Abridgment

Analytical Process for Coupling Economic Development With Multimodal and Intermodal Transportation Improvements

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This paper summarizes part of the first year's work in a 3-year research effort undertaken by a multiuniversity research team consisting of faculty and graduate students from the University of Alabama, Arkansas State University, Auburn University, Georgia Institute of Technology, Memphis State University, Mississippi State University, the University of Missouri, the University of North Florida, and Tennessee Technological University (1). The objective of the research is to develop a quantitative technique that can identify the nature and extent of transportation improvements needed to achieve significant breakthroughs in the economic development of an underdeveloped area. The underdeveloped area of interest is a broad arc that extends from the Atlantic Coast in the vicinity of Brunswick, Georgia, and Jacksonville to the Midwest in the vicinity of Kansas City, Missouri. This arc is known as the multistate transportation corridor (2).

The focus of the work is on economic breakthroughs—transportation improvements that will provide the incremental advantage needed to support significant economic developments that would not take place without the transportation improvements. To identify breakthrough opportunities, it is necessary to consider new transportation services and ingenious intermodal combinations of existing transportation services. The need to consider complex transportation services and to identify breakthroughs separates this work from other work that depends on maintaining existing economic relations and shipping patterns (3, 4, 5).

The analytical method is built around two mathematical models: (a) a cost-based economic model and (b) a network-based intermodal transportation model. Each of these models contains unique features that were necessary to preserve the generality of the analysis. Both models use a common geographical base and deal with a common set of commodity groups. The geographical base is a set of 120 zones of varying sizes that cover the continental United States. Zones in the multistate corridor are small; each zone includes the 6 to 10 counties that make up an area planning and development commission. Outside the corridor, zones are made up of integral numbers of basic economic areas (BEAs) (6). Zones near the corridor contain a single BEA. Zones remote from the corridor may contain as many as six BEAs.

This analysis deals solely with freight movements. The universe of freight movements is divided into 53 more or less homogeneous commodity groups. These groups are somewhat more detailed than the two-digit standard industrial classification code (7) but somewhat less detailed than would be desired. Initial or "present" commodity-flow data were taken from the National Transportation Policy projections of commodity flow (8) and augmented by a variety of census data. The vicissitudes of the analysis of commodity-flow data are a suitable subject for another paper (9) and will not be treated further here. Suffice it to say that, in one manner or another, data on zone-to-zone movement were developed for each of the 53 commodity groups.

ECONOMIC MODEL

The economic model provides a representation of each industry group as it draws raw materials from available sources, uses labor and capital, and incurs costs to produce the product it ships to existing markets. A geographic representation of each commodity group was drawn from the commodity-flow data by identifying major producing zones, major market zones, and important producer-market commodity flows. Production costs and raw material requirements per megagram of product were developed for each commodity group. Production cost elements include raw material, direct labor, indirect labor, energy, capital, and taxes. The cost C_{ij} of producing commodity i at location j is

$$C_{ij} = \sum_{k=1}^{6} a_{ik} C_{ijk} \qquad (1)$$

where

a_{ik} = amount of element k per unit of commodity i and
C_{ijk} = unit cost of element k for product i at location j.

All cost elements are location sensitive and had to be separately determined for each major producing zone and for each candidate zone in the multistate corridor.

Market costs $m_{ij\ell}$ were estimated for each producing zone j that supplies each market ℓ with a commodity i:

$$m_{ij\ell} = C_{ij} + \min_{m} \left\{ t^m_{ij\ell} + f_{1i}\tau^m_{ij\ell} + f_{2i}V^m_{ij\ell} \right\} \qquad (2)$$

where

$t^m_{ij\ell}$ = unit transportation cost of commodity i moving from j to ℓ by mode and route m,
f_{1i} = value of a unit of travel time to commodity i,
$\tau^m_{ij\ell}$ = travel time for commodity i from j to ℓ by mode and route m,
f_{2i} = value of service dependability for commodity i, and
$V^m_{ij\ell}$ = measure of service dependability for commodity i from j to ℓ by m (equal to the variance of delivery time).

The share of the commodity i market at ℓ enjoyed by producers in zone j depends on the value of $m_{ij\ell}$ as compared with costs in market ℓ for other producers. Inasmuch as all commodities were treated in general terms, product quality was not recognized as a market determinant. A cost-market share relation was estimated for each commodity group:

$$ms^i_{j\ell} = a_i \exp(-\alpha_i \Delta H_{ij\ell}) \quad (3)$$

where

$ms^i_{j\ell}$ = share of commodity i shipped to zone ℓ from zone j,
a_i, α_i = constants for commodity i,
$\Delta H_{ij\ell} = m_{ij\ell} - m_{ik\ell}$, and
k = zone that can deliver to market ℓ at the lowest cost.

Values of a_i and α_i were determined by regression analysis based on existing commodity movements. Correlation coefficients were on the order of 0.7, not exciting values but acceptable in view of the preliminary nature of the work, the data problems, and the many embedded assumptions. The following values of a_i and α_i were obtained for eight test commodities:

Commodity	a_i	α_i
Textiles	0.068 00	-0.000 46
Apparel	0.145 49	-0.001 71
Lumber	0.117 38	-0.090 96
Furniture	0.085 42	-0.003 89
Agricultural chemicals	0.077 02	-0.003 50
Plastic products	0.131 35	-0.008 85
Machinery	0.065 58	-0.000 44
Electrical equipment	0.104 89	-0.003 09

TRANSPORTATION MODEL

The purpose of the transportation model is to generate transportation cost, time, and time-variance data for the economic model. This process is vastly complicated by the need to deal with present and prospective modes of transportation and with intermodal combinations of present and prospective modes. Aside from the problems of dimensionality associated with a multicommodity network that has 120 nodes, 400 arcs, six transportation modes, and 53 commodity groups, the major technical problems were (a) developing a mode-abstract modal-split model and (b) determining intermodal paths through the network. Both problems were partially solved, but more work is needed.

Modal-split relations were developed from the commodity-flow data by using regression analysis on the modal share distribution of existing movements. A modified logit form (10) was used in which

$$f^m_{ij\ell} = U^m_{ij\ell} \Bigg/ \left(\sum_{p=1}^{P} U^m_{pj\ell} \right) \quad (4)$$

where $f^m_{ij\ell}$ = modal share of mode m for commodity i moving from j to ℓ and

$$U^m_{ij\ell} = \exp(a_0 + a_1 \Delta t^m_{ij\ell} + a_2 \Delta \tau^m_{ij\ell} + a_3 \Delta V^m_{ij\ell}) \div [1 - \exp(a_0 + a_1 \Delta t^m_{ij\ell} + a_2 \Delta \tau^m_{ij\ell} + a_3 \Delta V^m_{ij\ell})] \quad (5)$$

where

$\Delta t^m_{ij\ell} = t^m_{ij\ell} - t^b_{ij\ell}$,
$\Delta \tau^m_{ij\ell} = \tau^m_{ij\ell} - \tau^b_{ij\ell}$,
$\Delta V^m_{ij\ell} = V^m_{ij\ell} - V^b_{ij\ell}$,
$t^b_{ij\ell}$, $\tau^b_{ij\ell}$, $V^b_{ij\ell}$ = attributes of the base or highest utility mode,
$a_0 = \ln(0.5)$, and
a_1, a_2, a_3 = constants.

The regression analysis focused on maintaining commodity-specific but mode-abstract values for a_1, a_2, and a_3. The results, which yielded R-values between 0.6 and 0.7, were not particularly good, but these results compare favorably with many mode-specific studies. Mode-split parameter values for the eight test commodities are given below:

Commodity	a_1	a_2	a_3
Textiles	-0.0107	-0.000 033 3	-0.000 552
Apparel	-0.0010	0	-0.000 562
Lumber	-0.0075	-0.000 041 6	-0.000 008
Furniture	-0.0087	-0.000 083 3	-0.000 166
Agricultural chemicals	-0.0072	-0.000 023 3	-0.000 062
Plastic products	-0.0045	-0.000 096 6	0
Machinery	-0.0054	-0.000 150 0	0
Electrical equipment	-0.0050	-0.000 050 0	-0.000 160

Intermodal paths are determined by establishing node impedances to reflect the cost, time, and time variance associated with intermodal transfers. By using the exponential form, the logarithms of path utilities (cost, time, and time variance) are made directly additive to produce path utility for any modal combination. Thus, the best intermodal path can be found by using a modified shortest path routine.

COMPUTER PROGRAMS

A battery of computer programs was prepared to perform the economic analysis and transportation network analysis. The principal steps are

1. Introduce existing and new arc and mode information,
2. Construct a special network numbering system to simplify multimodal analysis,
3. Obtain shortest path trees for each existing origin,
4. Load existing commodity movements,
5. Obtain shortest path trees for candidate new production zones,
6. Determine production costs for candidate zones,
7. Determine market shares for candidate zones, and
8. Update commodity movement assignments.

Currently, transportation improvements are postulated as input to the analysis. Work is under way on analytical procedures to identify potentially attractive improvement programs.

ANALYTICAL RESULTS

The analytical procedure was tested for four zones in northern Mississippi. Four transportation programs were tested: (a) the present highway, railway, and waterway networks; (b) the present networks with accessibility improvements in northern Mississippi; (c) the present networks plus accessibility improvements and highway and railway improvements along the multistate corridor; and (d) the present networks with accessibility, highway, railway, and intermodal transfer improvements.

The results of the northern Mississippi test were encouraging. With the present transportation networks, market costs for the four test zones appeared to have realistic relations with market costs for other producing zones. Economic development opportunities matched present development experience. To illustrate, the following table gives the market cost comparison for agricultural chemicals in market 85 (Cincinnati) under the present networks (base case) and under improvement alternative 4:

Source Zone	Base Case	Alternative 4
98	311	311
105	342	289
84	345	345
C 2	318	294

In the base case, multistate corridor zone 2 (Tupelo, Mississippi) looks attractive relative to other supply zones. Its market cost (HIJK) is close to that of zone 98 (New Orleans), the lowest cost producer, and substantially better than that of zone 105 (Houston). Its potential market would be approximately 14 500 Mg/year (16 000 tons/year).

Under improvement alternative 4, the relative positions of the major suppliers to the Cincinnati market would change. Zone 105 (Houston) is able to take advantage of efficient modal interchange facilities at Memphis to put together an attractive rail-water route. Corridor zone 2 would also benefit from the transportation improvements but to a lesser extent than Houston, which is the new lowest cost supplier. New Orleans (zone 98) would not benefit from the transportation improvement and would fall to third position. The potential market for corridor zone 2 (Tupelo) would increase only slightly as a result of the transportation improvement, which suggests that this improvement program would not enhance economic development opportunities in agricultural chemicals.

FUTURE WORK

A second year's research effort will be directed toward improving the analytical procedure. During the third year, the procedure will be applied to the multistate corridor.

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REFERENCES

1. P. S. Jones, ed. Procedures for Multi-State, Multi-Mode Analysis: First Year's Research. Georgia Institute of Technology, Atlanta, 1977.
2. Highway Corridor Study, Brunswick, Georgia, to Kansas City, Missouri, Multi-State, Multi-Mode Transportation Route. William S. Pollard Consultants, Inc., and Traffic Planning Associates, Inc., Memphis, 1974.
3. C. C. Harris, Jr. Regional Economic Effects of Alternative Highway Systems. Ballinger Publishing Co., Cambridge, MA, 1974.
4. K. R. Polenski, C. W. Anderson, and M. M. Shirley. A Guide for Users of the U.S. Multiregional Input-Output Model. MIT, Cambridge, 1974.
5. P. F. Wendt. Transportation Planning Land Use Studies—The State of the Art. Georgia Department of Transportation, Atlanta, Research Rept. 5, 1975.
6. OBERS Projections: 1972 Regional Economic Activity in the U.S.—Volume 2, BEA Areas. U.S. Department of Commerce, 1976.
7. Office of Management and Budget. Standard Industrial Classification Manual. U.S. Government Printing Office, 1972.
8. R. W. Schuessler and P. A. Cardellichio. NTP Commodity Flow Projections—Data and Methods Description. Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, 1976.
9. M. A. Mullens, G. P. Sharp, and P. S. Jones. Development of a 47-Commodity Flow Table for BEA Zones. Proc., 19th Meeting of Transportation Research Forum, 1978.
10. R. E. Quandt and W. J. Baumol. The Demand for Abstract Transport Modes: Theory and Measurement. Journal of Regional Science, Vol. 6, No. 2, 1966.

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Regulatory Implications of Individual Reactions to Road Traffic Noise

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A basic problem in setting standards for acceptable levels of road traffic noise is deciding on a criterion of acceptability. The possible criteria reduce to three categories: noise impacts (i.e., activity interference and effects on health), attitudes toward noise, and actions taken to reduce the impact of noise (e.g., complaints). The rational selection of a criterion or criteria needs to be based on careful empirical analysis of two sets of relations: (a) the relations among the plausible criteria and (b) the relations between the criteria and noise measurements. The first set of relations is examined by using questionnaire data collected at 37 sites adjacent to highways in southern Ontario. The results show significant but relatively weak links between impacts and attitudes and between attitudes and actions. The analysis results (a) question the use of activity interference measures, and particularly speech interference, as a criterion for setting standards and (b) confirm the inadequacy of regulating against traffic noise on the basis of complaint action.

Faced with the problem of establishing acceptable levels of environmental noise, the difficulty immediately arises of deciding on a basis for defining acceptability. It seems obvious that the definition should be based on some measure of the adverse effects of noise on an exposed population. But the question remains as to