RELATING TRANSPORTATION TO GDP: CONCEPTS, MEASURES, AND DATA

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INTRODUCTION

Gross domestic product (GDP) is widely accepted as the most comprehensive measure of the size of an economy. Transportation, as a component of the economy, naturally is often measured against GDP. In popular press as well as in policy discussions, measures of transportation in relation to GDP are often cited to illustrate the importance or contribution of transportation to the economy. The problem is that the relationship between transportation and the economy is a multi-faceted one and measures of transportation in relation to GDP are not always based on a conceptual framework that explicitly and accurately reflects the underlying relationship. This has resulted in both incorrect measures and incorrect interpretations of correct measures. For example, the often-used transportation bill as in Eno (1996), a combination of freight bill and passenger bill, is not comparable with GDP, while GDP by transportation industry as in Lum et. al. (2000), contrary to the interpretation implied by its use, does not fully measure transportation's contribution to GDP. Simply put, measuring transportation in relation to GDP is a right thing that is often not done right.

To correct this shortcoming in transportation statistics requires an understanding of the many facets of both transportation and GDP. For example, transportation can mean a certain type of economic activities or a certain type of economic organizations, and GDP can be seen as a basket of goods and services that are not used up in the process of current production or as the sum of the value added produced by all industries. These and other aspects of transportation and GDP may be meaningfully combined in different ways. Measures of transportation and GDP in different combinations may mean totally different things. For example, when transportation as an industry is related to GDP as a basket of goods and services the appropriate measure shows how much transportation supplies to final users, while it shows how much transportation directly contributes to the creation of new economic value when GDP is seen as the sum of the value added. In any economy, transportation industries' supply to final users is not necessarily equal to the industries' contribution to GDP because the two are entirely different things. A good example is mining industry, which does not directly supply to final users but certainly contributes to GDP.

This kind of distinction has not always been clearly made in transportation analyses and transportation-related policy discussions, resulting in inaccurate and even misleading representation of transportation in relation to the economy. Because the conceptual bases for different measures are not clearly spelled out and the true meaning of those measures are not widely understood, statistics are often inappropriately used, innocently or intentionally. For example, the share of transportation as a final demand function in GDP is generally larger than the share of transportation as a value adding industry in GDP in industrialized economies. People who want to emphasize the importance of transportation tend to use the former as the measure of transportation's contribution to GDP while it actually measures how much of GDP is consumed by transportation.

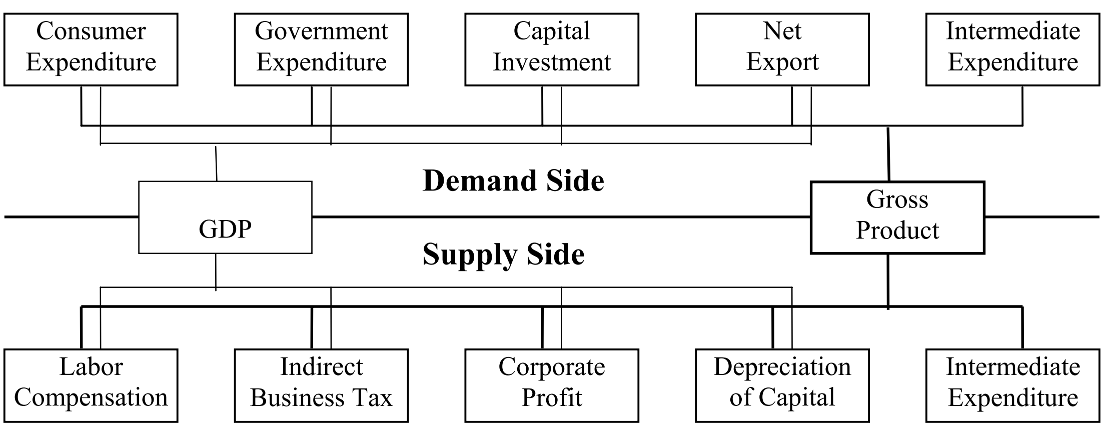
Over the past several years, some progress has been made both in terms of concepts and in terms of data. The conceptual work focuses on more specifically defining transportation and developing measures of transportation so defined. The related data work is largely an attempt to provide more detailed and more comprehensive coverage of transportation. The purpose of this paper is to provide an overview of these progresses. Starting with a summary discussion of different meanings of transportation and GDP and the relationship between the two, Section 2 shows that transportation can be measured from two different perspectives, one production perspective and the other final demand perspective. Section 3 presents five measures of transportation in relation to GDP. Section 4 introduces the U.S. Transportation Satellite Accounts (TSA) as a unified data source for the five measures discussed in the previous section. Section 5 summarizes.

TRANSPORTATION AND GDP

What is transportation? What is GDP? What is the relationship between the two? Answering these questions is the necessary first step toward building meaningful aggregate measures of transportation in relation to GDP. Before we develop our answers, it is worthwhile to emphasize that the transportation measures we want to build are those that are indicative of the underlying relationship or the relational measures. Sometimes two variables are put in a relation not because the two have any intrinsic underlying relationship but because one provides a benchmark for the other. The measures so derived can be called non-relational measures. For example, labor productivity is a relational measure because it relates output to labor input for the same production process. Chinese GDP as a percentage of U.S. GDP is a non-relational measure because U.S. GDP is used only as a benchmark or yardstick. Transportation is intrinsically related to GDP but GDP is also a commonly used yardstick. Therefore, both relational and non-relational measures for transportation may be built in relation to GDP. However, relational measures are far more common and non-relational ones also tend to be misused or misinterpreted as relational ones. We focus exclusively on relational measures in the following discussions.

As briefly mentioned in the introduction, GDP as a measure of production represents the final results of the production activities of resident producer units. From production perspective, GDP is the sum of gross value added of resident producer units (institutional sectors or, alternatively, industries). From demand perspective, GDP is equal to the sum of the final uses (or non-production uses or all uses except intermediate consumption) of goods and services (measured in purchasers' prices). The major components of GDP from both supply side and demand side and their relationship to output are shown in Figure 1.[i]

Figure 1. Major components of an economy



From demand perspective, the major components of GDP are consumer expenditures, government expenditures, capital investment, and net exports. These components are also often referred to as final demand, to be distinguished from intermediate demand.

From supply perspective, GDP consists of every industry's value added, which includes labor compensation (wage and salary), business taxes, corporate profits, and depreciation of fixed capital. GDP measured as total value added and as total final demand (or expenditure) is identical. In other words, GDP is a basket of goods and services supplied to final demand by industries and it is also the sum of value added created by industries. The two are equal in value.

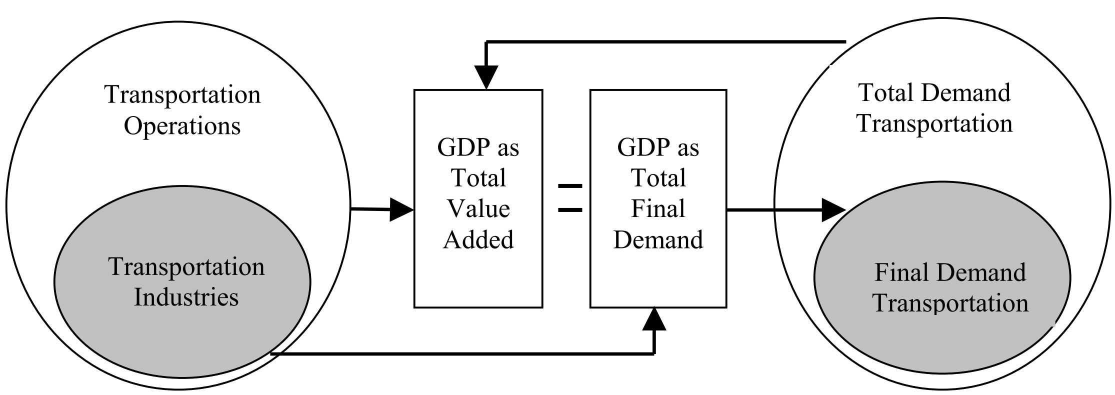
Transportation is essentially a certain type of services provided through operating vehicles and moving goods or people over the public system of roads, railroads, water ways, air ways, etc. There is also a demand side and supply side for transportation. The supply side of transportation is often designated as transportation industry. In both the Standard Industrial Classification (SIC, OMB 1987) system and the North American Industrial Classification System (NAICS, OMB 1997), transportation is identified as a separate industry group. However, transportation industries are not the whole supply side of transportation, because both SIC and NAICS or any other similar systems define industries according to certain standards, and not all transportation operations satisfy those standards. Therefore, a broader concept of transportation from supply side is transportation operations. All transportation services are supplied through transportation operations, while only some of those operations are classified into transportation industries.

From measurement point of view, three types of transportation operations can be distinguished: for-hire operations, in-house or own-account operations, and final user operations. For-hire operations are those conducted by transportation industries on a fee basis. Trucking operations conducted by a trucking company belong to for-hire operations. In-house operations are conducted by non-transportation industries for their own use. Trucking operations conducted by a grocery store belong to in-house operations. Final user operations are those by final users such as households and general governments. Although all these operations serve essentially the same purpose and have the same basic physical and economic characteristics, they are treated very differently in statistics. The supply side of transportation relates to GDP through industry value added. The problem, as it will become clear later on, is that this relationship does not stop at transportation industries.

If the supply side of transportation is the provision of transportation services, the demand side of transportation is then the use of goods and services for transportation purpose. Therefore, the demand side of transportation is a functional concept. Although this seems to be straight forward, several complications often lead to confusion. First, the demand side and the supply side often overlap. For example, the in-house transportation operations provide transportation services that are used by providers themselves. Similarly, final user operations are both provision and use. Second, the demand side goes beyond transportation services. For example, a household's purchase of vehicles belongs to transportation demand as much as its purchase of intercity passenger transportation services, because both serve the same purpose, which is to satisfy the household's transportation needs. Similarly, a government's purchase of highways goes to transportation demand because highways serve the same purpose as vehicles and purchased transportation services. Third, the demand side of transportation directly relates to GDP through final demand. The intermediate demand, or the demand by industries for transportation purpose, is not directly comparable to GDP but indirectly it can be.

In summary, the supply side of transportation includes all operations that are conducted to provide transportation services, and some of those operations are classified as transportation industries. The demand side of transportation consists of final demand and intermediate demand that serve the same purpose of satisfying transportation needs. The supply side of transportation contributes to GDP through its generation of value added and provides services to the GDP basket, while the demand side of transportation uses GDP through its purchase of goods and services in the GDP basket. Furthermore, the demand side of transportation affects GDP through its backward linkages to the entire supply side of the economy and therefore the GDP generation. Figure 2 provides a simple representation of the relationship between GDP and transportation.

Figure 2. Transportation in Relation to GDP



Several things are worth noting in figure 2. First, the size of transportation operations is not necessarily equal to that of transportation demand. As mentioned earlier, transportation operations produce transportation services while transportation demand includes goods like vehicles and gasoline. Similarly, transportation industries are different from transportation final demand. Second, all transportation operations contribute value added to GDP but only those in transportation industries supply to the GDP basket. This is so because transportation operations in non-transportation industries satisfy the industries' internal transportation needs. Third, all transportation demand induces GDP creation but only transportation final demand uses goods and services out of the GDP basket.

MEASURING TRANSPORTATION IN RELATION TO GDP

The relationship between transportation and GDP outlined in figure 2 can be quantified through five aggregate statistical measures. To simplify the discussion, the five measures can be called, respectively, transportation industry GDP, transportation GDP, transportation services in GDP, transportation final demand in GDP, and transportation-driven GDP. The first three measures the supply side relationship between transportation and GDP, the fourth measures the demand side relationship, and the last measures the GDP impact of transportation demand. As the following discussions will make it clear, all the five measures are relational because they are all based on intrinsic economic relations between transportation and GDP. Due to the different nature of the underlying relationship involved in different measures and to organize the discussions, we call the first four measures as primary measures and the last one as secondary measure.

The Primary Measures

The simplest of the four primary measures is transportation industry GDP that is the sum of the gross value added of all transportation industries. The gross value added is the difference between the industry output and the total industry intermediate input. Equivalently, it is equal to the sum of labor compensation, indirect business tax payment, allowance for the fixed capital consumption, and business profit. The common classification puts transportation in five separate industries: air, rail, water, road, and pipeline.

Since transportation industries are defined and classified in widely accepted systems that cover the whole economy, transportation industry GDP as a statistical measure is well defined and comparable to similar measures of other industries. However, since not all transportation operations are classified into transportation industries, transportation industry GDP does not fully measure exactly how much of GDP is generated in the process of transportation operations. In contrast, transportation GDP can be defined as the sum of value added generated in all forms of transportation operations, whether or not those operations are classified as part of transportation industries. Therefore, transportation GDP is conceptually the same as transportation industry GDP but covers transportation operations inside and outside of transportation industries. Quantitatively, it equals the transportation industry GDP plus value added generated by in-house transportation operations.[ii]

Transportation GDP counts all parts of GDP that have originated in transportation operations. Therefore, it is a more comprehensive measure of transportation's contribution to GDP. This is particularly useful for transportation analyses since other often-used measures of transportation, such as ton-kilometers, gasoline use, and transportation accidents cover the whole universe of transportation operations. Unlike transportation industry GDP, transportation GDP is not a widely accepted concept and readily available measure. Moreover, it may be argued that it causes comparability problems since in-house operations in other areas such as education, management services, and R&D are not similarly treated.

Transportation also supplies services to the GDP basket. The aggregate measure of this relationship is transportation service in GDP. This is still a supply side measure since it shows how much of the GDP as a basket of goods and services directly come from transportation. Unlike transportation GDP, which shows how much of the GDP as an aggregate net value of production originated in transportation, transportation service in GDP has nothing to do with value origination. A large share of transportation service in GDP does not necessarily mean transportation created a large share of GDP and vice versa. For example, as mentioned earlier, almost no mining products directly enter the GDP basket, but some amount of the GDP certainly originates in the mining industry.[iii] The measure of transportation service in GDP partially characterizes the physical composition of the GDP basket.

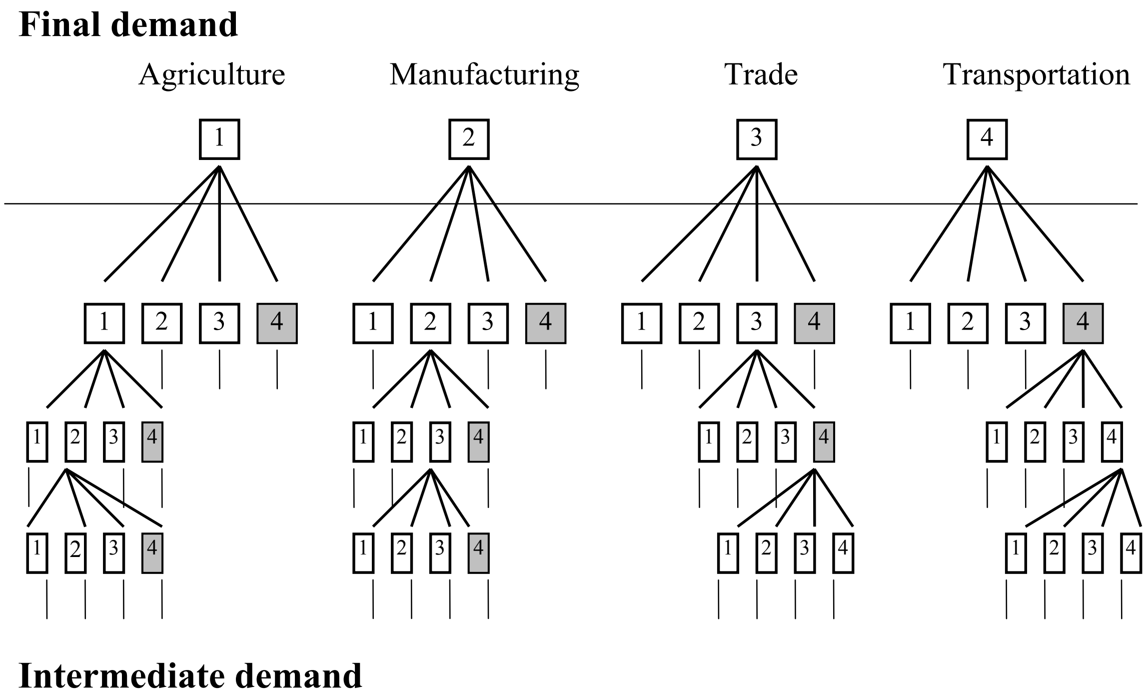
Transportation final demand in GDP is a demand side measure. It equals the sum of all final expenditures, including household expenditures, government expenditures, business investment expenditures, and net exports for transportation purpose. Transportation final demand in GDP measures the size of transportation function in relation to GDP. To include a demand in the measure of transportation as a function, the demand has to meet two criteria. First, it must be for transportation purposes, and second it must be a final demand. In other words, to avoid double counting, intermediate inputs used by production units to provide transportation services shall not be included. This is because the values of these inputs are embodied in goods and services delivered to final demand and are reflected in the measures of the functions.

The Secondary Measure

The primary measures discussed above quantify the direct relationship between transportation and GDP. For example, transportation industry GDP measures the direct contribution of transportation operations in transportation industry to GDP and transportation final demand in GDP measures how much of GDP is directly used to satisfy final users' transportation needs. In a general sense, transportation in all the four primary measures is a subcomponent of GDP. Transportation-driven GDP, the secondary measure, measures the direct and indirect relationship between transportation and GDP. In this measure, transportation is not a subcomponent of GDP. Instead, transportation is related to GDP through a more complex economic mechanism. This mechanism links transportation demand to the ultimate GDP creation. In a sense, transportation-driven GDP presents transportation as a driving factor behind GDP creation, hence the name.

Transportation-driven GDP is the sum of all the value added generated by productive activities that provide transportation services and that directly or indirectly produce inputs used by transportation services. In other words, transportation-driven GDP collects all value added created throughout the impact chain of an economy where productive activities are initiated by transportation demand. Although transportation activities at any stage of the impact chain induce further productive activities that create more value added, all the value added created through such induced activities cannot be added together. Since the transportation activities at later stage may have been induced by transportation activities at earlier stage, adding the value added induced by all the transportation activities throughout the whole impact chain would cause serious double counting. Figure 3 shows the entire impact chain of a given final demand vector.[iv]

Figure 3. Initial Intermediate Transportation Demand



The highlighted boxes are initial intermediate transportation demand that is defined as intermediate transportation demand not induced by other intermediate transportation demand. Value added generated in all stages following the highlighted boxes are counted in the transportation-driven GDP. Since all the transportation activities that follow the highlighted boxes are not counted as initial transportation demand and hence do not have any additional inducing effect, the double counting is avoided. Using an input-output approach, total initial intermediate transportation demand can be expressed as:

$$T = U \times (I - \widetilde{A})^{-1} \times (F - f) + f \qquad (1)$$

where U is a direct requirement matrix with goods and services used as inputs to transportation, $\widetilde{A}$ is the difference between direct coefficient matrix A and U, or the direct requirement matrix with goods and services directly required to meet non-transportation needs, F is the total final demand, and f is the transportation final demand. In words, equation (1) converts a total demand vector into a vector of demand for transportation without double counting, as indicated by the highlighted boxes in figure 3.[v]

Total output required to support transportation demand in the economy (or transportation-driven output) can then be calculated as:

$$X = (I - A)^{-1} \times U \times (I - \widetilde{A})^{-1} \times (F - f) + (I - A)^{-1} \times f \qquad (2)$$

Equation (2) is clearly a simple expansion of the standard equation, $G = (I - A)^{-1} f$. The transportation-driven GDP is the product of X and the value added coefficient vector.

Why Five Measures?

All five measures introduced above are necessary for a full characterization of the multi-faceted relationship between transportation and GDP depicted in figure 2, but why do we need such a full characterization? Are the five measures equally important? What are they useful for?

As mentioned earlier, relating transportation to GDP is done on a regular basis in both popular press and policy discussions, because GDP is the most commonly used aggregate measure of the economy and people tend to think that transportation's economic contribution is best shown by measuring transportation as a share of GDP. Since transportation means different things in different contexts, very different GDP shares are often seen for transportation. Although all such measures are not truly relational, they are almost always used to show transportation's economic contribution, explicitly or implied. Obviously, everything cannot be put in a relationship with GDP and even if it can be the result does not necessarily show its contribution to GDP. A non-relational measure of transportation in relation to GDP only uses GDP as a yardstick. Any other commonly used yardsticks such as total population and total employment can serve the same purpose. Actually, these other yardsticks are more preferable than GDP because the non-relational property of a measure may be made more self-evident. However, transportation value added, for example, is not often related to total population because total population seems to be too remote or unrelated a yardstick. Clearly one would prefer to use a more related yardstick for a non-relational measure. Problem is that the superficial relatedness in a non-relational measure is not clearly distinguished from the true relationship in a relational measure. The five measures introduced above constitute the complete list of relational measures of transportation in relation to GDP and, therefore, provide a full characterization of transportation's relationship with GDP that puts some necessary constraints on developing and using GDP-related transportation statistics.

More important, these five measures are useful for different analytical purposes. Although all analyses need more than just one statistical measure and all statistical measures can be used in more than one type of analyses, we only briefly discuss the major uses of the five measures to highlight the differences in their usage. Major uses are listed in table 1.

Table 1. Five Measures and Their Usage

Measures	Usage
(1) Transportation Industry GDP	Industry and market analysis; industry comparisons
(2) Transportation GDP	Transportation analysis; inter-temporal and international comparisons
(3) Transportation Service in GDP	Demand analysis; industry analysis; market analysis
(4) Transportation Final Demand in GDP	Functional analysis; international comparisons
(5) Transportation-Driven GDP	Impact analysis

For the conventional industry studies and inter-industry comparisons, transportation industry GDP is obviously the most relevant aggregate measure for transportation. Since industry-based information is generally available on other aspects of transportation, such as employment, compensation, profit, investment, transportation industry GDP can be used in conjunction with these other variables to give a detailed picture of transportation industry in relation to other industries and to the economy as a whole. Transportation industry is the supply side of transportation market. Transportation industry GDP also can be used in transportation market analyses.

A picture of transportation industry is not a picture of transportation because there are extensive transportation operations outside transportation industries. Transportation analyses associated with transportation planning and policy making routinely rely on physical measures such as ton-kilometers, passenger-kilometers, and vehicle-kilometers that cover transportation operations inside and outside transportation industries. Transportation GDP is a value measure with the same coverage. Transportation industry GDP in contrast is not consistent with these physical measures. Transportation GDP is also useful for inter-temporal and international comparisons. For example, in developing countries or in early stage of development of developed countries most of transportation operations may not be organized in official transportation industries due to less advanced division of labor. As economic development advances and division of labor deepens, transportation experiences consolidation and integration, resulting in bigger transportation industries. A simple comparison of transportation industries between countries or over time will not reveal the real underlying differences or changes in transportation, while such a comparison based on transportation GDP and other related measures will.

Transportation final demand in GDP is a functional measure. The goods and services in the GDP basket are used for different broad social functions, such as food, housing, education, health, and so on. Transportation as a social function competes with other social functions for the net output the economy produces. This measure shows the relative economic importance of transportation since the amount of social resources that a society devotes to transportation should be the ultimate measure of transportation's economic importance. This measure is also useful for international comparisons when countries with different level of motorization and personal car ownership in particular are involved. For example, in a developing country with low personal car ownership the transportation-related final demand consists mostly of purchased transportation services while in a developed country with high personal car ownership it consists of mostly car-related expenditures. Comparing transportation-related final demand for the two countries would provide a more accurate picture of different economic importance of transportation in different countries than just comparing transportation services in the final demand.

Transportation service in GDP shows how much services in GDP come from transportation industry. This measure may be used for a transportation demand and industry analysis. Transportation service in GDP is the total final demand for transportation services and also the total supply to final users by transportation industries. This is the only measure of the five where demand is equivalent to supply. Since transportation services as measured in this measure include all the market-based for-hire transportation services, the measure is also useful for transportation market analyses. However, this measure is not often seen in the literature probably because identifying GDP origination and final demand in GDP is more important than identifying the suppliers of goods and services in GDP at the aggregate level.

Impact analyses are often conducted for transportation. The aggregate impact measures are often related to GDP. Unfortunately, very often such impact measures include severe double counting. Transportation-driven GDP measures the impact of transportation demand without double counting.

A Unified Data System for Transportation

Data for implementing the five measures discussed above are not always readily available, and those available are often scattered in different places. The least problematic is the data for transportation industry GDP. At least in the United States, data on GDP by industry, or gross product originating (GPO), as it is more officially called, are compiled on a regular basis by the national account agency.[vi] Data for transportation final demand are also available from the national accounts, but a clear boundary is not provided. Analysts have to apply their own definition of transportation to decide what demand items to include in their measures.[vii]

There are two problems in the national accounts data that prevent a full implementation of the above five measures. First, the national accounts are based on the standard industry classification system, and therefore, do not include all transportation operations as part of transportation industries. The most obvious example is the in-house trucking carried by a retail store. Although the trucking operations are not in any way different from their for-hire counterpart, they are counted as part of retail rather than transportation. The second problem is that data on different aspects of transportation, when available, are compiled in different parts of the national accounts. For example, in the U.S., GPO data are compiled as part of industry accounts, while transportation demand data are in the national income and product accounts.[viii]

In response to these shortcomings, a unified data system was proposed and developed by the Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation and the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. This system is referred to as the U.S. Transportation Satellite Accounts (TSA).

Why Satellite Accounts?

Satellite accounts are frameworks designed to expand the analytical capabilities of the national accounts without overburdening them or interfering with their general-purpose orientation. In this role, satellite accounts organize information in a internally consistent way that suits a particular analytical focus, yet they maintain links to the existing national accounts. Further, because they supplement the existing accounts rather than replace them, they serve as a laboratory for economic accounting in that they provide room for conceptual development and methodological refinement. In their most flexible applications, satellite accounts may use definitions and concepts that differ from the existing accounts. For example, a satellite account may be built around a broader concept of industry, production, and capital formation than the existing accounts.

Two types of satellite accounts are identified by the System of National Accounts 1993 presented in CEC et. al. (1993). Each type is distinguished by its relationship with the central framework. The first type involves the rearrangement of central classifications and the introduction of complementary elements that differ from the central conceptual framework. An example of this type of satellite accounts is the travel and tourism satellite accounts prepared by BEA reported by Okubo and Planting (1998). The second type of satellite accounts is based on concepts that are alternatives to the ones of the central framework. A different production boundary or an enlarged concept of consumption or production may be introduced, or the scope of assets may be extended. An example in this case is BEA's environment accounts (BEA 1994), which include natural resources in the asset accounts and the use of natural resources as negative investments in the income and product accounts.

The satellite accounts approach is a natural choice for building the unified data system for measuring transportation in relation to GDP. GDP is the most important aggregate measure from the system of national accounts but the national accounts do not provide enough details for a full characterization of transportation in relation to GDP. To provide more transportation details, the information from the system of national accounts has to be extended or supplemented. However, such extensions and supplementation should not disturb the basic structure of the national accounts. Therefore, data for measuring transportation in relation to GDP should come from a special system that is more detailed on transportation but is generally consistent with the central system that provides GDP data. Satellite account is just another name for this special data system.

Key Features of TSA

There are two important features of TSA that allow its data to be used for implementing the five measures. First, it covers for-hire and in-house transportation operations. Second, it is presented in an input-output (I/O) system. The importance of the first feature is obvious for the implementation because transportation GDP cannot be derived without counting in-house transportation operations. The I/O presentation is important due to the basic structure of an I/O system. A simplified format of the I/O system is in figure 4 where row industries match column industries.

Figure 4. I/O System

	Column Industries	Final Demand Categories
Row Industries	Intermediate Demand	Final Demand
	Value Added	

As it is clear from the figure, the I/O system provides information on both value added and final demand. Industries on both rows and columns include transportation industries. Transportation industry GDP and transportation service in GDP are both immediately available from the regular I/O accounts. The final demand on the row for transportation industries is transportation service in GDP, while the value added on the column for transportation industries is transportation industry GDP. The information in the I/O accounts is also sufficient for deriving transportation-driven GDP.

Transportation final demand in GDP is not readily available from the I/O accounts since the final demand in the I/O accounts is not categorized according to the purposes that the demand serves. For example, I/O accounts show how much of final demand is personal consumption but do not show how much of personal consumption is for transportation purpose. To get that information, a re-categorization of final demand is needed. Transportation GDP is also hard to identify in the I/O accounts because regular I/O accounts do not include in-house transportation operations as part of transportation. Therefore, re-categorizing final demand and identifying in-house transportation operations are the key to make the satellite accounts a real unified data system for measuring transportation in relation to GDP.

Key Components of TSA

At the center of TSA is the transportation input structure table (TIST) in figure 5. TIST is a detailed matrix showing the inputs purchased by all industries for their transportation operations. For example, a(11) is industry 1's purchase of commodity 1 to support the industry 1's transportation operations and a(n2) is industry 2's purchase of commodity n to support industry 2's transportation operations. TIST looks like a standard I/O use table, except that its entries only count the inputs that are used for transportation purpose.

Figure 5. Transportation Input Structure Table (TIST)

	Industry 1	**Industry 2**	**……………….**	**Industry n**
Commodity 1	**a(11)**	**a(12)**	**……………….**	**a(1n)**
Commodity 2	**a(21)**	**a(22)**	**……………….**	**a(2n)**
:	**:**	**:**	**:::::::::::::::::**	**:**
Commodity n	**a(n1)**	**a(n2)**	**……………….**	**a(nn)**

Data from TIST are used to derive the full TSA, including TSA make table, TSA use table, and other derivative tables such as direct requirements table and total requirements table. The following equations specify the relationship between the TIST and other TSA tables. S(i) is the sum across columns of TIST, T(i) is the sum across rows of TIST, and Q is the overall sum of all TIST cells. Therefore, S(i) is the total input of commodity i to all industries for their in-house transportation operations, T(i) is the total input of all commodities and services including value added items to industry i to support the industry's in-house transportation operations, and Q is the total output of in-house transportation operations.

$$S(i) = a(i1) + a(i2) + \ldots + a(in)$$
$$T(i) = a(1i) + a(2i) + \ldots + a(ni)$$
$$S = [S(1), S(2), \ldots, S(3)]$$
$$T = [T(1), T(2), \ldots, T(n)]$$
$$Q = \sum T(i) = \sum S(i)$$

The relationship between the TIST and the TSA make and use tables can be seen in the following matrix representation of the make and use tables.

TSA Make Table

The TSA make table is an I/O make table with an additional column for in-house transportation commodity and an additional row for in-house transportation industry. An I/O make table shows the value of each commodity produced by each industry. Let M be the make matrix from the national I/O accounts, the TSA make table is in figure 6.

Figure 6. TSA Make Table

	I/O Commodities	In-House Transportation
I/O Industries	M	0
In-House Transportation	0	Q

In the TSA make table, traditional I/O industries do not produce any in-house transportation service because all those transportation operations are taken out of the originating industries and grouped under newly created in-house transportation industry. Similarly, the in-house transportation industry does not produce any traditional I/O commodities. it is clear that the output of all traditional I/O industries does not change but the total output of the economy increased by an amount equal to Q.

TSA Use Table

The TSA use table is an I/O use table with an additional row for in-house transportation commodity and an additional column for in-house transportation industry. An I/O use table shows the values of all intermediate and value-added inputs used by industries or final users. Let U be the use matrix from the national I/O accounts and u the TIST table, with value-added items excluded from both, and let v be the vector of value-added items for in-house transportation operations, the TSA use table is in figure 7.

Figure 7. TSA Use Table

	I/O Industries	In-House Transport	Final Demand
I/O Commodities	U-u	S'/v'	FD
In-House Transport	T	0	0
Value Added	V-v'	v'	

Several things are worth noting. First, all goods and services used to support in-house transportation (u and v) are taken out of I/O industries. Instead, they are shown as inputs to in-house transportation industry, S'/v' and v', where S'/v'is the vector derived from taking out value-added elements from S'. Second, I/O industries are shown as using in-house transportation commodity as a new input (T). By the equations given above, it is easy to see that the output for all traditional I/O industries do not change but the total output in the economy increased because a new industry is added. Third, the total value added or GDP does not change (V-v'+v'=V). Fourth, in-house transportation industry does not use any in-house transportation commodity. Last, the final demand section of the TSA table looks the same as that in the I/O accounts. In-house transportation commodity is not provided to final users because the TSA currently only covers the in-house transportation operations in industries although transportation operations in the final demand sector are extensive. Furthermore, the final demand is not re-categorized to facilitate the calculation of transportation final demand in GDP.

Extensions

The framework presented above has been successfully implemented for 1992 and 1996 in the United States. The key statistical results from TSA for 1992 and 1996 are reported in Fang et. al.(1998, 2000) and BTS (1999). Although these represent good progress for economic statistics on transportation, several extensions are needed to make the system a truly unified one for measuring transportation in relation to GDP.

First, in-house transportation services for all transportation modes should be covered. Due to data limitation and budget constraint, the in-house transportation in 1992 and 1996 TSA only includes trucking and bus. Although these two are certainly predominant at least in the United States, in-house transportation operations clearly exist in other modes. The obvious examples include corporate jet (air), company car (transit), and barges (water).

In-house rail transportation seems to be rather limited. It can be argued that industrial railroads found within mines and industrial plants should not be considered as part of the transportation system because they are not close substitutes of for-hire railroad services. There is an issue concerning railroad cars not owned by railroad industries. If a manufacturing company hires a railroad company to haul the shipment carried in cars owned by the manufacturer, should the service from those freight cars be counted as in-house railroad service? Dealing with this issue probably will be more limited by data than by concepts.

Second, a function-based final demand vector should be developed. For each category of final demand, goods and services that are purchased for transportation purpose have to be identified. Major items should include household and business purchase of vehicles, gasoline and automotive services, and public investment in transportation infrastructure. Most of these items are identifiable in a straightforward way provided that data in the I/O accounts are detailed enough. The difficulty is the allocation of those goods and services in the final demand vector that are not transportation-specific but are used for transportation purpose, such as cleaning materials.

The re-categorized final demand vector can be structured in several different ways. For example, all the existing final demand categories can be split into a transportation portion and a non-transportation portion. Therefore, personal consumption expenditure (PCE) will consist of a column for PCE for transportation and another column for PCE for other. Alternatively, the final demand vector can be organized into several separate functional groups such as food, housing, clothing, transportation, and so on. This will be very useful for comparing transportation with other social functions, although providing non-transportation details in a transportation satellite account may not be so easy because it requires expertise and data outside transportation.

There are other extensions that will make the satellite account more useful but also are more controversial. For example, household production of transportation services will be included as another new industry in the TSA, expanding the production boundary of the national accounts. This will change both transportation and GDP.

SUMMARY

We attempted to provide an overview of conceptual, measurement, and data issues concerning transportation and its relationship with GDP. Conceptually, transportation relates to GDP both on demand side and on supply side. On the supply side, transportation is an industry and a particular type of operations. On the demand side, transportation is a broad social function. GDP on demand side is a basket of goods and services that are produced by the economy and not used up in the production process. GDP on supply side is the total value added, or the value created in the current production process. We showed that relating transportation to GDP should be constrained by the number of meaningful combinations of transportation and GDP along these different dimensions. Within these constraints, we outlined five aggregate measures of transportation in relation to GDP and briefly discussed their different usefulness.

We then presented the U.S. transportation satellite account as a unified data system for implementing the five measures. We showed that this satellite account covers both for-hire and in-house transportation services and is presented in an input-output system. Due to these two features, data from this account provide a comprehensive and consistent basis for developing all the five measures. We also briefly discussed some useful extensions to the account.

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ENDNOTES

[i] This figure and the related discussion draws upon Han and Fang (1998).
[ii] Final user transportation operations are classified outside the production boundary in the current national accounting system. Counting this part will change the total value added or GDP. More discussions later.
[iii] Mining products may enter the GDP basket through inventory change and net export. These products are chosen as example because they are closer to the theoretical possibility that a certain industry does not supply anything to the final demand but creates value added by producing to satisfy the intermediate demand.
[iv] This figure and related discussion draw upon Han and Fang (1997, 2000).
[v] See Han and Fang (1997) for a detailed derivation of the equation.
[vi] See Lum, Moyer, and Yuskavage (2000) for a recent update.
[vii] See NIPA function tables in the Survey of Current Business from BEA.
[viii] See Fang and Han (1997) for a detailed discussion.