LONG-RANGE TRANSPORTATION INVESTMENT PLANNING: A FORECASTING APPROACH FOR ASSESSING THE IMPACT OF ALTERNATIVE HIGHWAY SYSTEMS ON REGIONAL DEVELOPMENT

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The increasing difficulties associated with justifying new highway systems are becoming well known. Reliance on the benefit-cost approach may not be adequate for determining which future highway improvements should be undertaken because of problems involved in incorporating social values and locational changes into the calculations. This paper presents a planning tool that may supplement benefit-cost analysis to improve the ability of highway planners in assessing the impact of alternative highway systems. The approach employs a forecasting model that explicitly shows the impact of changes in transportation costs due to improved highways on the regional location of the population and industry and on regional income and employment. The model being used is an operating interregional dynamic model that forecasts industry activity and other variables at the regional level. The researchers conclude that new transportation systems affect interregional trade, regional output, and transportation needs. Forecasting future transportation requirements, therefore, requires systematic evaluation of differential regional sensitivity to changes in transportation networks.

•COMPREHENSIVE evaluation of the overall impact of new transportation systems on national, regional, and subregional economic and demographic changes implies the need for a complex economic and transportation planning model. Earlier applications of input-output analysis used in dealing with this problem were limited to the measurement of the impact of a specific highway or highway system (3, 4, 9). Recently a synthesis of the TRANS network planning model, the University of Maryland multiregional and -industry forecasting model, and a linear programming transportation model has resulted in a new and improved tool for assessing the impact of highway improvements. Early highway researchers revealed the nature of highway transportation benefits to the economy in terms of mobility improvements and cost reduction (11); yet, the accurate measurement of the ripple effects of those improvements on regional comparative advantage (the cost trade-off patterns that determine how much each area exports and imports) has eluded researchers. When changes in transportation investments are planned, the feedback effect of those investments on new growth can be significant if the growth is cumulative during long periods of time. The synthesis of models described in this paper facilitates the identification of the range of potential economic and demographic impacts by evaluating the expected changes resulting from postulated hypothetical networks.

The remainder of the paper is divided into 4 parts. The first briefly explains the forecasting model. That is followed by an explanation of how transportation costs are affected by highway improvements; the second section also explains how transportation cost reductions due to highway improvements can be incorporated into the forecasting model and used to explain locational changes. The third section discusses the alternative highway systems that are being evaluated by the researchers. Finally, some preliminary conclusions and possible further uses of the forecasting model are presented.

THE FORECASTING MODEL

The multi-regional and -industry forecasting model is designed to make long-run regional forecasts under reasonable assumptions and to evaluate impacts of alternative governmental decisions on those forecasts. Essentially, forecasts are made based on no exogenous changes in governmental spending and on a set of predetermined changes. Comparison between the 2 sets of projections shows the economic impacts of the governmental decisions.

One of the major advantages that this model has over the typical impact model is that regional demand is dependent on supply. For example, in most input-output models, it is necessary to predetermine levels of final demand for each region and then use interdependence coefficients to produce the changes in output. Although this approach may have merit at the national level, it seems inappropriate on a regional basis. Because the national economy is essentially a closed economy, final demand forecasts can be predetermined; but, for a region, the final demand levels influence the output levels, which determine income levels, which in turn determine major components of final demand sectors. Because the location of demand and supply need not be in the same region, it is necessary for a model to specify these interrelations and to allow changes in the location of output and resources to occur.

The multi-regional and -industry forecasting model starts by forecasting industry output. The output or change in output of each industry is explained by the marginal costs or prices that firms face in each location. The parameters are estimated by using least squares estimating procedures with regional data as observations. (The data requirements for the model are enormous. For the nearly 100 input-output sectors, 1965 and 1966 county data are used to estimate employment, payrolls, output, and final requirements by consumption expenditures, capital expenditures, government expenditures, and exports. In addition, population is estimated by race, age, and sex; labor force, unemployment, and personal income are also estimated.) In addition, agglomeration also helps to explain output location. After output has been determined, then payrolls, employment, population, and personal income are derived. Also, the final demand sectors are forecast—consumption and governmental expenditures are related to income, investment is related to output, and foreign exports are determined exogenously.

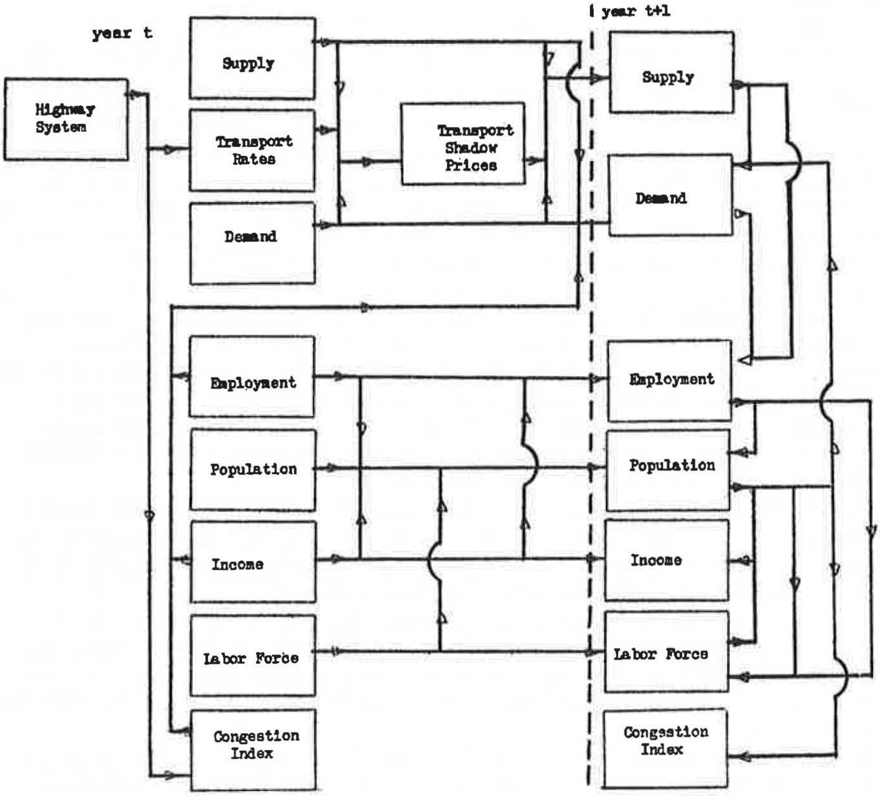
The model is recursive. The supply and demand data in the year t are used to forecast variables in the year t + 1. A simplified flow chart of the forecasting model is shown in Figure 1. On the left side of the chart, the data and computations are itemized for the year t. The connecting lines show how the data are used to make forecasts in year t + 1. After t + 1 forecasts are made, they are realigned as data (given in the left side of the chart) in order to forecast for year t + 2. In any given year, predetermined changes may be made in the data, such as changes in the governmental expenditures or in the highway system.

An important set of variables used to determine the location of output is the transportation variables. Those variables are the cost of transporting a marginal unit of a commodity either into or out of a region. They are derived by determining both rail and truck costs by weight class of shipping a unit of goods between each pair of regions (7). The least cost method of shipping goods in each weight class for each commodity is determined, and these costs are used in a linear programming transportation algorithm to produce the marginal costs, often referred to as shadow prices. The shadow prices are then used in the forecasting model to help explain industry location.

The quality of the highway system within each region may also affect the attractiveness of that region for the location of certain industries. In the equations that explain the location of output, highway quality is incorporated in a regional congestion index, and the index is used as an explanatory variable.

In addition to cost savings and highway quality, the construction of the highway itself may have an influence on the regional economies. Highway construction is part of the

Figure 1. Simplified flow chart of multi-regional and -industry forecasting model.



final demand for goods in a region, and the income of the construction workers contributes to the income of the region. Thus, industries that supply construction materials and consumer expenditures are affected by the location of the highway construction. Although construction has some impact on the expansion of the economy of a region during the construction phase, it must be remembered that when the construction stops decreases in the economy may occur.

The forecasting model, as it is used at the University of Maryland, uses counties as regions. However, because there are 3,112 counties, the model is very costly to operate; therefore, counties have been aggregated into 173 economic areas as determined by the Office of Business Economics (OBE). Not only is operation of the aggregated version of the model less expensive, but a regional delineation more appropriate than counties is provided for evaluating highway impacts. Most of the major highways in recent years have been built either to improve the travel time between major cities or to improve the travel time within a metropolitan area. Each of the OBE economic areas has a major city as its center; therefore, estimating travel time and vehicle costs between OBE economic areas is almost identical to estimating the time and cost between cities. The population centers are used as geographic points from which to compute the distance between regions.

ESTIMATING TRANSPORTATION COSTS FOR THE MODEL

The expected benefits from proposed highway improvements are usually estimated by determining what the reductions in vehicle operating costs, travel time, and accidents will be during the life of the project.

Past methods for evaluating highway benefits are not usable for the purpose of determining the regional reductions they produce in transport costs. Benefit studies that consider operating speeds fall into 3 distinct categories:

1. Those that treat the benefits of speed advances as being measurable from the tolls paid by toll-road users;
2. Engineering studies that do not translate into vehicle cost reductions; and
3. Efforts that change vehicle operating costs when average regional speeds change.

The above types of studies are discussed in order. The Highway Cost Allocation Study exemplifies the class of study that treats improvements as being reflected in the willingness of individuals to pay tolls. That analysis does not provide an adequate basis for estimating savings to shippers related to improvements of segments of the highway system because there is no way of knowing whether the tolls adequately approximate the benefits. Methodology more sensitive to specific highway betterments is needed to effectively assess the impact of highway improvements on vehicle operating costs.

Engineering studies treat the impacts of specific improvements in highways in great detail but do not make broad analyses that are useful for measuring general highway advances by segment. For example, elimination of curves, improvement of road surfaces, and reduction of grades are examined in these studies in terms of reductions in fuel costs, tire wear, engine oil consumption, and maintenance costs. But there are no generalizations made about reductions in vehicle operating costs that are associated with changing a roadway from 1-lane to 2-lane or unlimited access to limited access under various topographical and traffic conditions (15).

Several studies conducted at the Texas Transportation Institute made giant strides toward solving this problem. The data used were from ICC records and varied regionally and depended on the quality of the roads in the area. Benefits were measured in terms of time saved and could be attributed to improvements on particular road segments. There is, however, one major drawback in this approach. Average speeds were estimated on a regional basis and not on a highway-by-highway basis. Regional speeds were increased only if highway improvements had a significant impact on regional speeds; then the average speed was increased, but not the speed for the link that was improved (1, 5, 6, 14).

ICC data were used in estimating the cost reductions due to improved highways for the forecasting model because they reflect average speed conditions for 9 geographic regions of the United States. The data show how vehicle operating cost is affected by variations in speed for each of the regions. That is to say, the data present a functional relation between cost and speed in each of the 9 regions. Thus, the ICC data provide the clearest and most straightforward basis for linking motor carrier costs to speed. These formula rates reflect realistic estimates of the relation between speed and cost because they reflect road conditions and congestion as well as quality of roadway over varying topography.

It is unclear whether a change in costs will necessarily result in a change in rates (and thus factor prices). However, it can reasonably be assumed that reductions in highway transportation costs will be passed on to the users in the form of lower rates because of the high level of competition between private and for-hire motor carriage. [Oi and Hurter (10) give a complete discussion of private motor competition with for-hire motor transport as well as with rail transportation. Empirical evidence gathered in this study indicates firms of all sizes conduct private transportation. Competition is especially intense on the short haul. For-hire motor transportation forces competition from rail on the long haul. Thus, it is believed that the above assumption is realistic.]

The multi-regional and -industry forecasting model approximates motor carrier rates by using out-of-pocket costs plus an adequate markup to ensure revenue needs will be met. These charges are assumed to apply to all trucking, including intrastate movements and private carriage. A method of adjusting these average cost figures for those hauls that would benefit from improved highways was desired.

The out-of-pocket costs used in the model are the ICC figures for 1965. The cost of transporting a unit bundle from the jth to the kth region is based on average operating conditions in the jth region, plus terminal costs at both ends. The ICC data are average and do not relate operating costs to road type. However, they do include information on the average speed for each region, and tables are available that show the relation between operating costs per vehicle-mile and assumed speeds that range from 15 to 45 mph. These data, along with the national highway network model (TRANSNET) of the U. S. Department of Transportation, are used as the basis of an adjustment to the out-of-pocket cost figures for changes in speed due to highway improvements.

TRANSNET is a system whereby all the principal highways in the United States have been coded into links. Data available for each link include the number of miles, the speed, and the terrain characteristics of the area. The model assigns a given trip between 2 points in the most efficient (fastest) manner and computes the time of the trip in terms of minutes. Each of these highway links has been classified and coded by OBE economic areas, making it possible to compute the number of miles and the average speed for each major type of highway in each area and between areas. The highway classifications are limited-access toll roads, limited-access free roads, other divided highways, principal throughways, and local connectors. Regional speed figures were available for each of these classifications.

The transportation rates as used in the multi-regional and -industry forecasting model are a combination of truck and rail costs. Shipments are divided into weight classes, and the cost of shipping a unit of goods between 2 regions is computed for both rail and truck transport in each of the weight classes. In determining the cost of shipping a unit between each pair of regions, the lower of the 2 costs is chosen to represent the transportation costs in that weight class, and then the selected transportation costs by weight class are averaged by using information on the total weight of goods shipped in each weight class.

Both the rail and truck transportation costs are computed by using ICC formulas, which consist of line-haul costs and terminal costs. Thus, if a highway system were to improve the speed in that region, then the line-haul cost of trucks would decrease and truck transport might be substituted for rail transport in the forecasting model, depending on the magnitude of the decrease.

Based on the ICC relation between speed and line-haul cost, the truck vehicle-cost per mile is substituted for the speed data in TRANSNET. The network model is then run in order to compute the minimum vehicle-cost path between each of the economic regions, as was explained above.

HYPOTHETICAL HIGHWAY SYSTEMS TO BE EVALUATED BY FORECASTING MODEL

The 3 systems described here are the extended primary system, highways for economic development, and the urban highway system. All highway links for the proposed highway systems are constructed to Interstate standards. The federal highway expenditure level is assumed to be $4 billion annually from 1977 to 1986. The model is used to assess the regional impact of investing in each of these systems.

Extended Primary System

Objective—The extended primary system is designed to meet the needs of small cities that are not served by the Interstate System. Most of those cities have less than 50,000 population, and many are located in low population density regions. The likely benefit of such a system would be the decentralization of industry, shifting economic activity from large to small cities. Because the principal purpose of this alternative highway system is to improve transportation to small and remote cities, less than half of the construction expenditures would be for urban highways. Those states that received little funding for this system, because of their population densities or existing Interstate highway links, were appropriated some funds for improved highways, e.g., beltways, in their large urban areas to make the distribution of federal funds equitable.

Allocation of Federal Funds—For each $7 of federal funds expended, the states expend $3. The federal funds are divided into 3 equal portions as a first approximation. One portion is allocated to states according to the 1970 population. The second portion is allocated according to the square root of the land area of the state. The third portion is allocated according to the miles of federal-aid highways located in the state. Because the extended highway system is intended to provide better highways nationwide to the smaller cities, there is deviation from this formula if some states have more priority links than others. However, every state receives at least 50 percent of what it would receive under the formula allocation.

Nodal Points in the System—Nodal counties were found by ranking counties in each state by the size of their 1970 urban population. The nodal point in each county is the center of the largest city in the county. Those cities already served by Interstate System were eliminated from consideration. The largest remaining cities were allocated the highest priority and so on down to the smallest cities.

Highways for Economic Development

Objective—The economic development highway system reduces transportation cost to the economically depressed areas of the nation. It results in a shift of industry from the highly developed areas to the underdeveloped areas.

Allocation of Federal Funds—Because this system is designed to help poor areas, matching state funds are not required. Not all of the states are served with this system. Economic areas as defined by OBE were ranked according to their per capita income. Nodal points within each economic area were selected, and a highway system was planned to serve those nodes. The allocation to any state or economic area was not predetermined but depended on income needs.

Nodal Points in the System—The OBE economic areas are delineated to form what may be called "little economies." Although the areas are not self-sufficient, the economic activity of any one area with other areas is minimized. Each economic area has one or more central cities, and the central cities are designated as nodal points in the new highway system.

Placement of Road Segments—Road segments in the new system tie into the Interstate Highway System. A network of segments was planned, and each nodal point is served by at least one new road segment. The new road segment meets or crosses either another new road segment in the nodal county or an existing road of primary quality.

Priority of Segments—The new segments in the system are given a priority rating according to the per capita income of the economic area that it serves (beginning with the lowest per capita income and working upward). Road segments are built according to the priority ratings until the total amount of money is exhausted.

Urban Highway System

Objective—The urban highway system is designed to eliminate urban congestion where it is the greatest. It favors large metropolitan areas and, thus, influences industry to centralize and concentrate in large cities.

Allocation of Funds—Because not all states and cities are served by this system, no matching state funds are required. Allocation of funds is determined by the U. S. Department of Transportation's arterial highway congestion index. Urbanized areas are ranked according to the congestion index, and funds are allocated to the most congested urbanized area until its congestion index falls to the value of the congestion index in the second most congested city. The funds are allocated to the first and second urbanized areas until their congestion indexes are reduced to the value of the third most congested area. Then funds are allocated to the first, second, and third city until their congestion indexes are reduced to the congestion index of the fourth most congested area. This procedure is continued until the total amount of funds is exhausted.

PRELIMINARY RESULTS AND CONCLUSIONS

The conclusions drawn are tentative in that the results and analysis were not complete at the time of this writing.

Comparisons of population and economic variables among the alternatives should be meaningful even if the 1970-1990 forecasts are in error because of incorrect economic growth assumptions because the only assumptions that change among alternative computer runs are those pertaining to alternative highway systems. In other words, everything is held constant except the highway system; thus, a comparison of the results should give a realistic measurement of the relative impacts of the alternative systems.

When the completed Interstate System is compared with the 1970 Interstate System (base year), the areas that gain the most population are Phoenix, Arizona; Burlington, Vermont; and Billings, Montana. Buffalo, New York; Bismark, North Dakota; and Raleigh, North Carolina show the greatest losses. Burlington is also a large gainer when measured by per capita income. Other areas that have large gains in per capita income are Cheyenne, Wyoming, and Clarksburg, West Virginia. The areas that would lose the most per capita income because of the completed Interstate System are Brownsville, Texas; Omaha, Nebraska; and Eureka, California.

Many of the areas that benefit by the completed Interstate System in 1990 are made relatively worse off by the extended primary system. The extended primary system improves the competitive position of additional areas and, thus, relatively lowers the 1990 population and income in areas that already have highway systems. The extended primary system benefits the smaller economic areas relative to the larger areas. In terms of per capita income, the poorest areas are made better off with the extended primary system, and the highest income areas are made worse off. The east-south central and the mountain census regions are the largest gainers from the extended primary system. The Pacific region has less population with this system.

The low-income economic areas are definitely helped by the economic development system. Fifty-eight out of the poorest 60 areas show some income improvement under this system. Many areas that show improvement under the economic development system also show improvement under the extended primary system. The links of the highway system in certain areas could be identical under both systems. The small areas, measured by population, also gain with the economic development system. The east-south central and the west-south central census regions gain the most population under the economic development system, and the Pacific region loses relatively the most.

The urban system does not benefit many areas because only 29 areas received construction expenditures under this alternative. The percentage of change in population and economic variables is not so high under this alternative as it is under the previous alternatives because the urban system affects areas with large economic bases and existing populations. The urban system definitely helps the large areas and the highest income areas. The mid-Atlantic region is the largest gainer in terms of population; the New England and the east-north central regions also show slight gains. All other census regions show relative losses.

Table 1 gives a summary of the economic projections for 1990 under the 5 alternative highway systems for the Washington, D. C., OBE area. Four alternative systems are compared on an index basis with the 1970 system, which is taken as the base of 100. Completing the Interstate System has little relative impact on Washington, D. C. The area loses slightly under the extended primary and economic development systems, which would not benefit it at all, and gains significantly under the urban system. In comparative terms, Washington, D. C., would be the second largest gainer under the urban system alternative.

Table 1. Indexes of 4 future highway systems relative to 1970 Interstate System.

Item	Completed Interstate	Extended Primary	Economic Development	Urban System
Jobs				
National resources	106	96	99	119
Construction	99	99	96	103
Manufacturing	104	97	98	114
Public utilities	102	96	97	111
Wholesale trade	102	98	95	106
Retail trade	101	98	99	105
Finance and real estate	100	100	100	100
Services	100	100	100	100
State and local government	107	99	99	103
Federal government	100	100	100	100
Military	100	100	100	100
Total	104	99	99	103
Population	101	99	99	104
Personal income	101	99	99	104
Per capita income	100	100	100	100

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