

Bottlenecks and Flexibility: Key Concepts for Identifying Economic Development Impacts of Transportation Services

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Today, because of economic activity restructuring by function rather than sector, there is a need to reconsider the relationship between transportation and economic development. Most current analyses are static and do not consider capital stock in place, level and quality of service, and demand for transportation. Transportation services can be viewed as intermediate goods in the private production and consumption processes of firms and individuals. As is the case with other intermediate goods, different industries will demand different types, levels, and qualities. When adequate services are not available in a timely manner, bottlenecks arise. Bottlenecks are not limited to congestion on urban highways during peak hours; therefore, policy responses to them are not limited to simply building more highways. From this perspective, the transportation system can either aid or hinder public and private firms' production functions either directly or by complementing private inputs. Transportation networks also contribute to the attractiveness of a region. An analysis of linkages between transportation and economic development under such circumstances would begin by identifying the role and potential of various sectors and functions in the economy. Next, the importance of transportation services for the most important sectors and functions in the economy would have to be identified. This method would require a highly disaggregated analysis of the role of transportation services in the location of relevant industries and services that are now differentiated by function rather than by sector. Such an analysis can help identify situations where the lack of specific transportation services becomes a bottleneck to economic development. However, this analysis is a necessary first step toward a cost-effective policy for economic development, but is not sufficient for formulating or evaluating a transportation policy's contribution to economic development. To make this additional step, analyzing the attributes of both transportation services and prospective users is necessary. Specifically, the concentration ratios of users and operators need to be considered, as well as their footlooseness. These flexibility considerations are important to reduce the risk of long-term public investments being made on the basis of an ephemeral conjunction of circumstances in the rapidly changing economic scene.

In fiscal year 1987, federal, state, and local governments spent \$66.2 billion on transportation investment, operation, and maintenance—about \$272 for every man, woman, and child in the United States. (Transportation includes highways, streets, roads, bridges, waterways, airports, and airways.) Eighty percent of these funds were spent on the nation's network of highways, streets, roads, and bridges. However, spending for system improvement has fallen short of the need in high-

growth urban and suburban areas and, as a result, congestion was a problem on nearly half of the nation's Interstate urban highway system. This concern led the National Council on Public Works Improvement to conclude that the nation's infrastructure is insufficient to meet the demand of future economic growth and development (1).

Several studies suggest using standard or determined needs-based approaches or comprehensive planning approaches for addressing perceived transportation shortfalls (2,3). More recently, the National Council on Public Works Improvement (1) noted that the focus of such analysis should be on transportation services rather than engineering standards. Still, these approaches do not answer questions regarding ways to determine which transportation policies have the most effect on economic development and how transportation policies should be related to different types of economic development.

In the current environment of limited fiscal resources, the important policy question is how federal, state, and local government officials can use such limited resources effectively to provide the highest level and quality of transportation services. One element to consider in setting spending priorities to obtain maximum benefits from limited resources is the linkages between transportation and economic development.

Historically, transportation has been a necessary ingredient in almost every aspect of economic development. Transportation made possible ready access to resources, specialization of industry, commercialization of agriculture, and the rise of trade centers (4,5). The increasing ubiquity of transportation systems (particularly highways) in the United States led several influential analysts to suggest that the importance of transportation for economic development was declining (6,7). Because the U.S. economy was based on industrial production at the time of these analyses, most focused on the relationships between transportation systems and industry.

In recent years, the U.S. economy went through a series of crises and restructuring from such forces as technological change (sometimes termed the "information revolution") and increasing international competition and, as a result, many industries changed their production processes by substituting capital for labor as well as changing the location of their activities (8,9). Most of the job growth since 1970 has been in advanced services (primarily production services), education, and health (10,11). Both the service and industrial sectors of the economy were also affected by the shift in federal expenditures from welfare to defense (12). The outcome was a restructuring to a new service-oriented, postindustrial economy and, thus, to a new economic geography (13,14).

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Economic restructuring affects the demand and usage patterns of the transportation infrastructure (15). These effects, combined with the aging of transportation facilities, lead to increased maintenance costs. Along with changes in the financing and administration of transportation services, they have led to growing concern regarding the ability to maintain the existing infrastructure and to finance needed capital improvements (1,15). Because changes in economic structure and geography affect both the demand for transportation services and the ability to maintain and to improve transportation infrastructure, there is a need today to reconsider the relationship between transportation and economic development in the United States in the context of the emerging economic geography.

Traditionally, analyses of linkages between transportation and economic development focus on the multiplier effect of transportation investments and the impact of such investments on accessibility and land values. Most of these analyses are static and do not consider capital stock in place, the level and quality of services being provided, and the demand for transportation services. Thus, existing empirical evidence quantifying the linkages between transportation and economic development is mostly derived from cross-sectional analyses, and results in findings that are mixed and inconclusive. Such inconclusive findings reflect, in part, a lack of consideration of differences between places and across sectors in the economic development effects of transportation (16). As a result, current knowledge does not provide sufficient guidance for policy makers as to the type and location for transportation services needed to enhance their region's economic position. Today, there is no generally accepted framework for explaining why, where, and how various transportation services are linked to economic development in the context of the new postindustrial economy.

First, some initial steps toward developing a framework will be discussed that would enable researchers and policy makers to analyze the possible roles and potential of various transportation services for economic development in different settings within the new economy. Next, the importance of the private-goods nature of transportation services will be explored from the perspective of the individual firm. Last, a first step will be taken toward the formulation of a conceptual framework for analyzing linkages between the demand for transportation services and economic development from a policy maker's (federal, state, or local) perspective by reviewing economic restructuring and identifying its implication for transportation demand. In this context, two central concepts will be introduced for such a framework: bottlenecks and flexibility.

THE CHANGING FACE OF THE ECONOMY—A REVIEW

The economic restructuring taking place in the United States in recent years can be described by four transformations occurring concurrently, as follows:

1. Changes in intrafirm production processes;
2. Changes in the structure of the industrial sector (including both institutional structure and types of products being produced);

3. Shifts in the location of various economic activities; and
4. The increasing importance of the service sector in the economy.

All of these transformations are driven to some extent by the revolution in information technology and each has implications for the future demand for transportation services (13,17,18).

Changes in Nature of Production Processes

Since the industrial revolution, the primary direction of change in production processes has been toward mass production. Underlying this trend was a stable demand for undifferentiated products, resulting in the epitome of standardized production processes, the Ford-type assembly line.

However, in recent years there has been increasing economic uncertainty because of volatile energy prices and flexible exchange and interest rates combined with increasing international competition, much of it from countries with lower wages but high technological capabilities. This uncertainty has led to a need for differentiated production that would allow differences in products in response to changing preferences of various market segments (19). Many firms have adopted new techniques that allow rapid adaptation of production to changes in demand through the production of various goods on the same production line. These new techniques require, in addition to multiuse machines, complex task programming, higher skills, ability to receive diverse inputs just in time, and close relationships with markets.

In a recent study of the changing economy and its implications for future infrastructure use, the U.S. Department of Commerce observed that (20, p. 3.7)

The computer integrated flexible manufacturing system will break the hold that the search for economies of scale has had on manufacturing up to now. Big scale, single purpose, long production run plants will be a thing of the past.

The Commerce report continues by arguing that because of these new computer-integrated flexible manufacturing systems, production would become much more of a local matter with plants being able to make a batch of differentiated products almost on demand. These manufacturing centers would have the capability of manufacturing nearly an infinite variety of classes of products. Major cities would tend to become ringed by companies operating these computer-integrated flexible manufacturing systems.

Changes in Industrial Structure

The economic dislocations of the 1970s and early 1980s that were characterized by large layoffs of workers in basic industries can be viewed, in part, as the manifestation of a double transformation of the industrial sector (8). First, the institutional structure of the sector evolved from industrial firms to multinational corporations that often control a large number of spatially dispersed manufacturing and nonmanufacturing operations.

The emergence of these multinational corporations has contributed to the growing integration of the U.S. and world

economies, resulting in increased interdependence. Over the last 30 years, real merchandise imports into the United States have increased from about 3 percent of gross national product to over 11 percent, whereas merchandise exports have increased from about 3.5 to 6.5 percent. In such an interdependent world, international trade would influence the structure of U.S. industry through the remainder of this century as domestic firms respond to the challenges of the international marketplace. Thus, international trade would influence the future demand for domestic infrastructure services, including transportation.

Second, the composition of the industrial sector changed. New industries emerged as a result of the development of new information technologies at the same time that many basic industries in the United States declined. In contrast to the basic industries on which the U.S. economy was based for the last century, the new industries are characterized by the knowledge-intensity of their products and have research and development (R&D) as a major input in their production processes.

These industries, best characterized by the semiconductor, biotechnology, and computer industries, often have a bifurcated labor force that includes a large percentage of highly skilled engineers and researchers, as well as unskilled assembly workers (21,22). Firm location decisions for these industries must be sensitive to the availability of housing for both segments of the labor force. Any mismatch between the location of housing and employment would add stress on the demand for transportation services, as has been evident in Silicon Valley (22).

In many cases, the physical inputs and outputs of these sectors are small, yet highly valuable. As documented by the U.S. Department of Commerce (20), contracting sectors in the nation's economy tend to be relatively material-intensive and require large amounts of physical inputs to produce large amounts of physical outputs. On the other hand, the expanding industries tend to be less material-intensive. The report concludes that as a result of these differences, "... there is evidence supporting the notion that future economic growth will require less in the way of transportation of heavy industrial raw materials per unit of output" (20, p. 127). This shift from heavier inputs and outputs to lighter, high-value products has important implications for the relative use of competing transportation modes in the future.

Changes in Location of Economic Activities

Because of advances in telecommunications and computers, firms have been able to spatially separate different parts of their production processes (9,13,18). Thus, management, R&D, and various production phases can each be located at the best places for that function. For example, specialized production services could be located near management headquarters, whereas other services could be located elsewhere. This differentiation is increasingly taking on international dimensions and is not limited to industry but is just as pertinent for services as well. The result of the intrasectoral spatial differentiation of functions has been that places increasingly specialize in function, rather than in sector (10,23).

Before restructuring, regions were differentiated by the dominant sector driving their growth. For example, Detroit was dominated by the automobile industry whereas Pittsburgh

was the center of steel production. In each region, the most important source of jobs was the production within the dominant sector. Today, certain areas specialize and compete over production, whereas others specialize in management or R&D. Molotch and Logan (24), for example, identify five types of U.S. cities that are today differentiated by their role in the nation's economy—headquarter cities, innovation centers, module production places, migration entreports, and retirement centers.

Because of this trend toward multilocal and multinational firms, the amount of economic activity involving intra-firm transactions has increased. Market mechanisms are thus supplanted by intrafirm bureaucracies located in a few metropolitan centers, the headquarter cities. These bureaucracies require a large number of specialized producer services that agglomerate around them (10). One activity that increases the attraction of major financial centers for the location of corporate headquarters is the manipulation of corporate stock, sometimes to merge firms (whether in a friendly or unfriendly manner). This increasing paper entrepreneurialism identified by Reich (25) requires much face-to-face interaction.

R&D has a number of geographic patterns (26). Some R&D activity is directly related to corporate decision making and tends to locate near other production services in the headquarter city, whereas in other cases R&D may be linked directly to plant operations. The pure type of R&D, at the top of the product cycle, is often footloose so that agglomeration benefits from universities, public research institutions (military as well as civilian), and other private R&D units may be very important in its location (21,22).

Most places lack special qualities that would make them attractive for headquarters, R&D, or retirement centers so they compete for routine production tasks. These tasks are not limited to manufacturing because government and private services have many routinized functions requiring information processing.

Yet, as Saxenian (22) shows for the semiconductor industry, there is also a hierarchy of routine production tasks. Some require higher levels of skill than others and have different impacts on their environments. Thus, better-suited places may attract more desirable production activities, whereas less-endowed places may attract functions not desired elsewhere (such as waste handling). Generally, the lower the production function in terms of skills, the greater the importance of cost in determining locational desirability. For this reason, many of the most routinized low-skill functions have been shifted to low-cost developing countries.

In addition to the changes in national location patterns of economic activities, the intraregional location patterns of various activities have shifted. In particular, many activities not requiring extensive face-to-face contacts shifted to the suburbs or ex-urban locations. Thus, much of the differentiation of functions described at the national level is also reflected at the regional level. Although management functions remain in the central business district as well as associated services (such as financial and legal services), R&D and production functions, as well as routinized services (such as data processing) decentralize. Furthermore, some processes decentralize to the employee's home, resulting in so-called "telecommuting."

The demand for transportation services will be affected by these shifts, as different production activities would require

a different type, level, and quality of transportation service. Also, as economic activities become less tied to central cities, traditional transportation networks that serve downtown areas become less adequate.

Rise of the Service Economy

Most of the jobs created since 1970 have been in the service sector (10,11). Two reasons for the increase in producer services previously discussed were the need to manipulate corporate stock and the growing complexity of managing multilocal and multinational firms. A third reason is the increasing importance of functions such as marketing, product development, and finance in the new international competitive environment.

Services changed not only in terms of employment levels but also in terms of the nature of the services and the ways they are provided. For example, many routinized functions have been automated such as many routine bank transactions and most data processing. Services also became more specialized by focusing on the needs of specific market segments, much like the industrial sector. These changes in the nature of the service sector had important implications for the labor and locational requirements of various service functions. The exact nature of these implications, however, is highly sensitive to the exact type, or combination, of services provided (27).

From a national perspective, other types of services, such as retailing and distributive services (transportation, communication, wholesaling, and utilities) did not grow as fast as the rest of the economy. In certain areas, however, where tourism or retirements have become a major component of the local economic base, such services have grown dramatically. The locational and labor needs of these services are naturally different from those of producer or nonprofit (education, health, and government) services. Specifically, these services require a large unskilled or semiskilled labor force at the place of service provision.

TRANSPORTATION IMPLICATIONS OF ECONOMIC RESTRUCTURING

Because of the spatial differentiation of economic activity by function rather than sector and other structural changes taking place within the U.S. economy, locational considerations have become increasingly important in understanding economic development patterns. Thus, the transportation implications of economic restructuring also have to be analyzed within the context of locational considerations by economic functions rather than by sectors.

In this view, public and private transportation investments, including expenditures on operation and maintenance, interact to produce transportation services, i.e., mobility. The level and quality of service is a function of both the condition and use of the capital stock in place and the flow of new investment and operation and maintenance expenditures. These transportation services become intermediate goods in the private production and consumption processes of firms and individuals.

As is the case with other intermediate goods, different industries will demand different types, levels, and qualities of transportation services (28). When adequate services for any particular industry or firm are not available in a timely manner, bottlenecks arise. Bottlenecks are not limited to congestion on urban highways during peak hours; therefore, policy responses to them are not limited to simply building more highways.

From this perspective, transportation systems relate to economic development in two ways. First, they serve as an input in public and private firms' production functions either aiding production directly or complementing private inputs, thereby making them more productive. Similarly, transportation systems provide services that are inputs into private consumption and recreation activities. Second, transportation networks contribute to making a region relatively more attractive, thereby encouraging the location of firms and families.

The major concern for location of production activities, especially in the latter parts of the product cycle, is cost minimization. Cost minimization has two implications for transportation demand. First, the system has to provide good accessibility for the labor force. A congested transportation system may drive some production activities away by increasing labor cost as was demonstrated in the case of the semiconductor industry in Silicon Valley. As housing prices in the northern part of the valley soared, workers in production processes had to commute longer distances, resulting in traffic congestion. Eventually, most production functions left the area to reduce labor costs (22), a portion of which can be accounted for by commuting time.

Second, a transportation system has to provide low-cost movement of inputs and outputs. Because of changes in production processes that eliminated most inventories, deliveries are required on a timely basis. That is, all inputs and outputs have to move in and out of a production facility just at the time they are needed or completed. The total cost of transportation for production is thus a function of both the direct pecuniary cost and the timeliness of shipments.

At a time of intermodal freight transportation and overnight deliveries, small differences in transportation services may have important implications for the relative attractiveness of a place for the location of a particular type of production facility. For example, many high-technology industries have small, high-value products that make air freight transportation increasingly important (29). As a result, over time, there may need to be a reallocation of resources away from highways, which currently receive about 80 percent of governmental expenditures on transportation, to airports and airways.

Many studies indicate that a major consideration in the location of R&D facilities is the availability of a highly skilled, research-oriented labor force (17). The location of R&D facilities would thus be a function of the locational preferences of such a labor force (21). Although there is still much to be learned about their locational preferences, several studies indicate that access to other researchers and research centers, as well as quality-of-life considerations, play an important role in the preferences of this group. The transportation system must make a region attractive for such manpower by permitting access to other research institutions, primarily by air (29). In addition, the transportation system has to allow a high level of living usually through good access to services in an environmentally

sensitive manner. This characteristic accounts for the somewhat peculiar transportation preferences of high-technology industries reported in the literature (28).

A headquarter city functions as a locus of control over widespread operations and a center for interaction between firms (both face-to-face and remote). These cities require good air transportation and telecommunication for both control purposes and interactions between top executives (18). For headquarter cities, employee access appears to be a minor consideration in central management locational decisions resulting in highly congested cities' retaining their national and world economic position (30).

So far, the previous discussion focused on production activities associated with industrial firms; however, much of the current economy is oriented toward the service sectors. Most growing firms in the service sectors, including finance, real estate, business, and professional services, are relatively concentrated in central cities with many of their employees commuting from the suburbs (11). The main pull of central cities for such firms seems to be agglomeration economies (31). Yet, there is little empirical research regarding locational considerations of various service activities (both sectors and functions within sectors) and until such research is undertaken, the role of transportation in this increasingly important sector cannot be analyzed systematically.

In addition, the previous discussion outlining an approach for analyzing the implications of economic restructuring on the role of transportation in economic development was focused on the local or regional level. Clearly, the accumulation of these implications has ramifications at the national level. For example, the increase in demand for air transportation from production R&D and headquarter functions, noted by Toft and Mahmassani (29), may partly explain differences between the problems facing the air transportation system (congestion) and the maritime system (excess supply).

A highly differentiated analysis of the demand for transportation services by various agents and functions in the economy is needed. Such an analysis must consider the role of transportation services in the private production and consumption process. However, because of the large number of existing and potential functions and economic agents in a region, there is a need for a framework identifying which analyses should be undertaken and which of the possible improvements may be most beneficial.

BOTTLENECKS AND FLEXIBILITY

In order to identify situations where transportation services are important from an economic development perspective, a determination is made on when and where transportation services impinge on the location of economic activities. One condition impinging on economic activity occurs when the demand for a certain transportation service outstrips the supply of that service for a specific place or region, type of activity, or time period. This condition is a bottleneck and would be evident by the transportation service having a high shadow price in the location considerations of a specific economic activity.

The concept of bottlenecks is not new. Transportation has long been an enabling, but insufficient, factor for economic

development (4,7). The historical contribution of transportation to economic development essentially has been the removal of bottlenecks by providing access and alleviating congestion, thus allowing the economy to maximize its comparative advantages. In the past, however, such bottlenecks were seen as static and solely in the context of industrial development or resource utilization. Thus, once accessibility for freight had been assured and improved the bottleneck was seen as alleviated.

Today, in the context of economic restructuring such a view is untenable because bottlenecks are constantly emerging and changing as a function of changes in the economy. Furthermore, different places competing for different types of economic development face different types of bottlenecks. Thus, the notion of bottlenecks changes when they are viewed in the context of different types of transportation services being provided at different levels and qualities to different sectors.

The nature of bottlenecks would be a function of the economic activity in question. For example, in the case of production processes, relatively low levels of road congestion, freight backups, or unreliability of deliveries (in terms of timeliness) may prove to be important bottlenecks. In areas competing for R&D facilities, the lack of appropriate air travel services or the presence of high levels of transportation-related pollution or environmentally insensitive development may prove to be bottlenecks. Similar factors may be bottlenecks also for the development of tourist services.

Identifying bottlenecks would require detailed surveys of the locational considerations of various activities (both industrial and services) such as those conducted by Hummon et al. (28) for high-technology industries. However, such surveys would also have to be differentiated by functions within sectors because the major problem in bottlenecks identification may be which activities (sectors and functions) to survey. Addressing this problem may require a preliminary analysis identifying the potential sectors and functions that may locate in the area. Such an analysis would have to take into account the larger regional, national, and global restructuring processes. The relationships leading to the identification of bottlenecks are shown in Figure 1.

The realization that the economy is constantly changing, in what seems to be an accelerating pace, leads to a second concept that should be an integral part of any framework for analyzing the role of transportation services in the emerging highly dynamic economy. That concept of flexibility has two facets.

First, because demand for transportation services changes continually, but in manners sometimes difficult to predict, transportation services have to adapt. Thus, the first facet of flexibility is the ability of an element in a transportation system to adapt to changing types and levels of demand. The lower the cost of changing the attributes of service provided (in terms of volume, schedule, commodities, and needed inputs) the more flexible is that element in the system. In an evaluation of various policy options, the ability of investments to adapt to changing economic conditions should be included.

One element affecting the fluctuations in demand for a service is the diversity of its users and operators. If the type and number of users or operators are highly concentrated, changes in demand patterns of users or operation decisions by operators may have major effects on demand for the trans-

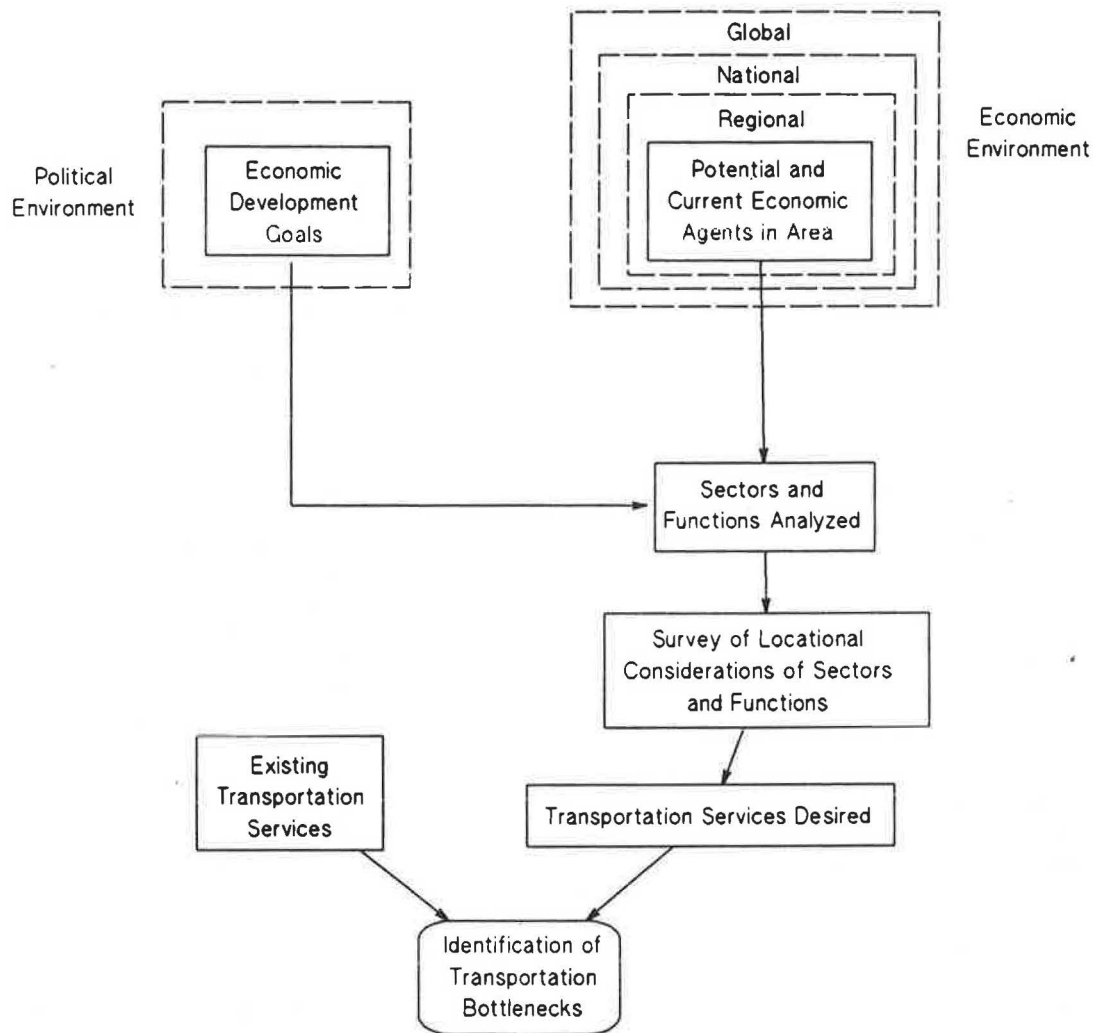


FIGURE 1 Identification of bottlenecks.

portation service. Thus, the lower the concentration ratio of users and operators of a transportation service the greater its flexibility.

Second, different economic actors have different levels of freedom in their locational decisions. Therefore, the second facet of flexibility is the ability of an economic activity to relocate (its locational elasticity of substitution). The lower the relocation cost for an economic activity, or the smaller the cost differential between alternative sites, the more flexible the activity is. This type of flexibility may have two different implications for transportation policy formulation. If an economic activity is inflexible it may sustain high transportation shadow prices before deciding to relocate. Even if the transportation services for the activity are not optimal, it may be reluctant to relocate, because of high relocation costs. In such cases, the use of public funds for transportation investments to retain the economic activity may be unwarranted because the activity would remain in the area without the investment, or may be willing to participate in financing the transportation services it wants.

On the other hand, when an economic activity is footloose, it has alternative sites at similar cost with low relocation costs,

and therefore long-term, single-purpose transportation investments for retaining or attracting such a footloose activity may be risky. By the time the investment is operational, the desired activity may have located elsewhere. However, short-term, multipurpose, publicly financed transportation services may prove important for attracting or retaining such firms.

This facet of the flexibility concept reemphasizes the importance of careful analysis of the various sectors and functions that are considered desirable for economic development before committing public resources for transportation services intended to attract them.

CONCLUSION

Most studies of linkages between transportation and economic development focus on the effects of transportation facilities on employment, or on some indicators of economic productivity. A first step toward an alternative approach would focus on transportation services as intermediary goods in production and consumption processes. Because of economic restructuring in the U.S. and global economies, production

and consumption processes are constantly changing over space and time. Thus, the role of various transportation services in the economy and their effect on economic development are constantly in flux.

An analysis of the linkages between transportation services and economic development under such circumstances would begin by identifying the role and potential of various sectors and functions in the economy (local, regional, or national). Next, the importance of transportation services for the most important sectors and functions in the economy would need to be identified. This method would require a highly disaggregate analysis of the role of transportation services in the location of relevant industries and services, differentiated by function rather than by sector.

Such an analysis can help identify situations where the lack of specific transportation services becomes a bottleneck to economic development. However, this analysis is a necessary first step toward a cost-effective policy for economic development but is not sufficient for formulating or evaluating transportation policy contributions to economic development.

To make this additional step, analyzing the attributes of both transportation services and prospective users is necessary. Specifically, the concentration ratio of users and operators needs to be considered, as well as their footlooseness. These flexibility considerations are important to reduce the risk of long-term public investments being made on the basis of an ephemeral conjunction of circumstances in the rapidly changing economic scene. The importance of such considerations is increasing because of the lower predictability of future economic forecasts for most specific sectors or agents caused by economic restructuring.

Much work must be done before these ideas can be coalesced into a coherent operational framework. It is hoped that they may stimulate enough interest to begin the work needed to formulate and apply such a framework.

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