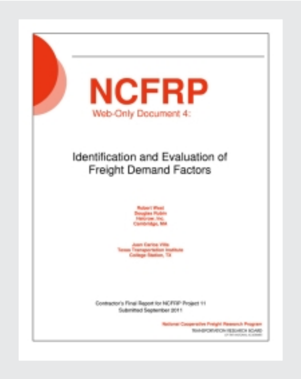
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Identification and Evaluation of Freight Demand Factors

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Contractor's Final Report for NCFRP Project 11
Submitted September 2011

National Cooperative Freight Research Program
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Robert West, Trade and Transportation Principal at Halcrow, was the initial Project Manager, with Douglas Rubin replacing him in the late fall of 2010 as co-Principal Investigator. Juan Carlos Villa, Associate Research Scientist at the Texas Transportation Institute was the other co-Principal Investigator.

EXECUTIVE SUMMARY

Many national freight forecasts have been predicting continued increases in the demand for freight transportation, and it has been generally accepted that the United States will have to invest many billions of dollars in new infrastructure. Many approaches to estimating freight growth have been used over time, for example Gross Domestic Product (GDP) or population growth. Over the past 30 years, various structural changes in the United States and even the world's economy require new approaches to understanding the key factors that influence freight demand.

The deregulation of most freight transportation markets in the early 1980s led to a new era of flexibility in the arrangements that providers could offer to their customers. Along with consolidation by providers, real prices decreased and demand increased as shippers, suppliers and retailers began to remake their production and distribution systems to take advantage of lower transportation costs and improved service. Economic expansion led to growth in freight transportation demand that was not necessarily evenly distributed and did not always move smoothly with GDP. Free trade agreements and the revolution of intermodal transportation led to longer supply chains and a shift in the utilization of transportation in the global marketplace.

The primary objective of this research effort was "to describe and analyze various types of demand drivers that shape the volume and movement of freight in North America." The goal was to identify a set of regularly generated, well-documented, easily-obtainable variables with high statistical significance in explaining the variability of different kinds of freight demand. Moreover, a contribution would be made if the research could identify one or more influencing variables that predicted changes in transportation demand during a subsequent period. By determining the significance and usefulness of these predictor variables, infrastructure investors and capital planners would be better able to predict freight transportation demands and make better decisions.

Although it is tempting to extend the relationship between exogenous economic and demographic variables to freight transportation demand on a regional basis, this effort was directed towards a national level. It was concluded that it was important to lay a firm foundation with regards to modeling freight demand using well-regarded, consistent and accessible economic data alongside reliable summaries of freight activity before trying to break the analysis down into sub-regions. In essence, the data as well as the desire for a strong foundation push the analysis toward national form. Whether the same relationships between the independent variables and freight demand that exist on a countrywide level also exist on a regional or state/local level is not demonstrated in this research, although in many cases it is an intuitively attractive hypothesis worthy of testing if appropriate data can be secured.

The research took the following steps as part of this analysis:

- Beginning with a review of NCFRP-01 "Review and Analysis of Freight Transportation Markets and Relationships," more than a hundred different studies and papers that examined the influencers of freight were reviewed so that the selection of independent variables would reflect state-of-the-industry and academic thinking regarding the question "What generates transportation?"

- It was determined that only those data that were readily and freely obtainable from 1980 through 2007 – beginning with the transitional event of US freight industry deregulation - would be considered. This assured a relatively long time series and results that others could replicate and build upon.
- Nine key measures of transportation demand, via trucking, rail and inland waterways -- 95% of domestic freight tonnage -- were summarized over 28 years sampled.
- A variety of statistical analyses – correlation, regression (with lagged/leading and dummy "shock" variables), and Principal Component Analysis – were used to derive multiple models that provided very high R^2 and low standard errors in respect to these measures.
- "Back casting" was performed to test and validate the quality of several of these models.

In brief, production factors such as GDP and Industrial Production measures are good predictors of "pure" transportation demand – namely total tonnage or volume of goods transported. Consumption factors such as Housing Starts and Imports, because of their associated lengths-of-haul, provide good predictive value to Ton-Mileage transported.

Trucking is more sensitive to consumer factors while rail is affected by a broader set of economic data including industrial production. Water freight grows with Total Capacity Utilization, Grain and Coal production, while water ton-miles have decreased as railroads have become more competitive at capturing share of long-hauls of heavy freight (such as export grain). Exogenous political factors like the deregulation of highway/railroad transportation during the early 1980's and the North American Free Trade Agreement (NAFTA) in 1993 led to significant, one-time increases in freight as well.

Besides the results of the models, major conclusions and takeaways include:

- The availability of quality data on economic activities and freight transportation demand is an inherent limitation that guides this analysis.
- While several of the economic variables or measures provide much of the explanatory variation regarding freight demand, other factors that might appear to be less significant serve to improve the various models.
- Early warning factors were identified by testing how well fluctuations in independent factors' values in one time period predicted changes in freight demand during the following time period by "lagging" the variables. Both the Purchasing Manager's Index and the Number of Households had significant effects on subsequent freight transportation demands, with Fuel Prices also having some effect. Independent of the other values, NAFTA led to a substantial increase in freight transportation as well.
- Principal Component Analysis provides a potentially helpful method to combine the explanatory benefit of multiple, similar independent economic factors on resulting freight transportation demand. While it is somewhat less intuitive and difficult to deconstruct, the method has been proven in other areas and appears to have some value at estimating freight demand from a large set of correlated independent factors.

- The backcasting analysis indicates strength and robustness of the test models as the calculated results shows good trending vs. the actual measures of economic data. A greater availability of quarterly data would have provided a richer detail to this end.
- The comparison of correlations and the effect of NAFTA and some of the other variables indicates that the relation of freight transportation demand to exogenous factors is not static. Since 1980, t here have been significant shifts in the way the same economic and demographic data affects demand for freight transportation. Future changes in these relationships as economies and countries transform are expected.

Ideas for additional research include extending the data capture through the 2008-2011 time period to determine how well the relationships between influencing variables and freight demand persist during and past the recent economic downturn. Also, if sufficient freight demand measures and independent economic variables exist on a multi-state regional basis, would similar analysis confirm that the same relationships that were found on a national level still apply?

1. Introduction

Background

In the last 25 years, the U.S. freight industry has transformed for a number of reasons. Population growth and migration have been fundamental factors, occurring alongside changes in the economy from goods to services. Transportation industry factors include the deregulation of freight railroads and trucking, the deployment of hub-and-spoke-based air freight, growth in international and domestic containerized intermodal freight, global supply sourcing, computerized-warehouse-based logistics, and, of course, the internet.

Changes in regulation led a new era of flexibility in the arrangements that providers could offer to their customers. Real prices decreased and demand increased as shippers, suppliers and retailers began to remake their production and distribution systems to take advantage of lower transportation costs and improved services. While freight flows via truck and rail grew at rate that basically matched overall economic growth, essentially doubling their ton-miles carried between 1980 and 2007, waterborne freight decreased by 40%.

But it would be simplistic to generalize and presume rail and truck transportation grows smoothly with GDP. The GDP index is made up of multiple components including service and government components that have grown faster than the non-durable and durable goods components. A million dollars of medical care or software does not generate the same demand for freight transportation as a million dollars of agricultural or automobile production does. This means that truck and rail transportation demands have actually grown faster than growth in the non-service sectors of the GDP.

Second, a simple comparison of year-to-year GDP growth with truck and rail ton-miles yields very poor correlations of 0.331 and 0.656, respectively. Housing Starts are a good proxy for economic optimism and consumption, and the Industrial Production Index, which measures the relative output of manufacturing, mining and energy producers, might be better measures of the segments of the economy that influence freight transportation demand.

There are other factors that affect freight transportation demand. Besides regulation, technological changes, such as intermodal containers and equipment tracking have made long-distance transportation less expensive and improved service quality. As customers continue to seek new products, best prices and high quality, suppliers and retailers have found it profitable to change their logistics strategies to utilize the advantages of the global marketplace. .

Advanced logistics and increasingly complicated supply chains, along with computerized sales and inventory tracking, has allowed the freight delivery industry to respond to small demand variations faster than ever before. In such periods of change, freight models must be updated to use the newest available data, and the modeler must be continually aware of changes in industry structure that may create the need for older models to be re-estimated. In particular, where freight models are being used to predict future volumes, whether short-term or long-term, it is useful to follow the axiom “If you are forecasting the future, do it often” in order to capture the latest developments.

An important goal of this research into freight demand factors is, ultimately, to provide insights into the structure of the U.S. freight system which can be used effectively to produce volume forecasts, both short term and long term. Nevertheless, using freight models to forecast future freight flows based on estimates of the input variables should be treated cautiously. Some of the concerns that should be heeded by the modeler when forecasting are:

- Historically estimated models may have become out-of-date.
- The input or independent variables themselves may be more difficult to forecast than the freight movement variable.
- The forecasts of the independent variables have, by definition, some amount of error.
- And finally, forecasts from freight models that were developed for one purpose are often used by their practitioners to solve or explain other problems outside the original scope and intent of the models.[1]

This study focuses on the identification of independent variables that can be used to explain gross measures of freight demand over historical periods long enough to capture some of the structural shifts described above.

Research Objectives

The federal government, as well as state and local agencies that oversee our nation's transportation system, seek to improve their understanding of factors that explain the magnitude and direction of changes in the demand for moving freight. Historically, projections of freight movement in the country have been imprecise. In particular, the more rapid growth experienced in freight compared to passenger transportation through the first part of this decade, the forecasts loosely described as a doubling of freight over the approaching years, and the depressed volumes that followed more recently, have together underscored the need to better understand the underlying factors affecting freight demand.

The goal is to enable decision-makers to more effectively plan transportation infrastructure and develop policies that improve the country's competitiveness. Consider that in 2008, 6.2% of the U.S, GDP was devoted to the cost of moving goods or services and 10.1% was spent overall on logistics. After almost two decades of efficiency gains following the deregulation of freight transportation in the early 1980s, a combination of higher fuel prices, increased demand, and realignment of supply meant that real costs of transportation were increasing and the 2008 figures were the highest percentage in eight years.[2]

The objective of this research is to describe and analyze various types of demand drivers that shape the volume and movement of freight in North America, principally within the U.S. Consumption of freight, the locations from which it is satisfied, and the modes, routes, and

[1] "What's Wrong with Freight Models?" Marcus Wigan, Frank Southworth, March 2009. "Confusion about what one can do with a given model is often founded on a lack of transparency as to the domain of application for which the model was originally designed and set up."
[2] Council of Supply Chain Management Professionals, State of the Logistics Union 2008

consolidations it utilizes result from many factors that interact at different geographic levels – global, national, regional, and local – as well as at different temporal spans, producing changes in magnitude and mode of transport used. This research seeks to identify those drivers that have the largest influence in explaining the variability and geography of freight demand, with the ultimate goal of producing better forecasts of freight volumes.

It is important to note that variables influencing demand cannot be analyzed in isolation, as it is often the specific combination and interaction of a collection of factors that influence the magnitude and direction of freight demand. Freight flows could be measured in several forms; the most common units are physical volumes like tonnage and vehicles, but units of work such as ton-miles and vehicle miles can be more expressive because they include the volume of goods combined with the distance moved.

Analytical Process

The following tasks comprised this research:

Task 1 – Prepare, Investigate, and Evaluate a Candidate List of Factors
Task 2 – Analyze the Candidate List of Factors
Task 3 – Determine Cost-Effectiveness of Factors
Task 4 – Define which Demand Factors are Good Early-Warning Indicators
Task 5 – Hold a Peer Exchange at the Beckman Center, Irvine, California
Task 6 – Address Outcome and Comments from Peer Exchange and Conduct Follow-Up Work
Task 7 – Prepare Draft Final Report and Presentation

The research team took the following specific steps:

1. Beginning with the bibliography from NCFRP-01 "Review and Analysis of Freight Transportation Markets and Relationships," a review of literature and current models was conducted to investigate recent industry and academic thinking on "What affects the demand for freight transportation?"
2. The team then investigated which economic and demographic variables, as well as one-time events (for example, the North American Free Trade Agreement or NAFTA) seemed to affect national transportation demand by highway, railroad and waterway. The most likely "drivers" of transportation demand were identified and then tested for collinearity because many may be tied to the same underlying factors, such as population or overall macro-economic activity.
3. The team chose a sparse number of key measures of freight moving by truck, rail, and waterway -- all but pipeline and air cargo (which accounts for an insignificant portion of total tonnage) -- that makes up 95% of United States domestic freight movements. To reflect the underlying demand for freight movement, variables such as tons handled and ton-miles moved were considered for each mode.

4. The team tested a variety of statistical analyses to come up with a number of models that utilize one or more of the independent economic variables to explain each of the separate modal transportation demands.
5. The team conducted additional analyses using an assortment of time-lagged independent variables to determine if various economic and demographic variables could be used to predict subsequent demand for transportation.
6. Finally, the team verified several of the models using existing data through a "backcasting" process, comparing actual data against model predictions for past periods.
7. The team presented preliminary findings at a peer exchange involving 31 participants from various freight industry sectors, government agencies, ports, consultants, and academia in Irvine, California, in May 2010. A summary of the feedback from the peer exchange is provided in Appendix A.
8. The research team prepared this final report, incorporating the peer exchange and other feedback received on the preliminary work.

2. Measuring and Estimating Transportation Demand

In Task 1, the research team reviewed existing freight demand models and related literature to identify and evaluate a wide variety of freight demand measurements and the potential independent factors that could be used to predict these demands. The following principles were applied to this review of potential measures of demand and of the independent, predictive variables:

- The independent variables that influence transportation demand should be easy and inexpensive to gather and should be recognized as important and regularly updated economic or demographic variables;
- The dependent variables that express transportation demand should provide insights into the overall activity of the nation's freight system and be useful in generating forecasted needs for new investment in operational improvements and infrastructure;
- The data representing all of the variables in the analysis, both the independent factors and the dependent measurements of transportation demand, should be publicly available at minimal cost.
- The mathematical form of the model should not be restricted or in any way pre-determined; many possible formulations should be considered.

Measures of Transportation Demand

The research team posited that the contributing factors to total freight volumes might be significantly different by mode. Most demands for freight transportation are predisposed to use a particular mode, based on commodity type, value, weight or size, origin and destination location, and urgency. This assumption is further supported when one notes that many carriers provide several "tiers" of service tied to price, speed and service guarantees to ensure their freight customers don't find the need to choose other services.

Of course there are important exceptions – "zones" of contestable traffic where modal qualities compete - although in terms of overall volume, they are a minority. Depending on traffic lane and shipment value or urgency, the movement of medium-value, containerized freight over a "medium-haul" of 750-1,500 miles can occur via either intermodal rail, with drayage moves on each end, or all-highway. The long-term decrease in waterborne freight tonnage and increased exportation via Columbia River ports suggests there may be some shifting of freight to railroads. Notwithstanding these exceptions, the preponderance of freight typically moves via a given mode based on its value, weight, origin-destination, and perishability.

The research team originally identified nine selected measures of transportation demand (dependent variables) that are described below, along with their data sources and frequency. It should be noted that all these datasets offered national-level data – with limited exceptions, data is generally not available on a regional or state-wide level. Railroad measurements are well represented, primarily because their data is better and their operations are plainly defined. Almost all United States rail freight moves over at least one of the seven Class I railroads which means that their activity is measured weekly, monthly and annually by both the Association of American Railroads (AAR) and Surface Transportation Board (STB). National measurements of truck freight are complex due to the challenge that "Counting Truckers Can be Complicated[3]" and the risk inherent in aggregate tonnage volumes that goods may be counted more than once as they are staged through the system (a problem that other modes may face as well, but with substantially lower incidence than trucking). Truck ton-mile and vehicle-mile measures avoid this problem, and are obtainable for long time periods. Waterborne traffic is available via annual summaries only from the Institute of Water Resources (IWR), a department of the Army Corps of Engineers.

Per the research team's communications and agreements, the data described below are freely available through the Research and Innovative Technology Administration (RITA), which coordinates the U.S. Department of Transportation's research programs, including the Bureau of Transportation Statistics (BTS)[4], the STB, or the IWR.

Rail Tonnage

This annual statistic, gathered and made public by the Association of American Railroads (AAR), provides a basic measure of the weight of goods transported, regardless of distance between their extraction, production, or importation supply points and their utilization, consumption, or exportation demand locations. As railcars continue to improve – the new 286,000-lb gross limit means that railcars can now carry 110-115 net tons of freight – railroads provide a very efficient method of moving heavy loads of goods long distances within North America.

Rail Ton-Miles

With a combination of higher terminal and train building costs, the rail mode tends to concentrate on longer hauls of freight than trucking. Railroads use net ton-miles (net weight of freight, vs. gross which includes the weight of the rail equipment itself) as the primary tally of their productive operations. These data are similar to rail revenue ton-miles (discussed below), with the relatively small exception of railroad-owned freight, such as maintenance-of-way material. The dataset is estimated on an annual basis by the BTS based on AAR data. Moreover, ton-miles are an important statistic for railroad operations as they are used for pricing or rate estimates. Ton-miles correlate well with railroads' consumption of fuel and their medium- and long-term requirements for locomotives and track maintenance.

Rail Train-Miles

Since railroad freight, as well as the equipment used to carry it, moves between stations and terminals in trains, it is also useful to measure train-miles. Annual estimates of train-miles and the next variable, rail car-miles, are both published by BTS as part of the National Transportation Statistics. While train-miles increase with traffic, efficiencies can slow train-mile growth even as rail transportation demand increases. For instance, railroads can haul more freight per train

[3] Transportation Research Circular E-C146, "Trucking 101 *An Industry Primer*," Transportation Research Board, December 2010,
[4] See http://www.bts.gov/publications/national_transportation_statistics/.

using double-stack intermodal cars sized for international container lengths and low-tare aluminum gondolas that carry 20 more tons of coal than steel gondolas. Railroads offer shippers discounts when they ship more railcars at a time because 90-car trains are not much more expensive to operate than 87-car trains.

Rail Car-Miles

Measuring the movement of railroad *cars*, as opposed to tons, provides a key insight when it is noted that for the purpose of this statistic, a car-mile refers to a mile run by a freight car *or* an intermodal trailer or container, with or without a load.[5] Besides the efficiencies of loading more tonnage into non-intermodal railcars, the increasing volume of intermodal "units" as a percentage of rail carriers' loadings affects this annual measure.

Rail Revenue Ton-Miles (Quarterly)

This is the only dependent variable included in the analysis gathered on a quarterly basis for two reasons. First, as explained above, freight transportation data is limited for the truck and waterway freight. Second is that Revenue Ton-Miles is the best metric of the railroad industry's productive efforts and used regularly in industry financials to explain revenues (with adjustments for traffic "mix"). The dataset is estimated by the Surface Transportation Board from AAR data. The smaller time frame allows for better identifying "lag" effects from some of the independent factors as predictors of increases or decreases in freight transportation demand. These data were utilized for a specialized "back-cast" to test the accuracy of the predictive model on freight demand.

Truck Ton-Miles

Surface freight moves primarily by truck. With intermodal rail capturing a moderately higher percentage of longer-distance hauls, most truck moves are less than 200 miles. Ton-miles is a good measure of how most, but not all, trucking companies price their services, as well as a proxy for the useful work trucks provide (and correlates well with the fuel they use and the emissions they generate), although ton-miles aren't particularly relevant to less-than-truckload (LTL), package and courier freight.

Truck Vehicle-Miles

Besides moving up to 25-28 tons of freight (depending on axle and tire configuration, applicable road restrictions, and tare of the cab and trailer equipment), trucks of various sizes may be utilized for shorter-distance deliveries and the essential "last-miles" for transporting air freight, intermodal and even small packages. LTL networks move small packages throughout the country, while courier services interface with air transport to connect nearly every office and home via "Next Day" or "2nd Afternoon" services. Indeed, the activity of truck movement, irrespective of the total tonnage they carry, is a key indicator of economic vitality as tracked by the regularly published National Transportation Statistics.

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[5] Per various Bureau of Transportation Statistics' publications on annual transportation statistics, for example: https://www.bts.gov/publications/transportation_statistics_annual_report/2008/html/appendices/glossary.html

Domestic Waterway Tons

In general, different kinds of freight moves on barges over domestic waterways than by railroad (the notable exception, in some cases, is grain). Barge freight is typically heavy, low-value, and high-volume where timeliness is not important. It also typically does not move far overland to or from its waterway origination or termination because these transfers would obviate the advantages of water transportation.

The Army Corps of Engineers' Institute of Waterway Research (IWR) measures how much revenue tonnage is loaded each year onto barges and ships moving domestically on United States river systems (mostly Ohio-Mississippi-Missouri) and various maintained waterways (mostly the Atlantic and Gulf Intracoastal Waterways (GIWW); see Figure 1). [6]

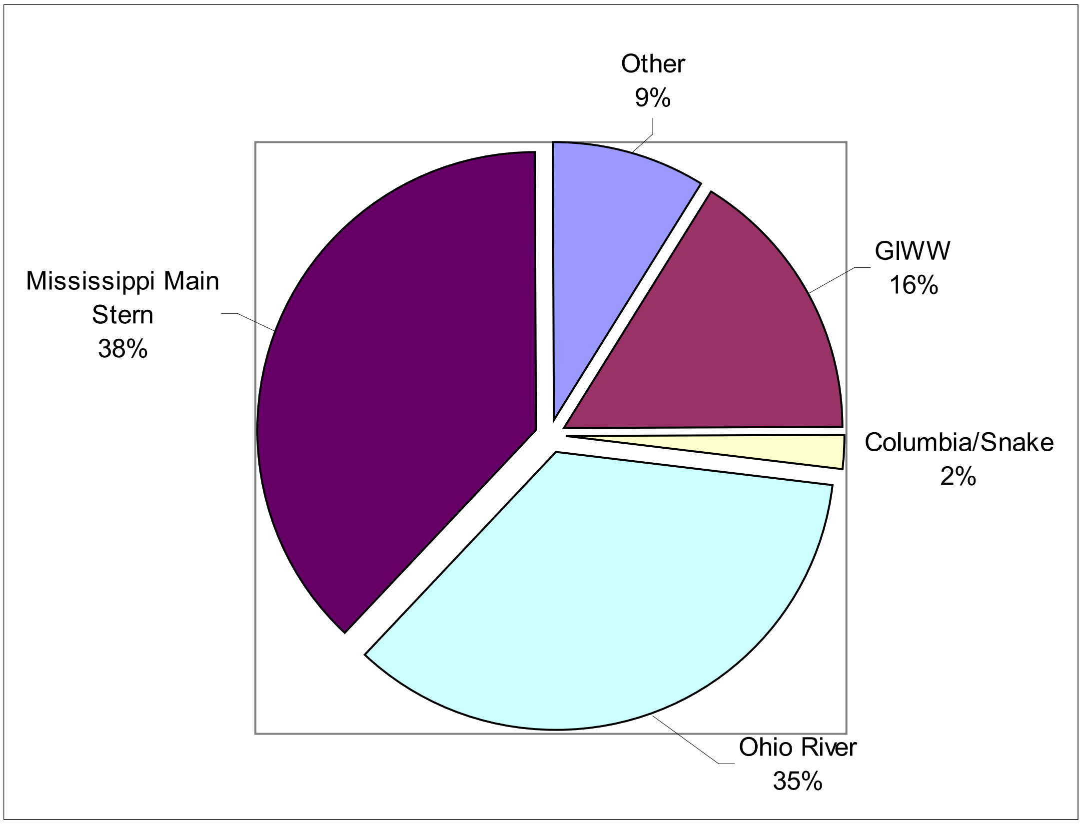

Figure 1. Composition of Internal Tonnage by Waterway
Source: Waterborne Commerce of the United States, Calendar Year 2005, Part 5-National Summaries, U.S. Army Corps of Engineers

Domestic Waterway Ton-Miles

Also available from the IWR is a summary of annual loadings in short tons times distance traveled over the domestic waterway system which is a good approximation of the value created by the waterway carriers and how much shippers and consignees paid for the services.

[6] Waterborne Commerce of the United States, CY 2005, Part 5 – National Summaries, U.S. Army Corps of Engineers

Waterways attract freight that is extremely heavy and usually has low value relative to its weight. The origin-to-destination transportation can involve, but does not require, a long length-of-haul to be appropriate to the water mode.

The Task 2/3 report describes in more detail the evaluation and selection of dependent measures of freight demand (see Chapter 3).[7]

Independent Factors Affecting Transportation Demand

The National Cooperative Highway Research Program (NCHRP) Report #388, "A Guidebook for Forecasting Freight Transportation Demand," provides a helpful overview of the various exogenous economic and societal factors that contribute to the demand for freight transportation. The Guidebook offered a wide variety of factors along with some guidance on how they affect a) either the total demand of goods transported, or b) the distances and origin-destination markets in which these goods were actually moved. As first described in the Task 1 report for this research,[8] these factors can be divided into two categories:

- "Pure" or direct factors affect transportation by creating or demanding "more stuff." Crop production, mineral extraction, population growth, housing starts, retail sales, and exports all impact the total volume or tonnage of goods that gets moved.

- "Network" or indirect factors affect transportation just as much by influencing where, when, and how goods are moved. Where people live and how and where they buy interact with new developments in logistics and sourcing strategies (e.g., an interconnected global village that comes to the big-box mall, vs. "buying locally" via markets and in downtowns). Public policies, infrastructure investments, and logistics technologies influence freight demand as much as the demographics of where people work and live.

In addition to the five general categories of factors described in the Scope of Work for this research effort – demographic, economic, environmental, technology, and public policy – the research team found that a sixth category, operations strategy (or logistics) was helpful in conceptualizing the research effort.

Demographics is a Direct Factor

How many people and where they live is one of the factors most basic to macroeconomic activity and hence, transportation demand for food, fuel, consumer goods, waste – in short, everything. People form households and utilize housing – another factor in transportation demand. A

[7] Project No. NCFRP-11, Identification and Evaluation of Freight Demand Factors, Report #2, Tasks 2-3, June 9, 2010.

[8] Project No. NCFRP-11, Identification and Evaluation of Freight Demand Factors, Report #1, Task 1, Candidate Demand Factors, Sept. 4, 2009; Chapter 1.

percentage of them become the labor force that provides the means of production, cultivation and extraction of other freight that must be transported.

Economic Activity is a Direct Factor

GDP, particularly the goods production component, is a fundamental measure of the national output of freight that gets that produced, consumed and at some level, transported. Production of durable goods tends to be more cyclical and correlates well with the growth in freight demand (as measured by ton-miles), while consumable goods correlate more closely with population size and average wealth.

Levels of production for goods that have a high transportation component – typically either because of their weight or the distance they are moved – were considered as candidate independent variables or factors in freight demand. Specific examples are coal and grain (including oil seeds), which typically move by railroad or water, and imported goods, which often move long distances over inland surface transportation networks after they are unloaded from container ships.

Globalization and the increased economic efficiency and prosperity of people around the world has resulted in increased demand for goods, as well as the ability to source supply from a much broader set of locations. Capital investment and effective labor mean that goods can be produced all over the world. The resulting economic wealth means that goods are now demanded and consumed by a greater diversity of the world. Not only does the Walt Disney Company source the toys for its Florida and California resorts from China and other locations in Asia, but as the Chinese economy grows it becomes wealthy enough to demand the attractions, entertainment and even food exported from the United States to the newest Disney parks in Hong Kong and (soon) Shanghai.

Fuel is both an Indirect and Direct Factor

Fuel constitutes a significant and relatively volatile component of cost for all freight modes, as well as a significant percentage of most consumers' cost of living. During the early 1990s, fuel accounted for 7.1% of total operating expenses for Class I railroads; fuel, oil, lubricants and coolants accounts for about 13.5% of operating expenses for truck-load carriers and about 6% of operating expenses for LTL carriers; and 30-40% for air carriers.9 Because of an approximately three-fold increase in price that has outpaced most other expenses, fuel has recently accounted for approximately 10~15% of railroad operating expenses and 15~25% of long-haul trucking. Higher fuel prices make long-haul trucking services less price-competitive against railroad alternatives, shifting some long-haul freight to intermodal rail.

The volatile increases in gasoline prices also tend to have a dampening effect on consumer economic activity, as much personal automobile travel is relatively price elastic over the short-medium term. As consumers pay more for gasoline, they have less money to spend on other things thereby dampening consumption and the economy.

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[9] *A Guidebook for Forecasting Freight Transportation Demand*, NCHRP Report 388, Transportation Research Board, 1997.

Environmental Policy is an Indirect Factor

Federal and state environmental policies may place particular restrictions on ports and waterways. Port expansion is limited by the Clean Water Act, requirements for "no net loss" of wetlands, or limitations and permitting processes for channel deepening or harbor dredging. The Oil Pollution Act requires oil tankers that have single hulls to be replaced with double hull tankers and tankers with single hulls are required to meet other criteria. With trucks, emissions controls and clean fuel requirements have also affected costs, and environmental policy towards carbon emissions is an unknown future factor in fuel prices. Air transport is often subject to noise reduction acts. By increasing transportation costs, all these factors can affect the demand for freight. In addition, environmental policies such as air and water quality regulations influence the locations at which raw materials are produced and those at which industrial plants are located.

Recycling and overall incentives to reuse solid waste may have an important effect on some transportation demands. Recycling plants, as well as waste-to-energy incinerators, are typically located near urban centers or the source of their raw materials, while industrial manufacturing plants that use virgin materials are usually located farther away with the need to ship their products much longer distances.

Technology is an Indirect Factor

The use of computers and telecommunication equipment has had an important effect on the freight industry. Air carriers and many leading manufacturers and retailers have implemented sophisticated systems for tracking shipments, as well as computers for sorting shipments and optimizing the use of freight vehicles such as aircraft and trucks. By improving efficiency, level of service, and reliability, these factors have indirectly promoted modern just-in-time (JIT) delivery methods. JIT systems focus on keeping inventories at minimum levels through coordination of input deliveries with production schedules. The effect on freight demand may be to increase the number of individual shipments, decrease their length of haul, or increase the importance of on-time delivery.

Public Policy is an Indirect Factor

The deregulation of various transportation industry sectors during the early 1980's allowed private operators to serve their freight customers with innovative and remunerative business offerings. These changes were phased in over several years during this period.

Almost all highway and waterway freight movement is dependent on publicly constructed, maintained and, in many cases, operated infrastructure. The 50 State Departments of Transportation, along with dozens of associated highway authorities are primarily responsible for building and maintaining intercity roads. They in turn are guided and heavily funded by the U.S. DOT Federal Highway Administration (FHWA). The Army Corps of Engineers maintains harbors and waterway channels. The FHWA works with state departments of transportation to maintain and improve the national highway system. While transportation infrastructure tends to be expanded and improved more slowly than many users would like, measures of public infrastructure investment in dollars or in the physical characteristics of lane-miles, miles of dredged channels, or new feet of runway could all be considered as independent variables. However, these measurements might actually be a result of increased freight demand, rather than a cause, so they were not considered as "influences."

User charges, directed tax revenues, and in many cases, tolls are used to fund U.S. infrastructure, including airports, ports and highways. Besides direct user charges such as tolls and facility charges, complementary taxes are levied on gasoline, highway diesel, and fuel sold along inland waterways. These taxes add to transportation costs and can make some modes more attractive relative to others.

While freight railroads largely operate on their own infrastructure, they too are impacted by tax, regulatory and other public policies. A rail infrastructure tax incentive provides economic encouragement for private railroad companies to invest in new roadbed and track that will ultimately provide more capacity and support greater demand.

International trade agreements reduce barriers to trade, encourage consistency in government regulations, and generally promote trade and cross-border freight traffic. NAFTA was a big boost to Mexico-United States trade and, over time, has led to hundreds of cross-border investments and greater use of transportation to access the competitive advantages of each country.

The Contestability of Freight is an Indirect Factor

Some kinds of freight shipments, depending on their weight and size per shipment, its value and per ton, and its perishability, can move on alternate modes. For example, most of the heavy, typically low-value/ton, freight that moves via waterways can also move via rail. In many cases, grain, fertilizer, and gravel/stone/sand also moves via truck, although typically these are short-haul, last-mile moves to and from waterway or rail terminal locations. It is a combination of new and changing services offered by the major freight transportation modes and changing factors in logistics and freight distribution that has affected the portion of freight that is contestable among mode.

There are two major shifts of freight between modes that have occurred over the past 30 years that are worth mentioning. One is the strong growth of intermodal movement of truck trailers, now superseded by the use of ISO containers, moving via railroad instead of over the highway for medium-long-hauls between North American metropolitan areas and/or ports. The second is that waterway traffic has lost a significant share of their long-haul freight, possibly because railroads are better able to connect the Midwest with Asia via Pacific Northwest ports than through the waterway modes' traditional connections via Gulf transloading locations.

Since the mid-1980's, *practically all intermodal rail traffic is a shift from trucking*. For railroads it's a big deal -- 14~15 million boxes of 10~16 net tons each, moving 750~2,000 miles (150~200 million tons and 300~350 billion ton-miles of freight) is now close to 1/4th of their freight revenues. For trucking, where the entire industry moves an estimated 10 billion tons of overall tonnage each year, that 1.5% share isn't so significant. Actually, trucking may not have lost *any* tonnage handled since all intermodal shipments move by truck – often twice!

Intermodal's effect on overall truck volumes is tiny, with the exception of long-haul, dry-van and reefer markets where it is a bit more significant. RITA data indicates trucking carries approximately 1.3 trillion ton-miles of freight, so intermodal rail accounts for a small, but still countable 2.3% of surface trailer traffic, mostly due to the skewing of intermodal competitiveness towards longer haul moves.

After another season of floods, we have seen more challenges to the movement of waterborne freight. As reported in the Wall St. Journal[10], increased siltation and delays in repairs to locks and channels by the Army Corps of Engineers have made it more difficult and expensive to move freight by waterways. Waterborne Commerce of the United States data indicates that while total tonnage has experienced a modest decline during the past 20 years, ton-miles have ***decreased by over a third*** indicating the loss of longer-haul freight. Since there weren't good explanations from independent economic variables including the Inland Waterway Fuel tax, and the volumes of underlying demand for goods movement haven't decreased, other factors such as the deterioration of the physical waterway network or the competitiveness of a rejuvenated railroad industry may have played a part in shifting this freight and accounting for the substantial decrease in waterway freight movements.

Operations Strategy (Logistics) is both a Direct and an Indirect Factor

Intermodal operations developed not only from technological innovation, but also from a change in operations by international shipping lines interested in extending their services between Asia and numerous U.S. inland origins and destinations. Interoperable equipment including standard-sized containers, twist-lock lifting mechanisms, and double-stack rail cars were technologies that allowed operational innovations.

At the same time, the trend has been towards using fewer, more efficient warehouses. Third-party logistics operators and innovative warehouse developers with advanced forklift, stacking and pallet-picking technologies have helped this trend by supporting advanced logistics management while improving the inventory/sales ratio. Appropriate measures beyond this ratio might be the number of firms using modern, computerized warehouses, or simply a count of square feet of warehouse space built or refurbished after the marriage of inexpensive PC-based information systems with modern storage technologies.

Trends in the location of distribution and manufacturing centers have influenced transportation mode choice. As new facilities have developed in rural, exurban locations along interstate highways, dependency on rail transportation has decreased, except for the heaviest, low-value freight.

Summary

All of the above factors were considered in varying degrees by choosing a set of independent variables that would represent most of these influences on freight transportation demand. For example Housing Starts (demographics, consumption, interest rates) and Industrial Production Index (manufacturing, mining and extraction, and goods processing) measure two distinct areas

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[10] Wall St. Journal, "Old Locks Jam River Traffic," January 6, 2011, and "Silt Buildup Muddies Trade on River," July 5, 2011"

of the economy while Exports and Imports summarize trading volumes, which generate significant demands in long-distance transportation.

Candidates for Factors that Affect Transportation Demand

Based on the guidance provided by the Transportation Research Board and discussed above, as well as on past and expanded review of literature and existing freight models, the research team identified potential candidates to be used as the independent factors affecting freight transportation demand. This was one of the key efforts of Task 1, and Appendix B presents the detailed results of the team's literature review.

The research team used a "case" approach to review and analyze a variety of recent and relevant studies on what factors affect the demand for transportation. First, a significant number of documents, including the bibliography of NCFRP-01, the "Review and Analysis of Freight Transportation Markets and Relationships," were scanned to identify relevant documents. A thorough review of these documents yielded a representative collection of freight demand models that have been used in the past. During the second step of the literature review process, the research team performed an in-depth analysis of the various models described in the studies summarized in the Appendix B – Literature Review.

In reviewing the literature, it was important to distinguish between general *demand factors* and the specific *datasets* actually utilized to represent these factors. In some cases, datasets employed to represent certain factors may actually be outputs of other models or summarizations (e.g., the output from an external regional economic growth model). For each of the complex and varied datasets in the model survey literature, the research team endeavored to tease out the underlying factors for consideration as independent variables.

In subsequent efforts as part of Tasks 2 and 3, these candidates were narrowed based on availability, differentiation from one another and the ability to predict transportation demand. Finally, the addition of new dependent variables measuring freight demand via inland waterways required several additional independent factors to be added.

Determining the Specific Independent Factors

In this step, the research team identified and evaluated specific datasets that could be used as independent variables in modeling freight demand. To maximize the benefit of using a limited set of independent factors that affect transportation demand, the research team had to determine which of the potential factors were most useful to model freight demand. As analyzed below, two important criteria in choosing the independent factors were a) their ability to explain key changes in the economy that affected transportation demand; and b) their independence or uniqueness vs. other potential independent factors. This work is described in greater detail in the Task 2/3 report.[11]

[11] Project No. NCFRP-11, Identification and Evaluation of Freight Demand Factors, Report #2, Tasks 2-3, June 9, 2010.

The initial goal was to consider data only if it was publicly available and collectable on a monthly, quarterly and annual basis. However since all but one of the freight demand measures were publicly available only on an annual frequency, the independent factors were summarized on an annual basis as well.

The candidate list includes most of the "pure" demand factors that were identified in the preceding section. The specific factors were next grouped into broad categories to identify and discuss their relevance to economic and demographic factors as well as to help evaluate the possibility that many of the factors measure the same things and therefore some might be unnecessary. These analyses were broadly broken down into the following categories of demand drivers:

- Income – as an indicator of the size of the economy and its strength;
- Housing Starts – a significant statistic which ties into other closely-followed macro-economic activities while corresponding with other goods acquisition and transportation activities;
- Production – various macroeconomic measurements of manufacturing and extraction as well as general business sentiment around imminent investment and business activity;
- Trade and Foreign Exchange – as international trade and the long supply chain of imported and exported goods movement are large consumers of demand, measuring the value of the dollar vs. the currencies of its major trading partners was expected to be helpful in predicting transportation demand to and from U.S. ports;
- Inventory/Sales Ratio – provides a counter-cyclical measure of business activity during times of increasing and decreasing economic activity;
- Retail Sales – offers the most direct measure of the quantity of goods consumed and pulled through the production-import-warehouse-store sequence of transport and logistics activity;
- Fuel Prices – changes can make many consumers feel less or more well off, affecting their demand for consumables and other goods. Also affects costs for trucking more than other freight modes, making rail transportation relatively more attractive.

Income

Included in the candidate list of demand factors are various measures of income. Real GDP and real GDP per capita are among the most widely used measures of economic activity. Figure 2 shows growth rates of per capita income-related factors including real GDP, real personal consumption and real disposable income based on data from the U.S. Bureau of Economic Analysis (BEA).

Freight demand typically follows growth in GDP.[12] However, during the current recession, freight traffic has declined more than the decline in GDP (for example, rail carloads and intermodal units declined more than 20% in May 2009 compared to May 2008.[13]). Similarly,

[12] Economic Impact of Freight. Bureau of Transportation Statistics (BTS). www.bts.gov/programs/freight_transportation/html/freight_and_growth.html.
[13] Levinson, Marc. "Freight Pain: The Rise and Fall of Globalization." *Foreign Affairs*, Vol. 87, No. 6, November/December 2008

growth in GDP – a broad measure of economic activity – translates into consumer (i.e., household) expenditures that are ultimately spent on purchasing goods and services, either domestically produced or imported, can be captured by real personal consumption. Historically personal consumption accounts for about two thirds of domestic final expenditures.[14] Real disposable income reflects what people receive from land, labor and capital after paying taxes and inflation.

These output and income measures reflect how much of household earnings go into purchasing goods and services and implicitly the demand for freight services.

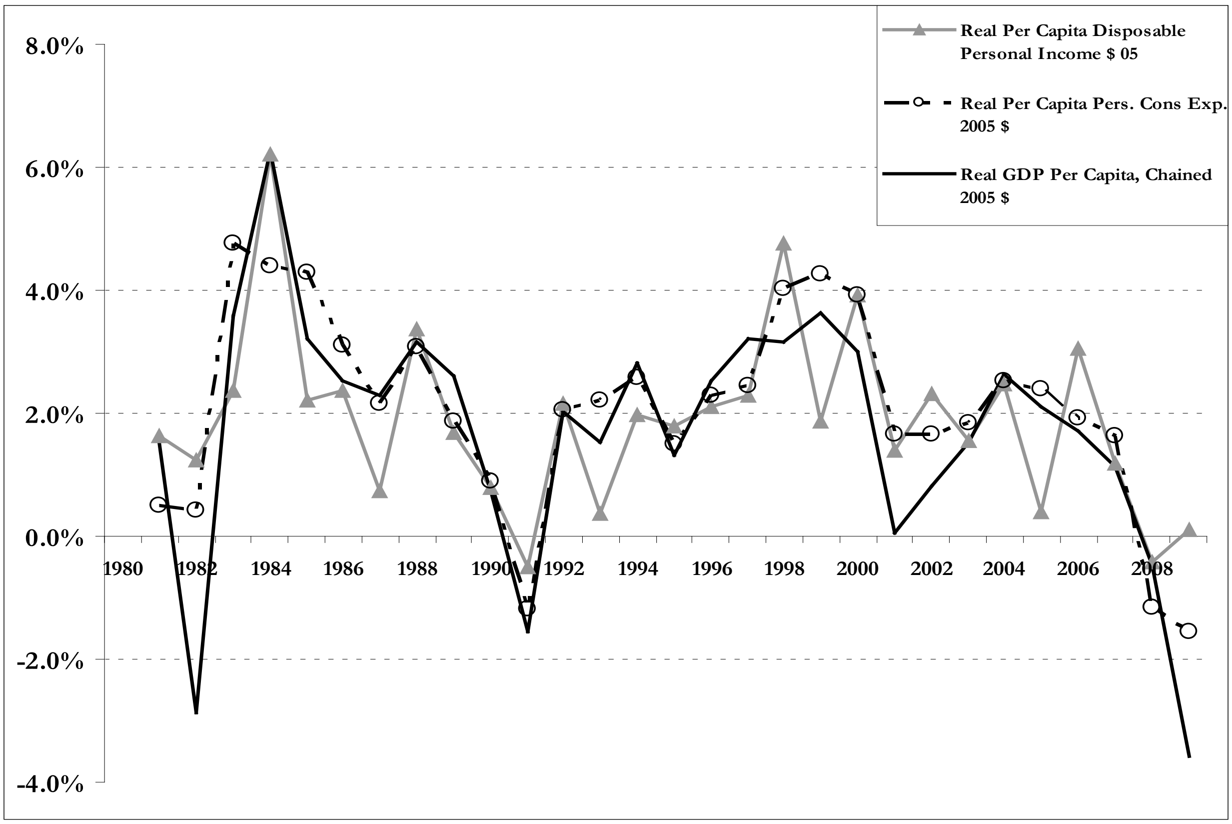

Figure 2. Per Capita Growth in GDP, Personal Consumption and Disposable Income
Source: Bureau of Economic Analysis

[14] *NIPA Handbook.* Bureau of Economic Analysis, October 2009, Chapter 5.

Housing

Housing starts are counted and released monthly by the Census Bureau and provide insight on construction trends in the U.S. They tend to follow closely-monitored, large macro-economic developments in the U.S. However, as the recent housing-led economic recession has proven, the slowdown in housing started much sooner than in the rest of the economy.

After reaching a peak in 2005, total housing starts in the United States started to decline from 2006 onwards (see Figure 3). Trends in housing have matched trends in freight. Rail carloads and intermodal units, for example, reached a peak in 2006 and have declined consistently throughout 2007, with large year on year declines (in excess of 5%) starting in the latter half of 2008 and increasing to more than 20% year on year in 2009.[15]

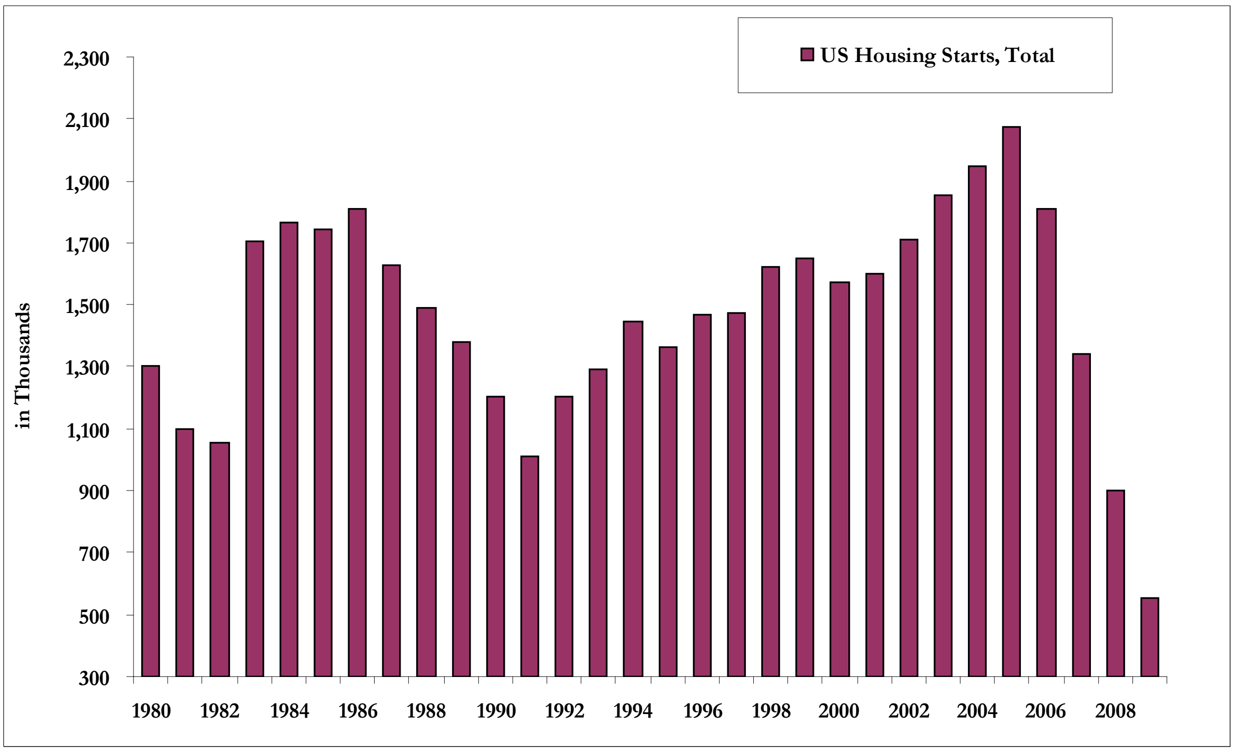

Figure 3. Total Housing Starts in the United States (Seasonally Adjusted at Annual Rates)
Source: U.S. Census Bureau

[15] Ibid

Production

The Federal Reserve Board measures production activities in the United States. These include goods produced domestically for consumption or exported, as well as imports of semi-finished goods that may be further processed in the U.S. before their final use. The Industrial Production Index includes activities of the manufacturing sector, including mining and utilities, while the Industrial Manufacturing Index excludes mining and utilities. In 2007 the Industrial Manufacturing Index accounted for 78.7% of the Industrial Production Index, vs. 85% in 1999.[16]

Total capacity utilization measures output in the manufacturing, mining and utilities industries against total capacity. This measure can be used to understand how well the resources in the economy are employed in production activities. Total capacity utilization measures are also maintained by the Federal Reserve Board. Figure 4 shows capacity utilization and industrial production for the historical period 1980 to 2007 based on data from the Federal Reserve Board.

The Purchasing Managers' Index (PMI) from the Institute of Supply Management is an important supplemental indicator for the U.S. economy. It is based on a survey of purchasing managers that weights: 1) new orders; 2) production; 3) employment; 4) supplier deliveries; and 5) new inventories. Conducted monthly, the PMI is considered a leading indicator of business sentiment, with values above 50 indicating that that the manufacturing economy is generally expanding while a reading below 50 shows that it is generally declining.[17] Figure 4 includes recent movement of the PMI along with other measures of production.

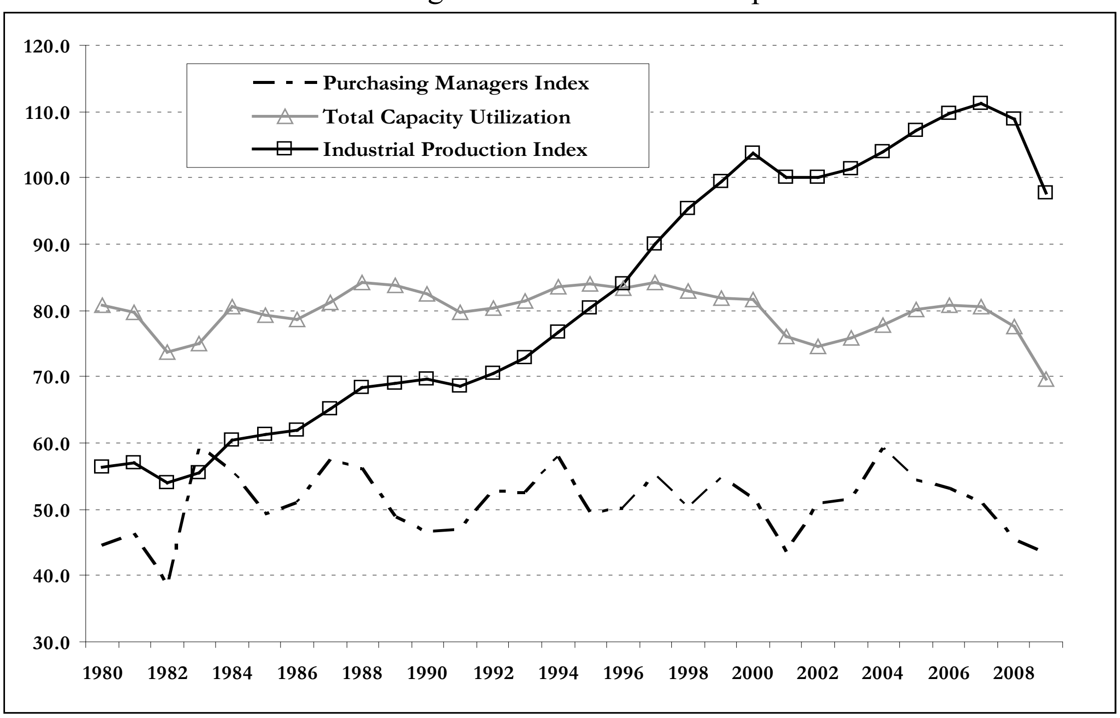

Figure 4. Industrial Production, Total Capacity Utilization and Purchasing Manager Index
Source: Federal Reserve Board

[16] Industrial Production and Capacity Utilization: The 2008 Annual Revision. *Federal Reserve Bulletin*, Federal Reserve Board, August 2008, p. A58
[17] Overview of the Manufacturing Report on Business. Institute of Supply Management, www.ism.ws/ISMReport

Trade and Foreign Exchange

In a world where supply chains have become increasingly globalized, trade as measured in both volume and value plays an extremely important role in determining freight demand. Imports to the U.S. have grown rapidly, partly as a result of increased containerization. The demand for freight transport is a derived demand; international trade and domestic consumption are the main drivers. The reduction in freight transport costs from deregulation and resulting efficiency gains helped bolster trade and enable the creation of long-distance supply chains.

Trade itself is partly a function of the exchange rate between the U.S. dollar and the currencies of its trading partners, and therefore such exchange rates also affect freight transport demand. For example, the Chinese government has been under considerable pressure to allow the Yuan to appreciate, since the low value of the Yuan keeps the price of Chinese goods artificially low, thereby stimulating U.S. imports from China. Figure 5 presents recent U.S. trade value data for the past 17 years.

Similarly, weakness in the U.S. dollar against Asian currencies has helped U.S. export growth, especially during the most current recession, as many of the healthiest segments of the American economy – agriculture, defense, and high-tech electronics – have been supported by a strong export market accompanied by dollar weakness.[18] The Trade Weighted Foreign Exchange Index, a measure of the U.S. dollar vs. the currencies of our country's primary trading partners, factors currency strength (or weakness) into observations on changes in imports and exports.

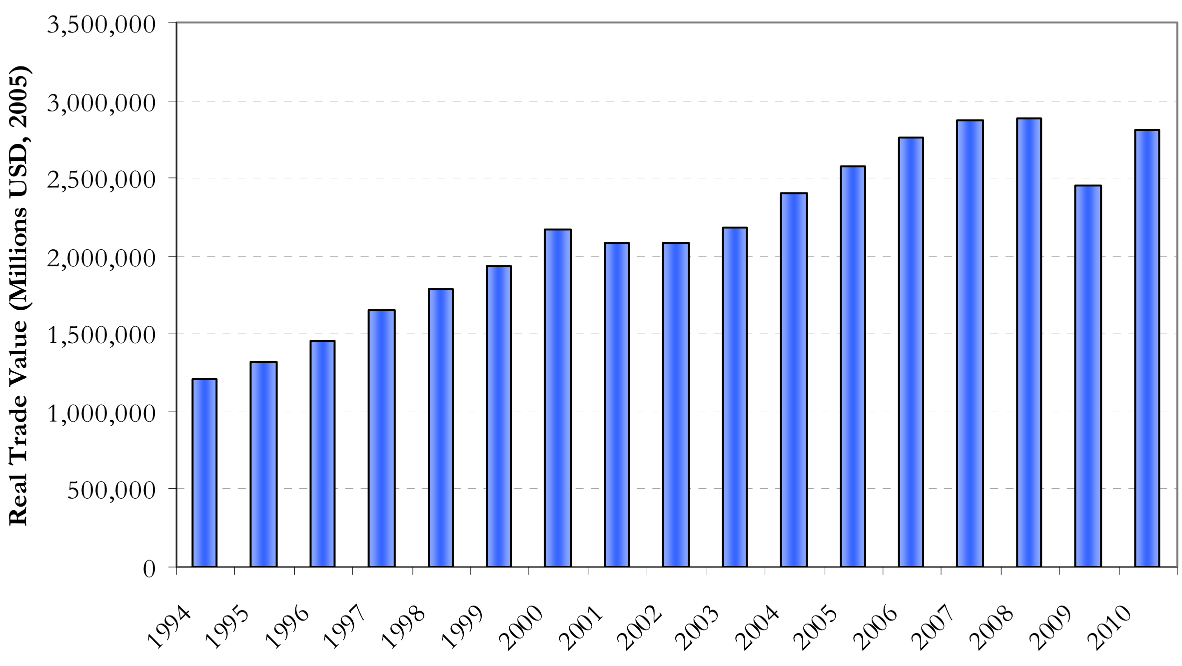

Figure 5. Real U.S. Exports & Imports
Source: US Census http://www.census.gov/foreign-trade/statistics/historical/

[18] Levinson, Marc. "Freight Pain The Rise and Fall of Globalization." *Foreign Affairs*, Vol. 87, No. 6, November/December 2008

Inventory/Sales Ratios

Inventory/sales ratios are a counter-cyclical measurement in that during an initial period of business slowdown, sales decline and inventory piles up. As business improves, sales increase while inventory initially is depleted (before orders can catch up). Inventory/sales ratios offer better insight than simply looking at sales or inventories; for example, during 2005 inventories increased while the inventory/sales ratio fell, because sales were increasing even faster. Figure 6 shows quarterly data on manufacturing and trade inventories held by firms in real U.S. dollars and a chained measure for inventory/sales ratio from the BEA. Generally, as can be observed in Figure 6, inventory-sales ratios increase rapidly during recessions and show a declining trend during periods of economic expansion.

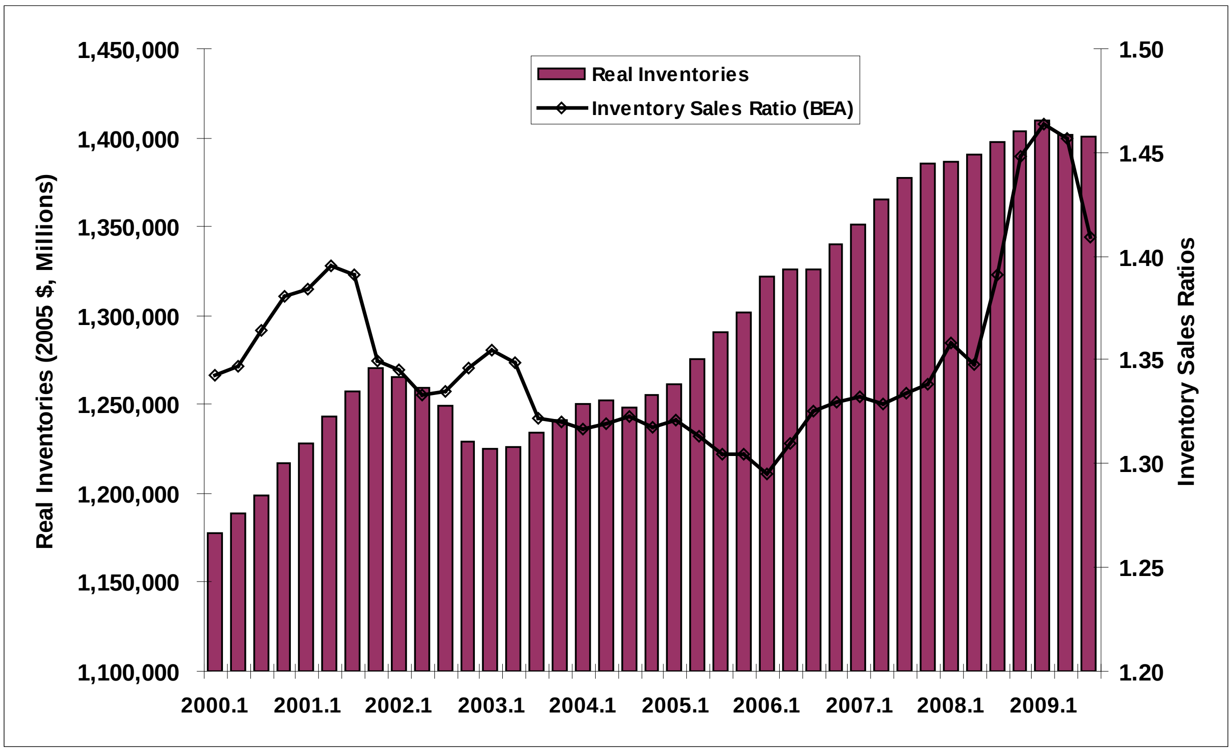

Figure 6. Recent Real Manufacturing & Trade Inventories and Inventory/Sales Ratios

Source: US Census of Manufacturing and Trade Inventories & Sales and BEA

Retail Sales

Retail sales are an important potential factor affecting transportation demand that was identified as part of the literature review.[19] Increased demand for goods by households due to economic growth leads to increased retail activity. Increased retail activity is an important generator of truck trips particularly in urban areas, as well as long-haul moves between ports and manufacturing regions to local markets. Figure 7 shows recent retail sales data from the Census Bureau in real 2009 dollars (deflated using the urban consumer price index from the Bureau of Labor Statistics). Real retail sales declined rapidly during the recession, declining to 2000 levels after experiencing robust growth during 2003 to 2006.

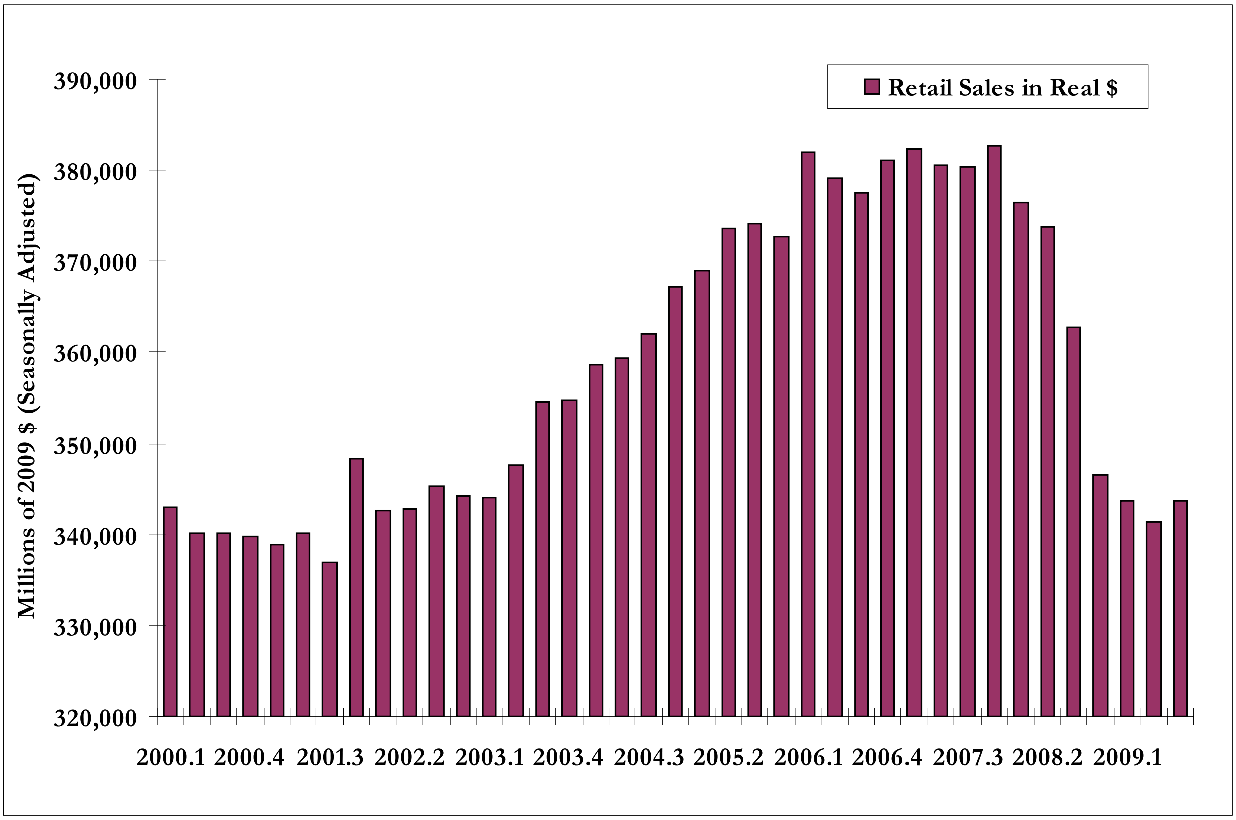

Figure 7. Recent Retail Sales in Real U.S. dollars

Source: U.S. Census Bureau

[19] Beagan, D., M. Fischer, and A. Kuppan, Cambridge Systematics, Inc. *Quick Response Freight Manual II*. Federal Highway Administration, 2007

Fuel Prices

Even though trucks and trains use diesel fuel, gasoline prices are a good economic indicator that may affect the demand for truck transportation. First, the price of gasoline is highly correlated with that of diesel. Higher fuel prices, which account for 35~40% of operating costs (including driver pay), directly makes trucking more expensive, also contributing to reduced demand. The impact of gas and diesel prices on rail freight is less because fuel is only 20-25% of railroad operating costs. Second, because the purchase of gasoline is essentially a staple requirement for many consumers, higher gas prices reduce disposable income and thus consumer demand for other goods, reducing demand for trucking those goods. Figure 8 shows both nominal and real urban average gas prices that have been deflated using the consumer price index (CPI) based on data from the Bureau of Labor Statistics.

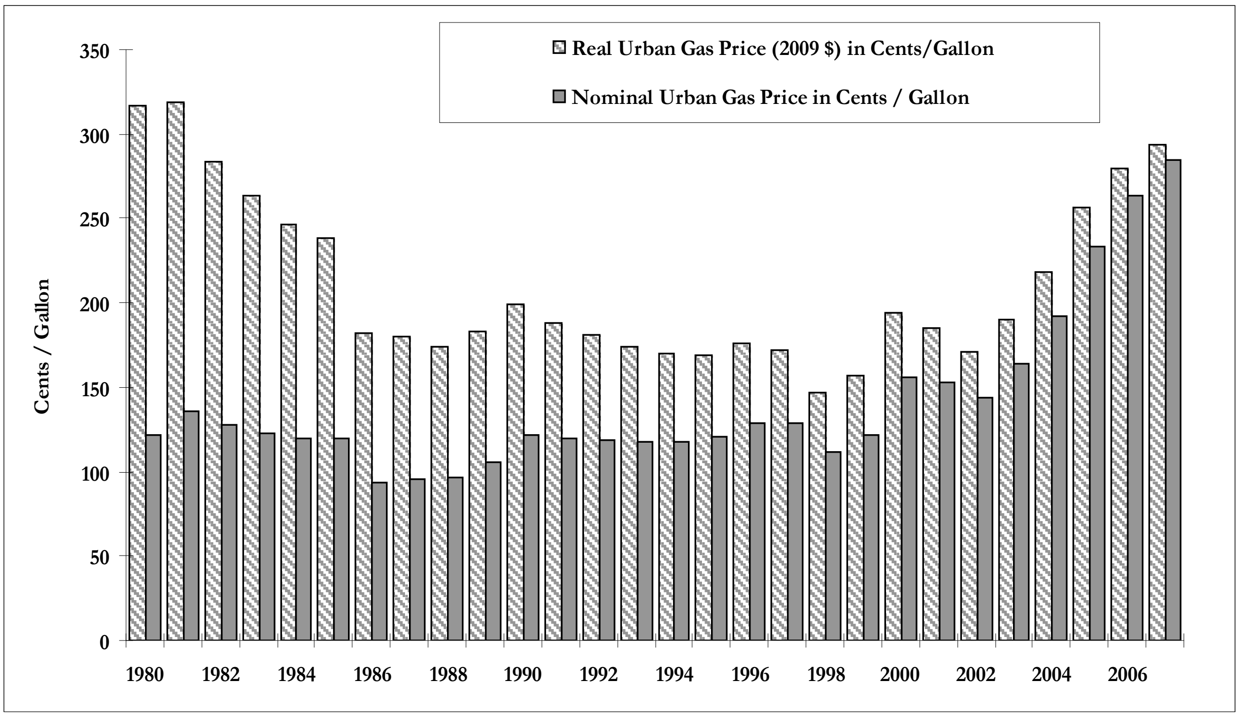

Figure 8. Real and Nominal Urban Gas Prices in U.S. Cents per Gallon

Summary

Based on these analyses, a set of independent factors representing a diverse set of economic activities influencing freight transportation demand were ultimately chosen. Consistent with the requirements that the data needed to be available, non-confidential and low-cost or free, the independent factors were chosen from highly accessible public sources such as the Census Bureau, Bureau of Labor Statistics, Bureau of Economic Analysis and the Federal Reserve Board.

The Table 1 below summarizes the list of candidate variables that, based on the literature review, are believed to drive total demand for goods transportation, which in turn drives infrastructure needs. The table lists the sources of each dataset and the specifics used.

TABLE 1 - Chosen Independent Factors

Variables	Sources	Notes
Real GDP 2005 Chained $	Bureau of Economic Analysis	GDP in 2005 dollars, chain price deflated
Real GDP 2005 Chained $/ Capita	Bureau of Economic Analysis & Census Bureau	Mid-year Population Estimates
Real Personal Consumption 2005 Chained $	Bureau of Economic Analysis	
Real Income / Capita, Chained 2005 $	Bureau of Economic Analysis & Census Bureau	Mid-year Population Estimates
Total Housing Starts	Census Bureau	Avg of Monthly Data
Industrial Production Index	Federal Reserve Board	Avg of Monthly Data
Industrial Manufacturing Index	Federal Reserve Board	Avg of Monthly Data
Purchasing Managers Index	Institute of Supply Management	Avg of Monthly Data
Trade Weighted Foreign Exchange Index (Broad Trading Partners)	Federal Reserve Board	Avg of Daily Data
Trade Weighted Foreign Exchange Index (Major Trading Partners)	Federal Reserve Board	Avg of Daily Data
Employment Total	Bureau of Labor Statistics	Total Non-Farm Payrolls, Avg of Monthly Data
Employment in Wholesale Industry	Bureau of Labor Statistics	NAICS code 42, Avg of Monthly data
Real Exports in Goods (in $)	Census Bureau	Census Basis, deflated with CPI, avg. of monthly
Real Imports in Goods (in $)	Census Bureau	Census Basis, deflated with CPI, avg. of monthly
Total Capacity Utilization (% of Total)	Federal Reserve Board	
Inventory Sales Ratio, Chained $	Bureau of Economic Analysis	Manufacturing & Trade, SIC Basis (1980-96) chained 1996 $, NAICS Basis (1996-09) Chained 2005 $, Avg. of Monthly data
Inventory Sales Ratio	Census Bureau	Total Business, SIC Basis (1980-91), NAICS Basis (1992-09),Avg. of Monthly data, actuals adjusted
Real Gas Price	Bureau of Labor Statistics	U.S. Urban Avg, CPI Deflated
Retail Sales in Real $	Census Bureau	U.S. Retail Sales, SIC Basis (1980-91), NAICS Basis (1992-09), actuals adjusted, CPI Deflated
Inland Waterway Trust Fund Fuel Tax/Gal (Lagged 1 year)	Inland Waterways User Board	Historic adjustments to the inland waterway user's excise tax on fuel
Grain and oil seed production (tons)	US Dept of Agriculture	Historic summaries of crop production
Coal production (tons)	Energy Information Admin.	Annual Coal Report
Total grain & coal production (tons)	US DoA and EIA	Sum of coal & grain, in short tons

SOURCE: Developed by the Research team

3. Modeling Transportation Demand – Analyzing the Results

As detailed in the previous section, the research team began this analysis by first reviewing the historical literature and various recent studies on "What influences transportation demand?" and then developing a list of potential independent variables that were thought to have an influence on the volume of freight transportation. Through the analysis of various segments of the U.S. economy in Section 2 above, duplicate variables were reconsidered and the best measures were chosen with the requirement that the independent data be regularly generated, well understood and freely available.

The considered group of independent variables was thus reduced to a set of 23, whose correlation with one another and with the nine measures of freight demand over the entire 1980 – 2007 time period was evaluated. Table 2, on the following page identifies the cross-correlations among the independent variables. Tables C-1 and C-2 in Appendix C identify how these independent variables correlate, and therefore potentially explain, the dependent measures of freight transportation demand.

Correlation analysis enables a quick assessment of the quality of a linear relationship between two variables: the independent economic variables and freight demand.[20] The quality measures the strength of the relationship of the two quantities under the assumption that they are linearly related. These correlation analyses were useful in identifying how some of the relationships between independent influencing variables and the dependent data on freight transportation demand changed over time. However, correlation measures give a poor understanding of the degree of impact, or weight, that a certain independent variable might have in influencing freight demand.

Ultimately, to understand the relative importance of the independent variables as predictors, regression analysis was used to develop weightings or factors to indicate the relative change in freight demand from a unit of change in an independent variable. Regression analysis works because the explanatory power of each candidate independent variable is tested against the hypothesis "Is the relative variability simply random, or is there some coincident activity?" to arrive at a model that uses a subset of the independent variables to explain much of the variation in the dependent variable of freight demand.

Additionally, independent variables from the time period (year) preceding the freight demand were tested to determine whether correlations between the independent factors and the freight demand measures in subsequent time periods were greater than the correlations within the same period.

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[20] Pearson's correlation coefficient can be written as Correlation $\rho_{X,Y} = \frac{Cov(X,Y)}{\sigma_x \sigma_Y}$ in which the covariance of two variables is divided by the product of their standard deviations. The basic assumption for the correlation coefficient is that two quantities are linearly related, meaning that if the distributions of X and Y over time do not follow a similar path, then the correlation coefficient is likely to be weaker. In interpreting a correlation coefficient, values fall between +1 and -1 where +1 means indicates a perfectly positive correlation in which quantities move together in a direct relationship. The -1 indicates a perfectly negative correlation in which an increase in one quantity is associated with a proportional decrease in the other quantity.

Table 2 – Potential Cross-Correlation of Independent Variables

	Real GDP in 2005 Chained $	Real GDP in Chained 2005$/ Capita	Real Personal Consumption Chained 2005$	Real Income in Chained 2005$ / Capita	Total Housing Starts	Industrial Production Index	Industrial Manufacturing Index	Purchasing Managers Index	Trade Weighted Foreign Exchange Index (Broad Trading Partners)	Trade Weighted Foreign Exchange Index (Major Trading Partners)	Employment Total	Employment in Wholesale Industry	Real Exports in Goods (in $)	Real Imports in Goods (in $)	Total Capacity Utilization (% of Total)	Inventory Sales Ratio, Chained 2005$	Inventory Sales Ratio	Real Gas Price	Real Retail sales	IWTF	Grain	Coal + Grain Tonnage	Coal Production
Real GDP in Chained 2005$	1.00																						
Real GDP in Chained 2005$/ Capita	.998	1.00																					
Real Personal Consumption 2005 Chained $	.999	.995	1.00																				
Real Income in Chained 2005$ / Capita	.997	.996	.998	1.00																			
Total Housing Starts	.454	.455	.468	.476	1.00																		
Industrial Production Index	.990	.990	.985	.983	.455	1.00																	
Industrial Manufacturing Index	.992	.990	.987	.985	.463	1.000	1.00																
Purchasing Managers Index	.171	.181	.171	.174	.550	.160	.167	1.00															
Trade Wghtd Foreign Exchg Indx (Broad Trading Partners)	.914	.920	.902	.906	.444	.937	.933	.125	1.00														
Trade Wghtd Foreign Exchg Indx (Major Trading Partners)	-.565	-.577	-.553	-.549	.153	-.521	-.520	-.163	-.402	1.00													
Employment Total	.983	.989	.974	.976	.389	.988	.986	.139	.950	-.591	1.00												
Employment in Wholesale Industry	.937	.951	.921	.928	.341	.958	.955	.112	.921	-.571	0.977	1.00											
Real Exports in Goods (in $)	.939	.935	.928	.918	.215	.947	.945	.086	.853	-.662	.948	.935	1.00										
Real Imports in Goods (in $)	.979	.971	.982	.975	.472	.967	.971	.181	.831	-.539	.938	.895	.931	1.00									
Total Capacity Utilization (% of Total)	.008	.049	-.027	-.014	-.186	.037	.031	.264	.010	-.465	.114	.245	.195	.006	1.00								
Inventory Sales Ratio, Chained $	-.890	-.894	-.885	-.886	-.694	-.903	-.906	-.502	-.847	.418	-.877	-.851	-.805	-.877	-.135	1.00							
Inventory Sales Ratio	-.956	-.952	-.954	-.947	-.508	-.947	-.949	-.342	-.846	.581	-.926	-.868	-.906	-.951	-.083	.929	1.00						
Urban Gas Price (Real$)	-.081	-.127	-.052	-.085	-.034	-.112	-0.101	-.177	-.361	.216	-.224	-.283	-.046	.091	-.396	.179	.017	1.00					
Retail Sales (Real$)	.997	.997	.995	.995	.497	.991	0.992	.195	.912	-.546	.981	.942	.928	.980	.027	-.909	-.956	-.090	1.00				
(Lagged) IWTF	.915	.916	.902	.899	.433	.939	0.936	.156	.960	-.485	.947	.929	.901	.859	.117	-.874	-.869	-.302	.915	1.00			
Grain	.676	.661	.671	.664	.253	.676	0.677	-.075	.600	-.277	.642	.616	.678	.697	-.045	-.542	-.646	.180	.659	.609	1.00		
Coal + Grain Tonnage	.912	.915	.900	.903	.308	.914	0.912	.032	.867	-.549	.923	.912	.908	.883	.146	-.778	-.854	-.128	.902	.870	0.86	1.00	
Coal Production	.930	.942	.915	.924	.299	.933	.929	.091	.909	-.638	.966	.966	.923	.875	.241	-.814	-.863	-.295	.926	.909	.654	.951	1.00

SOURCE: Developed by the Research Team

Results of this work include the statistical models that explain freight demand based on independent economic and demographic variables.

A challenge in this research has been the high correlations between the independent variables themselves—generally referred to as multicollinearity. A statistically rigorous method of addressing multicollinearity is the use of Principal Component Analysis (PCA) to construct the weights such that the variation in the linear composite of these candidate demand factors is maximized. Essentially, PCA creates a weighted average of independent factors instead of the independent variables themselves. One consequence of PCA is that the individual components are therefore lost to a composite index or "blend" of the otherwise somewhat duplicative independent factors in freight demand.

Finally, parsimonious regression models were developed using both independent variables and principal components. The regression models presented, particularly those based on PCA, indicate the importance of the independent variables that reflect economic activity, population, consumer or industrial sentiment, and currency exchange. The PCA-based models compare the log of the actual values with the log of the values of freight transportation demand, ensuring that relative changes and growth rates are properly compared. While the interpretation of the model coefficients is less obvious than for simpler regression models because the variables are blended together so that there is no intuitive connection, the results are generally very good at predicting freight transportation demand from the chosen independent factors. The PCA-based models were then used to form "back-casts" to illustrate how well this overall method works in forecasting freight demand.

Important Sub-Periods of Time

Potentially affecting the predictive ability of the independent factors at influencing transportation demand is the diversity of the historical sample period (1980-2007). The relationship of transportation demand to the rest of the economy went through multiple changes during this period as regulations, cost and reliance on transportation changed. Splitting the sample period into three smaller, but more homogeneous, spans of six, eleven, and eleven years, respectively, provides a benefit by allowing the consideration of political and societal changes affecting the relationship between economic activity and transportation demand during these three time periods:

i) 1980 to 1985

ii) 1986 to 1996

iii) 1997 to 2007.

Between 1980 and 1985, significant regulatory reform (Staggers Act, Motor Carrier Act financial deregulation, and a lowering of marginal tax rates) took place, affecting previous long-term associations between the candidate influencer variables and freight transportation demand. Deregulation augured a new period of railroad mergers and free entry of new trucking companies. The U.S. economy experienced a double-dip recession, and then transitioned into a much healthier period of growth through most of the 1980's. Besides the increased sales of

Japanese-manufactured automobiles, many new consumer electronics manufactured in Asia became affordable to a majority of American consumers.

Between 1986 and 1996, with the exception of a moderate recession in 1990-1991, the U.S. economy experienced significant expansion along with rapidly expanding trade due to several significant geo-political events (fall of the Berlin Wall, NAFTA). Between 1992 and 1996, the real value of imported goods increased on average 5.2 percent per year and the real value of exports increased even faster (an average of 7 percent per year).

While economic growth was slower between 1997 and 2007, and structural changes in the trucking and railroad industry subsided, trade continued to expand rapidly, particularly containerized imports, with many years reporting double-digit growth, driving activities at ports and a rapid expansion in long-haul movement via railroads. Driven by imports, U.S. consumption, and the trade deficit, grew much faster than GDP.

Collinearity Means Redundancy

A primary goal of the study was to establish which candidate demand factors do the best job at explaining variations in freight demand. Because many of the independent factors measure similar economic activity, a certain amount of collinearity among these variables was expected. For example, real income per capita and personal consumption are likely to move together, because absent radical changes in savings rates, when people have more money, they spend it. Thus, a natural first step in the analysis was to investigate correlation among the variables that were candidates for use as independent factors and the nine measures of freight demand. A summary Table that documents the correlation of the independent influencing variables with the various measures of freight demand is shown in Table 3.

Candidate independent variables exhibited a range of correlation with the nine selected dependent measures of freight demand. Those with correlations whose absolute value exceeds 0.75 are highlighted in Table C-1, but candidate variables with lower correlations might still be important since, in combination with other factors, they might still improve the ability to predict a particular transportation demand variable. A good example is the price for gasoline. Even though this variable has a relatively low correlation with the dependent measures of transportation demand (absolute value of correlations ranging from 0.43 to 0.59), it emerges as a helpful explanatory variable, in conjunction with other variables, in the regression models that predict truck ton-miles and truck vehicle miles.

The goal is to build a regression model that is well-specified – i.e., that accounts for all important theoretical components. As discussed above, developing a well-specified model can pose challenges, especially when many of the demand factors tend to move similarly. When candidate demand factors have high correlations they present problems of multi-collinearity. If both are used in a regression model, it becomes impossible to reliably distinguish whether demand factor A or factor B explains the change in freight demand.

The research team used multiple approaches to manage this potential duplication. Correlation tables like the one above were developed to help understand the various relationships. They were used in the effort to develop parsimonious yet highly explanatory regression models that would explain the variations in freight demand measures. Finally, as described above (and in detail below), PCA was used to compensate for the high degree of multicollinearity among the remaining independent variables.

Correlation measures were examined for the length of the whole sample, 1980 to 2007 (28 yearly measurements), to determine how and if these correlations changed during the sub-periods when different social, political, and economic factors were affecting transportation demand. The regression models that were ultimately developed utilize a subset of the independent variables to predict freight transportation demand over the *entire* time period.

Correlations between the Dependent and Independent Variables

This section presents the results of the first step in the statistical evaluation of the 23 independent factors in freight demand (as expressed by the nine selected measures of modal freight demand). The summary tables referred to below are presented in Appendix C. These correlations were explored based on t he logarithm transformed actual values of the independent influencing variables. As discussed below, additional exogenous factors were considered (e.g. deregulation), but since these factors are represented by dummy variables, an analysis of correlation with other independent or dependent variables was not meaningful.

As in any statistical modeling exercise, it is important to bear in mind that correlation does not imply causation. "What we can conclude when we find two variables with a strong correlation is that there is a relationship between the two variables, not that a change in one causes a change in the other."[21]

Table 3 below shows summary correlation ranks based on how well the candidate factors explain the nine measures of freight transportation demand via rail, truck, and domestic waterway. The factors are ranked based on correlations alone; thus for rail ton-miles, real GDP has the highest correlation and thus has the highest rank. The top five factors for each dependent variable are highlighted in the tables. For rail tons the most important candidate factors are inventory/sales ratio, imports in real U.S. dollars, Industrial Production Index, Industrial Manufacturing Index, and real GDP.

The Table provides initial suggestions on the most important independent influencing variables for each measure of freight demand. For example, the industrial production indices rank among the top five variables for both truck and rail freight demands. Also, it is interesting to note how some variables have more influence on freight demand via rail while others have more influence on the trucking demand measures.

[21] Statistical Techniques in Business & Economics, Robert D. Mason and Douglas A. Lind, Ninth Edition, 1996; p. 484.

Table 3 - Correlation Ranks of Candidate Demand Factors

Absolute Correlation Matrix	Rail Tons	Rail Ton-Miles	Rail Train-Miles	Rail Car-Miles	Rail Rev Ton-Miles Annual	Truck Ton-Miles	Truck VMT	Water Tons	Water Ton-Miles
Real GDP	6	4	6	6	3	3	3	21	4
Real GDP per Capita	8	6	8	5	6	2	2	17	7
Real Personal Consumption	7	7	9	7	7	8	8	16	3
Real Income Per Capita	9	8	11	8	8	7	7	19	6
Total Housing Starts	16	16	14	15	16	16	16	4	19
Industrial Production Index	4	1	4	3	1	4	4	20	2
Industrial Manufacturing Index	3	2	2	2	2	5	5	22	1
Purchasing Managers' Index	17	17	17	18	17	18	18	11	21
Trade Wt. Broad Cur. Index	14	13	15	14	13	9	9	14	13
Trade Wt. Major Cur. Index	15	15	19	19	15	15	15	3	20
Total Employment	11	3	3	4	5	1	1	9	9
Employment in Wholesale Sector	13	12	13	13	12	10	10	6	12
Exports in Real $	10	9	12	12	9	11	11	8	10
Imports in Real $	2	10	10	10	10	12	12	12	8
Total Capacity Utilization	19	19	18	17	19	19	19	1	22
Chained Inv. Sales Ratio (BEA)	12	14	7	11	14	14	14	18	16
Inv. Sales Ratio (Census)	1	11	5	9	11	13	13	15	11
Urban Gas Price in Real $	18	18	16	16	18	17	17	2	23
Retail Sales in Real $	5	5	1	1	4	6	6	23	5
Lagged Inland Waterway Trust Fund Tax/Gallon	NA	NA	NA	NA	NA	NA	NA	10	17
Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	13	18
Coal + Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	7	14
Coal Production (Tonnage)	NA	NA	NA	NA	NA	NA	NA	5	15

* NA indicates correlations were not determined for rail or truck demand variables with these waterborne-freight-related independent variables, which were added later in the analysis. SOURCE: Developed by the Research Team

Correlations by mode are presented in a series of tables (see Appendix C) that take a more detailed look at the candidate variables that influence freight transportation demand. For most of the rail freight demand measures, influencing variables including income (real GDP), the Industrial Production Indices, total employment, and inventory/sales ratios all appear to show a significant relationship (see Table C-2). Less significant are housing starts and the Purchasing Managers' Index.

For the trucking mode (see Table C-3), measures of income (such as GDP), production (such as industrial production), trade (such as imports and exports), inventory/sales ratio, and retail sales all appear to correlate strongly. Less correlated variables include real gas prices, total housing starts, and the Purchasing Managers' Index.

Water Tonnage correlates best with total capacity utilization – a surveyed measure of freight production capacity that fluctuates with the business cycle and that has exhibited a long-term downward trend concurrent with our nation's industrial production. Tons of freight via water correlates reasonably well with similar manufacturing measurements, although it will be shown later that these variables do not provide a clear enough explanation for the long-term decrease in the volume of this kind of freight transportation.

Sub-Period Correlation Analysis

As described above, this research investigated whether the independent variables might have a different relationship to freight demand by time period. Tables contained in Appendix C illustrate how well each of the independent variables correlates with each of the nine freight demand (dependent) variables during the three time periods. The tables summarize the entire time period, as well as the three sub-periods, the relative rankings of these correlations and their statistical significance (based on t-statistic). Candidate demand factors that have correlations 0.75 and above (or -.75 and below) are more likely to be statistically significant at the 95% level when their t-statistic (with 26 degrees of freedom via a two-sided test) is greater than 1.96 or less than -1.96.

For Rail Tonnage (Table C-4), real GDP, for example, has high correlation during all the time periods, except 1980 to 1985 where correlations are negative but not statistically significant. Inventory/sales ratio is negatively correlated over the full sample period including the early 1980's, but less so in the later periods. While not statistically significant (possibly due to the small number of observations) during 1980-1985, real value of imports appears to be one of the more important influences. Similarly, the Industrial Production Index and personal consumption are well correlated during the latter half of the sample, while not showing strong correlation during 1980 to 1985.

For Rail Ton-Miles (Table C-5), between 1980 and 1985, when the rail industry was changing due to deregulation and mergers, very few candidate demand factors other than inventory/sales ratio and total capacity utilization were statistically significant. Imports were important, albeit with a correlation just shy of 0.75. As the railroad industry changed, production-related factors, like industrial production, imports, exports and GDP indicate an important influence. Most recently, consumption-related variables, including retail sales, are significant factors of influence. As imports and exports often travel long-distances to get from/to seaports, trade has become an important explainer of railroad ton-miles.

For Rail Train-Miles (Table C-7), detailed data from the AAR was available only since 1990. Retail sales have the highest correlation for the full sample period, and more influence during the second half of the period than during the first. Factors influencing demand related to production like industrial manufacturing are important for the full sample, but their importance declines during 1997 to 2007. Interestingly, urban gas prices have a significant negative correlation during 1990-1996, but then have an even more significant positive correlation during 1997 to 2007, which suggests that railroad's efficient use of fuel had a positive effect on the domestic intermodal market, which grew during this period.

For Rail Car-Miles (Table C-8), many independent economic variables have a significant correlation with demand. These include the overall economic health variables such as GDP per capita and real income, but also the more specialized variables such as imports, exports, and retail sales. Interestingly, neither urban gas prices nor the Purchasing Managers' Index show much correlation.

Correlations for Truck Vehicle-Miles (Table C-9) suggest that trucking is truly a broad reflection of our economy. Total employment and real GDP, as well as trade- and consumption-related economic indicators, are all important. The time-period analysis reveals again that consumption and imports emerge in the latter period as more significant factors than manufacturing.

Sub-period correlations for Truck Ton-Miles (Table C-10) indicate that total employment, real GDP, and production and manufacturing are all important indicators. The analysis by time period reveals similar trends, with personal consumption emerging and employment diminishing as the most important factor in truck ton-miles. Trade variables have less importance to Truck Ton-Miles than they do to rail-related measures because trade generates longer freight hauls to/from ports at one end of the country and longer hauls tend to move by rail.

Main Results

Checking correlations by time period helps validate the relationship between candidate independent variables and measures of U.S. freight demand. This analysis indicates which variables are likely to explain the largest portion of recent and potential future variations in freight demand. It also validates that during the earlier part of the 1980-2007 time period studied, production-related economic factors such as industrial production and total capacity utilization were more important, while in the most recent sub-period, retail sales and consumption factors became relatively more important. Overall GDP and industrial production were important to total tonnage transported, while trade-related variables such as imports and exports seemed to affect mileage-based measures due to the longer hauls involved.

Differences between the modes of truck and rail are also important and interesting. For truck, important variables are general economic indicators such as real GDP or total employment, while in the case of rail trade, imports play a significant role in explaining variation due to their much longer average length-of-haul.

As the economy shifts – for example, as agricultural exports contribute more to the U.S. balance of trade – additional independent variables could be tested to determine if they correlate to national demand for freight transportation.

The Usefulness and Challenge of Predicting Demand

This section considers the potential of using the independent economic variables from preceding periods as "early warning indicators" to predict subsequent shifts in freight demand. This occurs regularly in the real world as businesses and consumers react to activities or use indices to predict future economic activity. While changes in economic variables or indices do not necessarily translate to subsequent changes in buying behavior, physical activity, or freight demand, sometimes they do.

The Potential of Independent Factors as "Early Warning Indicators"

Some of the independent variables may provide correlations with the freight demand measures during a subsequent time period that exceed their correlations with the same freight demand during the same-period. This is intuitively logical because planned investment and purchasing decisions may be postponed or eliminated based on unfolding events. Those investment and purchasing decisions often tie into freight transportation activities. Similar to what might happen to a household if one of its wage earners gains a promotion or is laid off – not much might change immediately, but in subsequent time periods, the household may make additional purchases or cancel a vacation. In our research, if an independent influencing variable measuring economic activity or perception during $time_{t-1}$ has a greater effect on freight transportation activities in $time_t$ than it does on freight transportation activities during the corresponding time period, it may be an "Early Warning Indicator,"

As part of Task 4, the research team tested if correlations between the independent factors and the freight demand measures in subsequent time periods were greater than the correlations within the same period. All the independent influencing variables were examined to determine whether their "lagged" values, i.e., their values in years 2000-2006, correlated better with the respective measures of freight demand in years 2001-2007, than their same-year correlations. If they did, a "yes" was indicated in Table 4.

Because our measures of freight transportation were primarily yearly summaries, our analysis was confined to "lags" of one year only. "Better" correlation means a higher absolute value of the correlation coefficient between the independent variable and the lagged measure of freight transportation – the five highest absolute values of this correlation to the lagged dependent variable are highlighted. Several of the independent variables – such as total housing starts, Purchasing Managers' Index, Trade-Weighted Foreign Exchange Index (broad trading partners), inventory/sales ratio, and real urban gas price – showed some indication that they were useful as "early warning indicators" in this respect (see Table 4).

Table 4 - Lag Correlations in Comparison with Prior Year

Demand Measures / Candidate Independent Variables	Rail Tons	Rail Ton Miles	Rail Revenue Ton Miles	Rail Train Miles	Rail Car Miles	Truck Ton Miles	Truck Vehicle Miles	Water Tons	Water Ton Miles
Real GDP	yes	yes	yes	no	no	no	no	no	yes
Real GDP per Capita	yes	yes	yes	no	no	no	no	yes	yes
Real Personal Consumption	yes	yes	yes	no	no	no	no	no	no
Real Income Per Capita	yes	yes	yes	no	no	no	no	no	no
Total Housing Starts	**yes**	yes	**yes**	**yes**	**yes**	**yes**	**yes**	no	yes
Industrial Production Index	yes	no	no	no	no	no	no	yes	yes
Industrial Manufacturing Index	yes	no	no	no	no	no	no	yes	yes
Purchasing Managers' Index	**yes**	yes	**yes**	**yes**	**yes**	**yes**	**yes**	yes	yes
Trade Wt. Broad Cur. Index	**yes**	yes	**yes**	**yes**	**yes**	**yes**	**yes**	no	yes
Trade Wt. Major Cur. Index	no	no	no	yes	yes	no	no	no	no
Total Employment	yes	yes	yes	no	no	no	no	no	yes
Employment in Wholesale sector	yes	no	no	no	no	no	no	no	yes
Exports in Real $	no	no	no	no	no	no	no	no	yes
Imports in Real $	yes	no	no	no	no	no	no	yes	yes
Total Capacity Utilization	yes	no	no	**yes**	**yes**	**yes**	**yes**	no	no
Chained Inv. Sales Ratio (BEA)	**yes**	yes	**yes**	no	yes	no	no	yes	yes
Inv. Sales Ratio (Census)	no	no	no	yes	yes	no	no	no	yes
Urban Gas Price in Real $	**yes**	yes	**yes**	no	no	**yes**	**yes**	yes	yes
Retail Sales in Real $	yes	yes	yes	no	no	no	no	yes	yes
Lagged Inland Waterway Trust Fund Tax/Gallon	NA	NA	NA	NA	NA	NA	NA	yes	yes
Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	yes	no
Coal + Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	no	no
Coal Production (Tonnage)	NA	NA	NA	NA	NA	NA	NA	no	yes

SOURCE: Developed by the Research Team
NA indicates correlations were not determined for rail or truck demand variables with these waterborne-freight-related independent variables, which were added later in the analysis.

For these variables, the values for the appropriate $time_{t-1}$ were included in the regression analyses along with the other independent variables from $time_t$ to be considered as potentially influential on freight demand in $time_t$. Several very good predictive models using both the current and lagged independent variables are discussed below and presented in Appendix D.

Regression Analysis Results

While the correlation analysis provided a simple series of measures of statistical relationships, it is difficult to develop a definitive idea of how various causal factors may influence freight correlation based solely on a paired relationship. While the various high correlations between the independent economic factors, both during current and previous periods, indicated a relationship between them and freight demand, regression analysis was used to identify the various weights, or levels of respective importance, for each of these factors. The regression models were constructed based on prior knowledge of freight demand trends, the correlation between dependent variables and independent variables, and statistical fitness diagnostics.

The regression models tested included candidate demand factors that were believed to be important determinants of demand (through the foregoing statistical analysis as well as theoretical motivations). Regression (ordinary least squares or OLS) models that were developed to identify weights for candidate demand factors are presented in detail in Appendix D, Regression Analysis Results and Diagnostics.

Regression as a Method to Identify Relative Importance

Linear regression models are a powerful approach to evaluate the effect of multiple influential variables on a dependent measure. Such variables may account for various macroeconomic conditions influencing freight demand, as well as controlling for exogenous impacts or one-time events such as recessions, mergers, or legislation that might impact the demand for freight.

From an econometrics perspective, regression methods should ideally be motivated by theory and guided by real-world logic in order to scientifically test the validity of theories and mechanisms that influence freight demand. Following this fundamental belief, the research team developed a theoretical basis for testing and improving the various regression models.

Considerations for Model Construction

In addition to checking if models meet fundamental assumptions such as normality, constant variance, and independence, among others, careful attention was paid to constructing models that can be interpreted with ease and satisfy linearity assumptions. When developing econometric models, the data are commonly transformed using various mathematical functions. Among such transformations is the natural logarithm, which is advantageous in terms of fitting a model as well as interpreting the model. Taking a logarithm of a variable may convert multiplicative relationships into additive relationships. Furthermore, variables with high growth curves that may resemble that of an exponential function are flattened to a linear trend. Interpretation of such transformations is dependent on where the transformation occurs. The table below provides a brief overview.

Table 5 – Interpretation of models using natural logarithm transformations

Model Type (Dependent-Independent)	**Representation**	**Interpretation**
Log-Actual	$LN(Y) = B_0 + B_1X + E$	A one-unit increase in X is associated with a B_1*100% change in the dependent Y
Actual-Log	$Y = B_0 + B_1LN(X) + E$	A 100% increase in X is associated with a B_1 unit change in the dependent Y
Log-Log	$LN(Y) = B_0 + B_1LN(X) + E$	A 100% increase in X is associated with a 100*B_1% change in the dependent Y
Actual-Actual	$Y = B_0 + B_1X + E$	A one-unit increase in X is associated with a B_1 unit change in the dependent Y

In the context of this research, when relationships are developed in log-actual, the model is assumed to fit the following form:

$$y_t = e^C X_t^\beta e^{S*(Shock)}$$

where

y_t = freight demand at time *t*

c = constant

X_t = candidate demand factor at time *t*

β = weight of the candidate demand factor

S = exogenous shock to the system

The S term explicitly adjusts for events that would impact freight demand, but would not necessarily be represented in changes to the independent variables. Examples of these included in this study are NAFTA and deregulation of the surface freight industry.

Transforming the above model by taking natural logarithms on the left and right sides of the equation produces a model which identifies elasticity of demand. For example, if a candidate demand factor increases by 10 percent while β = 1 then freight demand would be expected to increase by 10 percent as well. The transformed model is shown below.

$$\log(y_t) = c + \beta \log(X_t) + S*(\text{shock period Dummy}) + v_t$$

$$v_t = \rho v_{t-1} + \varepsilon_t$$

Where: v_t = error term that is correlated over time

ε_t = corrected error term that is uncorrelated over time

Correlated Error Corrections

Another concern in regression analysis is to correct for correlation among error terms from different time periods, also known as serial correlation. Serial correlation violates a fundamental regression assumption that error terms are uncorrelated. This is a concern in time-series models such as this one that have naturally trending time series. The consequences of serial correlation are that OLS is no longer efficient among linear estimators, and that standard errors are underestimated, therefore inflating the significance of independent predictors. To solve this issue, the research team used a technique known as an autoregressive model (denoted AR in summary tables) to compensate for errors in the estimated coefficients. This technique iteratively adjusts model estimates in order to ensure that error terms are not correlated over time.

Model Selection

The concept of model selection is arguably where the science and art of econometrics meet. To ensure that this work was reasonably completed, models were constructed following fundamental knowledge of the transportation and freight market and vetted using common statistical standards. Such standards include testing for heteroscedasticity (Breusch-Pagan Test and White Test), independence (Durbin-Watson), and multicollinearity (Variance Inflation Factors). In addition, model fitness was compared using R-squared values as well as relative goodness of fit measures such as the Akaike Information Criterion and the Bayesian Information Criterion. While models may be statistically fit, the expected direction of independent variable coefficients was a defining criterion in ensuring the logical sense of the models.

Factor Weights

Table 6 below shows estimates for the separate impacts of different independent influencing variables on the various measures of freight demand. Note that the factor weights summarize the coefficient estimates for all of the models developed so that variables repeatedly used to predict a given mode were averaged for ease of interpretation. When interpreting these results, it is necessary to keep in mind that these are log-log models, which as discussed previously, represent percentage changes. For example, a 10% increase in real GDP is estimated to match up with a 5.5% impact on rail tonnage, holding all other factors constant. Similarly, a 10% increase in retail sales (in real $) is estimated to accompany a 9.7% increase in rail ton-miles, but only a 2.6% increase in truck ton-miles.

The table also includes the estimated impact of the exogenous factors of NAFTA and freight industry deregulation, which presumably had a significant one-time effect on the overall demand for freight transportation. Following the ratification of NAFTA, freight demand increased, everything else being equal, by 4% while during the time period following deregulation (and the rail consolidation that followed) there was a 7% decrease in rail tons. That does not mean there is less rail tonnage now than during 1980; but it does indicate a temporary drop for 1980 to levels lower than expected.

TABLE 6 - Potential Factor Weights (Log Actual Models) of Independent Variables
(generated as a result of multiple regression models)

Candidate Demand Factors	Rail Tons	Rail Ton-Miles	Rail Train-Miles	Rail Car-Miles	Rail Rev Ton-Miles	Truck Ton-Miles	Truck VMT	Water Tons	Water Ton-Miles
Real GDP	5.51	11.20	5.73	6.56	10.61	-	-		
Real GDP per Capita	5.83	-	-	7.90	-	-	-		
Real Personal Consumption	6.75	-	-	3.26	2.81	-	-		
Real Income per Capita	-	-	-	-	11.51	-	-		
Total Housing Starts	-	-	1.48	-	-	-	-		
Lagged Housing Total	1.01	-	-	1.13	-	-	-		
Industrial Production Index	8.37	9.64	5.61	-	8.58	-	-		
Industrial Manufacturing Index	-	-	-	4.67	-	2.30	2.30		
Purchasing Managers' Index	1.00	-	-	-	2.23	-	-		2.53
Trade Wt. Broad Cur. Index	-1.43	-	2.47	-	-	-	-		
Trade Wt. Major Cur. Index	-	-	-	-	-	-	-		
Total Employment	-	13.11	-	-	20.06	3.70	3.69		
Employment in Wholesale Sector	-	-	-	-	-	-	-		
Total Trade in Real $	3.15	3.84	2.53	1.39	5.00	0.99	0.99		
Exports in Real $	1.54	2.80	-	-	-	0.55	0.55		
Imports in Real $	-	2.37	-	-	2.89	-	-		
Total Capacity Utilization	6.70	-	8.72	-	-	-	-	8.57	6.87
Chained Inv.-Sales Ratio (BEA)	-	-	-7.88	-	-	-1.94	-1.97		
Inv.-Sales Ratio (Census)	-5.82	-4.97	-	-4.84	-7.75	-	-		
Real Gas $	-	-	-	-	-	-0.46	-0.46	-0.90	-1.55
Lagged Real Gas from B.L.S.	-	-	1.88	-	1.00	-	-		
Retail Sales in Real $	6.58	9.69	7.84	9.51	-	2.61	2.60		
Rail Ton-Miles	-	-	-	-	-	-	-		-5.88
Lagged Inland Waterway Trust Fund Tax/Gallon	-	-	-	-	-	-	-		-1.26
Grain Tonnage	-	-	-	-	-	-	-	0.35	
Coal + Grain Tonnage	-	-	-	-	-	-	-	0.93	
Exogenous Impact									
NAFTA Impacts	0.39	-	-	-	-	0.14	0.14		
Lagged NAFTA Impacts	-	0.53	0.47	0.41	0.67	-	-		1.12
Deregulation Impacts	-0.7	-	-	-	-	-	-	-0.14	

SOURCE: Developed by the Research Team

Tables in Appendix D, Regression Analysis Results and Diagnostics, present the results of the regression analysis. The appendix contains 18 tables, two for each of the nine dependent measures of freight demand. The odd-numbered tables present the regression analysis results, while the even-numbered tables present the diagnostic values. For each dependent variable, the research team posited several different possible regression models involving different selections of independent variables. The selections were based on the foregoing analyses of correlations and on theoretical considerations about the likely relationship of variables to one another. The number of models developed for each dependent variable ranges from three (in the case of the waterborne freight-related variables) to seven (in the case of rail tons).

There are a variety of ways of determining how effective a regression analysis is at explaining fluctuations in value of a dependent variable to fluctuations in the value of one or more independent variables. Based on the regression model's goal of finding the right factors that are formed into an equation where

Dependent Variable = function(Constant + IndVariable_i, Ind.Variable_2 . .. . Ind.Variable_n)

The goal has been to make the calculated value for the Dependent Variable from the function come close to the actual values. These differences can be measured via the sum-of-squares difference between the set of predicted values vs. the actual values. The R^2 measures the proportion of total Sum of Squares (SS_{tot}) by the explained Sum of Squares (SS_{reg}). A fully explained, or perfect, regression would have an R^2 that is 1.00, while a value of .70 would mean that "70% of the variance in the dependent variable – in this case, fluctuating values of freight transportation demand – were explained by the specified independent influencing variables."

It should be noted that a reasonable regression model is one that is a "parsimonious" representation of theoretical relationships, and relies on a select set of independent variables that allow the model to meet fundamental assumptions. The frugality of the model's use of influencing variables is the guiding rationale for developing multiple alternative modes, each with only a few independent variables. Developing such a model can be as much an art as a science and therefore, several different models for each freight demand measurement, using a limited set of variables are shown in Appendix D.

Table D-1 shows regression results for the models that predict rail tons. The regression models explain dependent measures of freight transportation volumes well as seen by the very high R^2 values and low standard errors. Model 1 suggests that a 10% increase in the Industrial Production Index is associated with an increase in tons moved by rail of approximately 8.4%, while a 10% increase in the Trade Weighted (Broad) Currency Index is associated with a 1.4% decrease in rail tons.

Table D-3 shows regression results for models based on rail ton-miles. The regressions fit the past very well, as can be seen by the very high R^2 values and low standard errors. Model 1 suggests that a 10 percent increase in real GDP is associated with an increase in rail ton-miles of approximately 11.2 percent, while a 10 percent increase in industrial production in Model 2 is associated with a 9.6 percent increase in rail ton-miles.

Table D-5 shows regression results for five different ways to model rail train miles. Again, the regressions fit the past very well as can be seen by the very high R^2 values and low standard errors. Model 1 suggests that a 10% increase in real GDP is associated with an increase in rail train-miles of approximately 5.7%, reflecting the concurrent improvements in railroad efficiency that have increased the revenue that carriers generate per train-start. Model 1 also suggests that post-1995 rail train-miles were 0.5% higher, possibly based on the one-time "shock" of NAFTA.

Table D-7 shows regression results for models that predict rail car-miles. As before, the regressions fit the past very well as can be seen by the very high R^2 values and low standard errors. Model 1 suggests that a 10% increase in real GDP is associated with an increase in rail car-miles of approximately 6.6%, while a 10% increase in (lagged) housing starts is associated with a 1% increase in rail car-miles. Lagged NAFTA is a dummy variable that controls for years in which the free trade agreement came into effect with a one year lag. Thus, the model suggests that car-miles were 0.4% higher during 1994 and 1995, possibly as a result of the free-trade agreement.

Table D-9 shows regression results for models based on rail revenue ton-miles, as provided by the AAR. The regressions fit the past very well. Model 1 suggests that a 10% increase in real GDP increases rail revenue ton-miles by approximately 11%. The (lagged) NAFTA effect suggests revenue ton-miles were 0.6% higher during 1994 and 1995, possibly as a result of the free-trade agreement.

Table D-11 shows regression results for models based on truck ton-miles. These regressions likewise fit very well. Model 1 suggests that a 10% increase in total trade increases truck ton-miles by approximately 1%, while a 10% increase in real gas prices is associated with a 0.5% *decrease* in truck ton-miles.

Table D-13 shows regression results for models based on truck vehicle-miles. The regressions are good. Model 1 suggests that a 10% increase in total trade is associated with an increase in truck vehicle-miles of approximately 1%, while a 10% increase in the (chained) inventory/sales ratio is associated with a 1.7% *decrease* in truck vehicle-miles. These models also use auto-regressive corrections to reduce the loss of efficiency in the time series estimators.

Table D-15 shows regression results for models based on domestic waterway tonnage as reported by the Army Corps of Engineers Institute of Water Resources. The regressions are moderately good with R^2 between .66 and .76. Model 1 suggests that a 10% increase in total capacity utilization is associated with an increase in waterborne tonnage of approximately 9%, while a 10% increase in the amount of grain and coal produced is associated with a 0.9% increase in waterway tonnage. There is also a negative correlation between waterway tonnage and the real price of gas. Due to the presence of serial correlation, the waterborne models utilize the auto-regressive correction to adjust estimates for efficiency loss in estimation.

The construction of the waterway ton-mile freight demand models was challenging for a number of reasons. Unlike trucking and rail freight service, which handle a diverse geography and set of commodity groups, the carriage of freight via inland waterways is limited primarily to the Ohio-Tennessee-Missouri-Mississippi River system and the Atlantic and Gulf Intracoastal Waterways.

Moreover, only a limited number of heavy, low-value, high-volume commodities move via barge.

Over two decades of general economic growth in the U.S., waterway transportation demand actually *decreased*. With the exception of a tax applied to fuel used on the inland waterways that increased from $.04/gallon to the current rate of $.24/gallon between 1981 and 1995, there is very little positive correlation between changes in economic activity and waterway ton-miles.

Table D-17 shows regression results for models based on domestic waterway ton-miles as reported by the Army Corps of Engineers Institute of Water Resources. The regressions are good even though they rely on a high negative correlation with rail ton-miles – an intuitively understandable and statistically significant complementary variable. During the past 15 years, the railroad industry has captured an increasing share of long-haul movements of low-value freight, affecting waterway ton-mileage significantly. This is partially due to the fact that as rail service has gotten better and as the waterway network has become less efficient due to lagging maintenance, a larger share of freight that traditionally moved via waterway has become more contestable and now moves by railroad. Relationships of waterway ton-miles with total capacity utilization and real gasoline prices are comparable to those affecting waterway tonnage.

Overall Findings

The steps performed prior to the regression analysis helped establish the validity of these models. Established economic measurements were selected based on diversity and availability over the 28-year time period. Correlations between the independent influencing variables and the dependent measures of freight transportation demand were tested for consistency over the 28-year time period. Collinearity among the independent variables was noted to help with the appropriate choice-making. "Dummy" or shock variables were considered for major socio-economic events such as the transportation deregulation of the early 1980's and NAFTA during 1993 and 1994. Several variables were also tested to determine if their "lagged" values provided additional explanatory value.

The final result has been encouraging. A variety of parsimonious regression models were prepared for each of the nine measures of freight demand. With the slight exception of Waterborne freight, which decreased over a long period even as the economy grew, the explanatory measurement R^2 was quite high for nearly all the models. With the fundamental structure in place, and regression models relying on relatively few, not-too-collinear independent variables, it appears that these regression models provide a strong basis for explaining freight demand volumes.

Principal Component Analysis

Both the literature review and the analysis confirm that one of the primary challenges of researching the multiple economic, demographic, and other factors that influence freight transportation demand is that they are often similar to one another. Imports grow with exports as trade grows. GDP and population grow with new household formation, and so on. The correlation table in Appendix C identifies the generally high correlations among the independent variables themselves, which is generally referred to as multicollinearity.

The challenge of collinearity is one of choice – when a regression model contains multiple independent variables that are highly correlated with one another. The statistical condition may result in inflated standard errors meaning that statistical significance is harder to achieve and signs on coefficients that are vastly different from expectations. Depending on how variables are selected, some might appear statistically significant while others may appear meaningless, but these results will have more to do with the construction of the model than with the quality of the data. The challenge is to choose independent variables based on both intuition and the ability to produce the best prediction of the dependent variable.

One statistically rigorous approach of dealing with these multicollinearity challenges is principal component analysis (PCA). PCA has been applied most notably by the Chicago branch of the Federal Reserve Bank in calculating their National Activity Index.[22] The Chicago Fed National Activity Index (CFNAI) is based on a weighted vector of 85 monthly indicators of national economic activity, providing a single summary measure with insight into turning points and fluctuations in the business cycle. The PCA procedure first groups the 85 indicators into four categories (production/income, employment, personal consumption & housing, and sales/orders/inventories) and then determines the appropriate weighting of the 85 individual indicators, by month, into a single index component that the Chicago Fed uses to model overall economic activity.

PCA provides estimates of independent variable weightings so that the variation in the linear composite of these candidate demand factors is best utilized – i.e., the most appropriate weighted average of the independent influencing variables can be used instead of a chosen subset of the variables themselves. Thus, PCA reduces inefficiencies in the selection process, minimizes multicollinearity, and offers a more accurate predictor of the dependent variable. The PCA was useful for the trucking and rail analyses because of the multiple independent variables that showed, through their correlations, that they had predictive value. The virtues of the PCA's improved statistical results were considered vs. the drawbacks of losing the intuitive connection that allows, with a simpler regression model, to state that "If A goes up by 10%, then B goes up by x%".

Steps in Applying PCA to Freight Demand

Since the main goal of PCA is to remove multicollinearity, the list of independent variables was divided into categories such that each category is fully represented in the final model, while

[22] Background on the National Activity Index, Feb, 2010, Chicago Federal Reserve digital asset publications.

factors within each category that are highly correlated could be combined. Groups of variables were developed that measured employment, consumption, production, commodity prices and foreign exchange. Lag values of important candidate demand factors were also included.

For example, correlation between real GDP and real GDP per capita would be naturally high. Similarly, correlation between industrial manufacturing and industrial production would also be high since the former is a part of the latter. Detailed compositions of the groups and their correlations, as well as the weights that form the principal components, are included in Appendix E. Table E-1 shows the six categories or variable groups that were developed.

Extracted Principal Components and Weights

Tables E-2 through E-7 show the results of the PCA for each category. Each category has enough underlying data delineation to explain nearly all the variation. Principal component methods develop coefficients such that maximum variation in the candidate demand factors is captured. The resulting linear combinations are uncorrelated to each other, which is desired.

Table E-2 suggests that the first two commodity group principal components explain approximately 96% of the total variation in the candidate demand (refer to right-most column, Cumulative Proportion). The first component explains 78% with the second component adding another 19% to the cumulative proportion.

Table E-3 indicates that the first two consumption group principal components explain approximately 94% of the total variation in the candidate demand.

Table E-4 indicates that the two foreign exchange group principal components explain nearly 94% of the total variation with the first component explaining nearly 70%.

Table E-5 indicates that the two production group principal components explain over 99% of the total variation with the first component explaining the vast majority of the variation.

Table E-6 indicates that the first two purchasing manager index and capacity utilization group principal components explain approximately 96% of the total variation with the first component explaining approximately 66% of the variation.

Table E-7 indicates that the first two employment group principal components explain over 99% of the variation.

Tables E-8 through E-13 present the relative weighting of the factors comprising each principal component group.

Results

“Parsimonious” regression models, that is, with fewer and more significant explanatory variables, were developed for the nine freight demand variables (via truck and rail). These models are shown with their accompanying diagnostics in Tables E-14 through E-27. These regression models illustrate the relative importance of the grouped variables (e.g., production, employment, etc.) in determining freight demand. All the PCA-based models explain at least

90% of the variance of each dependent variable (R^2>0.90). While interpretation of the model coefficients is less obvious than in the simpler regression models, the PCA allows the incorporation of a broader range of independent influencing variables.

Table E-14 provides the results for rail tons regressed on principal components and Table E-15 shows the associated diagnostics. The regressions accurately fit historical values as suggested by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in the employment principal component is associated with an increase in rail tons of approximately 0.8%, while a 10% increase in the commodity principal component is associated with a 0.3% increase in rail tonnage.

Table E-16 provides the results for rail ton-miles regressed on principal components and Table E-17 shows the associated diagnostics. The regressions fit the past very well as can be seen by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in the production principal component is associated with an increase in rail ton-miles of approximately 1%, while a 10% increase in the commodity principal component is associated with a 0.1% increase in rail ton-miles.

Table E-18 provides the results for annual rail revenue ton-miles (reported by the AAR) regressed on principal components and Table E-19 shows the associated diagnostics. The regressions fit the past very well as can be seen by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in the production principal component is associated with an increase in rail revenue ton-miles of approximately 0.9%, while a 10% increase in the commodity principal component is associated with a 0.1% increase in truck ton-miles. According to this model, the advent of NAFTA was associated with a 0.9% increase in overall rail revenue ton-miles.

Table E-20 provides the results for rail train-miles regressed on principal components and Table E-21 shows the associated diagnostics. The regressions fit the past very well as can be seen by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in the employment principal component is associated with a 1.1% increase in rail train-miles, while a 10% increase in the commodity principal component is associated with a 0.1% increase in rail train-miles.

Table E-22 provides the results for rail car-miles regressed on principal components and Table E-23 shows the associated diagnostics. The regressions fit the past very well as can be seen by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in the production principal component is associated with an increase in rail car-miles of approximately 0.8%, while a 10% increase in the purchasing manager and capital utilization component is associated with a 0.1% increase in rail car-miles.

Table E-24 provides the results for truck ton-miles regressed on principal components and Table E-25 shows the associated diagnostics. The regressions fit the past very well as can be seen by the very high R^2 and low standard errors. Model 1 suggests that a 10% increase in total trade is associated with an increase in truck ton-miles of approximately 0.2%. These models have naturally trending time series with error terms that correlate over time. By using auto-regressive corrections AR(1) and AR(2), these correlated error terms are controlled for and their potential to bias model estimates and associated standard errors are reduced. Compared to other models, the apparent impact of NAFTA is far greater at 9.7%.

Table E-26 provides the results for truck VMT regressed on principal components and Table E-27 shows the associated diagnostics. The regressions fit the past very well. Model 1 suggests that a 10% increase in the production principal component is associated with an increase in truck VMT of approximately 0.2%.

Overall Findings

PCA provides some limited benefits above and beyond well-constructed, parsimonious regression models. In the research, it does not necessarily result in better results. For the sake of a few additional percentage explanation of the Ordinary Least Squares difference, many new collinear variables are introduced via a complex method that is difficult to explain the connection between independent influencing variable and the resultant change in freight demand. T he method reduces the intuitive connection between "if A does this, then it makes sense that B does that," which is a fundamental benefit of a simple regression model.

With the challenge of finding good predictive variables that have an intuitive connection to the decrease in waterborne freight, the Research Team decided that PCA analysis for Water Tons and Water Ton-Miles should not be performed. While the analysis *could* find a combination of factors that would predict the decrease in waterborne freight, as was shown by the negative correlations with many economic variables in Table C-1 in the Correlation Appendix, these connections are not intuitive and hence, more difficult to defend.

The quality of the regression models and the opportunity to improve the analysis by using a greater number of correlated, independent variables leads to the conclusion that the PCA offers benefits. The PCA results, using multiple independent variables is a more helpful explanatory model of truck and rail demand, at the expense of less transparent relationships. This may be a tradeoff worth making if basic correlations and regression relationships are apparent and an improved predictability is desirable.

Such a result was not pursued with the waterborne traffic measures as the quality and diversity of correlations with independent variables was not there. Because of the lack of correlation with a sufficient set of independent economic variables, PCA for Water-Tonnage and Water Ton-Miles was not attempted.

Reliability and Representative Tests

In order to evaluate the reliability and the ability of the models to predict actual freight demand, actual data was compared against the various model predictions of past periods in a technique known as *backcasting*. Whereas forecasting is a prediction of future levels of freight demand, backcasting looks at how well can the selected model predict historical values and informs researchers on the actual fitness of the model assuming that underlying economic relationships do not drastically change.

Base models, or models utilizing the full dataset for the 1980-2007 historical period, were selected at random from the pool of PCA analysis presented previously. Based on the model specification, the research team estimated a second set of models on a revised sample of the historical data that randomly excluded three years of data. This 'sample model' is used to test the assumption that the trends that were estimated in the main body of this research are not strongly influenced by any single data point or outlying influence.

By randomly omitting three years of the 28 periods of data, a model without high leverage observations would resemble nearly the same growth and levels as the base model. Please note that this testing is generalizable only to US national level indicators as the relationship of predictors and freight demand of different regions within the US or different nations will likely be correlated at dissimilar levels. If models retained their predictive power as demonstrated as a backcast that is similar if not the same as the full sample backcast, then we can assume that the models are well specified and robust for estimating freight demand relationships. In extending the rationale of the backcast check, if underlying economic relationships and rates of change remain constant in future years, then the model would also be robust and appropriate for forecasting.

Three models (rail revenue ton-miles, truck VMT, and truck ton-miles) were used to demonstrate the performance of the models developed in this research. Due to the generally stronger fit of models that include principal component predictors, these three models focus on three of the specifications that utilize principal component independent variables. To evaluate the forecasting accuracy, we use the Mean Absolute Percentage Error (MAPE). It is defined as:

$$M = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$$

where A_t is the actual value
F_t is the forecast value

For each of the following three backcast examples, three trends are graphed: the base model estimates, the sampled model estimates and the actual freight demand indicator. When interpreting the results, the research team sought to graphically examine the base and sampled estimates for any deviations. Significant deviations indicated that the base model is not robust for forecasting and early warning detection whereas no deviations indicates that the base model is robust for the study's purposes.

Rail revenue ton-miles were estimated using the following function:

> *Rail revenue ton-miles = f(PCA commodity component, PCA production component, PCA consumption component, NAFTA indicator, autoregressive correction)*

Data was available at the quarterly level between 1990 and 2009 Q3, which meant that the specified model could be estimated on 77 periods. Due to the larger data sample, seven randomly selected quarters of data were omitted from the analysis. The backcast predictions for the sampled data appeared to be statistically and graphically reasonable and close to the base data set estimates (see Figure 6). The MAPE is 1.82%, indicating a tight fit between the predicted freight demand data and the actual freight demand. Furthermore, there are no significant deviations between the base and sample estimates indicating that the base model is robustly specified. When the model was tested against the missing data, the predictions closely followed the actual recessionary trend, which suggests that the underlying PCA variables are dependable for modeling exercises.

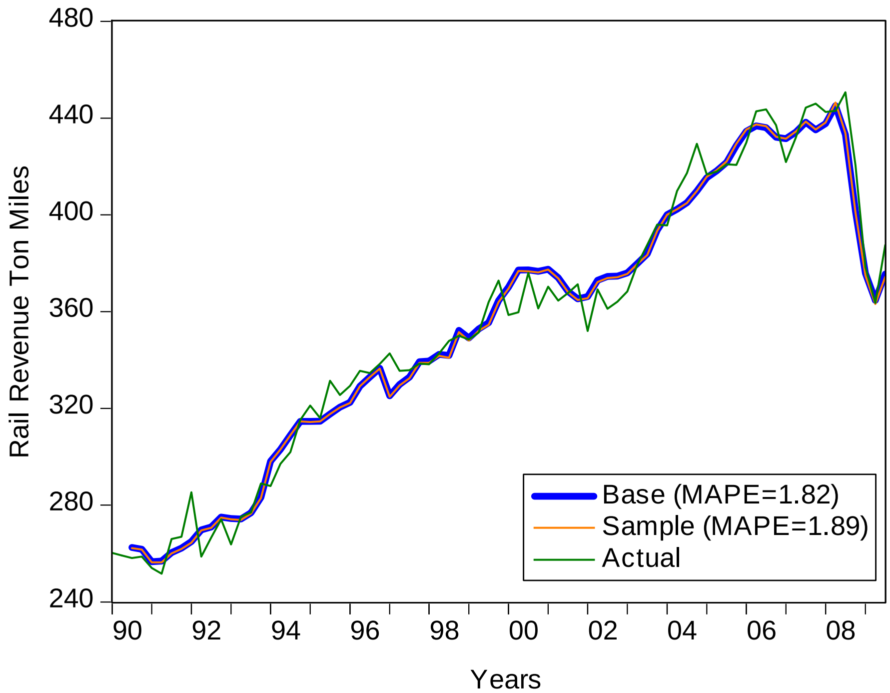

Figure 9. Backcast versus Actual Rail Revenue Ton-Miles

Truck ton-miles and truck VMT were also tested for reliability following a different backcast methodology. In order to randomly sample the data, a random number generator was constructed for a range between 1980 and 2007. For truck ton-miles, the years 1984, 1997 and 2002 were omitted. For truck VMT, the years 1984, 1991, and 2004 were omitted.

Truck ton-miles, using the PCA model, were estimated via the following:

Truck ton-miles = f(PCA commodity component, PCA consumption component, NAFTA indicator, autoregressive corrections for one and two periods)

Figure 10 below plots the observed number of truck ton-miles as well as the base model and the randomly sampled model. The randomly sampled model generates predictions that are very similar to the base model. The base model MAPE is 2.35, which rises to 2.57 upon removal of three randomly selected data points. Thus, the truck ton-miles model is reasonable in its predictive ability.

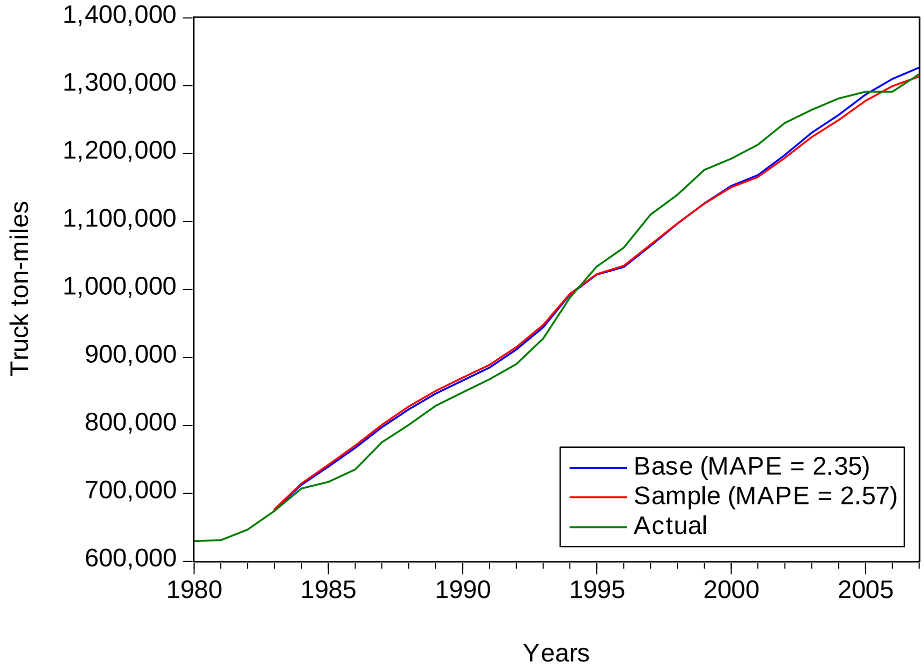

Figure 10. Backcast versus Actual Truck Ton-Miles

The truck VMT PCA model follows the following function:

Truck VMT = f(PCA commodity component, PCA consumption component, NAFTA indicator, autoregressive corrections for one and two periods)

Figure 11 below plots the observed number of truck ton-miles as well as the base model and the randomly sampled model. The base model MAPE is 2.36, which marginally rises to 2.42 upon removal of three randomly selected data points. Thus, the truck VMT model is reasonable in its ability to predict historical values and is not adversely or strongly influenced by specific years of data.

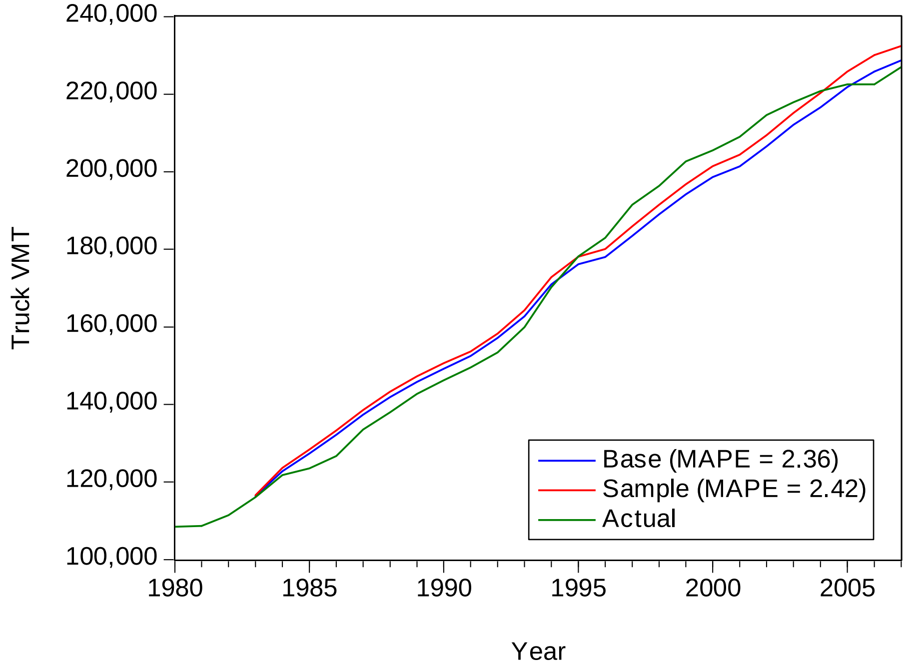

Figure 11. Backcast versus Actual Truck VMT

These three backcast examples demonstrate that the specified models are robust and are able to provide a consistently reliable and reasonably accurate prediction of freight demand factors. The tests check for strength and consistency and are particularly important in understanding if the regression models tested represents real relationships.

The general predicted trend indicates that the generated values from both the base and sample models are no more than an average 2.6% off from the actual values. While this analysis has focused almost exclusively on annual data, it should be remembered that models based on quarter-year data may offer reasonably robust predictions as well, subject to the availability of the relevant data. For example, the quarterly rail revenue ton miles backcast demonstrated above, overcomes seasonality in both the base and sample models and produces an accurate trend prediction. The annual analyses were successful in predicting the direction of trends, but do not offer the potential for more detailed analysis to understand the effect of shorter-term influences.

4. Conclusions and Recommendations

Forecasting the demand for freight transportation in our nation is crucial for many segments of our economy. Over the long term, forecasts support planned investments in infrastructure. Over the short term, forecasts identify challenges and opportunities to operators of transportation services and investors in transportation equipment. And because the various enterprises that provide freight transportation services require continued capital investment, operational enhancements, and improvements in technology and communication to ensure their existence, gaining an understanding of possible future demand is highly prized.

This research began by examining previous studies and other literature on factors influencing freight transportation demand. The research team sought to understand what factors affect the "pure" demand for transportation – the amount of tons of goods extracted, grown, produced and then utilized or consumed – vs. "network" factors that influence the timing, location, and distance goods are moved. A wide variety of potential independent influencing variables were considered that affect either these "pure" or direct freight demand factors, or the "network" or indirect factors. The analysis presumed that freight demand was independent by mode and, with only one notable exception, this proved to be the right choice.

The research team placed several constraints on the data that would be used to measure the influences on freight transportation demand. The data had to be regularly and freely available during the 28-year study period, which limited the ultimate selection. Expecting that a predictive model would apply for the entire time period might have been a strong assumption as suggested by sub-period correlations. However, the example backcasts may suggest otherwise. There have been significant shifts in the way the same economic and demographic data affects demand for freight transportation, indicating that the predictive models developed might be best suited for short-to-medium-term time periods.

Although a wide variety of prospective independent influences were originally considered, the variables ultimately chosen were primarily economic measurements tallied by the United States government. Few of the considered variables, especially the trucking data, had reliable information over time periods shorter than a year, limiting the team's ability to test a variety of time-lagged influences, for example by month or quarter-year. In subsequent research, it might be helpful to remove the constraint that utilized data must be widely and freely available. Information on warehouse development, housing patterns, transportation equipment costs, etc. might be difficult to obtain and isolate, but it might also help clarify some of the relationships that generate freight transportation growth.

The ability to "time lag" the independent factors provided some of the most interesting and beneficial results. Both the Purchasing Manager's Index and Housing Starts apparently had significant effects on subsequent freight transportation demands from year-to-year. Moreover, the models confirmed that the years following NAFTA saw a substantial increase in new freight transportation demand.

The regression analysis models indicated very good fit, with R^2values above .90 and a relatively parsimonious set of independent factors, across the various measures of freight demand. Rail car loadings have typically been a good historical indicator of industrial activity, and vice-versa as it turned out. Freight transportation plays a central role in the movement of materials and goods in our industrial as well as consumption economy, so this "fit" was not surprising.

There were observable differences that matched our intuitive understanding of what affects freight demand. Measures of "pure" industrial production and personal consumption affected rail tons while trade, imports and exports, because of their lengths-of-haul to and from seaports, affected both truck and rail ton-miles. Measures of inland waterway freight were more problematic to model since use of this mode has actually dropped during the past 20 years, even as the economy has mostly grown. Waterway ton-miles was the one dependent variable that showed very high negative correlation with a substitutable alternative – rail ton-miles.

Early warning indicators were identified by noting if and how well fluctuations in independent factors' values in one time period predicted changes in freight demand during the following time period. Depending on the freight transportation demand being measured, Purchasing Manager's Index, Number of Households (i.e., "Housing Starts") and even Fuel Prices, all showed some ability to predict freight transportation demand in subsequent periods, typically in conjunction with other economic variables. The predictive value of these "Early Warning" variables is even more helpful if they explain a large portion of changes in future freight demand.

Selected summary results from our Regression analysis include the following excerpts from the predictive models that show what the∆Change in Freight vs. 10% Change in Indepe ndent Variable would be for the two most primary independent influencing variables in one of the top predictive models of freight demand:

Freight Demand	**Primary Influencing Variable**	**∆Freight / 10% Change**	**Secondary Influencing Variable**	**∆Freight/ 10%Change**
Rail Tonnage	Industrial Prod. Index	8.4%	Trade Wghtd. Index (Broad Currencies)	- 1.4%
Rail Ton-Miles	Industrial Prod. Index	9.6%	Inventory/Sales Ratio	- 4.7%
Rail Train-Miles	GDP in Real$	5.7%	Purchasing Mgr's Index (Lagged from prior yr)	1.8%
Rail Car-Miles	GDP in Real$	6.6%	NAFTA – two yrs following	0.4%
Rail Rev Ton-Miles	GDP in Real$	10.6%	NAFTA – two yrs following	0.6%
Truck Ton-Miles	Total Trade in Real$	1.0%	Gasoline Price	- 0.5%
Truck Vehicle Miles	Total Trade in Real$	1.0%	Inventory/Sales Ratio	- 1.7%
Water Tonnage	Total Capacity Utiliz.	8.6%	Grain+Coal Tonnage	0.9%
Water Ton-Miles	Rail Ton-Miles	- 4.4%	IWTF Gas Tax (Lagged from prior yr)	- 1.3%

Out of concern that many of the independent influencing variables were closely correlated with each other, the team sought an additional method to overcome potential bias in the basic regression analysis. Principal Component Analysis (PCA) provided a helpful method to combine the explanatory benefit of multiple, similar independent economic factors on resulting freight transportation demand. While they are less intuitive and difficult to deconstruct, the method has been proven to be useful elsewhere and may help develop accurate predictive models even when mostly highly collinear independent data is all that is available.

PCA models do not provide good correspondence between changes in the independent variables with changes in the dependent measures of freight transportation since the construction of the components affects this correspondence. Still, PCA models developed by the research team for this project were able to explain most of the variability in the truck and rail demand measures, and performed well in a backcasting exercise, accurately matching predicted with observed data.

Recommendations for Additional Analysis

- Extend the data capture through the 2008-2011 time period to determine if the same relationships exist during our current recession.
- Experiment with more or different independent influencing variables and freight demand measurements that might be available on a monthly or quarterly basis, even if fees were involved or the data were available for shorter (5- to15-year) time periods.
- Consider regional measurements of economic and other freight-influencing data such as state GDP, housing starts and imports/exports by regional port. Compare with state-based measures of truck and rail traffic to determine whether similar predictive relationships exist on a regional basis.
- Evaluate new and emerging independent variables such as the growth in modern warehouse real estate development and technologies or the shift in U.S. agricultural exports towards the Pacific Rim

Appendix A - Peer Exchange Synthesis

The following pages present a synthesis of feedback on an earlier version of the work presented in this report from a Peer Exchange held May 18, 2010, at the Beckman Center in Irvine, CA. Participants invited to the Peer Exchange represented potential users of the project findings, including private-sector supply chain companies and trade associations (rail, trucking, and others), ports, U.S. and Canadian government officials at the local, state, and federal levels, academics, and consultants. The purpose of the one-day meeting was to discuss the preliminary research findings; obtain feedback; and facilitate a dialogue on freight demand factors, defining those that are cost-effective as early warning indicators of change in freight demand trends.

A list of Peer Exchange attendees follows the synthesis.

Synthesis of Feedback from Peer Exchange
NCFRP #11 – Identification and Evaluation of Freight Demand Factors
May 18, 2010 – Beckman Center, Irvine
Main themes:

- Relationship between this work (based on national-level demand factors) and forecasting needs at subnational (regional/multi-state, corridor, metro or local area) level.
    - Are any of the identified demand factors transferable (i.e., significant at the subnational level)?
    - Are data sources available?
    - Is the methodology transferable?
    - Do these answers depend on the geographic scale of the question? (e.g., small or large metro area, vs. multi-state corridor)
    - What is the relationship between this work and local/regional/state travel demand models?
    - Detailed private-sector data would be needed for more geographically localized models. (also, see Data availability)
    - Procedures for obtaining/using data at a subnational level, derived from the national methods used in this project, would be helpful for local/metro areas.
- Statistical issues and model specification
    - The model is not intended to provide a forecast (within the scope of NCFRP 11).
    - Should the model mix indices with actual values?
    - Need to examine lagging/leading variables. [Addressed as part of early warning indicator analysis]
    - Could the use of ratios (rates) in the model lead to spurious correlation?
    - Reconsider inclusion of closely correlated (collinear) variables in Principal Components Analysis (PCA).
    - Need to clarify how PCA was used in backcasting.
- Data analysis issues

- Many of the factors used in our model are also used by the private sector (e.g., railroads, trucking industry) in forecasting demand.
- What about the effect of specific commodities on freight transportation demand? A related factor is domestic vs. import/export shares.
  - Bulk agricultural products were evaluated in our work (though peer input indicated this system is in a state of change).
  - Coal transportation (see Baltic dry index; data sources include EIA and railroads)
  - Salt (as road de-icer)
  - Soda ash
  - Sand & gravel
  - Phosphate/fertilizer
  - High-fructose corn syrup (changing levels of demand due to public awareness, government policy?)
  - Both panel and peer exchange suggested removing some commodities (esp. coal and grain) from the analysis to see if model is still valid.
- How does the total tons moved by mode (as per our model) compare with national totals?
- How might it be possible to fold in air, water freight modes?
- How does the model account for industry/economic trends?
  - Increase in offshore manufacturing
  - Increase in transloading
- The RFP lists a wide range of factors, but many are not addressed in the model. Why?
- Could the model also be used to examine demand per capita and per unit of GDP?
- How does the model account for the impact of technology on freight demand throughout the supply chain? Productivity measures may be appropriate for this purpose [these may be captured in some of the identified demand factors].
- Can any measures of freight value (by truck or rail) be incorporated in the model?
- Could the development and use of supply chain data (as opposed to commodity-based data) offer a more robust means of model development for demand forecasting purposes? Supply chain archetypes could be developed as a framework for this approach.
- Could the model address factors related to transportation service levels or characteristics?
- What about the geographic focus (on U.S. only)? Could the model be used to forecast or backcast for Canadian, Mexican rail or trucking?

  - There was agreement that variability in data is increasing sharply, with recent examples (past ~18 months) from all sectors (e.g., fuel price, trans-border freight flows).
  - Need to be able to distinguish long-term trends from seasonal variations in freight demand.
  - How far out in time is it reasonable to forecast? Different government/private sectors may use widely varying time horizons (from one year to 50).
  - Which factors might prove to be leading indicators that are reliable more than 2-3 months into the future?
  - Early models of freight transportation separated competitive from non-competitive goods movement; this work does not.
- Data availability
  - Could the model be improved by considering data sources that are not available without charge (e.g., higher-frequency data for some indicators, private-sector data)? Could guidelines be developed based on the value of the data for decision making?
  - Private-sector data is not available except on a very limited basis, due to privacy/confidentiality concerns, potential release of competitive information, risk of use in enforcement or trigger of legal liability. These barriers can be overcome by being clear on purpose/use of data; use of written agreements to protect data privacy; de-identifying data sets (e.g. trucking company bid histories, truck probe data); identifying the benefits of data sharing for the private sector; developing a trust relationship over time as to how the data will be used; possibly paying for data.
  - Trade associations may offer some data, which may or may not be representative.
  - Private companies may share data via investor relations function.
  - The U.S. has a data gap in urban truck movements. Canada now monitors 25% of daily vehicle km, uses information to reduce congestion. Data could also be used in forecasting demand or the need for road maintenance or construction. Canadian data is more related to supply chain than commodities. Includes freeways, local roads, border crossings; engine type, fuel consumption, braking information, chained trips. Data is compared with volume- and speed-based performance measures.
  - The goal in this project was to develop a model that did not rely on the use of proprietary data sources or those that might be short-lived, or that specified measures where no data could be gathered. Not all government data is free, and not all public data is permanent or long-lived.
- Underlying (or overarching) trends & context
  - Long-term shift from consumption-oriented society? Would shift to consumption of services vs. goods affect the model?
  - Global climate change impacts on fuel/transportation modes and costs?

    - "Peak oil" effects on fuel cost.
    - Government/regulatory policy with regard to climate change (e.g., in California).
    - Consumption trends in other countries (e.g., China, India).
    - Resolution of U.S. trade deficit.
    - Growing trend towards internet sales.
    - First-time trend towards increasing U.S. household size.
    - National resources available for freight infrastructure construction.
    - Growing interest in local sourcing of food (may be a small fraction of market).
    - Trend towards denser, urban-infill development patterns.
    - Roadway congestion in urban areas.
- Value of this modeling effort
    - At the regional/local/gateway level, as a tool to help communicate to policy makers the role and value of freight movement in the overall economy.
    - At the national level, as a guide to infrastructure investment needs.
    - Can help academics teach students about freight demand trends.
    - Can help state/metro agency define the need for an infrastructure project, design funding strategy, and obtain funding.

List of Peer Exchange Attendees
(excluding Project Team members)

Name	Affiliation
Beningo, Steve	BTS/Research and Innovative Technology Admin.
Bingham, Paul	IHS Global Insight
Brodin, Doug	California Department of Transportation (Caltrans)
Casgar, Tina	San Diego Association of Governments
Deitz, Ron	Bureau of Transportation Statistics
Drumm, Scott	Port of Portland
Fuller, John	University of Iowa
Goodchild, Anne	University of Washington
Hancock, Kathleen	Virginia Tech
Holguin-Veras, José	Rensselaer Polytechnic Institute
Ivanov, Barb	Washington State DOT
Kirkpatrick, Mark	Canadian Pacific Railroad
Lahsene, Susie	Port of Portland
Lepofsky, Mark	Visual Risk Technologies
Logan, Bob	Consultant
Ludlow, Donald	Cambridge Systematics
McCormack, Ed	Washington State DOT
Mickle, Michael	Alpha Decision
Núñez, Juan	Burlington Northern Santa Fe Railway
Palmerlee, Tom	TRB
Petzold, Roger	FHWA, Borders & Corridors
Pisarski, Alan	Consultant
Regan, Amelia	University of California, Irvine
Resor, Randy	U.S. DOT
Rhodes, Suzann	Wilbur Smith
Rogers, Bill	TRB
Shalia, Rakesh	Federal Express
Shi, Huajing	Port Authority of NY/NJ
Short, Jeffrey	American Transportation Research Institute (ATRI)
Tardif, Robert	Transport Canada
Zmud, Johanna	NuStats

Appendix B - Literature Review

Literature Review to Investigate Factors Affecting Transportation Demand

The Research Team used a "case" approach to review and analyze a variety of recent and relevant studies on what factor affect the demand for transportation. The literature analysis was developed in two steps. The initial step included a review of a significant number of documents based on their relevance to freight demand estimation. NCFRP-01, the "Review and Analysis of Freight Transportation Markets and Relationships," was scanned to identify relevant documents. A thorough review of the papers/documents was conducted and yielded a representative collection of freight demand models that have been used in the past. During the second step of the literature review process, the Research Team performed an in-depth analysis of the various models that are featured in the following documents:

In reviewing the literature for the purpose of identifying factor affecting freight demand, it was important to distinguish between general *demand factors* and the specific *datasets* actually utilized to represent these factors. In some cases, datasets employed to represent certain factors may actually be outputs of other models or summarizations (e.g., the output from an external regional economic growth model). For each of the complex and varied datasets in the model survey literature, the Research Team endeavored to tease out the underlying factors.

The models in the literature are diverse. They include both commodity and vehicle-based models over a variety of different geographic contexts. For each model summary, a rough distinction is also made between factors used to help estimate *pure or economic demand* and factors that are used to help estimate *network demand*. With pure demand, the primary concern is generally the demand generation stage – which factors, if any, are used to determine the quantities and flow patterns associated with freight? They are often similar to those that are typically used in econometric demand modeling, such as employment, commodity characteristics and business activity. For the network demand, the factors tend to be associated with the *distribution* of freight traffic. Of course, there is some overlap between factors that can be used to inform about network demand. For instance, business activity and concentration of land use can help determine how much of a certain commodity is demanded. At the same time, such factors can help determine where and how the commodities are shipped.

Economic Indices for the Transportation Sector
Kajal Lahiri &Vincent Wenxiong Yao, Transportation Research Part A 40 (2006) 872-887

Indicators are developed for the transportation services sector to identify its current state and predict its future. The work tries to identify the relationship of the transportation sector to the aggregate economy as well as develop statistical procedures that can capture changes (ups and downs) in the transportation sector. A set of leading indicators is also developed using rigorous statistical processes and is found to be a useful forecasting tool.

Relevance to NCFRP 11:
Indicators identified help understand how the transportation service sector is changing both currently as well as in the future. While these indicators do show how the freight industry and broadly the transportation services sector is performing as well as how it might perform in the future, the nature of freight demand itself and its drivers is less well explored. Nevertheless, leading factors are identified that could be used as inputs to freight demand analysis.

Freight Demand Factors Cited:
Factors are identified that are representative and allow development of a composite leading indicator (CLI). The following list are not considered to be freight demand factors following the definition set forth for this project; however, these indicators may allow for identification and detection of trends and the transportation's conditions as well as serve as predictors for future freight performance. Below some of the factors that form the CLI are shown below which include the Dow Jones Transportation Average, PMI – Inventory diffusion index, New Orders (Transportation Equipment), Shipments (Transportation Equipment), Industrial production (Transportation Equipment), Payrolls (Transportation Equipment) and the consumer sentiment index.

US transportation leading factors	Factors (up to 12/2003)
DJTA (20 Stocks)	0.098
PMI - Inventory diffusion index (PMI-inventory)	0.091
NO (TE)	0.058
Shipments (TE)	0.140
IP (TE)	0.256
Payrolls (TE)	0.220
Consumer sentiment index (CSI)	0.137

Nationwide Freight Generation Models: A Spatial Regression Approach
David C. Novak, Christopher Hodgdon, Feng Guo, and Lisa Aultman-Hall
Networks and Spatial Economics

This paper investigates the application of linear regression models and modeling techniques in predicting freight generation at the national level within the U.S. Specifically, the paper seeks to improve the performance and fit of linear regression models of freight generation. The paper provides insight into different variable transformation techniques, evaluation of the use of spatial regression variables and the application of a spatial regression modeling methodology to correct for spatial autocorrelation. The paper concludes that the spatial regression model is the preferred specification for freight generation at the national level.

Relevance to NCFRP 11:
The paper adopts a freight generation modeling methodology at the nationwide level by using proprietary data sources such as *TransSearch* as using public data sources such as the Commodity Flow Survey (CFS). The dependent variables include county-level freight origin – destination for two commodities (paper and machinery excluding electronics). They also adopt spatial approaches to correct for inherent spatial autocorrelation, which introduces model more sophisticated interactions between different zones across the US (i.e. they attempt to model "spill-over" effects from one region to another).

Freight Demand Factors Cited:

- Total Employment and Employment in different sectors of the origin and destinations
- Distance between origins and destinations
- Port tonnage for particular zone
- Highway length for a particular zone

Forecasting freight demand using economic indices
Jonathon T. Fite, G. Don Taylor and John S Usher, John R. English, and John N. Roberts
International Journal of Physical Distribution & Logistics Management 32 (2002): 299-308

The paper describes the results of an effort to predict freight volume in the truckload (TL) trucking industry with an objective is to develop a method and identify relevant independent economic drivers that may provide a reasonable basis for forecasting demand. With a combined dataset that covers 31 months of nationwide volumes provided by J.B. Hunt Transport and a series of 107 economic indices, the authors pre-screen each variable to identify correlations and applicable lead times for national, regional and industrial segments. Then through a series of stepwise multiple linear regression models, the authors estimate the association between TL freight volume with independent demand indicators.

Relevance to NCFRP 11:
This paper conducts a search for independent economic variables that may potential indicators for forecasting. The authors make a specific effort to look into lead time structures rather than lag time structures. A number of the 107 variables utilized in the study are similar to the variables used in the freight demand factor research. Unlike the NCFRP research, Fite et al. (2002) findings on the regional and industrial segments, finding that smaller segment/cell models are more sensitive to event-specific effects

Freight Demand Factors Cited:

National level factors:

- Producer commodities price index of construction materials and equipment (3-mo lead)**
- Retail store sales of automotive dealers
- S&P 500 index
- Producer Commodities price index for household furniture
- US exports
- Dow Jones industrial stock index
- Producer commodities price index for commercial furniture

Regional factors:

- Retail inventories for all retail stores (a top pick)
- Producer commodities price index for processed poultry and meats**

The following is a complete list of factors that were considered for the analysis:

Truck tonnage index (American trucking association)
Purchasing managers' index
Dow Jones utilities index
S&P 500 stock index
Unemployment claims
Manufacturers' new orders of consumer goods and materials
Consumer expectation index
US exports
Total manufacturing prodtn index
Iron and steel prodtn index
Electric machinery prodtn index
Aircraft and parts prodtn index
Furniture and fixtures prodtn index
Paper products prodtn index
Canned and frozen foods prodtn index
Foods prodtn index
Consumer goods prodtn index
Materials prodtn index
Total manufacturing sales

Manufacturing sales of nondurable goods
Manufacturing finished goods inventories
Manufactures' total unfilled orders
Manufacturer's' unfilled orders of nondurable goods
Manufacturers' new order of nondurable goods
Total retail store sales
Retail store sales of nondurable goods
Retail store sales of furniture stores
Retail store sales of apparel and accessory stores
Retail store sales of general merchandise stores
Retail inventories for durable goods stores
Retail inventories for apparel stores
Retail inventories for food stores
Retail inventories for general merchandise stores
Total wholesale inventories
Wholesale inventories of nondurable goods stores
Producer commods. price index of all food
Producer commods. price index of livestock
Producer commods. price index of fluid milk
Producer commods. price index of fish
Producer commods. price index of processed poultry
Producer commods. price index of metals and metal products
Producer commods. price index of nonferrous metals
Producer commods. price index of machinery and motive products
Producer commods. price index of construction materials and equipment
Producer commods. price index of construction materials
Producer commods. price index of prepared paint
Producer commodity price index of lumber
Producer commodity price index of household furniture
Producer commodity price index of floor coverings
Retail premium unleaded gasoline prices
Interest rates for conventional mortgages
Interest rates for prime six month commercial paper
Interest rates for three month treasury bills
Composite long term government securities
Truck tonnage index three month CMA (American trucking association)
Dow Jones transportation index
Dow Jones composite index
Composite index of leading indicators
Contract/order plant equipment
Metal mining prodtn index
Nonelectric machinery prodtn index
Motor vehicle and parts prodtn index
Lumber and lumber products prodtn index
Rubber and plastic products prodtn index
Tobacco products prodtn index
Final products prodtn index
Equipment prodtn index
Manufacturing and trade inventories
Manufacturing sales of durable goods
Manufacturing materials/supplies inventories
Manufacturing work in process inventories
Manufacturers' unfilled orders of durable goods
Manufacturers' new orders of durable goods
Wage and salary disbursements
Retail store sales of durable goods
Retail store sales of building supply stores
Retail store sales of automobile dealers
Retail store sales of food stores
Retail inventories for all retail stores
Retail inventories for building supply stores
Retail inventories for nondurable goods stores
Retail inventories for furniture and appliance stores
Automotive retail inventories
Wholesale inventories of durable goods stores
Producer price index of all commodities
Producer commods. price index of grains
Producer commods. price index of eggs
Producer commods. price index of meat
Producer commods. price index of dairy products
Producer commods. price index of sugar and confectionary
Producer commods. price index of iron and steel
Purchasing power of the 1982 US dollar
Producer commods. price index of agricultural machinery
Producer commods. price index of electric machinery and equipment
Producer commods. price index of concrete ingredients
Producer commodity price index of flat glass
Producer commodity price index of plywood
Producer commodity price index of commercial furniture
Retail unleaded gasoline prices
Gasoline production
Interest rates for three month CD
Interest rates for prime 90 days
Interest rates for six month treasury bills
Gross domestic products
Housing starts
US imports

Truck Volume Estimation via Linear Regression under Limited Data
Maria Boilé and Michail Golias

The authors utilize a series of linear regression algorithms to 'train models' when training data is limited. Four algorithms are developed, including Ridge Regression (RR), Lasso Regression (LR), Partial Least Squares Regression (PLSR), and Constrained Linear Least Squares Optimization (CR).
Focusing on 14 highways in New Jersey, the authors test the models on data segmented by roadway class. Demand drivers were primarily socioeconomic indicators specific to each section, and the geographic area included was determined using a search for the optimal buffer zone from each roadway class. The robustness and optimality of a modeling exercise using limited data can be maximized by systematically testing multiple training models as well as incorporating the use of precision tools such as GIS.

Relevance to NCFRP 11:
The iterative process employed tested multiple types of models on data with varying coverage area. Similar to the NCFRP-11 process, testing multiple models may shed light on optimal utilization of data. The successful inclusion of local socioeconomic indicators provides evidence that regional indicators may be utilized in estimating truck traffic. Future work that considers regional modeling may benefit from GIS-based approaches to determine appropriate regional influences and augment precision of study estimates.

Freight Demand Factors Cited:
The paper considered 3 socioeconomic variables for 11 SIC industries were considered in addition to population.

Socioeconomic Factors

- Number of employees
- Sales Volume
- Number of Establishments
- Population

Industries for which socioeconomic factors (excluding population) are considered

- Mining
- Agriculture
- Manufacturing
- Construction
- Transportation
- Utilities
- Retail Trade
- Wholesale Trade
- Real Estate
- Finance/Insurance
- Services

Forecasting Truck VMT Growth at the County and Statewide Levels
Feng Liu and Robert G. Kaiser

In this article, the authors develop statistical models to forecast truck VMT growth of four facility categories at the county and statewide levels. The models incorporate both socioeconomic and transportation system supply variables, and various specifications were evaluated for statistical validity. The results indicate that local socioeconomic variables explain a considerable amount of the truck VMT variance, particularly for urban interstate and non-interstate facilities. Adding external driving forces such as truck corridor or contributing state gross sate product variables increase the models' explanatory power, particularly for rural interstate facilities. The authors find that the modeling provides reliable results across geographies and a cost effective solution to developing a statewide travel demand model.

Relevance to NCFRP 11:

Liu and Kaiser utilize simple OLS and Fixed Effects OLS models to construct forecasts of truck VMT. This paper largely follows similar estimation exercises by segmenting the data sample by class and incorporating socioeconomic factors to drive truck demand. The model is generalizable to broad road classes, which give some level of insight into the expected changes across a state.

Freight Demand Factors Cited:
Socioeconomic Factors

- Number of households
- Population and population density
- Employment and employment density
- Employment by sectors
- Per capita income and household income
- Population by age
- Retail sales

Freight/Transportation Data

- Commodity Flow Survey (CFS)
- Gross State Product (GSP)
- Lane Miles

Future Freight Transportation Demand (National Urban Freight Conference 2006)
Paul Bingham

The presentation focuses on underlying factors that drive freight demand. Trade growth is rapidly increasing with widespread pressure and demand for adequate levels of transportation and freight logistics services. Trade growth is influenced by factors beyond the common underlying demand for consumption of goods. The author makes particular note that global logistics sourcing, global trading blocks, harmonization of trade and regulatory policy, security standards, and increased freight and traffic congestion have dissimilar effects and thus leading to uneven growth trends across regions. A disproportionate share of freight growth is concentrating at major hubs, crossing and gateways in urban regions. Provided increased pressure, transport infrastructure is reaching capacity, and there is now increased demand for transport labor and optimal land-use.

Relevance to NCFRP 11:

The presentation brings into light some critical areas that are applicable to this research. While it may not be possible to explicitly model policy considerations that are not explicitly tied to demand, these qualitative concerns may aid in guiding the validity and logical assessment of forecast approaches. Provided the expansion in demand for transport, metrics concerning land-use and socioeconomics (e.g. employment) may be useful indicators for understanding the disproportionate changes in trade growth. Whereas national models may paint the overall picture, knowing that small patches of high growth are present at a regional level may suggest that regional models may be more appropriate in the future forecast environment.

Monthly Output Index for the U.S. Transportation Sector
Kajal Lahiri, Herman Stekler, Wenxiong Yao, and Peg Young

In this article, the authors develop a monthly output index for the U.S. transportation sector from January 1980 through April 2002, covering air, rail, water, truck, transit, and pipeline activities. Additional indices are developed for each freight and passenger demand segments. A Total Transportation Output Index is constructed using five freight component series and three passenger transportation series. It is found that the total transportation output index's performance is closely predicts the output indices produced by other federal agencies. Furthermore, the index appears to be suitable to capture growth slowdowns in the national economy. Generally, the index's historical performance tends to lead NBER growth cycle turning points by six months for peaks and five month for troughs.

Relevance to NCFRP 11:
The indices constructed by the authors present a method of estimating output of the transportation sector reflective on a subset of various mode performance indicators. The weighting method does not utilize a formal estimation method. A comparison between the constructed index and existing indices finds similar prediction accuracy. Compared with a formal econometric demand model, index construction approaches estimation of economic activity from a higher level using products of demand (e.g. air revenue miles) as opposed to demand factors (e.g. wages, population), and the index method is a suitable approach for understanding larger geographies where as formal modeling approaches may be more sensitivity to micro-level interactions.

Freight Demand Factors Cited:
The factors used to construct the index in this article are products of demand rather than the drivers themselves. A number of these factors are considered in the NCFRP-11 modeling exercise.

Freight Components:
- Trucking tonnage
- Air revenue ton-miles
- Rail revenue ton-miles
- Waterway tonnage indicators
- Pipeline movements of petroleum products

Passenger Components:
- Air revenue passenger miles
- Rail revenue passenger miles
- National transit ridership

Final Report on Contract Number NCTIP97-21: Development of a Freight Forecasting Model to Forecast Truck Flow Between NJ Counties Themselves and Between NJ Counties and Other States
Kenneth Lawrence and Gary Kleinman

The aims of the project are to develop a model with the capability of predicting commodity flow information via trucking. In the context of New Jersey, the authors develop a series of database tools to allow for decision makers to easily view the available data. A forecast analysis system is developed to inform agencies on the need for new roadways. The forecast modeling approach follows a gravity flow model for freight tonnage flows in which the best model is assumed to be one that generates the most accurate backcast. Drivers of the model included populations of O-D states, distance between O-D state, person incomes, wages, and total employment.

Relevance to NCFRP 11:
By explicitly incorporating physical or economic distance, the gravity model estimates the propensity to trade or move goods between two locations. Essentially, the propensity to move goods between points A and B can be a function of socioeconomic demand factors, which then allow researchers and policy analysts to understand traffic on certain links. The type of model has the ability to answer questions that are central to long term planning of transport links whereas national aggregate models for NCFRP-11 provide answers to issues with macro-scale implications.

Freight Demand Factors Cited:

Socioeconomic
- Total employment
- Population
- Earnings
- Total Personal Income

Commodity flow survey data (1993 CFS)
- Weight of shipment (or tons)
- Ton-miles
- Distance between origin and destination

Title: A Survey of the Freight Transportation Demand Literature and a Comparison of Elasticity Estimates
Chris Clark, Helen Tammela Naughton, Bruce Proulx, Paul Thoma
Prepared for Institute for Water Resources, U.S. Army Corps of Engineers

This study reviews various aggregate and disaggregate choice methodologies employed to estimate freight demand. Methods from notable contributions to demand estimation are discussed with close attention paid to functional form and level of aggregation. From comparing elasticity estimates across modes and methods, the authors find that generally aggregate and disaggregate models tend to produce noticeably different elasticity results noting that a number of contextual factors may also contribute to differences. Based upon the contrasting differences, the survey concludes with a discussion of considerations for improving demand estimation and research.

Relevance to NCFRP 11:
The authors review various modeling approaches and bring attention to a number of weaknesses that are common in model specification: 1) the lack of focus on between mode competition in demand modeling, 2) the imprecision of aggregate data in price elasticities, 3) a need to consider both short and long term estimation, and 4) a more solidified consideration for underlying motives of functional forms. An interesting insight is that the

Various models are examined:
Aggregate Demand Models: modal split models and neoclassical aggregate demand models
Disaggregate Demand Models: inventory and behavioral models

Freight Demand Factors Cited:
Factors considered in both types of models are similar; however, the main difference is the level of aggregation and the type of interaction. Disaggregate models may take the perspective from a shipping manager where as an aggregate model may be somewhat removed from theory at the individual decision level. The following highlight the inputs from a selection of example models:

> *Inventory-based demand (Disaggregate model)*
> Some authors may include: shipping cost per unit, mean shipping time, variance of shipping time and carrying cost per unit of time while in transit. In order to determine how a shipper chooses between modes, the shipper's indifference curve is specified
>
> *Neoclassical Aggregate Demand Models*
> The data may used may be commodity group-specific and consist of the distance of links, total tons moved, average freight rate, transit time and its variability by mode on each link.

Title: Commodity Flow Modeling
William R. Black
Transportation Research Circular (1999): 136-54

This research focused on the primary objective of creating a database of commodity flows of counties in Indiana and to allocate commodity tragic to the state's transportation network. The approach undertaken in the study utilized multiple quantitative and technical tools, including TransCAD (GIS), multivariate regression, entropy-based gravity model algorithms along with other database tools. A transportation planning framework is adopted to identify networks, to estimate production and attract of commodity flows, to determine traffic distribution from O-D pairs using a gravity model, to determine mode splits, and to assign traffic to links. Nineteen commodity groups were considered in this analysis and forecasts traffic for 2005 to 2015. The aims and implication of the modeling system is to aid decision-makers in determining and assaying alternative options for investment in transport infrastructure.

Relevance to *NCFRP 11:*
The commodity flow model utilizes an interdisciplinary approach to build a sophisticated representation of Indiana's transportation network and its commodity flow patterns. The author uses TransCAD to create the transportation network, update data and traffic assignment. The particular significance of using geographically precise data with micro-level ability diverges from the larger regional or national aggregate models that have been reviewed in this literature review.

Freight Demand Factors Cited:

Traffic generation drivers

- Population
- Employment by sector

Container Demand in North American Markets: A Spatial Autocorrelation Analysis
Wilson, William W and Camilo Sarmiento. 2007.

Researchers utilized a Cross-Sectional Spatial Autocorrelation Analysis to identify how and if demographic characteristics, primarily personal income and population were related to container demand. There was a significant positive relationship with income and population.

As the study was performed for various North American markets, there was the opportunity to analyze infrastructure and spatial characteristics of the markets in relation to one another. The number of terminating railroads in an area as well as the number of interstate highway miles in a focus area had significant positive relationships with container demand in that area. Location near a port facility also had a significant positive relationship with container demand, while container demand is overall, larger on the West Coast largely due to the relative proximity of those port facilities being in a favorable position to serve Asian trading markets. Some areas in the South also have relatively high demand.

Interestingly, locations adjacent to locations with high container demand had lower-than-expected demand for containers. While this is significant on a regional transportation planning basis (e.g., Nashville's demand for containerized freight will tend to be subordinated by Memphis' greater gravitational attraction due to its status as a rail hub), it has less relevance to a national planning study.

Relevance to NCFRP 11:
While the study examined and compared selected areas in North America to identify regional factors that influenced the relative demand for containers, key conclusions from the analysis indicate that both population and personal income have a significant positive relationship with the demand for containerized freight.

Freight Demand Factors Cited:

Socioeconomic

- Total population
- Total Personal Income

Freight Travel Demand Modeling – Synthesi s of Approaches and Development of a Framework,
Pendyala, Ram, V. Shankar and R. McCullough, 2000 William W and Camilo Sarmiento. 2007.

A study of commodity flow for the State of Indiana, the model included rail and truck traffic. Trip generation was performed using linear regressions with employment and population as independent variables. The model forecast commodity productions and attractions. Distribution used a constrained gravity model. For the State of Wisconsin, Pendyala et al. developed a model

Relevance to NCFRP 11:
While both independent variables of employment and population were utilized and helpful in explaining commodity flow, the Study Team at Halcrow and TTI noted the high colinearity between these two variables.

Freight Demand Factors Cited:

Socioeconomic

- Total population
- Total employment

Container Demand in North American Markets: A Spatial Autocorrelation Analysis
Wilson, William W and Camilo Sarmiento. 2007.

Researchers utilized a Cross-Sectional Spatial Autocorrelation Analysis to identify how and if demographic characteristics, primarily personal income and population were related to container demand. There was a significant positive relationship with income and population.

As the study was performed for various North American markets, there was the opportunity to analyze infrastructure and spatial characteristics of the markets in relation to one another. The number of terminating railroads in an area as well as the number of interstate highway miles in a focus area had significant positive relationships with container demand in that area. Location near a port facility also had a significant positive relationship with container demand, while container demand is overall, larger on the West Coast largely due to the relative proximity of those port facilities being in a favorable position to serve Asian trading markets. Some areas in the South also have relatively high demand.

Interestingly, locations adjacent to locations with high container demand had lower-than-expected demand for containers. While this is significant on a regional transportation planning basis (e.g., Nashville's demand for containerized freight will tend to be subordinated by Memphis' greater gravitational attraction due to its status as a rail hub), it has less relevance to a national planning study.

Relevance to NCFRP 11:
While the study examined and compared selected areas in North America to identify regional factors that influenced the relative demand for containers, key conclusions from the analysis indicate that both population and personal income have a significant positive relationship with the demand for containerized freight.

Freight Demand Factors Cited:

Socioeconomic

- Total population
- Total Personal Income

1. The Freight Story: A National Perspective on Enhancing Freight Transportation, Federal Highway Administration, 2008

Examines the nature of freight movement, identifies challenges to improving freight productivity and security, and presents strategies to increase freight productivity. Intended to be a point of departure for further examination of policies, programs, and initiatives that might be undertaken by stakeholders at all levels of government. This effort also involved the development of an integrated freight data and analytical system, called the Freight Analysis Framework (FAF), which is intended to enable decision-makers to identify areas in need of capacity improvements.

Relevance to NCRFP 11: Moderate relevance to NC FRP-11. Some freight demand factors are discussed, but the majority of the document focuses on decision-making related to key challenges facing the US freight network.

Freight Demand Factors Cited:

- Composition of the Local/State/National Economy (as this has shifted, the distance goods has travel increased), i.e., shift for manufacturing to a service economy in the US (Economic)
  - Customer demand changes (need for more flexible, reliable, timely service:
  - Growth in traffic of smaller shipments
  - Traditional, high-volume demand will be a smaller portion of overall demand

- Deregulation (Public Policy)
  - Rail: as a result of Staggers Act, increase in rail shipments
  - Trucking: as a result of truck dereg, increase in interstate carriers, decrease in in-house trucking, decrease in empty back-hauls
  - Air: growth in air freight, improved efficiency

- Shift from "push" logistics to "pull" logistics (Economic)
  - Greater multi-modal integration/coordinated logistics

- Globalization – increase in merchandize trade (from 11% in 1970 to 25% in 1997) (Economic/Public Policy)
  - increase in ocean shipping, container facility demand, intermodal demand, pressure on international gateways/feeder corridors
  - NAFTA – increase in North-South freight movement

2. Freight Demand Modeling – Tools for Public Sector Decision-Making, Transportation Research Board, Conference Proceedings 40

Proceedings of a conference designed to complement the Federal Highway Administration's work on the Freight Model Improvement Program and focused on (1) modeling methodologies, (2) applications of existing models at the national and local levels (including international examples), and (3) related data needed to support modeling efforts. As with other reports, there is the general sense that freight demand modeling is often not a priority and too often influenced by inadequate tools originally designed for passenger demand modeling.

Relevance to NCFRP 11: Moderate relevance. The series of papers presents a diverse overview of freight modeling issues designed for a policy conference setting, so relevant sections tend to be scattered throughout. Overall, there is more of a focus on modeling processes than on the fundamental demand drivers.

Freight Demand Factors Cited:

- Transportation/inventory costs (which, in aggregate, equal total logistics costs): The relative costs of each (the balance of total logistics costs) have an impact on freight decision-making
- Relative Regional Purchasing Power: increases in this will positively impact freight trip attraction
- Network capacity/ease of movement: typically influenced by policy decisions/ technology implementation and, in turn, has a direct impact on transportation costs
- Types of commodities produced/demanded and where
- "Real GDP growth in the long run is correlated well with truck transportation, but on a quarter-to-quarter basis it may not be" (p. 83) – Thus, the time period being considered may impact the relevance of certain factors.

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3. Review of Freight Modelling

http://www.dft.gov.uk/pgr/economics/rdg/rfm/

In September 2001, the UK Department for Transport commissioned a short research study to review the options for modeling and forecasting freight including those used in other countries in order to assess which techniques would be most suited in Great Britain. The review covered road freight and other modes as well as modeling light goods vehicle (LGV) movements. The study focused on three main areas:

A) What is needed? - Market structures and issues in freight

B) What is available? - Review of models and data

C) The way ahead - specification of models and data requirements

There's a lot of material on the project website and we haven't reviewed everything. It was determined that "Report A1: Issues in Logistics and the Freight Industry" and "Review of Data Sources" would be the most relevant to NCFRP11.

Relevance to NCFRP 11: Since the scope of the study is relatively broad, only a portion of the work product is directly relevant to the NCFRP 11 work. Specifically, the section that presents a "Review of Data Sources" includes a large number of factors that are likely to impact freight demand. However, while a number of factors are listed, it is not always clear how these factors might impact freight demand (direction and magnitude of change).

Freight Demand Factors Cited

(From the "Review of Data Sources" Section):

1) From subsection "Current Freight Models and Their Use of Data"
- National Road Traffic Forecasts (NRTF): documented relationships established for each industrial sector over the past 21 years. Also used economic growth forecasts by sector (linkage between economy and demand for freight tonnes). Generated separate forecasts for both LGV (light) and HGV (heavy) vehicles (based on simple relationship between the two).
- EUNET Trans-Pennine Model: combination of national input-output tables, regional accounts and employment data by economic sector/zone to estimate the inter industry trade linkages, ultimately generating the freight O/D movements…forecasts are based on forecasted growth by zone in final consumption for each economic sector
- Portland (Oregon) Model: similar to EUNET, but also incorporates shipment sizes by commodity/vehicle class, carrier characteristics by commodity type, operator behavior relationships, location of main transshipment centers, detailed land used data for allocation of shipments to detailed locations

2) From sub-section "Description of Data Source"

- Economic/financial data:
  How do operating costs/tariffs affect demand? How does the transport system react to a policy initiative that changes these variables?
- Aggregate Statistics/Trends:
  - value and volume of imports/exports by economic sector
  - regional value added and overall production by sector as part of the Regional accounts
  - National Input-Output Tables of the linkages in value units from producers to consumers in each economic sector for both domestic and international trade
  - Time series of past trends in economic variables
  - Problem: the bulk goods that are important in transport volume are often of lesser importance in terms of total economic value
  - Problem: Manufactured goods are often transported as mixed loads, so any miscellaneous loads are difficult to trace back to economic sectors of production
- Trends from Surveys / road/rail/port/airport traffic count series
- Land use data
  - Population trends (Census Numbers)
    - number of households (possible generators for freight trips);
    - number of employees by SIC/Journey to Work tables (useful indicator, but can be misleading as to actual activity at a site)
  - Land Use/Changes in Land Use – may form the basis of other data gathering
  - Business Registries – can be used to examine spatial changes in business activity
- Network characteristics/quality of connecting infrastructure/congestion measures

(From the "Issues in Logistics and the Freight Industry" Report)

- There is a relationship between GDP and freight movement, but the increasing importance of sustainability could result in a degree of uncoupling
- Increased international trade – materials/products are more likely to be transported over greater distances
- Changes in supply chain structures/ supply chain integration – longer distance freight transport movements/increase in volumes on key routes/reliance on a smaller number of supply chain partners
- Reductions in lead time/Just in Time – usually more frequent deliveries of smaller quantities, but there have been some JIT strategies that effectively consolidate flows/minimize transport intensity
- Developments in e-commerce – changes patterns, but impact on freight demand not entirely clear
- The increasing role of logistics service providers

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4. Truck Trip Generation Data, NCHRP Synthesis 298, 2001M

This Synthesis Report sets out to identify and evaluate the validity of available truck trip generation data and provides an assessment of the current state of the practice. It examines the key considerations in the development of truck trip generation data and provides a detailed review of available data sources. The report highlights the distinction between vehicle-based models and commodity-based models, each of which requires different inputs and results in different conclusions about trip generation trends.
When assessing the current state of the practice, the report focuses on statewide/metropolitan modeling, transportation engineering applications and general organizational willingness to share data. As with similar freight studies and reports, there is recognition that the state of the practice in truck trip generation data is less developed relative to practices used in assessing passenger vehicle movements.

Relevance to NCFRP-11: Moderate to high relevance. This synthesis focuses on truck trip generation data, which is one component of the NCFRP- 11 topic of freight demand factors. Some underlying demand factors emerge from the summaries of truck trip studies included in the “Review of Available Data Sources” section.
Some of the most relevant points focus on the difference between Vehicle-based Generation Models vs. Commodity-based Generation Models (and the applicability of each when modeling **short-haul** and **long-haul activity**):
- “Most of the **metropolitan** truck trip generation models developed to date have been **vehicle-based** models that adhere to methodologies similar to those used in 4-step passenger models….For studies that have more of a focus on freight transportation needs in **long haul corridors**, **commodity-based** approaches to trip generation are becoming more popular” (p. 34)
Explanation of this trend:
- The agencies that tend to focus on the Metropolitan/Short-Haul context tend to be most interested in the impact of regional truck activity. These regional agencies are usually

constrained to accept methodologies due to regulatory requirements (federal transport planning and air quality regulations). So, vehicle models often make more sense in this context. Also, commodity-based models do not include explicit consideration of all reload/tour activities, so they may not be as useful for the metropolitan/short-haul context (they would likely under-estimate urban travel activity). On the other hand, commodity-based models have proven to be more appealing/ revealing for those conducting long-haul/statewide models. However, commodity-based trip rates are rarely published and are hard to derive from available data.

Freight Demand Factors Cited:
The factors cited are all related to truck trip generation, including:
- **Land Use** – Variable examples include acreage of land used, square feet of building floor area, use designation (light industrial park, office, etc)
- **Employment by (major) industry** – Variable examples include manufacturing, construction, agriculture, etc. *– This factor is often used in generation models, not because it provides the most accurate results, but because it is often the only data measuring economic activity that are feasibly available to public agencies. Modeling inaccuracies can easily result if changes in labor productivity can impact the actual trip rates per employee. (p. 35)*
- **Economic output** – Some variable examples include annual sales, revenue, value of shipments, etc. *This may be a better measure of industrial activity than employment, but this type of information is not as easily obtainable. (p 35)*
- **Non-highway modal activity at intermodal terminals (special trip generators)** – Some variable examples include number of import/export container moves, TEUs, etc.
- **Split between "garage-based trips" (single round trips) and "linked trips" (multi-stop trips):** This is of particular relevance for metropolitan/short-haul demand studies. The way in which trips are typically executed will impact travel generation/demand.

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5. State-of-the-Practice in Freight Data: A Review of Available Freight Data in the US

Mani, A. and Prozzi, J., Center for Transportation Research, University of Texas at Austin, 2004
This study provides a comprehensive overview and evaluation of available US freight data sources (including both public and commercial databases). A short description of each database is provided, the methodology is explained, the featured freight demand characteristics are listed and the important limitations of the data source are outlined.

Relevance to NCFRP-11:
Low/Moderate Relevance to NCFRP-11 – While the featured databases provide information that is useful in demand forecasting, there is little discussion of the factors that potentially influence future demand. While historical demand is one determinant of future activity, there are also many other factors that come into play.

Freight Demand Factors Cited: Historical Demand /Freight Flow Patterns – Trends from past years can be projected in the future for reasonable estimates, but the impact of other external factors should also always be considered. In practice, the historical/current demand is often used as a starting point for calculating future demand.

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6. Characteristics and Changes in Freight Transportation Demand: A Guidebook for Planners and Policy Analysts

NCHRP Project 8-30, Cambridge Systematics, 1995.
http://ntl.bts.gov/lib/4000/4300/4318/ccf.html

The document was designed to be a guidebook to assist transportation planner with all stages of freight demand analyses. It examines the changing character and composition of US multi-modal freight transportation demand and outlines processes for effectively forecasting future demand. Demand forecasting for both existing and new facilities is explained. A structured approach for freight demand policy analysis is also presented.

Relevance to NCFRP-11: The document provides a good general overview of freight demand and ways in which it can be analyzed. Highly relevant to NCFRP-11 is Appendix A: Factors Influencing Freight Demand. This section presents a very comprehensive overview of factors, both those with direct impacts and those with indirect impacts on freight demand.

Freight Demand Factors Cited:
Factors with Direct Impact on Freight Demand

- The goods-production component of GDP/GNP, which has tended to grow more slowly than overall GDP/GNP and tends to fluctuate more with business cycles
- Industrial location patterns / spatial distribution of economic activity
- Globalization of business – global distribution patterns and how they fluctuate over time (very dynamic)
- International trade agreements
- Just-in-Time Inventory Practices – could increase the frequency of in-bound shipments; decrease lead-time/size for shipments; increase importance of receiving shipments on time
- Centralized Warehousing – results in increased transport demand and sometimes a shift between modes (from truck to air, for instance)
- Packaging Material – reduction in average density of shipments for some products (with a lot of packaging) – higher volume shipments with less actual weight
- Recycling Patterns – increasing the use of recycled materials affects the O/D patterns, lengths of haul, and modal usage for certain commodities. Location of recycling plant vs. location of processing plant.

Factors that Affect Demand Through Influence on Costs/Services

- Economic Regulation and Deregulation: Significant impact on Air & Road (creating more competitive markets) and Rail (improve mode profitability)

- International Transportation Agreements
- Intermodal Operating Agreements
- Single-Source Delivery of International LTL Shipments
- Carrier-Shipper Alliances
- Fuel Prices
- Publicly Provided Infrastructure
- User Charges
- Other Taxes
- Government Subsidization of Carriers
- Environmental Policies and Restrictions – emissions regulations, phase-out of single hull tankers, fuel quality requirements, air noise restrictions
- Safety Policies and Restrictions – speed limits, route restrictions for hazmat
- Effects of changes in Truck Size and Weight Limits
- Congestion
- Technological Advances

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7. Modeling Freight Demand and Shipper Behavior: State of the Art, Future Directions

Regan, A. and Garrido, Rodrigo., 2002

Freight transportation dem and and shipper beha vior have historically been evaluated separately. However, global supply chain trends have made it more important that freight demand models explicit incorporate shipper/ carrier behavior. This paper presents a thorough review and synthesis of research in both fields.

Relevance to NCFRP-11: Moderate/high relevance to NCFRP-11 –useful report that identifies the various approaches to freight demand modeling (categorized as either modeling the International, Intercity or Urban contexts) and outlines the variables typically employed in each.

Freight Demand Factors Cited:

- International Context (Goods Movement Between Countries)

- Ricardian theory of international trade: Wage rates, capital stock and prices
- Gravity: freight volumes, network "impedance" and spatial attraction
- Industrial organization: wage rates, commodity prices, costs functions and their inputs
- Input-Output Analysis: technical coefficients, trade coefficients, commodity prices
- Spatial and temporal interactions: series of flow in space and time

- **Intercity Context**

- Abstract mode Aggregate: level of service for each mode, sociodemographic characteristics
- Aggregate logit: market shares, freight rates, level of service for each mode
- Neoclassical theory of the firm: freight rates, firm's short-run cost function and their Inputs, firms expenditures
- Time series: level of service for each mode, transportation cost functions
- Disaggregate-inventory based: freight rates, commodity values, transit times plus all

the usual EOQ model inputs
- Disaggregate-utility maximization: level of service and commodities attributes
- Spatio-temporal interaction: spatial and temporal freight flows, sociodemographic data

- **Urban Freight Scope**
  - Gravity: total productions and attractions in each zone, impedance (usually distance or travel time) between zones
  - Input Output: technical coefficients, survey and non survey based data.

General Factors

- Impact of improved logistics technologies/increase in logistics service providers that broker information to shippers, carriers, warehousers, etc.

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8. The Decoupling of Road Freight Transport and Economic Growth Trends in the UK: An Exploratory Analysis

Alan C. McKinnon, October 2006 (was slated to be published in Transport Review in early 2007)

While previous decades have shown a very clear relationship between the growth in road freight movement and economic growth in the UK, this relationship has not been as strong in recent years. It has been observed that GDP increased significantly during the period 1997-2004, but the volume of road freight movement has remained relatively stable. This report reviews previous research on this decoupling issue and examines possible causes for this trend.

Relevance to NCFRP-11: High relevance, especially if we are going to cite economic growth (defined as GDP growth) as a significant factor for NCFRP-11, this paper helps to determine the actual magnitude of impact. It will be important to determine how many of these findings are applicable in the US context.

Freight Demand Factors Cited: The primary demand factor is GDP, which is observed to have a decreasing impact on freight demand. The paper determines that around 2/3 of this decoupling is due to three quantifiable factors:

- increased penetration of the UK road haulage market by foreign operators – this has an impact on reporting figures (not really a factor in the US)
- decline in road transport's share of freight market (increase in rail and water shares)
- real increases in road freight rates

And several factors that are more difficult to quantify

- relative growth of service sector
- diminishing rate of geographic centralization
- off-shoring of manufacturing

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9. Upper Midwest Freight Corridor Study—Phase I and II

Midwest Regional University Transportation Center, Adams, T., et al University of Wisconsin-Madison. 2007, see http://www.uppermidwestfreight.org/files/final2007.pdf for full collection of documents. The Phase II Final Report is currently saved in our files.
Drawn From NCRFP 1 Bibliography/Literature Review

This publication is based on eleven white pape rs that were written on factors r elating to freight movement and public policy throughout the Upper Midwest region of the United States. These papers provide information on f actors that influence performance of freight transportation in the regional context. Since the papers covering one or another aspect of our scope, we have outlined in some detail the relevant topics/headings and the associated references (for empirical data or other lit reviews that may be of relevance)

Relevance to NCFRP 11: Limited Relevance to NCFRP 11 since it primarily deals with freight planning policies. However, certa in demand factors do em erge from the discussion.

Freight Demand Factors Cited:
The initiatives/factors covered include:

- Federal Funding mechanisms
- Highway Technology:
    - Key items covered: short term gains, technology, policy
- Influence of Toll Roads-can be used to extrapolate the impact the cost of tolls to regional transportation.
- Alternative Freight Transport: Water based transport
- Intermodal Freight Facilities

Regional Freight Agenda for the Upper Midwest
Defines the priorities that would enhance re gional freight corridor through 12 initiatives. Information sources are useful for technology, economics and monitoring.
Conceptual Regional Technology Plan—set s the outline for a technology efficient tracking and the benefits of deployment.

Transportation and the Economy
Covers the effect of transportation on the economy with China and India as examples.

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10. Freight Transportation Infrastructure Survey: Causes and Solutions to the Current Capacity Crisis

MIT Center for Transportation and Logistics, Cambridge, MA, 2006
Drawn From NCRFP 1 Bibliography/Literature Review

This survey report investigates the perception gap among freight transportation stakeholders in order to discover the root causes of congestion and the capacity crisis, the resulting effects on business and the solutions that are or should be utilized to assuage these impacts. Following a discussion of the findings, recommendations for short and long term strategies to enhance communication among stakeholders are offered.
Questions asked:
1. What were the root causes of the freight transportation congestion and capacity crisis?
2. What were the impacts on business due to the crisis?
3. What actions are being, or should be, taken to alleviate these impacts in the future?

Relevance to NCFRP-11: Moderate relevance. While we often look at tangible "factors" contributing to freight demand and affecting freight patterns, it is all too often forgotten that stakeholder perception and the effectiveness of communication between various stakeholders are also a very real factors. Specifically, there appears to be a significant disconnect between government stakeholders and shipper/carrier stakeholders when identifying root causes of freight transport problems. This is obviously very difficult to model, but it still important to take this into consideration when trying to determine future freight demand. For instance, how will public investment and policy initiatives really affect shipper/carrier behavior? (probably not in the exact way that was initially intended)
Drawn From NCRFP 1 Bibliography/Literature Review

Freight Demand Factors Cited:
Root cause identified as Highway Congestion
- Operators concerned with operational inefficiencies
- Interfacing with larger population
- Inputs (drivers, fuel cost volatility, hours of service rule)

Top action items include:
- Meet more frequently with carriers
- Work on establishing contingency plans to avoid supply chain disruptions
- Request solution proposals from carriers
- Collaborate with carriers on transportation forecasts

- Carriers have most interaction with State, Local govt levels and minimum interaction at the Federal level.
Key Findings:
Collaboration between shippers and carriers is increasing.
Collaboration between shippers/carriers and government agencies is non-existent.
Perceptions in the causes and remedies of the congestion crisis differ between the government and the private sectors – but not much between shippers and carriers.
On a Scale of 1-4 the following are the rated responses:

1-5 ranked Root causes:

Root Causes of Current Congestion Crisis	Shipper Rank	Carrier Rank	Govt Rank
Driver shortages in the longhaul trucking industry	1	5	11
Growth of international imports	2	2	5
West Coast port congestion	3	1	6
Highway congestion near metropolitan areas	4	3	1
Volatility of fuel prices	5	16	12
Lack of 24/7 operations in West Coast ports	7	4	9
Lack funding for freight infrastructure by the federal governments	10	9	3
Lack of funding and investment in high priority projects by the railroads	12	8	4
Lack funding for freight infrastructure by the state governments	14	11	2

New Hours of Service agreement (HOS) not a major factor for carriers & govt. Shippers feel it is of medium importance.
Overall transport use increasing-whatever the mode-which indicates an increase in trade volume.

Ranking of ports usage:

	Gov	Rank	Shippers	Rank
East Coast Ports	2.75	4	2.44	1
North West Coast Ports	2.93	1	2.36	2
Gulf Coast Ports	2.27	6	2.32	3
Mexican Ports	2.83	2	2.20	4
South West Coast Ports	2.71	5	2.09	5
Canadian Ports	2.82	3	2.08	6

Why do govt ranking of east coat ports differ some much from the shippers ranking of east coast ports?

Possible solutions:

Rank	Actions	Shippers	Percent Shippers: Have Tried	Percent Shippers: Thinking of Trying	Percent Shippers: Not Interested
1	Meet more frequently with carriers	1.75	79%	18%	4%
2	Work on establishing contingency plans to avoid supply chain disruptions	1.62	64%	34%	2%
3	Request solution proposals from carriers	1.62	65%	32%	3%
4	Collaborate with carriers on transportation forecasts	1.48	55%	39%	7%
5	Request extensions of existing contracts from carriers	1.45	62%	22%	16%
6	Re-route freight from LA/Long Beach ports to other West Coast ports	1.34	52%	30%	18%
7	Re-route freight from West Coast ports to other US ports	1.31	50%	31%	19%
8	Introduce performance based contracts	1.22	32%	58%	10%
9	Increase the number of carriers being used	1.15	50%	15%	35%
10	Increase the length of term for transport contracts	1.15	42%	31%	27%
11	Establish flexible contracting with carriers	1.10	36%	39%	26%
12	Utilize a transload operation near a port	1.08	39%	30%	31%
13	Expand an existing dedicated fleet	1.07	41%	24%	34%
14	Shift shipping patterns to off-peak times	1.06	32%	42%	26%
15	Outsource more freight handling to 3PLs	1.00	37%	26%	37%
16	Introduce real options into carrier contracts	0.93	20%	53%	27%
17	Reduce the number of carriers being used	0.90	38%	15%	48%
18	Increase buffer or safety stock for inventory	0.86	32%	23%	45%
19	Expand an existing private fleet	0.80	25%	30%	45%
20	Establish a new dedicated fleet	0.71	22%	26%	51%
21	Run less frequent auctions	0.56	18%	20%	62%
22	Increased carrier rates preemptively	0.50	18%	15%	67%
23	Run more frequent auctions	0.41	11%	20%	69%
24	Establish a new private fleet	0.35	9%	18%	73%

Key investments:

- Improving existing highways
- Building new highways as

(Govt ranks neither of these in the top 5)

- airport or seaport investment not considered that important.
- only the Government respondents ranked building logistics hubs and parks as a top 5 investment.
- All stakeholders agreed on the importance of expanding existing intermodal yards and double tracking selected rail lines.
- . majority of respondents advocate mixed funding (PPP) strategy should be taken..
- All stakeholders agreed that the government should fund all highway infrastructure – to include both improvements and new

Detailed survey results important to have a glance through.

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11. Freight Capacity for the 21st Century

TRB Special Report 271, National Research Council. Morris, J. 2003
This TRB report identifies constraints in the freight planning process that have limited the efficiency and productivity of the transportation system. The report goes on to recommend changes in government policies that at will contribute to better planning through more rational investments which will ultimately improve the efficiency of freight transportation.
Drawn From NCRFP 1 Bibliography/Literature Review

Relevance to NCFRP 11: Moderate relevance to NCFRP 11. The paper is primarily concerned with US freight system capacity constraints and potential solutions for alleviating these. Any shortcomings in the transport infrastructure network will certainly impact freight operations and these factors should be considered when modeling demand.

Freight Demand Factors Cited:

Trends that affect

- growing congestion on important highway segments and
- slowing of the rate of addition of highway capacity,
- rail infrastructure downsizing and
- service disturbances,
- congestion at terminals and border crossings,
- lengthening lead times and
- rising costs of infrastructure projects, and
- freight–passenger conflicts in cities.

Issues:

- Increasing population density
- urbanization, and wealth ensure that conflicts between freight and passenger traffic;
- conflicts between freight transportation and residential,
- recreational, and other competing land uses; and
- Requirements to control pollution will increase.
- These forces will increase the cost of expanding capacity and add to th e risk of investment.

Possible solutions:

- Policy & increased spending on infrastructure projects.

Policy that will have long lasting effect:

Box 2-1

PENDING GOVERNMENT DECISIONS AFFECTING FREIGHT CAPACITY

Government management, operation, and regulation of transportation:

- Truck performance regulation (size, weight, safety, pollution)
- Railroad economic regulation
- International aviation regulation
- North American Free Trade Agreement freight transportation issues

Selection of funding sources for capital expenditures and operation of public facilities:

- Harbor dredging funding
- Toll funding of highways
- Future of user fee finance in state highway programs
- Port rate competition

Public investment choices:

- Structure of federal-aid programs
- Evaluating freight benefits in setting investment priorities
- Public-sector technology development programs
- Future development of the inland waterways system
- Application of environmental regulations to infrastructure projects

Redefining government responsibilities:

- Air traffic control reform
- Government grants to freight railroads

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12. Principles for a US Public Freight Agenda in a Global Economy

Robins, M., Strauss-Wieder, A., 2006, Principles for a U.S. Public Freight Agenda in a Global Economy. Transportation Reform Series, The Brookings Institute, Washington, D.C., http://www.uppermidwestfreight.org/files/Brookings_freightsystems.pdf.

The objective of this research is to summarize the key issues and trends affecting the nation's increasingly strained freight system, provide examples of efforts to address these strains and the land uses involved, and identify the current roles played by government agencies. It is determined that a nationwide systems-based and multimodal agenda is necessary to maintain America's competitiveness and economic well-being.
Drawn From NCRFP 1 Bibliography/Literature Review

Relevance to NCFRP-11: Moderate Relevance to NCFRP-11.

Freight Demand Factors Cited:

- Changes in the Global Economy: sourcing/production of goods at the lowest cost location (often off-shore) - US evolved into an "import economy". Results in an increase in goods traveling over long distances, which this trend expected to continue into the future (for all modes)
- Longer, more complex and leaner supply chains/Just-in-Time Practices

- Changes in the type of transport equipment: longer truck trailers, doublestack containers and massive ocean vessels – this may not be a major issue for commodity-based models, but vehicle-based demand models will be impacted
- Port and Route diversification: logistics professionals are finding ways to get around deficiencies in the US transport infrastructure - will reorient supply chain to minimize the impact of disruptions (even though it may not be the optimal use of infrastructure) This will shift demand from one part of the system to another, possibly without apparent cause
- Rise of "value-added" warehousing: shifts part of the "manufacture" of products to retail distribution centers
- Increasing community awareness/action: opposition to freight movement through communities can impact public transport policy, thus influencing the freight network and indirectly impacting freight flows

13. Forecasting Freight Demand Using Economic Indices

Fite, Jonathon T., et al. International Journal of Physical Distribution & Logistics Management, Vol 32, No. 4,2002, pp 299-308.

The purpose of this paper is to develop a simple model to forecast freight demand in the trucking industry. The authors use simple multiple regression tools to establish correlations between major economic indices and freight trucking data. One of the data sources that the authors use is the monthly US Department of Commerce release of economic indicators including the Composite Indexes of Leading, Coincident and Lagging Indicators.

Relevance to NCFRP 11: Moderate relevance to NCFRP 11. Primarily because the freight data used was of private, and the analysis was conducted over the relatively short time horizon of three years.

Freight Demand Factors Cited: Freight Demand factors are only cited in-directly in terms of those economic indices that work best within the framework of an econometric model (and correlate highly with the freight data). On the national level this is the producer commodity price index of construction materials and equipment. They also develop regional and commodity based models and describe their correlations.

Industrial or regional market segment	Indices remaining in model resulting from stepwise selection process	Indices' R^2	Model R^2	Model F-value	Model p-value	Percent of total volume	Average forecasting error (%)
Nation	PCPI-CM&E	0.5786	0.5786	35.6949	0.0001	100.00	6.86
Alcohol	Dow Jones utilities index	0.6845	0.6845	49.8910	0.0001	2.11	11.98
Beverage	PCPI – Iron and steel	0.6564	0.7062	26.4380	0.0001	1.09	13.97
	MNO – Durable goods	0.5720					
Consumer goods	Electrical machinery production index	0.7525	0.7525	75.0520	0.0001	9.97	11.66
Distribution	Dow Jones transport index	0.7761	0.7761	93.5710	0.0001	1.73	53.80
Food manufacturing	PCPI – processed poultry	0.6063	0.6712	23.4780	0.0001	7.58	13.90
	PCPI – meats	0.5677					
General merchandise	MNO – nondurable goods	0.7973	0.8436	59.3130	0.0001	13.23	22.13
	Aircraft and parts Production index	0.7127					
Glass and plastics	Aircraft and parts Production index	0.8125	0.8356	58.4400	0.0001	3.39	52.31
	PCPI – construction materials	0.6438					
Grocery	Composite index of leading indicators	0.6787	0.6787	48.5817	0.0001	0.92	54.82
Healthcare	US import	0.6625	0.7924	31.8080	0.0001	1.03	9.00
	Manufacturing and trade inventories	0.6489					
	Foods production index	0.6257					
Logistics	Retail inventories – all retail stores	0.8313	0.8313	113.7520	0.0001	1.49	12.82
Manufacturing	PCPI-CM&E	0.8094	0.8752	84.1490	0.0001	5.30	11.56
	PCPI – concrete ingredients	0.8079					
Paper	Retail unleaded gasoline prices	0.8159	0.8159	101.9630	0.0001	11.96	5.54
Retail	PCPI – prepared paint	0.6964	0.6964	61.9370	0.0001	13.62	13.99
Miscellaneous	ATA – truck tonnage index CMA	0.2905	0.4293	8.2740	0.0001	25.19	6.82
	Retail premium unleaded gasoline prices	0.1655					
North	Retail sales: automotive dealers	0.6299	0.6299	44.2450	0.0001	32.56	32.82
Northeast	PCPI – machinery and motive products	0.5253	0.5253	25.4470	0.0001	16.05	22.44
South	Long term government securities	0.3279	0.3279	12.6930	0.0001	22.36	11.56
Southeast	Retail inventories: all retail stores	0.7414	0.7414	65.934	0.0001	12.37	39.20
West	US imports	0.5482	0.5482	32.756	0.0001	15.85	3.88

Table III. Detailed summary of all model results

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14. Modeling the Demand for Freight Transport: A New Approach

Abdelwahab, Walid and Michel Sargious. Journal of Transport Economics and Policy, Vol. 26, Issue 1, pp 49-70, 1992.

The authors develop a simultaneous equation econometric model to determine decisions between mode choice as well as factors that derive demand for a particular mode. They identify two types of modeling approaches, aggregate and disaggregate. This study uses the disaggregate approach. They use data primarily from the US Bureau of Census, Commodity Transportation Survey.

Relevance to NCFRP 11: Moderate relevance to NCFRP 11 since the paper focuses more on the mode choice component than drivers of freight demand at the aggregate level.

Freight Demand Factors Cited: Some of the variables used can be divided into commodity attributes (value and density of the shipped cargo), modal attributes (such as freight charges, reliability and transit time by each mode) as well as the other attributes such as volume of commodity moved on each link by each mode.

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15. NCHRP Report 606 – Forecasting Statewide Freight Toolkit

The report deals with developing appropriate methodologies for forecasting freight at the state-wide level and providing regional planning organizations with modeling approaches that they can use to modify their planning needs. The main focus of this study is to document methodologies to forecast primary freight (i.e. goods moved over long distances and between cities as well as goods by local truck that are in their initial stages of long distance movement). It therefore excludes practices for forecasting secondary freight ie. Freight that moves from DC to DC.
The paper discusses in depth different modeling approaches including traditional 4 step models (trip generation, trip distribution, mode split, network assignment). They also look at 10 case studies and develop a template frame work for freight forecasting.

Relevance to NCFRP 11: Moderate relevance at NCFRP 11. The paper dwells in length on different forecasting methodologies that can be used to make freight forecasts. Many of the methodologies focus on forecasting traffic by commodity type.

Freight Demand Factors Cited:
The study identifies various socio-economic factors that can be used to adjust or feed-into the forecasting procedures identified above. Most of them relate to employment and population forecasts.
The study considers various case studies which consider the practices of different State and federal bodies. They look at some of the socio-economic drivers behind the forecasts these include:

- Industrial employment projections
- Labor projections for different counties
- Employment in Retail, Industrial, Public and Office sectors (was used to forecast trip rates in the New Jersey State wide model)
- Population is also used a driver of trip generation
- Employment by commodity sector
- Use of a spatial input / output model that identifies economic relationships between origin and destinations (MEPLAN model coefficients).
- county business pattern data from the census bureau

Sources of Freight Data:
US Bureau of Census, Commodity Transportation Survey
Surface Transportation Boards' Railroad Waybill Sample
US Bureau of Census, Annual survey of Manufacturers
US Bureau of Census, VIUS Survey
FAF State to State commodity flow database

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16. Freight Demand Characteristics and Mode Choice: An Analysis of the Results of Modeling with Disaggregate Revealed Preference Data

Jiang, Fei, Paul Johnson and Christian Calzada. Journal of Transportation and Statistics, December 1999, pp 149-158.

The purpose of this paper is to analyze how freight demand characteristics relate to and influence shipper's mode choice using a nested logit model as an analytical tool. A large scale national disaggregate revealed preference database is used for shippers in France in 1988.

Relevance to NCFRP 11: Moderate relevance to NCFRP 11. The author's focus on disaggregate data with a focus on understanding relationships between shipper's mode choice as well as their decision to pursue private (their own) versus public (sold in the market place) transport options.

Freight Demand Factors Cited:
Freight Demand characteristics are divided into three types: a firm's (shipper's or receiver's) characteristics, goods physical attributes, and the spatial and flow characteristics of shipments. Another way to look at these same factors is in terms of time horizon; Long term factors include the firm's nature, size, location, information system, structure and trucks owned by the firm (private i.e. a firms logistical capabilities reserved for its own use, versus publicly available transportation systems). Short term factors include: physical attributes of goods, physical flow attributes (frequency, distance, origin and destination)
They find that transportation distance, the shipper's accessibility to transportation infrastructure, the shipper's own transportation facilities and shipment packaging (pallets and parcel) are the critical determinants of the demand for rail and combined (rail + truck) transportation.

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17. What Determines Demand for Freight Transport?

Bennathan, E., Julie Fraser and Louis S. Thompson, Infrastructure and Urban Development Department, The World Bank, 1992.

This study looks at a cross section of countries (both high income and developing) and aims to derive long run freight demand characteristics. The authors use single equation econometric studies to identify key determinants of demand across the cross section of countries.

Relevance to NCFRP 11: Moderate relevance to NCFRP 11. Primarily since the authors looks at a cross section of countries, some high income and others developing that it is hard to make the conclusion that same factors might be relevant in the United States.

Freight Demand Factors Cited:
The authors try to establish a relationship between ton-km of freight and GDP and area of a country. They look at a cross section of developing and developed economies.

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18. Freight Travel Demand Modeling – Synthesis of Approaches and Development of a Framework

Pendyala, Ram, Venky Shankar and Robert McCullough. Transportation Research Record 1725, Paper No. 00-0200. pp. 9-16.

The authors try and synthesize approaches to freight forecasting by looking at current practices of different State and DOT to forecast freight as well as a brief examination of the various forecasting methods currently in use.

Relevance to NCFRP 11: Moderate relevance to NCFRP 11. The authors identify direct and indirect factors that drive transportation demand.

Freight Demand Factors Cited:
Figure 1 shows demand factors broken by direct and indirect factors. Direct factors contribute directly to the demand of goods and services. Obvious candidates for such factors are demographic trends (literally the number of people), the disposable income and wealth of the population, proportion the people spend on non-durable / durable goods and proportion of income consumed versus saved. Other macro variables that might influence are trade and how important trade is to the economy.

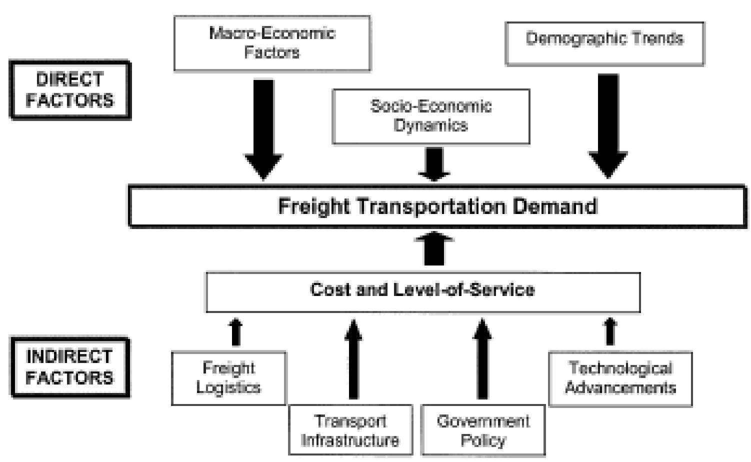

FIGURE 1 Factors affecting freight transportation demand.

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19. Logistical Restructuring and Road Freight Traffic Growth – An Empirical Assessment

McKinnon, Alan and Allan Woodburn. Transportation, May 1996 pp 141-161.

Forecasting of freight traffic has relied heavily on the close correlation between GDP and road tonne-Kms and not been rooted in the *causes* of freight traffic growth. This paper looks at these causes by focusing on the production, consumption and movement of food and drink products in the UK and by conducting a survey of the changing freight transport requirements of 88 large British-based manufacturers.

Relevance to NCFRP 11: Moderately relevant to NCFRP 11. This study under-takes a detailed examination of the drivers and causes of freight traffic growth. Although it focuses on a particular sector of the economy, the principles established are nonetheless of general import.

Freight Demand Factors Cited:
Four key factors are identified (albeit with regards to the food industry in the UK) are

i) value density,
ii) handling factor (the ratio of tons lifted to actual weight of products consumed or exported),
iii) average length of haul
iv) and consignment size.

Value density, typically increases with time i.e. end products are more valuable but weigh less i.e. they are more highly processed and more “value added”.

With regard to handling factor as supply chains become more complex and the number of intermediate processes increase, this factor becomes inflated and the amount of freight handled is bound to increase. Changes in this factor can be traced to increased weight loss in the production process, increase in the number of separate links in the supply chain and changes in the amount of packaging.

Another factor that has contributed to the rise in freight in this sector is the average length of haul. Average length of haul has increased significantly and that has growth has been driven by i) the geographical concentration of production and inventory ii) the expansion of market areas.

Lastly consignment size has grown significantly. This has been driven in turn by two factors, the increase in the maximum weights and dimensions of lorries; and the consolidation of food and drink into bulk loads and for further channeling at distribution centers.

Additionally a survey was conducted of a sample of firms in the UK and results of that survey produced what the main drivers of freight were a tightening of customers requirements driven by desire to cut their inventory levels and the second most important factor was the firms own desire to cut its inventory levels.

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20. Spatial Price Competition and the Demand for Freight Transportation

Inaba, Fred S. and Nancy E. Wallace. The Review of Economics and Statistics, Vol. 71, No. 4, November 1989, pp. 614-625.

Two important issues in econometric demand analysis are addressed: i) the simultaneity between quantity shipped and mode/destination choices and ii) the effect of spatial price competition on the demand for the transportation factor. The paper develops a theoretical model as well as a practical application that is applied to wheat shipments in the Pacific Northwest.

Relevance to NCFRP 11: Broadly relevant to NCFRP11. Evidence suggests that shippers choice of mode and shipment size are not independent of each other rather are made simultaneously. A theoretical model is developed wherein spatial price competition determines the firm's market area and thereby determines its sales and shipment size.

Freight Demand Factors Cited:
Shipment size
Firm's market area and choice of mode
Other factors that jointly effect mode destination (as illustrated by the decisions of country elevators that ship wheat in the pacific northwest) are, waiting cost (having negative effects) and the size of the market (increases as the size of the market increases).

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21. NCHRP Report 388: A guidebook for Forecasting Freight Transportation Demand

Cambridge Systematics

Freight demand factors are divided into two categories. Factors that effect demand directly and those that effect demand indirectly. The former consist of obvious candidates like population while the latter consist of those factors that effect the costs of one more transport modes and in some cases on the services offered; these factors affect demand indirectly as a result of changes in transport costs and rates and in the services offered.

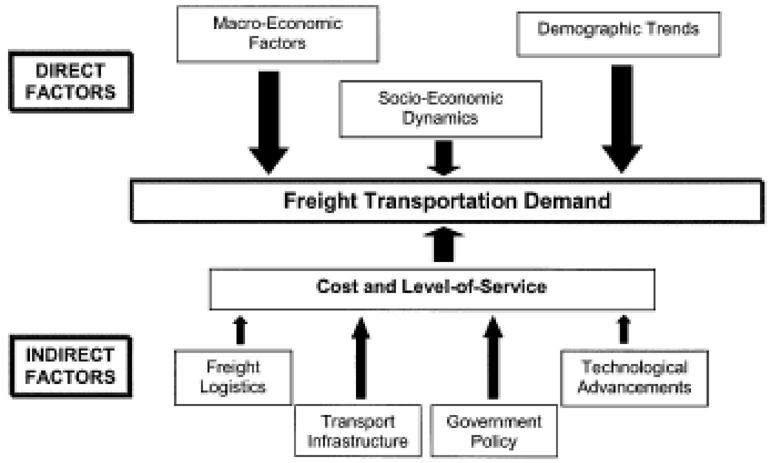

FIGURE 1 Factors affecting freight transportation demand.

Relevance to NCFRP 11: Direct relevance to NCFRP 11.

Freight Demand Factors Cited:

Direct Factors:

i) Level of economic activity: Level of economic activity can be measured with GDP, particularly goods production component of GDP. Goods production and particularly durables goods production tends to be more cyclical and correlates well with the growth in freight demand (as measured by ton-miles)

ii) Industrial Location Factors: The spatial distribution of manufacturing centers has a great influence on the demand for freight when measured in ton-miles or the distance that freight is transported. Spatial distribution of economic activity also has a major influence on the modes that are used. Plants located near specific modes tend to prefer that mode, for eg: factories located near rail tend to use rail more where as those located near major highways tend to use trucks more.

iii) Globalization of Business: Globalization has resulted in long supply chains that are spread all over the world. In general the longer the supply chain, the greater the demand for freight. This “supply chain sprawl” varies significantly from industry to industry. Additionally these supply chains are dynamic constantly adapting to the changing market and price conditions.

iv) International Trade Agreements: International Trade Agreements reduce barriers to trade such as reduction of trade barriers, bring about consistency in government regulations and generally promote trade and cross border freight traffic.

v) Just in Time Inventory Practices: Just-in-Time (JIT) systems focus on keeping inventories at minimum levels through a coordination of input deliveries with production schedules. Effects on freight demand are to increase the number of individual shipments, decrease their length of haul, and most importantly increase the importance of on-time delivery.

vi) Central Warehousing: As transportation systems have become more efficient there has been a trend towards using fewer warehouses. Third party logistics operators that specialize in distribution have helped this trend. This trend has increased transport demand and associated costs in order to save on inventory costs. The trend toward centralized warehousing results in increased transport demand (measured in ton-miles, shipment miles or value of service) and in some instances a shift from truck to air delivery. Appropriate measures, might be the number of firms using one or two warehouses and the value or tons shipped.

vii) Recycling: Recycling has an important effect on O-D patterns and lengths of haul and modal usage of several commodities. Recycling plants are located near urban centers or near the markets for the products while processing plants that use virgin materials are usually located near a major source of supply of these materials and they commonly ship their products long distances to their markets.

Indirect Factors:

Indirect factors include:

i) Deregulation: The different deregulation acts (Airline Deregulation Act, Motor Carrier Act, Stagger's Rail Act and the Shipping Act) have all had important effects by allowing private operators to operate freight links and allowed them to operate efficient and high quality service.

ii) International Transportation Agreements: There are many international agreements that limit or have recently allowed more competition to take place. For example in the air freight sector, the so-called "open skies" agreements, where carriers could provide service to airports other than the major gateway airports of New York, Miami, and Los Angeles. (Data on air traffic freight movements are available by airport by the North American Airport Traffic Report, published by the Airports Council International). For trucks for example, NAFTA allows carriers to flow freely between Canada and the US but not between Mexico and the US.

iii) Intermodal Agreements: Intermodal Operating Agreements like that of APL that used double stack trains to serve most inland origins and destinations. All major containership companies were using such services and many trucking companies were adapting their trucks to handle containers. Measures for these include the number of such agreements and the volume of intermodal traffic (these are published by the Association of American Railroads on a weekly and annual basis for movements on class I railroads).

iv) Fuel Prices: Fuel constitutes a moderately significant and relatively volatile component of cost for all freight modes. Fuel accounts for 7.1% of total operating expenses for Class I railroads: feul, oil, lubricants and coolants accounts for about 13.5% of operating expenses for truck-load carriers and about 6% of operating expenses for LTL carriers and about 30-40% for air carriers. Sources of Data include the Department of Energy that publishes rates for various end use categories

v) Publicly Provided Infrastructure: Air, water, and truck carriers are all dependent on publicly provided infrastructure. FAA is responsible for US airports, US Army Corps of Engineers maintains the waterway channels and the FHWA (Federal Highway Administration) and all three systems of transportation tend to be expanded more slowly than users would like resulting in congestion that increases travel times and operating costs. This leads to increased unreliability which is a particular problem for Just-in-Time inventory approaches. The quality of local infrastructure and the degree of congestion also effect carrier choices of ports and airports. Measures of public infrastructure include physical characteristics such lane-miles of road, channel depths, lengths of runways etc or financial characteristics such as capital, maintenance and operating expenditures.

vi) User Charges, Taxes and Subsidies: User Charges are used to fund most publicly provided infrastructure in the US including airports, ports and highway. The major exception is inland waterways which in some cases give subsidies to barge operators. Other taxes exist in the form of fuel taxes such as the federal tax on gasoline and highway diesel fuel. All these taxes add to costs of transportation and some cases make some modes more attractive relative to the others particularly barge transport is subsidized relative to rail.

vii) Environmental Policies and Restrictions: Environmental policies place particular restrictions on ports and waterways. Port expansion is limited by the Clean Water Act or the "no net loss" of wetlands. The Oil pollution act requires oil tankers that have single hulls to be replaced with double hull tankers and tankers with single hulls are required to meet other criteria. With trucks, emissions controls and clean fuel requirements have also effected costs. Air transport is subject to noise reduction acts. All these factors increase costs of transportation and do affect the demand for freight. In addition environmental policies influence the locations at which raw materials are produced and those at which industrial plants are located.

viii) Safety Policies and Regulations: Safety policies increase some costs for carriers but also reduce other liability costs and their effect tends not be significant in increasing costs.

ix) Effects of Changes in Truck Size and Weight Limits: Changes in truck size and weight limits can significantly affect the cost of goods movement by truck. Changes in truck size can result in shifts in freight to or from other modes most importantly rail. The TRB's *Truck Weight Study* estimated that eliminating the 80,000 pound limit on gross weight would result in a 2.2 percent reduction in rail traffic. To the extent that changes in Truck size and weight limits cause increase in the demand for all freight will depend on whether the savings in costs that result from these changes will be passed on to consumers. Additionally, changes in weight limits might cause total amount of freight shipped to increase (decrease) to the extent that it encourages (discourages) the centralization of production facilities.

x) Congestion: In many urban areas, increasing highway congestion is affecting the efficiency of reliable truck transport and the reliability required by just-in-time shipping.

xi) <u>Technological Advances:</u> The use of computers and telecommunication equipment has had an important effect on the freight industry. Air carriers and many leading companies have implemented sophisticated systems for tracking shipments, computers for sorting shipments and optimizing the use of aircraft, and freight trucks. All these factors have improved efficiency and improved the level of service and reliability and hence indirectly promoted modern Just-in-Time delivery methods to operate.

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23. Transport & Logistics in Regional Travel Demand Models – State of the Practice

Halcrow Consulting Inc.

This report investigates the state of the practice in modeling the demand for freight transportation, with a specific focus on regional transport models. It examines current approaches to regional freight models and highlights the limitations in current practice. The paper proceeds to examine case studies of metropolitan areas that have tried to move closer to commodity-based modeling on the regional level (including the techniques & data sources that they employ.) Also, it discusses the specific difficulties associated with modeling in and around Marine Gateways, which is highly dynamic and unpredictable (thus extremely difficult to model – very different factors involved). In general, it is determined that more complex models (with a lot of different factors) may not be the most effective at representing the freight industry's ability to change quickly.

Relevance to NCFRP-11: Highly relevant. In addition to exploring a universe of key factors (see below) it also provides some useful points regarding the current limitations of regional freight models, particularly in terms of future forecasting. For instance:
"The main limitation identified is the ability and efficacy of using current freight and truck models for future forecasting, particularly into the longer-term. **It is considered that the relationships that are generated between truck trips and land-use and other economic data make sense in representing the current industry and business practices, but these relationships are highly unlikely to be applicable into the future, given the rapid changes over the recent past.** Hence, the concern expressed is that the future year forecasts may follow the procedures properly, and would calibrate well with a projected version of the current situation, but the results are not credible as this is unlikely to reflect the future economy and freight practices. This is basically because the modelling practices typically employed simply cannot account in forecasts for the sometimes rapid and significant changes in the economic environment as well as freight transport technologies.….**The general thrust is that the eponymous four-stage process employed for personal travel is not appropriate to capture the full nature of freight, particularly in forecasting.**
…There is therefore a general feeling within US MPOs that commodity-based modelling approach tied to economic activity is ultimately the way forward."

(Note: This type of modeling is currently more common at the State-level and above (long-haul), where relevant data is more likely to be available and disaggregated details less significant.)

Freight Demand Factors Cited:
In addition to listing key demand factors, this report

- categorizes them as either related to (1) production, consumption & trade (2) logistics & associated transportation service factors or (3) network & routing factors
- describes the way in which they are typically incorporated in US transport models (as shown in the listing below)
- outlines the potential modeling issues/challenges associated with each of the three broad categories (see table below)

Production, consumption & Trade Factors
1) Economic activity • Only included in employment numbers, if these are used to generate truck trips
2) Commodity movements and trade patterns • Very limited in regional models. Some jurisdictions aiming to do so in future. Super-regional or statewide models more likely to include commodity modeling.
3) Changes to sources of raw materials and goods • May be incorporated into commodity modeling (where relevant)

Logistics & Associated Transportation Services Factors
4) Origins and destinations of freight • *Internal* truck matrices likely to be developed with limited reference to actual freight origins and destinations, based on features of the origin/destination (such as employment). *External* movements often incorporate origin/destination information based on surveys or other models
5) Distribution systems • The subtlety of distribution systems and the way that locations of distribution centers and use of modes and tour planning are coordinated is not considered. Hence the scope for these to change is largely ignored
6) Logistics facility locations • Some attempts to include locations as special generators or freight activity nodes
7) Modes available and modes used • Regional modelling usually concentrates on trucks. Mode split is then not relevant. Is generally included in commodity modelling and wider area models
8) Operational practices • Empty moves and positioning tacitly included in internal trip generation, but not specifically allocated to the key facilities that generate the need for such practices
9) Ownership of transport provider • Relates to operational practices and distribution systems and how decisions are made for forecasting purposes
10) Costs of freight transport to the users • Incorporated into assignment through generalized costs for trucks. Does not encapsulate the overall cost of goods movement, especially in so much as this is part of a production methodology that may span the globe

Network & Routing Factors

11) Network availability (road, railway and waterway) • Generally not included unless multi-modal assignment modeling is done. May be included in commodity modeling

12) Access to the networks – intermodal • Intermodal freight interchanges are specifically identified if they are considered important freight generators. This is unlikely to include direct reference to transhipment.

13) Network restrictions • Assignment process include restrictions for vehicle classes

14) Network instability • Linkage to overall traffic modeling results in congestion being modelled in assignment process Tour planning • Inferred in the generation of internal trips. Similarly to operational practices, there is no specific reference to origins and destinations and hence potential trip-chaining

15) Actual routes used by Trucks • See network restrictions

Table 1: Freight Transport Modelling – features, issues, factors & challenges

Freight transport features	Potential modelling issues	Key factors	Challenges
Production, consumption and trade	• Commodity movements (raw materials, part/fully finished) – basic trip generation • Linkage between freight demand and the economy, through consumption patterns • Local, regional, national, international nature of trade	• Economic activity • Commodity movements and trade patterns • Sources of raw materials and finished goods	• Linkage between freight & economy not uniform • Commodity movements not always recorded in sufficient detail (or at all) • Actions of individual companies and organisations can be swift, and not reflected in current data
Logistics and associated transportation services	• Inventory amounts and supply chain management • Facility locations • Choice of freight transport mode and use of intermodal transport (including use of specific vehicles, such as specialist trailers or light goods vehicles)	• Origins and destinations of freight to be moved (see also 'production and consumption') • Distribution systems (including trunk hauls, break-bulk and consolidation practices) • Logistics facility locations (such as distribution centres and transhipment points) • Modes available and modes used • Operational practices such as requirement for empty moves (including positioning) • Ownership of transport provider (own-account or third party supplier) • Costs of freight transport to the users	• Detailed commodity origins and destinations not generally known • Distribution systems are dynamic and evolve to meet individual requirements • Third-party providers can alter systems independent of customers • Relationship between freight and 'background' operational practices largely unknown • Cost of freight transport is commercially sensitive
Network and routing	• Availability of multi-modal freight options • Consignment and tour planning • Routing and congestion (including restrictions)	• Network availability (highway, railway & waterway) • Access to the networks (intermodal access to/from rail or water) • Network restrictions (for example in urban areas) • Network instability (such as congestion) • Tour planning (optimisation process) • Actual routes used by trucks (driver behaviour)	• Responses to network changes and restrictions may be to change the distribution system • Detailed distribution routing (tour planning) varies day-to-day according to need

Source: based on 'Freight Modelling: An Overview of International Experiences', Tasvassy, 2006 (published in 'Freight Demand Modelling: Tools for Public-Sector Decision-Making', CP40, TRB, 2008)

To be included in bibliography (not in lit review)

Behavioral insights in to the mod eling of freight transportation and distribution systems

Hensher and Figliozzi, Transportation Research, 2007

Assessing Rail Freight Solutions to Roadway Congestion: Final Report

Bryan, Joseph , Glen Weisbrod, and Carl Martland. 2006

Appendix C - Correlation Analysis

Table C-1 - Correlations of Candidate Demand Factors

Absolute Correlation Matrix	Rail Tons	Rail Ton-Miles	Rail Train-Miles	Rail Car-Miles	Rail Rev Ton-Miles Annual	Truck Ton-Miles	Truck VMT	Water Tons	Water Ton-Miles
Real GDP	0.939	0.983	0.955	0.976	0.982	0.978	0.978	-0.010	-0.979
Real GDP per Capita	0.928	0.981	0.954	0.977	0.979	0.981	0.981	0.037	-0.971
Real Personal Consumption	0.938	0.977	0.943	0.966	0.976	0.969	0.969	-0.046	-0.980
Real Income Per Capita	0.925	0.971	0.934	0.961	0.969	0.971	0.971	-0.023	-0.975
Total Housing Starts	0.466	0.414	0.839	0.827	0.422	0.428	0.428	-0.307	-0.481
Industrial Production Index	0.950	0.988	0.965	0.984	0.983	0.977	0.977	0.014	-0.980
Industrial Manufacturing Index	0.951	0.987	0.966	0.985	0.983	0.975	0.975	0.003	-0.981
Purchasing Managers' Index	0.166	0.199	0.321	0.260	0.219	0.252	0.252	0.091	-0.137
Trade Wt. Broad Cur. Index	0.824	0.925	0.833	0.834	0.915	0.966	0.966	0.066	-0.902
Trade Wt. Major Cur. Index	-0.498	-0.579	-0.001	0.014	-0.586	-0.555	-0.555	-0.519	0.425
Total Employment	0.910	0.984	0.966	0.984	0.979	0.993	0.993	0.119	-0.954
Employment in Wholesale Sector	0.862	0.944	0.873	0.899	0.936	0.961	0.961	0.210	-0.909
Exports in Real $	0.922	0.962	0.895	0.899	0.962	0.925	0.925	0.135	-0.912
Imports in Real $	0.958	0.956	0.936	0.955	0.960	0.919	0.919	-0.083	-0.967
Total Capacity Utilization	0.006	0.077	-0.302	-0.356	0.089	0.083	0.083	0.844	0.108
Chained Inv. Sales Ratio (BEA)	-0.866	-0.890	-0.955	-0.937	-0.892	-0.890	-0.890	-0.033	0.871
Inv. Sales Ratio (Census)	-0.963	-0.951	-0.957	-0.955	-0.956	-0.900	-0.900	-0.048	0.911
Urban Gas Price in Real $	0.028	-0.197	0.516	0.549	-0.180	-0.354	-0.354	-0.544	0.092
Retail Sales in Real $	0.945	0.981	0.968	0.986	0.979	0.972	0.972	-0.003	-0.977
Lagged Inland Waterway Trust Fund Tax/Gallon	NA	NA	NA	NA	NA	NA	NA	0.117	-0.857
Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	-0.075	-0.700
Coal + Grain Tonnage	NA	NA	NA	NA	NA	NA	NA	0.149	-0.890
Coal Production (Tonnage)	NA	NA	NA	NA	NA	NA	NA	0.262	-0.890

The five independent variables with the highest absolute correlations were highlighted. NA indicates correlations were not determined for rail or truck demand for the independent variables added especially to model waterborne traffic. Developed by the Research Team

TABLE C-2 Filtered Correlations by Mode (Rail) in Actual, 1980 - 2007

Demand Measures (Dependent Variables)	Variables with which Correlations are > 0.75						Variables with lower Correlations
	Income	Production	Foreign Exchange	Employment	Trade	Other	
Rail Tons	Real GDP, Real GDP/Cap., Real Pers. Cons., Real Inc./Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Emp., Emp. Wholesale	Real Imports, Real Exports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Real Retail Sales	Trade Wt. Major Index, Total House Starts, Purch. Mgr. Index, Real Gas Price, Total Cap. Util.
Rail Ton-Miles	Real GDP, Real GDP/Cap., Real Pers. Cons., Real Inc./Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Emp., Emp. Wholesale	Real Imports, Real Exports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Real Retail Sales	Trade Wt. Major Index, Total House Starts, Purch. Mgr. Index, Real Gas Price, Total Cap. Util.
Rail Train-Miles	Real GDP, Real GDP/Cap., Real Pers. Cons., Real Inc./Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Emp., Emp. Wholesale	Real Imports, Real Exports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Total Housing Starts, Real Retail Sales	Trade Wt. Major Index, Purch. Mgr. Index, Real Gas Price, Total Cap. Util.
Rail Car-Miles	Real GDP, Real GDP/Cap., Real Pers. Cons., Real Inc./Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Emp., Emp. Wholesale	Real Imports, Real Exports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Total Housing Starts, Real Retail Sales	Trade Wt. Major Index, Purch. Mgr. Index, Real Gas Price, Total Cap. Util.
Rail Rev Ton Miles (Annual)	Real GDP, Real GDP/Cap., Real Pers. Cons., Real Inc./Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Emp., Employment Wholesale	Real Imports, Real Exports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Real Retail Sales	Trade Wt. Major Index, Total Housing Starts, Purch. Mgr. Index, Real Gas Price, Total Cap. Util.

SOURCE: Developed by the Research Team

TABLE C-3 Filtered Correlations by Mode (Truck) in Actual, 1980–2007

Demand Measures (Dependent Variables)	Variables with which Correlations are > 0.75						Variables with which Correlations are < 0.75
	Income	Production	Foreign Exchange	Employment	Trade	Other	
Truck Ton Miles	Real GDP, Real GDP/Capita, Real Pers. Cons., Real Income/Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Employment, Employment Wholesale	Real Exports, Real Imports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Real Retail Sales	Total Housing Starts, Purch. Mgr. Index, Trade Wt. Major Index, Total Cap. Util., Real Gas Price
Truck VMT	Real GDP, Real GDP/Capita, Real Pers. Cons., Real Income/Capita	Indus. Prod. Index, Indus. Mfg. Index	Trade Wt. Brd. Index	Total Employment, Emp. Wholesale	Real Exports, Real Imports	Inv.-Sales Ratio BEA, Inv.-Sales Ratio Census, Real Retail Sales	Total Housing Starts, Purch. Mgr. Index, Trade Wt. Major Index, Total Cap. Util., Real Gas Price

SOURCE: Developed by the Research Team

TABLE C-4 Rail Tonnage Sub-Sample Correlation Ranks (in actual)

Rail Tons (Correlation Ranks in Actual)	Rank Full Sample		Rank Short-Term Sample 1		Rank Short-Term Sample 2		Rank Short-Term Sample 3	
	1980-2007	t-stat	1980-1985	t-stat	1986-1996	t-stat	1997 - 2007	t-stat
Real GDP	6	**11.3**	13	-0.3	9	**5.4**	3	**23.7**
Real GDP per Capita	8	**11.0**	17	-0.1	7	**6.1**	2	**25.8**
Real Personal Consumption	7	**11.2**	8	-0.7	10	**5.3**	4	**17.8**
Real Income per Capita	9	**10.9**	9	-0.6	8	**5.7**	5	**14.7**
Total Housing Starts	16	**2.7**	14	-0.2	18	-0.3	15	1.1
Industrial Production Index	3	**13.3**	10	0.5	3	**9.0**	8	**10.6**
Industrial Manufacturing Index	4	**12.9**	11	0.4	4	**8.9**	6	**11.8**
Purchasing Managers' Index	17	1.0	18	0.1	19	-0.2	19	0.4
Trade Wt. Broad Cur. Index	14	**6.1**	6	-1.2	13	**3.7**	18	-0.7
Trade Wt. Major Cur. Index	15	**-3.0**	5	-1.5	14	**-3.1**	12	**-2.9**
Total Employment	11	**10.0**	19	0.0	6	**6.7**	9	**8.2**
Employment in Wholesale Sector	13	**8.2**	16	-0.1	5	**7.2**	16	1.1
Exports in Real $	10	**10.7**	3	**2.4**	11	**4.9**	13	**2.4**
Imports in Real $	2	**16.8**	4	1.6	1	**9.7**	7	**11.8**
Total Capacity Utilization	19	0.0	2	**3.4**	15	**3.1**	17	-1.0
Chained Inv.-Sales Ratio (BEA)	12	**-9.1**	12	-0.4	16	-1.8	14	**-2.3**
Inv.-Sales Ratio (Census)	1	**-18.8**	1	**-3.8**	12	**-4.2**	10	**-6.6**
Urban Gas Price in Real $	18	0.1	7	1.2	17	-1.4	11	**5.9**
Retail Sales in Real $	5	**12.6**	15	0.1	2	**9.4**	1	**27.7**

SOURCE: Developed by the Research Team

TABLE C-5 Rail Ton-Miles Sub-sample Correlation Ranks (in actual)

Rail Ton-Miles (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2		Short-Term Sample 3	
	1980–2007	t-stat	1980–1985	t-stat	1986–1996	t-stat	1997–2007	t-stat
Real GDP	1	**17.4**	18	0.1	6	**18.2**	1	**17.4**
Real GDP per Capita	2	**16.7**	13	0.4	4	**18.9**	2	**16.7**
Real Personal Consumption	4	**15.2**	15	-0.3	5	**18.2**	4	**15.2**
Real Income per Capita	5	**13.6**	17	-0.2	7	**16.9**	5	**13.6**
Total Housing Starts	17	0.9	19	0.1	18	-0.8	17	0.9
Industrial Production Index	9	**8.5**	6	1.0	1	**51.3**	9	**8.5**
Industrial Manufacturing Index	7	**9.2**	8	0.8	2	**44.7**	7	**9.2**
Purchasing Managers' Index	19	0.2	16	0.3	19	-0.3	19	0.2
Trade Wt. Broad Cur. Index	18	-0.7	9	-0.8	11	**7.9**	18	-0.7
Trade Wt. Major Cur. Index	12	**-2.7**	5	-1.0	14	**-4.0**	12	**-2.7**
Total Employment	8	**8.6**	12	0.5	3	**19.1**	8	**8.6**
Employment in Wholesale Sector	15	1.1	14	0.3	13	**5.3**	15	1.1
Exports in Real $	13	**2.6**	4	1.7	10	**9.8**	13	**2.6**
Imports in Real $	6	**10.7**	3	**2.1**	8	**13.1**	6	**10.7**
Total Capacity Utilization	16	-1.0	2	**5.5**	15	**2.3**	16	-1.0
Chained Inv.-Sales Ratio (BEA)	14	**-2.1**	10	-0.7	17	-1.4	14	**-2.1**
Inv.-Sales Ratio (Census)	11	**-5.7**	1	**-5.9**	12	**-5.8**	11	**-5.7**
Urban Gas Price in Real $	10	**6.5**	7	0.8	16	-1.7	10	**6.5**
Retail Sales in Real $	3	**16.2**	11	0.5	9	**10.8**	3	**16.2**

SOURCE: Developed by the Research Team

TABLE C-7 Rail Train-Miles Sub-Sample Correlation Ranks (in actual)

Rail Train Miles (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2	
	1990–2007	t-stat	1990–1996	t-stat	1997–2007	t-stat
Real GDP	6	**15.2**	2	**15.9**	4	**10.3**
Real GDP per Capita	7	**13.9**	6	**13.6**	3	**10.4**
Real Personal Consumption	8	**13.5**	4	**15.0**	5	**9.2**
Real Income per Capita	11	**11.3**	9	**10.3**	6	**8.2**
Total Housing Starts	15	**6.6**	14	**4.2**	15	1.4
Industrial Production Index	4	**16.1**	5	**14.0**	10	**6.7**
Industrial Manufacturing Index	2	**16.7**	3	**15.2**	9	**7.3**
Purchasing Managers' Index	17	1.4	19	1.0	18	0.8
Trade Wt. Broad Cur. Index	14	**6.7**	8	**10.6**	16	-1.1
Trade Wt. Major Cur. Index	19	-0.1	18	-1.6	12	**-3.6**
Total Employment	5	**15.6**	10	**10.2**	11	**5.4**
Employment in Wholesale Sector	13	**7.3**	17	**2.7**	17	0.9
Exports in Real $	12	**9.5**	11	**8.3**	14	**2.6**
Imports in Real $	3	**16.7**	1	**17.6**	1	**12.3**
Total Capacity Utilization	18	-1.3	15	**3.3**	19	-0.7
Chained Inv.-Sales Ratio (BEA)	9	**-12.8**	12	**-6.0**	13	**-2.9**
Inv.-Sales Ratio (Census)	10	**-12.2**	13	**-5.6**	8	**-7.8**
Urban Gas Price in Real $	16	**2.3**	16	**-2.8**	7	**7.9**
Retail Sales in Real $	1	**17.8**	7	**10.8**	2	**11.3**

SOURCE: Developed by the Research Team

TABLE C-8 Rail Car-Miles Sub-Sample Correlation Ranks (in actual)

Rail Car Miles (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2	
	1990–2007	t-stat	1990–1996	t-stat	1997–2007	t-stat
Real GDP	5	**22.4**	9	**9.5**	9	**16.5**
Real GDP per Capita	7	**20.7**	5	**12.9**	5	**17.5**
Real Personal Consumption	8	**18.7**	10	**8.4**	10	**13.3**
Real Income per Capita	9	**15.5**	7	**11.7**	7	**12.0**
Total Housing Starts	15	**6.2**	15	**3.2**	15	1.2
Industrial Production Index	3	**22.8**	2	**23.4**	2	**9.2**
Industrial Manufacturing Index	2	**24.0**	3	**19.5**	3	**10.2**
Purchasing Managers' Index	18	1.1	19	0.4	19	0.6
Trade Wt. Broad Cur. Index	14	**6.5**	11	**5.8**	11	-0.9
Trade Wt. Major Cur. Index	19	0.0	18	-1.6	18	**-3.3**
Total Employment	6	**22.3**	1	**32.2**	1	**6.8**
Employment in Wholesale Sector	13	**8.3**	12	**4.1**	12	1.0
Exports in Real $	12	**9.5**	6	**11.7**	6	**2.5**
Imports in Real $	4	**22.8**	4	**16.4**	4	**13.6**
Total Capacity Utilization	17	-1.5	16	**3.2**	16	-0.8
Chained Inv.-Sales Ratio (BEA)	11	**-10.9**	13	**-3.7**	13	**-2.6**
Inv.-Sales Ratio (Census)	10	**-12.2**	14	**-3.5**	14	**-7.5**
Urban Gas Price in Real $	16	**2.5**	17	-1.9	17	**6.5**
Retail Sales in Real $	1	**29.7**	8	**11.5**	8	**18.9**

SOURCE: Developed by the Research Team

TABLE C-9 Truck Vehicle-Miles Sub-Sample Correlation Ranks (in actual)

Truck VMT (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2		Short-Term Sample 3	
	1980–2007	t-stat	1980–1985	t-stat	1986–1996	t-stat	1997–2007	t-stat
Real GDP	2	**39.6**	5	**6.1**	2	**30.0**	3	**15.7**
Real GDP per Capita	6	**32.4**	7	**4.3**	5	**14.9**	4	**13.5**
Real Personal Consumption	5	**33.5**	1	**12.0**	1	**38.3**	1	**20.9**
Real Income per Capita	8	**26.0**	2	**11.3**	3	**15.9**	2	**20.1**
Total Housing Starts	16	**2.5**	9	**3.3**	18	-1.0	16	1.3
Industrial Production Index	4	**33.7**	14	**2.4**	6	**14.6**	8	**6.3**
Industrial Manufacturing Index	3	**35.2**	13	**3.0**	7	**14.5**	6	**6.5**
Purchasing Managers' Index	18	1.4	16	1.4	19	-0.3	19	0.3
Trade Wt. Broad Cur. Index	11	**17.7**	4	**8.9**	8	**13.1**	18	-0.3
Trade Wt. Major Cur. Index	15	**-3.4**	6	**5.2**	14	**-3.9**	12	**-2.3**
Total Employment	1	**43.7**	12	**3.0**	4	**15.0**	10	**5.8**
Employment in Wholesale Sector	10	**17.8**	11	**3.0**	13	**4.1**	17	0.4
Exports in Real $	12	**12.6**	10	**-3.2**	9	**9.8**	15	1.6
Imports in Real $	9	**19.0**	17	1.1	10	**8.6**	7	**6.3**
Total Capacity Utilization	19	0.4	19	0.2	15	1.7	14	-1.8
Chained Inv.-Sales Ratio (BEA)	14	**-10.1**	15	-1.9	17	-1.2	13	-2.0
Inv.-Sales Ratio (Census)	13	**-10.4**	18	0.4	12	**-5.7**	9	**-6.0**
Urban Gas Price in Real $	17	-1.9	3	**-9.9**	16	-1.7	11	**4.3**
Retail Sales in U.S. $	7	**27.3**	8	**3.7**	11	**7.4**	5	**12.7**

SOURCE: Developed by the Research Team

TABLE C-10 Truck Ton-Miles Sub-Sample Correlation Ranks (in actual)

Truck Ton Miles (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2		Short-Term Sample 3	
	1980–2007	t-stat	1980–1985	t-stat	1986–1996	t-stat	1997–2007	t-stat
Real GDP	2	**39.7**	5	**6.1**	2	**30.0**	3	**15.6**
Real GDP per Capita	6	**32.5**	7	**4.3**	5	**14.9**	4	**13.5**
Real Personal Consumption	5	**33.5**	1	**12.0**	1	**38.2**	1	**20.7**
Real Income per Capita	8	**26.0**	2	**11.3**	3	**15.9**	2	**20.1**
Total Housing Starts	16	**2.5**	9	**3.3**	18	-1.0	16	1.3
Industrial Production Index	4	**33.7**	14	**2.4**	6	**14.6**	8	**6.3**
Industrial Manufacturing Index	3	**35.2**	13	**3.0**	7	**14.5**	6	**6.5**
Purchasing Managers' Index	18	1.4	16	1.4	19	-0.3	18	0.3
Trade Wt. Broad Cur. Index	11	**17.7**	4	**8.9**	8	**13.1**	19	-0.3
Trade Wt. Major Cur. Index	15	**-3.4**	6	**5.2**	14	**-3.9**	12	**-2.3**
Total Employment	1	**43.7**	12	**3.0**	4	**15.0**	10	**5.8**
Employment in Wholesale Sector	10	**17.8**	11	**3.0**	13	**4.1**	17	0.4
Exports in Real $	12	**12.6**	10	**-3.2**	9	**9.8**	15	1.6
Imports in Real $	9	**19.0**	17	1.1	10	**8.6**	7	**6.3**
Total Capacity Utilization	19	0.4	19	0.2	15	1.7	14	-1.8
Chained Inv.-Sales Ratio (BEA)	14	**-10.1**	15	-1.9	17	-1.2	13	-2.0
Inv.-Sales Ratio (Census)	13	**-10.4**	18	0.4	12	**-5.7**	9	**-6.0**
Urban Gas Price in Real $	17	-1.9	3	**-9.9**	16	-1.7	11	**4.3**
Retail Sales in Real $	7	**27.3**	8	**3.7**	11	**7.4**	5	**12.7**

SOURCE: Developed by the Research Team

TABLE C-11 Waterborne Tonnage Sub-Sample Correlation Ranks (in actual)

Truck VMT (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2		Short-Term Sample 3	
	1980–2007	t-stat	1980–1985	t-stat	1986–1996	t-stat	1997–2007	t-stat
Real GDP	15	0.36	22	-0.02	**11**	**1.34**	**3**	**-5.03**
Real GDP per Capita	**12**	**0.49**	19	0.26	**5**	**1.72**	**5**	**-4.86**
Real Personal Consumption	19	0.20	**14**	**-0.40**	**14**	**1.25**	**2**	**-5.60**
Real Income per Capita	20	0.14	17	-0.32	**7**	**1.54**	**1**	**-5.63**
Total Housing Starts	**4**	**-1.41**	20	-0.17	15	-1.23	**13**	**-1.21**
Industrial Production Index	**14**	**0.42**	**9**	**0.87**	**8**	**1.53**	**8**	**-3.66**
Industrial Manufacturing Index	**13**	**0.42**	**10**	**0.68**	**9**	**1.46**	**7**	**-3.67**
Purchasing Managers' Index	**10**	**0.63**	21	-0.15	20	-0.28	20	0.39
Trade Wt. Broad Cur. Index	**11**	**0.59**	**8**	**-0.89**	17	0.63	18	-0.56
Trade Wt. Major Cur. Index	**3**	**-2.93**	**6**	**-1.18**	**2**	**-2.76**	15	1.03
Total Employment	**8**	**0.84**	**13**	**0.45**	**6**	**1.71**	**6**	**-3.99**
Employment in Wholesale Sector	**5**	**1.22**	16	0.33	**3**	**2.49**	21	-0.11
Exports in Real $	**6**	**1.15**	**4**	**2.04**	**4**	**1.89**	17	-0.61
Imports in Real $	18	0.21	**3**	**2.16**	**12**	**1.31**	**10**	**-3.04**
Total Capacity Utilization	**1**	**8.00**	**1**	**5.15**	**1**	**3.61**	**9**	**3.08**
Chained Inv.-Sales Ratio (BEA)	21	-0.11	18	-0.31	22	-0.09	**14**	**1.10**
Inv.-Sales Ratio (Census)	22	-0.08	**2**	**-3.35**	16	-0.93	**11**	**3.01**
Urban Gas Price in Real $	**2**	**-3.50**	**7**	**0.93**	19	0.42	**12**	**-2.27**
Retail Sales in U.S. $	16	0.30	15	0.40	**10**	**1.46**	**4**	**-4.87**
Grain & Coal Tonnage	**7**	**0.94**	**11**	**0.61**	**13**	**1.26**	16	-0.84
(Lagged) Inland Waterway Trust Fund Fuel Tax Rate	**9**	**0.70**	**5**	**-1.29**	18	0.53	22	0.00
Grain Tonnage	17	-0.25	**12**	**0.54**	21	-0.13	19	-0.46

SOURCE: Developed by the Research Team

TABLE C-12 Waterborne Ton-Miles Sub-Sample Correlation Ranks (in actual)

Truck Ton Miles (Correlation Ranks in Actual)	Full Sample		Short-Term Sample 1		Short-Term Sample 2		Short-Term Sample 3	
	1980–2007	t-stat	1980–1985	t-stat	1986–1996	t-stat	1997–2007	t-stat
Real GDP	**8**	-17.41	**10**	-1.18	**2**	-4.94	**3**	-11.44
Real GDP per Capita	**9**	-16.27	**14**	-0.98	**1**	-5.09	**5**	-10.63
Real Personal Consumption	**5**	-18.09	**8**	-1.40	**5**	-4.84	**2**	-11.78
Real Income per Capita	**6**	-18.07	**5**	-1.68	**6**	-4.84	**4**	-11.22
Total Housing Starts	18	-2.76	18	-0.52	22	0.69	19	-0.59
Industrial Production Index	**2**	-18.90	17	-0.69	**7**	-4.34	**9**	-7.25
Industrial Manufacturing Index	**3**	-18.54	15	-0.73	**9**	-4.30	**8**	-7.52
Purchasing Managers' Index	20	-0.79	21	0.28	19	1.12	21	0.25
Trade Wt. Broad Cur. Index	15	-8.80	**4**	-1.81	**3**	-4.93	20	0.48
Trade Wt. Major Cur. Index	19	2.45	**1**	-1.99	16	1.71	**13**	2.24
Total Employment	**10**	-13.75	**13**	-1.03	**4**	-4.89	**7**	-8.31
Employment in Wholesale Sector	**12**	-10.51	**9**	-1.26	**13**	-3.31	18	-1.11
Exports in Real $	**13**	-9.77	**6**	1.62	**11**	-4.11	**14**	-2.23
Imports in Real $	**1**	-19.64	20	-0.29	**12**	-3.90	**10**	-6.69
Total Capacity Utilization	21	0.55	19	0.43	17	-1.30	17	1.32
Chained Inv.-Sales Ratio (BEA)	**14**	9.34	22	-0.07	21	0.72	15	1.62
Inv.-Sales Ratio (Census)	**11**	11.79	**3**	-1.85	15	2.63	**12**	4.46
Urban Gas Price in Real $	22	0.46	**2**	1.91	20	0.84	**11**	-4.83
Retail Sales in Real $	**4**	-18.30	16	-0.72	**10**	-4.29	**6**	-9.79
Rail Ton-Miles (substitute service)	**7**	-17.59	**11**	1.18	**8**	-4.31	**1**	-12.02
(Lagged) Inland Waterway Trust Fund Fuel Tax Rate	16	-7.20	**7**	-1.44	**14**	-3.11	NA	NA
Grain Tonnage	17	-4.58	**12**	-1.14	18	-1.23	16	-1.45

SOURCE: Developed by the Research Team

Appendix D - Regression Analysis & Diagnostics

TABLE D-1 Rail Ton Log-Actual Regressions

Model	1	2	3	4	5	6	7
Candidate Demand Factor Weights							
Period of Estimation	1981-07	1981-07	1981-07	1981-07	1981-07	1981-07	1981-07
R - Squared (adjusted)	**0.97**	**0.97**	**0.97**	**0.97**	**0.97**	**0.98**	**0.96**
S.E. of Regression	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**
Durbin Watson Statistic	**2.38**	**2.01**	**2.16**	**2.16**	**2.11**	**2.11**	**2.36**
Model Coefficients							
Constant	**11.20**	**8.29**	**8.36**	**5.38**	**9.99**	**8.20**	**2.23**
t-stat	28.3	23.2	24.5	4.2	15.4	7.8	1.4
Candidate Demand Factor Weights							
GDP in Real $			**0.55**				
t-stat			10.0				
Real Personal Consumption				**0.67**			
t-stat				7.4			
Industrial Production Index	**0.84**						
t-stat	7.7						
Total Capacity Utilization				**0.67**			
t-stat				2.8			
Total Trade in Real $		**0.36**			**0.27**		
t-stat		12.0			6.2		
Exports in Real $							**0.15**
t-stat							1.5
Lagged Housing Total		**0.10**	**0.12**		**0.1**		
t-stat		2.2	1.8		1.7		
Real Income Per Capita						**0.58**	
t-stat						5.2	
Inv. Sales Ratio (Census)					**-0.45**	**-0.71**	
t-stat					-3.2	-4.5	
Retail Sales in Real $							**0.66**
t-stat							4.3
Lagged Purchasing Managers' Index						**0.1**	
t-stat						1.7	
Trade Wt. Broad Cur. Index	**-0.14**						
t-stat	-1.7						
Exogenous Impact Controls							
Lagged NAFTA Impact	**0.04**		**0.03**	**0.04**		**0.04**	
t-stat	2.1		2.6	5.6		3.9	
Rail Deregulation	**-0.07**			**-0.05**		**-0.07**	**-0.09**
t-stat	-2.9			-2.0		-6.2	-3.6
Statistical Error Corrections							
AR (1)	**0.78**	**0.43**	**0.49**	**0.82**	**0.49**	**0.61**	**0.81**
t-stat	7.2	3.5	4.2	10.7	3.6	4.6	7.6

SOURCE: Developed by the Research Team

TABLE D-2 Rail Ton Log-Actual Diagnostics

Rail Ton Diagnostics							
Tests	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Number of Observations	28	27	27	28	27	27	28
AIC (Information Criteria)	-116.79	-104.26	-87.90	-91.10	-109.72	-100.32	-99.35
BIC (Information Criteria)	-110.13	-100.37	-82.72	-84.44	-104.53	-93.84	-92.69
Structural Model R - Sq	0.86	0.92	0.74	0.80	0.93	0.93	0.84
DW stat (AR corrected)	2.38	2.01	2.22	2.15	2.11	2.04	1.72
DW stat (original)	1.37	0.87	1.53	1.53	0.89	1.10	1.91
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)							
Breusch-Pagan Test *(p-value)*	0.08	0.04	0.00	0.00	0.11	0.10	0.00
White Test *(p-value)*	0.44	0.21	0.12	0.37	0.40	0.19	0.11
Variance Inflation Factors (Regressors)							
GDP in Real $			**1.4**				
Real Personal Consumption				**1.8**			
Real Income Per Capita						**9.0**	
Industrial Production Index	**9.0**						
Total Capacity Utilization				**1.5**			
Total Trade in Real $		**1.4**			**11.4**		
Exports in Real $							**7.2**
Inv. Sales Ratio (Census)					**12.8**	**8.8**	
Lagged House Total		**1.38**	**1.4**		**1.6**		
Lagged Purchasing Managers' Index						**1.1**	
Retail Sales in Real $							**9.3**
Trade Wt. Broad Cur. Index	**12.2**						
Lagged NAFTA Impact	**1.0**		**1.0**			**1.0**	**1.2**
Rail Deregulation	**2.3**			**2.2**			**2.0**

TABLE D-3 Rail Ton–Miles Log-Actual Regressions

Candidate Demand Factor Weights					
Model	**1**	**2**	**3**	**4**	**5**
Period of Estimation	1981-07	1981-07	1981-07	1981-07	1981-07
R - Squared (adjusted)	**0.97**	**0.99**	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.03**	**0.02**	**0.03**	**0.03**	**0.02**
Durbin Watson Statistic	**2.19**	**1.99**	**2.33**	**2.09**	**1.98**
Model Coefficients					
Constant	**3.81**	**9.98**	**8.84**	**-4.53**	**-4.34**
t-stat	6.2	29.0	4.4	-1.5	-3.4
Candidate Demand Factor Weights					
GDP in Real $	**1.12**				
t-stat	16.9				
Industrial Production Index		**0.96**			
t-stat		13.8			
Total Employment				**1.31**	
t-stat				3.4	
Total Trade in Real $			**0.38**		
t-stat			3.2		
Imports in Real $				**0.24**	
t-stat				2.1	
Exports in Real $					**0.28**
t-stat					3.5
Inv. Sales Ratio (Census)		**-0.47**	**-0.52**		
t-stat		-3.6	-3.2		
Retail Sales in Real $					**0.97**
t-stat					6.8
Exogenous Impact Controls					
Lagged NAFTA Impact	**0.05**	**0.06**			
t-stat	4.1	7.2			
Statistical Error Corrections					
AR (1)	**0.64**	**0.56**	**0.94**	**0.65**	**0.55**
t-stat	4.3	3.7	13.0	4.4	2.9

SOURCE: Developed by the Research Team

TABLE D-4 Rail Ton-Miles Log-Actual Diagnostics

Rail Ton Miles Log – Actual Diagnostics					
Model	**1**	**2**	**3**	**4**	**5**
Number of Observations	28	28	28	28	28
AIC (Information Criteria)	-84.68	-118.38	-109.90	-97.42	-116.17
BIC (Information Criteria)	-80.68	-113.06	-105.90	-93.43	-112.18
Structural Model R - Sq	0.95	0.97	0.70	0.94	0.97
DW stat (AR corrected)	2.19	1.99	2.33	2.09	1.98
DW stat (original)	0.45	0.98	1.08	0.63	0.92
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)					
Breusch-Pagan Test *(p-value)*	0.00	0.19	0.00	0.04	0.92
White Test *(p-value)*	0.03	0.40	0.14	0.04	0.47
Variance Inflation Factors (Regressors)					
GDP in Real $	**1.0**				
Total Employment				**16.7**	
Industrial Production Index		**7.0**			
Total Trade in Real $			**10.0**		
Imports in Real $				**16.7**	
Exports in Real $					**5.6**
Inv. Sales Ratio (Census)		**6.9**	**10.0**		
Retail Sales in Real $					**5.6**
Lagged NAFTA Impact	**1.0**	**1.0**			

SOURCE: Developed by the Research Team

TABLE D-5 Rail Train Miles—Log Actual Regressions

Candidate Demand Factor Weights					
Model	**1**	**2**	**3**	**4**	**5**
Period of Estimation	1990-07	1990-07	1990-07	1990-07	1990-07
R - Squared (adjusted)	**0.97**	**0.98**	**0.98**	**0.99**	**0.97**
S.E. of Regression	**0.02**	**0.02**	**0.02**	**0.01**	**0.02**
Durbin Watson Statistic	**2.22**	**1.27**	**1.90**	**2.08**	**1.56**
Model Coefficients					
Constant	**0.37**	**2.48**	**1.80**	**1.80**	**-5.15**
t-stat	0.2	1.8	10.4	6.7	-3.3
Candidate Demand Factors					
GDP in Real $	**0.57**				
t-stat	7.1				
Industrial Production Index			**0.56**		
t-stat			9.9		
Total Capacity Utilization				**0.87**	
t-stat				7.2	
Total Trade in Real $		**0.25**			
t-stat		5.5			
Lagged Real BLS Gas			**0.10**	**0.27**	
t-stat			5.5	12.1	
House Total			**0.18**	**0.17**	**0.09**
t-stat			4.4	4.8	4.0
Chained Inv. Sales Ratio (BEA)		**-0.79**			
t-stat		-2.5			
Lagged Trade Wt. Broad Cur. Index	**0.13**	**0.11**		**0.50**	
t-stat	2.4	1.7		14.1	
Lagged Purchasing Managers' Index	**0.18**	**0.11**			**0.08**
t-stat	3.4	1.7			2.1
Retail Sales in Real $					**0.78**
t-stat					17.4
Exogenous Impact Controls					
Lagged NAFTA Impact	**0.05**		**0.06**	**0.03**	**0.05**
t-stat	3.2		6.4	2.3	5.5

SOURCE: Developed by the Research Team

TABLE D-6 Rail Train-Miles Log-Actual Diagnostics

Rail Train Miles Log – Actual Diagnostics					
Model	**1**	**2**	**3**	**4**	**5**
Number of Observations	18	18	18	18	18
AIC (Information Criteria)	-82.35	-89.55	-88.07	-97.55	-85.47
BIC (Information Criteria)	-77.89	-85.10	-83.62	-92.21	-81.02
Structural Model R - Sq	0.98	0.95	0.98	0.99	0.98
DW stat (AR corrected)	2.22	1.72	1.90	2.09	1.56
DW stat (original)	2.22	1.27	1.90	2.09	1.56
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)					
Breusch-Pagan Test *(p-value)*	0.41	0.91	0.14	0.34	0.09
White Test *(p-value)*	0.49	0.25	0.39	0.43	0.95
Variance Inflation Factors (Regressors)					
GDP in Real $	**6.95**				
Industrial Production Index			**4.03**		
Lagged Purchasing Managers' Index	**1.32**	**1.41**			**1.27**
Total Capacity Utilization				**1.65**	
Lagged House Total			**3.65**	**3.82**	**3.18**
Total Trade in Real $		**6.87**			
Lagged Real BLS Gas			**1.37**	**1.08**	
Inv. Sales Ratio (Census)		**8.20**			
Retail Sales in Real $					**3.24**
Lagged Trade Wt. Broad Cur. Index	**6.04**	**5.35**		**4.51**	
Lagged NAFTA Impact	**6.95**		**1.08**	**1.22**	**1.13**

SOURCE: Developed by the Research Team

TABLE D-7 Rail Car Miles—Log Actual Regressions

Candidate Demand Factor Weights					
Model	**1**	**2**	**3**	**4**	**5**
Period of Estimation	1990-07	1990-07	1990-07	1981-07	1981-07
R - Squared (adjusted)	**0.99**	**0.98**	**0.99**	**0.99**	**0.98**
S.E. of Regression	**0.01**	**0.02**	**0.01**	**0.01**	**0.02**
Durbin Watson Statistic	**2.35**	**2.21**	**1.98**	**1.74**	**1.19**
Model Coefficients					
Constant	**3.47**	**4.55**	**7.75**	**-4.03**	**2.47**
t-stat	5.1	3.0	35.3	-4.8	0.7
Candidate Demand Factors Weights					
GDP in Real $	**0.66**				
t-stat	6.6				
Real Personal Consumption		**0.33**			
t-stat		1.6			
Industrial Manufact. Index			**0.47**		
t-stat			18.5		
Total Trade in Real $		**0.14**			
t-stat		1.9			
Lagged House Total	**0.1**	**0.1**	**0.1**		
t-stat	2.1	1.7	2.9		
Real Income Per Capita					**0.79**
t-stat					2.5
Inv. Sales Ratio (Census)			**-0.49**		**-0.48**
t-stat			-6.4		-1.4
Retail Sales in Real $				**0.95**	
t-stat				17.1	
Exogenous Impact Controls					
Lagged NAFTA Impact	**0.04**		**0.04**	**0.03**	**0.05**
t-stat	4.3		8.5	4.7	3.3
Statistical Error Corrections					
AR (1)	**0.66**	**0.71**	**-0.44**	**0.54**	**0.81**
t-stat	3.3	2.0	-1.4	2.2	3.2

SOURCE: Developed by the Research Team

TABLE D-8 Rail Car Miles—Log Actual Diagnostics

Rail Car Miles Log – Actual Diagnostics					
Model	**1**	**2**	**3**	**4**	**5**
Number of Observations	18	18	18	18	18
AIC (Information Criteria)	-95.97	-80.18	-116.86	-103.49	-77.43
BIC (Information Criteria)	-92.41	-76.62	-112.41	-100.82	-73.87
Structural Model R - Sq	0.95	0.86	1.00	0.98	0.76
DW stat (AR corrected)	2.34	2.21	1.96	1.74	1.20
DW stat (original)	0.89	0.70	2.76	1.06	0.59
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)					
Breusch-Pagan Test *(p-value)*	0.94	0.55	0.95	0.91	0.80
White Test *(p-value)*	0.83	0.33	0.51	0.55	0.29
Variance Inflation Factors (Regressors)					
GDP in Real $	**6.70**				
Real Personal Consumption		**17.88**			
Real Income Per Capita					**11.53**
Industrial Production Index			**8.93**		
Total Trade in Real $		**19.13**			
Lagged Total House	**6.49**	**6.89**	**6.52**		
Inv. Sales Ratio (Census)			**7.95**		**11.16**
Retail Sales in Real $				**1.04**	
Lagged NAFTA Impact	**1.08**		**1.06**	**1.04**	**1.11**

SOURCE: Developed by the Research Team

TABLE D-9 Rail Revenue Ton–Miles (Annual)—Log Actual Regressions

Candidate Demand Factor Weights						
Model	**1**	**2**	**3**	**4**	**5**	**6**
Period of Estimation	1981-07	1981-07	1981-07	1981-07	1981-07	1981-07
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.03**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**
Durbin Watson Statistic	**2.22**	**2.11**	**1.86**	**1.96**	**1.96**	**1.89**
Model Coefficients						
Constant	**11.23**	**17.39**	**11.27**	**9.57**	**3.26**	**-4.55**
t-stat	20.3	41.6	20.7	6.1	2.8	-1.9
Candidate Demand Factors						
GDP in Real $	**1.06**					
t-stat	17.8					
Real Personal Consumption			**0.28**			
t-stat			1.7			
Industrial Production Index		**0.86**				
t-stat		10.4				
Total Employment						**2.12**
t-stat						10.6
Total Trade in Real $			**0.50**			
t-stat			3.9			
Exports in Real $					**0.27**	
t-stat					3.2	
Real Income Per Capita				**1.15**		
t-stat				7.8		
Inv. Sales Ratio (Census)		**-0.64**		**-0.91**		
t-stat		-3.9		-4.3		
Retail Sales in Real $					**0.93**	
t-stat					6.7	
Purchasing Manager Index						**0.18**
t-stat						4.5
Exogenous Impact Controls						
Lagged NAFTA Impact	**0.06**	**0.07**		**0.07**	**0.04**	**0.07**
t-stat	5.3	9.8		3.6	7.0	7.8
Statistical Error Corrections						
AR (1)	**0.59**	**0.58**	**0.44**	**0.67**	**0.53**	**0.78**
t-stat	3.6	3.7	2.4	4.7	2.9	8.1

SOURCE: Developed by the Research Team

TABLE D-10 Rail Revenue Ton–Miles (Annual)—Log Actual Diagnostics

Rail Revenue Ton Miles Log - Actual*Diagnostics						
Model	**1**	**2**	**3**	**4**	**5**	**6**
Number of Observations	28	28	28	28	28	28
AIC (Information Criteria)	-85.95	-123.79	-115.00	-101.20	-109.84	-71.78
BIC (Information Criteria)	-81.95	-118.46	-111.00	-95.88	-104.51	-66.45
Structural Model R - Sq	0.94	0.97	0.97	0.93	0.96	0.89
DW stat (AR corrected)	2.22	2.11	1.86	1.97	1.96	1.89
DW stat (original)	0.56	1.28	1.16	0.85	0.88	0.34
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)						
Breusch-Pagan Test *(p-value)*	0.00	0.08	0.42	0.23	0.29	0.15
White Test *(p-value)*	0.03	0.20	0.83	0.72	0.78	0.03
Variance Inflation Factors (Regressors)						
GDP in Real $	**1.0**					
Real Personal Consumption			**18.6**			
Real Income Per Capita				**5.9**		
Total Employment						**1.1**
Industrial Production Index		**7.0**				
Purchasing Managers Index						**1.1**
Total Trade in Real $			**18.6**			
Exports in Real $					**6.1**	
Inv. Sales Ratio (Census)		**6.9**		**5.9**		
Retail Sales in Real $					**5.9**	
Lagged NAFTA Impact	**1.0**	**1.0**		**1.0**	**1.1**	**1.0**

SOURCE: Developed by the Research Team

TABLE D-11 Truck Ton–Miles—Log Actual Regressions

Candidate Demand Factor Weights				
Model	**1**	**2**	**3**	**4**
Period of Estimation	1981-07	1981-07	1981-07	1981-07
R - Squared (adjusted)	**0.997**	**0.997**	**0.997**	**0.998**
S.E. of Regression	**0.01**	**0.01**	**0.01**	**0.01**
Durbin Watson Statistic	**1.65**	**1.77**	**1.57**	**1.63**
Model Coefficients				
Constant	**13.82**	**10.34**	**11.19**	**14.21**
t-stat	17.3	6.6	5.5	10.7
Candidate Demand Factors				
Industrial Manufacturing Index				**0.23**
t-stat				4.4
Total Trade in Real $	**0.10**			
t-stat	2.3			
Exports in Real $		**0.05**		
t-stat		1.5		
Total Employment			**0.37**	
t-stat			2.6	
Chained Inv. Sales Ratio (BEA)	**-0.17**		**-0.22**	
t-stat	-2.0		-2.7	
Retail Sales in Real $		**0.26**		
t-stat		2.9		
Gas Price in Real $	**-0.05**	**-0.05**	**-0.03**	**-0.04**
t-stat	-1.3	-1.4	-1.1	-1.4
Exogenous Impact Control				
NAFTA Impact			**0.01**	**0.02**
t-stat			1.5	1.5
Statistical Error Corrections				
AR (1)	**0.98**		**0.99**	**0.98**
t-stat	74.8		57.4	55.3

SOURCE: Developed by the Research Team

TABLE D-12 Truck Ton–Miles—Log Actual Diagnostics

Truck Ton Miles Log - Actual* Diagnostics				
Model	**1**	**2**	**3**	**4**
Number of Observations	28	28	28	28
AIC (Information Criteria)	-95.93	-111.13	-114.88	-114.35
BIC (Information Criteria)	-90.60	-105.80	-108.22	-109.02
Structural Model R - Sq	0.34	0.36	0.42	0.44
DW stat (AR corrected)	1.65	1.77	1.57	1.62
DW stat (original)	0.89	0.71	0.83	0.89
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)				
Breusch-Pagan Test *(p-value)*	0.09	0.05	0.28	0.67
White Test *(p-value)*	0.27	0.12	0.41	0.39
Variance Inflation Factors (Regressors)				
Total Employment			**4.9**	
Industrial Manufacturing Index				**1.1**
Total Trade in Real $	**4.6**			
Exports in Real $		**5.7**		
Inv. Sales Ratio (BEA)	**4.8**		**4.6**	
Retail Sales in Real $		**5.9**		
Real Gas Price	**1.1**	**1.1**	**1.3**	**1.2**
NAFTA Impact				**1.1**

SOURCE: Developed by the Research Team

TABLE D-13 Truck Vehicle Miles—Log Actual Regressions

Candidate Demand Factor Weights				
Model	**1**	**2**	**3**	**4**
Period of Estimation	1981-07	1981-07	1981-07	1981-07
R - Squared (adjusted)	**0.997**	**0.997**	**0.997**	**0.998**
S.E. of Regression	**0.01**	**0.01**	**0.01**	**0.01**
Durbin Watson Statistic	**1.66**	**1.78**	**1.58**	**1.64**
Model Coefficients				
Constant	**12.05**	**8.59**	**9.43**	**12.44**
t-stat	15.1	5.5	4.7	9.4
Candidate Demand Factors				
Industrial Manufacturing Index				**0.23**
t-stat				4.3
Total Trade in Real $	**0.10**			
t-stat	2.3			
Exports in Real $		**0.06**		
t-stat		1.5		
Total Employment			**0.37**	
t-stat			2.6	
Chained Inv. Sales Ratio (BEA)	**-0.17**		**-0.22**	
t-stat	-2.0		-2.7	
Retail Sales in Real $		**0.26**		
t-stat		2.9		
Gas Price in Real $	**-0.05**	**-0.05**	**-0.03**	**-0.04**
t-stat	-1.3	-1.4	-1.1	-1.3
Exogenous Impact Control				
NAFTA Impact			**0.01**	**0.02**
t-stat			1.5	1.5
Statistical Error Corrections				
AR (1)	**0.98**	**0.98**	**0.99**	**0.98**
t-stat	74.6	66.2	57.2	54.9

SOURCE: Developed by the Research Team

TABLE D-14 Truck Vehicle Miles—Log Actual Diagnostics

Truck Vehicle Miles Travelled Log - Actual*Diagnostics				
Model	**1**	**2**	**3**	**4**
Number of Observations	28	28	28	28
AIC (Information Criteria)	-95.96	-111.12	-114.87	-114.33
BIC (Information Criteria)	-90.63	-105.79	-108.21	-109.01
Structural Model R - Sq	0.34	0.35	0.42	0.44
DW stat (AR corrected)	1.66	1.78	1.58	1.62
DW stat (original)	0.89	0.72	0.83	0.89
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)				
Breusch-Pagan Test *(p-value)*	0.09	0.05	0.27	0.67
White Test *(p-value)*	0.27	0.12	0.41	0.39
Variance Inflation Factors (Regressors)				
Total Employment			**4.9**	
Industrial Manufacturing Index				**1.1**
Total Trade in Real $	**4.6**			
Exports in Real $		**5.7**		
Inv. Sales Ratio (Census)	**4.8**		**4.6**	
Retail Sales in Real $		**5.9**		
Real Gas Price	**1.1**	**1.1**	**1.3**	**1.2**
NAFTA Impact			**1.1**	**1.1**

SOURCE: Developed by the Research Team

TABLE D-15 Water Tons—Log Actual Regressions

Candidate Demand Factors			
Model	**1**	**2**	**3**
Period of Estimation	1981-2007	1981-2007	1981-2007
R-Squared Adjusted	**0.76**	**0.75**	**0.66**
S.E. of Regression	**0.02**	**0.02**	**0.02**
Durbin Watson Statistic	**1.75**	**1.91**	**1.72**
Model Coefficients			
Constant	**15.53**	**17.61**	**16.39**
t-stat	23.24	26.89	21.42
Candidate Demand Factors Weights			
Total Capacity Utilization	**0.86**	**0.82**	**0.88**
t-stat	6.63	5.73	5.07
Grain and Coal Tons	**0.09**		
t-stat	2.68		
Grain Tons			**0.03**
t-stat			3.00
Real BLS Gas	**-0.10**	**-0.08**	
t-stat	-3.01	-3.14	
Lagged Inland Waterway Trust Fund Tax/Gallon			**-0.03**
t-stat			-1.03
Exogenous Impact Controls			
Rail Deregulation		**-0.01**	
t-stat		-0.70	
Statistical Error Corrections			
AR(1)	**0.66**	**0.53**	**0.86**
t-stat	4.32	3.31	5.22

TABLE D-16 Water Tons—Log Actual Diagnostics

Model Coefficients			
Number of Observations	28	28	28
AIC (Information Criteria)	-148.56	-145.51	-139.02
BIC (Information Criteria)	-143.23	-140.18	-133.69
Structural Model R-Squared	0.79	0.78	0.70
DW Stat (AR Corrected)	1.75	1.91	1.72
DW Stat (Original)	0.98	1.04	0.74
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test (*p-value*)	0.14	0.27	0.02
White Test (*p-value*)	0.09	0.12	0.13
Variance Inflation Factors (Regressors)			
Total Capacity Utilization	**1.19**	**1.25**	**1.05**
Grain and Coal Tons	**1.02**		
Grain Tons			**1.63**
Real BLS Gas	**1.20**	**1.60**	
Lagged Inland Waterway Trust Fund Tax/Gallon			**1.65**
Rail Deregulation		**1.61**	

TABLE D-17 Water Ton Miles—Log Actual Regressions

Candidate Demand Factors			
Model	**1**	**2**	**3**
Period of Estimation	1981-2007	1981-2007	1981-2007
R-Squared Adjusted	**0.95**	**0.87**	**0.96**
S.E. of Regression	**0.04**	**0.03**	**0.03**
Durbin Watson Statistic	**1.82**	1.95	**1.62**
Model Coefficients			
Constant	**23.23**	**26.13**	**24.65**
t-stat	11.01	22.93	26.83
Candidate Demand Factors Weights			
Rail Ton-Miles	**-0.44**	**-0.65**	**-0.68**
t-stat	-4.13	-11.95	-26.29
Real BLS Gas	**-0.15**		
t-stat	-2.79		
Total Capacity Utilization			**0.69**
t-stat			3.88
Lagged Inland Waterway Trust Fund Tax/Gallon	**-0.13**		
t-stat	-2.30		
Purchasing Managers Index		**0.25**	
t-stat		2.70	
Exogenous Impact Controls			
Lagged NAFTA Impact	**0.14**	**0.11**	**0.09**
t-stat	4.54	8.25	3.59
Statistical Error Corrections			
AR(1)		**0.51**	
t-stat		3.76	

TABLE D-18 Water Ton Miles—Log Actual Diagnostics

Model Coefficients			
Number of Observations	27.00	27.00	28.00
AIC (Information Criteria)	-95.91	-103.48	-107.08
BIC (Information Criteria)	-89.43	-98.30	-101.75
Structural Model R-Squared	0.96	0.88	0.97
DW Stat (AR Corrected)	NA	1.95	
DW Stat (Original)	1.82	1.20	1.62
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test (*p-value*)	0.48	0.03	0.71
White Test (*p-value*)	0.72	0.20	0.97
Variance Inflation Factors (Regressors)			
Rail Ton-Miles	**13.04**	**1.09**	**1.02**
Real BLS Gas	**2.55**		
Total Capacity Utilization			**1.11**
Lagged Inland Waterway Trust Fund Tax/Gallon	**16.03**		
Purchasing Managers Index		**1.07**	
Lagged NAFTA Impact	**1.16**	**1.03**	**1.12**

Appendix E - Primary Component Analysis Tables

TABLE E-1 Principal Component Analysis Groups

Demand Factor	Commodity	Consumption	Foreign Exchange	Production	Purchasing Manager Index & Capacity Utilization Group	Employment
1	Urban Gas Price in Real $	Real Personal Consumption 2005 Chained $	Trade Weighted Foreign Exchange Index (Broad Trading Partners)	Real GDP 2005 Chained $	Purchasing Managers Index	Total Employment
2	Increase in Coal Producer Price Index	Total Housing Starts	Trade Weighted Foreign Exchange Index (Major Trading Partners)	Real Income/Capita, Chained 2005 $	Change in Capacity Utilization	Employment Wholesale
3	Urban Gas Price in Real $ 1 yr Lag	Inv.-Sales Ratio (Census)	Trade Weighted Foreign Exchange Index (Broad Trading Partners) 1 Yr. Lag	Industrial Production Index	Purchasing Managers Index 1 yr Lag	Total Employment, 1 Yr. Lag
4		Chained Inv.-Sales Ratio (BEA)	Trade Weighted Foreign Exchange Index (Major Trading Partners) 1 Yr. Lag	Industrial Manufacturing Index		
5		Retail Sales in Real $		Real Exports in Goods (in $)		
6		Real Imports in Goods (in $)		Real GDP 2005 Chained $, 1 Yr. Lag		
7		Real Personal Consumption 2005 Chained $, 1 Yr. Lag		Real Income Per Capita 2005 Chained $, 1 Yr. Lag		
8		Total Housing Starts, 1 Yr. Lag				
9		Inv.-Sales Ratio (Census),1 Yr. Lag				
10		Chained Inv.-Sales Ratio (BEA),1 Yr. Lag				
11		Retail Sales in Real $ 1 Yr. Lag				

SOURCE: Developed by the Research Team

TABLE E-2 Principal Component Results for the Commodity Group

Commodity Group Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.3521	1.8060	0.7840	2.3521	0.7840
2	0.5461	0.4444	0.1820	2.8983	0.9661
3	0.1017	---	0.0339	3.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-3 Principal Component Results for the Consumption Group

Consumption Group Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	9.1971	8.0693	0.8361	9.1971	0.8361
2	1.1279	0.7319	0.1025	10.3250	0.9386
3	0.3960	0.2716	0.0360	10.7210	0.9746
4	0.1244	0.0527	0.0113	10.8453	0.9859
5	0.0716	0.0076	0.0065	10.9170	0.9925
6	0.0641	0.0550	0.0058	10.9810	0.9983
7	0.0091	0.0036	0.0008	10.9901	0.9991
8	0.0055	0.0020	0.0005	10.9956	0.9996
9	0.0035	0.0026	0.0003	10.9991	0.9999
10	0.0008	0.0007	0.0001	10.9999	1.0000
11	0.0001	---	0.0000	11.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-4 Principal Component Results for the Foreign Exchange Group

Foreign Exchange Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.7825	1.7142	0.6956	2.7825	0.6956
2	1.0683	0.9215	0.2671	3.8508	0.9627
3	0.1468	0.1444	0.0367	3.9976	0.9994
4	0.0024	---	0.0006	4.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-5 Principal Component Results for the Production Group

Production Group Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	6.8376	6.7103	0.9768	6.8376	0.9768
2	0.1273	0.0969	0.0182	6.9648	0.9950
3	0.0303	0.0274	0.0043	6.9951	0.9993
4	0.0029	0.0019	0.0004	6.9981	0.9997
5	0.0010	0.0002	0.0001	6.9991	0.9999
6	0.0008	0.0008	0.0001	7.0000	1.0000
7	0.0000	---	0.0000	7.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-6 Principal Component Results for Manager Index/Capacity Utilization Group

Purchasing Manager Index & Capacity Utilization Group Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	1.9898	1.0921	0.6633	1.9898	0.6633
2	0.8977	0.7852	0.2992	2.8875	0.9625
3	0.1125	---	0.0375	3.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-7 Principal Component Results for Employment Group

Employment Group Results					
Principal Components in Actual					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.9597	2.9224	0.9866	2.9597	0.9866
2	0.0373	0.0342	0.0124	2.9969	0.9990
3	0.0031	---	0.0010	3.0000	1.0000

SOURCE: Developed by the Research Team

TABLE E-8 Principal Component Candidate Demand Factor Weights: Commodity Group

Principal Component Candidate Demand Factor Weights: Commodity Group			
Actual			
Candidate Demand Factors	1	2	3
Urban Gas Price in Real $	0.62	-0.26	-0.74
Increase in Coal Producer Price Index	0.51	0.85	0.12
Urban Gas Price in Real $ 1 yr Lag	0.60	-0.45	0.66

SOURCE: Developed by the Research Team

TABLE 1 Principal Component Candidate Demand Factor Weights: Consumption Group

Principal Component Candidate Demand Factor Weights: Consumption Group					
Actual					
Candidate Demand Factors	1	2	3	4	5
Real Personal Consumption 2005 Chained $	0.32	-0.16	0.14	0.28	0.03
Total Housing Starts	0.19	0.72	0.45	-0.01	0.45
Inv.-Sales Ratio (Census)	-0.32	0.07	-0.15	0.53	0.41
Chained Inv.-Sales Ratio (BEA)	-0.31	-0.16	-0.33	0.24	0.38
Retail Sales in Real $	0.33	-0.11	0.10	0.26	-0.02
Real Imports in Goods (in $)	0.33	-0.12	0.01	0.01	-0.04
Real Personal Consumption 2005 Chained $, 1 Yr. Lag	0.32	-0.19	0.11	0.28	0.01
Total Housing Starts, 1 Yr. Lag	0.23	0.55	-0.64	0.14	-0.38
Inv.-Sales Ratio (Census),1 Yr. Lag	-0.31	0.19	0.31	0.57	-0.49
Chained Inv.-Sales Ratio (BEA),1 Yr. Lag	-0.32	-0.05	0.34	-0.06	-0.31
Retail Sales in Real $ 1 Yr. Lag	0.32	-0.18	0.00	0.30	0.02

SOURCE: Developed by the Research Team

TABLE E-10 Principal Component Candidate Demand Factor Weights: Foreign Exchange Group

Principal Component Candidate Demand Factor Weights: Foreign Exchange Group				
Actual				
Candidate Demand Factors	1	2	3	4
Trade Weighted Foreign Exchange Index (Broad Trading Partners)	0.52	0.48	0.22	-0.67
Trade Weighted Foreign Exchange Index (Major Trading Partners)	-0.50	0.47	0.70	0.19
Trade Weighted Foreign Exchange Index (Broad Trading Partners) 1 Yr. Lag	0.52	0.47	-0.14	0.70
Trade Weighted Foreign Exchange Index (Major Trading Partners) 1 Yr. Lag	-0.46	0.56	-0.66	-0.17

SOURCE: Developed by the Research Team

TABLE E-11 Principal Component Candidate Demand Factor Weights: Production Group

Principal Component Candidate Demand Factor Weights: Production Group					
Actual					
Candidate Demand Factors	1	2	3	4	5
Real GDP 2005 Chained $	0.38	-0.13	0.04	0.14	-0.87
Real Income/Capita, Chained 2005 $	0.38	-0.31	0.12	0.76	0.35
Industrial Production Index	0.38	0.03	-0.58	-0.16	0.27
Industrial Manufacturing Index	0.38	0.00	-0.56	-0.07	-0.07
Real Exports in Goods (in $)	0.36	0.88	0.26	0.13	0.06
Real GDP 2005 Chained $, 1 Yr. Lag	0.38	-0.12	0.28	-0.53	0.15
Real Income Per Capita 2005 Chained $, 1 Yr. Lag	0.38	-0.31	0.44	-0.27	0.12

SOURCE: Developed by the Research Team

TABLE E-12 Principal Component Candidate Demand Factor Weights Manager Index/Capacity Utilization Group

Principal Component Candidate Demand Factor Weights: Purch. Mangr. Index & Capacity Utilization Group			
Actual			
Candidate Demand Factors	1	2	3
Purchasing Managers Index	0.64	-0.38	0.67
Change in Capacity Utilization	0.68	-0.11	-0.72
Purchasing Managers Index 1 yr Lag	0.35	0.92	0.19

SOURCE: Developed by the Research Team

TABLE E-13 Principal Component Candidate Demand Factor Weights: Employment Group

Principal Component Candidate Demand Factor Weights: Employment Group			
Actual			
Candidate Demand Factors	1	2	3
Total Employment	0.58	-0.20	-0.79
Employment Wholesale	0.57	0.79	0.23
Total Employment, 1 Yr. Lag	0.58	-0.59	0.57

SOURCE: Developed by the Research Team

TABLE E-14 Rail Tons PCA—Log Actual Regressions

Rail Tons Log – Actual*				
Model	**1**	**2**	**2***	**3**
Period of Estimation	1981-2007	1982-2007	1982-2007	1981-2007
R - Squared (adjusted)	**0.94**	**0.98**	**0.99**	**0.95**
S.E. of Regression	**0.03**	**0.02**	**0.01**	**0.03**
Durbin Watson Statistic	**1.21**	**1.70**	**2.38**	**1.19**
Model Coefficients				
Constant	**14.25**	**14.25**	**14.24**	**14.25**
t-stat	2143.5	3983.9	4401.7	2151.3
Principal Component Regression Weights				
Production Principal Component				**0.05**
t-stat				21.12
Employment Principal Component	**0.08**			
t-stat	21.36			
Employment Comp Lag		**0.02**	**0.03**	
t-stat		2.19	6.59	
Consumption Principal Component		**0.03**	**0.03**	
t-stat		6.94	12.74	
Commodity Principal Component	**0.03**	**0.01**	**0.00**	**0.02**
t-stat	6.20	4.82	2.19	3.64
Purch. Mngr. & Cap. Util Component	**0.01**			**0.01**
t-stat	4.23			2.07
Exogenous Impact Control				
Lagged NAFTA Impact	**0.03**	**0.03**	**0.03**	**0.03**
t-stat	2.40	3.74	4.50	2.31

SOURCE: Developed by the Research Team

TABLE 2 Rail Tons PCA—Log Actual Diagnostics

Rail Tons Log - Actual* Model	**1**	**2**	**2***	**3**
Number of Observations	27	26	23	27
AIC (Information Criteria)	-104.26	-117.92	-132.99	-104.08
BIC (Information Criteria)	-97.78	-111.63	-127.31	-97.61
Adjusted Model R - Sq	0.94	0.97	0.99	0.94
DW stat (original)	.	1.70	2.38	1.19
Serial Corr. LM Test (1-lag)	0.16	0.44	0.31	0.12
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)				
Breusch-Pagan Test *(p-value)*	0.05	0.06	0.81	0.05
White Test *(p-value)*	0.59	0.01	0.02	0.20
Variance Inflation Factors (Regressors)				
Production Principal Component				**1.0**
Employment Principal Component	**6.17**			
Employment Comp Lag		**7.82**	**6.17**	
Consumption Principal Component	**7.35**	**7.71**	**7.35**	
Commodity Principal Component	**1.58**	**1.27**	**1.58**	**1.15**
Purch. Mngr. & Cap. Util Component				**1.09**
Lagged NAFTA Impact	**1.06**	**1.06**	**1.06**	**1.07**

SOURCE: Developed by the Research Team

TABLE E-16 Rail Ton Miles PCA—Log Actual Regressions

Rail Ton Miles Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1981-2007	1981-2007	1982-2007
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.03**	**0.02**	**0.03**
Durbin Watson Statistic	**1.36**	**1.81**	**1.76**
Model Coefficients			
Constant	**14.02**	**14.04**	**14.48**
t-stat	2456.6	1667.5	12.7
Principal Component Weights			
Production Principal Component	**0.10**		
t-stat	41.5		
Employment Lag Principal Component		**0.16**	
t-stat		35.6	
Commodity Principal Component	**0.01**	**0.02**	**0.01**
t-stat	1.8	3.8	2.0
Consumption Principal Component			**0.05**
t-stat			2.8
Purch. Mngr. & Cap. Util Component		**0.03**	
t-stat		6.5	
Exogenous Impact Control			
Lagged NAFTA Impact	**0.07**	**0.08**	**0.05**
t-stat	9.1	9.1	10.7
Statistical Error Corrections			
AR (1)		**0.32**	**0.98**
t-stat		2.3	17.0

SOURCE: Developed by the Research Team

TABLE E-17 Rail Tons Miles PCA—Log Actual Diagnostics

Rail Ton Miles Log - Actual*			
Model	**1**	**2**	**3**
Number of Observations	27	25	26
AIC (Information Criteria)	-111.42	-111.25	-100.60
BIC (Information Criteria)	-106.23	-105.15	-94.31
Adjusted Model R - Sq	0.99	0.98	0.56
DW stat (original)	1.36	1.18	0.43
DW stat (corrected)	-	-	-
Serial Correlation LM Test	0.55	0.05	0.00
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.11	0.24	0.18
White Test *(p-value)*	0.04	0.52	0.05
Variance Inflation Factors (Regressors)			
Production Principal Component	**1.0**		
Employment Lag Principal Component		**1.02**	
Consumption Principal Component			**1.01**
Commodity Principal Component	**1.09**	**1.12**	**1.07**
Purch. Mngr. & Cap. Util Component		**1.0**	
Lagged NAFTA Impact	**1.06**	**1.1**	**1.1**

SOURCE: Developed by the Research Team

TABLE E-18 Rail Revenue Ton Miles PCA—Log Actual Regressions

Rail Revenue Ton Miles Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1981-2007	1982-2007	1982-2007
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.03**	**0.03**	**0.03**
Durbin Watson Statistic	**1.20**	**1.43**	**1.34**
Model Coefficients			
Constant	**20.90**	**20.92**	**20.89**
t-stat	4050.1	3856.0	1043.9
Principal Component Weights			
Production Principal Component	**0.09**		
t-stat	45.4		
Employment Lag Principal Component		**0.14**	
t-stat		53.5	
Commodity Principal Component	**0.01**	**0.03**	**0.01**
t-stat	3.2	7.8	1.3
Consumption Principal Component			**0.05**
t-stat			9.0
Purch. Mngr. & Cap. Util Component	**0.01**	**0.04**	
t-stat	3.8	8.4	
Foreign Exchange Principal Component			**0.06**
t-stat			3.8
Exogenous Impact Control			
Lagged NAFTA Impact	**0.09**	**0.12**	**0.04**
t-stat	12.9	11.4	5.0

SOURCE: Developed by the Research Team

TABLE E-19 Rail Revenue Ton Miles PCA—Log Actual Diagnostics

Rail Revenue Ton Miles Log - Actual*			
Model	**1**	**2**	**3**
Number of Observations	27	26	26
AIC (Information Criteria)	-116.65	-111.48	-113.94
BIC (Information Criteria)	-110.17	-105.19	-107.65
Adjusted Model R - Sq	0.99	0.99	0.94
DW stat (original)	1.20	1.43	0.50
DW stat (corrected)			
Serial Correlation LM Test	0.25	0.21	0.00
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.14	0.43	0.08
White Test *(p-value)*	0.04	0.16	0.83
Variance Inflation Factors (Regressors)			
Production Principal Component	1.04		
Employment Lag Principal Component		1.02	
Consumption Principal Component			3.93
Commodity Principal Component	1.15	1.12	1.29
Purch. Mngr. & Cap. Util Component	1.09	1.04	
Foreign Ex. Principal Component			4.48
Lagged NAFTA Impact	1.07	1.07	1.18

TABLE E-20 Rail Train Miles PCA—Log Actual Regressions

Rail Train Miles Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1990-2007	1990-2007	1990-2007
R - Squared (adjusted)	**0.97**	**0.97**	**0.98**
S.E. of Regression	**0.02**	**0.02**	**0.02**
Durbin Watson Statistic	**1.24**	**1.53**	**1.22**
Model Coefficients			
Constant	**6.05**	**6.05**	**6.08**
t-stat	707.7	745.2	823.0
Principal Component Weights			
Production Principal Component		**0.07**	
t-stat		18.0	
Employment Principal Component	**0.11**		
t-stat	17.2		
Commodity Principal Component	**0.01**		
t-stat	2.0		
Consumption Principal Component			**0.05**
t-stat			23.7
Purch. Mngr. & Cap. Util Component	**0.03**	**0.01**	
t-stat	4.0	2.2	
Exogenous Impact Control			
Lagged NAFTA Impact	**0.05**	**0.06**	**0.05**
t-stat	6.6	8.1	5.8

TABLE E-21 Rail Train Miles PCA—Log Actual Diagnostics

Rail Train Miles Log - Actual*			
Model	**1**	**2**	**3**
Number of Observations	18	18	18
AIC (Information Criteria)	-80.17	-85.17	-88.18
BIC (Information Criteria)	-75.72	-81.61	-85.51
Adjusted Model R - Sq	0.97	0.97	0.98
DW stat (original)	1.24	1.53	1.22
DW stat (corrected)			
Serial Correlation LM Test	0.18	0.63	0.32
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.23	0.24	0.42
White Test *(p-value)*	0.76	0.98	0.08
Variance Inflation Factors (Regressors)			
Production Principal Component		**1.11**	
Employment Principal Component	**1.25**		
Consumption Principal Component			**1.04**
Commodity Principal Component	**1.31**		
Purch. Mngr. & Cap. Util Component	**1.02**	**1.05**	
Lagged NAFTA Impact	**1.08**	**1.05**	**1.04**

TABLE E-22 Rail Car Miles PCA—Log Actual Regressions

Rail Car Miles Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1990-2007	1991-2007	1990 2007
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.01**	**0.01**	**0.02**
Durbin Watson Statistic	**1.42**	**2.07**	**2.20**
Model Coefficients			
Constant	**10.26**	**10.31**	**10.27**
t-stat	2226.9	1161.9	1565.3
Principal Component Weights			
Production Principal Component	**0.08**		
t-stat	30.4		
Employment Lag Principal Component			**0.12**
t-stat			26.1
Commodity Principal Component			**0.01**
t-stat			2.5
Consumption Principal Component		**0.05**	
t-stat		18.1	
Purch. Mngr. & Cap. Util Component	**0.01**		**0.03**
t-stat	3.1		11.9
Exogenous Impact Control			
Lagged NAFTA Impact	**0.05**	**0.04**	**0.08**
t-stat	6.2	3.4	10.5
Statistical Error Corrections			
AR (1)		**0.50**	
t-stat		2.5	

TABLE E-23 Rail Car Miles PCA—Log Actual Diagnostics

Rail Car Miles Log - Actual*			
Model	**1**	**2**	**3**
Number of Observations	18	17	18
AIC (Information Criteria)	-99.41	-97.50	-92.81
BIC (Information Criteria)	-95.85	-95.00	-88.36
Adjusted Model R - Sq	0.99	0.97	0.99
DW stat (original)	1.42	1.11	2.20
DW stat (corrected)	-	-	-
Serial Correlation LM Test	0.72	0.06	0.48
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.17	0.93	0.73
White Test *(p-value)*	0.28	0.79	0.67
Variance Inflation Factors (Regressors)			
Production Principal Component	**1.11**		
Employment Lag Principal Component			**1.32**
Consumption Principal Component		**1.04**	
Commodity Principal Component			**1.34**
Purch. Mngr. & Cap. Util Component	**1.05**		**1.02**
Lagged NAFTA Impact	**1.05**	**1.04**	**1.10**

TABLE E-24 Truck Ton Miles PCA—Log Actual Regressions

Truck Ton Miles Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1982-2007	1983-2007	1984-2007
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.01**	**0.01**	**0.02**
Durbin Watson Statistic	**1.36**	**1.91**	**2.13**
Model Coefficients			
Constant	**14.43**	**14.56**	**13.80**
t-stat	52.1	26.7	1289.8
Principal Component Weights			
Production Principal Component	**0.02**		
t-stat	3.1		
Employment Lag Principal Component			**0.14**
t-stat			15.8
Commodity Principal Component	**0.00**	**0.00**	
t-stat	-1.9	-1.0	
Consumption Principal Component		**0.00**	
t-stat		-1.0	
Purch. Mngr. & Cap. Util Component			**0.01**
t-stat			3.5
Exogenous Impact Control			
NAFTA Impact	**0.97**	**0.01**	**0.02**
t-stat	80.4	2.0	2.4
Statistical Error Corrections			
AR (1)	**0.97**	**1.42**	**1.25**
t-stat	80.4	6.6	6.5
AR (2)		**-0.44**	**-0.64**
t-stat		-2.1	-3.6

TABLE E-25 Truck Ton Miles PCA—Log Actual Diagnostics

Model	1	2	3
Number of Observations	26	25	24
AIC (Information Criteria)	-153.31	-156.20	-127.40
BIC (Information Criteria)	-5.65	-5.72	-4.61
Adjusted Model R - Sq	1.00	0.65	0.63
DW stat (original)	0.00	0.00	0.00
DW stat (corrected)			
Serial Correlation LM Test	0.87	0.04	0.07
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.78	0.06	0.22
White Test *(p-value)*	0.00	0.00	0.00
Variance Inflation Factors (Regressors)			
Production Principal Component	**1.03**		
Employment Lag Principal Component			**1.00**
Consumption Principal Component		**1.01**	
Commodity Principal Component	**1.09**	**1.07**	
Purch. Mngr. & Cap. Util Component			**1.03**
NAFTA Impact	**1.06**	**1.06**	**1.03**

TABLE E-26 Truck VMT PCA—Log Actual Regressions

Truck VMT Log - Actual*			
Model	**1**	**2**	**3**
Period of Estimation	1982-2007	1983-2007	1984-2007
R - Squared (adjusted)	**0.99**	**0.99**	**0.99**
S.E. of Regression	**0.01**	**0.01**	**0.02**
Durbin Watson Statistic	**1.38**	**1.92**	**2.14**
Model Coefficients			
Constant	**12.67**	**12.80**	**12.04**
t-stat	45.8	23.6	1120.7
Principal Component Weights			
Production Principal Component	**0.02**		
t-stat	3.1		
Employment Lag Principal Component			**0.14**
t-stat			15.7
Commodity Principal Component	**0.00**	**0.00**	
t-stat	-1.8	-1.0	
Consumption Principal Component		**0.01**	
t-stat		2.1	
Purch. Mngr. & Cap. Util Component			**0.01**
t-stat			3.5
Exogenous Impact Control			
NAFTA Impact	**0.02**	**0.01**	**0.02**
t-stat	1.3	1.9	2.4
Statistical Error Corrections			
AR (1)	**0.97**	**1.41**	**1.25**
t-stat	80.0	6.5	6.5
AR (2)		**-0.43**	**-0.63**
t-stat		-2.0	-3.6

TABLE E-27 Truck VMT PCA—Log Actual Diagnostics

Truck VMT Log - Actual*			
Model	**1**	**2**	**3**
Number of Observations	26	25	24
AIC (Information Criteria)	-153.04	-149.71	-117.58
BIC (Information Criteria)	-5.64	-5.70	-4.60
Adjusted Model R - Sq	**0.99**	**0.99**	**0.99**
DW stat (original)	0.83	0.65	0.63
DW stat (corrected)			
Serial Correlation LM Test	0.00	0.00	0.00
Heteroskedasticity Tests (Null Hypothesis: Constant Variance)			
Breusch-Pagan Test *(p-value)*	0.87	0.04	0.07
White Test *(p-value)*	0.78	0.06	0.22
Variance Inflation Factors (Regressors)			
Production Principal Component	**1.0**		
Employment Lag Principal Component			**1.00**
Consumption Principal Component		**1.01**	
Commodity Principal Component	**1.09**	**1.07**	
Purch. Mngr. & Cap. Util Component			**1.0**
NAFTA Impact	**1.06**	**1.1**	**1.0**