

***WORKING PAPER SERIES***

**Center for Transportation Studies**



**Working Paper # CTS2002A**

<http://www.bu.edu/transportation/WPSeries.html>

# Transportation Infrastructure, Freight Services Sector and Economic Growth

**T. R. Lakshmanan**  
**William P. Anderson**  
Center for Transportation Studies  
Boston University

**A White Paper prepared  
for  
The U.S. Department of Transportation  
Federal Highway Administration**

**January, 2002**

## TABLE OF CONTENTS

Figure and Table Legend .....	4
I. THE FREIGHT SERVICES SECTOR: TECHNICAL CHANGE, EVOLUTION, AND CONTRIBUTION TO ECONOMIC GROWTH .....	7
A Statistical Profile of the U.S. Freight Services Sector.....	8
The Changing Context of the Freight Services Sector.....	18
The Emerging Freight Services Industry.....	20
Linkages Between Transport Investments, Freight Services Sector, And Overall Economic Performance.....	25
Different Approaches to Measuring the Economic Benefits of Transport.....	31
II. TRANSPORT-ECONOMY LINKAGES—CONCEPTS AND DEFINITIONS.....	34
A Definitional Digression .....	37
The Macroeconomic Approach .....	40
The Microeconomic Perspective .....	42
The Spatial/ Regional General Equilibrium Effects Perspective.....	44
III. TRANSPORT-ECONOMY LINKAGES: THE MACROECONOMIC VIEW .....	49
Production and Cost Functions: A Brief Primer.....	51
Selective Review of Macroeconomic Studies of Transport-Economy Linkages.....	53
The Aschauer Story: Claims and Counter Claims .....	56
Nadiri and Mameneus Contribution.....	59
Lessons Learned from Macroeconomic Analysis of Transport-Economy Linkages .....	61
IV. MICROECONOMIC BENEFITS .....	71
Total Logistics Costs.....	75
Consolidation of Facilities.....	79
Incorporating Logistical Savings and Consolidations in CBA.....	82
Location Effects .....	86
Transportation and Value Added.....	88
Market Structure and CBA .....	89
V. GENERAL EQUILIBRIUM EFFECTS .....	92
Gains from Trade .....	93
Comparative Advantage.....	94
The New Economic Geography.....	100
Technology Shifts .....	109
REFERENCES .....	115

## **FIGURE AND TABLE LEGEND**

Figure 1. Growth of the Economy and the Passenger Freight Mobility .....	9
Figure 2. Growth of Freight Traffic by Modes, 1970-1995 .....	10
Figure 4. GDP Freight Intensity .....	12
Figure 5. Freight Rates.....	12
Figures 6. and 7. International Comparison of Freight Traffic Intensity I and II.....	17
Figure 8. Factors of Underlying the Transformation of the Transport Enterprise .....	20
Figure 9. Components of a Freight Transportation System .....	21
Figure 11. Linkages Between Transport Policy and Investments, Freight Services Sector and Overall Economic Productivity .....	27
Figure 12. Worldwide Logistics Costs Exceed \$1 Trillion, Of Which \$610 Million Is Non- Transport Logistics Service Charges .....	30
Figure 13. Infrastructure and Economic Growth.....	40
Figure 14. Microeconomic Impacts.....	44
Figure 15. Transport Infrastructure Supply Freight Services Sector and Full Economic Effects	45
Figure 16. Infrastructure and the Efficiency of Production .....	50
Figure 17. Net Rates of Return of Highway Capital, Private Capital, and Private Interest Rate, 1951-1989, computed by Nadiri and Mamuneas (1996).....	60
Figure 18. User Benefits .....	72
Figure 19. CBA with Externalities .....	73
Figure 20. Congestion Effects .....	74
Figure 21. Total Logistics Costs.....	75
Figure 22. Substitution Framework .....	82
Figure 23. Shift in Demand for Services.....	83
Figure 24(a). Imperfect Competition .....	90
Figure 24(b). Imperfect Competition.....	91
Figure 25. Two Region Case.....	99
Figure 26. Configuration of Three Regions .....	106

Table 1. The Evolution of the U.S. Freight Sector, 1960-98 .....	13
Table 2. U.S. Freight by Value , 1993, 1997.....	15
Table 3. Top 5 Freight Sectors by Value and Ton-Miles, 1993, 1997 .....	16
Table 4. Estimated Returns from World Bank Projects.....	35
Table 5. Summary of Output and Cost Elasticities of Highway and Other Public Capital in Various Countries .....	61
Table 6. Summary of Studies of the Productivity Effects of Highway Infrastructure and Other Public Capital.....	64
Table 7. Measures Of Travel Time Reduction Impacts On Costs (Hickling, Lewis, Brod, 1995) .....	78
Table 8. Logistics Cost Savings due to Facilities Consolidation, Medical and Surgical Products Case Study .....	80

The U. S. Department of Transportation, Federal Highway Administration (FHWA) has had a long interest in gaining a clear understanding of the nature of linkages between transport infrastructure investments and economic growth and performance.

Several factors underlie this continuing interest of FHWA. First, FHWA directly and indirectly invests significant amounts in highway infrastructure each year, and needs to know that these investments are justified by rational decision criteria. Second, FHWA is committed by the Department's Strategic Plan to promote the nation's economic growth and economic competitiveness in the way it conducts its investment and non-investment activities. To accomplish this strategic mission, FHWA clearly needs knowledge on the nature and scope of the relationships between the provision of highway investments and economic growth and performance. An important dimension of these economic impacts relates to the impacts of transport investments on the performance of the rapidly evolving freight services sector, whose improved productivity in turn enhances the productivity of the overall economy.

Research aimed at improving our understanding of these linkages between transport infrastructure, the freight services sector, and economic performance can potentially address a range of issues:

- What is the nature and magnitude of the relationship between transport investments and the performance of the freight services sector, of other economic sectors, and indeed of the overall economy? What effects does transport public capital have on the productivity of labor and capital? What is the willingness to pay on the part of a private sector firm or industry for an additional increase in transport public capital? How robust are these relationships when the transport infrastructure investments are made in different contexts—say a link completion in a core region vs. a road in a peripheral region, or an investment in a growth period vs. in a declining era, etc.? To what degree does transport investment influence economic growth and to what extent is it in turn an outcome of economic growth?

Since the convergence of transport policy reforms (particularly the new economic incentives and competition created by transport deregulation and liberalization in recent years) and novel transport and information technologies have promoted major productivity-enhancing service and process innovations in the freight services sector, a further question arises: what is the role played by transport public investments in promoting such structural changes as the reorganization of the logistical processes, which may augment productivity both in the transport service sectors and in the many transport-using sectors in the economy? In other words, what are the multiple and complex linkages between public investments in transport, the freight services sector and economic performance?

Yet, our current understanding of these transport-economy linkages derives largely from models of aggregate relationships between transport and the economy. How should we open such 'black box' models? How do we characterize and analyze the economic mechanisms by which improvements in transport infrastructure and freight services course through the national and regional economies? As freight transport cost-service improvements promote market expansion and integration, what interactive changes occur in labor, land, and product markets within and between various economic sectors? How do these interactions turn out in the world of 'The New Economic

Geography' with its increasing returns and imperfectly competitive markets? How can we trace the general equilibrium responses rippling through the economy, integrating under the stimulus of transport infrastructure improvements? What implications follow from this analysis for assessing transport's role in the nation's economic competitiveness?

This White Paper surveys and assesses current knowledge on these multiple and complex linkages among transport infrastructure investments, the freight services sector, and economic performance, as viewed from the perspective of the issues raised above.

## **I. THE FREIGHT SERVICES SECTOR: TECHNICAL CHANGE, EVOLUTION, AND CONTRIBUTION TO ECONOMIC GROWTH**

The growth of the freight transport services sector in the last four to five decades has made possible and in turn has been made possible by the growth of the American economy. In this period, the U.S. economy has undergone deep structural changes: an increasing shift from goods production to a service economy; towards a less material-intensive and energy-intensive production system; from an emphasis (in the early decades after 1950) on the fuller integration of national markets -- incorporating the Southern and Western regions into the national network of production—towards becoming part of a globally organized and distributed production system.

In the last two decades there has been a parallel evolution of the freight services sector, enabled and motivated by driving forces such as technical change in transport and information technologies, transport infrastructure investments, the reforms in the policies of transport governance, and the globalization process. In the environment of new economic incentives and competitive regimes created by these drivers, the freight services sector has witnessed considerable technical change, organizational innovations and restructuring of the logistical process. The consequence is a broad *qualitative* change in the scope of services offered to transport-using economic sectors. The freight services sector is offering to its customers a variety of service and process innovations -- greater speed and reliability at lower overall costs, time-definite global delivery of goods, sourcing and distribution functions, flexibility in destinations, etc..

The role of transport infrastructure investments in the evolution of the freight services sector, and its subsequent economic impacts -- as the changed freight cost-service mix courses through the larger economy promoting integration of labor and product markets and economies of scale and scope -- are of considerable interest to decision makers concerned with transport infrastructure investments.

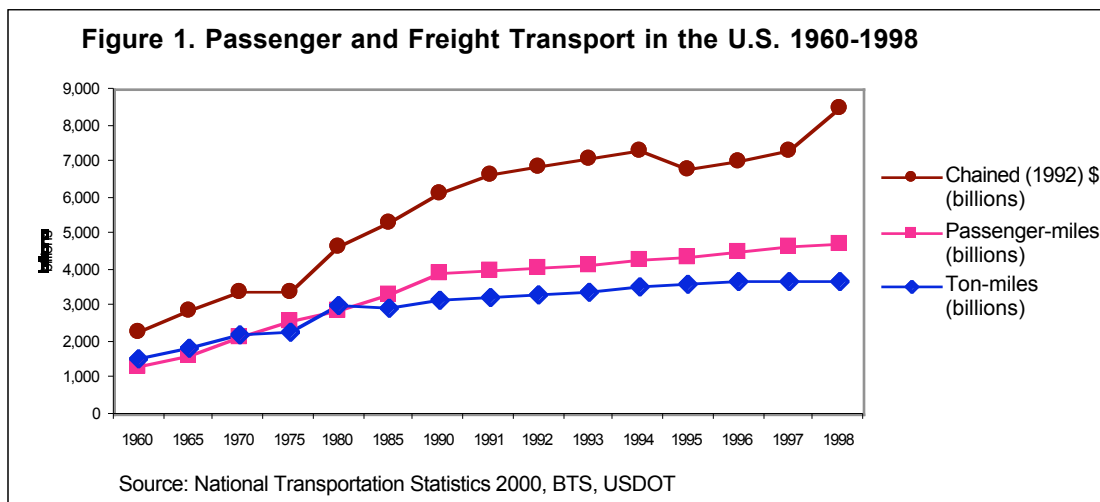
This section of the White Paper briefly outlines a) the processes which are transforming the freight services sector, and b) the mechanisms which translate improvements in freight services into a range of economic impacts in the broader economy. It opens with a statistical profile of the U.S. freight services sector in recent decades, charting its quantitative growth, its changing composition and spatial organization, and providing a comparison to its counterparts in selected affluent industrialized countries. It proceeds to a brief description of the changing context and scope of the freight services sector, as well as the forces underlying these changes. Next, it identifies and discusses the linkages between transport investments, freight services sector, and overall economic performance. This sets the stage for identifying and briefly characterizing the three analytical approaches currently available for measuring the impacts of transport infrastructure investments on the freight services sector and on the performance of the larger economy.

### **A Statistical Profile of the U.S. Freight Services Sector**

Two attributes capture the crux of the progress of the U.S. freight services sector in recent decades. The first characteristic evident in the last four decades is *the quantitative change*, namely the continuous growth of the volume of freight moved and the distance over which the merchandise has been moved at ever lower prices. Between 1965 and 1998 total tonnage moved in the U.S. rose from 4.54 billion tons to 6.21 billion tons (an increase of 37%), while ton-miles rose more sharply from 1854 billion ton-miles to 3710 billion ton-miles (an increase of 100%). As noted below, these aggregate changes reflect the interacting effects in this period of several broad economic processes—increasing spatial integration and robust growth of the American economy, increasing shift to less material-intensive service sectors, and a variety of technological and organizational changes in the economy.

The second attribute is a broad *qualitative* change in the last two decades in the scope of the freight services being offered to transport-using firms—in the form of greater speed and reliability, time-definite global delivery of goods, flexibility in destinations, etc.. These freight services, made possible by recent technical innovations in transport, information, and financial services, by transport policy reforms and by the consequent structural changes in the freight services sectors, not only reduce costs but also add to the production value of transport user firms.

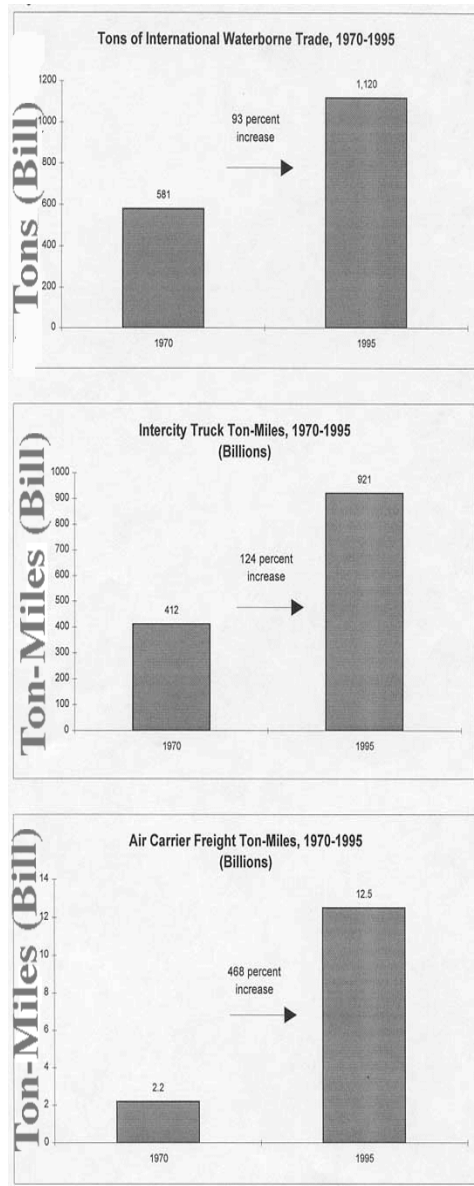
Over the last four decades, the growth of freight and passenger movements has broadly paralleled the growth of Gross Domestic Product indicating high levels of freight and passenger mobility (Figure 1). Passenger-miles have kept pace with GDP particularly in the 1960-90 period with an income elasticity over the entire period of close to one (0.94). Ton-miles of freight exhibit a slower relative growth (income elasticity of 0.50). In the decades of 1960s and 1970s, however, freight traffic growth kept pace with GDP growth, but has subsequently slackened.



**Figure 1. Growth of the Economy and the Passenger Freight Mobility**

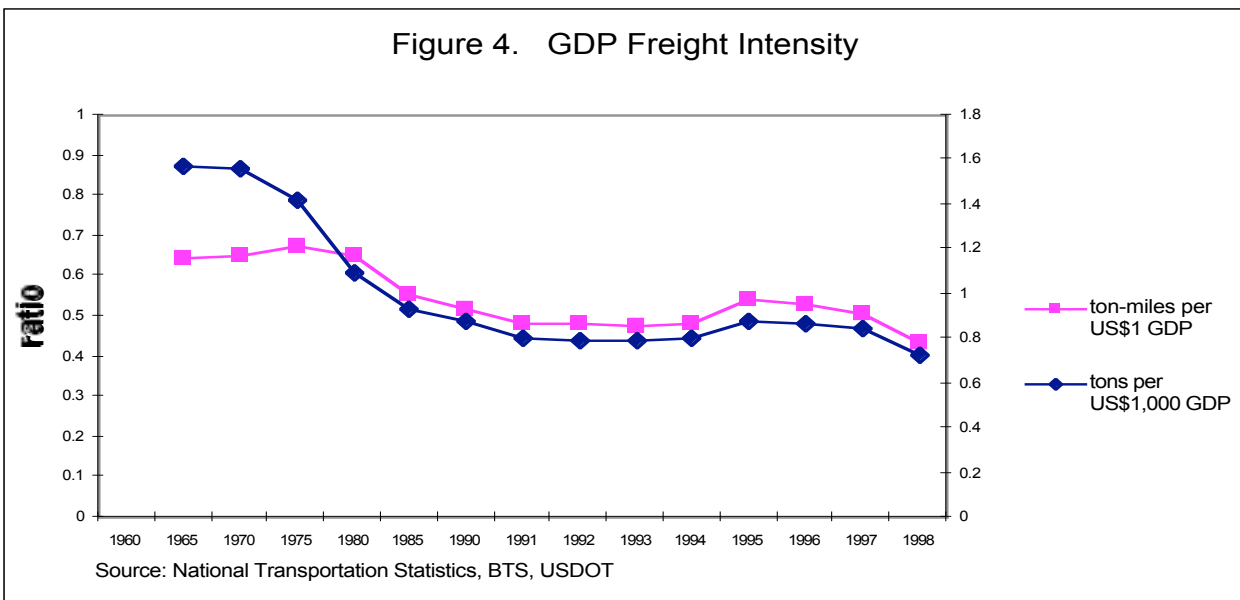
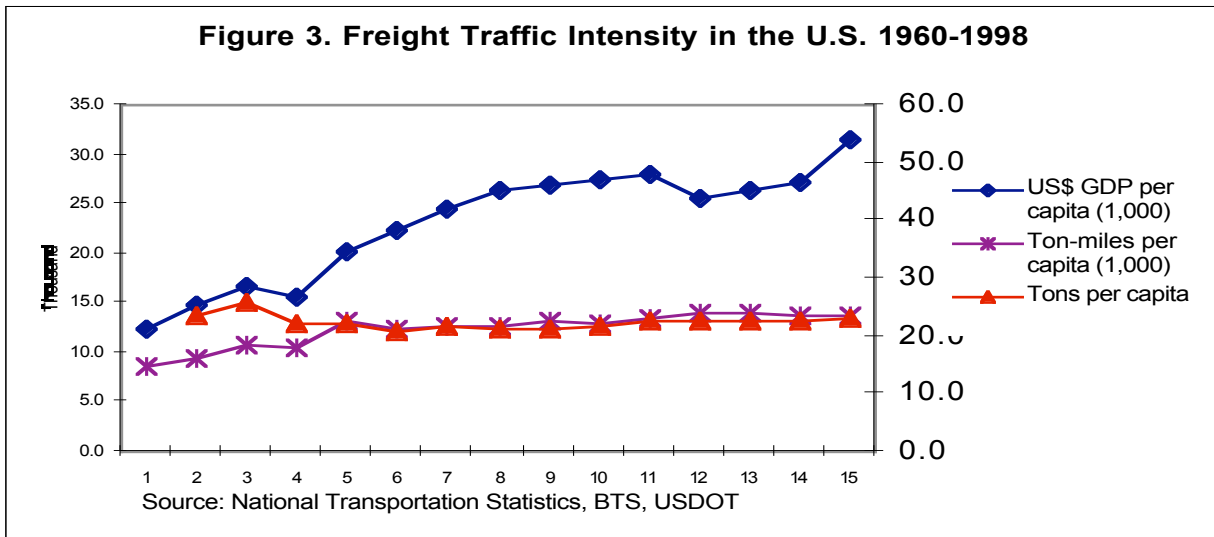
In about the same period (1970-95), the growth in tonnage and ton-miles varied, however, by mode (Figure 2). Intercity trucking ton-miles grew by 124%, while air freight ton-miles grew by 468%.

**Figure 2. Growth of Freight Traffic by Modes, 1970-1995**



The measure of freight intensity relating freight levels to GDP tell the same story more sharply. Tons per U.S.\$ (000) GDP (1992 prices) dropped between 1965 and 1998 by 54% from 1.58 to 0.73 tons. Ton-miles per U.S.\$ GDP dropped between 1960 and 1998 by 36% from 0.69 miles to 0.44 miles (Figure 4). Clearly, the economy shows a consistent trend towards lower intensity of freight use.

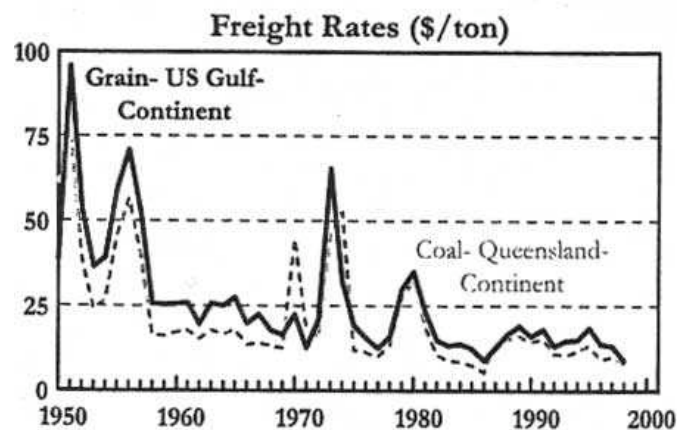
**Figures 3. Freight Traffic Intensity in the U.S 1960-1998**



#### Figure 4. GDP Freight Intensity

Both sets of measures of freight intensity reflect the recent transformation of the U.S. economy, with less and less of the GDP deriving from goods production. The oft-noted increasing shift in the U.S. to a service economy over this period signifies a reduced resource and energy intensity and the consequent lower intensity of goods generation for movement. At the same time in this period, transport technology changes (e.g. containers, The Interstate System, jet aircraft, etc.) continued to lower transport costs sharply. The common measure of shipping costs (the ratio of c.i.f. trade value—measured as cost to the importing country -- to f.o.b. trade value - - measured as it leaves the exporting country) declined from 9.5% in 1950 to about 6% in 1990 (Frankel, 2000). Sharp drops in freight rates as evident in Figure 5 have pervasive effects. In competitive regions, lower transport costs promote expanded markets and improved export opportunities, which in turn enhance their output. As 'peripheral regions' confront the influx of cheaper goods and the resultant import competition, there is restructuring of activities (with firms arriving and exiting), leading to lower production costs and enhanced efficiency in those regions. The outcome of these processes is greater market integration, as various regions in the nation are integrated into the national network of production. In turn, regional specialization of production develops and leads to greater intra-industry and inter-regional trade and freight movements over an expanded

Figure 5. Freight Rates



Source: No Author, 2000, Special Feature: Commodities in the 20<sup>th</sup> Century, Global Commodity Markets, January 2000.

production space. This scenario is in many ways a stylized description of the incorporation of the Southern and Western States into the U.S. national production system in the 1960s and 1970s-- in the context of the emerging transport technologies (Interstate system, jet planes, containers) and the then on-going brisk population shift from the Snowbelt to the Sunbelt States.

One clear upshot of this regional and national economic integration argument is the longer distances over which goods get transported and the sharper rise of ton-miles of freight as compared to tons moved. More light can be thrown on this matter, if we reconsider the freight sector's fortunes for two distinct periods, namely 1960-80 and 1981 to 1998 (Table 1).

**Table 1. The Evolution of the U.S. Freight Sector, 1960-98**

<b>Indicator</b>	<b>(Percentage Increases)</b>	
	<b>1960-1980</b>	<b>1981-1998</b>
Tons	11	23
	(1965-80)	
Ton-miles	92	24
Tons / capita	-5.5	4
Ton-miles /capita	59	4
Tons /\$U.S.(000)GDP	-31	-33
Ton-miles /\$U.S. GDP	-7	-31

A quick look at Table 1 suggests the significant differences between the two periods. The 1960-80 era witnesses a sharp rise (59%) in the ton-miles of freight moved /capita as contrasted with the decline in tons/capita (-5.5%), indicating that relatively smaller freight tonnage is hauled over longer average distances and the spatial integration of the national economy is over longer distances (and areas). There is a decline in the freight intensity of GDP, (31% on a tonnage basis and 7% on a ton-mile basis) indicating the increasing importance of less freight-intensive sectors that make up the GDP.

The second period, 1981-98, exhibits a markedly different pattern. Reversing the trend in the first period, tons /capita start growing modestly, keeping pace with ton-miles /capita growth.

The decline in GDP freight intensity is about the same for both tons and ton-miles. Two comments are in order. First, the trend towards longer average freight hauls noted in the first period seems to be abating in the second period. The average distance of freight haul increased in the first period (1960-80) from 408 miles to 593 and barely afterwards to 597 miles in 1998. Has the process of increasing spatial reach and integration of the U.S. economy, noted in the first period, abated? Second, why does the tonnage moved double its growth rate in the 1981-98 era (as compared to 1960-80 period) at a time when the economy is shifting more towards services and becoming less material-intensive? What changes in the freight services industry and the forces underlying its evolution do these new trends in the 1980s and 1990s suggest?

We argue that this different pattern of aggregate freight indicators in the second period of the 1980s and 1990s reflects the operation in this era of new forces underlying the evolution of the freight sector. As elaborated in the next section, a variety of economic, technological, institutional, and policy changes in the 80s and 90s have converged to promote major innovations in the freight services industry, which in the process has been restructured to offer its users a range of new services at ever dropping costs (e.g. TRB, 1996, Hickling, 1994; Chatterjee, 2000; Lakshmanan and Anderson, 2000, Lakshmanan, Subramanian, Anderson, and Leautier, 2001). An understanding of this recent evolution of the freight services industry and the underlying processes is crucial to an analysis of the role that transport infrastructure investments play in the improvement of freight industry and its contribution to productivity of the economy.

Before proceeding to an elaboration of this argument, two other aspects of the freight industry are worthy of note.

First, in the American economy where the transition to knowledge-intensive sectors is advanced, the characterization of the freight sector in terms of tons and ton-miles is inadequate and somewhat misleading in view of the changes in the value and weight composition of goods. The Commodity Flow Surveys conducted by USDOT Bureau of Transportation Statistics (BTS) in 1993 and 1997 provide a rare measurement of freight by value (in addition to tons and ton-miles), and a richer view of some of the recent changes in the freight services industry.

Table 2 displays the freight moved measured in value terms in 1993 and 1997. The value of freight moved in the U.S. in this period grows three times as fast as GDP. The value of freight to be moved for a dollar of GDP rises between 1993 and 1997 by 6 cents or 6.6%. High value-added sectors are increasingly contributing to freight movements and the size of the economy.

**Table 2. U.S. Freight by Value , 1993, 1997**

<b>Indicator</b>	<b>1993</b>	<b>1997</b>	<b>(% increase, 1993-1997)</b>
GDP (Billions) Chained 1992 dollars	7054	7270	3
Freight (value)	6335	6944	9.6
Freight (value) / GDP	0.90	0.96	6.6

**Source: BTS Commodity Flow Survey, 1993-1997**  
Special Tabulations by Felix Amatagoe, 2001.

Table 3 throws more light on the varying composition of commodities that make up the freight stream, when ranked by value and ton-miles. The top 5 commodities by value account for just under 40% of the value and 6% of the ton-miles. The top 5 commodities by ton-miles account for a little over 40% of the ton-miles and 10% of the value. However, two contrasting sets of commodities emerge as the top 5 when they are ranked by the different measures of freight—value or ton-miles. The top value commodities derive from knowledge-intensive high value adding industries such as electronics and electrical equipment, motorized vehicles, machinery and textile and leather products. The top commodities in terms of ton-miles are low value raw materials such as fossil fuels, basic chemicals, grains, etc. Since the usual statistical picture of the progress of a freight system derives from the available data on ton-miles, one often misses the trends in the emerging high value adding sectors whose growing importance and freight requirements are changing the spatial reach, nature of operations, functions, and services of the freight services industry.