Regional Economic Impact Model for Highway Systems (REIMHS)

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This paper provides a brief overview of the Regional Economic Impact Model for Highway Systems (REIMHS), a description of the methodology's components, and a sample application for the 16-county Dallas/Fort Worth area. Relying on the Bureau of Economic Analysis' multipliers for regional industrial output, earnings of employees in those industries, and employment, the methodology takes standard highway data input and derives industrial output, earnings, and employment impacts of addressing or not addressing highway construction or rehabilitation needs on a variety of highway systems. For example, this prototype methodology and model showed that not addressing construction needs on a typical Interstate highway results in a loss in motorist benefits for the Dallas/Fort Worth area equivalent to $1.8 million in regional output, $580,000 in regional earnings, and 27 jobs. On the other hand, undertaking $10 million in Interstate improvements will stimulate $17.6 million in regional output, $4.6 million in earnings, and 203 jobs. These findings were compared with earlier studies and found to be reasonable. The highway data input consists of allocating highway investments to the various highway industries and estimating and allocating savings resulting from highway construction and rehabilitation improvements. The savings result from increased efficiency, mobility, and safety for vehicular traffic exposed to congestion. The authors conclude that the methodology is practical and workable and that the results are reasonable.

The decision to build highways is always based on the supposition that highways are beneficial. Yet, how much they improve the economy has been an elusive question to answer. If the answer were readily available, state and local governments could more intelligently differentiate between the various alternatives for highway construction and, with more certainty, make a decision that maximizes the benefit of their investment to their economy.

The importance of answering this question was first noted in 1959 at the Highway Research Board Workshop on Economic Analysis in Highway Programming, Location, and Design. A number of observations were made, such as, "It is extremely important that some means be made available to properly evaluate changes in the highway system. . . ." and "any system analysis should consider the impact on the total economy. . . ."

Today, it makes just as much sense to focus highway resources on those roads that yield the greatest return for the investment.

We conducted a review of the practice and identified a range of methodologies for conducting project economic analysis but only a few for conducting regional system economic analysis. After a review of the methodologies, we determined that we needed a broader and more robust analytical framework. We decided to explore the use of input-output models.

Input-output, or interindustry models, were published by W. Leontief (*1*) as early as 1936, when a model of the American economy was developed. Since then, the use of interindustry analysis has become commonplace in the field of economics.

In the field of highway transportation, interindustry analysis has had a shorter, sporadic history. In 1971, R. W. Hooker of the University of Wyoming developed and used an interindustry model to estimate the impacts of the state highway department's investment, the nonlocal traveler's spending, and the local private investment on the economy of Unita and Sweetwater counties in the southwest corner of Wyoming, where the new 200-mi Interstate highway was to be built (*2*). In 1982, the Regional Science Institute developed, for the National Cooperative Highway Research Program, two manuals to assist state departments of transportation (DOTs) in performing regional economic analysis for policy analysis (*3*). In 1984, the North Central Texas Council of Governments used the interindustry model to estimate the local economic impacts of transportation fuel consumption (*4*). In 1987, the Washington DOT used the interindustry model to estimate the impact of changes in demand for transportation services on the rest of the economy (*5*). Finally, in 1987, the Ontario Ministry of Transportation constructed an input-output model to assist its member jurisdictions in predicting economic impacts of a variety of highway projects (*6*). Other transportation uses have been made of interindustry models, but they are not extensive.

Perhaps its sporadic history is because of the complexity of the analysis required. Yet, interindustry models can provide valuable information in support of a highway project or a program implementation decision. If the analysis were to be simplified, the models could be brought to bear more extensively on highway issues. For example, interindustry models could be adapted to answer these questions: which highway investment has the greatest potential for improving the regional economy? and by how much? Hence, we suggest a need to develop sketch planning tools for the application of the interindustry model.

In this development of a prototype regional economic analysis model, we make no judgments as to the relative economic impacts of alternative investment strategies. That is, we do not consider the regional economic impacts of investing $10 million in the private sector or other public infrastructure projects. We took such examination to be outside the scope of this exploratory study.

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METHODOLOGY

Overview

Expenditures by highway agencies have secondary impacts on the economy, beyond providing new or better services. Such impacts are employment, income, and production. Moreover, these impacts are explicitly traceable from the transportation sector to other sectors of the regional economy.

For example, building a highway requires inputs of labor, raw materials, government services, unfinished products, and so on. Some inputs may be purchased within a region and others from outside a region. The services provided by the highway are likewise used by industries within a region and outside a region. To the extent that interdependencies between the highway construction sector and other sectors of the economy exist, a change in the production of highway service will affect the production of other industries in a region's economy (*2*). Construction of highways may specifically affect regional industries by (*7*)

- Decreasing the cost of transporting a product within or through a region;
- Increasing the income of a region through payment of construction workers and, in turn, other industries through the purchase of goods and services by construction workers; and
- Increasing income of those industries that supply construction materials.

These changes also bring about corresponding changes in employment and production of regional industries.

Process

The process of developing a methodology for applying the interindustry model to highway construction took the form of

- Distributing the monetary investment among the relevant highway industries of the region;
- Translating the efficiency, safety, and mobility improvements to equivalent monetary benefits;
- Using the investments and benefits as inputs to the interindustry multiplier matrices; and
- Observing the resulting impacts on the region's total economy.

The process and the interrelationships between these components are diagrammed in Figure 1.

Procedure

The process consists of 10 steps, as indicated in Figure 1. Each of the steps is described generally here. Steps 1 through 5 are described in more detail in the Technical Appendices, which are available on request from the FHWA Office of Planning. Appendices are entitled Appendix A: Investment in Highway Material Industries; Appendix B: Efficiency Savings—User Costs; Appendix C: Mobility Savings—Travel Time; and Appendix D: Safety Savings—Accident Costs.

- *Step 1: Distribute project cost as investment of money in regional highway material industries and to households.* A $10 million investment in construction funding was allocated among nine highway-related industries, including new construction, maintenance construction, petroleum refining, lumber, stone, metal, electric equipment, miscellaneous manufacturing, and households. The basis of allocation was the quantity of industry-related materials used by each of the project types. Twenty-eight projects were used, covering 11 construction categories.
- *Step 2: Calculate equivalent monetary benefits of operating efficiency savings.* For construction improvements, savings in maintenance repair, fuel, tire, oil, and depreciation were calculated for that traffic exposed to congestion, defined as a volume to capacity ratio of 0.77 or more. Savings were taken as the difference between operating costs, before the improvement, minus the operating costs, after the improvement. These are savings that would be available to households and industries for other discretionary expenditures. Some savings, such as fuel and oil, are of a shorter-term nature and are out of pocket. Others are not and may be felt in the longer term. Nevertheless, the savings or the lack of savings will influence household budgets and expenditures in the regional economy.
- *Step 3: Calculate equivalent monetary mobility savings.* For the traffic exposed to congestion, savings in travel time were calculated. Travel time savings were based on the vehicle miles of travel, the differences in running speeds after and before the improvement, and the value of travel time. For automobiles, the value of travel time was calculated as $8.20/hr, using AASHTO Redbook guidance; for trucks, it was $13.98/hr. It is easier to see that mobility savings of the truck fleets would lead to cash monetary benefits for industries. It is more difficult to understand the noncash benefits of commuter travel time. We reason that a commuter's time loss could also be translated to lost wages.
- *Step 4: Calculate monetary benefits of safety savings.* Using the total vehicle-miles of travel, the number of accidents per 100 million vehicle-mi, the cost of fatal, injury, and property-damage-only accidents, and accident reduction factors for various highway project types, it is possible to calculate savings in accident costs. Total vehicle-miles of travel were used, rather than vehicle-miles of travel exposed to congestion, because accidents are likely to be reduced at both congested and noncongested periods. These benefits are also noncash benefits, which may extend existing household and industry expenditure patterns.
- *Step 5: Distribute monetary savings to relevant industries and to households.* All savings of Steps 3 and 4 were calculated for automobiles and trucks. Automobile savings were attributed to households; truck savings were distributed to the regional industries. Distribution to the trucking industries was done on a basis of truck vehicle-miles of travel for various uses as reported by the Truck Inventory and Use Survey of 1982 (*8*). Where uses could be identified with regional industries, personal transportation, retail trade, and so on, vehicle-miles of travel data were used directly. Where uses were too general to be identified with specific regional industries, such as manufacturing, a further breakdown of truck vehicle-miles of travel was made on the basis of number of employees in that subindustry, such as electrical equipment manufacturing. The Department of Commerce's *County Business Patterns* was used as a basis for this breakdown (*9*). The percentage of truck vehicle-miles of travel for each industry was thereby calculated and used to distribute savings of Steps 2 and 3.

Savings in Step 4 were attributed to the household sector

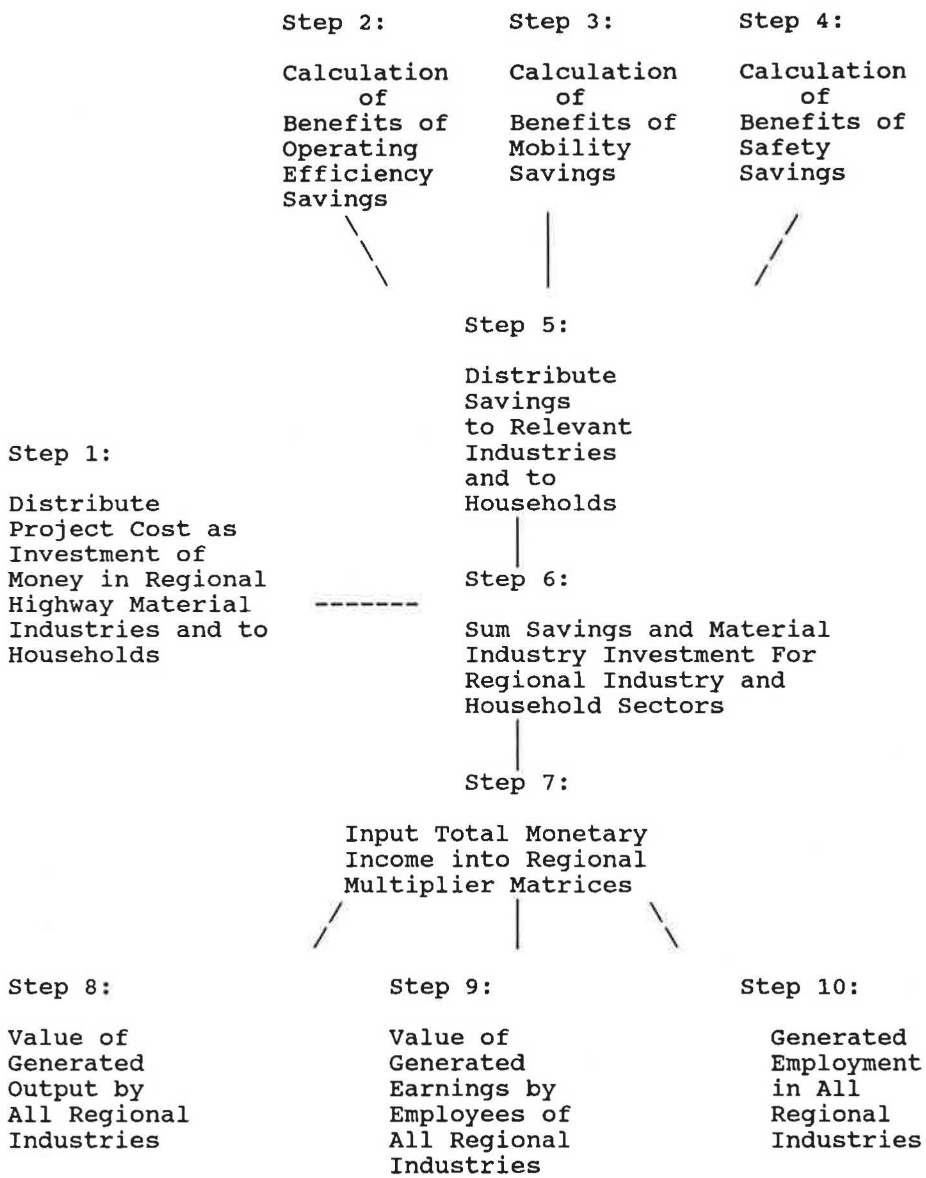

FIGURE 1 Process for developing the regional economic impact model for highway systems.

and to the insurance sector at the rate of 1:10, assuming that, in the event of an accident, households could incur 10 percent of the cost in the form of deductibles and increases in insurance premiums and that the insurance sector would bear 90 percent of the losses.

• *Step 6: Sum savings and material industry investment for regional industry and household sectors.* Step 1 distributes project costs among 9 industries, Steps 2 and 3 among 18, and Step 4 among 2. There is considerable overlap. The total number of different industries is 23. For each of the 23 industries, the sum of construction investment and efficiency savings was calculated.

• *Step 7: Input total monetary income into regional multiplier matrices.* Output, earnings, and employment multiplier matrices are available from the Bureau of Economic Analysis (BEA), Department of Commerce, for any region consisting of one or more counties. For this study, we used BEA's aggregate multiplier matrices of 39 industries (*10*). Each of these matrices is a closed set of interdependent coefficients representing the interrelationships of a study area's economy. The coefficients are called multipliers because they are dollar multiples of the initial dollar spent in each industry (*10*). Each coefficient is equivalent to the change in output that occurs in a regional industry, given a change in the input industry. The input of highway investment monies and monetary savings of efficiency, mobility, and safety improvements in the relevant industries results, through the use of the interdependent coefficients, in the estimation of required output for each and every industry in the region.

For this prototype model, we use multipliers that represent total requirements coefficients. These include direct, indirect, and induced economic impacts of an investment in a regional economy.

• *Step 8: Value generated output by all regional industries.* Finding the product of (a) all the monetary investment and savings for each of the 23 input industries and (b) the respective multiplier of the output matrix for each and every one of the 39 output industries, it is possible to obtain an estimate of the monetary value of all items produced by the regional industries. This we can label generated output.

- *Step 9: Value generated earnings of all regional industries.* Finding the product of (a) the sum of monetary investment and savings for each of the 23 input industries and (b) the respective multiplier of the earnings matrix for each and every one of the 39 output industries, it is possible to obtain an estimate of the monetary value of employee salaries in the regional industries. The salaries result from the infusion of travel savings and construction investment in the regional economy. This we can label generated earnings.
- *Step 10: Value generated employment in all regional industries.* As with Steps 8 and 9, Step 10 follows similar reasoning to arrive at the number of jobs created, or employment generated, for the regional economy.

CASE STUDY APPLICATION

Background

No process, methodology, or model is practical, unless it can be shown to yield anticipated results. A sample application also shows the capability of the analytical tool.

For the sample application of the interindustry model, the 16-county North Central Texas Council of Government's region is the focus. This region is shown in Figure 2. At its center the region has the Dallas/Fort Worth urbanized area. Counties adjacent to but outside the Dallas/Fort Worth Consolidated Metropolitan Statistical Area include Wise, Palo Pinto, Erath, Hood, Somervell, Navarro, and Hunt. These are rural counties.

Employment, earnings, and output multiplier matrices for analysis year 1986 were made available for our application by the generosity of the North Central Texas Council of Governments, which purchased the multipliers to conduct an FAA-sponsored study of airport expansion alternatives.

Data

Transportation data for this study were available through existing data bases. For highway material industry investment, usage data were available from Form FHWA-47, Statement of Materials and Labor Used by Contractors on Highway Construction Involving Federal Funds. This form provides such data as project type, highway system, total construction cost, labor cost, length of project, quantity of materials used, and total material cost. A total of 76 projects were reviewed, and 28 were used.

Six system types were used: Interstate, primary, and urban in urban areas and Interstate, primary, and secondary in rural areas. Travel data from the 1986 Highway Performance Monitoring System (HPMS) submissions of the Texas State Department of Highway and Public Transportation were used to determine percentage of vehicle-miles exposed to congestion, percentage of truck-miles under congested conditions, vehicle-miles for each of eight vehicle classes, and average urban and rural volume to capacity ratios.

For efficiency savings, consumption data for maintenance and repair, fuel, tire, oil, and depreciation were available from an unpublished FHWA-sponsored study on operating costs developed by Zaniewski in 1982 and entitled "Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Congestion Factors." Consumption data were available for the 1980 vehicle fleet; unit prices were available for 1980 and 1985. The unit prices were updated to 1986, using straight-line extrapolation. Accordingly, 1986 consumption data are based on the consumption rates of 1980 automobile and truck vehicle fleets.

For mobility savings, running speeds were obtained from the use of the HPMS Analytical Process, Version 2.1 (*11*). Running speeds are a function of average highway speeds and volume to capacity (*V/C*) ratios. Average highway speeds were obtained from FHWA's *Highway Statistics 1986* (*12*, p. 60); average *V/C* ratios were obtained from 1986 HPMS data reported by the state of Texas. The differences in running speeds, resulting from changes in *V/C* ratios, were used to estimate savings in travel time. The monetary values of time for automobiles and trucks were obtained by applying the AASHTO manual on user benefits (*13*, p. 17), updated to 1986, using the Consumer Price Index (CPI) and the Wholesale Price Index for Industrial Commodities (*14*).

For accident savings, cost data were obtained from a 1984 FHWA publication titled, *Alternative Approaches to Accident Cost Concepts—State of the Art* (*15*, p. 123). This source was chosen because it provides recent data that integrate well with other travel data. Also, these estimates are conservative compared to many other sources considered. This source was used for direct cost of a fatality, of an injury accident, and of a property-damage-only accident. Accident reduction factors for each project type were obtained from a 1982 report by FHWA (*16*, p. 1). The accident rate data were obtained from two annual reports of accident statistics published by FHWA (*17*, p. 5) and the National Safety Council (*18*, p. 47). The 1985 rates are used because the 1986 reports were not yet available. All cost data were updated to 1986 using the CPI.

For all calculations, with the exception of accident costs, congested vehicle-miles of travel (CVMT) were used as the base statistic. CVMT were derived for each highway system's sample of highways by dividing (a) total daily vehicle-miles of travel (DVMT) with *V/C* at or over 0.77 by (b) the total DVMT. This ratio was then applied to the average DVMT for the respective highway system to arrive at CVMT. Total and average DVMT for each highway system were calculated using the 1986 sample data submitted by the state of Texas. Total DVMT were used for accident cost calculations, because we believed the benefits of accident improvements would be felt by all travelers.

Because HPMS data are not reported for bridges, travel data for a bridge project on a given highway system were assumed to be the same as the average of all roads on that system. For example, a bridge project on a primary system was assigned the same total and average DVMT as a highway project on a primary system.

Results

A $10 million highway improvement can be expected to stimulate industry production valued at between $12.8 and $18.5 million in a region; workers in those industries are estimated to earn between $3.8 and $5.1 million; and the number of jobs stimulated is expected to be between 159 and 232. These

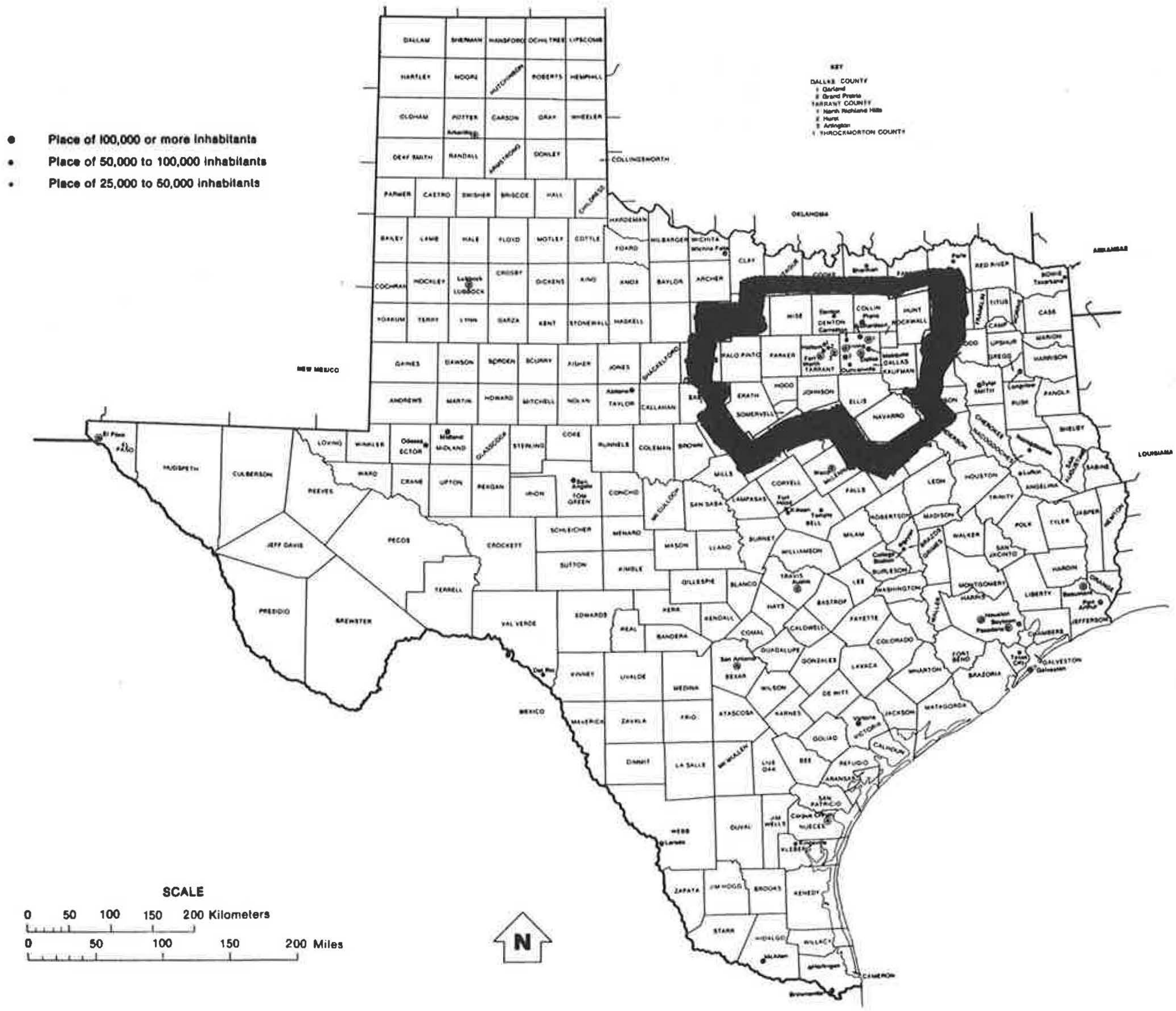

FIGURE 2 The 16-county Dallas/Fort Worth region (data from County Business Patterns, Texas; U.S. Bureau of Census, 1985).

results include the economic impacts of construction and of the attendant transportation improvements.

The construction impacts occur over a number of years as do the transportation impacts. The precise number of years may be a function of how long it takes the infusion of construction funds to completely circulate through the region and how long it takes for the transportation benefits to be completely negated by increased congestion. No assumptions were made regarding the temporal nature of the economic impacts.

For urban areas, five highway project types were considered. Of these, a rehabilitation project on the primary system can be expected to generate the most economic impact, and a bridge construction project on the urban system the least.

For rural areas, six highway project types were considered. Of these, a 3-R project on the Interstate system would generate the most impact on industry output; a new construction project the most impact on industry earnings and on new jobs. The least impact on industrial output is generated by a bridge 3-R project on the primary system; the minor widening project on the secondary system generates the least impact on industry earnings and new jobs.

These economic impacts result from the sum of $10 million invested in the region's highways and the corresponding monetary savings that the region would realize from improvement in operating efficiency, mobility, and safety of vehicular travel. Improvements in operating efficiency include such user benefits as savings in fuel, oil, tire, repair and maintenance, and depreciation; mobility benefits include travel time savings; and safety benefits include reduction in property-damage, fatal, and injury accidents.

Benefits from mobility savings were the greatest, topping the equivalent of $2.6 million for construction projects on the Interstate system. Benefits from savings in safety improvements were next in order of significance, topping $0.77 million for bridge projects on the primary system. Of least significance were benefits from operating efficiency. These topped $0.25 million for rehabilitation projects on the primary system.

These savings all used CVMT as a base statistic, and CVMT in urban areas was uniformly greater than for similar system types in rural areas. For example, CVMT on highway systems in urban areas is 10 to 80 times greater than CVMT for highway systems in rural areas. Correspondingly, improvements for urban areas uniformly resulted in higher savings in operating efficiency, mobility, and safety, when compared with improvements in rural areas.

This study does show that highway projects and, indeed, highway systems can be evaluated for their comprehensive impacts on the regional economy in an expeditious and inexpensive manner, using a sketch planning application of a region's interindustry model. This method allows comparison of practical economic impacts in terms of dollars and jobs, instead of the relative indicators provided by traditional benefit-cost analysis.

Table 1 summarizes the regional economic impact of a $10 million investment and the corresponding motorist benefits in efficiency, mobility, and safety savings. These impacts are provided for construction projects and maintenance and repair projects. Improvements in operating efficiency include such user benefits as savings in fuel, oil, tire, repair and maintenance, and depreciation; mobility includes travel time savings; and safety includes reduction in property-damage, fatal, and injury accidents.

If road construction and repair projects were not constructed, the existing road would be denied efficiency, mobility, and safety benefits. These benefits are the same as those used in Table 1 and were estimated to be the difference between efficiency, mobility, and safety costs before and after a prospective improvement. The calculations and the result would be identical to the calculations and results used for Table 1, with one exception. The exception is that if the investment in the highway construction industries would not occur, no project would be constructed. Inserting only the foregone user

TABLE 1 REGIONAL IMPACT OF A $10 MILLION HIGHWAY IMPROVEMENT ($ MILLIONS, EXCEPT JOBS)

Area Type	Project Type	Motorist Benefits			Impact		
		Efficiency	Mobility	Safety	Output	Earnings	Jobs
Urban	Interstate: New Construction	.15	2.6	.68	17.6	4.6	203
	Primary: Rehabilitation	.26	1.2	.70	18.5	5.1	224
	Primary: Bridge "3-R"	.26	1.2	.78	14.9	4.6	203
	Urban: Realignment Construction	-.003	.07	.18	16.6	4.9	223
	Urban: Bridge Construction	-.003	.07	.17	12.8	3.6	159
Rural							
	Interstate: New Construction	-.02	.27	.05	17.2	5.1	232
	Interstate: "3-R"	-.02	.27	.04	18.3	4.2	180
	Primary: Bridge "3R"	.002	.028	.05	15.0	4.4	191
	Secondary: Construction	-.0002	.016	.02	17.8	4.3	190
	Secondary: Minor Widening	.003	.02	.01	17.0	3.8	163
	Secondary: Overlay	.003	.02	.02	18.0	4.8	210

benefits in the output, earnings, and employment matrices, we can reasonably interpret the resulting impacts as those regional economic losses that could occur as a result of the loss in motorist benefits. Table 2 summarizes the impacts of efficiency, mobility, and safety losses on the regional economy assuming no investment is made in the highway system.

In urban areas, the results of no investment in highways is greatest where Interstate new construction, primary bridge widening, and primary rehabilitation projects are needed. The amount of industry output lost can be as high as $1.8 million, employee earnings as high as $0.59 million, and the number of jobs lost as high as 27. In rural areas, the results of no investment is greatest where Interstate construction projects are needed. In this case, the amount of output lost is valued at $0.17 million, employee earnings at $0.05 million, and the number of jobs at 2. As with the observations made regarding Table 1, the impacts are greater in urban areas. This is because cost data are driven by vehicle-miles of travel exposed to congestion, and it is much higher for urban areas than for rural areas.

In Table 2, operating efficiency includes such user measures as expenditures in fuel, oil, tire, repair and maintenance, and depreciation; mobility includes travel time costs; and safety includes reduction in property-damage, fatal, and injury accidents.

Analysis of Results

By comparing the impact of construction investment and user cost savings with the impacts of user costs alone, we can see that the magnitude of the construction investment can overshadow the magnitude in efficiency, mobility, and safety benefits or costs of their impacts on the regional economy. For

TABLE 2 REGIONAL IMPACT OF NO HIGHWAY IMPROVEMENTS ($ MILLIONS, EXCEPT JOBS)

Area Type	Project Type	Motorist Losses: Efficiency	Mobility	Safety	Impact: Output	Earnings	Jobs
Urban	Interstate: New Construction	.15	2.7	.68	1.8	.58	27
	Primary: Rehabilitation	.26	1.2	.70	1.6	.54	24
	Primary: Bridge "3-R"	.26	1.2	.78	1.8	.59	27
	Urban: Realignment Construction	-.003	.07	.18	.38	.13	6
	Urban: Bridge Construction	-.003	.07	.17	.37	.12	6
Rural							
	Interstate: New Construction	-.02	.27	.05	.17	.05	2
	Interstate: "3-R"	-.02	.27	.04	.15	.05	2
	Primary: Bridge "3R"	.002	.028	.05	.11	.04	2
	Secondary: Construction	-.0002	.016	.02	.04	.01	1
	Secondary: Minor Widening	.003	.02	.01	.03	.01	1
	Secondary: Overlay	.003	.02	.02	.04	.01	0

a rural Interstate construction project, $17.2 million is the output of regional industries receiving a $10 million highway investment and improvements in efficiency, mobility, and safety (Table 1). For this same project, $0.17 million is the output of regional industries receiving efficiency, mobility, and safety losses alone (Table 2). The corresponding impact of the $10 million investment alone is $17.0 million. These comparisons are valid only until the $10 million investment filters through the economy, or until the congestion level decays to the area's average. Over the life of the project, perhaps 20 years, user benefits may, indeed, equal and exceed the impact of the construction investment. This assumes of course that traffic does not increase measurably on the facility and thereby decrease the user benefits.

Lastly, mobility savings proved to be the most significant, ranging from $2 thousand to $2.6 million. Savings in safety improvements were next in order of significance, ranging from $14 thousand to $0.78 million. Operating efficiency savings were least significant. These ranged from losses of $22 thousand to savings of $0.26 million. The losses were a result of the nature of consumption curves for fuel, oil, tire, repair and maintenance, and depreciation. Consumption curves are concave for both fuel and oil with a minimum corresponding to a certain point. Beyond this low point, consumption increases as speed increases. For tire and for repair and maintenance, the higher the speed, the higher the cost of these consumption factors. Lastly, depreciation cost decreased with speed. Accordingly, the construction of a highway improvement, and the attendant increase in speed, does not necessarily result in savings in operating costs. Fortunately, savings in mobility and safety exceeded increases in operating costs, resulting in a net increase in user benefits from the highway improvement.

EVALUATION

Interpretation of Results

Given the investment of $10 million to construct an Interstate project in an urban area, Table 1 indicates that regional industries will generate $17.6 million in output, $4.6 million in earnings, and 203 jobs. These and other results on regional economic impacts are derived using the existing economic infrastructure. These results do not imply that new industry will locate in the region or that the new industry will generate so much economic impact. The industrial interrelationships are assumed fixed, and the mathematical description of the regional economy is closed. Results, then, indicate how well the existing economy uses a given investment. As such, REIMHS can be used to evaluate the regional economic impacts of alternative investments and the potential economic growth of the existing industrial base, but not the potential new growth in the regional economy.

Validity of Results

In the early 1980s, the FHWA monitored the number of jobs directly created by highway construction. These studies were updated as recently as 1985 (*19*, p. 2). Nationally, it was found that a $1 million investment would directly generate 10 on-site full-time construction jobs. REIMHS indicates that 16 to 23 jobs are created per $1 million in the 16-county region around Dallas/Fort Worth. REIMHS' results are reasonably close, given that the figures represent (a) the number of jobs that are on site, off site, construction-related, and service-industry-related and (b) related increases in consumer demand (direct, indirect, and induced effects). REIMHS' jobs cover all sectors of the economy, including construction jobs. Lastly, REIMHS' jobs also include the results of the expenditure of monetary savings in operating efficiency, mobility, and safety costs.

In the middle 1970s, the Bureau of Labor Statistics used an interindustry input-output model to determine the employment impact of highway construction (*19*, p. 2). It estimated a total of 57.8 jobs per $1 million of highway investment. Using the transportation CPI to find the current dollar equivalent for 1986, we estimate that 22.5 jobs would be generated for every $1 million invested in the highway construction industry. This number is reasonably close to REIMHS' results.

Reliability of Results

The REIMHS is capable of yielding consistent results with each application at various locations and at various intervals of time. This remains true if the output, earnings, and employment matrices are replaced to reflect the change in location of study area and if the period of elapsed time between applications is limited. If too long a period of time lapses between application, perhaps 7 to 12 years, then the nature of the study area's economy may not be reflected by the model. This is because it is likely that the nature of a region's economy will change over a 7-to-12-year period. Nevertheless, the model would remain reliable for sensitivity analysis, because it is the relative changes in regional impact that would be of interest in such an analysis.

Caveats

The results obtained in this prototype development of REIMHS are based on data and information for the 16-county Dallas/Fort Worth area. The following simplifying assumptions were made to circumvent the paucity of data and to facilitate analysis:

- Highway sample travel data from the state can be used to represent project and network data.
- Vehicles-in-use data can be used to partition vehicle-miles-of-travel into three automobile classes.
- Travel cost savings are experienced predominantly by traffic exposed to congestion.
- Excess consumption of stop-and-go conditions is negligible compared to consumption at uniform speeds and excess consumption resulting from speed slowdowns.
- The pavement condition for improvements other than 3-R types is good before the improvement.
- Accident cost savings are experienced by congested and noncongested traffic equally.

In applying this prototype model to other regions, it is important to rely on actual state and local project and areawide data as much as possible to increase the model's relevance to local conditions and possibly avoid making the simplifying assumptions.

Issue of Imputed Monetary Benefits

This analysis assumes that out-of-pocket and noncash savings in operating efficiency, mobility, and safety costs can be treated as money to be spent into the regional economy. We recognize the existence of a debate as to whether these savings are realistic to include in an input-output analysis. Operating efficiency benefits include savings in tire, fuel, oil, depreciation, and maintenance and repair. Mobility benefits include the monetary value of travel time. Safety benefits include savings in accident costs. Savings in tire, fuel, and oil costs directly result in more discretionary monies to spend. However, savings in depreciation and in maintenance and repair are probably less noticeable. Travel time cost savings may not be noticed at all in a household or industry's budget. Savings in accident costs are not noticeable until an accident occurs and the household or industry budget is constrained. Nevertheless, use of user benefits is a long-standing practice in the highway community to evaluate the merits of highway projects, and this application is only a modest expansion of its use. Moreover, in the interest of comprehensiveness, we judged it wise to consider the total range of possible savings from the construction of a highway improvement.

Model

Efficiency Versus Cost

The interindustry model is one of the best analytical approaches for determining the impact of transportation on the regional economy (*2*). It is efficient because it explicitly and directly uses comprehensive data relevant to the region's specific economy. It does not use surrogate measures of economic activity. It takes into account economic changes at a regional level, a level that may implicitly incorporate internal counterbalancing changes of member jurisdictions. The multipliers do cost, however. Were a state such as Florida interested in applying a sketch planning model for its member metropolitan planning organizations (MPOs) (21 in all), the cost would be $750 for each set of multipliers, or $15,750. Applying such a model for the state itself would cost $1,500, the price if only one set of multipliers is purchased. Because the interindustry multipliers can be applied to impact analysis in other fields as well as transportation, the multipliers may well pay for themselves.

Complexity Versus Computer Efficiency

The detailed 531-industry classification matrix prepared by the BEA requires the use of a mainframe and a programming language as demonstrated by the experience of the Regional Science Research Institute. Such detailed analysis provides impacts at very detailed levels of the economy. However, for sketch planning purposes, it is more prudent to use the matrix of 39 industry aggregates. Reliance on the 39 industry aggregate matrix makes the task of data analysis and manipulation more manageable with microcomputers and existing software. Such software includes Lotus 1-2-3. As a sketch planning microcomputer tool, an interindustry model will make sensitivity analysis of differing highway system improvements on the regional economy very time efficient.

Implicit Causality

Because the multipliers are developed from actual expenditures in each of the national industries, and because the expenditures of these industries are mathematically interrelated, then as a mathematically closed system, any change in one sector of the economy directly causes changes in the other sectors. The causal relationship between highway improvement and impacts on the economy is implicit. This is because the nature of the highway improvement is structured in monetary terms for input into the existing relationship—the mathematical system is not altered.

Timeliness of Multipliers

A typical interindustry table comes from two data sources of the BEA: (a) its national input-output table, showing the inputs and outputs of the 531 national industries and (b) county wage-and-salary data (*10*). The national input-output table is available 7 years after the last census. County wage-and-salary data are available about 16 months after the last county-based survey (BEA staff, unpublished data). An interindustry table of multipliers purchased in May 1988 will have 1986 data and will be based on 1977 input-output relationships. In using the multipliers, the analyst assumes that the basic structure of the economy has not changed since the last available survey. This is a plausible assumption, given that the local economy's wage and salary data, which are updated much more frequently, are used to show a region's industrial and trading pattern.

The seriousness of these issues does not appear to be overwhelming and indeed is workable in applying the prototypical sketch planning model to a real and existing project improvement.

CONCLUSION

This paper demonstrates that interindustry models, and specifically REIMHS, can be used efficiently and effectively to evaluate alternative highway project investment decisions at the regional level. Given a choice of investments, for example, constructing a variety of highway projects, REIMHS can be used to estimate which investment will result in the greatest monetary value of production of regional industries, the number of jobs generated, and the earnings of employees in those regional industries. REIMHS can also serve as a reasonable sketch planning tool for determining the economic development potential of a region, if we take economic development potential to mean growth in existing regional industries, rather than bringing new industries to the region.

Moreover, the process is equally applicable at the project or network level. We have seen an application at the project level. Application at the network level can be undertaken by using the Urban Transportation Planning System (UTPS) model to provide total vehicle-miles of travel, congested vehicle-miles traveled and vehicle-hours of delay for the entire road network. The UTPS model would be run for the conditions of before and after the improvement, and the resulting differences in transportation data would be used as input to REIMHS. Over 150 MPOs already have the UTPS and can use its output to fashion a network application of REIMHS.

Applying REIMHS at the network level with actual project data is a possible future activity, as is converting the current Lotus IA-based REIMHS to Fortran or "C." Network testing, unfortunately, cannot be efficiently done at the national level but must be done at the state or local level because access to local UTPS networks and data is lacking. Conversion of REIMHS from a discrete set of about 10 Lotus files to Fortran or "C" is a better possibility. Conversion of REIMHS to a compilable programming language may make it more efficient, more flexible, and easier to apply.

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