Modeling and Evaluating the Indirect Impacts Of Alternative Northeast Corridor Transportation Systems

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This paper describes the design-conceptualization and implementation of the model system for forecasting and evaluating the indirect impact of alternative transportation systems in the Northeast Corridor. The set of computer models developed for forecasting and evaluating the indirect impacts of alternative transportation systems contains two sub-models. The first of these is an interregional interindustry input-output model, the formulation of which includes transportation sensitivity between major subregions in the corridor. The second model is an intraregional allocation model which is transportation-sensitive at the more "micro" level of counties. Since the models have not yet been completed the descriptions of them are rather brief, with a good deal of the text being devoted to an exposition of alternative evaluation measures and their appropriate uses within the context of the overall project.

•THE Northeast Corridor Transportation Project of the U. S. Department of Commerce is a comprehensive regional transportation planning activity to determine passenger and freight transportation requirements in the region to 1980 and beyond. This paper describes the work done to date toward modeling and evaluating the indirect impacts of alternative transportation systems within the Northeast Corridor.

The overall project design calls for interrelated studies to forecast the regional change and the demand for transportation, to simulate the operation of transportation networks, to analyze the impact of network modifications on the region and its subareas, to evaluate these alternatives, and to examine ways of managing and financing possible future transportation systems. Other studies will provide information on future transportation technologies and their costs, on state and metropolitan plans likely to affect or be affected by the regional planning activity, and on various patterns of spatial organization in the region and its subareas.

In previous transportation systems planning studies, the predominant approach has been to project employment, population, and land use independently of the expected internal transportation system from which anticipated origin-destination patterns were derived. These in turn form the framework for ultimate transportation system design. In the Northeast Corridor Project, however, an attempt is being made to evolve methods for estimating the impact of the transportation system design and facilities themselves on the projected levels and spatial distributions of employment, population, and land use, and also to develop methods for evaluating network designs for consistency with alternative regional spatial orderings and regional development objectives.

The Northeast Corridor Transportation Project staff specified the following objectives for the economic and demographic impact studies:

Paper sponsored by Committee on Indirect Effects of Highway Improvements and presented at the 46th Annual Meeting.

1. To seek to determine whether transportation effects on the rate of growth of the entire region can be isolated for analysis.
2. To determine the influence of such effects, in isolation or in combination with others, on the rate of growth of the region.
3. To determine the redistributive effects of alternative transportation network mixes on the location of population and employment.
4. To estimate the gross patterns of change in land use to be expected.
5. To ascertain the effects, short- and long-term, of alternative levels of expenditure on transportation facilities on a region such as the Corridor.
6. To develop quantitative measures of benefit and cost resulting from changes in transportation systems performance, through new technology or facilities or both, in the region and its subareas. In effect, an effort to develop community benefit-cost criteria was desired.

THE OVERALL MODEL SYSTEM

The present modeling effort has been designated as the "Phase I" model system. The design and construction of these models placed emphasis on their being completed at the earliest possible time so that they might be used for gross policy determination. As a consequence much attention was given to the derivation of feasible models from the present state of the art rather than any concerted effort to extend it. At the same time that these models are being used, they are also being retested and evaluated, during the latter stages of the Phase I efforts. A proposed Phase II effort will both refine the Phase I models and design new ones, including, when necessary, confrontation with the problems of having to advance the state of the art.

The Phase I model system is designed to produce information necessary to study the following questions:

1. What is the preferred mixture of land uses, economic, and residential activity, from the standpoint of net economic and social benefit?
2. Which multi-county areas correspond to given degrees of social and economic interchange (both personal and interindustry), and the performance of multi-county governmental functions?

The Phase I impact analysis will be based primarily on the concept of "accessibility" and will reflect the consequences of changes in accessibility that result from changes in transportation networks or their characteristics. The Phase I impact modeling system consists of several interrelated sub-models (1). The overall relationships between these sub-models is shown in Figure 1.

The primary inputs to the Phase I impact models are of three types: (a) forecasts of regional totals of income, population, and employment; (b) distributions of the existing levels of all of the impact variables; and (c) data on existing and proposed transportation networks. The forecasts of regional totals of income, population, and employment are produced by an econometric model (2). The network information is provided by the project staff.

INTERREGIONAL INPUT-OUTPUT MODEL

The first of the impact sub-models is IRIO, the interregional input-output model. This model first converts the forecasts of regional totals from the econometric model into vectors of "final demand." The model considers the Northeast Corridor region as divided into from three to five major subregions. The remainder of the United States is treated as being divided into another three to five major subregions. The industrial sectors correspond roughly to the major employment classes of "County Business Patterns" (3).

Realizing that the theory of multiregional input-output analysis is well established, and differences in approach, for the most part, can only be subtle ones, variations in approach are principally in the treatment (both theoretical and operational) of flows between regions. The motives of this study strongly dictate that the analysis be rendered transport-sensitive. In accordance with the criterion that the model must not

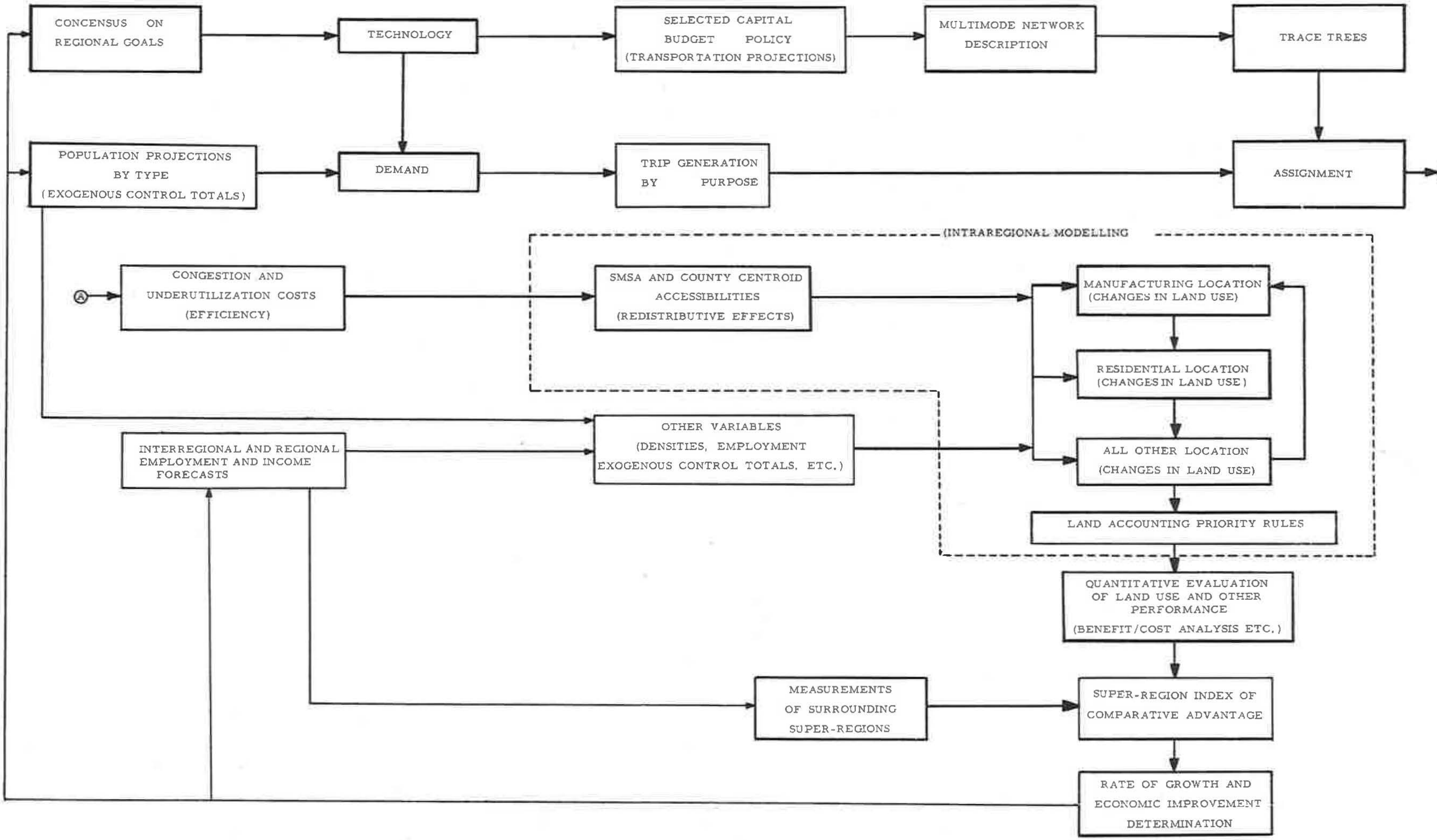

Figure 1. Northeast Corrior analysis on the basis of small-area allocations.

only be transport-sensitive in theory but that sensitivity must be capable of being exploited straightforwardly at an operational level, the respective influences on interindustry, interregional flows of the transportation network and the technology of industry were to be dichotomized, to the extent possible. An approach which referred to merely one coefficient for each combination of originating industrial sector and region and terminating sector and region (frequently used in past efforts) would provide no such dichotomy (and, incidentally, would require more detailed data than are available). The separation of such a coefficient into two additive components (one for the transportation, the other for the interindustry, technology) would not help much in the way of reducing obscurity either.

The basic formulation (5) of IRIO is a modification derived from the Leontief-Strout framework. The Leontief-Strout (4) framework very explicitly separates the intraregional industrial structure from the interregional trade structure, utilizing a concept of regional supply and demand pools for each good to link the two structures in a manner that leads to a simultaneous solution to both. The interregional system is basically a gravity formulation which distributes pool-to-pool flows as a function of pool levels and of the resistance offered by the transportation network.

Three primary modifications to the Leontief-Strout model were necessary to adapt it to the requirements of the IRIO model problem for the Northeast Corridor Project. First, instead of solving the system for a single point in time or a single horizon year, the alternative version of Leontief-Strout is solved for discrete steps in time. Second, while the Leontief-Strout system requires the interregional distribution of shipments for each industrial sector, the extended version of the model has the additional flexibility of allowing for the combination of several sectors into more aggregated shipment sectors to alleviate the problems which we anticipate in data collection. Third, the Leontief-Strout model incorporates only one sector of final demand, whereas the modified version of the model may have a number of such sectors of final demand—that is, households, government, farm, trade, etc.—whichever are deemed necessary upon completion of thorough analysis of the data. In fact, analysis of the data may show it to be desirable to partition some of the final demand sectors, or those sectors which are normally considered final demand, into a final demand and an intermediate demand sector, such as the case where the government might for instance be consuming intermediate goods as well as final goods.

INTRAREGIONAL ALLOCATION MODEL

The outputs of IRIO become the inputs to INTRA, the intraregional allocation model. These outputs consist of projections of employment by major Corridor subregions, by the previously mentioned type classes. INTRA requires two other classes of input data: (a) an inventory of data on the obtaining distributions of population, employment, and land use; and (b) information on the transportation facilities, both present and proposed.

From these inputs, INTRA produces projections of population, income, employment, and land use on two areal system bases (6). The first of these areal systems is the super-district system which defines twenty-nine areas within the Corridor, each of which is an aggregate of several districts. The second of these systems is the basis of the first and is the district areal system consisting of about one-hundred-thirty areas within the Corridor, the majority of these areas being counties (see Fig. 2). The district areal system is the smallest areal unit being considered in the Phase I impact studies.

The basic structure of INTRA is both sequential and iterative. This structure is a logical derivation of the Lowry "Model of Metropolis" (7) and CONSAD's TOMM (8). The structure of the model (1, Chap. IV) is as follows.

1. Inputs are:
    a. Region total projections of income population, and employment by types.
    b. Present and forecast transportation facilities.
    c. Obtaining distributions of income, population and employment by type by area.

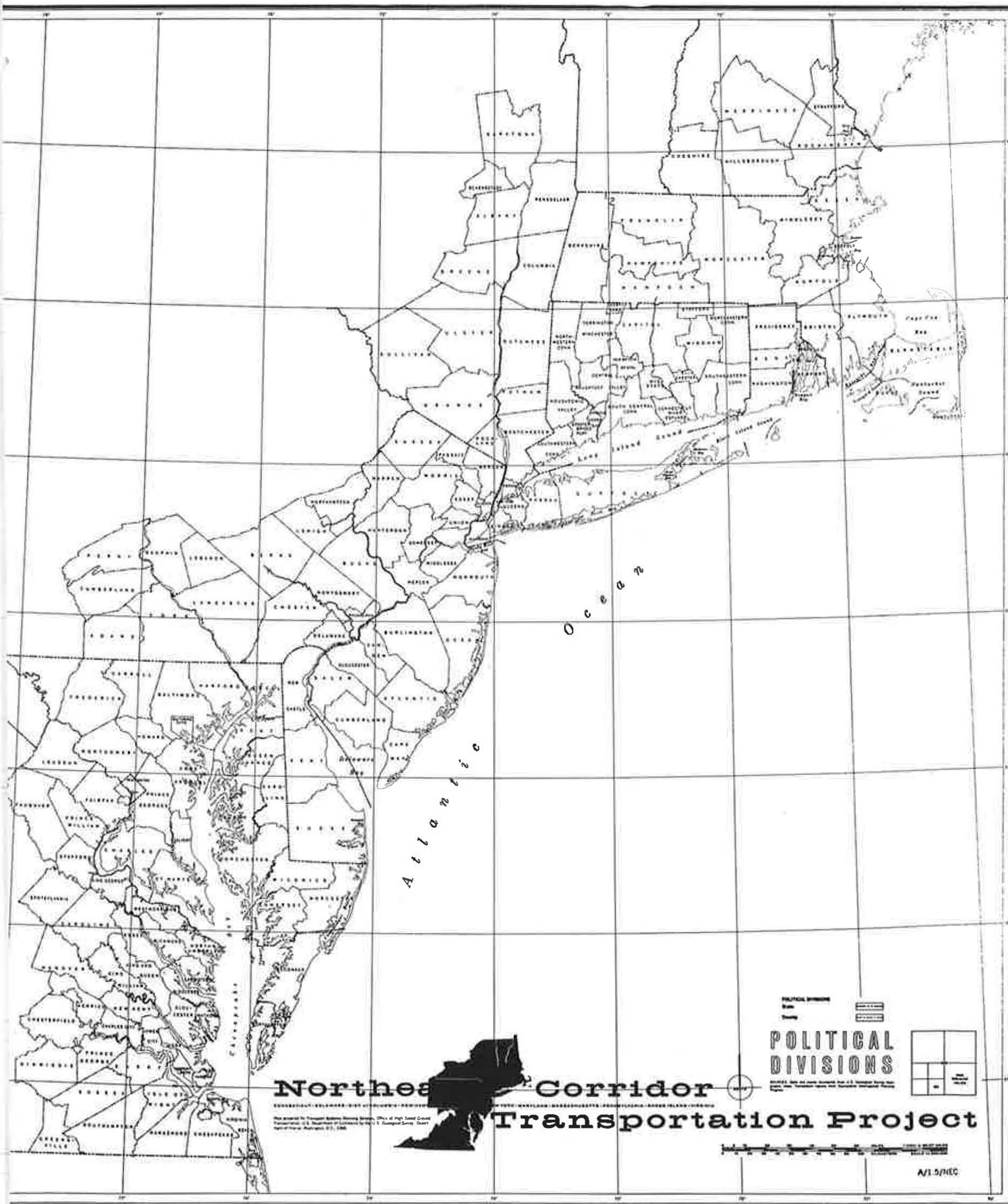

Figure 2. The Northeast Corridor area.

2. Allocation of Class I employment forecasts to areal units.
3. Trial income and population allocations to areal units.
4. Trial allocation of Class II employment to areal units.
5. Trial allocation of Class III employment to areal units.
6. Recycle to steps 3, 4, and 5 until the difference between the n'th and the (n + 1)'th trial allocations is less than a given tolerance (usually 1%).

The classes of employment are derived from "County Business Patterns" data according to the following scheme:

Class I:
- Type 1—Agricultural services, forestry, fisheries
- Type 2—Mining
- Type 3—Contract construction
- Type 4—Manufacturing
- Type 5—Transportation and other public utilities

Class II:
- Type 1—Retail trade
- Type 2—Finance, insurance, real estate
- Type 3—Services

Class III:
- Type 1—Wholesale trade

Further disaggregations of employment are being calibrated, such that certain individual 2-digit S. I. C. classes of employment can be allocated. All of these allocations are made to the Corridor district level of areal detail.

The impact of transportation facilities enters the allocation calculations through an accessibility term. In each of the above allocations (except that of Class II employment) the data on network characteristics are combined to produce a term which is summed over all of the network links and to which the intensity of the activity being allocated is inversely proportional. Alternative networks are therefore tested by observing the results of varying network characteristics which are input to IRIO and INTRA.

Thus this set of models produces as outputs the primary economic-demographic impacts of alternative transportation systems. These outputs are, to summarize: (a) population by district, (b) employment by class-type, by district, and (c) personal income.

There are numerous other variables for which estimating equations have been or are being developed. These variables include such things as labor force, occupation classes, auto ownership, land values, local government revenues and expenditures, and other socioeconomic indicators. Another set of impacts calculated is that of various composite measures. These measures are of such things as dispersion of various activities, measures of global accessibility, measures of average local accessibility, various measures of market and supplier accessibility, and others of the same ilk.

Finally, all of this information is manipulated in order to develop the evaluation outputs to be described in the next section.

EVALUATION

The methods to be used in evaluating the "goodness" or "badness" of alternative Corridor transportation system alternatives, the criteria which guide the evaluation effort, the strategy for implementing the evaluation process, and the attributes of the various techniques which might be utilized for evaluation purposes have been discussed elsewhere (9; also 1, Chap. VI). The discussion here will be restricted to evaluation of the "indirect" effects, since the consideration of the time and cost consequences to those who use the facilities (as well as those who pay for the facilities) are considered elsewhere in the overall Corridor Project.

The following list summarizes the criteria to be applied to evaluation techniques per se.

1. The methods must be capable of evaluating costs and benefits when there are radical changes in the environment.

2. The methods must recognize the diversity of quantities and qualities of existing investments in developing new investment requirements.

3. The methodology should attempt to produce lists of effects, including growth, resource allocation, and distributional consequences. While initially the methods should be "forward-seeking" (in extrapolating the trend and structure of the current systems into the future), they should eventually be capable of "backward-seeking" evaluation. Here, with specifically stated growth, distributional and resource allocation objectives for the regions under consideration, the method would produce the desirable, feasible and preferred transportation systems for each alternative budget and set of system cost functions (10).

4. The method should reflect other policy measures, conceivably more or less expensive in application than a transportation policy. Thus, the results are to be consistent with the program budgeting methods used in ultimate and overall resource allocation decisions (11). The method, therefore, must evaluate alternative uses of resources, not activities, per se.

5. The method should be able to differentiate at areal, travel type, socioeconomic class, and sectoral levels.

6. The analytic level of detail must carry below the regional level to differing activity densities and contextual mixtures.

7. The criteria which govern the evaluation process must permit users to sort program budgets into resources needed for various end-state requirements, including such classifications as (12):

   a. Functional budget allocation criteria (i.e., within or between transportation, housing, public safety, etc.). An example of such a criteria might be "a balanced transportation system" or "integrated housing."

   b. Urban/regional budget allocation criteria (e.g., the proportion of dollars devoted to basic maintenance of city facilities vs dollars devoted to maintenance of "the impoverished," vs dollars to "develop all the peoples").

   c. Subject area budget criteria (e.g., social, physical, fiscal, aesthetic, economic).

   d. Absolute vs relative budget criteria (e.g., "nobody in essence has less than $2,000 to spend per family spending unit").

   e. Effects budget criteria (e.g., users vs nonusers and, within the latter, completely vs partially collective).

8. There is no intent to "optimize" the use of resources in application to the entire system; where constraints for subsystems can be correctly specified, however, optimization techniques can be used.

9. Maximum use of expert (human) intervention at critical nodes in the evaluation process, such as in alternative specifications, and weighting of effect vectors, is encouraged.

The model system discussed previously is part of the creation of a set of "evaluation accounts" for each alternative examined. But it also follows, from the above discussion, that evaluation analysis must begin with a specification of the arguments of one or more objective functions (i.e., the identification of all of those effects which should receive nonzero weights in aggregating effects). It is appropriate to launch this specification with a listing of those effects which most obviously belong in the welfare function, viz., the goals of the Corridor.

It appears reasonable to assert that a primary objective of the Corridor Project is economic efficiency. To be feasible and attractive the program must assert minimally that investment in improved transportation facilities in this region would yield a stream of goods and services which, when properly valued and discounted, would outweigh the costs of constructing, operating and retiring these facilities. Included among the returns to be generated by the new facilities are increased output due to improved spatial organization, lower vehicular operating costs, decreased congestion costs, and greater comfort and safety. The primary costs of the project are the value of material and the opportunity costs of land and labor used to construct and operate the facilities. The objective of economic efficiency dictates that the time stream of goods and services generated by the project be included as arguments in the welfare function, and that their discounted unit values be used as their weights. The assignment of proper unit values is crucial to the evaluation process.

In addition, improved transportation facilities are often desired on grounds other than those of economic efficiency. There are political and social goals which can be satisfied by a more widely traveled citizenry. Improved transportation may also have a beneficial effect on defense capability. All that can be suggested is that such effects be noted. The weighting of these effects should be left to the policy maker.

The task of evaluating the Corridor Project would be vastly simplified if the primary objectives were the only significant consequences of transportation improvements. However, there are many ramifications, the most obvious of which is income redistribution. Income redistribution has long been recognized by economists as an element in a social welfare function. Most persons have a vague notion that extreme income inequality is undesirable but do not know exactly how much weight to attribute to it; political experts must explicitly choose between alternative distributions. To assist this, the models must permit the tracing through and identifying of all major income redistribution effects associated with each alternate program. Again, it will be up to the policy maker to weigh these effects.

In addition to income redistribution, there are other intangible economic, social and political effects which may be attributed to the Corridor Project, such as aesthetic considerations, degree of population density, the urban-suburban mix, Federal vs local control, viability of metropolitan governments, erosion or growth of state and local tax bases. For the most part, each of these effects is extremely difficult to quantify, although first approximations to population distributions and government control could be obtained by measures of land-use patterns suggested above. It may be argued that the very nature of public investment, particularly in transportation, has a disproportionate effect upon these intangibles, and hence they must be taken into account. The most that the evaluation analysis can do is to identify them and include them in the vector of effects so that, as with income redistribution effects, policy makers will have the information to assess their relative importance.

Use of Models in Analysis

In Table 1 are listed seven different levels of evaluation probes, the types of analyses which are to be used to perform the evaluations, and six "dimensions," or evaluation choices. Turning to the latter first, there is the set of choices associated with whether or not:

1. A project or an entire program is being evaluated, i.e., whether the entire Corridor system is seen as an interconnected system of projects constructed at different times;
2. Local or national considerations are dominant, i.e., whether or not only local (in a geographical sense) effects are considered;
3. Only transportation, or associated multi-county public functions, such as the provision of water resources, the control of pollution, or the pursuit of regional economic development, are considered;
4. Quantitative alone, or both quantitative and qualitative factors are considered;
5. The human decision maker is an integral part of the evaluation process, either as an estimator of parameters or chooser of values (at least in an ordinal sense);
6. A partial or general solution is obtained, i.e., whether a general equilibrium approach considering all interactions within a closed system is used.

The following paragraphs elaborate upon each of these methodologies, and their use in the Corridor Project.

<u>Project Appraisal: Benefit-Cost Analysis</u>—This traditional approach to the appraisal problem ordinarily presumes that all economic benefits are represented by the savings in transportation costs incurred by users, as measured (or, more appropriately, estimated) "at the source." It offers a predominantly supply-side view of the problem,

TABLE 1

CLASSIFICATION OF NORTHEAST CORRIDOR EVALUATION PROBLEMS, TYPES OF ANALYSES, AND EVALUATION DIMENSIONS

Classification of Evaluation Problems	Types of Analyses	Dimensions: Project or Program	Local or National	Transp. or All Functions	Quant., Qual., or Both	Degree of Man-Machine Interaction	Partial or General Solution
A. Project appraisal	Benefit-cost	Proj.	Local	Transp.	Quant.	Little	Partial
B. Systems of projects appraisal	Search and/or programming optimization models	Prog.	Local	Transp.	Quant.	Little	Partial
C. Measures of effects of projects/ programs: simple, unweighted	Truncated moments (measures of relative accessibility)	Prog.	Local	All	Quant.	Little	Partial
D. Evaluating pricing consequences	Simulation of priced-out transportation networks	Either	Local	Transp.	Quant.	Little	Partial
E. Distributional consequences:		Prog.	Local	Transp.	Quant.	Much	Partial
1. Regional 2. Sectoral (nontransportation) 3. Transportation industry	Comparative and absolute regional advantage, analysis of transport-sensitive industries, financial analysis						
4. Individuals, families, and households	Corridor econometric, INTRA, and IRIO models						
F. Combining different effect sectors	Cost-effectiveness analysis	Prog.	National	All	Both	Much	Partial
G. Developing systemwide indices	General equilibrium analysis	Prog.	National	All	Quant.	Much	General

referring to demand only implicitly through the relation of operating costs to transportation output. The technique itself traditionally ignores explicit attention to the non-quantifiable, thus rendering all pertinent benefits and costs to be commensurable. Costs refer to all "public costs," namely, capital and maintenance expenditures required to implement the project. Of course, with all benefits and costs both quantifiable and commensurable, the concept of project appraisal in the context of this approach implies a once-and-for-all binary decision regarding whether the project is justified. The general criterion which guides this decision is to determine whether the discounted total time stream of net benefits exceeds the discounted time stream of costs. Because benefits are defined strictly in terms of user costs, the problem may also be approached from the point of view of minimizing total transportation costs (either in terms of present worth or annual costs). Both interpretations, used correctly, give identical results. Frequent use of net benefit/cost ratios by the disciplines responsible for this approach has led to the fashioning of the term "benefit-cost analysis." This approach is not intended to invalidate the "consumer surplus" approach, the use of which does look to the differences in utility among various users. The consumer surplus concept is distinguished from the benefit-cost approach primarily in that consumer surplus focuses directly on demand for its measurement of benefits, while benefit-cost analysis takes more of a supply viewpoint.

Systems of Projects Appraisal: Search and/or Programming Models—The problem, here, is to define an appropriate model for selection of programs consisting of groups of projects under conditions where (a) risk and uncertainty are important, (b) compromise must be made between realism and computational feasibility, and (c) the real world is characterized by discreteness, project interdependency, real budget constraints, time interdependency and multiple goals. Under these circumstances, with the number of network links contemplated in the Corridor Project a quadratic programming technique has been tentatively selected as the method best suited to assist in the choosing of both an optimal program set (within numerous constraints) as well as an optimal time-staging of the program. Basically, the model used is an extension of benefit-cost analyses but examines the interactions between the timing of each project relative to the whole system.

Measures of Effects of Projects/Programs: Simple, Unweighted Truncated Measurements—In at least four instances, it is possible to use the population, land use, economic activities and density consequences of INTRA and IRIO to develop moments reflecting access to opportunities, truncated at different "reasonable" time and distance estimates, e.g., one hour for the journey-to-work measures. These movement-measures would reflect: (a) people to jobs, (b) people to recreation opportunities, (c) business to customers (final goods), and (d) governmental bodies serving multi-jurisdictional clients. Complexity can be introduced by using weighting systems (e.g., business products by the value added of each business sector), and by developing separate measures for "people," "job," "business," "recreation," and "customer types." These measures would be intended to reflect the shifts (Fig. 3) showing an indifference surface (or trade-off between space/activity and access) caused by higher incomes, A to A′, and shifting production possibility surface, B to B′, caused by technological shifts (i.e., transportation improvements). The resulting changes in demand and supply functions would determine the new "equilibrium" solution for access and space use functions (vs price and income).

Evaluating Pricing Consequences: Simulation of Priced-Out Transportation Networks—To the extent that market pricing prevails, the evaluation of new systems must take the possible variation of prices into account. Prices may be exogenously determined, such as those paid for tools, gasoline, or automobile depreciation, or may be endogenously determined in a model, such as the amount of congestion cost to be charged to delay of passengers. These "administered" and nonadministered or marketplace figures must be classified and provided as either inputs or made determinable by within-model relationships. There is an interaction between the proportion of total passengers who are available to use each mode, the amount of congestion and underutilization experienced, the manner in which the costs thereof are accounted for, and the way in which prices are set. On the other hand, indirect costs could be quite different—namely, the

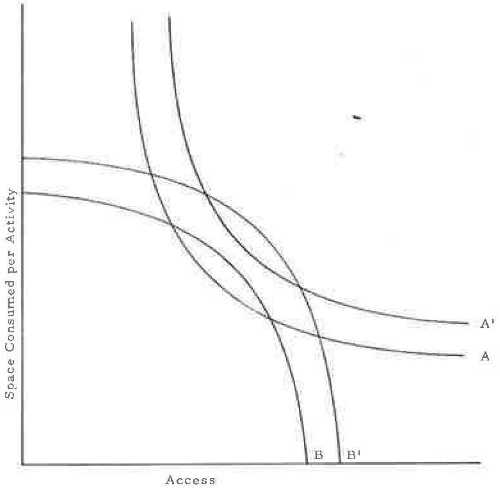

Figure 3. Shifting indifference and production surfaces.

costs of underutilization and overutilization of the transportation facilities. The costs of underutilization are the opportunity costs of owning twice as much or more facility, for example, as would be needed if the trips were distributed evenly, in both directions, each hour of the 24 hours per day. Indirect costs would include discounted capital costs, costs of unused crews, depreciation, and maintenance, and should include loss of tax revenue on wider rights-of-way, and so forth. These indirect costs are almost completely invisible to the passenger, but again, not to the policy maker. A simulation model is being constructed which allows experimentation with pricing methods, demand functions, network characteristics, and variable and fixed cost functions.

Distributional Consequences: Regional, Sectoral, Transportation and Individuals—There are a number of analytic methods to be used to measure and depict the distributional consequences of differential transportation alternatives. As for regional differences, e.g., whereby large portions of the Corridor are measured against large portions of the "remainder of the world" with respect to changes in the ability of each to engage in interregional trade, there is a "dynamic comparative advantage" model under development which draws upon the knowledge and theory underlying the economics of international trade. The substantial differences, however, between "regions" and "nations" has entailed significant modification in the overall theory. Other analytic methodology, including the use of linear programming methods to define the new, normative locational patterns for "transport-sensitive" industries following a substantial change in transportation technology, will be used to explore some likely tendencies for changes in industrial locations. And, finally, the models described in earlier sections of this paper will be used to ascertain the changes in income distribution, by population socioeconomic type, by geographic area. The income distribution will not be of the functional variety (e.g., return to rents, labor, capital, etc.) but will indicate the degree to which overall real income is distributed more or less "equitably" following the technological transportation changes and the other associated changes.

Combining Different Effect Sectors: Cost-Benefit Analysis—Cost-benefit analysis (as distinguished from benefit-cost analysis) is that broad methodology of project appraisal of which economists are the main proponents. Cost-benefit analysis concentrates more on uncovering and presenting all probable consequences of a public project, rather than devoting most attention to the easily quantified effects. It is much more like cost/effectiveness analysis than any of the preceding techniques. Cost-benefit analysis takes on two facets. First and foremost, it represents a methodology. Prest and Turvey emphasize this point (13):

> ...Cost-benefit analysis as generally understood is only a technique for taking decisions within a framework which has to be decided upon in advance and which involves a wide range of considerations, many of them of a political or social character....

In this sense, the approach discussed here is a methodology or a framework, and hardly a cut-and-dried computational procedure for making a decision. It specifically aims toward including effects other than user consequences. For a good description of the methodological facet of cost-benefit analysis, it suffices to recall here that three fundamental pursuits are involved: (a) the identification of all (nonredundant) costs and effects (overtime, of course); (b) the measurements of such costs and effects insofar as possible; and (c) the valuation of these estimates, insofar as possible. The identification problem consists of specifying the length of two vectors (i.e., identifying all relevant effects, one to each vector element). The measurement task consists of entering estimates into the elements of the row of vectors. The valuation task involves entering estimates into the elements of the column vector. While both vectors should be completed insofar as possible, some effort may be saved by passing over the measurement of those effects for which a valuation of zero is anticipated (e.g., based on feedback from policy makers). Where entering into these vectors is impossible, honesty dictates the use of a question mark. While any description of cost-benefit analysis usually warns against double-counting, it is presumed that there are non-redundant effects consequent to a public investment project over and above those incurred "at the source." These effects are treated by filling in the two vectors insofar as possible (the methodological facet). Those effects for which the corresponding elements in both vectors have been filled in are then "partitioned" from other effects, and the two partitioned vectors multiplied together (the comparison of commensurable effects facet).

Developing Systemwide Indices: General Equilibrium Analysis—When investment in transportation is so large that it alters prices other than that of the transportation project itself (therefore feeding back and causing a shift in the demand curve for the project), the partial equilibrium approach is no longer adequate. The simplest form of general equilibrium approach, namely, interregional input-output analysis, is of use only in this evaluation analysis if it is rendered transport-sensitive and if it utilizes demand theory in such a way that prices are not obscured by the analysis. Several general equilibrium models have been designed which, though complicated, offer promise. For example, Friedlaender (14) solves three models for total net (social) benefits, defined by the vector expression $w\ \Delta p\ (Q_1 + Q_2)$ where each element in a vector represents a different commodity, and compares these results to the more traditional estimate given by the weighted sum of the cost savings multiplied by the sum of the levels of traffic before and after the improvement. In all three models a difference is demonstrated, although the direction of that difference is indeterminate in general terms, depending as it does on such unknowns as the elasticity of the various factor supplies, the nature of the factor substitutions and the nature of the commodity substitutions. All models attribute all consequences, of course, to the transportation improvement, and therefore their application for purely forecasting purposes is not warranted (15).

The general equilibrium approach offers the maximum opportunity to satisfy the evaluation criteria specified above. First, the size of the proposed transportation investment is such that it probably requires a general equilibrium approach. Second, the total social net benefits estimated by such a formulation can be compared with that generated by the consumer (and producer) surplus approach. Third, the construction of an interregional input-output framework is required, for other purposes, within the family of models already under construction for this study (freight forecasting, for example). Fourth, the areal level of detail of the study would appear to require an interregional approach, and a general equilibrium model is one well suited to this need.

SUMMARY AND CONCLUSIONS

This paper has described the model system and evaluation techniques being used by CONSAD to evaluate the indirect impacts of alternative Northeast Corridor transportation systems. The impact model system consists of two sub-models: IRIO, an interregional input-output model, and INTRA, an intraregional allocation model. The problems of selecting an evaluation measure (or measures) are also described.

As of the date of the writing of this paper (September 1966) the status of each of the sub-models is as follows: IRIO is fully programmed and debugged, the final data are being sought for use in calibration, the remainder of the data are being processed; INTRA is fully programmed and debugged, preliminary calibrations have been completed and work is being done to refine these where necessary.

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