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Introduction

The Transportation Satellite Accounts (TSAs), produced by the Bureau of Transportation Statistics (BTS), provide a comprehensive measure of transportation activity (e.g., trucking carried out by groceries to move goods from distribution centers to stores and driving by households in personal motor vehicles) in the U.S. BTS jointly developed the TSAs with the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce[1]. The TSAs re-organize the U.S. Input-Output (IO) Accounts produced by BEA.

The IO accounts produced by BEA show the contribution of the for-hire transportation industry to the U.S. economy and the industries using for-hire transportation services. For-hire transportation consists of the services provided by transportation firms to industries and the public on a fee-basis, such as air carriers, railroads, transit agencies, common carrier trucking companies, and pipelines. The TSAs re-organize the IO accounts to show the dollar value of transportation activity carried out by nontransportation industries for their own purposes (known as in-house transportation) and transportation activity carried out by households through the use of a private motor vehicle (known as household production of transportation services (HPTS)) – neither of which are shown in the IO accounts.

The IO accounts do not explicitly measure in-house transportation. A portion of in-house transportation is captured under for-hire transportation when it is provided by an establishment, owned and operated by a nontransportation enterprise, and large enough to be identified as a separate establishment producing primarily transportation services (e.g., fleet truck transportation owned by a grocery store chain to move food stuffs from distribution centers to local stores). Transportation provided by smaller scale establishments within nontransportation enterprises and transportation incidental to a business establishment (such as delivery service provided by a local furniture store) are not measured as transportation in the standard IO accounts (the IO accounts would capture the value added by these types of in-house transportation under the industry to which the establishment provides services)[2]. In the supplementary IO accounts, BEA reassigns some of the secondary products to industries in which the products are primary[3]. This reassignment, however, does not provide a complete or separate measure of in-house transportation services. The IO accounts provide no measure of household transportation. As such, the most prominent data sources on industry providers of transportation services do not fully capture all transportation activities.

To provide an explicit measure of in-house transportation and HPTS, the TSAs rearrange the IO accounts[4]. In rearranging IO data, the TSAs maintain the following IO accounts approach:

- Classification of industries and commodities using the IO industry and commodity classification system and the special definitions and conventions in the IO accounts, with the only exception made to form in-house transportation as a new industry and a new commodity.
- The reassignment – or using IO terminology, the "redefinition" – of secondary products to industries in which they are the primary products. Reassignment in the TSAs involves moving all intermediate and value-added inputs of in-house transportation from the industry in which production is secondary to the newly defined in-house transportation industry.
- Valuation of transactions in producers' prices.

The TSAs additionally maintain the following measures made in the IO accounts:

- Transportation costs (the costs to move commodities from producers to intermediate or final users) and trade margins.

The TSAs differ from IO standards in two ways:

1. In the TSAs, in-house transportation service covers the operation of an industry's own aircraft, railcars, trucks, and/or water vessels to move the industry's intermediate inputs or output. This coverage differs from that for for-hire transportation in the IO accounts. In the IO accounts, the use of for-hire transportation by an industry does not include transportation expenses associated with moving output; only transportation expenses associated with moving intermediate inputs to the industry, plus the expenses for certain direct transportation services. For example, if a for-hire truck carries wheat from a farm to a mill, the IO use table credits this activity to the industry using the wheat for production – which, in this instance, is the mill. Whether the farm or the mill purchased the transportation services is not relevant. The industry paying for the transportation services is relevant when in-house transportation, rather than for-hire transportation, is used. If an in-house truck of the mill transports the wheat from the farm, the TSAs use table shows the mill as providing the transportation services and conversely, shows the farm as providing the transportation services when an in-house truck of the farm transports the wheat to the mill.

2. The TSAs from 2002 forward provide a measure of household transportation conducted using private motor vehicles. Inclusion of household transportation requires expanding GDP by the contribution of household transportation since this value is not already captured in the IO accounts. The contribution of household transportation is equal to the depreciation of owning and operating a private motor vehicle. The time households spend operating a private motor vehicle for personal use is not included, because it is not within the scope of the IO accounts, upon which the TSAs are built. The IO accounts, by design, do not include unpaid labor, volunteer work, and other non-market production.

The following explains the estimation of in-house and household transportation and the formation of the TSA tables: the make, use, direct requirements, and total requirements tables. These explanations apply to the TSAs developed by BTS since 2002 (TSAs developed by BTS prior to 2002 were developed using slightly different methodology).

TSAs

Overview of Methods

As a satellite account to the IO accounts, the TSAs provide a systematic and consistent framework and dataset for conducting analytical studies of the role of transportation in the economy, both on an industry and commodity basis. The TSAs cover all activities related to the use of vehicles (such as aircraft, railcars, trucks, and water vessels by nontransportation industries and private motor vehicles by households) and related structures (such as airports, railroad stations, highways, and port facilities). The TSAs present detailed industry use of transportation services for the seven for-hire transportation industries reported in the U.S. IO accounts, the created in-house transportation industry, and the created household industry (see table 1)[7]. The created in-house transportation industry covers air, rail, truck, and water transportation services produced by nontransportation industries to carry out business activities, and the household industry includes household production of transportation services through the use of a private motor vehicle.

Table 1. For-Hire and In-house Transportation Industries Included in the TSAs

	NAICS sub-sector	Description
For-hire transportation services		Services provided by transportation firms to industries and the public on a fee-basis.
Air transportation	481	Scheduled and non-scheduled air transportation of passengers and/or cargo using aircraft. Does not include scenic and sightseeing air transportation or air courier services.
Rail transportation	482	Rail transportation of passengers and/or cargo using railroad rolling stock. Does not include scenic and sightseeing rail transportation and street railroads, commuter rail, and rapid transit.
Water transportation	483	Deep water, sea, coastal, Great Lakes, and inland water transportation of passengers and cargo using watercraft, such as ships, barges, and boats. Does not include scenic and sightseeing water transportation.
Truck transportation	484	General and specialized, over-the-road transportation of cargo using motor vehicles, such as trucks and tractor trailers.
Transit and ground passenger transportation	485	Passenger transportation activities, such as urban transit systems; chartered bus, school bus, and interurban bus transportation; and taxis. Does not include scenic and sightseeing transportation. Includes, by redefinition, State and local passenger transit.

Pipeline transportation	486	Transmission of products, such as crude oil, natural gas, refined petroleum products, and slurry via pipeline. Includes the storage of natural gas.
Other transportation	487, 488, 492, 493	Scenic and sightseeing transportation; support activities for transportation; couriers and messengers; warehousing and storage.
In-house transportation services		Services provided by nontransportation firms for the firms' own consumption
In-house transportation produced and consumed by nontransportation industries for business activities[a]		Private air, rail, water, and truck transportation operations in all non-transportation industries for their own use. For these operations, in-house transportation covers vehicles of all body types used primarily on public rights of way. Supportive services to store, maintain, and operate those vehicles also included.
Household production of transportation services (HPTS)		Household production of transportation services through the use of a private motor vehicle.

NOTES: [a] Methodology for measuring in-house transportation in the 2002 TSAs is different that in the 1997 TSAs. Methodology for 2002 TSAs revised because of changes in input data sources.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

The TSAs measure the magnitude of in-house transportation services by estimating the inputs used by each nontransportation industry in the IO accounts for its in-house transportation activities and by estimating the inputs to the production of household transportation using a private motor vehicle. To do this, the TSAs rearrange the IO accounts using data on transportation from other sources. The major data sources are identified in table 2.

Table 2. Principal Data Sources

Data		Sources
Estimates of input-output accounts		U.S. Input-Output data produced by the U.S. Department of Commerce, Bureau of Economic Analysis. 2002 TSAs based on 2002 benchmark U.S. Input-Output data (as of 06/2010); 2003-2006 TSAs based on annual U.S. Input-Output data (as of 12/2015), 2002 benchmark U.S. Input-Output data (as of 06/2016), and 2007 benchmark U.S. Input-Output data (as of 06/2010); 2007 TSAs based on 2007 benchmark U.S. Input-Output data (as of 06/2016); and 2008-2016 TSAs based on annual U.S. Input-Output data (as of 12/2017).
Air	Statistics on aircraft pilots and flight engineers (NAICS 53-2010)	U.S. Department of Labor, Bureau of Labor Statistics, Employment Projections, Industry-occupation matrix data, 2002-2016
Rail	Industry use of railroad rolling stock manufacturing commodity	U.S. Department of Commerce, Bureau of Economic Analysis, Input-Output Accounts
Truck	Statistics on heavy and tractor-trailer truck drivers (NAICS 53-3032) and light truck or delivery services drivers (NAICS 53-3033)	U.S. Department of Labor, Bureau of Labor Statistics, Employment Projections, Industry-occupation matrix data, 2002-2016
Water	Statistics on captains, mates, and pilots of water vessels (NAICS 53-5021)	U.S. Department of Labor, Bureau of Labor Statistics, Employment Projections, Industry-occupation matrix data, 2002-2016
HPTS	Depreciation of private motor vehicles	U.S. Department of Commerce, Bureau of Economic Analysis, Fixed Asset Tables (as of 12/2017)

HPTS = Household production of transportation through the use of a private motor vehicle

Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities

Rearrangement of the IO data with the supplemental data sources listed in table 2 occurs in the following steps. These steps are used to estimate in-house transportation conducted by nontransportation industries for business activities:

1. *Identifying transportation-related inputs (TRIs).* The TSAs define a set of inputs unique to or mostly used for transportation by a specific mode. These inputs, derived from the items in the IO accounts, are called "transportation-related inputs" (TRIs).

2. *Developing industry distribution weights*. Distribution weights are developed to distribute TRI commodities to industries. The weights assign a larger portion of TRI commodities to industries that employ a larger share of transportation workers.[5].

3. *Estimating and distributing the value of in-house transportation*. TRIs, such as gasoline, are aggregated from the item to the commodity level after removing the component that is part of final demand; the component used for nontransportation purposes, such as gasoline used for heating or for operating machinery; and the component used for transportation modes other than the one for which the TRI is selected, such as gasoline used in transportation modes other than trucking when trucking is the mode for which the TRI is selected. The resulting value is the dollar estimate of the commodity used for in-house transportation purposes. The value is distributed across industries by applying the distribution weight matching to the TRI, e.g., the share of fuel consumed by industries for trucking is used to distribute the estimated value of motor gasoline used for in-house transportation operations.

4. *Estimating inputs to in-house transportation production.* Transportation activities require inputs, some of which are not unique or primary to transportation (e.g., office supplies and accounting services). The TSAs assume nontransportation industries use inputs in the same proportion as for-hire transportation industries.

5. *Post-processing*. Adjustments are made after estimating inputs to ensure that the value of the transportation and nontransportation component of each commodity used by an industry equals that in the IO use table before rearrangement.

   Each of the steps above is explained in detail below. These steps apply only to the estimation of in-house air, rail, truck, and water transportation.

1. Identifying air, rail, truck, and water transportation related inputs

   A transportation related input (TRI) is an item unique or primarily used to generate transportation services in a specific mode of transportation. Typically, a TRI is a nondurable good (i.e., a good that has an average lifespan of less than three years), such as fuel and tires, that comprises a relatively high proportion of the total value used by a for-hire transportation mode. Some goods, like airplane propellers, comprise a relatively high proportion of the total value used by a for-hire transportation mode but do not make good TRIs, as they are durable goods. Other goods account for a high proportion of the total value used by a for-hire transportation mode but do not make good TRIs, as they are not used exclusively for transportation and/or by the mode. For instance, inland marine insurance is not a good TRI for estimating in-house water transportation, because inland marine insurance may be purchased by nontransportation industries to cover the movement of freight purchased from for-hire transportation industries. These industries would appear to be producing and consuming in-house water transportation, when they are not, if inland marine insurance is selected as a TRI.

One or more TRIs are selected from the IO item control table for each mode included in estimating in-house transportation services (air, rail, truck, and water). The selected TRIs are identified in table 3. All comprise a relatively high proportion of the total value of the commodity to which they belong. The selected rail TRIs are all items belonging to the railroad rolling stock commodity. For simplicity, the commodity name itself is listed as the TRI in table 3 rather than each of the items. The items selected as rail transportation inputs are a mixture of durable (e.g., locomotives and freight train cars) and nondurable (e.g., brake equipment and other railroad parts and accessories) goods. The durable items are retained as the nondurable items alone do not comprise a large proportion of total value of the commodity. There are no nondurable items belonging to another commodity that are used primarily for rail transportation and comprise a large proportion of the total value of the commodity.

Table 3. Transportation-related Inputs (TRIs)

Transportation Mode	Transportation related input(s)	Type
Air	Aviation gasoline (except jet fuel)	Item
	Jet fuel	Item
Rail	Railroad rolling stock manufacturing	Commodity
Truck	Motor gasoline	Item
	Light fuel oils	Item
	Liquefied refinery gases, for uses other than chemical raw material	Item
	Tire rebuilding and retreading	Item
	Truck and bus (including off-highway) pneumatic tires	Item

Water	Commercial ships and barges rental and leasing, without crew	Item
	Marine cargo Handling	Item
	Navigational services to shipping	Item

NOTE: All TRIs are items selected from a detailed item table obtained from the Bureau of Economic Analysis. Multiple items make up a given commodity in the IO tables. The TRI for rail is the name of a commodity in the IO tables as all items were selected as TRIs. TRIs are used to estimate the value of the items used for in-house air, rail, truck, and water operations by nontransportation industries.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

The following steps (a) and (b) are performed for each TRI that is an IO item; the steps are not performed for TRIs that are commodities.

a. Developing split factors for transportation related inputs

For each item in the TRI master list (table 3), the producers' value includes both the nontransportation and the transportation related value of the item and includes both the component used in the intermediate portion and the final demand portion of the IO use table. The intermediate value is derived by multiplying the producers' value by a share privately obtained from the Bureau of Economic Analysis that is a proportion of the item used for intermediate production. To extract the transportation value from this, a split factor was applied to each.

transportation value = producers' value* intermediate share * split factor

The split factor is the proportion of the TRI commodity used for transportation. The split factors are shown in table 4. Split factors for motor gasoline, light fuel oils (referred to as distillates), and liquefied refinery gases items used in truck transportation are derived from industry energy use information. All other split factors are set to 1 as the items are deemed to be used exclusively in transportation[8]. All split factors are specific to the TRI; hence, for each TRI, one minus the split factor equals the proportion of the TRI commodity used for nontransportation purposes.

b. Developing modal shares for transportation related inputs
As many of the TRIs are used by more than one transportation mode, a modal share was applied to the transportation value.

mode value = transportation value * modal share.

The modal share indicates the proportion of the TRI used by a specific transportation mode

For fuel items, modal shares are derived from data on fuel use by mode[9]. The proportion is relative to all other transportation modes in the intermediate portion of the IO use table. For example, the modal share for motor gasoline – one of the selected TRIs for trucking – is the amount of motor gasoline used for trucking relative to the total amount of motor gasoline used in transit and passenger ground, truck, air, water, pipeline, and rail transportation. The amount used in transit and passenger ground transportation is limited to the amount used in bus transportation as the available data provides only an estimate for bus transportation.

All non-fuel related TRIs for trucking are derived from highway vehicle miles of travel (VMT) data[10]. For the truck transportation TRI “tire rebuilding and retreading”, the modal share is relative to total highway VMT. For the truck transportation TRI “truck and bus pneumatic tires”, the modal share is relative to truck and bus highway VMT.

For the remaining TRIs, the modal share is set to one as the item was deemed to be used exclusively by the mode and by no other mode in the intermediate portion of the IO use table. Modal shares are shown in table 4.

Table 4. Spilt factors and modal shares for TRIs, 2002 and 2007

Trans-portation mode	Com-modity code	Trans-portation related input(s)	Split factor			Modal share		
			2002	2007	Derivation	2002	2007	Derivation
Air	324110	Aviation gasoline (except jet fuel)	1	1	N/A	1	1	N/A
	324110	Jet fuel	1	1	N/A	1	1	N/A
Truck	324110	Motor gasoline	0.9789	0.9792	Percent of all (commercial, industry, and transportation) motor gasoline consumed by the transportation sector. (a)	0.9446	0.9498	Percent of highway (bus and truck) and non-highway gasoline and gashol used by trucks. Trucks include: light duty vehicles with a long wheel-base; other 2-axle 4-tire vehicles; trucks identified as having single-unit 2-axle 6-tire or more body; and trucks identified as a combination body. (c)
	324110	Light fuel oils	0.6717	0.7238	Percent of all (commercial, energy, industry, residential, and transportation) distillate fuel oil consumed by the transportation sector. (a)	0.833	0.845	Percent of highway (bus and truck) and non-highway diesel fuel used by trucks. Trucks include: light duty vehicles with a long wheel-base; other 2-axle 4-tire

							vehicles; trucks identified as having single-unit 2-axle 6-tire or more body; and trucks identified as a combination body. (c)
324110	Liquefied refinery gases, for uses other than chemical raw material	0.0047	0.0075	Percent of all (commercial, industry, residential, and transportation) liquefied petroleum gases consumed by the transportation sector. (a)	0.9882	1	Percent of highway (bus and truck) and non-highway liquefied petroleum gas (lpg) used by trucks. Trucks include: light duty vehicles with a long wheel-base; other 2-axle 4-tire vehicles; trucks identified as having single-unit 2-axle 6-tire or more body; and trucks identified as a combination body. (c)
326212 32621M*	Tire rebuilding and retreading	1	1	N/A	0.2784	0.2939	Percent of truck and bus highway vehicle miles traveled by trucks. Trucks include: light duty vehicles with a long wheel-base; other 2-axle 4-tire vehicles; trucks identified as having single-unit 2-axle 6-tire or more body; and trucks identified as a combination body.(b)
326211 32621M*	Truck and bus (including off-highway)	1	1	N/A	0.9835	0.984	Percent of all highway vehicle miles traveled by trucks. Trucks include: light duty vehicles with a long

		pneumatic tires						wheel-base; other 2-axle 4-tire vehicles; trucks identified as having single-unit 2-axle 6-tire or more body; and trucks identified as a combination body.(b)
Water	488300	Marine cargo Handling	1	1	N/A	1	1	N/A
	488300	Navigational services to shipping	1	1	N/A	1	1	N/A
	532411	Commercial ships and barges rental and leasing, without crew	1	1	N/A	1	1	N/A

* Commodity code in 2007 IO accounts

N/A: Not applicable as entire commodity assumed to be used to produce transportation.

SOURCE: Tabulations by U.S. Department of Transportation, Bureau of Transportation Statistics from data obtained from: (a) U.S. Department of Energy, Oak Ridge National Laboratory, Transportation Energy Data Book: Edition 24 and 28, table 2.5.; (b) U.S. Department of Transportation, Federal Highway Administration (FHWA), Highway Statistics. Data for 2002 received as special tabulation from FHWA. Data specially tabulated so as to categorize highway vehicle miles traveled per the same vehicle body types used for the 2007 data. Data for 2007 as reported in U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics: Chapter 1, table 1-35 [as of September 2014]. (c) Fuel consumed by trucks obtained from FHWA Highway Statistics. Energy use by fuel type tabulated by multiplying total amount of fuel consumed by trucks by the fuel shares listed in Appendix A.5 (for light trucks – light duty vehicles with a long wheel-base and other 2-axle 4-tire vehicles) and A.6 (for medium and heavy trucks – trucks identified as having single-unit 2-axle 6-tire or more body or combination body) of the Transportation Energy Data Book, Edition 28 and converting to BTU using the BTU conversion factors listed in in Appendix A.5 (for light trucks) and A.6 (for medium/heavy trucks) of the Transportation Energy Data Book, Edition 28.

2. Developing industry weights
   TRIs derived from the items table of the detailed IO accounts must be distributed across industries as the IO tables themselves do not show the value of items used by industries, only the value of commodities. Distribution is performed using distributional weights. The weights assign a portion of TRIs (aggregated to the commodity level after determining the modal value of each item) to each industry based on the industry's employment of transportation workers involved in the operation of the vehicle (aircraft, railcars, trucks, and water vessels) relative to the total stock across all industries[11]. Specifically, the weight for industry *j* relative to all industries (j=1,…,n) within mode *k* is:

   $\text{industry weight}_{jk} = \text{employment}_{jk} \div (\Sigma n\ j=1\ \text{employment}_{jk})$

   As the industry weight indicates the proportion of the stock used by an industry within a given mode, the sum of all weights within a mode equals one.

   Three types of weights were created are shown in table 5. Weights are not developed to distribute TRIs that are commodities themselves because the amount used by industries is shown in the IO use table.

Table 5. TSAs Industry Weights

Transportation mode	TRI commodity code(s) to which applied	Weight Type	
		Code	Description
Air	324110	A	Aircraft Pilots and Flight Engineers (53-2010)
Truck	324110	T	Heavy and Tractor-Trailer Truck Drivers (53-3032); Light Truck or Delivery Services Drivers (53-3033)
	326211		
	326212		
Water	488300	W	Captains, Mates, and Pilots of Water Vessels (50-5021)
	532411		

NOTE: Values in parentheses are the occupation codes.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

The specific steps involved in creating the weights follow.

a. Industry weight creation for all modes:

Industry employment of transportation workers are from the Bureau of Labor Statistics Employment Projections Program. This program provides industry by occupation and occupation by industry data. The TSAs use industry by occupation data for that year (e.g., the 2002 TSAs use the 2002 industry by occupation data). Employment of: aircraft pilots and flight engineers; heavy and tractor-trailer truck drivers; light truck or delivery service drivers; and captains, mates, and pilots of water vessels are extracted. These particular occupations are extracted as they are occupations corresponding to the actual operation of the vehicles (aircraft, railcars, trucks, and water vessels). It is assumed that if an industry employs persons to operate an aircraft, railcar, truck, or water vessel, then it is producing its own transportation. The extracted data are used to develop the four types of weights shown in Table 5. The weights represent the fraction of the total number of transportation workers related to mode, *k*, employed by an industry, *j*, in the IO accounts.

$weight_j = employment_k \times \Sigma_j\ 1 \div employment_{jk}$

where j = IO industry and k = transportation mode

3. Estimating and distributing the value of in-house transportation
For TRIs that are commodities, the value of the commodity used for in-house operations is taken directly from the IO use table. Assume, for example that the commodity railroad rolling stock manufacturing is the selected TRI. If a non-transportation industry consumes 3000 dollars of railroad rolling stock manufacturing, then value of railroad rolling stock used for in-house operations is 3000 dollars.

For TRIs that are not commodities themselves, the portion of the TRI used for in-house transportation operations is estimated by: (1) removing the component used for nontransportation purposes, such as gasoline used for heating or for operating machinery and the component used for transportation modes other than the one for which the TRI is selected, such as gasoline used for transportation modes other than trucking; (2) aggregating the resultant value from the item to the commodity level; and (3) then subtracting the producers' value of the commodity (from the IO use table) used by the relevant for-hire transportation, as shown below.

value of TRI used for in-house operations = mode value – producers' value (for TRI commodity used by for-hire mode k)

The resulting estimate then is distributed across industries by applying the distribution weight matching to the TRI, e.g., the share of fuel consumed by industries for trucking is used to distribute the motor gasoline used for in-house operations. The values are distributed only across industries that used a given TRI commodity and had a positive weight.

4. Estimating inputs used in producing in-house transportation
   Transportation activities require inputs, some of which are not unique or primary to transportation (e.g., office supplies and accounting services). The TSAs assume nontransportation industries use inputs in the same proportion as for-hire industries. This is performed through the development of a transportation input structure table (TIST) for each mode. The TIST table contains iTIST values which indicate, for each mode, how much of a commodity is used to generate in-house transportation services. iTISTs were calculated by multiplying the sum of the distributed TRI (calculated in the previous step) by a ratio, with the type of ratio being applied depending on whether the commodity is an intermediate or a value-added commodity. Both ratio types assume that private transportation uses inputs in the same proportion as for-hire transportation.

   For all nontransportation related intermediate commodities used by for-hire mode *k*, the ratio is the value of the nontransportation related input (R_{ik}) to the total value of the TRI used by the for-hire mode (D_{k1}). General ratios are not prepared for value-added commodities in this step as they are estimated during post-processing.

   For the for-hire mode 481000 (air transportation), the procedure for calculating the aforementioned ratios is shown in table 6 for several commodities, which are used by the for-hire air industry but are not on the TRI master list. The values are example values and not actual values from the TSAs. Example values are used as the values are not the same across all TSAs; the method, however, is the same. The values are unique to the IO benchmark year from which the data are drawn.

Table 6. General Ratio for Selected Nontransportation Related Inputs (nTRI) Used in Air Transportation

Nontransportation Related Commodities Used in Air Transportation

Commodity code	Commodity description	Value of nontransportation related input (R_{ik})	General ratio (G_{ik})
541910	Market research and public opinion polling	120.7	$G_{ik} = R_{ik} / D_{k1} =$ 120.70/10055.05
323116	Manifold business forms printing	715.4	$G_{ik} = R_{ik} / D_{k1} =$ 715.40/10055.05

NOTE: Values are examples and not actual values from the TSAs.

j = jth industry; i = ith commodity; k = kth mode

D_{k1} = total value of all transportation related inputs (TRIs) used by the for-hire mode k

R_{ik} = value of nontransportation related input (commodity *i*) used by the for-hire mode k

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

Within mode *k*, the resultant general ratios for all commodities except value-added commodities are applied to the sum of in-house transportation for industry *j* (I_{jk}) to find the iTIST for commodity *i* ($iTIST_{ijk}$) in the IO use table. This process is shown in table 7 for selected nontransportation related commodities used in air transportation.

Table 7. iTIST Values for Selected Nontransportation Related Inputs (nTRI) Used in Air Transportation

Commodity code	Commodity description	Industry code	Industry Description	General ratio (G_{ik})	In-house transportation value (I_{jk})	$iTIST_{ijk}$
541910	Market research and public opinion polling	11114D	Food grains	0.012	16.87	$iTIST_{ijk} = G_{ik} * I_{jk} = 0.012 * 16.87$
323116	Manifold business forms printing	11114D	Food grains	0.071	16.87	$iTIST_{ijk} = 0.071 * 16.87$

NOTE: Values are examples and not actual values from the TSAs

j = jth industry; i = ith commodity; k = kth mode

iTIST = amount of nontransportation related commodity *i* needed to generate in-house transportation services

G_{jk} = general ratio for industry j and mode k

I_{jk} = in-house transportation value for industry *i* and mode k

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

a. Calculating trade margins and transportation costs
After calculating the iTIST values, industry by commodity margin and transportation cost ratios are applied to the iTIST values to find the markup on the commodity when delivered to its final use. The margin and transportation cost ratios are expressed in terms of the producers' value for commodity *i* and industry *j*[13]. As the IO table already contained a wholesale and retail trade adjustment commodity, both are removed before applying the margins to the iTIST.

b. Appending margins to iTIST table
The calculated margins and transportation costs are appended to the iTIST table.

No modification is made in this step to reflect whether the in-house value is derived from a TRI classified as an item versus a commodity as none was needed.

5. Post-processing.
No modification was made in the following steps to reflect whether the in-house value is derived from a TRI classified as an item versus a commodity as none was needed.

a. Calculating the nTIST
The iTIST tables calculated in the previous step are summed across mode to create the combined TIST table. The resulting TIST values are subtracted from the producers' value of the commodity (from the IO use table) to find the portion of the commodity used in providing services other than transportation, which is called the nTIST.

b. Balancing the TIST table
After calculating nTIST values, adjustments are made to ensure that the nTIST values are positive for all commodities used by industries with a positive producers' value. Adjustments are made per the following formula which distributes the net shortfall across each mode according to the original proportion of in-house transportation that each mode accounts for.

$$iTIST_{NEW} = iTIST_{ORIGINAL} + (nTIST_{ORIGINAL} * (iTIST_{ORIGINAL}/combinedTIST_{ORIGINAL}))$$

To verify that the iTIST values are updated appropriately, the values are summed across modes to create a new TIST table, in which the summed iTIST values are subtracted from the producers' value to calculate a new nTIST value.

c. Calculating value added by in-house transportation related to business activities
For value added commodities used by a for-hire mode *k,* the ratio is the value of value-added commodity *i* to the value of all intermediate commodities. The value-added ratio is calculated for each for-hire mode and is applied to the sum of the preceding iTIST values (after balancing) for each industry.

d. Re-calculating the nTIST and re-balancing the TIST table

The estimated values from step c are appended to the balanced TIST table (prepared in step b above). The iTIST values in this new table are summed across modes to create the combined TIST table. The resulting TIST values are subtracted from the producers' value of the commodity (from the IO use table) to find the portion of the commodity used in providing services other than transportation, which is called the nTIST. The adjustment process used in step b is then repeated to ensure that the nTIST values were positive for all commodities used by industries with a positive producers' value.

Annual TSA Derivation

The annual TSAs (the TSAs developed in between IO benchmark years) are developed per the aforementioned framework with a slight modification. They are not developed in exactly the same manner because the BEA annual IO data, from which the annual TSAs are derived, do not provide the required detail. The annual accounts lack the following:

1. A detailed list of items that make up each commodity included in the accounts and the value of each.

2. Detail on the use of commodities used by for-hire transportation industries to produce transportation services. The annual IO data show the commodities used but not at as detailed level as in the benchmark IO data. The detail is needed to estimate the value of in-house transportation, which is assumed to be the total value of items relevant to transportation (e.g., aviation gasoline) less the value of those same items used by for-hire transportation. The value of the items used by for-hire transportation is proxied by the value of the commodities that make up the selected items. In the benchmark data, the selected items account for a large portion of the value of the commodity to which they belong. In the annual data, the selected items do not because the commodities to which they belong are combined with other commodities. Using these commodities as proxies results in a larger value being subtracted from the total value of transportation related inputs and hence in an underestimate of in-house transportation.

3. An estimate of the transportation costs and wholesale and retail trade margins for each commodity by industry. These estimates are required to accurately estimate the price paid by an industry for each commodity used to produce in-house transportation. The inputs to in-house transportation are estimated from the IO use table, which displays inputs to an industry at producers' prices. Producers' prices do not include the cost of transporting goods to the industry and any trade margins required to acquire the inputs.

4. Detail on personal consumption expenditures. The National Income Product Account Tables provide detailed information on personal consumption expenditures, but as a total, rather than by commodity as in the IO benchmark accounts. This lack of detail prevents a detailed list of inputs from being developed for household production of transportation services. Only the total of intermediate inputs and total output can be estimated with the NIPA tables for non-benchmark years.

Given the lack of detail in the annual IO accounts, the benchmark IO accounts are used in conjunction with the annual IO data in the development of the annual TSAs. Data from the benchmark year preceding the annual year and data from the benchmark year following the annual year are used when data are available for both benchmark years. The following describes how the data are used and the method employed when data are available for only the benchmark year prior to the annual year.

Developing Annual TSAs When Preceding and Following Benchmark Data Are Available

When data for both the benchmark year prior to and after the annual year are available, the value of transportation related inputs used for in-house operations in each benchmark year is used to estimate the value in the annual year. In annual years, the value of transportation related inputs is not known; only the value of the commodity is known. So the transportation related inputs used for in-house operations in the each benchmark year is summed to the commodity level and then divided by the total intermediate value of the commodity in the each benchmark year. The resulting value is multiplied by the value of the commodity in the annual year. This yields the portion of the commodity used in the annual year for in-house transportation operations. Two values are obtained as the calculation is performed using data from each benchmark year. Only the intermediate value of the commodity is included in this calculation because in-house transportation is an intermediate and not a final good. The values then are distributed to industries (per step 3 of the above section "Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities") using the same data for and at the same level of detail in each benchmark year.

The next step involves estimating inputs used for in-house transportation operations. As in the benchmark year, it is assumed that industries use inputs to produce in-house transportation in the same ratio as for-hire transportation. The ratio is the value of the input relative to the value of the transportation related inputs used by for-hire transportation. The ratios are calculated for each input used and for each of the four for-hire transportation industries estimated in the TSAs (for-hire air, rail, truck, and water transportation) using the annual data. The ratios are applied to the distributed value of the commodities used for in-house transportation operations, as calculated in the step above. The resulting estimates are at the annual level of detail. They are subtracted from the producers' value of the commodity (from the annual IO use table) to find the portion of the commodity used by the industry for purposes other than in-house transportation operations.

The next step involves making adjustments to the estimates. In some cases, the estimated value of a commodity used for in-house transportation operations is larger than the total value of the commodity used by the industry. Adjusting the data at annual level of detail results in fewer adjustments. As a result, a larger portion of the total value of an input is designated for use in producing in-house transportation. This appears to be an over-estimate. Evidence of it being an over-estimate comes from adjusting the benchmark TSAs at the annual level of detail. When adjusted at the annual level of detail, in-house transportation is significantly larger in value than when the benchmark TSAs are adjusted at the benchmark level of detail.

For more accurate adjustment, the annual estimates are re-estimated at the benchmark level of detail by assuming that the items making up the commodity make up the same proportion in the annual year as in the benchmark year. Because two benchmark years are available, two sets of estimates are calculated – one set derived using the benchmark data prior to the annual year of interest and the other set derived using the benchmark data following the annual year of interest. The values for the annual year of interest are calculated by taking a weighted average of the two values. The weight is ratio of the number of years between the annual year of interest and the benchmark year to the total number of years between the two benchmark years.

The data then are balanced, as described in step 5 of the above section "Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities". The value added by in-house transportation is calculated (as described in step 5 of the above section "Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities") using the annual IO data and rebalanced. Afterwards, the data are summarized to the annual level and balanced a final time.

Developing Annual TSAs When Only the Preceding Benchmark Data Are Available

The value of in-house transportation is calculated differently for years between benchmark years when only the preceding benchmark data are available. As when benchmark data are available for the year prior to and after the annual year, the annual data are used to estimate transportation-related inputs. In the benchmark year, this is done at the item level. In annual years, the value of multiple items are summed together to form commodities and only the commodities values are available. For the commodities that contain an item selected in the benchmark year as a transportation related input, the portion of the commodity used for in-house transportation in the annual year is estimated. This is done by multiplying the value of the commodity in the annual year by the ratio of the value used for in-house transportation in the benchmark year to the intermediate use of the commodity in the benchmark year. This value then is adjusted to account for changes post the benchmark year that may have changed the portion of the value used for in-house transportation. To allow relative change, the change in the value of the corresponding for-hire transportation mode's use of the commodity to the value of the commodity from the previous year was calculated and applied to the estimated portion used for in-house transportation operations. The value for each mode then is distributed to industries (per step 3 of the above section "Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities").

As in the benchmark year, it is assumed that industries use inputs to produce in-house transportation in the same ratio as for-hire transportation. The ratio is the value of the input relative to the value of the transportation related inputs used by for-hire transportation. The ratios are calculated for each input used and for each of the four for-hire transportation industries estimated in the TSAs (for-hire air, rail, truck, and water transportation) using the annual data. The ratios are applied to distributed value of the commodities used for in-house transportation operations, as calculated in the step above. The resulting estimates are at the annual level of detail. They are subtracted from the producers' value of the commodity (from the annual IO use table) to find the portion of the commodity used by the industry for purposes other than in-house transportation operations.

The next step involves making adjustments to the estimates. In some cases, the estimated value of a commodity used for in-house transportation operations is larger than the total value of the commodity used by the industry. Adjusting the data at annual level of detail results in fewer adjustments. As a result, a larger portion of the total value of an input is designated for use in producing in-house transportation. This appears to be an over-estimate. Evidence of it being an over-estimate comes from adjusting the benchmark TSAs at the annual level of detail. When adjusted at the annual level of detail, in-house transportation is significantly larger in value than when the benchmark TSAs are adjusted at the benchmark level of detail.

For more accurate adjustment, the annual estimates are re-estimated at the benchmark level of detail by assuming that the items making up the commodity make up the same proportion in the annual year as in the benchmark year. The data then are balanced, as described in step 5 of the above section “Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities”. The value added by in-house transportation is calculated (as described in step 5 of the above section “Estimating In-house Air, Rail, Truck, and Water Transportation by Nontransportation Industries for Business Activities”) using the annual IO data and rebalanced. Afterwards, the data are summarized to the annual level and balanced a final time.

Estimating In-house Transportation by Households

The TSAs follow the framework of the IO accounts. Per this framework, the inputs to production are shown for individual industries. The household production of transportation services (HPTS) can be thought of as an industry. Adding HPTS to the TSAs therefore requires estimating the value of intermediate inputs used by households for user-operated transportation activities and the value-added inputs for HPTS. The time households spend in their cars and the costs households impose on the environment in driving their cars are not counted. Both are outside the scope of the IO accounts, upon which the TSAs are built. The IO accounts, by design, do not include unpaid labor, volunteer work, and other non-market production.

1. Estimating the intermediate inputs for HPTS

   Inputs for household production of transportation services can be classified into two major components: ownership and operating inputs. The IO accounts provide information on both in personal consumption expenditures (PCE). Estimating the inputs for HPTS therefore requires extracting the information from PCE.

   Adding HPTS to the TSA requires extracting the PCE relating to ownership and operating inputs and reclassifying them so as to show their value within the IO framework. Ownership inputs are reclassified as fixed private investment in the final use portion of the IO use table and operating inputs are reclassified as intermediate inputs into HPTS, which is added as an industry and commodity to the intermediate portion of the IO use table. Table 8 lists the PCE and input classification.

   In the annual IO accounts, both ownership and operating inputs are classified as PCE. However, the detail is not available for extracting and reclassifying each PCE as in the benchmark year. The total amount spent on new and used motor vehicles and the total amount spent on goods related to the operation of a motor vehicle by a household are available in the Bureau of Economic Analysis’ (BEA) fixed asset tables.

Ownership inputs are estimated for the annual year using the fixed asset data. The value of each intermediate input is assumed to account for the same proportion of the total amount spent on new and used motor vehicles as in the benchmark year. The ratio of each intermediate input to the total amount spent on new and used motor vehicles is calculated using the benchmark data and applied to the total amount spent on new and used motor vehicles in each year where only annual data are available.

Intermediate inputs to HPTS are likewise estimated for the annual year using the fixed asset data. The value of each intermediate input is assumed to account for the same proportion of the total amount spent to operate motor vehicles as in the benchmark year. The ratio of each intermediate input to the total amount spent to operate motor vehicles is calculated using the benchmark data and applied to the total amount spent to operate motor vehicles in each year where only annual data are available.

Table 8. Personal Consumption Expenditure (PCE) Inputs into the Household Production of Transportation Services (HPTS)

Ownership inputs for HPTS (PCE related to ownership in I-O accounts)

Personal Consumption Expenditure	Components	2002 IO code*	Industry re-assigned to
New motor vehicles	New domestic autos	CNDC02	Fixed private investment
	New foreign autos	CNFC02	Fixed private investment
	New light trucks	CNWT02	Fixed private investment

Operating inputs for HPTS (PCE related to motor vehicle operation in I-O accounts)

Personal Consumption Expenditure	Components	2002 IO code*	Industry re-assigned to
Motor vehicle parts and accessories	Tires	CTAT02	HPTS
	Accessory and parts	CPAA02	HPTS
Motor vehicle fuels, lubricants, and fluids	Gasoline & other motor fuel	CGAS02	HPTS
	Lubricants & fluids	CLUB02	HPTS

	New motorcycles	CNMC02	Fixed private investment
Net purchases of used motor vehicles	Used autos	CNPU02	Fixed private investment
	Used light trucks	CNWT02	Fixed private investment
	Used motorcycles	CUMC02	Fixed private investment

Motor vehicle maintenance and repair	Motor vehicle maintenance and repair	CVMR02	HPTS
Other motor vehicle services	Truck leasing	CTLE02	HPTS
	Auto leasing	CALE02	HPTS
	Motor vehicle rental	CMVR02	HPTS
	Motor vehicle insurance	CAIN02	HPTS
	Parking fees and tolls	CPFT02	
	Other road transportation services	CORT02	

PCE = personal consumption expenditure

HPTS = household production of transportation services

* Code is different in each benchmark year, although it is descriptively the same personal consumption expenditure. The 2002 code provided as an example.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics.

2. Estimating the value-added by HPTS
The value-added by HPTS can be defined as the sum of the value of labor services, indirect taxes, and other value added (primarily the value of capital services).

a. Labor services:
The IO accounts do not count the value of unpaid labor; therefore, the value of time spent driving is not counted.

b. Indirect taxes:
Assumed to be zero because of a lack of detailed data. Indirect taxes such as license fees are not presented explicitly in the IO accounts which the current TSAs are based.

c. Other value added:
Two components: return to capital and annual depreciation of household-owned vehicles. The return to capital is assumed to be zero since households are a non-profit sector. Annual depreciation in relation to household-owned motor vehicles are obtained from the BEA fixed asset tables.

Table 9 lists the primary data sources used in the above two steps for estimating HPTS.

Table 9. Primary Data Sources for Estimating Household Production of Transportation Services

Data	Source
Input-output accounts	U.S. Department of Commerce, Economic and Statistics Administration, Bureau of Economic Analysis, Benchmark Input-Output Accounts for the U.S. and detailed underling data files for the benchmark I-O accounts
Annual total depreciation of motor vehicles owned by consumers	U.S. Department of Commerce, Economic and Statistics Administration, Bureau of Economic Analysis, Fixed Asset Tables

Creating the TSA tables
The final step in the TSAs involves the production of the make, use, direct requirement, and total requirements tables. The steps for creating these tables are outlined below.

1. Creating the TSAs make table
The TSA make table is formed by adding five additional columns and a five additional rows to the IO make table containing the values of the five in-house modes. The value at the

intersection of the in-house transportation column and row for each mode *k* produced to conduct business activities equals the total output of in-house transportation from the iTIST table for mode *k*; the value for all other cells in the in-house transportation column and row equal zero. In all remaining cells, the cell value is the same as in the IO make table. The value at the intersection of the in-house transportation column and row for household transportation is the sum of the intermediate inputs and the value added (total output) by household production of transportation services through the use of a private motor vehicle. The resulting make table is shown in table 10.

Table 10. Derivation of the Values for the TSAs Make Table

Industry	$Commodity_1$	Commodity In-house transportation Air	 Rail	 Truck	 Water	 HPTS	$Commodity_n$	Total industry output
$Industry_1$	I-O make $value_{11}$	0	0	0	0	0	I-O make $value_{1n}$	Row sum
In-house transportation								
Air	0	$\sum iTIST_{AIR}$	0	0	0	0	0	Row sum
Rail	0	0	$\sum iTIST_{RAIL}$	0	0	0	0	Row sum
Truck	0	0	0	$\sum iTIST_{TRUCK}$	0	0	0	Row sum
Water	0	0	0	0	$\sum iTIST_{WATER}$	0	0	Row sum

HPTS	0	0	0	0	0	Total output of HPTS	0	Row sum
Industry_m	I-O make value_{m1}	0	0	0	0	0	I-O make value_{mn}	Row sum
Commodity output	Column sum	Column sum	Column sum	Column sum	Column sum	Column sum	Column sum	Column sum

KEY:

HPTS = household production of transportation services

iTIST = amount of nontransportation related commodity *i* needed to generate in-house transportation services for specified mode. Value at the intersection of the row and column of same in-house transportation mode is equal to the sum (∑) of all iTIST values for that mode.

columns are 1 to n; rows are 1 to m; mn = mth row and nth column

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

2. Creating the TSA use table
   The TSAs use table is an IO use table modified to show estimates of transportation related inputs. The estimates of transportation related inputs to produce business related in-house transportation are derived from the adjusted iTIST tables and added as additional columns and rows to the matrix formed from the nTIST values in the adjusted TIST table. The resulting matrix is appended to the final-demand portion of the IO use table (as altered so as to estimate household transportation) to form the TSA use table. The estimates of transportation related inputs to produce household transportation are those taken from the final use portion of the IO use table and those calculated in the preceding section on estimating the value added by the household production of transportation services. The resulting TSA use table is shown in table 11.

   In the TSA use table, inputs for for-hire transportation industries are all zero because these industries, by assumption, do not have any in-house transportation activities. In the in-house transportation row for business activities, the following cells equal zero:

a. The cell at the intersection of the in-house transportation row and column (the use of in-house transportation services to support in-house transportation activities), and
b. The cell at the intersections between the in-house transportation row and the for-hire transportation columns (the use of the in-house transportation services to support for-hire transportation activities)

With regards to household production of transportation services, the following cells equal zero:

c. The cell at the intersection of the in-house transportation row and column (the use of in-house transportation services to support in-house transportation activities) takes a value of zero.
d. The cell at the intersections between the in-house transportation row for household transportation and each intermediate industry.

All of the aforementioned cells take a zero value as in-house transportation services are provided only by nontransportation industries for their own use.

For the in-house transportation and all other rows, the sum of all entries equals the total output of the commodity. Similarly, the sum of all entries in each column equals the total output of the corresponding industry. The sum of the total commodity output column is the IO use value increased by the value of in-house transportation output.

Table 11. Derivation of the Values for the TSAs Use Table

Commodity	Industry$_1$	Industry					Industry$_n$	Final demand			Total commodity output
		In-house transportation						Personal consumption	Private Fixed Investment	Other	
		Air	Rail	Truck	Water	HPTS					
Commodity$_1$	$nTIST_{11}$	$\Sigma_i iTIST_{AIRi=1}$	$\Sigma_i iTIST_{RAILi=1}$	$\Sigma_i iTIST_{TRUCKi=1}$	$\Sigma_i iTIST_{WATERi=1}$	Amount of commodity 1 used to support private motor vehicle operating expenditures (taken from PCE)	$nTIST_{1n}$	I-O use value less private motor vehicle ownership and operating inputs	I-O use value increased by private motor vehicle ownership inputs from PCE	I-O use value	Row sum

In-house transportation											
Air	Σ_i iTIST$_{AIRj=1}$	0	0	0	0	0	Σ_i iTIST$_{AIR\ j=n}$	0	0	0	Row sum
Rail	Σ_i iTIST$_{RAILj=1}$	0	0	0	0	0	Σ_i iTIST$_{RAIL\ j=n}$	0	0	0	Row sum
Truck	Σ_iiTIST$_{TRUCKj=1}$	0	0	0	0	0	Σ_i iTIST$_{TRUCK\ j=n}$	0	0	0	Row sum
Water	Σ_iiTIST$_{WATERj=1}$	0	0	0	0	0	Σ_i iTIST$_{WATER\ j=n}$	0	0	0	Row sum
HPTS	0	0	0	0	0	0	0	Total HPTS output	0	0	Row sum
Commodity$_m$	nTIST$_{m1}$	Σ_j iTIST$_{AIRi=m}$	Σ_j iTIST$_{RAILi=m}$	Σ_jiTIST$_{TRUCKi=m}$	Σ_jiTIST$_{WATERi=m}$	Amount of commodity i used to support	nTIST$_{mn}$	I-O use value less private	I-O use value increa	I-O use	Row sum

						private motor vehicle operating expenditures (taken from PCE)		motor vehicle ownership and operating inputs	sed by private motor vehicle ownership inputs from PCE	value	
Total intermediate inputs	Intermediate input column sum	Intermediate input column sum	Intermediate input column sum	Intermediate input column sum	Intermediate input column sum	Intermediate input column sum	Intermediate input column sum	N/A	N/A	N/A	N/A
Total value added	$\Sigma_{j=1} nTIST_{i=VA}$	$\Sigma_j nTIST_{AIRi=VA}$	$\Sigma_j iTIST_{RAIL\ i=VA}$	$\Sigma_j nTIST_{TRUCKi=VA}$	$\Sigma_j nTIST_{WATER\ i=VA}$	Depreciation of motor vehicles	$\Sigma_{j=n} nTIST_{i=VA}$	N/A	N/A	N/A	N/A
Industry output	Intermediate input + total value added	Intermediate input + total value added	Intermediate input + total value added	Intermediate input + total value added	Intermediate input + total value added	Intermediate input + total value added	Intermediate input + total value added	N/A	N/A	N/A	Column sum

KEY: N/A = not applicable

VA = value -added

i = ith commodity

j = jth industry

columns are 1 to n; rows are 1 to m; mn = mth row and nth column

Σ_i iTIST $_{kj}$ = column total from the iTIST table for industry j and mode k, where k = air, rail, water, or truck

Σ_j iTIST $_{ki}$ = row total from the iTIST table for commodity i and mode k, where k = air, rail, water, or truck

Σ_j iTIST $_{ji=VA}$ = row total from the iTIST table for all value-added commodities used in mode k, where k= air, rail, water, or truck

Σ nTIST $_{VAJ}$= sum of nTIST values for value-added commodities for industry j

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

3. Creating TSA direct requirements table
   The TSAs direct requirements table shows the direct requirement coefficients for each commodity and industry. These values are the amount of a commodity (on a row) required by an industry (on a column) to produce a dollar of the industry's output.

   The direct requirements table comes from the TSA use table. The coefficients a_{ij} in the table are derived by dividing the TSA use value for each commodity *i* used by industry *j* by the total output for the industry:

   a_{ij} = (TSA use $value_{ij}$) ÷ ($\Sigma_{j=1}$ TSA use $value_{ij}$)

   The coefficients for industry *j* sum to unity. Coefficients are calculated for all industries in the TSAs use table but not for the components of final use or GDP. The resulting table is shown in table 12.

Table 12. Derivation of the Values for the TSAs Direct Requirements Table

Commodity	$Industry_1$	Industry					$Industry_n$
		In-house transportation					
		Air	Rail	Truck	Water	HPTS	
$Commodity_1$	a_{11}	a_{1AIR}	a_{1Rail}	a_{1Truck}	a_{1Water}	a_{1HPTS}	a_{1n}
In-house transportation							
Air	a_{AIR1}	$a_{AIRAIR}=0$	$a_{AIRRAIL}=0$	$a_{AIRTRUCK}=0$	$a_{AIRWATER}=0$	$a_{AIRHPTS}=0$	a_{AIRn}
Rail	a_{RAIL1}	$a_{RAILAIR}=0$	$a_{RAILRAIL}=0$	$a_{RAILTRUCK}=0$	$a_{RAILWATER}=0$	$a_{RAILHPTS}=0$	a_{RAILn}
Truck	a_{TRUCK1}	$a_{TRUCKAIR}=0$	$a_{TRUCKRAIL}=0$	$a_{TRUCKTRUCK}=0$	$a_{TRUCKWATER}=0$	$a_{TRUCKHPTS}=0$	a_{TRUCKn}
Water	a_{WATER1}	$a_{WATERAIR}=0$	$a_{WATERRAIL}=0$	$a_{WATERTRUCK}=0$	$a_{WATERWATER}=0$	$a_{WATERHPTS}=0$	a_{WATERn}
HPTS	0	0	0	0	0	0	0

Commodity$_n$	a_{m1}	a_{nmAIR}	a_{mRAIL}	a_{mTRUCK}	a_{mWATER}	a_{mHPTS}	a_{m1}
Industry sum	Column sum	Column sum	Column sum	Column sum	Column sum	Column sum	Column sum

KEY:

HPTS = household production of transportation services

i = ith commodity

j = jth industry

columns are 1 to n; rows are 1 to m; mn = mth row and nth column

a_{ij} = TSA use value$_{ij}$ ÷ $\Sigma_{j=1}$ TSA use value$_{ij}$ = direct requirement coefficient for intermediate commodity *i* for industry j (excluding final uses)

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics

4. Creating TSA total requirements table
   The TSA total requirements table shows the commodity by industry total requirements coefficients. These coefficients show the production directly and indirectly required to deliver a dollar's worth of goods and services to consumers and other final users. Each column shows the commodity delivered to final users, and each row shows the demand for an industry's output in response to a dollar increase in the final demand for the commodity. The last row shows the sum of all the changes in industry outputs that are required to deliver a dollar's worth of goods and services to final users. Because each of these sums is a dollar multiple of the initial dollar spent of an industry's output, the sum often is referred to as an "output multiplier". These multipliers can be used to estimate the impact of changes in the final demands of commodities on total industry output.[14] Hence, the table shows the interdependence among producers and consumers in the economy and can be used to derive estimates of the direct and indirect effects of changes in final demand on for-hire and in-house transportation industries and commodities. For instance, the table can be used to analyze the relative effects on transportation and nontransportation industries from an increase in government expenditures on transportation or from a change in the composition of fixed investment that results from a change in business activity.[15]

   The values in the table are calculated per the method used by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) (June 2008)[16]. The following describes the method.

Table 13. Variables, Constants and Symbols Used in Derivation of Total Requirements Table

Variable/ Constant Notation	Type	Description
q	Column vector	Commodity output vector. Shows the total amount of the output of a commodity.
g	Column vector	Industry output vector. Shows the total amount of an industry's output, including its production of scrap.
U	Matrix	Intermediate use table. Commodity-by-industry matrix in which each entry in a column shows the amount of each commodity used by the industry, including non-comparable imports, scrap, and second-hand goods.
V	Matrix	Adjusted make table. Industry-by-commodity matrix in which entries in each column show the amount of the commodity made by each industry.

		Adjusted to show zero entries in the column for scrap, noncomparable imports, and used and second hand goods.
e	Column vector	A column vector in which each entry shows the total final demand purchases for each commodity from the use table.
B	Matrix	Use coefficient matrix. Commodity-by-industry matrix in which each entry in a column show the amount of a commodity that an industry used per dollar of its output. Derived from matrix U.
D	Matrix	Market share matrix. Industry-by-commodity matrix in which each entry in a column shows the share of an industry in total output of a given commodity. Derived from matrix V.
i	Column vector	Unit vector. All entries are 1.
I	Matrix	Identity matrix. Square matrix in which value of 1 appears in the main diagonal cells and the value of zero appears in all other cells.
-	Matrix	Diagonal matrix. Symbol used to indicate a diagonal matrix. When placed over a vector, it indicates a square matrix in which the elements of the vector appear in the main diagonal cells and zeros in the other cells.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, available at https://www.bea.gov/industry/pdf/total-requirements-derivation.pdf, as of February 2017

Derivation of the total requirements table used the following mathematical procedure, which involves the following identities[17]:

1. $B = U \times g^{\wedge -1}$
2. $D = V \times q^{\wedge -1}$
3. $q = U \times i + e$
4. $g = V \times i$

We arrive at the commodity-by-commodity total requirements table through the following:

From (1) and (3) we derive

5. $q = B \times g + e$

And from (2) and (4) we derive

6. $g = D \times q$

Substituting (6) in (5) and solving for q, we obtain

7. $q = (I - B \times D)^{-1} \times e$

Where $(I - B \times D)^{-1}$ is the commodity-by-commodity total requirements matrix

We arrive at the industry-by-industry total requirements table through the following: Substituting (5) into (6) and solving for g, we obtain.

8. $g = (I - D \times B)^{-1} \times D \times e$

Where $(I - D \times B)^{-1}$ is the industry-by-industry total requirements matrix

We arrive at the industry-by-commodity total requirements table through the following: Substituting (6) into (7)

9. $g = D \times (I - D \times B)^{-1} \times e$

Where $D \times (I - D \times B)^{-1}$ is the industry-by-commodity total requirements matrix

Only the commodity-by-commodity and industry-by-commodity total requirements table was published for the TSAs.

Concluding Remarks

There are several weaknesses to the TSA methodology. Many of these weaknesses can be attributed to assumptions in the IO accounts, including the assumption that:

1. There are no economies or diseconomies of scale in the production process. In other words, there is a direct, linear relationship between inputs consumed by an industry and the level of output of an industry within a single year. This assumption is contrary to most production functions in economics, which are non-linear in nature, as well as to most industrial organization theory, which assumes that some industries are more economically competitive and hence do not use commodities in the same proportion as less competitive industries.

2. Each industry produces a single commodity with a unique input structure. The commodity is assumed to be homogenous and hence to possess no distinguishing qualities or features.

3. Changes in price do not affect the proportion of inputs used. The level of inputs changes only in response to a change in final demand.

4. Inputs are not substitutable. This means that within a given technology there is one preferred set of input ratios that will continue to be preferred regardless of final demand quantities.

These assumptions in part contribute to the following weaknesses in the TSAs:

1. The assumption that production processes are linear and exhibit constant returns to scale even though likely to vary across industries, for the reasons discussed above.

2. The assumption that larger employment numbers are an indicator of greater in-house transportation production and consumption.

3. Reasonability in the scale of inputs to other inputs when preparing the general ratio. The general ratio is constructed under the assumption that the inputs are related and that production processes are constant.

Other weaknesses in the TSAs include the following:

1. Split factors and modals shares are commodity, not item specific. TRIs comprising the same commodity are assumed to be used in transportation and by a specific transportation mode in the same proportion even though they are different items.

2. The TSAs do not incorporate measures of capital stocks. This problem, however, can be corrected with estimates from the Transportation Infrastructure Capital Stocks Accounts (TICSAs).

Not all of the weaknesses in the TSAs can be corrected, particularly those that arise from assumptions in the IO accounts.

The TSAs from 2002 forward improve upon previous TSAs by:

- Using a single data source to distribute the in-house value of air, rail, water, and truck transportation,
- Using the annual IO accounts to produce annual TSAs, and
- Providing an estimate of the value added by household production of transportation services.

The TSAs reflect BEA's IO data as of the date received or downloaded from the BEA website. 2002 TSAs based on 2002 benchmark U.S. Input-Output data (as of 06/2010); 2003-2006 TSAs based on annual U.S. Input-Output data (as of 12/2015), 2002 benchmark U.S. Input-Output data (as of 06/2016), and 2007 benchmark U.S. Input-Output data (as of 06/2010); 2007 TSAs based on 2007 benchmark U.S. Input-Output data (as of 06/2016); and 2008-2016 TSAs based on annual U.S. Input-Output data (as of 12/2017). BEA updates IO data on an on-going basis; hence, data are subject to change. These changes are captured only when the TSAs are revised.

In summary, the TSAs extend the IO accounts and provide a more complete picture of the contribution of transportation to the economy by explicitly showing the contribution of in-house air, rail, truck, and water transportation and measuring the contribution of household transportation conducted using a private motor vehicle.

[1]The original TSAs were designed by the MacroSys Research and Technology under a subcontract with AMTI (Contract No. SK-97-2). The first version, using the 1992 benchmark IO accounts, was delivered at the end of April 1997 and the second version, using the 1996 benchmark IO accounts, was completed in the year 2000. Revisions to the original method were made by the Bureau of Transportation Statistics to produce TSAs for the years1997 through 2012.

[2]For information on how the treatment of transportation in NAICS differs from that in the Standard Industrial Classification System (SIC), see the section "Changes in Method in the 1997 TSAs and Comparability" in this report.

[3]For information on the treatment of secondary products in the 1997 U.S. IO accounts, see: Lawson, Ann M. et al., "Benchmark Input-Output Accounts of the United States, 1997," *Survey of Current Business*, December 2002, pg 27.

[4]The U.S. IO accounts are the foundation for the TSAs. The TSAs make no attempt to verify or correct any problems that may exist in the IO accounts.

[5]The weights used in the 1997 TSAs were developed from data on the stock of transportation vehicles (aircraft, railcars, trucks, and water vessels). Because of the difficulty in acquiring this data, the TSAs from 2002 forward were developed from data on the employment of transportation workers, published by the Bureau of Labor Statistics as part of the Employment Projections program: http://www.bls.gov/emp/

[6]Adjustments were made after applying the for-hire relationship to ensure that the value of the transportation and nontransportation component of each commodity used by an industry equals that in the IO use table before rearrangement.

[7]The TSAs are developed using the *after redefinitions* version of the IO accounts. "Redefinitions are made when an industry's production of a secondary product has very different inputs ("recipe") than those for the production of its primary product. In such as case, the secondary product (output and inputs) is moved ("redefined") from the industry in which the output occurs to the industry in which the product is primary. For example, the output and associated inputs for the restaurants located in hotels are moved from the hotels and lodging places industry to the eating and drinking places industry." (Concepts and Methods of the U.S. Input-Output Accounts, U.S. Department of Commerce, Bureau of Economic Analysis, April 2009, http://bea.gov/papers/pdf/IOmanual_092906.pdf) Redefinitions can result in transportation produced by a nontransportation industry, for its own use, to be reclassified as for-hire transportation. However, there is no significant evidence of this occurring or at an increasing (or decreasing) rate over time as the total industry output for each for-hire transportation mode is minimally different in the IO tables *before redefinition* and those *after redefinition*.

[8]U.S. Department of Energy, Energy Information Administration, Annual Energy Review, as of October 2014, tables 5.13a-5.13d and table 6.5.

[9]U.S. Department of Energy, Oak Ridge National Laboratory, Transportation Energy Data Book: Edition 24 and 28, table 2.5. Light fuel oils are referred to as diesel in this publication.

[10]U.S. Department of Transportation, Federal Highway Administration (FHWA), Highway Statistics. Data for 2002 received as special tabulation from FHWA. Data for 2007 as reported in U.S. Department of Transportation, Bureau of Transportation Statistics, National Transportation Statistics: Chapter 1, table 1-35 [as of September 2014].

[11]Stock values are used rather than flows because there are not readily available flow estimates indicating the intensity in which industries use transportation in their production process. It is assumed that employing a larger number of transportation workers implies that an industry uses a larger share of the related transportation mode in producing output. The actual employment values are not used; rather, the number of employed persons is used to create shares that indicate an industry's relative use of a mode.

[12]Nontransporation commodities are commodities in the IO table not classified as for-hire transportation

[13]The received 2002 IO use table did not balance with the make table. As a result, the margin ratios were derived from the summary IO use table (after redefinition) on the BEA website. As the online table contains less detail than that in the received table, industries and commodities were grouped (per the NAICS IO table released by the BEA with the 2002 Benchmark IO data made available online) and iTIST values summed together before applying the ratios. To ensure correct groupings, the received make table (for which the total value equaled the total value of the IO make table on the BEA website) was matched to the summary make table (after redefinition) on the BEA website.

[14]For more information on the derivation of the industry-by-commodity total requirements table, see: *Handbook of Input-Output Table, Compilation and Analysis* (New York: United Nations, 1999).

[15]When deriving the TSAs industry-by-commodity total requirements coefficients, the underlying IO assumptions are maintained. This includes the assumption that the technology and relative prices defining the relationships between producers and consumers within a given year remain constant. For more information, see: U.S. Department of Commerce, Bureau of Economic Analysis, “Concepts and Methods of the U.S. Input-Output Accounts,” September 2006.

[16]The total requirements coefficients released by BEA cover the transportation required to produce a commodity for consumers. They do not include the transportation required in shipping the good to the final user. In following BEA’s methodology for producing a total requirements table, the total requirements coefficients in the TSAs do not capture the transportation required to move the good produced by an industry to consumers.

[17]As mentioned in the discussion, these are identities which are not calculated as part of the total requirements table.

Updated: Friday, February 16, 2018