Productivity and Accessibility: Bridging Project-Specific and Macroeconomic Analyses of Transportation Investments

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ABSTRACT

Many studies of the local economic impacts of individual highway projects rely on overly narrow measures of economic benefits. Another type of research, focusing on economic productivity, defines benefits more broadly but is also limited by geographic and functional aggregation constraints. This paper attempts to bridge these two perspectives, describing how project-specific analysis methods can shed light on the overall macroeconomic effects of transportation infrastructure spending. It first identifies—at a micro level—the different functional elements of economic development benefits and business productivity. It then critically assesses the state of current methods and data for both aggregate-level analysis of capital investment benefits and local-level analysis of specific highway project impacts. Results of recent research are then used to illustrate how the analysis of local impacts of specific highway projects can be more fully measured in a context consistent with overall productivity and other economic concepts.

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MEASURING ECONOMIC DEVELOPMENT BENEFITS

Investments in highways and other types of transportation system improvements are widely recognized as an important means for achieving economic growth and development at the local, state, and national levels. Expansion and improvement of transportation facilities serve to reduce business costs and expand economic opportunities, ultimately helping to raise incomes and standards of living.

Current research on this topic is incomplete and tends to focus on partial economic effects in a given locality or on national economic effects of aggregate highway spending. On the one hand, there are national studies on the relationships between overall levels of highway capital investment and rates of change in business cost, productivity, and output at the state and federal levels. That "top-down" line of research is important for justifying overall spending and investment levels, but by itself yields little guidance on how targeting specific types of projects or settings can optimize the value of economic development benefits. On the other hand, there are regional (local and state) studies of the economic development benefits of improving highway speeds and throughput for specific corridors and facilities. This "bottom-up" line of research often focuses more on localized job creation and business attraction costs, rather than emphasizing total macroeconomic changes in employment, productivity, and income measures.

The challenge is to capture total economic productivity measurements when conducting local or state studies of specific project and program impacts. An approach that unifies disaggregate analysis with an evaluation of overall economic benefits will enable us to: 1) develop a more sophisticated understanding of economic development benefits at the project level, and 2) better guide decision-making in the area of state and federal budget planning. The need for a unified approach is based on our review of the existing literature, with empirical examples based on our recent research. The need to evaluate transportation investment at a geographically specific (micro) level is discussed in terms of travel cost effects, logistics cost effects, and "accessibility/agglomeration" effects. The accessibility/agglomeration effects are illustrated using a model of product differentiation, scale economies, and transportation costs for counties in Michigan. Total economic changes are described in terms of national and subnational macroeconomic structures, and illustrated for an application using the REMI regional economic model.

BRIDGING LOCAL AND GLOBAL PERSPECTIVES

It is important to establish a common understanding of how highway investment relates to jobs and economic benefits. Ultimately, the goal of economic development is to improve people's standard of living and quality of life; a major means for achieving this is by raising net income—resulting from wage increases and/or the creation of additional jobs. It is for this latter reason that studies of regional economic impacts tend to focus on jobs and associated income as a central measure of benefits.

Viewed from a regional perspective, the attraction of new income generated by additional jobs may be seen as a benefit regardless of whether the jobs are created by regional business expansion or by businesses moving into the area. From a national or global perspective, however, productivity is the driver that ultimately leads to additional income and business growth. Internal relocations of business are then seen as a benefit only to the extent that there is some element of productivity-induced growth associated with them. It is for this reason that studies of the national implications of transportation investment tend to focus on productivity gains.

There are several aspects of productivity that can be affected by transportation investment. Overall, productivity is defined as the ratio of output per unit of total factor inputs (which include labor, capital, and fuel). Productivity can be affected by many factors, including most notably the level of technology and the quality and capacity of supporting infrastructure, including: 1) education networks, 2) financial networks, and 3) transportation networks. Public spending on infrastructure, insofar as it improves one or more of these factors, can increase productivity and thus also increase wage income.

In addition to providing direct income benefits, greater productivity can also increase a region's competitive advantage. Increased business activity resulting from this regional advantage can therefore also lead to further income growth as jobs are attracted to the region. In the case of productivity improvements that occur equally across the United States, long-term employment growth may not occur unless there is idle labor—either preexisting unemployment or opportunity for expansion in labor force participation. Productivity increases in all regions, however, can still serve to increase national per capita income and wages. Thus, the analysis of productivity impacts can benefit from an integrated approach that considers regional-level competitive effects as well the aggregate national (or global) effects. In this respect, regional and national-level productivity research can improve our understanding of the true magnitude of net real benefits of transportation investments to the economy of an area.

LOCAL AND REGIONAL ECONOMIC EFFECTS OF HIGHWAYS

In order to understand the relevance of productivity measurements, it is first important to understand the ways in which individual highway investments can improve productivity and lead to economic growth at a micro (local business) level. In general, highway system improvements can reduce business costs of *current operations*, or provide new opportunities for production economies associated with *expanded operations*. Either way, greater income and higher levels of business activity can result. These cost impacts can be classified into three broad categories:

1. reduced *travel costs* for serving existing trips;
2. reduced *inventory/logistic costs*; and
3. greater operating *scale and accessibility* economies.

All of these components of business costs contribute to aggregate measures of overall economic productivity. However, each of these components can vary (and be examined separately) when analyzing how specific highway projects affect specific location areas and classes of trips. Thus, analysis of productivity changes caused by these accessibility factors needs to be conducted on a geographically detailed level. The ways in which each of these elements occur and can be measured are discussed below.

Travel Cost Effects

Nearly all major highway projects are justified by some calculation of user cost savings and its economic value. Typically, state and regional highway network models are used to estimate the level of time and cost savings for users—both on a per vehicle basis and for all vehicles anticipated to use the facilities. By applying generally accepted unit values of time savings, it is straightforward to translate those savings into dollar amounts and compare them with the project cost.

It is important to note that some elements of user benefits—for example, reduced travel times for truck shipments and "on-the-clock" business travel—lead directly to cost savings and hence productivity benefits for businesses. Other elements of user benefits (e.g., time savings for personal automobile trips) are important to society and improve "quality of life," although they do not create any additional business productivity. Therefore, any measurement of economic benefits of highway spending that consider productivity benefits without valuing *personal* (*nonbusiness*) *benefits* will underestimate the full social value of highway investment (although correctly value effects on money flow).

Reviews of the wide range of project-level impact studies generally find that the business element of highway project cost savings varies depending on the composition of the local and regional economy, the nature of the highway improvements, and the specific corridor direction (Lewis 1994). For instance, a study of truck shipping patterns in Indiana showed that travel was: 1) predominantly north-south for wood, furniture, and paper products, but 2) predominantly east-west for fabricated metal and machinery products (Black and Palmer 1993). Given that all industry groups had access to the exact same highway network in Indiana, it is reasonable to attribute the differences in shipment directions to the locations of input suppliers and/or product buyers among the relevant industries. The result of these differences in shipment patterns, then, was the finding that a new north-south highway would significantly reduce costs for the first set of industries but yield minimal cost savings for the second set of industries. A parallel type of finding emerged from the study of east-west highway improvement in Wisconsin (Weisbrod and Beckwith 1992).

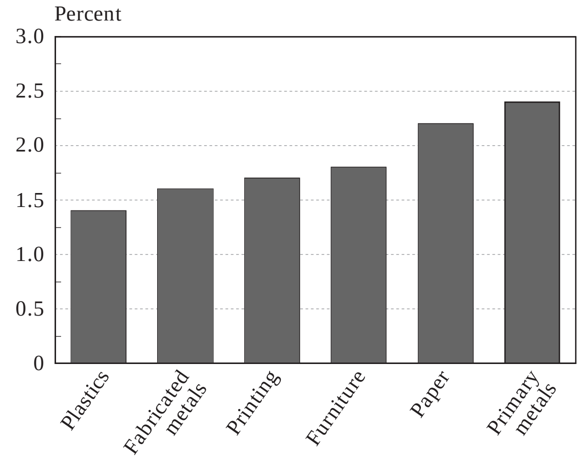
Since benefits for particular industries can differ depending on the highway corridor direction, it follows that estimates of the total value of highway benefits can differ if industry-specific effects are considered in the benefit valuation, in contrast to the traditional approach of benefit valuation (which does not separately consider such effects). To include industry-specific effects, the total value of manufacturing productivity benefits from travel cost savings needs to be defined as the outcome of multiplying four different factors:

1. the extent to which the planned project(s) will reduce shipping or other travel costs for users of the proposed (or improved) highway;
2. the extent to which each different industry has (or will have) patterns of shipping that will make use of that highway;
3. the portion of total business operating cost in each different industry that is affected by road vehicle travel costs; and
4. the size of each different industry in the study area (state, regional, or national economy).

Figure 1 shows the portion of total business costs that are sensitive to highway travel times (factor 3, above). The cost sensitivity is defined as the element of cost associated with the purchase of trucking services and use of in-house motor vehicles (including associated costs of drivers, mechanics, and repair services). The figure shows that these costs vary across industries. The actual pattern of business benefit may be very different, however. If, for instance, we were contemplating a program of improving north-south highway travel in Indiana, then the savings in business costs for fabricated metal manufacturing would be significantly less than if an alternative corridor direction were being considered.

There are three factors affecting the applicability of traditionally measured user travel costs for total benefit valuation, and their relationship to productivity:

FIGURE 1 Highway Transportation as a Percentage of Total Business Costs



Notes: Highway portion of total business costs represents the sum of business costs associated with purchases from the trucking industry, purchases of in-house vehicle fleets, and costs of drivers and mechanics.

Subsequent to this study, the Bureau of Transportation Statistics produced Transportation Satellite Accounts to address this topic (Fang et al. 1998).

Sources: U.S. Department of Commerce, input-output technological tables and industry-occupation matrices.

1. *Difference in business and nonbusiness effects.* Only a portion of user travel costs—that associated with business-related travel—directly affects business productivity.
2. *Difference in short-term user and long-term business effects.* The values of time and cost used in traditional travel demand models are derived from measures of direct effects on driver and passenger travel decisions, which are not necessarily the same as the long-term implications of transportation system speed or reliability changes on business inventories, logistics, scale economies, or manufacturing processes. (The derivation of value of time is reviewed in USDOT OST 1997).
3. *Differences in business responses.* Even if a highway project or policy had the exact same user cost savings impact on every type of business in the affected area, there would still be very different effects on business growth and income generation among the various industries. This occurs because there are differences among industries in their ability to relocate, their ability to expand into broader markets, the nature of market response to lower prices, and

the attractiveness of reinvesting cost savings in local expansion vs. distributing or reinvesting the profits elsewhere.

Logistic Cost Effects

Industrial location is a central strategic decision for manufacturing firms, and location relative to highway connections can represent an important basis for the long-term competitiveness of the production that takes place at a given establishment. For most industries, the cost of highway transportation is small in comparison to labor, capital, and other input costs. The operation of manufacturing in high-wage, high-rent but low-transportation cost locations therefore seems inconsistent with the overall magnitude of transportation costs in production. Only by consideration of total logistics costs, including inventory holding costs, can we fully capture the importance of highway transportation to industrial production.

Total logistics costs include ordering, inventory, and absolute transportation costs (McCann 1996). These costs are borne both for the use of inputs and the supply of final output. Models that evaluate only absolute transportation costs generally conclude that firms using heavy and bulky goods will be located close to the supplier or market. Total logistics cost considerations, however, would lead us to conclude that the value of goods shipped plays a significant role. Since inventory holding costs are a significant part of total production costs, the value of inputs and outputs determine the location of the producer and the wage and rent that the producer is willing to pay at any given location.

Logistics cost considerations are central to freight modal choice. Transportation options such as truck, rail, and ship offer a tradeoff between costs per unit and frequency of trips. While a large shipment of goods from one site to another may provide relatively lower average costs than would occur with smaller amounts, the reduced frequency of shipments may be an overall disadvantage for the firm. Since inventory costs are significant, the production location, transportation mode, and shipment frequency are interconnected decisions faced by manufacturers.

Another area of research on "time-based competition" examines how speed and reliability of product delivery have become increasingly important factors in business growth (Blackburn 1991). The cost savings associated with "just-in-time" processing is one example of the broader set of logistics cost considerations. More generally, producers solve the "logistics cost location production problem" in order to determine the optimal shipment frequency and modal choice (McCann 1993). The cost of acquiring and transporting goods must be balanced with the cost of holding inventory. In the long term, the profit maximizing location of production (and hence also the measure of economic benefit) may differ if logistics costs are added to direct user travel costs.

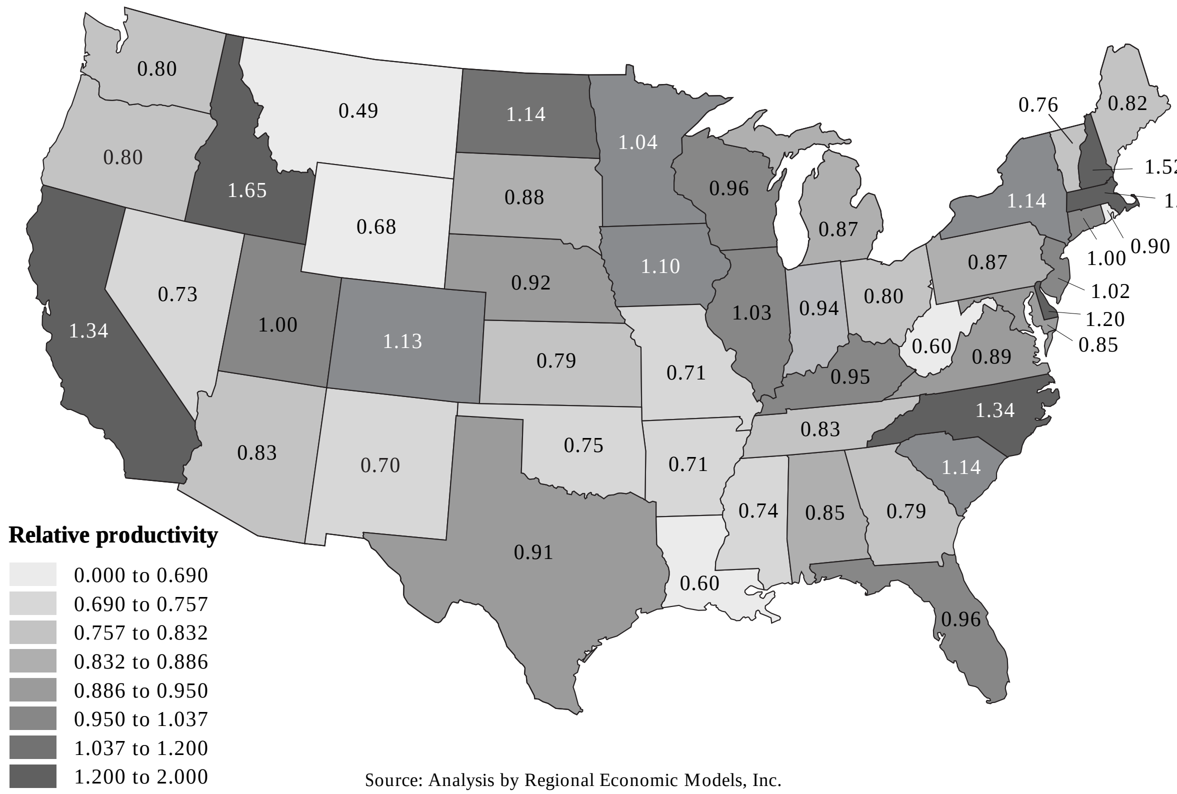
Accessibility and Scale Economy Effects

Highway projects have an important spatial location characteristic, beyond travel cost and logistics cost effects. They can serve to expand the market reach of businesses, allowing businesses an opportunity to realize "economies of scale" by serving broader markets more economically. In addition, highway system improvements can provide businesses with access to a greater variety of specialized labor skills and specialized input products, helping them to become more productive. (While the market expansion and scale economies of some firms may be partially offset by market loss and diseconomies for other firms, normally the net productivity effect of greater system accessibility would still be positive.)

The importance of accessibility and market size as it affects business productivity becomes apparent when we look at the major differences in productivity among U.S. locations, as well as among U.S. industries. Widely examined productivity differences between "core" and "periphery" regions persist, despite long-term trends toward convergence. Of particular interest are regional differences in productivity of industries, which vary both by state and by sector.

Figure 2 illustrates the relative total factor productivity differences by state in the Machinery and Computer industry (SIC 35). The most productive states are those with high-technology centers, such

FIGURE 2 Relative Productivity in Machinery and Computers (SIC 35): 1994



Source: Analysis by Regional Economic Models, Inc.

as the Silicon Valley in California, the region centered on Route 128 in Massachusetts (including Southern New Hampshire), and Research Triangle in North Carolina. Other high-productivity states with major computer industry facilities include Idaho and New York.

On an aggregate basis, disparities in productivity are large. In 1988, output per worker ranged from $44,488 in New Jersey to $26,196 in South Dakota, reflecting factors such as differences in workforce skills, technology investment, transportation access, and the nature of activity within those industries. The agglomeration of economic activities clearly appears to be important, however. Recent studies show that these productivity differences are directly related to the density of employment (Ciccone and Hall 1996). Highly productive states such as California, Illinois, and New York rank in the top 10 for employment density, while states with lower productivity indices such as Maine, Mississippi, and Montana are among the most sparsely populated states.

Density of employment and population is a major determinant of a business' accessibility to specialized inputs, and is also related to high levels of productivity in locations with concentrations of economic activity. Industrial and urban agglomerations provide high levels of productivity, because of the availability of a wider variety of labor skills and product inputs.

The importance of accessibility can be demonstrated by looking at how industrial and urban agglomerations function. These concentrations of economic activity, while highly productive, often involve significant congestion and other costs. Improvements in the transportation system can increase producers' access to specialized inputs and labor. In this way, the productivity benefits would mitigate the negative effects of urbanization. Empirical studies (e.g., McConnell and Schwab 1990) confirm the value of agglomeration economies and accessibility factors through business location preferences.

While highway investments may not greatly change the density of cities, they can help relieve urban congestion, which limits the productivity gains that can be achieved through agglomeration. Highway investments can also affect the pattern of interregional linkages, which can provide accessibility benefits similar to those of agglomeration economies. Recent research on interregional trade within the United States has in fact demonstrated how it is possible to model trade flows within counties and states, and estimate the benefits of accessibility to specialized labor and input products. One example is a recent modeling approach that utilizes estimates of transportation costs and accessibility to differentiated inputs as a basis for explaining wide differences in regional productivity (Treyz and Bumgardner 1996). This approach also provides a means for estimating interregional trade flows and benefits to improved locational accessibility.

MODELING ACCESSIBILITY THROUGH TRADE FLOWS

Much interregional trade and economic geography modeling utilizes estimates of transportation costs and accessibility to differentiated inputs as a basis for explaining wide differences in regional productivity (Krugman 1979, 1995). This type of modeling approach also provides a means for estimating travel flows and benefits associated with differences in locational accessibility. It does this by recognizing that when firms operate under a market structure of monopolistic competition, each produces a slightly differentiated product representing a specific market niche. Scale economies are incorporated in a production function in which output is produced using a fixed labor (overhead) requirement for each firm, a marginal labor requirement for each unit of output that is produced, and transportation costs proportional to output and distance. The demand for specialized consumption and inputs is represented under conditions where each firm faces a downward-sloping demand curve and therefore will set prices at a fixed markup over marginal costs. Similar approaches based on transportation networks and differentiated labor and intermediate inputs are widespread in the regional and urban literature (Ciccone and Hall 1996; Fujita 1989; Krugman 1995).

Relationship of Accessibility to Productivity

While the monopolistic competition model may be a simplification of reality, it does explain not only the trade in differentiated goods and services, but also the productivity benefits of access to these goods and services. Complete specifications of this model may take different forms and have been developed elsewhere. The following equations, however, serve to illustrate the relationship between transportation and productivity that is a common feature of these models.

Let the production of a manufactured good (x) use inputs of capital (k), labor (l), and differentiated services (v). This is specified in the Cobb-Douglas form:

$$x_j = k_j^{\alpha_1} l_j^{\alpha_2} v_j^{1 - \alpha_1 - \alpha_2} \qquad (1)$$

with $0<\alpha_1,\alpha_2<1$. Furthermore, let the service input be defined by following the constant elasticity of substitution (CES) sub-production function:

$$v_j = [\textstyle\sum_h z_{hj}^{(\sigma - 1)/\sigma}]^{\sigma/(\sigma - 1)} . \qquad (2)$$

The service input is a composite of slightly differentiated services (z), where the subscript h represents each variety of service. The elasticity of substitution between varieties is given by σ, with $1 < \sigma < \infty$. While high values (of σ) indicate that different services can be easily substituted for each other, values (of σ) near 1 means that services are not substitutable. In evaluating transportation policy, an inability to substitute between services implies that access to a large number of specialized services is an important productivity determinant.

The total costs of each manufacturer (TC_j) depend on input prices and the use of inputs, given by

$$TC_j = c_j k_j + w_j l_j + \textstyle\sum_{hj} p_{hj} z_{hj} \qquad (3)$$

where c is the cost of capital, w is the wage rate, and p_{hj} is the price of each service in j, including transportation costs. If reduced transportation costs result in a lower price for services in location j, then manufacturers can produce the same level of output at a lower cost. Since manufacturers seek to maximize profits, a reduction in transportation costs for services would result in an increase in the productivity of labor and capital.

The demand for services can be derived by assuming profit-maximizing behavior for manufacturers. The demand function for services determines service trade, shown as:

$$z_{ij} = \frac{(1 - \alpha_1 - \alpha_2)\lambda_i X_j}{p_{ij}^{\sigma} \sum_i \lambda_i \, p_{ij}^{1-\sigma}} \quad (4)$$

where z_{ij} is exports of all services h in location i to location j, $(1 - \alpha_1 - \alpha_2)$ is the total use of the service composite, λ_i is the proportion of all services in the economy that are produced in location i, X_j is the total production of manufacturers in location j, and p_{ij} is the price in location j of a service that is produced in location i, including transportation costs. Locations with a large variety of services, such as cities, have correspondingly high values of λ and therefore export more services. The price competition of each location i with other locations is incorporated in the denominator. If transportation costs decline between locations i and j, this would result in a reduced price p_{ij}, and an increase in exports from i to j, z_{ij}. Thus, reducing transportation costs results in both more trade and higher productivity.

Application of Accessibility Modeling

The above type of model can be solved for manufacturing or nonmanufacturing industries. The specific method shown in this paper is appropriate for service industries, where reliable, comprehensive transportation data is unavailable. (The U.S. Census of Transportation covers only shipments of manufacturing and natural resource products.) An approach for estimating trade flows in service industries is vital, since this type of industry accounts for a majority of U.S. employment.

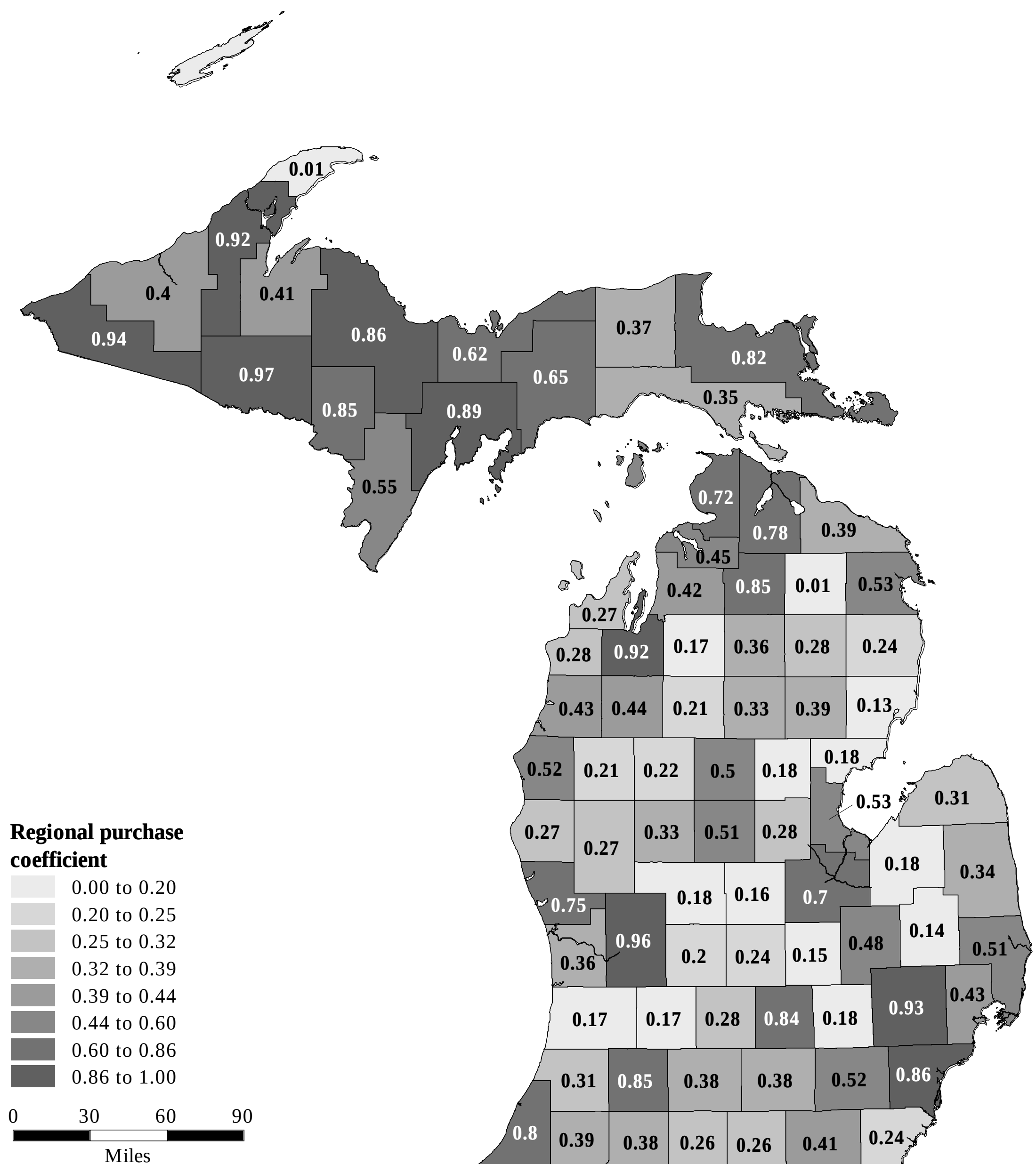
The basic inputs into the model are demand and supply by county, factor costs (e.g., the wage rate), and distances between counties. The elasticity of demand is calculated based on an econometrically estimated production function using U.S. Census of Services data. A calibration technique is used to estimate the transaction cost of distance, such that excess profits/losses (i.e., prices different from unity) are minimized.

"Regional purchase coefficient" (RPC) estimates from the model calibration for legal services in Michigan are shown in figure 3. The RPC is the proportion of local demand supplied locally, a summary statistic calculated from the complete 83-county by 83-county trade flow matrix. This proportion is relatively high in large, urban counties, such as the central counties in the Detroit area. In dense locations, consumers and producers are able to satisfy their needs for specialized legal services within the county. Other areas that supply a high proportion of their own demand include counties in the upper peninsula, in which distances are large and transportation costs prohibitive. RPCs are lowest in rural counties that have relatively easy access to large cities. Less than 25% of local demand is supplied locally in many of the counties surrounding Grand Rapids, Lansing, and Detroit. The model, therefore, shows a type of urban hierarchy, in which large cities provide specialized services that supply smaller cities, towns, and suburbs.

To illustrate the trade flows that occur among counties, the demand and supply interactions between Ingham county and the rest of Michigan are shown in figures 4 and 5. Ingham county is located in south central Michigan, and covers most of the urbanized area of the state capitol, Lansing. Figure 4 shows the location of legal service production that is purchased in Ingham county. The majority of legal services are supplied from the county itself (as shown in the RPC calculation above). Oakland and Wayne (Detroit Region) counties supply well over 5% of Ingham county's demand, since more specialized legal services are available from these locations. Thus, they are able to sell more legal services to Ingham county than are supplied by adjacent suburban counties.

Figure 5 shows the distribution of sales of legal services produced by Ingham county. Most of these services are sold within the county, yet about 15% of the output goes to adjacent and nearby suburban counties. Despite high levels of demand in Oakland and Wayne counties, they purchase less than 1% of Ingham county's output of legal services. The basis of this trade relationship is that Detroit region counties are able to obtain a variety of legal services from within their metropolitan area. This example illustrates how it is possible to model flows of goods and services within states based on accessibility measures. This approach also provides a basis for identifying and measuring the value of accessibility improvements to industries. Of course, the value of this approach (and need to apply it) for transportation investment

FIGURE 3 Michigan Counties: Regional Purchase Coefficient for Legal Services



Source: Analysis by Regional Economic Models, Inc.

decisionmaking will depend on the extent to which proposed system improvements are expected to significantly affect intercity (or intercounty) linkages in the network.

TOTAL PRODUCTIVITY BENEFITS OF HIGHWAY INVESTMENT

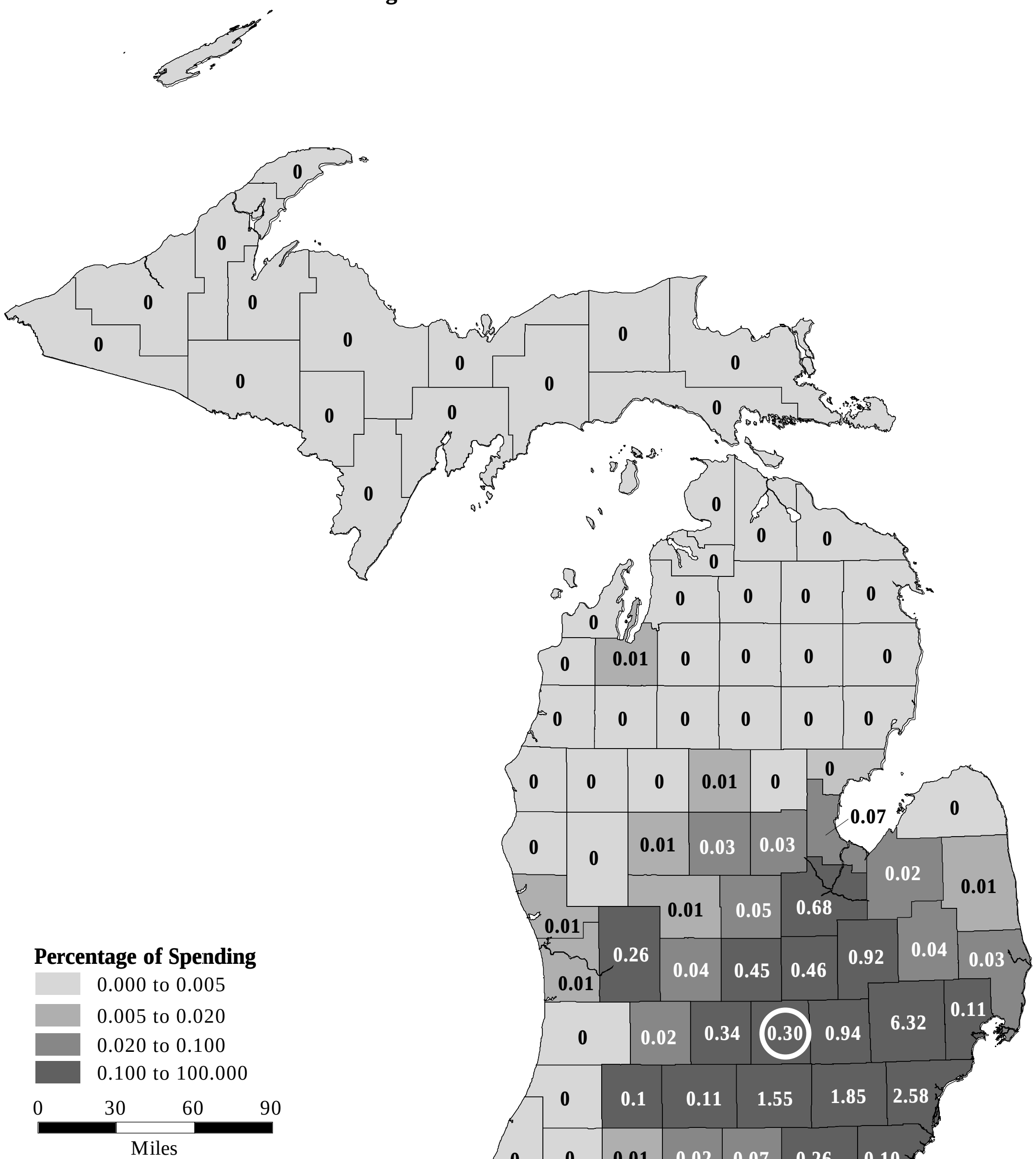
Overview of Productivity Research

The macroeconomic approach for assessing the productivity impacts of transportation investments is to estimate production (or cost) functions, which represent the causal relationship of public infrastructure ("capital stock") to changes in business output (or costs). The general form of the statistical models for production functions is as follows:

Output = function of the quantity and productivity of the various input factors (which include employment, private capital investment, and public infrastructure investment).

A number of reports have documented the relationship between rising business output levels over time and infrastructure spending levels (predomi-

FIGURE 4 Ingham County: Percentage of Legal Services Spending Flowing to Suppliers Located Elsewhere in Michigan

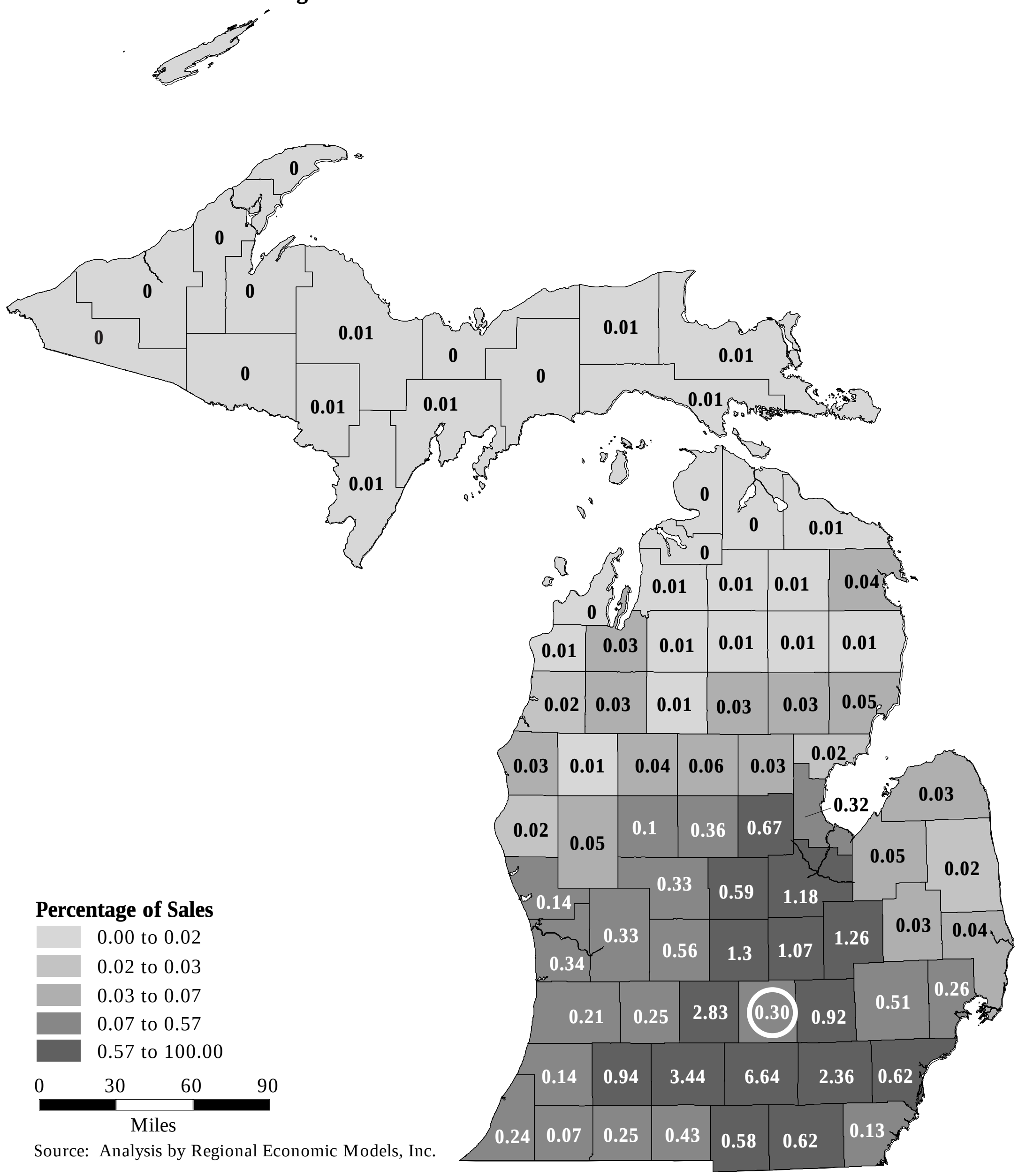


Source: Analysis by Regional Economic Models, Inc.

nantly highway capital stocks) over that same period of time (USDOT BTS 1995; Madrick 1996; Sturm et al. 1997). These studies were conducted at national, state, and metropolitan area geographic levels. Some addressed overall public infrastructure spending, while others focused on transportation investment, or just highway investment.

In general, the consensus findings to date are that there is a positive relationship of increasing business output levels to capital spending on infrastructure, although the impacts span a range above, at, and below the private return on capital. The relationship of [% Δ output / % Δ public capital] is most often found to be in the range of 0.2–0.4 at the national level, around 0.15 at the regional or state levels, and as low as 0.04 at the metropolitan levels (Aschauer 1989; Munnel 1990; Duffy-Deno and Eberts 1991; Toen-Gout and Van Sinderen 1994; Nadiri and Mamuneas 1996). The economic effect of transportation infrastructure

FIGURE 5 Ingham County: Percentage of Legal Services Sales from Purchasers Located Elsewhere in Michigan



Source: Analysis by Regional Economic Models, Inc.

spending appears to be lower for smaller geographic areas, because many of the broad network interconnection benefits to businesses are outside of these areas. The net sum of these effects is, however, reflected in the national measures of productivity.

Uses and Limitations of Productivity Research

By definition, the measurement of aggregate productivity effects reflects net overall changes in business costs and output levels. Additionally, it shows the net result of all positive and negative factors affecting productivity, including existing trip costs, inventory costs, scale economies, and accessibility cost factors. This type of research may be of significant potential use as an indicator of the value of public spending on transportation infrastructure (capital stock), and as a tool for identifying the optimum level of public spending on infrastructure given the magnitude of the current economy.

Of course, different kinds of transportation system improvements will have a range of impacts on the overall cost of business output in each industry. Transportation infrastructure investments can also lead to different marginal benefits for industries and geographic areas. The situation is even more complicated: highway infrastructure investments directly affect business costs and scale efficiencies, and can indirectly affect population inflow/outflow patterns, labor markets, and wage levels, all of which also affect demand for products and thus business output levels, jobs, and income generated.

There are also three significant limitations associated with this research, when used in isolation:

1. *Aggregate level of analyses.* There is currently only a limited base of information on how productivity effects of transportation investment can differ by specific combinations of mode, industry, and region. Even more important, the research has necessarily focused on overall transportation or highway capital spending, without distinguishing how productivity effects can differ depending on the type of highway improvement, intensity of highway use, or level of congestion. (Recent unpublished research by Jones et al. at Oak Ridge National Laboratory and Eberts at Upjohn Institute applies measures of highway accessibility rather than highway capital stock as the explanatory factor in productivity studies.)
2. *Treatment of changes over time.* The research to date has necessarily been retrospective, examining past trends. The marginal impact of future highway spending may be different, as business technologies and facility location patterns continue to evolve, as intensities of use and congestion grow on significant urban roads and inter-urban links, and as the mix of future projects changes.
3. *Nonvaluation of individual and consumer impacts.* Estimates of aggregate productivity impacts reflect producer cost and output changes, but generally place no value on improvements in nonbusiness travel affecting consumer (shopping) activities and personal (social and recreation) time. They also place no value on environmental benefits, which are similarly not included in the national income and product accounts.

Overall, then, we cannot be sure that the *marginal* benefits to productivity associated with current and *future* projects will be the same as the *average* benefits to productivity associated with *past* highway spending.

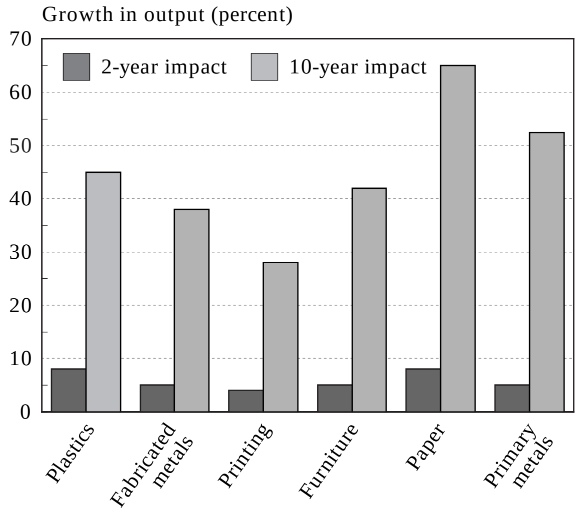
MEASURING TOTAL ECONOMIC EFFECTS

In order to measure the total economic implications of transportation infrastructure investments, the project-specific effects described in the preceding section need to be taken into consideration. These project effects in themselves, however, do not represent a full economic analysis. Changes in costs and productivity affecting an industry at the project level have broader economic repercussions for the locality or region. To show total U.S. macroeconomic effects of transportation investments, the national labor force availability also needs to be considered when calculating regional effects.

Thus, a bottom-up approach starting at the project-specific level can be applied to represent national macroeconomic effects of transportation investments. Accessibility and other direct effects are important determinants of regional macroeconomic changes; the combination of regional changes determines national economic effects, subject to national labor force and other constraints. Total national economic effects can therefore be calculated from specific transportation investment information.

The direct project-level changes in regional productivity and cost competitiveness can have implications for longer term forecasts of regional economic growth. Such forecasts can be generated by regional simulation and forecasting models that reflect inter-industry linkages and their effects over time on trade, production costs, wage rates, and other productivity factors. A few examples of the application of regional economic simulation models to evaluate major transportation improvements are studies of the Netherlands (Evers et al. 1987) and Wisconsin (Weisbrod and Beckwith 1992). In this paper, we provide an example for the REMI model for Indiana. The application of such models is illustrated in figure 6, which shows how a constant 10% reduction in highway transportation costs would affect economic model forecasts of industry growth.

FIGURE 6 Forecast of Business Growth Due to a 10% Reduction in Highway Travel Cost



Source: REMI (Regional Economic Models, Inc.) simulation model for Indiana.

In this example, the cost reductions increase employment through key interactions in the economy. These economic linkages are captured in the structure of the economic model. The highway cost decrease has the direct effect of reducing production costs. Lower production costs increase business activity in the region, as export and local market shares increase for the affected industries. Output increases to supply internal and external demand, and more workers are hired to produce the additional output. As employment increases, wage rates are driven up. Workers migrate into the region, lured by the additional employment opportunities and higher wages, and their additional spending has a further positive effect on economic activity. All variables in the economy are interrelated, and are solved simultaneously by the economic model.

By comparing figure 6 with figure 1, it becomes apparent that the ultimate effects of highway improvements on business output (and hence income creation) may not necessarily reflect the pattern of highway impact on total business costs. These results also show how long-term and short-term impacts on business growth can be different. Therefore, it becomes important to understand the competitive context of industries and locations affected by highway improvements. Any estimation of economic effects that simply equates cost reduction impacts with business growth impacts, ignoring demand response factors, may be subject to substantial error.

Furthermore, the multiregional U.S. model configuration can be used if major transportation investment results in a fiscal stimulus for the entire country. In that case, an increase in overall employment can cause the Federal Reserve to raise interest rates, in order to maintain the labor force utilization at the non-accelerating inflation rate of unemployment. For example, direct transportation investments for a national highway development program can be input separately for each affected region into a multiregional U.S. model. Then, the model can be solved, accounting for economic changes within each region, competitive effects among regions, and national labor force constraints. Thus, the total national economic effect of specific transportation projects can be obtained using a bottom-up approach, where direct changes on a geographically disaggregate level determine variations in state or local economic activity, which sum up to national-level total economic changes (Treyz and Treyz 1996).

CONCLUSION: SELECTING APPROPRIATE ECONOMIC IMPACT MEASURES

Highway improvements can affect overall transportation costs for businesses, including traveling costs, logistic and scheduling costs, and other costs related to supplier accessibility or market scale effects. A variety of analysis methods can be used to assess the current or past magnitude of these overall costs. The challenge for highway planning, however, is to adequately reflect the magnitude of business cost savings and productivity increases when estimating the benefits of planned new highway improvements. Such benefits can be much more than just the simple time savings due to faster trips, as estimated from a network model. This is especially true if the highway improvements provide affected businesses with new opportunities for logistic efficiencies, scale economies, or broader supplier access.

Key Findings

It is important for local, state, and federal decisionmakers to identify the appropriate level of spending for highway infrastructure and the appropriate projects to maximize social benefits. Traditional methods used to value transportation user benefits and economic benefits for specific highway projects, based on simple calculations of savings in travel time and vehicle operating expense, can understate total project benefits by missing other important aspects of productivity enhancement. Current research on productivity is at a sufficiently aggregate level so as to miss potentially important location-specific aspects and congestion relief elements of needs for highway system development, which may affect future benefits from highway improvements (in ways different from past benefits of highway investment). Methods are emerging for identifying and assessing accessibility market and logistic benefits of highways, and they may be applicable for local highway studies as well as for broader government policy analyses.

While it is not possible or practical to engage in sophisticated modeling for all of the elements of economic impact for every highway project, it is nevertheless important and possible to recognize the breadth and nature of potential impacts during the decisionmaking process.

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