# Four Measures of Transportation's Economic Importance

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**ABSTRACT**

As a commodity, transportation has a supply side and a demand side. Unlike many other commodities, however, transportation's supply and demand overlap extensively. A significant portion of transportation is provided by consumers for their own use. Therefore, "transportation" means not only transportation industries, those businesses whose primary activity is to provide transportation services for a fee, but also it includes the transportation activities of other business establishments and consumers. Further, transportation can indicate transportation equipment, infrastructure, and other transportation-related goods and services. Differing concepts of transportation make it difficult to produce a single measure of the size of transportation in the economy that is satisfactory to all people for all purposes. Many widely used statistics of the size or importance of transportation in the economy do not correlate with the concepts they are intended to measure. This paper presents four measures of transportation's economic importance, namely, transportation industry's gross domestic product (GDP), transportation final demand, transportation-related GDP, and trans-

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portation-driven GDP. All four of these measures are conceptually consistent with the framework and accounting rules of the Systems of National Accounts and are statistically comparable to the GDP. With each targeted at a different aspect of transportation, together the four measures provide a complete frame of reference for the size and importance of transportation in the U.S. economy.

## INTRODUCTION

One tends to associate the importance of transportation with its benefits rather than with its costs. Consequently, "benefits" and "importance" are often used interchangeably in transportation economic analyses. For example, transportation's share in the GDP is frequently cited as a measure of transportation's importance in the economy and also as the benefit of transportation to the economy. Although this interchangeable use of terms may seem reasonable at first, it lacks a valid conceptual basis. Ultimately, the economic importance of transportation should be measured by how many economic resources are required to produce it. On the other hand, the benefit of transportation should be measured by the "willingness to pay" of all transportation users, plus possible net externalities (UKDOE 1999). As progress is made in transportation technology and management, the transportation system is becoming more efficient in that the same benefit is produced at a lesser cost or a greater benefit is produced at the same cost. In other words, transportation services are becoming less and less expensive. As a result, it is quite possible that the importance of transportation in the economy, as measured by transportation's share in the GDP, decreases, while the actual benefits of transportation remain the same or even increase. Historically, this is what has happened to agricultural industries and to many manufacturing industries. Since the cost and the benefit of an economic activity may differ significantly, a large measure of economic importance does not necessarily imply a high benefit/cost ratio or a high rate of return to investments. The economic importance of transportation should reflect how many economic resources are devoted to supporting the nation's transportation needs. Given the level of transportation services, the less spent on transportation and, therefore, the smaller the share of transportation in the GDP, the better. For this reason, the economic importance of transportation should not be used as a criterion for investment decisions. Instead, a benefit/cost ratio and marginal benefit and cost analysis should be used. This paper focuses on the measures of transportation's economic importance, not the benefits of transportation.

It might seem clear that transportation's importance in the U.S. economy should be measured by transportation's share in the GDP. However, very different ideas exist about what the share of transportation in the GDP represents because there exist very different concepts of what transportation entails. For example, some believe transportation is those activities directly involved in transporting people and freight from one place to another. Some equate transportation with transportation industries. Others consider transportation a social function that includes all economic activities that support people's transportation needs, directly or indirectly. These different concepts reflect the various perspectives on transportation, and, therefore, are all valid[1]. Accordingly, transportation's importance has to be measured from these different perspectives as well.

1992 and 1997 estimates of the four different but related measures of the economic importance of transportation presented here are based on data

[1] To consumers, transportation means not only the transportation services but also the commodities and other services they purchase for transportation purposes, such as cars, gas, and auto insurance. For example, in the Consumer Expenditure Survey (USDOL BLS 1997), transportation expenditure includes vehicles, gas, auto insurance, auto repair service, tolls, parking fees, and purchased transportation services. To a government, in addition to all of the above, transportation also means infrastructure investments, traffic control, and law enforcement. For an industry, transportation means a special group of businesses whose primary economic activity is providing transportation services. Therefore, transportation industry output may include not only transportation services but also other services or goods if the transportation establishments have secondary products. From a functional perspective, transportation means all goods and services produced for transportation purposes, including narrowly defined transportation services. From a resource perspective, all economic resources used, directly and indirectly, that support the transportation needs of a society may be considered transportation. Clearly, different definitions describe different aspects of transportation and are useful for different transportation-related analyses.

from U.S. Transportation Satellite Accounts for 1992 (TSA92) (USDOT BTS 1999) and the most recent data from the U.S. National Income and Product Account (USDOC BEA 1993–1999). All four of these measures are consistent with the conceptual framework and accounting rules of the System of National Accounts (Commission of the European Communities 1993). There are six sections in this paper. Following the introduction, the second section discusses transportation industry GDP, the conventional measure of transportation's importance in the economy. Estimates of the contribution of in-house transportation to the U.S. GDP are highlighted. The third section presents transportation final demand, a measure of transportation's importance to the economy from a demand and "function" perspective. The relationship between transportation industry GDP and transportation final demand is also illustrated. The fourth section introduces a new measure, transportation-related GDP, which has the advantage of being consistent with a broad concept of transportation while still being comparable to the GDP. The fifth section introduces another new measure, transportation-driven GDP, which captures the direct and indirect impact of transportation on the economy and presents an input-output method developed by Han and Fang (1997) for the derivation of transportation-driven GDP. The last section presents some concluding remarks.

## TRANSPORTATION INDUSTRY GDP

The gross domestic product (GDP) is the sum of the gross value-added of all productive activities taking place within a nation. Transportation GDP is the sum of all the gross value-added created in the process of conducting transportation activities or providing transportation services. However, statistics on transportation GDP are rarely available because the economic census in the United States, which is the primary data source for the U.S. national accounts, is based on establishments (basic productive units) rather than on activities. Because transportation industries are the most important providers of transportation services and represent a large portion of transportation activities in the economy, transportation industry GDP is often used as a surrogate for transportation GDP.

In both the Standard Industrial Classification (SIC) system (U.S. Executive Office of the President 1987) and the newly published North American Industry Classification System (NAICS) (U.S. Executive Office of the President 1997), transportation industries are shown to include establishments that provide passenger and/or freight transportation services. Establishments in transportation industries use transportation equipment and transportation-related facilities as productive assets. Based on the type of equipment used, these establishments are classified into five modes of transportation: air, rail, water, road, and pipeline. Since the GDP is the sum of the gross value-added of all industries in the economy, the importance of transportation industries in the economy can be effectively measured by the share of their gross value-added in the GDP. The gross value-added of transportation industries is the net output of transportation services. Quantitatively, it is the difference between the value of transportation output and the value of intermediate input, such as gasoline and vehicle repair services, that are consumed in the production of transportation services.

While the GDP of transportation industries as defined in the SIC and NAICS systems is a widely used measure, it does not completely measure the importance of transportation from the supply side since transportation services are not only supplied by transportation industries. Based on the SIC system, only establishments providing passenger and freight transportation services to the general public or to other business enterprises for a fee, such as railroad companies, common carrier trucking companies, and pipeline companies, are included as transportation industries in the U.S. national accounts system. Their output is counted as the transportation industry's output, and their gross value-added is counted as the transportation industry's GDP. A considerable amount of in-house transportation activities within nontransportation firms, for which there are no observable market transactions or value, is not separately identified. The output of these activities is not counted as transportation output but rather as output of the industries that host them. For example, transportation activities conducted by a grocery company's truck fleet moving goods from warehouses to

the retail outlets are counted not as transportation output but as output of the retail industry. As a result, the magnitude of transportation services has long been underrepresented in national economic statistics; therefore, most estimates of the economic benefits of transportation investments have been low. Clearly, an inclusive supply-side measure of transportation must cover in-house as well as for-hire transportation activities. Only with this broad definition of the transportation industry can transportation industry GDP closely represent transportation GDP.

Because our definition of transportation industry GDP, as a supply-side measure of transportation, includes in-house transportation, it has two major advantages for transportation analyses when compared to traditional national accounts measurements. First, it is more comprehensive in measuring transportation's contribution to the economy. Second, it is not affected by changes in the way transportation is provided and, therefore, offers a more reliable representation of transportation in the economy. For example, when a grocery company contracts out its internal trucking operations to a common carrier trucking company, the national accounts estimates show an increase in the output of transportation industries. When the company switches back to internal operations for its trucking needs, the national accounts estimates show a decrease in the output of transportation industries. In contrast, the estimates of transportation industry GDP as defined here remain unchanged in both cases. Empirical results also indicate the importance of including in-house transportation in a more complete supply-side measurement. According to the TSA92 (USDOT BTS 1999), developed by the Bureau of Transportation Statistics of the U.S. Department of Transportation and the Bureau of Economic Analysis of the U.S. Department of Commerce, in-house transportation activity was significant in the U.S. economy in 1992. It alone contributed $122 billion to the GDP, accounting for 39% of all transportation industry's GDP. In-house transportation was even larger than the agriculture and mining industries. See Fang et al. (1998) for more details on TSA92.

Deriving estimates for transportation industry GDP as defined in this paper requires more statistics than are available from the national accounts. Fortunately, TSA92 provides a set of detailed statistics that can be used as a benchmark. In this paper, data from TSA92 and the 1997 U.S. national accounts (USDOC 1993–1999) are combined to develop estimates for 1997.[2] The results, as well as statistics for 1992 from TSA92, are presented in table 1. Between 1992 and 1997, transportation industry GDP increased from $314 billion to $411 billion in its support of the growth of the U.S. economy. Its share in the U.S. GDP increased from

[2] Specifically, estimates of transportation industry's GDP for 1997 were derived by applying the 1997 U.S. final demand data from U.S. National Income and Product Accounts (USDOC 1993–1999) to TSA 1992 technical coefficient matrices. Since the application assumed that there were no technical changes from 1992 to 1997, the estimates are accurate reflections of the changes in transportation industry's output and value-added caused by economic growth and changes in final demand structure from 1992 to 1997. How close they are to the real changes in transportation industry's output and value-added depends on the magnitude of technical changes in the economy during the same period. The smaller the technical changes, the more accurate the estimates.

**TABLE 1 Transportation Industry's GDP: 1992 and 1997**

| | 1992 | | 1997 | |
|---|---|---|---|---|
| **Industry** | **Value-added** | **Percentage of GDP** | **Value-added** | **Percentage of GDP** |
| Railroads and related services | 34,390 | 0.55 | 43,633 | 0.54 |
| Motor freight and warehousing | 83,371 | 1.34 | 108,882 | 1.36 |
| Water transportation | 12,796 | 0.21 | 17,884 | 0.22 |
| Air transportation | 42,166 | 0.68 | 57,367 | 0.72 |
| Pipeline and related services | 19,624 | 0.31 | 25,859 | 0.32 |
| In-house transportation | 121,531 | 1.95 | 157,765 | 1.97 |
| **Total** | **313,886** | **5.04** | **411,391** | **5.13** |

5 to 5.1%. Within transportation industries, the share of the air transportation industry in the GDP increased the most, followed by the motor freight and warehousing industries. In-house transportation industry's share also increased. Only railroad industry's share in the GDP decreased slightly.

## TRANSPORTATION FINAL DEMAND

The gross domestic product (GDP) at market prices represents the net output of the production activities of resident producer units. Since goods and services are the specific forms of industry output, the GDP is also frequently viewed as a special category of goods and services. In other words, the GDP, in physical terms, is a basket of goods and services produced in the economy not used up in the production process itself. This basket of goods and services is put to final use, as opposed to current period production use. Final use is collectively called final demand. Therefore, the value of final demand is always equal to the GDP.[3]

Goods and services can be classified into categories according to the "purposes" or "objectives" of the product's use. This classification is called "functional classification" in the System of National Accounts. Based on the principles of functional classifications, final demand can be classified into six broad categories: food, housing, health care, education, transportation, and other. Transportation's final demand is the sum of the values of all goods and services in the GDP basket delivered to final users for transportation purposes. Goods and services of transportation's final demand include motor vehicles, motor fuels, highway construction, and auto repair services, among others. (See Han and Fang 1998 for further discussion of this topic.) As part of the GDP, transportation final demand shows how much of the economy's net output is used for transportation purposes. In addition, the share of transportation final demand in GDP is a good indicator of the importance of transportation as a driving force in the economy since, given the manner of production, total output and GDP of an economy go up and down as a function of changes in final demand.

Table 2 shows the size of transportation final demand and its share in the U.S. GDP for 1992 and 1997. Table 3 shows the commodity components of transportation final demand. Measured in current dollars, transportation final demand for the U.S. economy was $669.4 billion in 1992, equivalent to 10.7% of the GDP. Between 1992 and 1997, transportation final demand grew faster than the overall GDP. It reached $904.8 billion in 1997, and its share in the U.S. GDP increased to 11.2%. This means that the importance of transportation final demand increased as a driving force in the economy. Among the six broad functions, transportation was almost as large as food by 1997. It was smaller than housing and health but about twice as large as education.

[3] Final demand is defined in the System of National Accounts as the sum of the value of goods and services delivered to final users, less the value of imports. Final users include personal consumption, government consumption, capital investment, and exports.

**TABLE 2 Gross Domestic Product by Major Social Function: 1992 and 1997[1]**

| | 1992 | | 1997 | |
|---|---|---|---|---|
| **Major social function** | **Billions of current dollars** | **Share in GDP (percent)** | **Billions of current dollars** | **Share in GDP (percent)** |
| Gross Domestic Product | 6,244.4 | 100 | 8,110.9 | 100 |
| Housing | 1,468.7 | 23.5 | 1,969.1 | 24.3 |
| Health | 880.2 | 14.1 | 1,151.1 | 14.2 |
| Food | 803.1 | 12.9 | 955.7 | 11.8 |
| Transport | 669.4 | 10.7 | 904.8 | 11.2 |
| Education | 427.9 | 6.9 | 558.7 | 6.9 |
| Other | 1,995.0 | 31.9 | 2,571.5 | 31.7 |

[1]Calculated from data published in U.S. Department of Commerce (USDOC), Bureau of Economic Analysis (BEA), *Survey of Current Business*, various issues, 1996–98.

**TABLE 3 Components of Transportation Final Demand: 1992 and 1997[1]**

| Type of final use and commodity | 1992 | | 1997 | |
|---|---|---|---|---|
| | Billions of current dollars | Share in total (percent) | Billions of current dollars | Share in total (percent) |
| Total final uses for transportation | 669.4 | 100 | 904.8 | 100 |
| Personal consumption of transportation | 471.6 | 70.5 | 636.3 | 70.3 |
| Motor vehicles and parts | 206.9 | 30.9 | 269.5 | 29.8 |
| Gasoline and oil | 106.6 | 15.9 | 126.5 | 14.0 |
| Transport services | 158.1 | 23.6 | 240.3 | 26.6 |
| Gross private domestic investment | 89.9 | 13.4 | 158.1 | 17.5 |
| Transportation structures | 3.7 | 0.6 | 6.1 | 0.7 |
| Transportation equipment | 86.2 | 12.9 | 152.0 | 16.8 |
| Net exports of goods and services | –15.5 | –2.3 | –40.7 | –4.5 |
| Exports(+) | 125.0 | 18.7 | 164.2 | 18.1 |
| Civilian aircraft, engines, and parts | 37.7 | 5.6 | 41.4 | 4.6 |
| Automotive vehicles, engines, and parts | 47.0 | 7.0 | 74.0 | 8.2 |
| Passenger fares | 16.6 | 2.5 | 20.9 | 2.3 |
| Other transportation | 23.7 | 3.5 | 27.9 | 3.1 |
| Imports(–) | 140.5 | 21.0 | 204.9 | 22.6 |
| Civilian aircraft, engines, and parts | 12.6 | 1.9 | 16.6 | 1.8 |
| Automotive vehicles, engines, and parts | 91.8 | 13.7 | 140.8 | 15.6 |
| Passenger fares | 10.6 | 1.6 | 18.2 | 2.0 |
| Other transportation | 25.5 | 3.8 | 29.3 | 3.2 |
| Government transport-related purchases | 123.4 | 18.4 | 151.0 | 16.7 |
| Federal purchases | 16.8 | 2.5 | 19.7 | 2.2 |
| State and local purchases | 95.3 | 14.2 | 123.1 | 13.6 |
| Defense-related purchases | 11.3 | 1.7 | 8.2 | 0.9 |

[1]Sources: US Department of Commerce (USDOC), Bureau of Economic Analysis (BEA), NIPA tables in the *Survey of Current Business*, various issues, 1996–98.

In 1992, about 70% of transportation final demand was personal consumption demand for motor vehicles, gasoline and oil, and transportation services. Private, domestic investment in transportation equipment and structures added another 13%. Government transportation-related purchases, such as purchases of transportation equipment and transportation services, investment in public roads, and expenditures in transportation programs, accounted for about 18%. U.S. exports of aircraft, automobiles, and transportation services also contributed to transportation final demand. However, its effect was completely offset by U.S. imports of similar goods and services. The net effect of international trade on U.S. transportation final demand was –$15.5 billion. In other words, the United States imported $15.5 billion more of transportation goods and services than it exported of the same in 1992.

Between 1992 and 1997, U.S. transportation final demand increased about 35% from $669.4 billion to $904.8 billion. Its composition, however, stayed relatively stable. The most noticeable changes were the increased share of private, domestic investment and the decreased share of government purchases in transportation final demand. Private, domestic investment in transportation equipment and structures was $89.9 billion in 1992, accounting for 13.4% of transportation final demand. By 1997, private, domestic investment reached $158 billion, and its share in transportation final demand increased to 17.5%. During the same period, government purchases of transportation-related goods and services grew only 22%, from $123.4 billion to $151 billion. Its share in transportation final demand decreased from 18.4 to 16.7%.

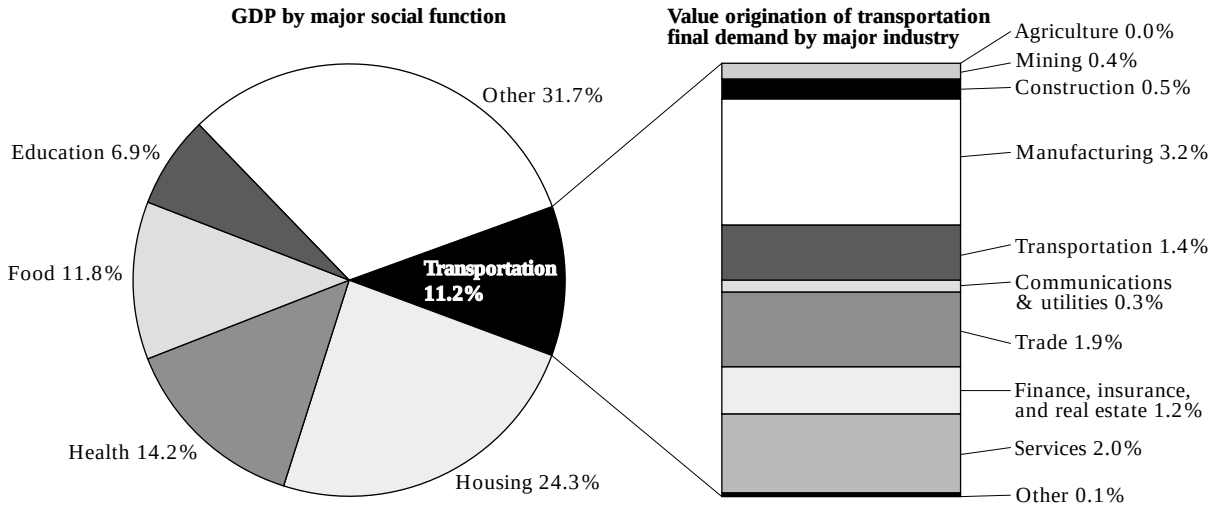
It is worth emphasizing that transportation final demand does not measure the importance of transportation as a value generator. This is because the value embodied in the goods and services delivered to final users for their transportation needs is gen-

erated not just by transportation activities but also by other productive activities that directly or indirectly provide input for the production of these goods and services. For example, the value of a car is generated partially by the automobile industry, the steel industry, the tire industry, and all other industries providing input to the automobile industry. For all other goods and services, a similar breakdown of value by origination can be done. Figure 1 shows the value origination of transportation final demand by major industry group in 1997. Out of the 11.2% that transportation final demand accounts for in the GDP, only 1.4% originated from transportation services, including the services of for-hire transportation industries and in-house transportation services of nontransportation industries. The remaining 9.8% originated entirely from nontransportation industries in the economy. The largest portion of the value of transportation final demand was from the manufacturing industry. Following manufacturing were the service industry and the wholesale and trade industry. Together, these three industry groups contributed more than 63% of the value of transportation final demand. It is clear that transportation services were a relatively small source of the value of transportation final demand. At the same time, however, only a small portion of the value generated by transportation services ended up in transportation final demand. In 1997, the value-added of transportation services was $411.4 billion, out of which only $116.1 billion were embodied in transportation final demand. This means that more than 71% of the value-added of transportation services was embodied in goods and services delivered to final users for nontransportation purposes or nontransportation final demand.

## TRANSPORTATION-RELATED GDP

As a social function, transportation has a supply side, which includes many transportation and nontransportation industries such as automobile manufacturing, petroleum refining, and highway construction. In order to elucidate the importance of transportation to the economy from a supply perspective, we introduce the concept of transportation-related GDP, defined as value-added (or net value) generated in producing goods and services to satisfy the society's transportation needs. These goods and services include transportation services such as freight and passenger transportation services as well as transportation input such as motor vehicles and gasoline. The difference between transportation-related GDP and transportation industry GDP is that in addition to the value-added generated by transportation services (or transportation industries), transportation-related GDP also includes the value-added generated in the production of direct input for transportation services, such as the production of motor vehicles and gasoline.

**FIGURE 1 Transportation Final Demand and its Value Origination: 1997**



Transportation-related GDP has several advantages over the previous two measures. First, it has a definitional boundary consistent with that of transportation expenditure. Statistics on transportation expenditures always cover not only the expenses of transportation services but also the expenses of transportation equipment, gasoline, and other operational costs (ENO 1998). In comparison, transportation industry GDP covers only transportation services.[4] Second, transportation-related GDP measures the importance of transportation to both final users and business, while transportation final demand covers final users only. By tracing the quantity of transportation-related goods and services required for business and final use, transportation-related GDP allows separate measures of the importance of transportation to business and final users and separate measures of the role of business transportation demand and final user's transportation demand in stimulating the production of various industries.

We derive transportation-related GDP with input-output methods and data from National Income and Product Accounts (USDOC 1993–1999) and the U.S. Transportation Satellite Accounts for 1992 (USDOT 1999). We first calculate the transportation portion of each industry's output by summing the industry's output delivered to final demand for transportation purpose and its output used by business for providing transportation services. We then estimate the industry's value-added generated in producing the transportation portion of its output by multiplying the output used for transportation with the industry's average value-added rate per one dollar's worth of output. The sum of the transportation portion of every industry's output yields the total transportation-related output of the economy. The sum of every industry's transportation-related value-added yields the transportation-related GDP of the economy.

In 1992, transportation-related GDP for the U.S. economy was $666.6 billion, accounting for 10.7% of the U.S. GDP. In 1997, it increased to $888.3 billion or 11.1% of the U.S. GDP. One point worth noting is that the size of transportation-related GDP was very close to the size of transportation final demand in both 1992 and 1997. However, these phenomena occurred by chance with no intrinsic reason for their seeming correspondence. As we have discussed, transportation final demand measures the value of goods and services delivered to final users to serve their transportation needs. A large portion of this value originated from nontransportation related production activities. For example, the value of the steel embodied in a car that was purchased by a consumer is counted as transportation output, but the value originated with the steel industry. Transportation-related GDP, on the other hand, measures the value generated by business activities that provide either transportation services or direct input to transportation services. The transportation services may be consumed either by businesses as input to production or by final users as final consumption. Therefore, a large portion of the value of transportation services may not be captured by transportation final demand. A good example of this point is the sharp difference between the small final demand for steel and the considerable GDP of the steel industry. Steel is an important input to many industries, but only a small amount of steel becomes final consumption.

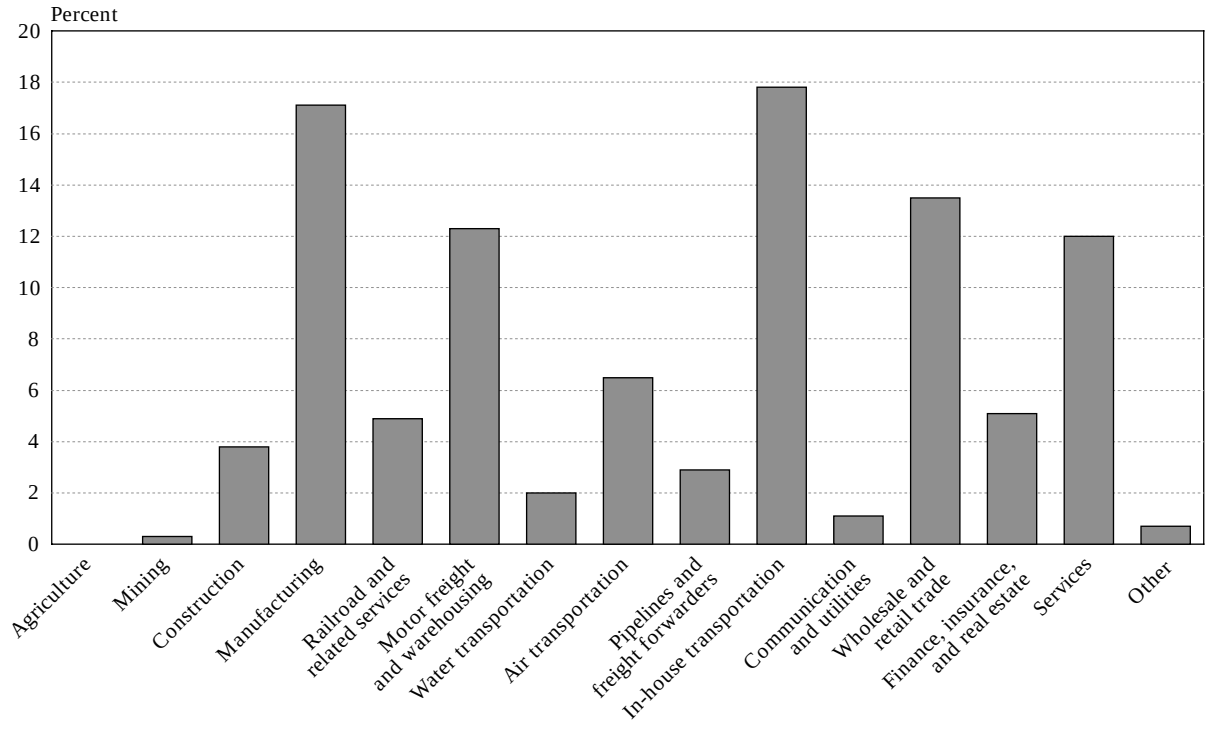
Table 4 and figure 2 show the distribution of transportation-related GDP across major industries. Out of the $888.3 billion transportation-related GDP in 1997, about 46% originated from transportation industries, while the rest originated from the production of direct transportation input by nontransportation industries. If all economic activity is aggregated into 16 industries, the in-house transportation industry ranks number 1 in terms of contribution to transportation-related GDP, accounting for 17.8% of the total. The manufacturing industry ranked number 2 and contributed 17.1%. The largest for-hire industry, motor freight and warehousing, contributed

[4] The consistency between the definitional boundaries of transportation-related GDP and the common measures of transportation expenditure is also important for estimating transportation-related GDP. Transportation expenditures are frequently used as surrogates for transportation-related output. Without expenditure information, it will be very difficult to estimate the transportation portion of the output and value-added of some transportation-related industries, such as petroleum refinery, because their products can be used for both transportation and nontransportation purposes

**TABLE 4 Transportation-Related GDP by Major Industry: 1992 and 1997**

| Industry | 1992 | | 1997 | |
|---|---|---|---|---|
| | Millions of dollars | Share in total (percent) | Millions of dollars | Share in total (percent) |
| Agriculture | 12 | 0.0 | 16 | 0.0 |
| Mining | 2,026 | 0.3 | 2,522 | 0.3 |
| Construction | 21,786 | 3.3 | 33,915 | 3.8 |
| Manufacturing | 122,879 | 18.4 | 152,023 | 17.1 |
| Transportation | | | | |
| Railroad and related services | 343,90 | 5.2 | 43,633 | 4.9 |
| Motor freight and warehousing | 83,371 | 12.5 | 108,882 | 12.3 |
| Water transportation | 12,796 | 1.9 | 17,884 | 2.0 |
| Air transportation | 42,166 | 6.3 | 57,367 | 6.5 |
| Pipelines and freight forwarders | 19,624 | 2.9 | 25,859 | 2.9 |
| In-house transportation | 121,531 | 18.2 | 157,765 | 17.8 |
| Communication and utilities | 7,164 | 1.1 | 9,452 | 1.1 |
| Wholesale and retail trade | 90,928 | 13.6 | 119,730 | 13.5 |
| Finance, insurance, and real estate | 32,115 | 4.8 | 45,660 | 5.1 |
| Services | 70,798 | 10.6 | 106,914 | 12.0 |
| Other | 5,009 | 0.8 | 6,629 | 0.7 |
| **Total transportation-related GDP** | **666,593** | **100** | **888,251** | **100** |

**FIGURE 2 Industry Share in Total Transportation-Related GDP: 1997**




12.3%. However, motor freight and warehousing ranked fourth, after the wholesale and retail industry, which contributed 13.5% to the total. Although this kind of ranking reflects the size of an industry as much as its affinity with transportation, it demonstrates that for-hire transportation industries are only part of the entire transportation system and represent only a small portion of the GDP generated in relation to transportation.

**FIGURE 3 Share of Transportation-Related Value-Added in Industry Total Value-Added: 1997**

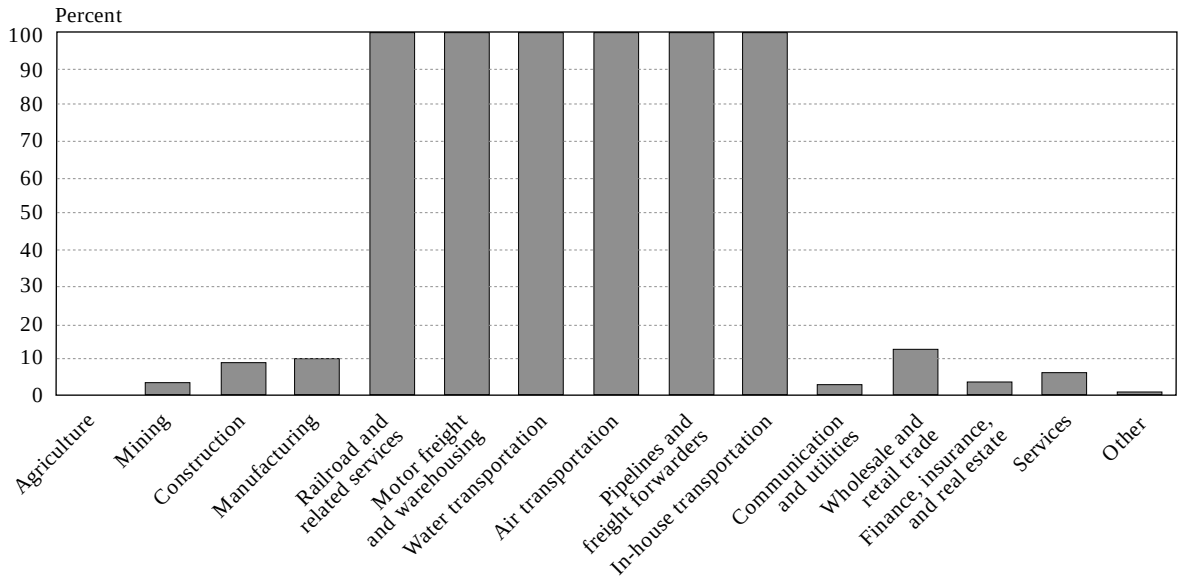
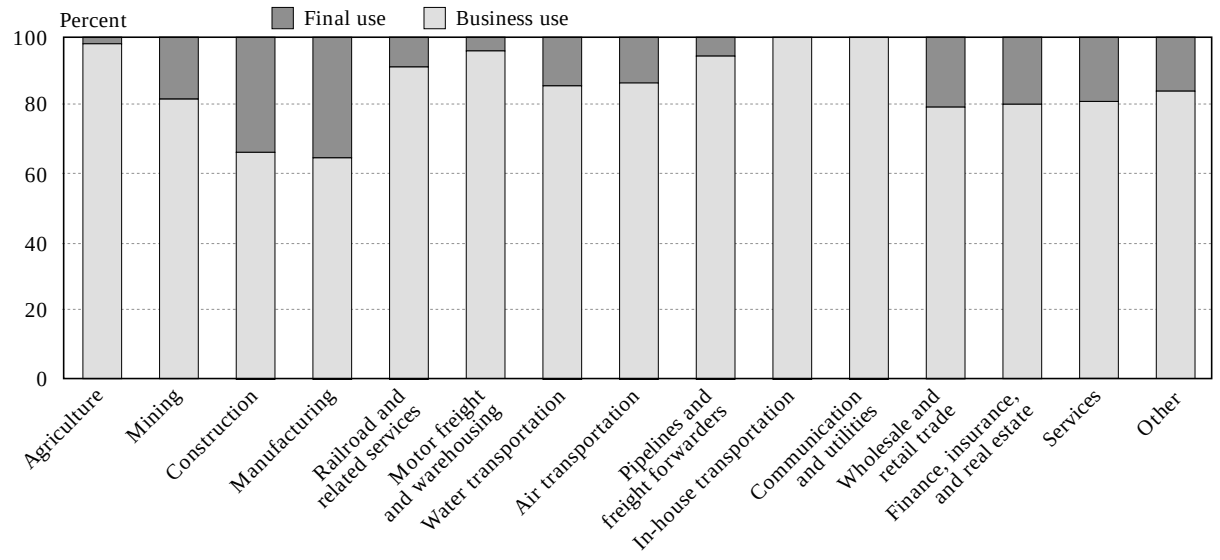



Figure 3 shows the degree of affinity of an industry with transportation using the share of its transportation-related value-added in its total value-added. By definition, all transportation industries, from railroad to in-house transportation, are 100% transportation-related. Among other industries, the share of transportation-related value-added in the total GDP was the highest for the wholesale and retail trade industry, 12.5%. For the manufacturing industry, the share was 11%. Another two industries closely related to transportation were construction and services. Their shares of transportation-related value-added in total value-added were nine percent for the construction industry and six percent for the services industry. Agriculture was the only industry that had almost no relation to transportation by this particular measure.

As mentioned earlier, transportation-related GDP allows separate measures of the importance of business transportation demand and transportation final demand. In 1997, 84% of the $888.3 billion transportation-related GDP was generated by supplying business transportation demand, and 16% was generated by directly supplying the transportation demands of final users. Figure 4 shows the dichotomy of transportation-related GDP by industry between business use and final use. Since the in-house transportation industry is made up of transportation activities conducted by nontransportation firms to meet their own transportation needs, in-house transportation industry's GDP was 100% generated by providing transportation services to business. The communication and utilities industry was another industry whose transportation-related GDP was almost completely driven by business demand. The communication and utilities industry is transportation-related because its output is used by for-hire transportation industries as input in providing transportation services. The industry that had the highest share of final use in total transportation-related GDP among all the industries was the manufacturing industry. About 35% of its transportation-related GDP was generated from supporting final users' transportation needs. Obviously, this was because a great deal of transportation equipment, such as cars, trucks, and boats, were used not only by businesses but also by consumers and governments. The share of final use in total transportation-related GDP was 14% for water transportation and 13% for air transportation, the highest in final use of the five for-hire transportation industries. The motor freight and warehousing industry has the lowest final use orientation. Only four percent of its services was directly consumed by final users. On average, for-hire transportation industries generated 92% of their total GDP by providing transportation services to business and only 8% from services to final users.

**FIGURE 4 Dichotomy of Transportation-Related GDP Between Business Use Origin and Final Use Origin, 1997**




## TRANSPORTATION-DRIVEN GDP

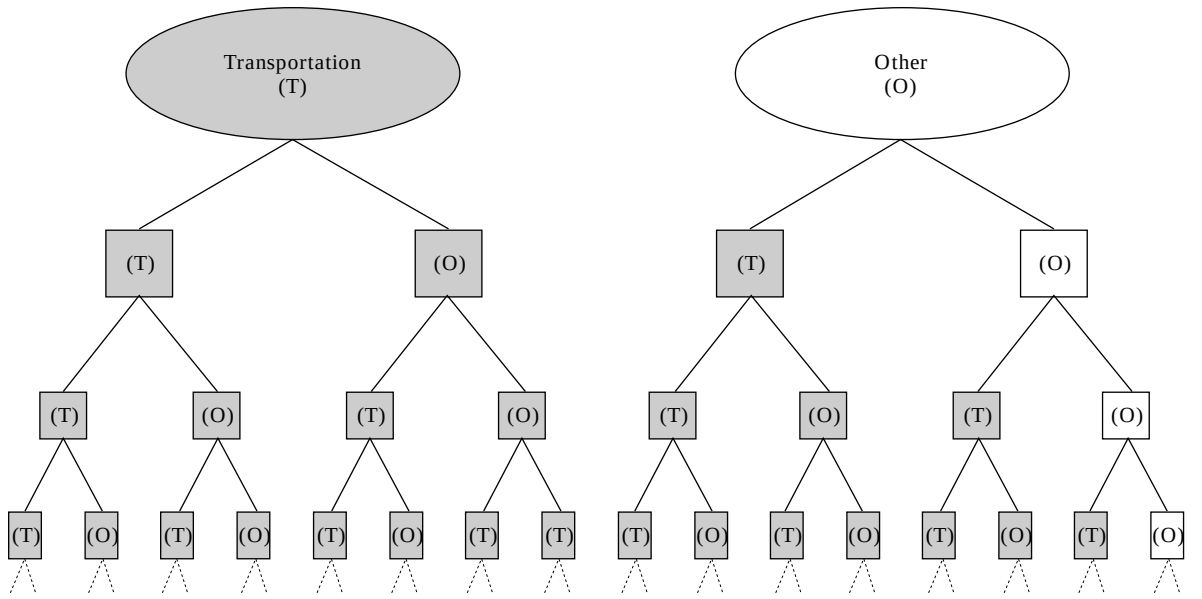
Transportation-related GDP expands transportation industry GDP by including the value of transportation input. To avoid double counting, only the producing industries' value-added embodied in the output which is used as direct input to transportation is included. The value-added embodied in the input used to produce that transportation input is not included. To illustrate this point, we will assume that trucking is the only transportation service and that it takes only labor and trucks to produce trucking service; only labor, steel, and trucking service to produce trucks; and only labor, iron ore, and trucking service to produce steel. In this scenario, transportation industry GDP equals the value of labor used in providing trucking service. Transportation-related GDP is the sum of transportation industry GDP and the value of labor used in producing trucks. The value of labor used in producing the steel needed for producing trucks is not included. Therefore, if asked how much of the GDP would be lost if demand for transportation suddenly dropped to zero, transportation-related GDP would not provide us with the correct answer.[5]

To address this question, we introduce the concept of transportation-driven GDP and present a method that allows us to derive an empirical measure that correlates with the concept. We define transportation-driven GDP as the sum of all the value-added generated by productive activities that provide transportation services and that directly or indirectly produce input used by transportation services. Transportation-driven GDP differs from transportation-related GDP by including the value-added generated in productive activities that indirectly support transportation services through an input-output chain. In our previous example, transportation-driven GDP includes the value of the labor used to produce the steel that was used to produce trucks. Since the industries of the economy are interconnected through input-output chains and since transportation services are also used by other industries as input in their production, which support other social functions, transportation-driven GDP and the GDP driven by other social functions will not be mutually exclusive. They will add up to a total larger than the GDP. We emphasize transportation here and use transportation services as the key link to sort out the interconnected input-output chain.

Figure 5 illustrates the concept of transportation-driven output in an interconnected production system. For simplicity, we assume that there are only two types of production in the economy:

[5] Clearly, many economic activities would not be able to take place if transportation suddenly ceased to exist. However, the impact of transportation's enabling function is not what is of concern here. What we try to measure here is transportation's economic impact from a purely accounting perspective, assuming that other economic activities would be able to continue without transportation services.

**FIGURE 5 Transportation-Driven Output**




transportation-related (T) and other (O). Each of the two types of production uses the output of the other as input. The ovals represent final demand for the output of each of the two types of production. The boxes represent intermediate demand for output of the two types at each round of production.[6] Since transportation-driven output is defined as the output of all industries used directly and indirectly for transportation purposes, output of transportation-related production, used by either final users or business to meet their transportation needs, is by definition transportation-driven output. Output of nontransportation production is also transportation-driven if it is indirectly used to support the production of transportation-related goods and services. For example, steel is an output of nontransportation-related production because it is not used as a direct input to transportation services. However, some steel is used as an input to produce vehicles used for transportation purposes. Therefore, the steel used for vehicle production indirectly supports the demand for transportation.

Since transportation services are a necessary input to every industry's production, nontransportation final demand also generates demand for output of transportation-related industries. These demands for transportation services will further induce demands for transportation-related output and nontransportation-related output and so on. All the output induced by intermediate demands for transportation-related output are also transportation-driven output, although the initial demand is not transportation-related. Therefore, transportation-driven output is equal to the sum of all the output represented by the darkened areas in figure 5.

The challenge is to quantitatively determine the transportation-driven output at each round in an infinite series of production. Since it is the use of the output of an industry and not who produces it that determines if an output is transportation-driven, we have to start with demand. The input-output approach enables us to go from the demand side to the supply side through the standard equation

$$G = (I–A)^{-1} f \qquad (1)$$

where $f$ is the final demand vector, $G$ is the output vector, and $A$ is the technical coefficient matrix. In other words, output $G$ is driven by final demand $f$.

[6] In figure 5, the sizes of the ovals and boxes do not represent or imply the size of the output of the two types of production. Nontransportation-related final demand and intermediate demand are much larger than their transportation-related counterparts.

If $f$ takes the value represented by the darkened oval in figure 5, then the equation gives an output $G$ equal to the sum of all darkened areas on the left side of the figure. To calculate $G$ as equal to the sum of the darkened areas on the right side of figure 5, we need an $f$ that is equal to the sum of those darkened boxes that immediately follow the light boxes, the initial intermediate transportation demand. Conceptually, initial intermediate transportation demand is the sum of transportation output that must be produced to satisfy the production of nontransportation output driven by nontransportation demands at each round of an infinite production process. Demand for transportation output to support the production of nontransportation output that, in turn, is needed to support the production of transportation output is not initial intermediate transportation demand. In matrix notation, the initial intermediate transportation demand can be expressed as

$$f = U(I-\tilde{A})^{-1}O \quad (2)$$

where $O$ is nontransportation final demand, $U$ is a direct requirement matrix with goods and services used as input to transportation, and $\tilde{A} \equiv A-U$, a direct requirement matrix with goods and services directly required to meet nontransportation needs. For those goods and services not directly required for transportation needs, the corresponding coefficients in $U$ are zero. For those goods and services directly required for both transportation and nontransportation needs, such as gasoline purchased by a farmer to run his trucks and harvesting machines, the corresponding coefficients in $A$ are split into one part for $U$ and another part for $\tilde{A}$. The detailed mathematical derivation of the equation for initial intermediate demand can be found in Han and Fang (1997).

With initial intermediate transportation demand, the total transportation-driven output can be expressed as the following equation

$$X = (I-A^{-1})[T + U(I-\tilde{A})^{-1}O] \quad (3)$$

where $T$ is transportation final demand and $O$ is nontransportation final demand. The interpretation of the equation is straightforward: $(I-A^{-1})T$ is the output driven by transportation final demand, while $(I-A^{-1})U(I-\tilde{A})^{-1}O$ is the output driven by transportation demand that itself is driven by nontransportation final demand.[7] A simple matrix multiplication of $X$ with the value-added coefficient vector of the economy yields the value-added generated by all industries of the economy in their production to directly and indirectly support all, final and intermediate, transportation demands in the economy. This transportation driven GDP is a comprehensive measure of transportation's economic impact on the economy.

In 1992, transportation-driven GDP was $988.6 billion, accounting for 15.9% of the U.S. GDP. As the economy grew, transportation-driven GDP also grew (table 5). In 1997, transportation-driven GDP increased to $1,321.6 billion, accounting for 16.5% of the U.S. GDP. This means that about 16% of the U.S. GDP was generated by economic activities that either provided transportation services or were involved in supporting transportation directly or indirectly. Other things being equal, without transportation final demand and business demand for transportation, the U.S. GDP would be 16% smaller. For-hire transportation industries' GDP was only a small portion of transportation-driven GDP, accounting for about 19% of the total in both 1992 and 1997. Adding in-house transportation GDP to for-hire transportation industries' GDP boosted the share of transportation industry GDP in transportation-driven GDP up to 31%. This means that more than two-thirds of transportation-driven GDP was from economic activities outside the transportation industries. The manufacturing industry alone accounted for 22% of the transportation-driven GDP in 1992 and 21% in 1997.

Transportation relies heavily on nontransportation industries. It is also an important demand that drives many industries' production. In 1997, the share of transportation-driven GDP in the industry's total GDP was 56% for the mining industry, 20% for the manufacturing industry, 18% for the wholesale and retail trade industry, 12% for the construction industry, 11% for the service industry,

[7] $(I-\tilde{A})^{-1}O$ is the nontransportation output driven by nontransportation final demand, and $U(I-\tilde{A})^{-1}O$ is the total initial intermediate transportation demand driven by nontransportation final demand. Initial intermediate transportation demand is equivalent to transportation final demand in terms of driving the economy's production process.

**TABLE 5 Transportation-Driven GDP: 1992 and 1997**

| Millions of dollars<br>Industry | 1992<br>Millions of dollars | 1992<br>Percentage of total | 1997<br>Millions of dollars | 1997<br>Percentage of total |
|---|---|---|---|---|
| Agriculture | 2,113 | 0.2 | 2,911 | 0.2 |
| Mining | 36,889 | 3.7 | 46,809 | 3.5 |
| Construction | 29,913 | 3.0 | 44,682 | 3.4 |
| Manufacturing | 219,403 | 22.2 | 281,503 | 21.3 |
| Transportation | | | | |
| Railroad and related services | 34,390 | 3.5 | 43,633 | 3.3 |
| Motor freight and warehousing | 78,450 | 7.9 | 102,444 | 7.8 |
| Water transportation | 12,796 | 1.3 | 17,884 | 1.4 |
| Air transportation | 42,166 | 4.3 | 57,367 | 4.3 |
| Pipelines and freight forwarders | 19,624 | 2.0 | 25,859 | 2.0 |
| In-house transportation | 121,531 | 12.3 | 157,765 | 11.9 |
| Communication and utilities | 28,171 | 2.8 | 37,613 | 2.8 |
| Wholesale and retail trade | 128,266 | 13.0 | 170,966 | 12.9 |
| Finance, insurance, and real estate | 87,395 | 8.8 | 120,874 | 9.1 |
| Services | 135,546 | 13.7 | 195,136 | 14.8 |
| Other | 11,905 | 1.2 | 16,202 | 1.2 |
| **Total** | **988,558** | **100** | **1,321,649** | **100** |

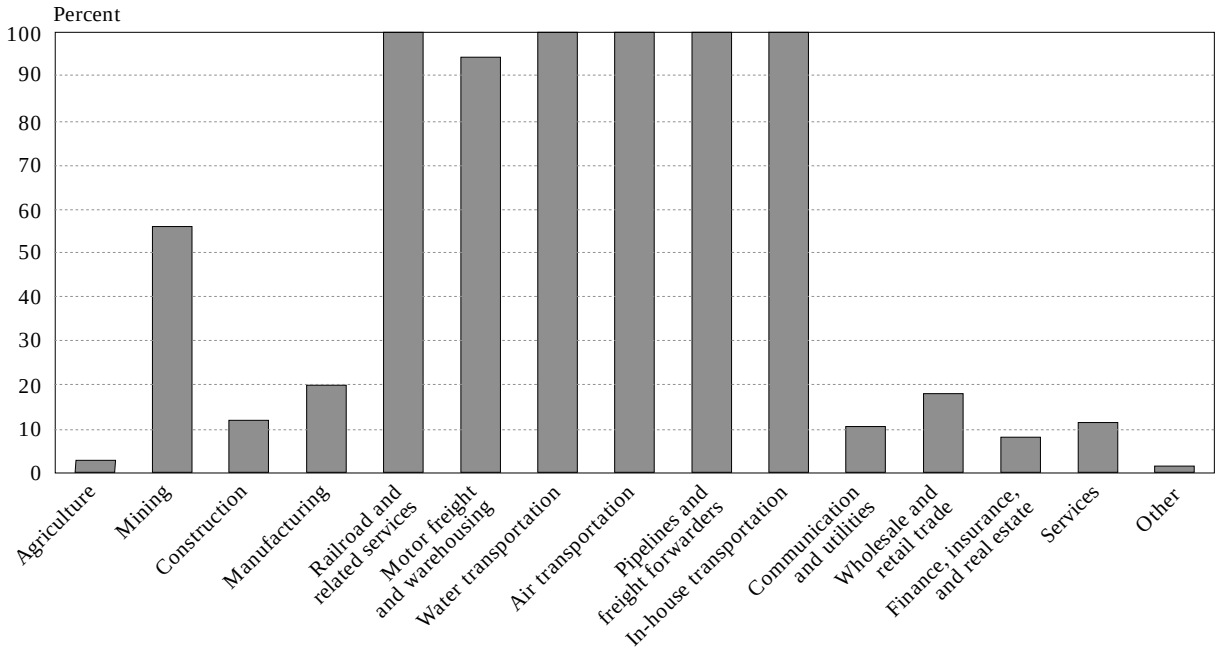
and 10% for the communication and utilities industry (figure 6). Recall that only three percent of the mining industry's GDP was from its output used as input to the production of transportation services. The sizable difference between the share of transportation-related GDP and the share of transportation-driven GDP in the mining industry's total GDP (3% versus 56%) reflects the fact that many industries are involved in supporting transportation services, and a large portion of these industries are themselves intensive users of the products of the mining industry. It also highlights the importance and necessity of measuring transportation-driven GDP in order to understand the impact of transportation on the economy.

## CONCLUSION

While all four of the measures of transportation's economic importance presented here have the GDP as the common denominator, the numerators in the different measures characterize transportation from different perspectives: transportation as an industry, as a social function, as the complete supply side of the transportation function, and as the complete impact chain of transportation functions. Transportation industry GDP is the sum of the gross value-added of transportation industries. Traditionally, only the gross value-added of for-hire transportation industries is counted as transportation GDP. The considerable value generated by in-house transportation activities within nontransportation firms has not been explicitly identified in the past and has been implicitly counted as nontransportation GDP. TSA92 reveals that in-house transportation activity was significant in the U.S. economy. Not including the value of in-house transportation services, traditional statistics on transportation GDP in the U.S. national accounts has underestimated the contribution of business transportation services to the GDP. These data may also be misleading if used in analyses of the relationship between transportation and the economy.

Transportation final demand is the sum of the values of all goods and services delivered to final users for meeting their transportation needs. Since it makes up a part of final demand and final demand drives the economy (in the short run), transportation final demand is an indicator of the importance of transportation as a driving force in the economy. The relationship between transportation industry GDP and transportation final demand is a complicated one. Many industries are involved in supporting the economy's transportation final demand, while a sizable portion of transportation

**FIGURE 6 Share of Transportation-Driven GDP in Industry GDP: 1997**




industry GDP is embodied in (or is used to support) nontransportation final demands. Without statistics on transportation final demand, we would miss a significant portion of the importance of transportation to consumers and, therefore, our understanding of the importance of transportation in the economy would be severely distorted.

Transportation-related GDP is the sum of the value-added generated by all production activities that produce transportation services or transportation input. Transportation-related GDP extends transportation industry GDP by including the value-added generated by producing direct inputs for transportation services, such as motor vehicles and gasoline. Unlike transportation industry GDP, transportation-related GDP covers the complete supply side of transportation. The consistency in coverage between transportation-related GDP and transportation expenditures, which include expenditures on such things as transportation equipment and fuels as well as transportation services, provides a critical link between transportation statistics on the supply side and those on the demand side, beneficial to many types of transportation analyses.

Transportation-driven GDP is the sum of all the value-added generated by production activities providing transportation services or producing input directly or indirectly for transportation services. Transportation-driven GDP extends transportation-related GDP by including the value-added generated in production activities that support transportation services indirectly through an input-output chain. Among the four measures, transportation-driven GDP is the only one that measures the total impact of transportation on the economy and provides a comprehensive description of the intertwined relationship between transportation and other industries in the economy.

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