relatively complete systems-analytic research on these services is in hand, based largely on work in the US and the UK over the past eight years. Indeed, not only research but operating experience is available: many of the results have been put into practice by pioneering local service organizations and found to work well -- some have already been tested on the firing line for more than five years.

In addition, from the work on emergency services and from related work on general service productivity, we have distilled basic, applicable principles that show how to improve the planning and management of nearly all services. This work thus has the potential to advance the broader literature on service management, per se -- a literature that is surprisingly sparse, considering the major roles services play in all governments and developed economies.

Approach

Building on this relatively advanced state of the art. we are working to synthesize what is known (doing research in parallel to fill gaps) and to document the material to meet the needs of practicing analysts and analytical practitioners. The documentation is being prepared as a monograph, most likely to be included in IIASA's "Systems Analysis State-of-the-Art" series, to be published by John Wiley.

Our aim is to provide methods, analyses, ideas, and insights that can help managers, and those who assist and advise them, in the near term, and to provide the analytical and intellectual framework that will help shape the way the future will evolve. Though short-run and long-term

considerations are often separated and handled by different groups of people who sometimes seem to speak different languages, we are trying to avoid such a bifurcation.

To bridge the potential gap in interests, backgrounds, and styles between "managers" and their advisers on the one hand, and "planners" or "analysts" on the other, we are drawing heavily on case examples. Selected from experience in at least two countries (and, we hope, several more if we are able to obtain sufficient details about relevant work in Europe and the USSR), these examples are used to illustrate concretely what analytical results mean, how methods can be (and, indeed, have been) applied in real situations, and how non-analytic (e.g., psychological, political) considerations can be taken into account.

To highlight key points from the more technical sections, we are providing "executive summaries" and extracting into separate sub-sections the most important policy and programmatic implications. We are also developing some handbook-like details, such as managerial and planning check lists and step-by-step instructions for collecting and analyzing specialized data, to assist in translating complex methods and ideas into practice. And, in overall style, we seek to achieve an effective middle ground between what is often perceived as the over-generality of writings for general management and the arcane aridity of writings for specialists. With this organization and style, the book should also prove of interest to students and professionals in such fields as management, public administration, planning, urban studies, operations research, economics, and engineering.

Detailed Agenda

As it is now being written, the book has three central foci:

1. Basic principles of service management, concerned with problems and issues common to all urban services, and to many others as well. This part provides a conceptual foundation for service management, in general, and for the rest of the book, in particular. It sets in context emergency service problems and solution methods, showing how they follow naturally from the basic principles we have developed.

For example, we briefly review here some of the essential characteristics of services, and of public services, that distinguish their management tasks, style, and concepts from those of production management, which overwhelmingly dominate the literature. In more depth, we examine the features of urban services that determine how they can be

supplied, developing a systematic typology that reveals major points of leverage for making improvements.

Since the writing stems from research done jointly with operating agencies, it includes material typically omitted from systems analysis. For example, in discussing criteria and measures, we develop the use of such neglected, but societally important, measures as robustness (ability to perform well under widely varying conditions) and resilience (ability to recover quickly and effectively from stress). In another section, we develop operational concepts of equity and present ways to analyze and treat distributions of costs and benefits. Also we present methods that can help shape or revise service objectives and link them to societal goals and the service "products" people demand.

2. Planning and management of emergency services, the main focus of the book. This subject divides naturally into four unequal parts:

What the "real world" is like -- detailed descriptions of the functions, roles, and settings of emergency medical, fire protection, and police emergency services. Using examples and data from several countries, we describe, as concretely as possible, what these services do, how they are organized and operate, what personnel and technologies they use, what planning and management problems arise, and how the operating services are embedded in larger systems (e.g., ambulances and emergency rooms in the health care system), and where points of leverage typically are. We spotlight key areas where change could be induced, or already seems likely to occur, especially in the larger milieu, where changes could significantly reshape the services' futures. We also note major international variations and emphasize the essential similarities and differences between the services.

Longer-range planning and management questions, focussing on issues common to nearly all emergency services. We distinguish demand and supply.

Under demand, we consider the nature of demands for emergency services and the ways in which these can be reduced, modified, or at least well understood. Some of the more costly features of emergency services mainly provide physical insurance against dangerous risks; if the risk magnitude (hazard) and/or the frequency of occurrence can be reduced, so can the premium that the public pays. Topics we treat here include identifying points of leverage in the causal loops, setting priorities

for resource allocation, comparing regulatory and economic approaches to "prevention", uses of marketing methods, secondary and tertiary impacts, and -- since the field is as yet not well understood -- pilot program design, testing and evaluation.

Under supply, we develop the analytical methods, prescriptions, and insights needed to make the relatively infrequent strategic decisions that determine the aims, levels, and quality of service. Much of this part relies heavily on a host of mathematical models, which are developed and described in enough depth to permit most analysts to use them in good conscience. The really gritty details are provided mostly by reference, except where the original source is inaccessible or incomplete. Supply topics covered include: setting objectives and designing services; examining budgetary and organizational questions; establishing levels of service standards, demands; larger milieu; setting numbers of personnel and facilities; choosing locations for personnel and facilities; selecting technologies and assessing their impacts; dealing with the future.

Shorter-range planning and management questions, where we develop the methods, ideas, and insights, and prescribe the tactics needed to make the frequent, rapid, short-range decisions that immediately influence the quality of the service provided. Even more than the preceding section, this part builds heavily on quantitative models, many of which have been or can be used in "real time". Shorter-range topics covered include: generating and selecting short-range alternatives; setting policies for response initiation; establishing the bases for real-time choice (e.g., for choosing the kind and size of response to be made); analyzing policies; allocating personnel; implementing policies.

Basic methodological problems encountered in analyzing all emergency services. On the whole, these problems are common to many other fields, such as ecological and energy policies, where progress toward solving or understanding them is also incomplete. A number of topics are treated briefly; three main areas are covered in moderate detail. These are: demand and risk (hazard) analysis, by time, location, and contributing factors that can be influenced by policy; time preferences and the comparison of impacts occurring at different times (e.g., short-term and long-term effects); risk preferences and their implications for service standards, including questions of the "value of life", the marginal value of response time, and the identification of service impacts.

Where possible, we present methods that work respectably well on typical real problems, given the current state of the art.

3. Implementation, concerned with putting results into practice and conducting real-world analyses. We stress the operational, strategic, and managerial considerations that underly success. In the latter area, we present a kind of handbook for planning specific systems analyses on emergency services. Here we emphasize key priorities and methods that have been found to work well but about which the literature is surprisingly mute.

Epilogue

At this point, one might well ask: what is the value of these sophisticated methods? Experience provides some answers. In the city of New York, for example, putting into practice only some of the programs flowing from the research on which this book is based has resulted in gains estimated at $10,000,000 per year or more in the Fire Department alone. These are gains in effectiveness and quality of service that would have cost vastly more to achieve by traditional means as well as actual budgetary savings made possible by improved efficiency. Estimates of gains to be realized from more extensive implementation have produced figures at least twice as large.

In other service departments, the gains have been similarly significant, and the potential gains from straightforward improvements have been estimated to be as much as ten percent of the overall budget. Estimating the gains to be realized in better service and lower costs from more sweeping improvements, such as the material in the book can prescribe, is obviously much more speculative. But one can say with some confidence that the methods presented will repay many times over the costs of applying them -- wherever mortality, morbidity, property loss or crimes remain too high, or where emergency services demand resources society would rather not have to supply.

COMPUTERIZED URBAN TRAFFIC CONTROL AND GUIDANCE SYSTEMS

Horst Strobel

Motivation

The environmental, economic, and social problems resulting from the increasing use of private cars are sufficiently well known. Time losses due to traffic congestion in Paris approximately equal the working time of a city of 100,000 inhabitants; financial losses due to accidents in the Federal Republic of Germany are estimated at about one billion dollars per annum; about fifty percent of man-made air pollution in US cities is produced by cars.

These problems vastly influence the quality of urban living. What solutions can be offered? Roughly, the known proposals are of three kinds: change the rules of the game, that is stagger working hours, limit fuel consumption, create pedestrian zones, and so forth; improve existing systems; and provide new technological options.

In this section we consider the role of computerized traffic control in the latter two approaches: improvement, and new options.

Urban Traffic Problems

The social, economic, and other effects of urban traffic problems, particularly important to cities of the IIASA NMO countries, are illustrated in Table 3 and [5, 14, 15, 31]. They may be divided into problems of conjestion, accidents, and environmental hazards.

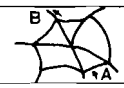
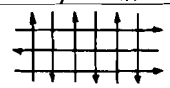
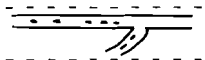
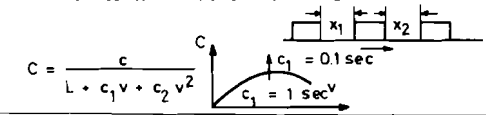
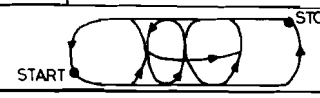
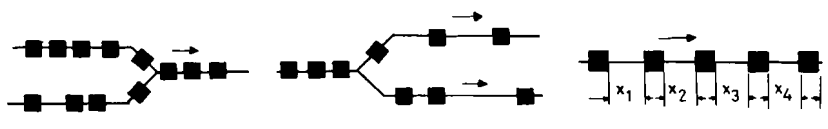
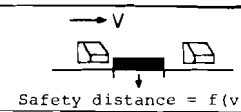
		PRIVATE MOTOR CARS			PUBLIC TRANSPORTATION	
(A)	PROBLEMS	TRAFFIC CONGESTION	ACCIDENTS	ENVIRONMENT	ATTRACTIVITY	EFFICIENCY
	Economic, social, energy, and others	- Paris: time losses = working time in a city with 100,000 inhabitants - economic losses ⇝ $9.6 million yearly - air pollution ↑ - noise level ↑ - energy ↑	USA: 50,000 FRG: 20,000 FATALITIES per year - economic losses 2.6 billion DM per year	USA: 50% of all man-made air pollution - noise levels - cutting off the city ⇝ migration to suburbans ⇝ increasing traffic	Low compared with private car (no door-to-door transportation etc.)	Increasing personal costs
(B)	PROPOSALS for the SOLUTION of the PROBLEMS	(1) CHANGING THE RULES OF THE GAME (staggering working hours, limiting fuel consumption, pedestrian areas, park and ride, car pools, exclusive bus lanes) (2) IMPROVEMENT OF EXISTING SYSTEMS (3) PROVIDING NEW TECHNOLOGICAL OPTIONS (3.1) OPERATIONAL INNOVATIONS (dial-a-bus) (3.2) TOTAL-SYSTEMS INNOVATIONS - people movers and guideways - dual mode concept				
(B 2)	IMPROVEMENT of EXISTING SYSTEMS using TRAFFIC CONTROL	LEVEL I: OPTIMAL GUIDING OF TRAFFIC STREAMS IN REAL-TIME OPERATION 			LEVEL I: OPTIMAL SCHEDULING AND COORDINATION OF RAIL, BUS AND OTHER SYSTEMS	
		LEVEL II: - AREA TRAFFIC CONTROL  - MERGING CONTROL  - REG. OF A STRING OF VEHICLES 			LEVEL II: OPTIMAL CONTROL WITH THE AIM OF MINIMIZING DELAYS	
		LEVEL III: SPEED CONTROL, COLLISION PREVENTION			LEVEL III: ENERGY OPTIMAL AND SPEED CONTROL	
(B 3.2)	TOTAL-SYSTEMS INNOVATIONS - CONTROL OF GUIDE WAY SYSTEMS	LEVEL I: SUPERVISING AND OPTIMAL CAR-GUIDING THROUGH THE NETWORK 				
		LEVEL II: TRAFFIC CONTROL IN STATIONS AND ON GUIDEWAYS 				
		LEVEL III: SPEED CONTROL COLLISION PREVENTION 				

Table 3: Urban traffic problems and solution possibilities by means of computerized traffic control system.

1. Traffic congestion - losses in time and money due to congestion are tremendous. It has been estimated by the UK Road Research Laboratory that the loss to the community from traffic delays in a city with about 100 intersections is in the magnitude of $10 million. This value does not take into account the increase in air pollution and noise levels resulting from congestion.

2. Traffic accidents and fatalities - one can observe a close correlation between the number of human beings killed by accidents and the number of private cars. In 1970 about 50,000 fatalities occurred in the US and 20,000 in the FRG. The economic losses caused by street accidents in the FRG are estimated to be about one billion dollars per annum. In other countries, e.g., the East-European countries including the USSR, the number of private cars, is rapidly increasing, and, with a certain delay, similar difficulties can be expected.

3. Air pollution and noise levels - about fifty per cent of all man-made air pollution in US cities is produced by cars. These increasing levels, and the demolition of urban areas by bigger and better freeways, motivate migration from cities to suburban areas, thus creating more traffic.

What solutions can be offered for these problems which vastly influence the quality of urban living? The known proposals can be classified under the following headings (cf. Table 3, and [5]): (1) changing the rules of the game by staggering working hours, limiting fuel consumption, creating pedestrian zones, park and ride systems, etc.; (2) improving existing systems; and (3) providing new technological options.

The work of the Urban Project on traffic control dealt with a problem on the operational level: how can advanced computerized traffic control systems contribute to the solution of urban traffic problems, taking into account vehicular street traffic as well as existing or new public transportation systems? -- an essential part of the general question, how can we operate in an optimal manner an existing or new urban center with a given or planned industrial, social, cultural and traffic structure.

We will examine here in particular the role traffic control systems can play in approaches (2) and (3) above -- improving existing systems, and providing new options.

Improvement of Existing Systems by Computer Control

Here we distinguish three levels of a hierarchical control structure:

1. Adaptive route guidance systems, where the control systems assist the driver in finding the quickest route through an urban area, (cf. Table 3), taking into account the real traffic densities and congestion. So far, such complex control systems could not be implemented for a large urban street network; but experience with some simplified systems for interurban traffic in France suggests that adaptive route guidance could have the following results: a remarkable reduction of travelling times; the avoidance or at least reduction of traffic congestion, and a decrease in the number of accidents; a decrease in the levels of noise and air pollution (cf. [31]).

A hierarchically structured computing system has been coupled with several thousand signalized intersections (8,000 in the final stage) in a Tokyo system using a multi-criterion control strategy with feedback features (cf. [15], 20]).

A comparison of the operational experiences with the 1969 (non-computerized) system and the new (1973) computerized one showed that in spite of a fifteen per cent increase in traffic volume during one year, there was a thirteen to thirty-one per cent decrease in delays and about a thirty per cent decrease in traffic accidents (cf. [15]). The travelling speed during rush hours could be increased from about eight to sixteen mph.

The installation of traffic signal control systems is easier and less expensive than alternative measures such as building new roads or replanning the city center. Cost/benefit analysis made in cities that have installed such systems (West London, Madrid, Turin) shows that the installation cost is balanced by the benefits accumulated in the first six months of operation (cf. [14]), without taking into account the decrease in accidents. Such a favorable ratio is at least one order of magnitude above the most optimistic results expected in any public works or business enterprise. From the methodological point of view it must be emphasized that the cost/benefit relation is highly dependent on the efficiency of the control strategy used.

A second very important control problem of level II (cf. Table 3) deals with the optimal control of highway traffic flow, the merging process and the distances in a string of moving vehicles (cf. [8]).

New Technological Options

Innovative techniques for solving urban traffic problems may be operational (dial-a-ride or dial-a-bus, [15]); or may deal with total systems (peoplemovers, guideway, and PRT systems, the dual-mode concept). The terms "peoplemover" and "guideway systems" refer to automated transportation systems somewhat like scaled-down rapid-transit networks. At the highest level of service visualized, a network would consist of a grid of guideways with stations spaced close enough to permit reasonable working access to the system. On-demand service would be provided by four to twelve passenger vehicles providing nonstop computer-controlled origin-to-destination travel. Obviously such a system would be highly competitive with the automobile.

In the dual-mode concept a vehicle operates as an ordinary vehicle on city streets and then enters stations where it is switched onto a guideway and controlled in much the same way as described above. An economic advantage of the system is that the costly, low-density, suburban collection and distribution functions could be performed by persons driving their own vehicles to and from stations just as they drive to and from freeways today.

A comprehensive computer-aided systems analysis of urban transportation made by a group in the US suggests that for cities of over 0.5 million inhabitants a combined guideway and dial-a-bus system is already more economical and attractive than e.g., new subways. They estimated that such personal transit could be developed and tested within five years at a cost of about $100 million, which is insignificant compared with the cost of any sizeable subway: about $1 to $2 billion. As this result cannot be generalized for other cities, a systems analysis approach is needed to assist decision makers in different countries in choosing an acceptable solution to their urban traffic problems. The complexity of this subject needs international cooperation at a very early stage, and IIASA could play a clearinghouse role and analyzing the results of the NMO transportation research centers.

What significance will traffic control problems have for these new transportation systems? One can simply say: they are of vital importance, and their effective solution will determine the efficiency and attractiveness of the whole transportation system. What kind of control problems must we consider? In this connection it is interesting to observe that we have to deal with a three-level hierarchical control system which contains problems that are very similar to those occurred in vehicular traffic

control: the network level, i.e. supervising and control of the traffic in the whole network including adaptive routing and optimal distribution of empty cars; the station and guideway level, i.e. merging control and regulation of a string of moving vehicles with the aim of maximizing guideway capacity and, the vehicle level, i.e. speed control, collision avoidance, etc.

Aim of Future Research Work

It seems clear that computerized traffic control systems are an important tool for improving the efficiency of existing and new urban traffic systems; that all NMO countries must deal with such systems, at least with computerized control and guidance for vehicular traffic in urban networks and on interurban highways; and that essential differences exist among various countries (USA/Canada and Japan; Europe and Japan; Europe and USA/Canada). These consist mainly in the following:

- philosophy of traffic control;
- applied methodology;
- structuring of the computing system (centralized or decentralized computing power);
- integration of traffic signal control with a traffic information system and adaptive route guidance systems;
- cost/benefit considerations;
- risk evaluation (e.g. destroying a control center coupled with a large number of intersections).

In view of these differences, it would be useful to prepare a comparative analysis of computerized traffic control systems in Japan, North America and Europe as a contribution to IIASA's Handbook Project. This work, which is under way and should be finished in 1975, will identify advanced concepts, methods and software packages for traffic control and simulation, as well as for reliability and risk evaluation and cost/benefit analysis.

Concerning risk evaluation quite new problems seem to occur with new control centers coupled with a large number of intersections in the case of sabotage acts, etc. IIASA could be a favourable place for such an activity since

the big national traffic research centers are almost only interested in problems of their own countries; this work can be done with modest research resources and it would be a contribution to IIASA's clearinghouse function.

A second aim of our work is to investigate and enlargement of the identified methodology in a case study. It has been proposed to prove the feasibility of an adaptive route guidance system for Vienna. Preliminary research would be required on the following topics:

1. Availability and quality of traffic data of the selected city (Vienna); these investigations have been carried by external work at the Technische Hochschule Vienna, supported by a IIASA grant;

2. State-of-the-art studies to identify the most advanced methodology for traffic simulation and control;

3. A comprehensive traffic simulation program in IIASA's program library.

A decision on the extent of this real-life experiment will be made after evaluation of these preliminary studies.

RESOURCE-CONSERVING URBAN DESIGN

Harry Swain

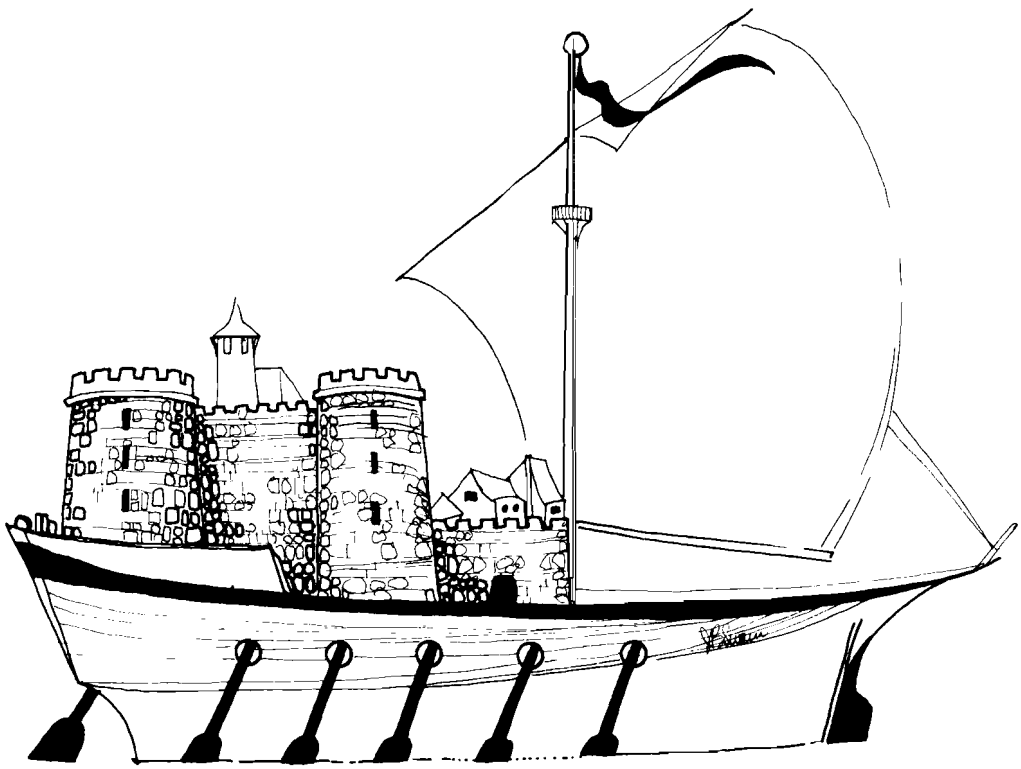
Let me make clear from the start that this is an area where we have only intentions, not yet accomplishments. Nonetheless members of our group share with the Ecology, Energy and Industrial projects the conviction that much of the waste, inefficiency and overconsumption that characterizes so much of modern society is concentrated in urban regions, and may even be inherent in the nature of modern urbanization processes. Now, the volume of new urban fabric which will be built in the remainder of this century is roughly equivalent to all that now exists. Unless we make some improvements in design, in the broadest sense, and operation, rates of technological progress are indeed likely to be swamped by materials scarcity and growth in demand.

Underlying modern cities' profligate use of resources are three basic problems: overly low discount rates, a disregard for 'the tragedy of the commons,' and an inability to manage very rapid rates of social and technological change efficiently. To a certain extent, though by no means wholly, these problems and their everyday manifestations may be alleviated through changes in pricing policies so that a more accurate allocation of external or social costs is reflected in the prices of goods and services. More fundamentally, though, the problems are those of human values, which raises again in a new context the oft discussed IIASA question of education for the 21st century.

It is not clear where we should start. For that reason, the meager resources we are devoting to this topic in 1975 are exploratory only, intended to pave the way for genuine implementation as a continuing IIASA concern in 1976 and beyond. We have already had internal seminars on the subject and have petitioned UNEP for help in this exploratory phase. In practical terms, we shall likely seek practical

ways of adding criteria on resource conservation and resilience to the standard desiderata for the design of new urban fabric. At this point in our short history, however, we have a growing menu of topics for research, and will not be making any final decisions for several months yet. Correspondence from interested parties would be welcomed.

Whatever direction we finally take will be closely linked to the concerns of other IIASA projects, and will necessarily have to deal with the application of human values to technological options. It is in the light of this developing interest that the final contribution to this report should be read. Dr. Baecher has been dividing his time between the Urban and Energy groups, and his review of plan evaluation techniques for the siting of large power facilities makes a good beginning to a new stream of work at IIASA.



PLAN EVALUATION

Greg Baecher

Plan evaluation is a problem which pervades regional planning and civil works development. While many techniques and criteria have been proposed for evaluation, there is little agreement on the relative appropriateness of competing methods, and the theoretical or methodological foundations have often been neglected. A project has therefore been under way at IIASA to review the methodological foundations of evaluation procedures, and possibly to modify or refine those which hold most promise.

Policy evaluation questions deal primarily with "open systems"; in other words, with systems involving sets of variables and impacts too numerous or complex to be enumerated in analysis and some which *a priori* cannot even be identified. For this reason, we decided to select a test problem as a vehicle for comparing existing methodologies which was conceptually simple and "closed": a problem for which most impacts could be enumerated and for which tertiary or higher order impacts were minimal. After reviewing then-current work at IIASA and after an initial review of the literature on plan evaluation, the decision was made to use the problem of site selection for large constructed facilities as this vehicle.

Siting Decisions

Large facilities produce impacts on a host of economic, environmental, and social objectives society holds to be important; some of these impacts are considered beneficial while some are considered adverse. A large power production plant, for instance, produces electricity which is used to satisfy a variety of social and economic goals, but it also produces environmental and social degradations. The only way the latter impacts can be mitigated is at the expense

of some beneficial impacts (for example, by increasing costs). Therefore, site selection, such as evaluation problems in general, reduces to establishing technically feasible combinations of impacts, both favorable and unfavorable, which in aggregate are preferred to other combinations.

The structure of siting decisions is typically divided into four parts:

1. Some geographical region is first screened to identify "feasible" sites on the basis of a set of exclusionary spatial and engineering criteria. This results in a drastically reduced number of most-favorable sites, which may then be analyzed more intensively.

2. Next, important criteria or objectives are identified for which impacts will be predicted, and indices with which to measure impacts against each objective are selected.

3. Predictions of impacts for each site are made in terms of the chosen indices.

4. Finally, an objective function is specified over the chosen indices with which the sets of impacts generated by alternative sites are ordered according to desirability.

While the process of selecting sites depends on this structure, evaluation itself rests on a balance of the results of steps three and four. Predictions of impacts yield a quantitative description of technically feasible trade-offs among different impacts; that is, they indicate the marginal rates of substitution among impacts which *can physically* be realized. The objective function yields a quantitative description of desirability trade-offs among different impacts; that is, it indicates the marginal rates of substitution among impacts which are *equally desirable*. Clearly, the optimum alternative is that for which these rates balance; the optimum decision is that for which changes in one impact toward more desirable levels force changes in others toward less desirable levels, such that the net result is a decrease in *total* desirability.

The bulk of the literature of siting deals with predicting impacts of large facilities; this is clearly important, but it is only part of the problem. Impact prediction is essentially the same for all evaluation methodologies, so what actually differentiates these is the character of their objective functions. Therefore,

the present work has concentrated on differences and similarities in the objective functions of evaluation methodologies and the assumptions these functions are based on.

If methodologies are classified according to the character of their objective function, one finds that current approaches to site evaluation can be generally classified into three groups: cost-benefit analysis, matrix techniques, and preference theories. Of prime importance to us in these objective functions, and hence in evaluation methodologies generally, are the explicit or implicit assumptions made about the *structure* of desirability over impacts -- linearities and non-linearities, interdependencies, and marginal rates of substitution. In Table some of these assumptions and other properties of the three groups of methodologies are briefly abstracted. Although one might carry on at length [1] on the assumption and applicability of each, the major points may be summarized rather briefly.

Cost-Benefit Analysis

Cost-benefit analysis with its modifications has been the primary tool for public works programs for several decades. It is a well understood technique with which we have considerable experience, and this in conjunction with its conceptual simplicity makes it widely acceptable to decision makers.

Traditionally, cost-benefit analysis has based desirability on the sole criterion of economic efficiently defined as the net balance of benefits and costs accruing to society as a result of some program alternative. More recently, attempts have been made to include externals within this analysis (i.e., environmental and social impacts), but these are always evaluated in the context of *economic* impact, which often biases or incompletely accounts for actual levels of desirability. On the other hand, assessments of desirability are made from market or market-like data, which is a more straightforward approach than with some evaluation methodologies.

Because impact desirabilities are scaled in monetary units, cost-benefit analysis rests on implicit assumptions about the structure of desirability which may not be valid. First, most applications assume linearity of desirability over impact levels; this is not actually necessary and non-linearities could be introduced, but they seldom are. Second, because monetary impacts are directly additive,

the desirabilities of different impacts are independent. Third, together these two assumptions lead to constant marginal rates of substitution among the desirabilities of impacts. Finally, because there is no rigorous theoretical basis for handling uncertainty it is usually treated by ad hoc rules.

Matrix Methods

Matrix methods were developed primarily to mitigate the difficulty of including external impacts within the context of cost-benefit analysis. These methods present impact predictions in tableaus or matrices (hence the name) in unaggregated or partially aggregated form, and require the decision maker to aggregate judgmentally in arriving at an evaluation. Often impacts are listed according to societal group and sometimes with respect to time as well. The underlying assumption of these methods is that impacts on different objectives are fundamentally non-comparable and attempts to compare them only distort the true levels of desirabilities by making inherently invalid assumptions. Uncertainty is treated in the same way by exhibiting ranges of possible impacts.

In some cases aggregation of impacts is attempted by using simple judgmentally assigned weighting schemes, usually measured to an ordinal scaling (e.g., the range 1 to 10), then taking a weighted sum with respect to the importance of each. These schemes are notoriously untrustworthy as they frequently perform arithmetical operations on ordinally scaled data, leading to totally unpredictable results.

Preference Theories

Preference theory approaches to evaluation have arisen mostly out of work on individual decision making under uncertainty, and have begun finding application to public decisions, and evaluation only in the past few years. What differentiates preference theory methods from those already discussed is that they are based on a small number of simple axioms of preference from which can be derived a rigorous theory accounting for complex inter-relationships in preference for multi-attribute uncertain impacts.

The two preference theory methods most commonly used in public applications are the indifference surface concept of classical economics, which is an ordinal scaling of desirability; and the utility function of von Neumann and Morgenstern, which is an interval scaling. However, as

indifference surfaces become exceedingly difficult to apply when the number of impacts exceeds three, for most interesting evaluation problems utility functions are the only preference theory method used.

The advantages of preference theory over other evaluation tools are the rigorous handling of inter-relationships in preference, which allows non-linearities, dependencies, and changing rates of marginal substitution; and the formal; ized mechanism for treating uncertainty, which is unique among evaluation methodologies.

However, utility theory is not without drawbacks, which stem more from difficulty in application than in theory. Essentially, the problems of applying utility theory are threefold: it is conceptually complex so not readily accepted by decision makers; we have little evaluated experience with its use; and the assessment of utility functions is time-consuming and difficult, and may lead to bias errors of unknown magnitude. Nevertheless, were we able to overcome these drawbacks, in particular the last one, utility theory would seem the superior technique for making siting decisions.

Future Work

The state-of-the-art report is based on theoretical aspects of evaluation. The clear next step is to look at applications and to see just how sensitive "optimal" plans are to methodological changes. From this work we hope to gain insight into presently unrecognized difficulties of application and to learn more about the incremental improvement in evaluation offered by more complex methodologies.

The second thrust of future work will be directed at developing a theory of assessing interest group preferences for impacts generated by large facilities. A failing of application, largely owing to the difficulty of utility assessment. If we are to use preference theory in evaluation, and thus benefit from its rigorous theoretical foundation, we must first develop better and simpler methods of assessment.

Assessment schemes for individuals have been discussed and refined in the literature of individual decision making, and we have some experience with their application. The two problems which must be worked on for application to public project evaluation are, (1) does direct assessment as opposed to market (i.e., "behavioral") approaches generate significant bias errors or temporal inconsistencies; and (2) how can utility functions for interest groups be estimated?

These are very different questions -- how can we *scale individual preferences*; how can we *sample group preferences*? -- and will require answers from different sources. Work on the former is being carried out by John Collins of the University of British Columbia, in collaboration with work on the latter here at IIASA.

Now, if one assumes that bias errors in individual assessment can be made small (and this is the purpose of Collins' work), the problem of interest group utility assessment reduces to one of sampling. By making a small set of intuitively reasonable assumptions one can demonstrate that interest group utility functions can be constructed from the distribution of the parameters of individuals' utility functions. Thus, estimating group utilities reduces to estimating the parametric distribution and this in turn can be addressed using Bayesian sampling theory. Economic data of the sort used for cost-benefit analysis are incorporated in this analysis as a "prior distribution".

The hope is that by combining Collins' work with a rigorously based theory of sampling, one can directly assess interest group utilities which include uncertainty in estimates of utility parameters, economic data, and reflective choice. Such a result would contribute substantially toward making the use of utility theory practical in plan evaluation.

Methodology	Aggregation of Impacts Into Scalar Index	Implicit Assumptions On Desirability	Are There Impacts External To The Analysis?	Assessment	Miscellaneous
Cost-Benefit Analysis	yes	usually but not necessarily linear in impact index independence between impact desirability constant rate of marginal substitution	based on economic facets	economic data (comparitively easy)	evaluated experience decision maker acceptance "objective" no rigorous treatment of uncertainty
"Matrix" Methods	usually not, otherwise ad hoc	usually assumes non-intercomparability	none	no desirability assessment	impossible when number of impacts is large scaling problems
Preference Theories	yes	rigorously defined inter-relationships: non-linearity inter-dependence non-constant rate of marginal substitution	theoretically none	difficult unknown bias errors	little evaluated experience conceptually complex

Table 4:

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Appendix 1:

Papers by Members of the IIASA Project on Urban and Regional Systems

May 15, 1975

Note: The WP series are informal, in-house working papers which are distributed outside IIASA for comment and criticism solely at the discretion of their author(s). We include their titles here only to inform readers of the kinds of topics currently exercising project members. All other papers may be ordered through the IIASA Publications Department.

Baecher, Gregory B. "Spatial process modelling for air pollution standards: a problem statement," WP-75-40

Baecher, Gregory B. "Subjective sampling approaches to resource estimation," RM-75-00 (forthcoming)

Baecher, Gregory, Jacques Gros and Karen McCusker, "Balancing apples and oranges: methodologies for facility siting decisions," RM-75-00 (forthcoming)

Berry, Brian J.L. "Do variations in urban form affect environmental quality?" RM-74-24

Blum, Edward H. "Combined migration-diffusion models: analogies for regional development," WP-75-24

Blum, Edward H. "Square root laws for urban regions," RR-75-00 (forthcoming)

Blum, Edward H. "Caveats and questions about large models," RM-75-00 (forthcoming)

Blum, Edward H. "Concepts of distributional equity and their implications," RR-75-00 (forthcoming)

Blum, Edward H. and Harry Swain, "Urban UNEP proposal," WP-75-52

Casti, John and Harry Swain, "Catastrophe theory and urban processes," RM-75-14

Collins, John B. "How much environment should energy cost? (or how to find out)," WP-75-20

Cordey-Hayes, Martyn, "Models of national settlement systems. 1: a preliminary perspective," WP-74-23

Cordey-Hayes, Martyn, "Models of national settlement systems. 2: How should one approach policy-oriented modelling of poorly understood systems?" WP-74-28

Cordey-Hayes, Martyn, "A preliminary comparison of rates of population restructuring," RR-75-00 (forthcoming)

Cordey-Hayes, Martyn, "Migration and the dynamics of multi-regional population systems," forthcoming in Environment and Planning

Cordey-Hayes, Martyn, and David Gleave, "Dynamic models of the interaction between migration and the differential growth of cities," RR-74-9

Gambrelle, Jean-Marie, "A comparison of simple models for the projection of regional populations," RR-75-00 (forthcoming)

Kudinov, Oleg V. "Principles of the distribution of productive forces in the USSR," WP-74-69; revised version forthcoming in Swain (ed.) National settlement systems

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MacKinnon, Ross D. "A first attempt to combine interregional migration and spatial diffusion models," WP-75-22

MacKinnon, Ross D. "Geographical diffusion processes: a working paper on alternative methodological approaches of an operational type," WP-75-29

de Narbonne, Claire, and Harry Swain, "Urban research institutions in France," RM-75-19

Raup, Philip M. "Perspectives on the world food crisis," RM-75-00 (forthcoming)

Rousselot, Michel, ed. Proceedings of the IIASA planning conference on urban and regional systems, 1973

Sievering, Herman, with Brenda Forster, "Public attitudes and systems analysis: need for a communications framework," WP-74-62

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Sokolov, Valeri, "Models aiding national settlement policies in the USSR," forthcoming in Environment and Planning

Swain, Harry, "Proposed research program for management of urban systems," October 1973

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Wilson, Alan G. "A maximization problem associated with Drew's institutionalized divvy economy," RM-74-5

Wilson, Alan G. "Linear programming and entropy maximizing models," RM-74-6