# The Transportation Services Index: Its Methodology and Relationship to the Business Cycle

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**Summary**

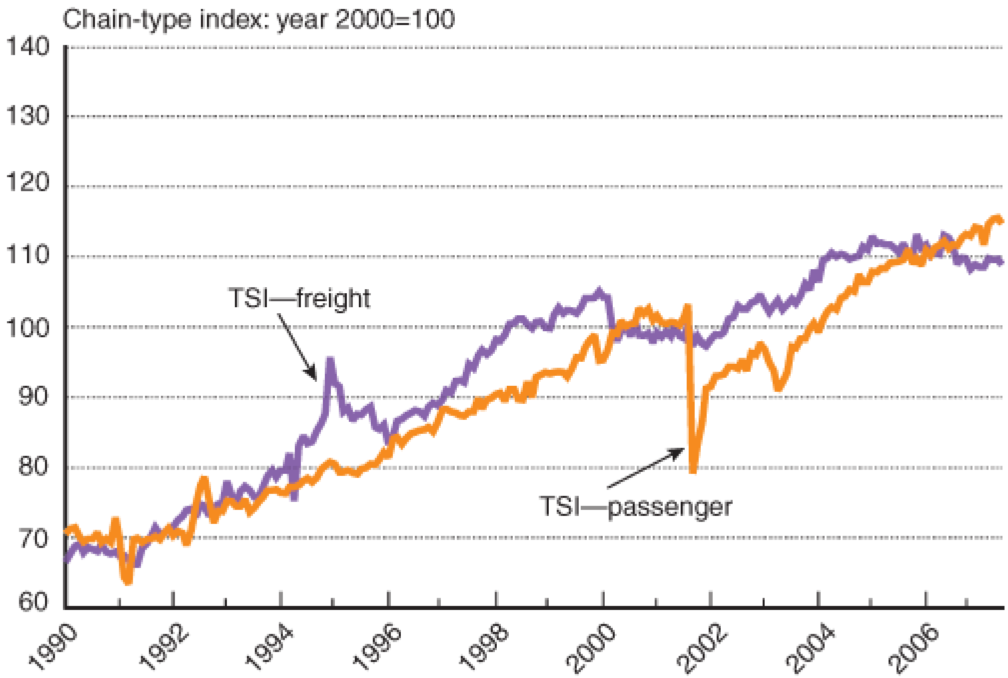
The March 2005 release of the Transportation Services Index (TSI), an economic measure of freight and passenger movements,[1] marked the Bureau of Transportation Statistics' (BTS') entry into the company of federal statistical agencies that produce monthly U.S. economic indicators. The TSI consists of three component indexes: a freight index, a passenger index, and a combined (or total) index. Figure 1 shows the freight and passenger indexes as recently displayed on the BTS website.

The TSI is the broadest monthly measure of U.S. domestic transportation services and, as such, provides the best current measure available of these services. As an index, the TSI reflects real monthly changes in freight and passenger services in the United States.

After development of the TSI, followed by additional research, it became clear the TSI moved in conjunction with other indicators of the national economy, in particular the business cycle of recession and expansion, and the growth cycle. The TSI, as presently published on the BTS website, spans the time period from 1990 to the present and covers two recessions (plus the present recession, thus far) . But, extending the TSI back to 1979 allows coverage of two additional recessions[2] and numerous growth cycles. By comparing the turning points in the extended TSI with other economic data series, it is possible to ascertain whether and how transportation services relate to movement in the overall economy (this study does not include discussion of the current recession, which is still under study). Analyzing the relationships between the turning points of the TSI and measures of the broader economy reveal some interesting results.

One finding is that the freight component of the TSI, which encompasses five modes of transportation, shows a strong leading relationship to the business cycle. When the accelerations and decelerations of the freight TSI (the turning points in the detrended series) are compared to the growth cycles of the economy, the freight measure leads by an average of approximately 4 to 5 months. The passenger TSI was identified as a coincident indicator with the general economy.

# Figure 1: The Transportation Services Index, January 1990 to June 2007




SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

**Background**

In 2002, a team of academic researchers, under a grant from BTS, developed the Transportation Services Output Index (TSOI) to measure the economic activity of the transportation sector (Lahiri and Stekler, 2002). This monthly output index of for-hire U.S. transportation services represented passenger and freight movements. Their early research indicated a relationship between changes in the transportation services sector and the recessionary phase of the business cycles (Lahiri et al., 2003 and 2004).

Recognizing the potential importance of the TSOI to the transportation and economic communities, BTS developed what was initially an experimental version of the index, the Transportation Services Index, or TSI. It included an overall measure of transportation services and two additional indexes derived by separating the passenger and freight components.

The sections that follow discuss the data components of the TSI along with the procedures for deseasonalizing, indexing, and weighting the data to create the indexes. This is followed by discussion of economic hypotheses on the nature of the relationships between the TSI measures and the recessions and growth cycles. Then, the discussion focuses on how the turning points are determined and analysis of the turns of the TSI against the turns in the business and growth cycles. The final section provides conclusions as well as suggestions for future research.

**The Transportation Service Index**

Transportation services are employed to either move freight or move passengers. Given that the freight and passenger sectors are influenced by different forces in the economy and may exhibit different trends, the TSI is represented by three indexes: freight transportation services (freight TSI), passenger transportation services (passenger TSI), and total TSI, which is a combination of the freight and passenger data.

The TSI includes only domestic "for-hire" transportation operated on behalf of or by a company that provides transport services to an external company for a fee. Not included in the for-hire population is transportation in vehicles owned by private firms providing services to that firm, taxi and intercity bus services, and noncommercial passenger transportation (e.g., trips in the family car). According to a prior BTS report, "*Transportation Satellite Accounts: a New Way of Measuring Transportation Service in America*" (Washington, D.C., February 1999), the for-hire transportation services component constitutes approximately 50 percent of total transportation services.

Analyses of the TSI were initially constrained by the limited duration of the published index, which covers the period from January 1990 to the present. For research purposes, BTS extended the index back to 1979. This allowed BTS to determine how the TSI behaves in relation to the U.S. economy by comparing the turning points in its cycles against those of key national economic variables. Table 1 provides a synopsis of the data sources. What follows is a discussion of the data utilized in the TSI, along with the methodology employed to aggregate the data.[3]

# Table 1. Data Sources for the Transportation Services Index (TSI)

| Mode | Source | Measure |
|---|---|---|
| **Freight** | | |
| Trucking | American Trucking Associations | Index of tonnage |
| Air | Bureau of Transportation Statistics and carrier websites | Freight ton-miles |
| Rail | Association of American Railroads | Carloads & Intermodal units |
| | Federal Railroad Administration (FRA) | Quarterly ton-miles |
| Water | U.S. Army Corps of Engineers | Tons |
| Pipeline | Energy Information Administration | Thousands of barrels, billion cubic feet |
| **Passenger** | | |
| Air | Bureau of Transportation Statistics and carrier websites | Revenue passenger-miles |
| Rail | Federal Railroad Administration | Revenue passenger-miles |
| Transit | American Public Transportation Association | Unlinked trips |

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

**Data Sources**

**Trucking** Data are obtained from the American Trucking Associations (ATA). Data on movements by truck are provided through a truck tonnage index, calculated by the ATA; this index is a relative measure of the total tonnage transported by the motor carrier industry for a given month. For the most recent data, BTS employs a preliminary value of the truck tonnage index (provided by ATA); when the official data become available, the preliminary values are replaced.

**Air Freight** U.S. air carriers operating between airports located within the boundaries of the United States and its territories report freight ton-miles monthly to BTS. As with the air revenue passenger-miles, the ton-mile data are drawn from air carrier reports to BTS on Form 41 Schedule T-100. See section on air passenger-miles for details.

**Rail** The rail freight data from 1990 to 2005 are derived from monthly carloads and intermodal units made available by the Association of American Railroads (AAR). These data are not a direct measure of ton-miles, but their monthly behavior is assumed to be similar to monthly ton-miles. For data prior to 1990, monthly data were not available, so BTS used quarterly rail ton-mile data taken from the Federal Railroad Administration (FRA). These quarterly values are then interpolated, using a quadratic polynomial to expand to monthly values.

**Water** Waterborne freight includes ton and ton-mile data, collected by the U.S. Army Corp of Engineers (USACE), for internal U.S. waterways. All maritime vessels are required by law to report freight and tonnage to the USACE, with the exceptions of the following: military cargo on military vessels; cargo carried on general ferries; fuel products, such as coal and petroleum, loaded from shore facilities directly into vessel bunkers; and insignificant amounts of government materials.

**Pipeline** Petroleum supply data are collected by the Petroleum Division in the Office of Oil and Gas of the Energy Information Administration (EIA), U.S. Department of Energy (DOE). The data in the TSI, which consist of the monthly sum of natural gas consumption, Alaska petroleum production, and the movement between PADDs (Petroleum Administration for Defense Districts), approximate the movement of natural gas and petroleum. [4]

**Air Passenger** The largest component of the passenger TSI is aviation. Aviation data are collected and compiled from two sources: Form 41, Schedule T-100 data submitted to BTS' Office of Airline Information (OAI) and from airline websites. The primary source of data, the T-100 dataset, contains extensive information on passenger air travel as well as freight movement by air. The TSI passenger index uses revenue passenger-miles data from the T-100 dataset.

In those instances where the current data may not yet be available in the T-100 database, BTS uses the carriers' web site postings of current passenger-miles. When T-100 data become available, these website values are replaced with the official data in the T-100.

**Rail** Rail revenue passenger-miles are compiled from the U.S. Department of Transportation, Federal Railroad Administration (FRA) data series for Amtrak and the Alaskan Railroad Corp. Commuter rail is not included in this measure because it is covered in the transit data.

**Transit** The final component of the TSI passenger index is transit. Monthly transit data from transit agencies operating heavy rail systems, bus systems and nearly all light rail and commuter rail systems, are collected by the American Public Transportation Association (APTA). Historic monthly revenue passenger-miles were not available for public transit from a federal agency; so the index uses APTA's monthly measure of unlinked trips.[5]

**Methodology** The individual modal data series are seasonally adjusted, and then indexed. The deseasonalized and indexed series are then combined into the three published series (passenger, freight, and total) using weighting and chaining techniques.

**Seasonal Adjustment** Examination of individual series data confirms anecdotal information about the seasonality of transportation activity. In order to portray real growth, BTS used a method called X-12-ARIMA to deseasonalize the data[7]. In applying the X-12 methodology to the transportation services time-series data, BTS found that each time series component of the TSI displays strong seasonal patterns.

The X-12 ARIMA method[6] is based on an approach that evolved over many decades starting in the 1950s at the U.S. Bureau of Census. Called X-12-ARIMA, Release 0.2, this procedure recently evolved out of the "X-11 Variant of the Census Method II Seasonal Adjustment Program." (Shishkin et al., 1967) The name, X-11, means 11 variations precede it.

Fundamentally, X-12 (without ARIMA) is a robust nonparametric method, which achieves its estimates through a series of iterative steps. As such, it is an "empirical" approach as distinguished from a "model-based" approach to seasonal adjustment. Although seasonal adjustments of the transportation series used in the TSI have been relatively small, statistical properties of the estimators, such as confidence intervals, are lacking.

ARIMA modeling was added to X-11 methods in 1975, thereby providing a statistical component to an iterative approach of successive smoothings. The ARIMA was introduced to model the data to produce forecasts that are used to extend the data series before undergoing the adjustments and smoothings. The seasonal adjustments were then found to be more reliable as measured by the reductions in revisions of estimates near the end of the series.

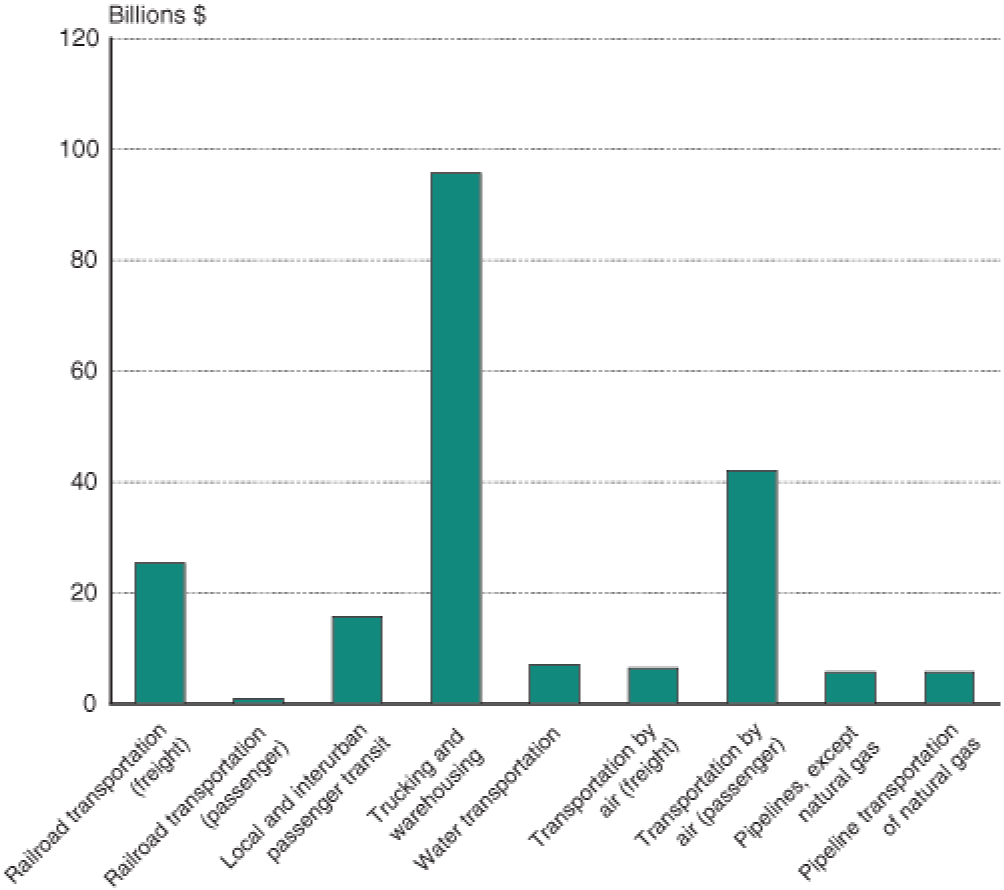
With the exception of transit, all time series used in the published TSI begin at January 1990. Table A-1 summarizes the characteristics of each of the 10 transportation time series employed in constituting the TSI. Note that with the exception of natural gas, the Auto-Regressive Integrated Moving Average (ARIMA) model that best suits the data can be specified as the Box-Jenkins "airline model," otherwise known as an ARIMA(011) (011)12. Note, too, that no suitable ARIMA model has been found for the carloads component of rail freight.

The longer historical time series data had the same distribution characteristics as the current data with one exception (trucking). For this reason, the decision was made to incorporate the same holidays in the historical time series models and to use the same parameter values for each holiday used in the current data. The pattern for historical data for trucking differed slightly with that in the published TSI; the historical data had to be modeled with a log transformation.

**Indexing, Weighting, and Chaining** After the individual data series are deseasonalized, the data are indexed using the 12-month average of data from the year 2000 as the base. Each modal series is indexed individually. Then weights for each transportation mode are created using Gross Domestic Product (GDP) value-added – as reported each year in the November issue of the *Survey of Current Business*, issued by the U.S. Department of Commerce's Bureau of Economic Analysis. Inputs to transportation, which are already counted in measures of other sectors, are not included. The index thereby acts as a measure of the economic activity added by the transportation sector itself.

These annual weights are "smoothed" to remove the abrupt end-of-year changes from December to January. The weights are then applied to integrate the individual modal indexes into combined freight, passenger, and overall transportation indexes. Figure 2 provides a graph of the relative impacts, represented in billions of dollars for a single year, to illustrate the relative weightings.

# Figure 2: Value-Added for TSI Components, 2002

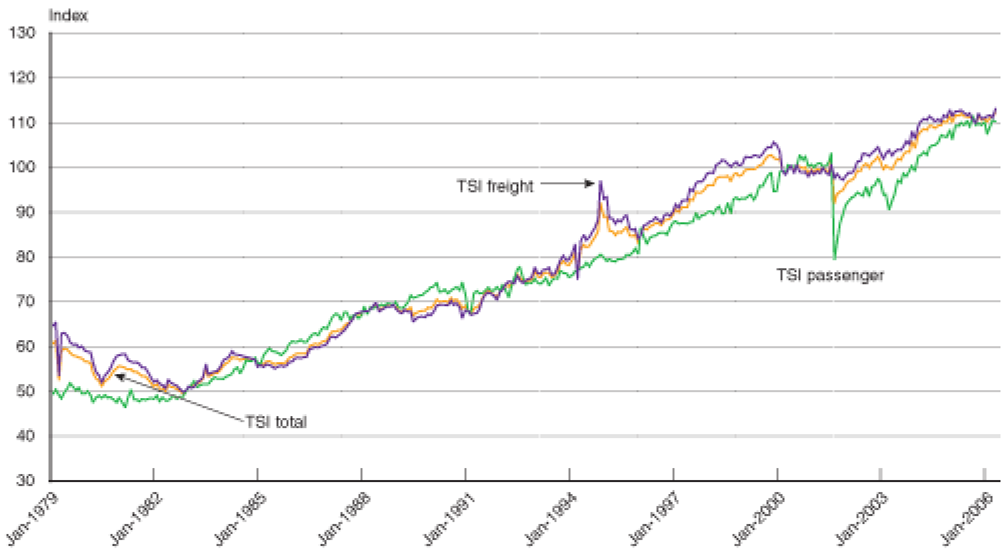



SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

The Fischer Ideal methodology (see Lent, 2004) is used to combine the indexes. Chaining is also used to generate period-to-period changes that are independent of the base year, because period-to-period changes are the focus of the index. When the indexing, weighting, and chaining have been completed, the final three indexes can be created: the total TSI, the passenger TSI, and the freight TSI.

As can be seen in figure 1, the TSI has experienced upwards growth throughout most of the reference period. Occasional dips and drops are obvious, and the impact of the terrorist attacks of September 11, 2001, is pronounced. Figure 3 shows the extended history of the TSI back to 1979. Discussed next is whether the changes in direction of the TSI measures can be related to the changes in direction of the economy.

# Figure 3: Three TSI's: Total, Freight, and Passenger, January 1979 to May 2006




SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

**The TSI, Transportation, and the Business Cycle**

Transportation services involve the movement of people, goods, and services. All transportation freight services, and many transportation passenger services, are undertaken to support other economic activities. Freight services move the products produced by the mining, agricultural, and manufacturing sectors of the economy; connect manufacturers to their sources of raw materials, intermediate goods, and spare parts; and provide the goods sold by wholesalers and retailers. Many passenger transportation services are used by business travelers whose travel is directly connected to economic activity.

Therefore, one would expect a measure of transportation services to have some relationship to other measures of economic activity, and perhaps track macroeconomic cycles. Indeed, GDP has been identified in the transportation economics literature as one of the main drivers of demand for freight transportation services (Wilson, 1980).

A measure of the output of the transportation sector, such as freight, might be even more valuable if it leads the other economic measures as it could then be used in forecasting those measures as well as macroeconomic cycles. There are a priori reasons to expect transportation to be a precursor of economic activity. Freight transportation activity, in particular, is directly tied to the supply chain and to the build-up and maintenance of inventories, and so transportation of finished goods may anticipate growth in sales at the retail and wholesale levels. A significant portion of freight volume consists of raw materials and other intermediate goods, which may be ordered in anticipation of growing activity in the manufacturing sector. Alternatively, a decline in freight shipments may result from anticipations of declines in economic activity in the downstream sectors. The build-up and decline of inventories probably explains why rail traffic figures have historically been used as a general economic indicator (Page and Wirtz, 2003).

These a priori reasons indicate that the transportation sector overall could be strongly related to the general economy. Individual transportation modes have been used in the past as indicators of the business cycle. However, there is reason to expect a *multimodal* measure of transportation to be superior to any single mode as an indicator of the overall economy, aside from the well-known statistical fact that indexes of several factors are nearly always more stable than single factors. A multimodal measure should be superior as an indicator because, by incorporating all modes, it "absorbs" the competition among the modes, and reflects the overall economic change more accurately than a single measure. Railroad carloads, for instance, could decrease if there were a change in the economic situation facing railroad customers and their logistics patterns due to problems in the economy, or the carloads could decrease due to a shift in traffic to waterborne transportation or to trucks. By contrast, an index that incorporates *all* modes is less subject to such vicissitudes in modal share.

Hence, it is reasonable to expect that changes in a multimodal index are more likely to represent the influence of macroeconomic factors. The TSI freight index works especially well in this regard because "for-hire" freight makes up a large portion of all freight movement. By contrast, the "for-hire" passenger TSI only includes a small portion of passenger transportation because travel by the private automobile is excluded.

**Business Cycles and Growth-Cycles**

The majority of cycle research in economics focuses on the business cycle, in which recessions and expansions are identified. In recent years, the U.S. economy has experienced fairly long time periods between recessions. Macroeconomists have identified growth cycles that occur within the larger business cycle. Growth cycles represent the cyclical changes in the economy once the long-term trend has been removed. Therefore, growth cycles highlight the accelerations and decelerations in the economy.

If downturns in the TSI also signal downturns in the growth cycle, then looking only at the business cycle and ignoring the growth cycle would cause the TSI to appear to generate "false positives," i.e., to indicate a change in the business cycle when no such change followed. This would make the TSI an imprecise indicator, even if all recessions were preceded by TSI downturns. By adding growth cycle slowdowns to the relatively few recessions, BTS can more completely test the relationship of the TSI to the economy. No particular reason exists to expect the TSI to have a different relationship to growth slowdowns, which likely impact inventory levels, ordering processes, and other transportation related supply chain factors, than to recessions.

**Identifying the Business Cycle and its Turning Points**

In 1946 Arthur Burns and Wesley Mitchell wrote the first major paper on business cycle turning points in the American economy. Turning points signal a shift from recession to expansion or expansion to recession, and are found at the trough or the peak of a business cycle. Using hundreds of historic data series, Burns and Mitchell identified clusters of turning points in the overall business cycle. (Burns and Mitchell, 1946)

The fundamental components of the business cycle described by Burns and Mitchell are still used today. However, because it is often not clear which observation is the "true" low or high point of a cycle until much later, methodologies for recognizing turning points have been refined frequently during the past 60 years.

**NBER and the Definition and Identification of Recessions**

The Business Cycle Dating Committee of the National Bureau of Economic Research (NBER) is regarded as the authority on identifying the turning points in business cycles. A recession is often considered a period of two consecutive quarters of decline in Gross Domestic Product. The Committee defines a recession as "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales," and determines peaks and troughs based on multiple sources, but requires no set methodology.

During the period from 1980 to the present, the Committee found four recessions. However, these shifts in the business cycle were not identified by NBER in real time; each of these recessions was identified several months, or years, after its conclusion. As a result of this time delay, as well as its lack of a formal methodology for duplication, the NBER process cannot be used to make real-time declarations about the economic conditions of the country. This delay in recognizing the cyclical turning points exists not only for the business cycle, but for the growth cycles as well, which are discussed next.

**Growth-Cycles and Turning Points**
Economists have determined that the growth cycles *within* a business cycle also have turning points. Turning points may signal the end points of expansions and recessions, or they may signal the endpoints of growth cycles. A growth cycle is a general slowdown in growth around a trend that continues to grow. As noted by Zarnowitz and Ozyildirim (2001), "growth cycles are generally shorter, more frequent, and much more nearly symmetrical than business cycles." Unlike business cycles, growth cycles are not declared by NBER. Various end points of growth cycles have been identified and are available in academic literature. For this analysis, the TSI team used the growth cycles as identified by Zarnowitz and Ozyildirim; their research utilized the composite index of coincident indicators (CCI), as defined and maintained by the NBER, to identify the economy's growth cycles. See table 2 for dates of these cycles.

Academics have developed procedures that formalize the identification of turning points for business cycles. One technique used as a starting point for many methodologies is an algorithm developed by Bry and Boschan (B&B) in 1971. Application of the B&B algorithm is also the first step in many growth cycle analyses. Two of the most widely used and academically vetted methodologies, the Phase-Average Trend and the Hodrick-Prescott filter, use the B&B technique to prepare the cycle for more in-depth analysis. The basic procedure for the B&B approach to identifying turning points, summarized in Appendix A[7], can be used to measure the turning points in other cycles, e.g., the TSI.

# Table 2: Dates of Business and Growth Cycles

| Business Cycles (Peak-Trough-Peak) | Growth Cycles (Peak-Trough-Peak) |
|---|---|
| Jan-80 – Jul-80 – Jul-81 | Mar-79 – Jul-80 – Jul-81 |
| Jul-81 – Nov-82 – Jul-90 | Sep-84 – Jan-87 – Jan-89 |
| Jul-90 – Mar-91 – Mar-01 | Jan-89 – Dec-91 – Jan-95 |
| | Jan-95 – Jan-96 – Jun-00 |

SOURCE: Zarnowitz and Ozyildirim (2001).

**Calculations of TSI turning points**

**TSI and Business Cycle turning points**
Utilizing the B&B procedure, BTS first took a 12-month moving average of the TSI data and then applied the 13-point Spencer curve[8] to all three series. The 12-month centered moving average allowed identification of the general location of the turns, whereas the Spencer curve helped pinpoint the date. Then, by referring back to the original data, BTS selected the peaks and troughs indicated by the moving average and Spencer curve. To see the impact of the moving average, BTS illustrates the freight and passenger indexes against their 12-month moving averages in figures 4 and 5.

After identifying the general dates of the peaks and troughs, BTS eliminated inappropriate turns, as specified in appendix B. The peaks and troughs in the two indexes were then compared to the turning points in the recessions, as identified by the NBER. The TSI results are displayed in table 3, along with the dates of the recessions. In figure 6 the smoothed freight and passenger time lines are compared graphically to the turning points of the business cycles (the shaded areas within the graph represent the recessionary periods).

The freight index tends to signal well the NBER declared recessions, but the changes in direction between the recessions raise the possibility of the freight index being too sensitive a measure. The passenger index, in contrast, shows little consistency regarding the lead / lag relationship. Unlike the freight index, the passenger index does not appear to be sensitive enough to relate to turns in the economy. The question suggested by figure 15 is why the freight index over-signals recessions. Studying the growth cycles helps explain the relationship found between the freight TSI and recessions.

# Table 3: Dates of Turning Points of TSI Freight and Passenger Against the Recessions

| | Economy | TSI freight | TSI passenger |
|---|---|---|---|
| Peak | Jan-80 | NA | NA |
| Trough | Jul-80 | Jul-80 | Mar-81 |
| Peak | Jul-81 | Feb-81 | |
| Trough | Nov-82 | Nov-82 | |
| Peak | | Apr-84 | |
| Trough | | Jul-85 | |
| Peak | | Dec-88 | |
| Trough | | Jul-89 | |
| Peak | Jul-90 | Aug-90 | Oct-90 |
| Trough | Mar-91 | Mar-91 | Mar-91 |
| Peak | | Dec-94 | |
| Trough | | Jan-96 | |
| Peak | Mar-01 | Dec-99 | Sep-00 |
| Trough | Nov-01 | Oct-01 | Sep-01 |

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

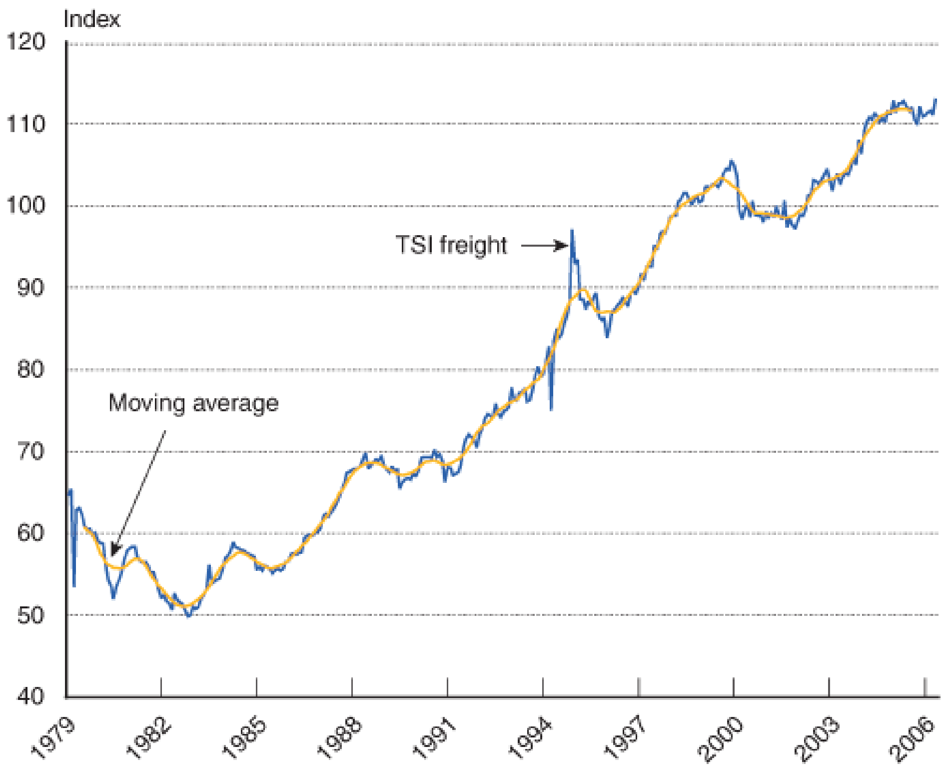
**TSI and Growth Cycles**

As noted in Zarnowitz and Ozyildirim (2001), recession turning points are not the only changes of interest in economic time series: the turning points affiliated with growth cycles also are of interest. This was first suggested in the original TSOI research performed by Lahiri et al. (2003).

In order to specify the growth curve turns, the data need to be detrended and, in its research, BTS chose to use the H-P, or Hodrick-Prescott, filter to remove the trend in the values in the time series.[9] The smoothed and detrended data for the two series are provided in figure 7.

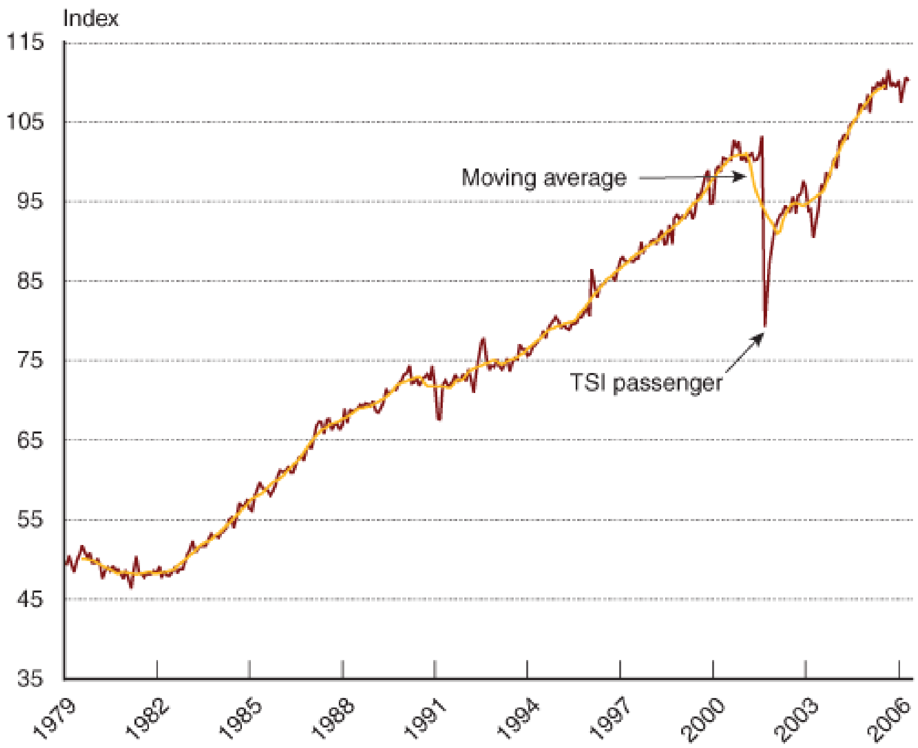
The resultant time series are specified in figure 8, along with the turning points of the Composite Coincident Index, or CCI, which indicate turns in the growth cycle of the economy as calculated by Zarnowitz and Ozyildirim (2001).[10]

# Figure 4: Freight TSI and 12-Month Moving Average, January 1979 to May 2006



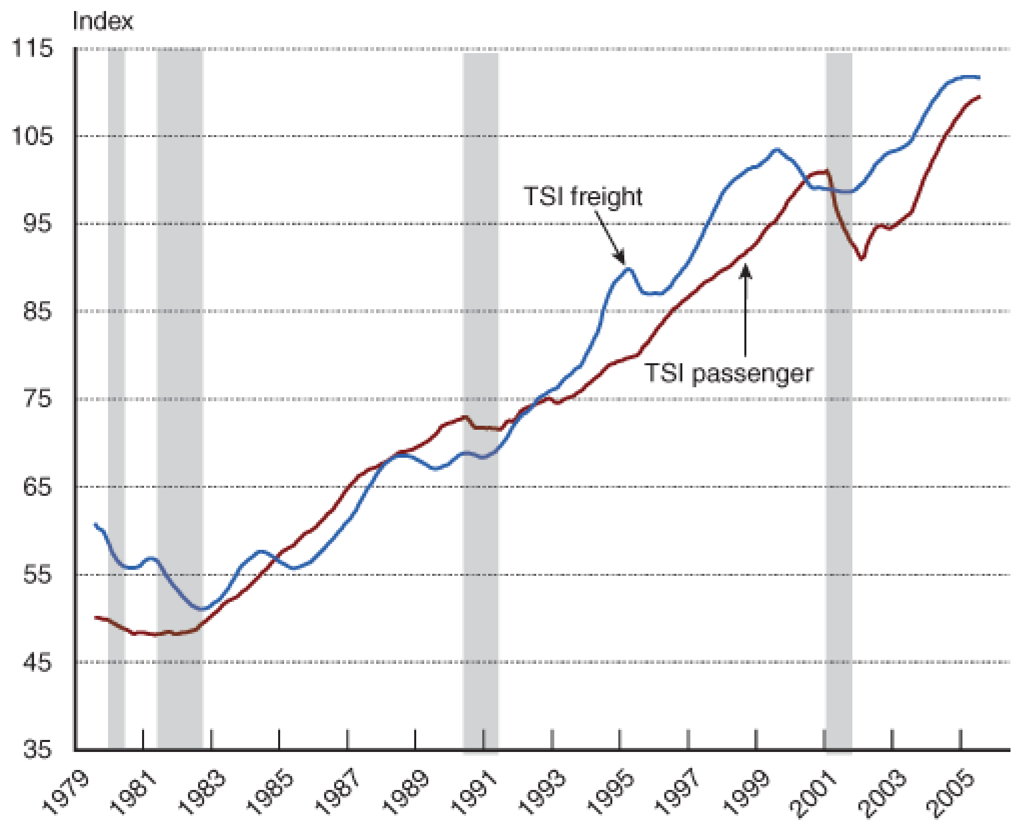

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

**Figure 5: Passenger TSI and 12-Month Moving Average, January 1979 to May 2006**



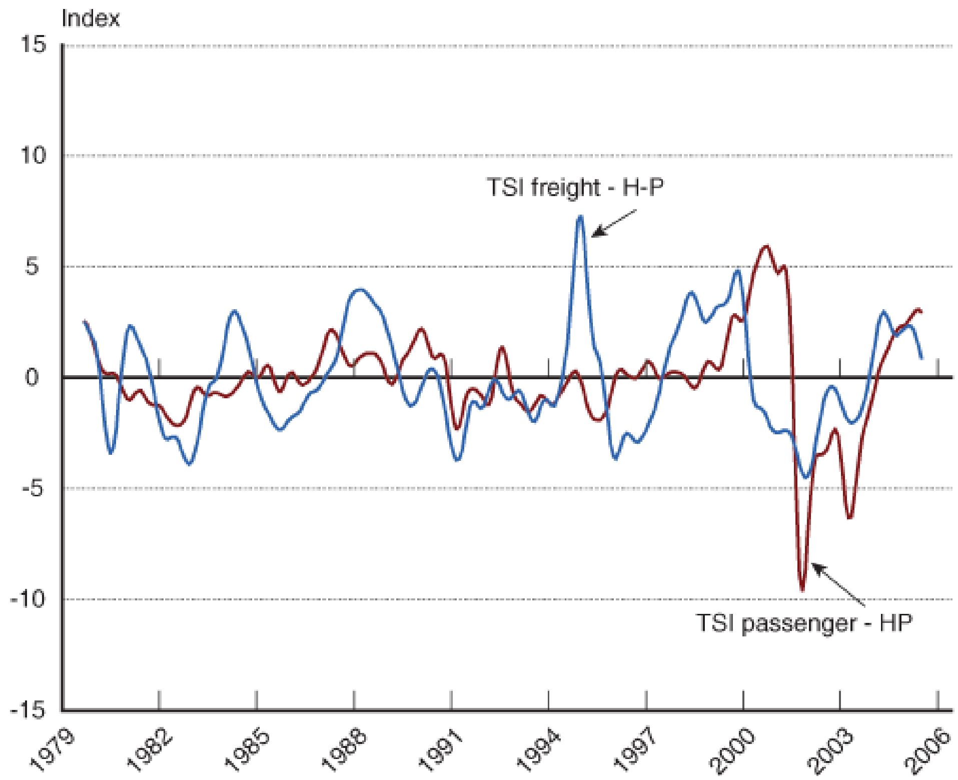

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

## Figure 6: TSI Matched Against the Recessions, January 1979 to August 2005

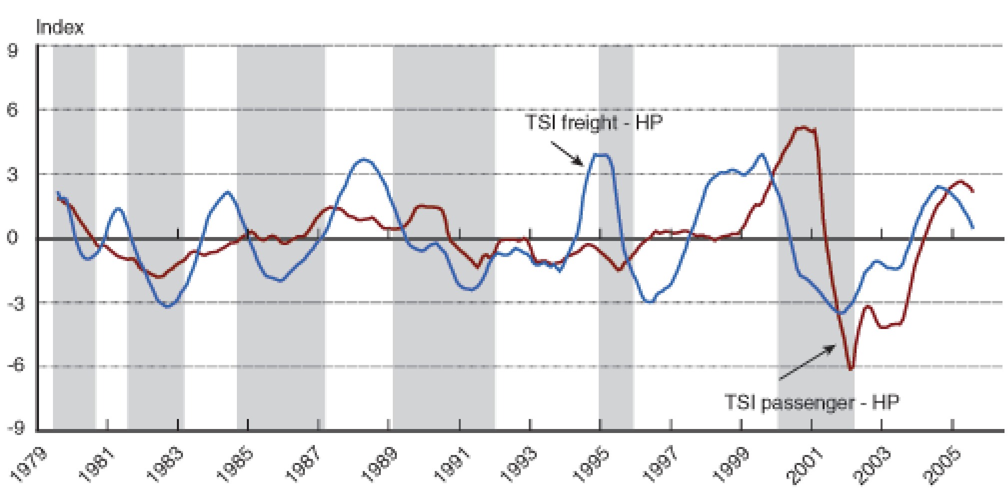



SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

## Figure 7: H-P filtered TSI, January 1979 to July 2005




## Figure 8: Smoothed TSI Freight and Passenger Against the Growth Cycles, January 1979 to August 2005




SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

As indicated in the figure, the turns in the freight component track more closely with the turns in the growth cycle. The passenger cycles are still not clear; this result might be attributable to the inclusion of only “for-hire” modes in the index, which thus lacks a very large component – automotive vehicle miles traveled (VMT). Consequently, BTS chose to examine further only the relationship of the freight index to the turns in the growth cycle.

Employing the same rules to eliminate spurious turns and then referring back to the original to pinpoint actual months in which the turns occurred, BTS compared the dates of the peaks and troughs against the turns in the growth cycle in the table 4. (Note that, although a downturn in the growth cycle may be occurring, as well as in the freight TSI in 2004 or 2005, BTS chose not to portray that potential turn so close to the endpoint of a time series.)

The TSI freight tends to lead the identified growth cycles at the peaks as well as at the troughs. To quantify the degree of lead, the final column in the table provides the number of months of lead or lag. On average, the TSI freight leads by 4 to 5 months for the troughs and 4 to 5 months for the peaks. The range of the degree of lead for the troughs is wider than the lead for the peaks, possibly indicating a more consistent relationship between the freight TSI and the peaks, or downturns, of the growth cycle. Only two false cycles occurred in the TSI freight – the first with a peak at July 1989 and a trough at March 1990, and the second with a peak at July 1992 and a trough at July 1993.

# Table 4: HP-filtered TSI Turning Points Against the CCI Growth Cycles

| | Economy | TSI freight - HP filtered | Lead / Lag of TSI in months |
|---|---|---|---|
| Peak | Mar-79 | | |
| Trough | Jul-80 | Jul-80 | 0 |
| Peak | Jul-81 | Jan-81 | +6 |
| Trough | Dec-82 | Nov-82 | +1 |
| Peak | Sep-84 | Apr-84 | +6 |
| Trough | Jan-87 | Oct-85 | +13 |
| Peak | Jan-89 | Jun-88 | +7 |
| Trough | | Jul-89 | -- |
| Peak | | Mar-90 | -- |
| Trough | Dec-91 | Mar-91 | +9 |
| Peak | | Jul-92 | -- |
| Trough | | Jul-93 | -- |
| Peak | Jan-95 | Dec-94 | +1 |
| Trough | Jan-96 | Jan-96 | 0 |
| Peak | Jun-00 | Nov-99 | +2 |
| Trough | Feb-02 | Sep-01 | +5 |

| | Peak | Trough |
|---|---|---|
| **Average lead in months** | **+4.4** | **+4.7** |
| **Range in months** | **1 to 7** | **0 to 13** |

SOURCE: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov.

## Conclusions and Future Research

The historical freight index anticipated the four NBER declared recessions in the 1979 – 2006 time period, but other turns in the index did not precede full-blown recessions or expansions. The passenger index showed little consistency regarding the lead / lag relationship with recessions. The final comparison of the turning points in the freight TSI against the turning points in the growth cycles, however, proved to be a strong relationship: *the freight TSI tends to lead the growth cycle, both at the peaks as well as at the troughs*, at least for the time periods from 1979 to the present. Economic theory provides justification of this leading characteristic.

While the above conclusion regarding the *history* of the TSI can be ascertained, it should be noted that it may be difficult to use this information in real-time to predict changes in the economy through turns in the TSI. Because the employed procedures utilize moving averages, 6 months of the most recent data are lost in the analysis. By our calculations, the freight TSI leads by less than that amount, thereby making it difficult to use the index as a predictor in real-time. In addition, several months of data after the turning point are needed to ascertain if the change in direction is more than just local variation; the usual rule-of-thumb is a change of direction that is maintained for at least 3 months. This additional requirement for monthly data further limits the ability to use the TSI as a real-time predictor of turning points in the economy, but it does not weaken the findings in the historical data. Transportation services, freight in particular, appear to lead the economy. The for-hire passenger TSI did not prove to be as predictive. But, again, this may be due to the fact that personal automotive VMT was not included in this index. By expanding the passenger TSI to include automotive VMT in the future, a more complete passenger travel index would be available for evaluation.

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**Appendix A: Bry and Boschan procedure**

I. Determination of extremes and substitution of values.
II. Determination of cycles in 12-month moving average (extremes replaced).
    a. Identification of points higher (or lower) than 5 months on either side.
    b. Enforcement of alternation of turns by selecting highest of multiple peaks (or lowest of multiple troughs).
III. Determination of corresponding turns in Spencer Curve (extremes replaced).
    a. Identification of highest (or lowest) value within ± 5 months of selected turn in 12-month moving average.
    b. Enforcement of minimum cycle duration of 15 months by eliminating lower peaks and higher troughs of shorter cycles.
IV. Determination of corresponding turns in short-term moving average of 3 to 6 months, depending on MCD (months of cyclical dominance).
    a. Identification of highest (or lowest) value within ± 5 months of selected turn in Spencer curve.
V. Determination of turning points in unsmoothed series.
    a. Identification of highest (or lowest) value within ± 4 months of selected turn in short-term moving average.
    b. Elimination of turns within 6 months of beginning and end of series.
    c. Elimination of peaks (or troughs) at both ends of series which are lower (or higher) than values closer to end.
    d. Elimination of cycles whose duration is less than 15 months.
    e. Elimination of phases whose duration is less than 5 months.
VI. Statement of final turning points.

[1] USDOT press release, January 29, 2004, available at: http://www.bts.gov/press_releases/2004/dot005_04/html/dot005_04.html.

[2] The National Bureau of Economic Research (NBER) declared recessions from January 1980 – July 1980, July 1981–November 1982, July 1990 – March 1991, and March 2001 – November 2001.

[3] For further detail regarding the data sources, the reader can refer to the TSI webpage on the BTS website: http://www.bts.gov/programs/economics_and_finance/transportation_services_index/html/source_and_documentation_and_data_quality.html.

[4] The pipeline data are only available back to 1980. This means that, for 1979, the freight component of the index does NOT include pipeline data. Rather, this component of freight was introduced into the index in 1980.

[5] The Federal Transit Administration began producing monthly data in January 2003 after the TSI was launched.

[6] For a reference on X-12-ARIMA, see Ladiray and Quenneville (2001).

[7] Taken from Bry and Boschan (1971), table I, page 21.

[8] The Spencer curve is a smoothing formula that uses simple averages to approximate more complex quadratic equations. For further information, see Kendall and Ord (1990).

[9] The HP filter used an alpha of 108,000 as suggested by Zarnowitz and Ozyildirim (2001) and by Lahiri et al. (2003).

[10]The turning points for the growth curves as specified by Zarnowitz and Ozyildirim (2001) only go up to June 2000. To estimate the trough of the final cycle noted by Zarnowitz and Ozyildirim, BTS applied the B&B turning point procedure to the recent Composite Coincident Index data. We did not attempt to estimate additional growth cycles, which do appear on the graph to be "in p