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# The Need for Evaluative Methodologies in Land Use, Regional Resource and Waste Management Planning

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Center for Environmental Studies

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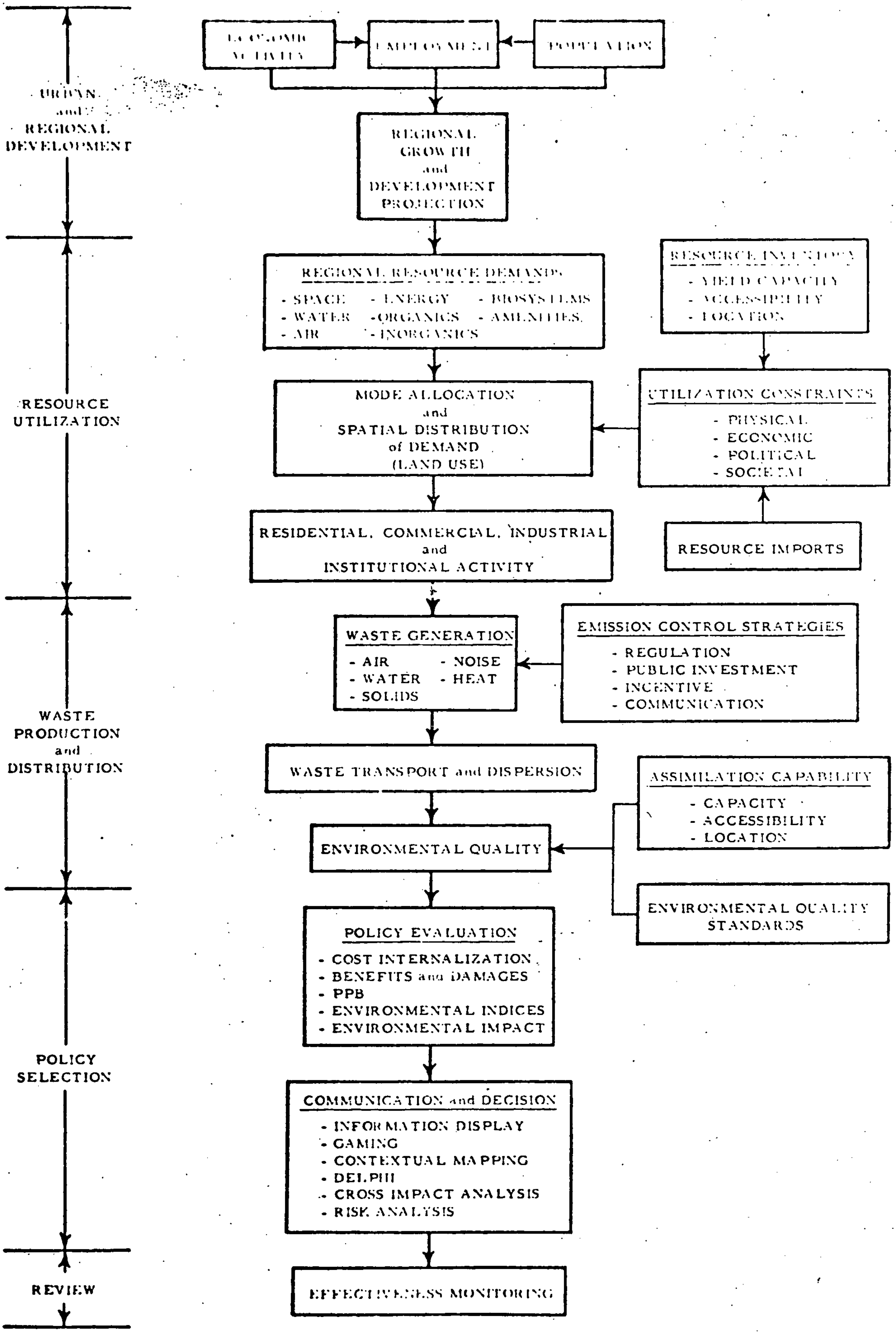
## Introduction

The transfer of planning methodology from the research community to the practitioner very frequently takes the form of analytical and evaluative techniques and procedures. In the end, these become operational in the form of data acquisition, management and display systems, computational schemes that are codified in the form of manuals and handbooks, and computer simulation models. The complexity of the socioeconomic and physical processes that govern environmental resource and waste management have reinforced the need for computer assisted, scientifically sophisticated planning models that are fully operational, dependent on an attainable data base and accessible in terms of the resources normally available to practitioners of regional resource management, waste management, and land use planning.

A variety of models and procedures that attempt to meet one or more of the needs of these practitioners have been proposed, developed, and tested during the past two decades, though few have reached the operational stage and fewer have attained the transferability that is required of a general methodology. It is worth the effort to classify these models and to articulate the relationships between them, because each component of an idealized, comprehensive resource-waste planning methodology represents a perceived need for technique, and the structure of an idealized comprehensive planning methodology could do double duty as the structure of a national research program. The accompanying figure illustrates this comprehensive methodology (but omits many of the feedback loops that an economist, biologist, or environmental protection planner would insist upon).




EVALUATIVE METHODOLOGIES IN LAND USE, REGIONAL RESOURCE AND WASTE MANAGEMENT

Planning and evaluation methodology can be stratified into five general functional groups:

1) Urban and Regional Development
2) Resource Utilization
3) Waste Production and Distribution
4) Policy Evaluation and Selection
5) Effectiveness Review and Monitoring.

Within each of these categories is an array of models and techniques. Many of these have been explored, developed, and tested (with limited success) in the recent past. Some have been developed and applied in contexts other than resource-waste management and others remain in a purely conceptual state at present. In a few notable cases, investigators such as Hamilton (in the Susquehanna basin) and Czamanski (in Nova Scotia) have integrated and applied some of the key components of the comprehensive planning methodology indicated in the figure to evaluate regional management policies for specific resources.

Urban and Regional Development Models

Regional econometric models, including open system input-output models, have been on the scene for many years (for example, Bell's Massachusetts Model and L'Esperance's Ohio Model), but these have not generally yielded satisfactory performance, have been structured at a very high level of aggregation, and have tended to focus on key export industries rather than land or other natural resources which could, theoretically, be expressed as factors of production. More work is needed to internalize the costs of waste management in these models - possibly along the general lines indicated by Leontief's recent research.

Age- and sex-specific multisectoral demographic models that express births, mortality, and interregional migration have been available for some time (Keyfitz and others), but their ability to treat gross and net migration is not particularly impressive. Such models could, in principle, be adapted to reflect the mortality effects associated with exposing populations to environmental pollution, and to relate the availability of employment opportunities, resources, and amenities to migration patterns, but little work to explore this potential has been done and relatively few practitioners have sought to access the available models for planning at the regional level.

Regional growth and development projection models (such as Cohen's) have been available in one form or another for many years. Most are dependent on some form of implicit or explicit trend projection according to some reasonable and constrained growth curve (linear, exponential, logit, etc.). The more sophisticated versions of these projection models resort to empirical, statistical relationships between dependent variables of interest and independent variables that are trend-projected. There is a need for growth models that are based to a greater extent on first principles and less on extrapolation of past performance.

Models that can be used to replicate the consequences of both absolute growth and of relative growth (or redistribution of population and economic activity) among new and existing urban centers are required - particularly at a time when we are groping toward the articulation of a national growth policy. An absolute increase of population and/or economic activity is likely to entail both accelerated depletion of natural resources and increased production of waste no matter what spatial distribution is involved.

Although it is somewhat artificial to partition absolute growth from relative growth (or development), the former is, to an extent, the driving force for the latter in somewhat the same sense that "basic industry" is the driving force in an export base econometric model. The interfaces between absolute growth, relative growth, and the regional resource and waste product redistribution process should therefore be investigated as an integral part of any attempt to formulate environmentally-oriented growth policies.

Resource Utilization

The estimation of regional demands for space, energy, and natural resources is generally based on an ad hoc set of historical, empirical relationships, which are derived either from relatively immutable physical relationships (gallons of water per acre of wheat) or on less absolute societal standards (dwelling space per capita). For the most part, these relationships fail to reflect the actual or potential impact of technological developments or changes in the cost and accessibility of land and other resources. There is a need for a variable coefficient regional resource demand "model" that not only provides a consistent matrix of demand relationships but also includes computational schemes to modify these coefficients to reflect particular regional, physical, economic, social, or political constraints and technological impacts.

Resource inventory data acquisition, retrieval and display techniques are fairly well developed, as is exemplified by the Lake Tahoe type of system, but the convenience and versatility of computer-assisted inventory schemes is far from a ubiquity at present. Moreover, little has been done to explore the feasibility of coupling current, essentially descriptive, resource inventory schemes with projection models that would yield estimates of future regional resource availability or with normative planning models that would enable evaluation of alternative futures.

In general, a resource inventory should include not only an indication of the type, yield capacity, and location of resources such as water and mineral deposits, but should indicate their accessibility in physical and economic terms. Moreover, multidimensional inventory formats are required that allow the planner to assess the capacity of land parcels to accommodate alternative uses or mixes of uses. The conception of alternative land use and resource inventories is by no means novel (e.g., New York State and the Atlanta, Ga., region), but research is required to develop, quantify, and codify a rational mixed-use capacity catalog for general use.

An array of spatial demand allocation models have been developed during the past twenty years. These range from the early transportation system demand models (intervening opportunity, abstract mode, etc.) through more elaborate urban land development models (Penn-Jersey, EMPIRIC, the Lowry-PLUM series, the San Francisco Housing Model, etc.). Most of these activity allocation models have been very dependent on large amounts of data and few have been wholly successful in an absolute sense. Most were designed to assist in the formulation of public investment policies and the design of region-wide public works projects. Little has been done to exploit their potential for indicating the spatial distribution of the demand for resources and the production of waste under the constraints of a regional land use plan. This generation of models should be upgraded, rendered operational, and adapted for use in a land/resource/waste management planning context, but there is a serious need for additional innovation in the area of land use and resource-waste modeling.

One such innovation would entail the development of a prototype urban or regional metabolic model that would establish the mass-energy balance of an urban concentration to the extent necessary to assess the impact of alternative growth and redevelopment policies and the resource demands, public works, and waste loads associated therewith.

Given the inherently probabilistic nature of land development, another promising new approach is provided by stochastic spatial distribution models of the kind that A. Rogers and others have recently explored. Research is required to develop user-oriented operational, stochastic land use models adapted to use in the assessment of the spatial distribution of resource demands. One of the more interesting prospects for applying stochastic models is to generate probabilistic constraints on the activity clustering patterns yielded by more "deterministic" models of the Lowry-Garin-PLUM type.

Waste Production and Distribution

Simulation models that replicate the operating cycles and control constraints associated with specific resource-consuming and waste-producing economic activities and sectors are required to quantify the short and long time horizon mass and energy flows associated with urbanized, industrially developed regions. An immediate use for such models is found in their applicability to the estimation of pollution discharge rates and volumes. This information is required as input for pollution transport and dispersion models, as well as for the development of the fine structure of present and future pollution emission inventories. In the longer run, such models, in the aggregate, would be a major component of an urban metabolic model. Some activities have been simulated with fair success (e.g., Argonne National Laboratory power plant simulation and airport activity simulation models). This work should be extended to include all significant resource-consuming, waste-producing urban activities (not necessarily more than a few dozen in number). The Monte Carlo approach offers one of the more promising means of quantifying diurnal, seasonal, and annual activity cycles. To develop these, studies of current and projected processing technologies are required.

Pollution source operating cycle models cannot in themselves generate waste production estimates. Sets of what are generally termed "emission factors" (pounds of sulfur oxide per ton of coal consumed, etc.) are necessary. EPA has funded considerable work in this area, although the nature and rate of generation of the more exotic and secondary pollutant species associated with various economic activities are not yet well understood, nor are what might be termed "variable coefficient" emission factors yet available for most pollution producing processes (with the possible exception of large fossil-fueled power plants and some automotive and aircraft systems).

Waste discharges are controlled by imposing an array of control strategies that may involve technological devices, substitution of resources, process and operating cycle alterations, relocation of pollution producing sources, or curtailment of activities. All of these controls are applied through one or more of the four basic powers of government (regulation, public investment, incentives, and communication). Control strategy simulation models which can translate an array of such control concepts into a resultant quantitative reduction in waste discharges for present and projected pollution sources are required. Some models of this kind are currently operational - particularly for the simulation of the effectiveness of air pollution emission control regulations (e.g., the IPP strategy model) and wastewater treatment system performance specifications.

The effects of economic incentives are not well understood and have not been effectively modeled. Neither has the public response to conservation or pollution-control-oriented information programs. (Both of the latter are difficult problems, but some precedent is found in the form of transportation system mode choice models.)

The utility of models that can simulate the effect on waste discharges of emission control strategies should be evident to the land use planner, since the more effective technological and operational controls are, the fewer constraints are imposed on the allocation of land. The interface that needs to be investigated is the one that links demographic and economic activity indices (population, employment, land use, intensity of development, etc.) with the consumption of materials and energy and the concomitant production of waste. These linkages must be established so that the output of socioeconomic prediction and evaluation models can be used to generate natural resource demand estimates and projected pollution emission inventories. In particular, an environmentally-oriented taxonomy of land uses is required to serve the needs of planners. Neither the SLUC system, the SIC system, nor any other prevalent activity or land use classification scheme is presently capable of satisfying this need. Some work in this area is currently in progress at Argonne National Laboratory under EPA sponsorship, and at the University of Florida under Department of the Interior sponsorship. If direct relationships between land use class, intensity of development, resource demand types and volumes, and waste discharge types and volumes can be developed, a regional land use plan would in itself express a resource-waste distribution and management plan.

Given that the present and/or projected spatial distribution of pollution producing sources throughout a region have been determined, an array of waste transport and dispersion models are required. These include

1) Atmospheric dispersion models
2) Surface and subsurface hydrology models

3) Surface and subsurface water quality models
4) Thermal energy dispersion models
5) Noise propagation contours
6) Solid waste transport network models.

Versions of all of these classes of models exist and others are being developed under state and federal auspices during the course of programs that often include massive validation data acquisition programs (for example, the METROMEX and RAPS programs), but there remain a number of significant problems that must be resolved before an array of operational and generally applicable models can be made available for routine use by land use planners. These include

1) The simulation of the effect of topographic effects, aero-chemical transformation and particulate fallout on atmospheric transport and dispersion.
2) Predictive and evaluative models to simulate groundwater and runoff water transport, dispersion, and quality are required to relate these phenomena to land use practices.
3) Simulation of the processes of heat and pollution dispersion in very large lakes, and their relationship with basinwide land use practices.
4) The relationship between the structure and dynamics of the urban "heat island" and the spatial structure of urban areas.

The extent to which the natural environment is degraded by pollutant species is clearly dependent on its capacity for assimilating waste. The ability of the planner to allocate land to uses that are compatible with its natural assimilative capacity would be enhanced by the development of user-oriented, bio-ecological capacity models and evaluative techniques. Much of the basic research required is currently in progress, and institutions such as the University of Michigan have undertaken to develop prototypical models of certain processes, but these are far from being operational in a form that could be exploited by practitioners and policy-making authorities.

For the planner to be able to gauge the degree of environmental damage that can be tolerated as a consequence of a given regional land use plan, environmental quality standards must be available against which to compare estimated or observed ambient pollution concentrations and other indices of environmental degradation and resource damages. These standards are normally established by federal and state environmental protection agencies on the basis of objective observations of biological damages. Considerable research in the area of identifying these damages has been and is now in progress under EPA and other federal auspices, but the fact that the national environmental protection program is geared largely to the control of events that occur on a 24-hour to 1-year time horizon (plus the inherent difficulty of the research problem) has left a deficiency in the area of establishing pollutant dosage standards for long time horizons - particularly those that are characteristic of land use planning (25 years or more). Research to support long-term-low-level dosage standards is therefore needed. Studies of the synergistic effects of exposure to combinations of pollutants are also required.

## Policy Evaluation and Selection

Even if the planner is equipped to develop estimates of ambient pollution concentrations associated with alternative land use plans and has a set of environmental quality standards with which to compare this information, this direct measure of effectiveness is not sufficient for the evaluation of land use policy alternatives which generally entail a variety of physical, economic, political, and societal consequences.

Research is required to develop reliable methods of internalizing the costs, benefits, and concomitant (economic and social) damages of alternative land use policies, and, to the extent that land use planning and resource management involves massive public investment programs, techniques such as the planning, programming, and budgeting (PPB) methodology must be adapted to accommodate the special requirements associated with land use planning. (This, because it is virtually imperative that implementation planning be integrated with land use plan development in order to insure that desirable land use patterns can be realized in practice.)

There is also a need for better cost accounting models to assess the cash flow implications of the capital investments, debt service, operating and maintenance costs, etc., associated with major public investment programs. This long-standing deficiency has only recently been highlighted through the stimulus of the federal wastewater facility construction grant program.

In a broader vein, land-use-oriented environmental indices and impact statements are necessary for policy evaluation, but the state-of-the-art in both of these areas is not yet well developed, and research programs to develop model index systems and impact statement formats and procedures are required.

Other decision-making techniques, equivalent to the Delphi method and cross-impact analysis, should also be developed and adapted for operational use by land use planners and decision-makers. In particular, there is a need for gaming models that require a relatively modest data base to qualitatively replicate the consequences of alternative management policies. These, coupled with Tahoe-type display schemes, could provide a means of sensitizing decision-makers and the public to the full impact of major policy decisions. Such models could be used to simulate the confrontation situations that occur at the state, regional, and local levels in the arena of environmentally-oriented land use planning and policy making. At the state level, such models should facilitate and reconcile the decision-making process among state agencies having conflicting missions (Business and Economic Development, Mines and Minerals, Transportation, Agriculture, Environmental Protection, Public Health, Water Resources, Soil Conservation, etc.). Similar interfaces exist at the regional and local levels of government. Appropriate gaming models could also be structured to facilitate dialogue between agencies of government having equivalent missions but which operate at different jurisdictional levels.

Finally, because virtually any planning decision is an attempt to optimize an uncertain future, the feasibility of applying decision theory techniques analogous to the mini-max returns procedure should be explored within the context of operational, environmental-protection-oriented land use planning.

Effectiveness Review and Monitoring

Land use planners are rarely equipped to systematically monitor the effectiveness with which their plans are implemented and to assess the extent to which the normative goals of a plan - once implemented - are actually realized. In a field wherein the acquisition of data tends to be costly, difficult, and time-consuming and wherein rapidly changing physical, economic and societal conditions continually alter the ground rules, it is to be expected that effective, in-depth review programs would be uncommon. One of the results of this deficiency, however, is that land use planners are seriously impeded from developing and implementing timely plan revisions when needed. The problem is largely associated with what a control theoretician might term the phase lag, feedback characteristics, and nonlinearity of the response to land use and environmental protection measures. Although the only conclusive test of the success of a long-range plan is reflected in such direct measures as settlement density or air quality, the time required to detect and interpret such signals is often long enough that near-irreversible, undesirable consequences can occur before the need for corrective action is perceived. To avoid this difficulty, it is not only necessary to develop methodologies by which short-term trends in the direct measures of plan effectiveness (and their time derivatives) can be interpreted, but to identify intermediate, indirect but fast response indices that reflect the effectiveness with which a plan is implemented rather than the effectiveness with which its ultimate objectives are attained. (For example, expenditures for wastewater treatment facility construction might serve as a short-term, indirect surrogate for water quality.)

The feasibility of developing and deploying a systematic land use, resource and waste management plan effectiveness monitoring and review methodology should be investigated. Basic data requirements should be defined, information acquisition and display systems should be developed and general guidelines for modifying a plan that is in the implementation stage should be prepared. The costs of operating such a monitoring and review process should be estimated.

## The Time Horizon and Research Organization for Evaluative Methodology Development

The level of complexity and state-of-the-art of the models and methodologies that comprise the planning systems described above vary widely. Certain of them could be developed, rendered operational, and disseminated to practitioners in a relatively short time and with the expenditure of a comparatively modest effort. For example, some emission control strategy models, certain activity cycle and emission factor estimation methodologies, the less sophisticated single and multiple (stationary) source, steady-state atmospheric dispersion models, and some data management and display techniques are nearly in a state of on-line readiness. The applied research required to render these fully operational would focus largely on an effort to generalize them, field test them, and communicate them to users with maximum effect. The time required to accomplish such tasks is on the order of 1 to 2 years.

In the mid-range research area lie the studies required to develop, validate, and upgrade waste transport and dispersion models, devise impact assessment methodologies, design an environmentally-oriented land use taxonomic system, develop various communication and decision models (gaming, risk analysis, etc.), conduct mass-energy balance studies of individual urban activities and industrial processes, and develop planning effectiveness monitoring schemes. Such studies may extend over the next 5 to 10 years.

Long-range research at a comparatively high level of effort will be required in order to develop satisfactory econometric-demographic models; transportation demand and urban growth and development models; an urban metabolism model and some of the more complex policy evaluation techniques - particularly those associated with internalization of all of the societal costs of land use, resource and waste management. Certain of the ecosystem assimilation capacity estimation techniques and the development of long-term, low exposure level dosage standards also fall into the category of long-range research. This work may extend over the next 10 to 15 years.

It is important to note that all of the research described above must be performed in such a way that its effectiveness in terms of practitioner utility as well as scientific validity is closely monitored. This is essential if the experience acquired through failures or near successes (and there will be many of these) can be preserved to provide a base on which to build more successful techniques. The need for this kind of communication has been illustrated dramatically by the indifferent success of the large-scale socioeconomic, transportation demand and urban development modeling efforts of the past 25 years.

In general, the most desirable approach to organizing and administering this research - particularly in the long-range topical areas - would be to implement a series of large-scale demonstration projects that include a formal interface with practicing planning and policy making agencies. Forced communication among such projects should be a standard feature of the total program. As methodologies are rendered operational, dissemination should be accomplished through some systematic, formal mechanism.

There are a host of substantive and aesthetic reasons for focusing this array of methodology-development demonstration projects on the problems of demographic-economic regions, but the indifferent success that the DHUD, the EPA and its predecessors have experienced during recent years in attempting to do business at the metropolitan regional level provides a clear warning of the hazards involved. In part, this is attributable to the fact that government at the regional level is generally weak or nonexistent (COG's notwithstanding). Moreover, the natural bounds of certain resource-waste management problems tend to dominate any political boundaries - as is the case for major river basins. The fact is that both historical precedent and recent EPA policy have established the states as the prime repositories of jurisdictional authority and economic power. It therefore seems likely that any attempt to realize a rational land use/resource/waste management program at the regional level that fails to recognize and internalize the powers of state government will be a risky, and perhaps self-defeating, proposition.

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