Freight Benefit/Cost Study

Compilation of the Literature

(Final Report)

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1. INTRODUCTION

FHWA wants to develop the ability to identify and measure the full benefits of improvements in freight transportation. More specifically, the agency wants to estimate the costs and benefits of investing in improvements in intermodal links between the highway system and railroads, ports, and airports, as well as in highway corridors where significant volumes of freight move. Although estimating costs may present some difficulties (e.g., cost allocation issues), the real analytical challenge is the estimation of benefits.

Improvements in freight carriage can be expected to have important economic effects. Lower costs or better service, or both, in freight movement must have a positive effect on all firms engaged in manufacture and distribution of goods. Reducing per-mile cost of goods carriage means that any factory or distribution point can serve a wider market area, with potential gains from scale efficiencies. It also means a factory can draw supplies from a wider area with potential gains in terms of the cost and/or quality of parts and materials coming to the factory.

Beyond lower dollar costs to shippers, reductions in transit time and/or increases in schedule reliability will also have significant impacts. These gains in terms of time allow firms to manage their inventories and supply chains more efficiently. Increased reliability, for example, reduces the requirement for "buffer" stocks, inventory held to protect against delivery failure. Lower transit times reduce some costs, e.g., drivers' wages for a given trip length. Further, as with lower dollar costs, less time for a move extends the "reach" of a factory or warehouse.

Consequently, much of a firm's response to transportation-cost reduction will be reorganization of its logistics. It will respond to the lower costs by moving goods longer distances, using fewer warehouses, and carrying less inventory for a given level of sales. It will buy more transportation and realize gains from improved logistics. But firms can make other changes in the ways they do things; lower costs might lead to product improvements, for example. We need to be clear about the different kinds of effects that may flow from freight-transportation improvement; they have to be treated differently in the analysis. The following classification scheme for benefits and other effects should facilitate understanding of the problem and the analytical approach to it.

Table 1: Effects of Improved Freight Transportation	
First-order Benefits	Immediate cost reductions to carriers and shippers, including gains to shippers from reduced transit times[1] and increased reliability.
Second-order Benefits	Reorganization-effect gains from improvements in logistics[2]. Quantity of firms' outputs changes; quality of output does not change.
Third-order Benefits	Gains from additional reorganization effects such as improved products, new products, or some other change.
Other Effects	Effects that are not considered as benefits according to the strict rules of benefit-cost analysis, but may still be of considerable interest to policy-makers. These could include, among other things, increases in regional employment or increases in rate of growth of regional income.

In these several ways, freight improvements can spread reductions in cost and gains in productivity through all the economic sectors that produce or distribute goods. Improvement in highway-freight carriage is one of the ways that government can make a truly valuable contribution to the efficiency of the American economy. While this may seem obvious, the impacts of freight-transportation improvements have been neglected, or been given scant attention, both in the scholarly literature on social benefits of highway improvements and in more general discussion.

1.1 FHWA's Freight Benefit/Cost Study

The underlying objective of FHWA's Benefit/Cost Study (hereafter referred to as the "Freight BCA Study") is to develop a comprehensive analysis tool that can capture the full benefits and costs of freight transportation improvements. Such a tool will help to ensure that decision-makers (at all levels of government) can conduct both project planning and assessment processes in a manner that better recognizes the unique contributions of freight transportation to a region's economy.

[1] Carrier effects include reduced vehicle operating times and reduced costs through optimal routing and fleet configuration. Transit times may affect shipper in-transit costs such as for spoilage, and scheduling costs such as for inter-modal transfer delays and port clearance. These effects are non-linear and may vary by commodity and mode of transport.

The Freight BCA Study comprises three tasks:

- Task 1: Historical and Current Approaches to Freight B/C Analysis—the objective of this task is to conduct a comprehensive literature review and analysis that can inform the development of the benefit/cost analysis (BCA) framework.
- Task 2: Method and Data—under which we will develop a benefit-cost model that will treat the first and second-order benefits of freight-transportation improvements in a single analytical framework, and we will identify the data needed to use this model. Further, we will make an initial effort to estimate the key parameters required to calculate productivity gains.
- Task 3: Integration and Development of Initial Approach—whose goals will be to 1) develop methods for addressing the third-order benefits and other effects that will be treated outside the model and 2) bring these results together with the model results in a way that will be meaningful and useful for policy makers and others.

An important first step in the development of the BCA framework is a thorough review of previous literature on:

1. assessments of the economic impacts of transportation investments,
2. methodologies used to quantify impacts from these investments, and
3. industry experiences that demonstrate how economic agents respond to transportation investments in the field.

This report provides a compilation of the literature. We have structured the literature review as follows:

- Studies on Economic Growth/Productivity and Social Impacts (Section 2)
- Theoretical and Freight Transportation Studies (Section 3)
- Literature on Industry Experiences and Case Studies (Section 4)

[2] Improvements include rationalized inventory, stock location, network, and service levels for shippers.

2. STUDIES ON ECONOMIC GROWTH/PRODUCTIVITY AND SOCIAL IMPACTS

2.1 Introduction

None will dispute that transportation investment (particularly in highways) affects both economic and non-economic factors in the areas proximate to new facilities and even in those more distant. The ways in which new and improved highways, for instance, influence society are complex and often indirect. In the short run, investment in transportation increases employment directly and, in turn, stimulates other industries as workers spend their income on other goods and services. Long-term impacts flow from more extensive, improved, and inter-connected roadways.

The ultimate goal of transportation investment is social—an improved quality of life for a region's or country's inhabitants. However, the ultimate benefits of investments are accrued from a combination of *generative* and *distributive* impacts.

- *Distributive effects* are those that lead to a redistribution of income, population, and employment; these may or may not be associated with a net gain in output.[3]
- *Generative effects* are those that increase income by using resources more effectively and/or by using resources previously underutilized.

2.1.1 Impact Types

A great deal of literature relating to transportation investment impacts focuses on generative and distributive effects rather than ultimate outcomes. In essence, these effects trigger fundamental changes in economic and social structure, which are often described in the literature as the productivity and national income impacts of infrastructure investments.

- <u>Productivity and National Output</u>—Transportation improvements affect both economic development and productivity. Economic development may be regional in

[3] Even without net gains in output, however, redistribution may increase national or regional welfare *if* social goals are achieved (e.g., reduced racial or geographic disparities in employment).

nature and the result of improved access to labor pools, investment in new or expanded enterprises in a given area, or access to larger markets—without a concomitant increase in productivity.[4]

Productivity improvements, which directly generate increased output or development without countervailing offsets elsewhere, are more difficult to isolate since the changes occur within the production process. Yet productivity is key to development—particularly if labor is already nearly fully employed—and investment in capital is key to productivity. New transportation systems are a form of capital investment that can stimulate productivity of labor and private capital.

For example, reduced transportation costs and/or easier access to materials or markets affect business location decisions. That is, decisions on location for new investments may be altered. Changes in transportation costs and ease may even induce existing enterprises to relocate and take advantage of new conditions; such shifts may be intra-regional and thus have no net effect on regional output. Or, such shifts may affect the competitiveness and scale of operations of the affected enterprises, which then achieve higher productivity and make a net positive contribution to national output.

The manner in which generative and distributive effects drive ultimate outcomes and affect the economy is complex. Consequently, it is important to understand the types of economic impacts that may be generated by transportation investments.

- Costs of Production and Competitiveness—Improved highway systems reduce costs for delivery of goods and services; they also support faster, more reliable

[4] Note that economic development and growth in productivity are not one and the same, though they are closely related. Economic development is an increase in production of total goods and services for a state, region, or nation—often measured by increases in national output or income. Development can be generated by increases in labor or investment in private capital inputs, or by greater productivity of these inputs. Improved productivity is an increase in output without a commensurate increase in inputs, particularly labor, types of economic (and quasi-economic) impacts that may be generated by highway investments. Descriptions of impact types are provided below.

transportation from one place to another. These, in turn, reduce the costs of collecting inputs and delivering products to markets in several ways:

✓ less driver time on the road thus lower labor costs;

✓ increased trip miles per time period per vehicle and thus smaller vehicle fleet needed for the same amount of work ("freight efficiency");

✓ lower vehicle repair and operating costs; and

✓ improved transportation reliability.

The first three work directly to reduce total product costs. Improved transportation reliability works to reduce production costs via reductions in inventories of inputs, spare parts, and/or finished goods.

Cost reductions that are realized will enhance the competitive position of enterprises with access to the improved highway network. In turn, this can stimulate increased trade domestically and/or internationally, resulting in improved trade balances. Moreover, expanded demand can generate economies of scale and improved productivity as enterprises take advantage of these market opportunities—thus inducing another round of cost reduction. The relative impact of these effects vary among sectors (i.e., the type of economic activity or industry) and vary according to the level of pre-highway urbanization and development.

- <u>Labor Pool</u>—Because labor can more readily reach employment locations from farther away (assuming there are vehicles to transport them over the highway system), enterprises have a larger employment pool from which to draw. Competition could reduce wages, but an expanded labor pool should also encourage a more efficient match between skills and jobs. In some circumstances, improved connections between hometown and employment opportunities prompts workers to move closer to employment opportunities since they do not need to sever their ties to family when they migrate. Thus improved access can affect demographic patterns as well as production costs of individual enterprises.

- Economic Structure—Transportation costs and improved physical access may change the mix of economic activities. That is, major investments can alter the mix of economic activities where transportation cost (or access) was an inhibiting factor. For example, previously self-sufficient areas may specialize in those activities that earn the greatest income and use that income to "import" products that used to be produced locally. The lure of reduced transportation costs can lead to shifts in geographic distribution of economic activity to take advantage of these changes. To the degree that such structural changes improve productivity, national output (per capita) is increased.

- Geographic Impacts—New highway systems can trigger geographic shifts in population and economic activity. These effects are of interest in and of themselves because they affect income distribution and personal lifestyle. Investments in major highways can benefit some sectors or geographic areas without affecting others. Although the effects are uneven, there are no "losers." On the other hand, a new highway can shift the focus of new investment from one area to another within the region (e.g., to secondary urban areas away from primary urban centers), thus generating an internal shift in activity but no net short-term gains. Even without net income gain, these re-distributive effects can be positive because they can reduce inter-regional disparities. It is also possible for distributive effects to exacerbate regional disparities if, for example, highway investment stimulates out-migration of industry from more remote areas.

- Trade Balance—In addition, reductions in input costs (transportation), increased transport reliability and access to markets, and enhanced productivity improve international or inter-state competitiveness, thus improving balance of trade. Balance of payments could be further strengthened by increased foreign investment and/or reduced capital outflows as domestic investment returns and exchange stability improve.

Highway investments can also affect changes in personal welfare that are important in their own right. These changes may also contribute to productivity and output. But their most immediate impact is on quality of life. A review of the types of *welfare* impacts that stem from highway investments is provided below.

- Safety—Foremost among the welfare effects of improved highways is travel safety. Wider roads, more lanes, better alignment, and improved road surfaces all help to reduce vehicular accidents—and thus reduce morbidity and mortality. Although vehicles travel at higher speeds on limited access highways (in good condition), drivers face fewer dangerous surprises. (e.g., curves that are too sharp, potholes not identified in advance, etc.). Drivers also can overtake slower vehicles without crossing into lanes of opposing direction.
- Life Style—Improved access and mobility contribute to quality of life in other ways as well. First, improved transportation expands the choice of leisure activities within reach and/or saves time for those making such trips. For example, visiting friends and family in other areas takes less time. By expanding the labor shed for individual establishments, improved highway transportation also allows those who lived within the original, smaller labor drawing area to move further away from work without having to change jobs. In this case, businesses remain in place but labor disperses within the expanded drawing area to achieve a preferred life style.
- Human Capital—Transportation improvements can also improve access to health care and education. Individuals can travel more easily to established health care and education sites that used to be beyond reach. Similarly, specific "extension" personnel are more able to make regular visits to individuals, homes, schools, and local clinics.

2.2 Literature Review and Summary of Results

Investments in freight transportation systems can be expected to affect the economy via:

- changes in productivity and national income,
- changes in the structure of the economy,
- impacts on international trade and competitiveness, and/or
- quality of life improvements as dictated by safety, health, and other social impacts.

The purpose of this sub-section is to summarize the results of the literature review on the economic impacts of transportation infrastructure investments (particularly of highway investments in the US), and in this manner to provide evidence of the linkages between transportation investments and economic and quality of life parameters.[5]

2.2.1 Productivity and National Income

A number of studies document the relationship between investment in infrastructure (public capital) and either output or productivity, which is one of output's immediate antecedents. Researchers generally employ "macro" analytical techniques—broad statistical studies that link highway or other public infrastructure directly to output itself or to productivity.[6] This sub-section reviews research on both productivity and output, which are often treated together in the same study and which are explored by similar techniques.

David Aschauer and Alicia Munnell are credited with focusing attention on the role of infrastructure in national income or economic growth. Using econometric analysis of data on national output, labor, private capital investment (in plant and equipment), and capital stock of specific public works, these economists estimated the separate contribution to productivity associated with improvements in infrastructure such as roads, water and wastewater treatment. They showed that increases in productivity and national income in the US could not be explained by labor inputs and private capital alone. That is, that

[5] It should be noted, the majority of the literature focuses on highway investments in general, rather than freight improvements in particular. However, many of the impacts associated with highway improvements apply to freight transport. Moreover, most of the literature on geographic impacts focuses on effects associated with major highway investments, such as the US Interstate Highway System. The relevance of that literature is minimal to the study at hand; so we do not summarize that part of the literature in this report.

[6] Various models are used to substantiate the relationships between transportation and productivity. Many use production-function formats to compute statistical relationships implied by inter-regional or inter-state variations in outcomes and causative factors. Studies using such models conclude that publicly-provided infrastructure (including transportation) is an important element of economic growth (Garcia-Mila and McGuire, 1992; Munnell, 1992).

investment in public works is positively correlated with increases in national productivity—which increases total output from the same pool of labor and private capital. Nadiri and others have carried on the exploration of the connection between public works and national income. Nadiri's research focuses on the role of public investment in reducing costs of production.

Many other studies have followed in the wake of the initial recognition of a connection between transportation and economic development. Studies of the relationship between highway capital and national output, or other factors contributing to output and social welfare, are of several types:

- Cost-benefit analyses: which estimate the costs and benefits to society or groups of people from transportation investments;
- Macro-economic approaches: that explore the relationship between a defined variable (e.g., output per capita) and causative factors using national (or regional) level data in a statistical model;
- Regional methods: which use a variety of models that measure region-specific economic (or demographic) impacts from transportation investments; and
- Case studies: that describe the administrative, operational, or financial decisions made by an individual firm or agency to affect economic development or economic productivity in response to transportation initiatives.

Review of the Literature—Virtually all of the studies reviewed in this sub-section employ macro-economic approaches or regional methods to explore linkages between transportation and its impacts on society. A synopsis of the most compelling evidence of the linkages between highway investments and economic performance is provided below.

1. Nadiri (1996) uses a cost function approach to estimate the relationship between highway capital investment and productivity in the US. His key findings suggest:

- ✓ The net social rate of return[7] on total highway capital investment averaged approximately 28 percent over 1950 to 1989, generated mainly through savings in labor, private capital, and intermediary inputs. For non-local highways alone, the social rate of return was estimated to be 34 percent over the same period.
- ✓ When the US was building the Interstate Highway System, initiated in 1956, these returns were at their highest, showing a 35 percent social rate of return across the entire road network in the years prior to 1970.
- ✓ In more recent years, however, social rates of return declined to 16 percent in the 1970s and to about 10 percent in the 1980s.

2. Munnell (1990b) uses an aggregate production function model for the 48 contiguous US states and found that a one- percent increase in public capital investment would raise national output by 0.15 percent. In addition, the study also reported that, on average, $1 of additional public capital investment appears to increase private investment by $0.45.

   Using cross-section data, Munnell (1990a) postulates that a one- percent increase in public capital stock would increase output by 0.34 percent. Given the size of public capital stock and total output, these figures imply that the marginal productivity of public capital stock is roughly double that of private capital.[8]

[7] The net social rate of return from public capital is most easily described as the ratio of the sum of marginal benefits to cost, less the depreciation of public capital. Since marginal benefits represent the dollar value of savings in production cost resulting from a $1 increment in highway capital (which is also an indication of how much an industry would be willing to pay for an additional unit of highway capital), the net social rate of return is essentially just an assessment of the extent to which marginal benefits of an investment can offset the costs. For a highway investment then, the net social rate of return is obtained from industry-specific marginal benefits and the user cost of highway capital, accounting for the effects of taxation needed to finance public infrastructure capital. Depending on the type and level of investment and general changes in the economy, social rates of return will obviously vary over time.

[8] Munnell also notes that various analyses indicate that public capital has a positive impact on several measures of state-level economic activity: output, investment, employment growth (Munnell, 1992). Effects on employment are probably part of the synergy between public infrastructure and private capital

3. Aschauer (1989) examined the role of infrastructure in the US using the concept of an aggregate production function. His study found that the elasticity between output and public investment ranges between 0.31 to 0.39. These results imply a 50 to 60 percent annual return to public investment.

4. Attaran and Auclair (1988) found that for every 10 percent increase in the stock of highway infrastructure in the US, an increase of 2.2 to 2.4 percent in real private sector output occurs. In addition, their findings suggest that although highways represent only a third of all infrastructure in the US, it has been responsible for 57 to 60 percent of the gain in private sector output.

5. Findings by Wilson and Mohamed (1985) from a study of several Canadian provinces on the importance of highway investment suggest that if no money was spent on highways, the residents of the Fredericton region (in Canada) would incur a relative loss in earnings of approximately $51 per year per person.

6. Shah (1992) using a cost function approach estimates that total returns to public infrastructure investment range from approximately 5.4 percent to 7.3 percent.

7. Remy (1996) uses a production function model for France to estimate a 12 percent rate of return to public infrastructure investment. The elasticity of output to infrastructure investment is estimated to be about 0.08.

8. Nadiri and Mamuneus (1991) found infrastructure investment to be a significant factor in reducing the cost of production for 12 US manufacturing industries for the years 1956 to 1986. Specifically, the social rate of return for infrastructure investments for use in these 12 industries was found to range from 4.6 percent to 6.8 percent.

9. In its Plan Directora de Infrastructuras (1994), Spain's Ministerio de Obras Publicas dedicates an entire chapter to the economic impacts of infrastructure investment.

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investment, where additional public infrastructure increases private capital investment and the average annual rate of employment growth. That is, investment in public infrastructure stimulates expansion in production inputs as well as productivity, again testifying to the complex interrelationships among public capital, output, and production inputs (Munnell, 1990).

Using a Cobb-Douglas production function approach, the Ministerio finds that a 100 percent increase in the public capital stock will increase Spain's productivity by 23 percent (i.e., the model reports a public capital stock elasticity of 0.23). Further analysis that disaggregates public capital into its various sectors (e.g., transport, sewers, water systems, utilities, etc.) shows that the stock of transportation infrastructure is the most important contributor to productivity increases and Spain's competitiveness as a nation—the transportation infrastructure stock elasticity is reported to be 0.18.

10. Results from the US Department of Transportation's (DOT) 1995 Highway Economic Requirement System (HERS)—a national level benefit-cost model to evaluate highway improvements—suggests that highway investment leads to a benefit-cost ratio of approximately 4.1:1.

11. According to Winston (1990) benefit to cost ratios of new highway investment may reach 10:1.

12. Keeler and Ying (1988) focus on the impact of the investment in the US Interstate Highway System on intercity trucking industry costs. Their study finds that public investment had significantly improved the productivity of the trucking industry. For example, the savings to the trucking industry are calculated at approximately 2 cents (in 1973 dollars) per ton-mile. They also calculated benefit-cost ratios for different elasticities of demand. The ratios ranged from 0.34 with a demand elasticity of -2 and a discount rate of 12 percent, to 0.81 with an inelastic demand for trucking services and discount rate of 6 percent. This implies the savings from trucking costs alone cover almost one-third of the capital costs of the Federal-aid highway system between 1950-73!

13. Queiroz and Gautam (1992), in a study of 98 countries, indicate a very close correlation between per capita GNP and investment in paved roads—$4.60 in per capita income per $1.00 investment in roads, although causality was not explored. The authors address this issue when they related per capita income to physical road density in the US. They investigate several different formulations and find that the

strongest relationship (statistically) was between per capita GNP and road density four years prior, thus indicating that highway density contributed to, rather than resulted from, growth in income.

Other studies focus less on the monetary value of public capital stock or investment and work directly with measures of physical infrastructure itself. These studies also testify to the relationship between transportation infrastructure and output. Three studies stand out.

1. Queiroz, Haas and Cai (1993) explore the relationship between paved road density and per capita income and, because increases in income can cause (rather than result from) road improvements, they also investigate the direction of causality by lagging income behind road density in a time series analysis. Results support the hypothesis that road density leads rather than follows changes in income.

2. Lombard (1991) shows that multilane highways (such as interstates) may have an even more significant role in development—a 5 to 10 times stronger association with regional development than the highway system as a whole (which also includes local, arterial, and collector roadway types).

3. Categorizing roads even more finely by type, Kuehn and West (1971) focus on an underdeveloped part of the US (the Ozarks area which includes 125 underdeveloped counties in the states of Arkansas, Missouri, and Oklahoma). Their analysis indicates that highway investment geared to development should focus first on state highways that interconnect with existing federal highways (i.e., the interstate system) and second on local roads that offer rural access to urban centers.

Discrepancies in Studies—In general, statistical studies linking highway stock (or investment) and output (or productivity) have established a positive relationship. Moreover, although increases in output can generate increases in infrastructure investment, there is statistically significant evidence that highway investments generate increases in productivity and output (i.e., causality runs in both directions). Findings, however, vary with respect to the strength of the linkage between highway investment and economic output (or productivity).

Aschauer, Munnell, and Nadiri have been in the forefront of analyses that show strong and significant impacts of highway infrastructure on total output, evidenced directly or through its effect on productivity and input costs. Others, however, find a weaker statistical relationship between highway investment and regional development (Wilson, Graham, and Aboul-Ela, 1985; Harmatuck, 1996)—or that, on average, an increase in highway stocks is associated with only modest reductions in manufacturing costs (Holleyman, 1996).[9]

Some contend that output growth is due more to increases in factors of production, that is, private capital and/or labor inputs, than to increases in public infrastructure. More specifically, they explain inter-regional variations in output growth rates by different rates in growth of private capital and labor, not to changes in rates of growth in productivity or public infrastructure (Hulten and Schwab, 1984).

The question, then, is how does one explain this variation in empirical results and the resulting range of opinions on the strength of the highway-output and highway-productivity linkages?

Researchers offer a number of plausible explanations. Some believe that highway investment might be a substitute for private capital, labor, and purchased services (Holleyman, 1996; Shah, 1992). Aschauer himself admits that his estimated effect of public infrastructure on productivity may be too large, and that studies do not agree on magnitudes (Aschauer, 1993). He attributes the range of results and opinions to the following factors:

- ✓ definition of public capital stock may differ across studies,
- ✓ geographic scope of studies may differ, and

[9] One study went so far as to assert that there is no evidence that infrastructure and productivity are related in the US outside the Post-WWII period (Ford and Poret 1991). The study's authors acknowledge that there is some evidence that countries with high infrastructure investment also have high productivity growth. However, they believe that this is not balanced by an equally strong relationship between low infrastructure investment and low productivity, thus their study does not support Aschauer's assertion that slowing of infrastructure growth explains slowing in productivity growth.

✓ studies may involve different or combined sectors of the private economy.

Clearly, the linkages between a region's transportation infrastructure investment and economic production are more complex than implied by the structure of many basic statistical studies. This might suggest that estimates from these models are subject to specification-error bias and simultaneous-equation bias (Tally, 1996).[10]

Moreover, variation in opinions about infrastructure's impact on productivity and output may be due to failure to differentiate among industries and other factors that distinguish one case from another. That is, if regional differences in growth in public capital do not adequately explain inter-regional differences in productivity, it may be necessary to disaggregate the analysis by industry since impacts may not show up at an aggregated output level (Hulten and Schwab, 1991) and the impact on output levels of specific industries is likely to be quite diverse (Transportation Systems Center, 1983).

In addition, a weak observed relationship between highway investment and output or productivity may be due to the fact that the primary impact of transportation investment changes over time as societies develop. For example, one study describes three phases of highway development in New Brunswick (Canada):

- the network is not developed to a stage at which it is capable of encouraging regional development,
- the network acts as an agent for regional development, and
- highways become agents for personal mobility.

Thus, as an area becomes saturated, the highway network contributes relatively less to economic development (Wilson, Graham, and Aboul-Ela, 1985). As discussed in earlier parts of this report, data on US highway investment indicates noticeable differences in returns for different time periods. Although Nadiri derives an overall social rate of return

[10] Weak statistical relationships or variation in results of different models may also be due to the high level of data aggregation (Harmatuck, 1996), insufficiently rigorous conceptual frameworks, reliance on reduced form equations, and limited or no consideration of simultaneously determined effects, which raises doubts about causality (Gillen, 1996).

on US highway investment of approximately 28 percent over the period 1950-1989, he estimates returns to investment to reach 35 percent in the earlier 1950-70 period. Rates then declined to 16 percent in the 1970s and even further to 10 percent in the 1980s.

Finally, studies on the relationship between public infrastructure investment and economic output suggest that the elasticity (or the degree of responsiveness of output to public investment at each level of government) tend to be very similar across studies (Munnell, 1992). The variation between estimates occurs as the unit of observation moves from the national level to state and city levels. Researchers have found that, in general, as the geographic focus narrows, the estimated impact of public capital becomes smaller. The most obvious explanation is that, because of leakage, focusing on a small geographic area cannot capture the entire payoff to an infrastructure investment.

In any event, variation among studies does not disprove the positive effect of highway investment on the economy. Rather, it suggests that productivity of transportation investment varies among regions and sectors (depending on complementary factors) and with the state of the highway system and perhaps development itself. Thus failure to disaggregate or to include all causative factors can mask strong highway-productivity and highway-development relationships.

2.2.2 Structure of the Economy

No economy remains constant for long periods of time, and an observed increase in output could be due to more efficient use of the inputs of production. When output increases, while the level of labor and capital inputs remain the same, a productivity increase has occurred. In other words, productivity arises when there is a more efficient use of inputs to production.

As discussed above, transportation infrastructure improvements can affect both economic development and productivity. Economic development effects are usually regional in nature and result from improved access to labor pools or to larger markets. Productivity improvements, on the other hand, are more difficult to isolate since the changes occur within the production process (e.g., inventory savings plus production gains resulting from better transport networks allow for "just-in-time" production methods).

The change in production methods resulting from transportation investment will create structural changes to the local, regional, and national economy. Improved transportation can accomplish more than enabling firms to engage existing physical plants and business processes at lower cost. Transportation improvements can create a cascade of productivity and organizational benefits that influence activities well beyond transportation and logistics.

Review of the Literature—The bulk of the literature on the impacts of highway investment on the structure of an economy focuses on the following types of structural issues:

- infrastructure and sector output,
- economic diversification, and
- technological innovation.[11]

Although the literature on the linkages between highway investment and changes in an economy's structure does not provide a significant amount of quantitative evidence, it does reiterate the importance of such investments to economic development.

- <u>Infrastructure and Sector Output</u>—Infrastructure investment has perhaps the most dramatic effects on production costs and profitability in the agricultural sector, which creates profound structural changes in a rural economy. Various studies recognize and accept the relationship between agricultural development and infrastructure development including the affect on income levels, specialization, and relocation.

  For example, Antle (1982) focuses on the effects of transportation infrastructure on aggregate agricultural productivity. He documents that infrastructure investments do contribute to agricultural productivity in developing countries His report estimates a production function for agriculture in 47 less developed countries (including Argentina) and 19 developed countries. He finds that infrastructure contributes to the

[11] There is also significant literature on the linkages between transportation investment and poverty alleviation and structural impediments to growth. This literature focuses on issues commonly confronted in developing economies.

explanation of aggregate agricultural productivity in each case. Furthermore, the report sets forth the idea that economic impact is not necessarily determined by the level of resource endowment, but rather by the utilization of infrastructure resources.

Binswagger, Khandker, and Rosenzweig (1989) use cross-district data in India to control for infrastructure differences in explaining agricultural output. When climatic effects are taken into account, roads are found to have a significant positive impact on aggregate agricultural output. This is not merely because of their impact on private investment, but because of induced marketing opportunities and lower overall transaction costs. Highway investment is shown to enhance agricultural output during the period; directly contributing 7 percent to output growth.

- Economic Diversification—Improving the stock of highways and roads, for example, not only increases total production, but also can have an effect on income levels, on the availability of alternative sources of income, and on regional economic growth. As an economy develops, the agricultural sector of the economy (as a percentage of total employment) begins to shrink. This, inevitably, produces shifts between sectors of the economy and population movements between regions.

  While better-developed areas may reap greater benefit from rural infrastructure investment, this investment will determine the location of many firms, further developing business and commerce in certain regions. A system-wide improvement to the road network may create (or enhance) economic centers of activity based on economies of scale, factor utilization, and geographic location.

  Stephanedes (1989) finds that for the State of Minnesota, regional centers can demonstrate long-term, sizable, employment improvements following an increase in transportation investment. This researcher's results agree with US census data, which indicate that 66 percent of the state's population works in regional center counties although only 47 percent live there. This implies that about 19 percent of the state's population commutes on highways to their jobs. Outside these areas the report shows evidence of favorable effects in the wholesale sector of rural counties due to firms gaining increased access to markets. Thus, the analysis finds improvements in certain rural areas that have a strong natural resource base or that can benefit from improved access to markets.

- Technological Innovation—In today's modern society, infrastructure enables modern technology in almost all sectors. Kessides (1996) mentions the "information revolution" of recent decades and its potential to dwarf all previous advances in productivity. Transportation networks are benefiting from technologies such as information processing, communications, and electronics. These benefits will enhance the efficient use of infrastructure resources, effectively making significant improvements in safety, mobility, accessibility, and productivity.

2.2.3 Geographic Distribution

Transportation investments often have direct effects on the spatial distribution of a region's or country's population and economic activity. Improved access to employment centers, decreases in the travel time of trips, and changes in the distribution of economic centers affect the location decisions of people and businesses.

Review of the Literature—Factors such as regional availability of raw materials and proximity to markets play a role in how highways affect the distribution and redistribution of economic activity. Wilson, Stevens, and Holyoke (1982) use survey data and factor preference indices to determine the relative importance of 13 factors on location decisions. They conclude that proximity to highways was the third most important factor in the location decisions of Canadian enterprises in the post World War II era (to 1960). Highway access was preceded by proximity of raw materials, owner-manager residence, and closely followed by proximity to markets—all of which can be influenced by efficiency in the transport system.

For the full sample time period (1945-69), proximity to highways ranked sixth in importance for secondary manufacturing industries; it was preceded by labor availability, proximity to prospective markets, government financial incentives, owner-manager residence, and accessibility to railways. Consequently, highways most definitely influence location decisions, but they are not the sole determinant.

Logically, investment in transportation will affect some economic sectors more than others, although the evidence is mixed. Stephanedes and Eagle (1986) document immediate employment gains in manufacturing and retail trade from highway investment. Data used in their analysis indicate that a 10 percent increase in highway expenditure generates a 0.3 percent increase in manufacturing employment in the following year. However, the intermediate and longer-term effects are smaller. They also find that the same 10 percent increase in highway expenditures generates a 0.17 percent increase in retail trade in the same year. The effects are more dramatic in counties near large cities, attesting to the drawing power of metropolitan areas when access is improved.[12] Some evidence indicates that tertiary industries (including government as well as services) have been more affected than other sectors (Rephann, 1993).

Will development in a particular area be a net gain for the region or country (generative)? Or is this development at the expense of another area (distributive only)? In part, the answer depends on the unit of analysis—small state or city, or whole country. Something that is generative in a state or limited region may be only distributive in a national context because one region benefits at the expense of another.

Redistribution seems to be the case in selected US examples. One econometric study, which compared counties in the state of Minnesota (Stephanedes and Eagle, 1987), concluded that increases in highway expenditure promote intra-state shifts in employment favoring economic centers in the state *and* away from adjacent counties and rural areas. Stephanedes (1989) also notes that economic development is a cause as well as an effect of highway funding, that is, transportation planners respond to economic growth by providing funding for transportation needs, thus reinforcing geographic differences.

2.2.4 International Trade

Transportation-induced changes in balance of trade can be triggered by several intermediate effects, including reduced costs of production, lower c.i.f. costs and/or

[12] A subsequent study by the same authors indicates that a 10 percent increase in highway expenditures over one year would be followed by an average of 0.02 percent decline in jobs over the next decade, again attributed to the pull of regional centers (Stephanedes and Eagle, 1987).

improved delivery times and reliability (i.e., improved access to markets). Consequently, changes in balance of trade are a corollary of productivity, geographic redistribution, and structural change impacts. That is, improvements in balance of trade occur when transportation improves productivity and a region's competitiveness (i.e., comparative advantage). Such improvements affect market demand, and any countervailing contractions or disbenefits (if they occur) are outside the designated boundaries. Furthermore, balance of trade, particularly for a nation as a whole, is of interest in its own right because of the repercussions for national welfare (i.e., the effect on welfare of stable exchange rate, availability of imports, attractive environment for foreign and domestic investment, appropriate government budget and stable financing conditions, etc.).

Unfortunately, few studies have been conducted that quantify the impact of transportation investments on international trade. Of the studies that address this linkage, only indirect effects are cited.

Review of the Literature—Evidence supports the logical contention that sophisticated transportation systems support an improved trade position. The US Interstate Highway System not only improved safety and defense readiness but, by improving national productivity, also positioned the US for improved international competitiveness (Cox and Love, 1996). Of course, highway and other infrastructure can only raise productivity and improve competitiveness when complementary factors are present as well (Kessides, 1996).

Both faster/more reliable transport to markets and reduced transport costs have a role in improved competitiveness. One estimate indicates that the US Interstate Highway System generated cost savings to trucking firms ranging from 0.73 percent per year in 1950 (in the early years of the system build-out) to 19.32 percent per year in 1973—a savings of about 2 cents per ton-mile (Keeler and Ying, 1988). The importance of truck transport in interregional and international trade logistics is echoed in other nations. For example, most shippers in the Indian market would state that they prefer truck transport to rail because of its greater operational flexibility and door-to-door deliveries (Peters, 1990).

2.2.5 Safety and other Social Impacts

Investments in transportation infrastructure influence the personal welfare of people across all economic groups. Improvements in highway transport may not only yield economic benefits by lowering transportation costs and in turn the prices of goods and services, but can also provide users with safer and more convenient access to a range of those services. Adequate highway infrastructure can directly contribute to quality of life by:

- enhancing safety,
- increasing accessibility to goods and services,
- and expanding social and economic opportunities.

This sub-section focuses on the safety benefits of transportation improvements (in particular highway investments) by drawing on the experience of the US.

Review of the Literature—Foremost among the social impacts of improved highways is travel safety. Travel on highways, particularly interstate highways, is often safer than travel on other roads because of the high design standards imposed during construction and maintenance phases. In countries with low highway performance standards and insufficient traffic capacity, the accident rate is far higher than that of countries with more stringent highway standards. The fatality rate in China, for example, is 20 to 30 times that of developed countries with high quality highways (Ning 1993). Wider roads, more lanes, better alignment, and improved road surfaces associated with highway travel all contribute to reduced vehicular accidents and thus reduce morbidity and mortality.

A study by Forkenbrock, Foster, and Pogue on the safety benefits from highway improvement investments used two semi-log regression models to determine the factors contributing to the number of highway accidents. The findings suggested that attributes affecting accident rates most are the number of curves on a broad segment of road and average daily traffic per lane (Forkenbrock, Foster, and Pogue, 1994). By upgrading a road to four lanes, improving its pavement quality, and widening the right shoulder, the accident rate per million vehicle miles traveled (VMT) is predicted to drop from 1.28 to 0.56.

In the US, the fatality rate for interstate highways is nearly 60 percent lower than the rest of the system, and the injury rate is 70 per cent lower on interstate highways than on the rest of the system (Cox and Love, 1996). An estimated 6,100 fatalities and 440,000 injuries were avoided in 1994 through the use of interstate highways (Cox and Love, 1996). Compared to other transport modes, such as rail, interstate highway travel is often one of the safest. Urban areas, in particular, benefit from highway usage, as urban interstate fatality rates are over 50 percent lower than that of other roads and 65 percent lower than that of urban rail. Rural areas also realize safety benefits from highway use. Fatality accident rates on rural sections of the interstate system are 40 percent of that of non-interstate highways in rural areas (US DOT, FHWA).

A variety of studies have been conducted that estimate the economic benefits from improved highway safety. To estimate the benefits from highway safety, the costs of traffic accidents are applied to number of accidents avoided, and in this manner cost savings can be estimated from improvements in highway safety. These accident costs savings estimates are often used in benefit-cost studies of potential highway investments. The US National Safety Council provides such estimates of accident costs. Using these cost figures, Cox and Love estimated that in 1994, lower interstate accident rates produced $17.2 billion in direct economic savings (1996). The authors further estimated that from 1957 to 1996, the safety related direct economic losses avoided due to the use of the interstate system are $368 billion.[13]

In addition to effects on value of time, improvements that result with savings also provide non-quantifiable benefits that contribute to standard of living. Improved roads, for instance, can expand the choice of leisure activities within reach and/or save time for

[13] Forkenbrock, Foster, and Pogue (1994) and Forkenbrock and Foster (1997) surveyed US state departments of transportation (state-DOTs) regarding the value of lives saved, injuries prevented, and property damage averted. The surveys revealed that the cost estimates used by state-DOTs vary, because the sources upon which the values are based differ substantially. According to survey results, the average accident cost values are $1,202,623 per fatality and $3,186 per accident involving property damage only. The Federal Highway Administration's (FHWA) value of $2.7 million per fatality is high relative to that average, while Iowa's DOT value of $500,000 per fatality is comparatively low (Forkenbrock, Foster, and Pogue, 1996, p. 45).

those making such trips. Likewise, expanded mobility and accessibility expands the range of opportunities and activities. Rural areas can benefit because transportation improvements create access to goods and services between major population and production centers. Access to job opportunities in both urban and rural areas are a benefit of a highway network, as users are thus able to seek a broader range of employment or other opportunities.

Some studies undertaken to assess the role of highway investment as a regional economic development tool have also noted the importance of a highway network as an agent for personal mobility. A study on New Brunswick, Canada by Wilson, Graham, and Aboul-Ela (1985) found that the initial benefits of investment in a highway system impacts society in a macro sense, with regional development encouraged and accessibility heightened. However, even after the initial accessibility improvements, increased mobility, and development of new or improved production centers, users will continue to benefit from the highway investment by way of the increase in personal mobility (Wilson, Graham, Aboul-Ela, 1985).

2.3 Relevance of this Body of Literature to the Freight BCA Study

The work reviewed in this section is largely concerned with impacts of highway investment on productivity (at a national or regional level), safety, and geographic distribution of economic activity. The Freight BCA Study is primarily aimed at developing estimates of the benefits of improved freight transportation using micro-economic analysis in the specific context of benefit-cost analysis. With the possible exception of the work by Keeler and Ying, the literature considered here does not focus on freight as such, and the work on productivity and geographic distribution does not use micro-economic principles. Much of the work on safety is done in the same way that safety improvements are valued in standard benefit-cost analysis—average dollar values for crashes avoided or lives saved are estimated and multiplied by estimated numbers of crashes avoided, lives saved, and so forth. But the connection between safety gains and freight improvements, as such, is not a close one. What, then, is the relevance of this body of work for the study at hand?

The principal relevance of this work lies in the macroeconomic analysis of the effects of highway investment on productivity and firms' costs. The preponderance of the statistical studies finds a clear link between better roads and a more productive economy. This is especially true for Nadiri's 1996 work, widely regarded as the most robust of these analyses. While his study is not focused on freight movement as such, freight carriage is clearly one of the effects that it captures, albeit not the only one. (Passenger transportation is also important for businesses.) What it tells us, though, is that impacts of freight improvements are definitely significant, and our search for these effects with microeconomic analysis is a sensible undertaking. Put another way, we can be confident that the effects we seek to measure are real; we are not looking for something that does not exist. This support from the macroeconomic analyses is also reinforced by the results of the work on geographical distribution of activity; these studies demonstrate the economic force of transportation improvements.

What the work reviewed in this section does not do is give any guidance as to how to measure benefits of freight improvements in a benefit-cost analytical process. The analytical techniques used for statistical analysis on a national or regional scale are quite different from those used for analysis of the benefits and costs of a project or a set of projects. Guidance for the Freight BCA Study is to be found in the microeconomic and benefit-cost analyses reviewed in Section 3 following.

2.4 Concluding Remarks

The literature reviewed in this section of the compilation focuses on the productivity and national income impacts, the safety benefits, and the geographic distribution impacts of highway investments—particularly as experienced in the US. Although consensus has not been reached on the magnitude of impacts, there is sufficient evidence that demonstrates the strong, positive linkage between highway investments and economic prosperity. With respect to safety, few can argue against the beneficial impacts of interstate highways. Finally, although less evident from the literature, highway investments play an important role in the decentralization of economic activity and population, and on the inter-regional and international competitiveness of regions and countries.

3. THEORETICAL AND FREIGHT TRANSPORTATION STUDIES

The previous section focuses on literature that assesses the direct and indirect economic impacts of transportation investment, particularly investment in highways. Although methodologies that have been used to quantify the productivity effects of investments in infrastructure provide a wealth of information on the relationships between transportation and industry structure and performance, most of the work reviewed in Section 2 says little about the specific role of freight transportation. Likewise, the methodologies that have been used to quantify productivity impacts are not based on benefit-cost analysis. Consequently, to better inform this Freight BCA Study, literature specific to freight transportation (such as that on logistics management) and literature on economic impact analysis methodology are reviewed and evaluated in this Section of the Compilation Report.

3.1 Introduction

A number of themes emerge from the literature that focuses on 1) theoretical approaches to assessing the economic impacts of transportation and 2) the associated effects or issues attributable to freight transportation.

- First, there is a body of work on broad ***policy*** issues, trends and barriers to economic development. More recent papers discuss the evolving transportation sector driven by e-commerce and globalization.

- Second, a set of reports discuss ***methodologies and approaches*** for structuring and conducting benefit cost analysis, including the use of multi-criteria approaches, quantifying all types of external costs to reflect full marginal costs. On a related theme, works focusing on economic productivity and development quantify in various ways the effects (including empirical estimation) of public investment on economic performance and productivity.

- Third, a body of work addresses the impact and response of ***logistics*** systems to highway improvements, including inventory, warehousing, and supply chain management.

- Finally, a group of papers deals specifically with advances in ***technology***, including benefits of ITS, policy, standards, and interoperability of trucks and inter-modal facilities.

3.2 Theme 1: Policy and Trends in Freight Transportation

Several papers focused on policy issues, trends and barriers to economic development, and the evolving transportation sector driven by e-commerce and globalization. Regan et al. (2000) discusses freight transportation and logistics trends and challenges in the new millennium. The paper identifies the key issues that affect freight planning and logistics. These include: increased demands for freight transportation and logistics services, and the ability of the physical and information infrastructure to meet these demands; the role of road pricing in urban freight transportation; the impact of information technology on goods movement; and new development in logistics management. Their work draws significantly on Delaney's 10th Annual State of Logistics Report "A Look back in Anger at Logistics Productivity". Delaney also recently delivered the 11th Annual State of Logistics Report, where he discusses logistics trends and the impact of the Internet. There he reports that business logistics costs were approximately 10% of GDP, with transportation costs continuing at a nominal 6% of GDP for the 7th year in a row. Third party logistics firms are experiencing significant growth in the US.

Specific freight industry attitudes towards policies to reduce congestion are reported by Golob (2000) in an extensive survey of California-based carriers. Given that freight transportation plays a vital role in the economy of the nation and of the state of California in particular, the 1998 California Transportation Plan for goods movement developed by the California Department of Transportation (Caltrans) identifies four constraints and deficiencies affecting freight transportation in the state: 1) capacity and congestion, 2) safety, 3) geometry and surface conditions, and 4) intermodal connections. This study addresses the first and last of these factors and touches on the second and third, from the point of view of trucking companies. It examines the impact of congestion on trucking operations, the use and usefulness of information technologies in their operations, and the value and efficiency of intermodal transfer facilities across the state. Results could help structure case studies.

In European Transport and Communication Networks, and Transport in a Unified Europe Banister et al. discuss evolving European/EC networks together with policy responses to a very broad range of issues. The collection of papers covers trans-European networks, the effects of dissolution of borders and remaining barriers, private sector investment and network diversity. They conclude that there needs to be a European strategy for transport and communications infrastructure investment, agreed by all member states and neighboring countries. They suggest moving away from increasing the physical capacity and extent of the network to a broader range of options including means to limit growth in demand through pricing, regulation and management, to optimize freight fleets and multi-modal transport, and to explore private sectors' role in new developments.

In sum, works on policy and trends provide the context for benefit cost analysis of freight transportation improvements. The main message is that cooperation between private and public sectors will be needed to ensure a transportation system that meets the evolving freight needs of business and consumers. With increasing demand for transportation, it is ever more important to have a sound framework for evaluating all costs and benefits.

3.3 Theme 2: Theoretical Approaches to Benefits and Productivity Assessments

Within this theme, the literature focuses on macro-economic, micro-economic, and overall cost-benefit analyses, as well as estimation of parameters.

3.3.1 Macro-Economic Analyses

Studies by and for the Federal Highway Administration Office of Policy Development have documented the effects of public highway capital on logistics system and commercial sector economic performance. In particular, Jacoby notes that Nadiri's 1996 study provides empirical evidence of the contribution of highway capital on the total output growth and productivity of 35 industry sectors of the US economy. This work and others on productivity studies are reviewed in more detail in Section 2 of this report.

From the perspective of methodologies employed to assess the productivity impacts of transportation investments various approaches have been employed by researchers. For example, Bell (1994) reviews macroeconomic analyses of the linkages between transportation investments and economic performance. Xin (1996) uses an input/output model to study regional economic benefits of transportation system projects. Duffy-Deno models the relationship between capital stock and per capita income as an economic development indicator.

A recent comprehensive review by Khanam examined empirical work on the relationship between highway capital stock and the output and productivity of goods-producing industries. In the published literature, the bulk of which is based on US data, the impact of public capital stock of various types on the output and productivity of different economic sectors has been examined. As discussed in Section 2, the evidence from these studies suggests that a positive relationship exists between public highway capital and private sector output and productivity; and the estimated size and significance of this relationship are very diverse and depend to a large extent on the approach followed. The results, expressed as output elasticities, range from 0.04 to 0.56; in some models, the estimates are statistically insignificant (from zero) or negative. The report compares results (output elasticities) obtained using Cobb-Douglas and Translog models.

Keeler (88) uses a translog cost function econometric model for an analysis of the benefits of Federal-aid highway infrastructure investments in the United States on costs and productivity of firms in road freight transport industry. The average sum of marginal benefits across all industries is about 0.294. This means that a $1 increase in net capital stock generates approximately $0.3 of cost saving producer benefits per year. These benefits continue over the design life of the road improvement.[14]

3.3.2 Micro-Economic Analyses

Of the papers reviewed in this report, Mohring and Williamson (1969) is the first formal analysis of what has been termed "reorganization" benefits. These benefits result from adjustments in logistical arrangements that shippers make in response to lower costs of

[14] Approaches to measuring the impact of highway investment on productivity could complement what has been developed in the White Paper. As argued by Mohring and Forkenbrock, productivity enhancements are not an additional benefit to that already captured by the benefits-cost analysis framework, they are another useful measure of impact of highway investment.

freight movement. Typically, such adjustments would involve fewer warehouses and more miles of truck movement as shippers take advantage of lower freight costs to consolidate storage facilities and reduce inventory costs. These effects are the principal source of benefits not captured in the conventional approach to benefit-cost analysis.

The main conclusion of this paper is that the commonly used consumer's surplus measure of benefits is just as valid for transportation investments (including possible logistics re-organization) as it is for other types of investments. Regardless of whether situations reflect fixed or varying output level, derived demand schedules for transport inputs provide an exact measure of benefit from transport improvements. In fact, Mohring generalizes this result by going one step beyond to include cost reductions of inputs that were formerly not employed in the production process.[15] Using a simple production model, Mohring derives a quotient relationship between direct and total benefits for different scale economies. This theorem demonstrates that the magnitude of indirect benefits can be of the order of 12 percent of direct benefits.

Mohring's paper provides the theoretical foundation for the cost benefits analysis micro-economic framework. It demonstrates the validity of using consumer surplus in estimating net benefits of transportation investments under very broad conditions.

Subsequent work by HLB on behalf of the ATA Foundation addressed, in a micro-economic framework, the policy impact of full social cost pricing on the trucking industry. In response to the 1997 Highway Cost Allocation Study, this work considered both the positive and negative externalities of trucking, and found that the policy risk associated with social cost pricing goes beyond the transport sector and could affect productivity and competitiveness. The analysis is based on a partial equilibrium model of demand for trucking services and quantifies the change in consumer surplus as a result of tax collections. The model was implemented within a risk analysis framework accounting for uncertainties in key assumptions.

[15] Such as new or enhanced IM/IT systems.

3.3.3 Benefit/Cost Analysis

Forkenbrock (1990) discusses two types of benefits of corridor highway investments, reductions in transportation costs and increases in economic activity. Although road user benefits should form the basis for decisions of whether or not to invest public funds to upgrade highways, policy makers often wish to see estimates of economic development. The question of which benefits should be taken into account depends on the geographic perspective, whether regional (where transfers can occur), or national (where road user net benefits can be demonstrated). Economic development impacts to corridors were estimated using IMPLAN, an input/output model. This paper is consistent with the micro-economic framework. Regional economic impacts, if reported at all, should be seen as adjunct information. To include them depends primarily on the geographical perspective.

Although the existence of positive network externalities remains a matter of debate in transportation circles, their quantitative significance is not doubted in related fields, such as telecommunications. Capello and Rietveld make a compelling argument for government policy as a means of correcting for an <u>under-supply</u> of highway infrastructure due to the existence of positive network externalities. By way of example, the authors argue that logistics-oriented telecommunications systems are characterized by positive externalities in the adoption process and, given the high fixed costs of acquisition, government policy might be justified in order to ensure the economically optimal critical mass of users. Other examples point to positive externalities in vertically integrated sectors where improvements for shippers in forward markets generate un-priced advantages for shippers in backward-linked markets. Government policy might be able to exploit such positive spillovers with policies that accelerate the take-up of advanced logistics in forward markets. HLB (for the American Trucking Foundation) found that even small positive network externalities per truck-mile could add up to an aggregate sum as large as the negative congestion externalities attributed to heavy trucks.

There are only a few studies that contain the basic theoretical and conceptual discussions underlying the approach proposed for FHWA's Freight BCA Study to evaluating benefits of freight-transportation improvements. The amount of key research is small because the great preponderance of the work on highway benefit-cost analysis simply does not address the issue of improvements for freight carriage. And, even where benefits to freight carriage are addressed, the treatment is usually incomplete, since effects of shippers' longer-run responses to lower freight costs are not, in most of the literature, considered.

3.3.4 Parameter Estimation

A number of studies focus on empirical estimation of elasticities. Bjorner makes an explicit distinction between traffic (km) and transport demand (ton-km), where the former is an input in the shipper's production of transport services, while the latter is derived from firm's production of output. Estimated price elasticity with respect to traffic is shown to be considerably higher than elasticity with respect to transport.

The most extensive review of alternative demand models and their elasticity estimates is given by Oum (1989) and Oum et al. (1992). Transport demand models of four types are described and elasticities for all commodities are provided for rail and truck transport with respect to freight rates, speed, and reliability. Oum distinguishes between elasticity of aggregate market demand, mode specific elasticities, and mode choice elasticities. Goodwin examines elasticities of transport demand with respect to petrol price and transport price for bus, rail and metro.

Rolle (1997) develops a model for the computation of demand for rail passenger travel as a function of own price and other mode prices (car, bus, plane etc) for the Swiss railway. Additional factors included in the model are rail and road network density, density of population and other socio-economic variables. This work is relevant only in that it provides an econometric approach to elasticity estimation. Roson (1995) models transportation cost as a concave function of distance and determines a method to find profit maximizing fares. The article is informative more than directly relevant.

The need for freight transportation data as well as current sources and challenges are summarized in a TRB report by Hancock. Policy issues for improved data management and sharing are discussed and a list of data sources is provided.

Elasticity estimation approaches need to be reviewed as to the most applicable and robust method for the BCA study. In the case of quantifying the re-organization effect, elasticity estimation was to be based on survey interviews and case studies. These need to be compared to baseline estimates obtained by other means.

3.4 Theme 3: Logistics

A number of studies focus on quantifying the relationship between transportation and other logistics processes. This includes:

- the interaction of transportation and inventory decisions (Constable),
- estimating the effects of carrier transit time on logistics cost and service, and
- the scale of indirect logistics savings as a function transport cost reductions.

Blanchard et al. explore relationships between highways and production costs through case studies, tactical logistics models, and theoretical treatments. The most compelling and general work is Mohring. (Case Studies) He also summarizes findings from Case studies carried out by KPMG for Transport Canada who have investigated, in a qualitative manner, the relationship between highways and logistics performance.

McKinnon (1996) examines the relationship between traffic growth and production and changes in logistics practices in the UK. Traffic growth for trucking is shown to be the result of logistics management interactions between planning, supplier/distributor choices, production scheduling, and transport fleet management. He shows that traffic growth is not simply a function of GDP growth, but also of restructuring effects and just-in-time freight scheduling. This paper might provide useful background information to help structure case studies.

3.5 Theme 4: Advances in Technology and Intermodal Freight Transport

A body of work deals with advances in ***technology***, including benefits of ITS, policy, standards, and interoperability of trucks and inter-modal facilities. While conventional efforts to improve trucking productivity have typically focused on the separate components of the system, Fawaz explores combinations of trucks, roads, and operations at the system level to achieve productivity gains. An evaluation framework and model is demonstrated through a specific case study.

Various papers explore the impact of new technologies. The 1990 TRB report on new trucks for greater productivity explores the Turner proposal for new truck configurations. Effects related to safety, road wear, and overall operating costs and required infrastructure investments are quantified as compared to present standards.

An earlier 1980 USDOT study examined the impact of technological change on regional productivity. Although the study could only find a weak impact of technological change on a regional economy, it did highlight the importance of urban highways in the shaping of urban form. Another study examined the inter-operability of vehicles among NAFTA countries. Recommendations for making motor transport under NAFTA more efficient are addressed. Norris (1996) evaluates the status of intermodal freight in the US in general, while Zavattero discusses integrating intermodal freight needs into the transportation planning process. Muller (1997) provides an excellent overview of intermodal developments, movements, technologies, barriers, and future trends. It appears to be [the] reference on inter-modal transport operations.

Studies on advances in technology and intermodal developments provide useful background information, but do not contribute directly to the development of a comprehensive BCA framework. A number of benefits of intermodal freight capacity were identified by Norris including congestion reduction, lower emissions, higher fuel efficiency, greater safety, reduced highway deterioration, cost savings and greater systems efficiency. Congestion reduction is achieved by diverting freight traffic away from highways. For each 10 containers carried on intermodal rail, a minimum of 7 trucks are taken off highways. Lower emissions are a result of a five fold lower hydrocarbon emission per ton-miles for rail as compared to truck.

The main message of intermodal transport is that for long haul trips rail may be more efficient and cost effective provided intermodal capacity exists. Challenges for intermodal freight include regulatory barriers, operational, structural, and technological limitations, and demand driven impediments.

3.6 Relevance of this Body of Literature to the Freight BCA Study

The core literature on theoretical treatment of freight improvements, so far identified by this project team, and reviewed in the initial Microeconomic Framework White Paper consists of the following items:

- Herbert Mohring and Harold Williamson, Jr., "Scale Economies of Transport Improvements," *Journal of Transport Economics and Policy*, Volume 3, Number 3, September 1969.
- D A. Quarmby, "Developments in the Retail Market and their Effect on Freight Distribution," *Journal of Transport Economics and Policy*, Volume 23, Number 1, January 1989.
- Herbert Mohring, *Transportation Economics,* 1977, especially chapters 8 and 11.
- Hickling Corporation (with Charles Rivers Associates and Christensen and Associates), *Methodologies for Evaluating the Effects of Transportation Policies on the Economy, Technical Report*, supplement to NCHRP Report 342, March 1991, especially Chapter 14 and Appendix D.
- Hickling Lewis Brod Inc., *Measuring the Relationship between Freight Transportation and Industry Productivity* (NCHRP 2-17(4)), June 1995.
- G. Blanchard, *Highways and Logistics and Production Performance*, Transport Canada/Economic Analysis Special Infrastructure Project, Report TP 12791E, June 1996.

All of these papers make an important contribution. Note, however, that the Mohring and Williamson paper is the first formal analysis of what Herbert Mohring refers to as "reorganization effects"—the adjustments in their logistical arrangements that shippers make in response to lower costs of freight movement. Typically, such adjustments would involve fewer warehouses and more miles of truck movement as shippers take advantage of lower freight costs to consolidate storage facilities and reduce inventory costs. These effects are the principal source of benefits not captured in the conventional approach to benefit-cost analysis.

The most complete, to date, theoretical and mathematical treatment of these effects is in the supplement to NCHRP 342, and particularly in Appendix D. Much of this material is highly technical and not easily accessible to a reader without a strong knowledge of micro-economic theory and a good grasp of mathematics. Quarmby's article describes reorganization effects in a manner readily comprehended by non-specialists. Quarmby wrote this paper, not as an economist (which he is), but as a senior executive of a major British supermarket chain considering the interplay of transportation and logistics costs. Parts of NCHRP 2-17(4) also provide a non-mathematical discussion of some of the issues.[16]

The main and most important result is the quantification of "reorganization" benefits. It was developed by Mohring and later reviewed by Blanchard. Based on Mohring's work, indirect savings as a fraction of direct savings are shown at Figure 1. As demonstrated by Mohring, these savings are a function of manufacturing scale economies. One very interesting insight is that, the greater the manufacturing scale economy, the lesser the relative importance of the indirect benefits. This result, which on the surface may be counter-intuitive, is explained by Blanchard as follows: Industries with large scale economies have a more transport intensive cost structure; before the cost reduction, they would already be operating from fewer plants, each with a large market area. As a consequence, there is relatively little room for restructuring their production and to accrue indirect savings. On the other hand, the relative importance of indirect benefits is greatest for industries with small-scale economies, a significant portion of the US economy.

[16] We have focused our attention on the technical expositions (especially on Appendix D to NCHRP 342) of these articles. Significant effort has gone into the review of the mathematical analysis presented in Appendix D, since this is the formal statement of the economic theory that will be the foundation of the method that has been proposed to FHWA for the BCA framework. ICF has subjected the mathematical arguments to intensive review, and there have been two all-day meetings of members of the ICF and HLB teams to discuss and resolve issues that were identified.

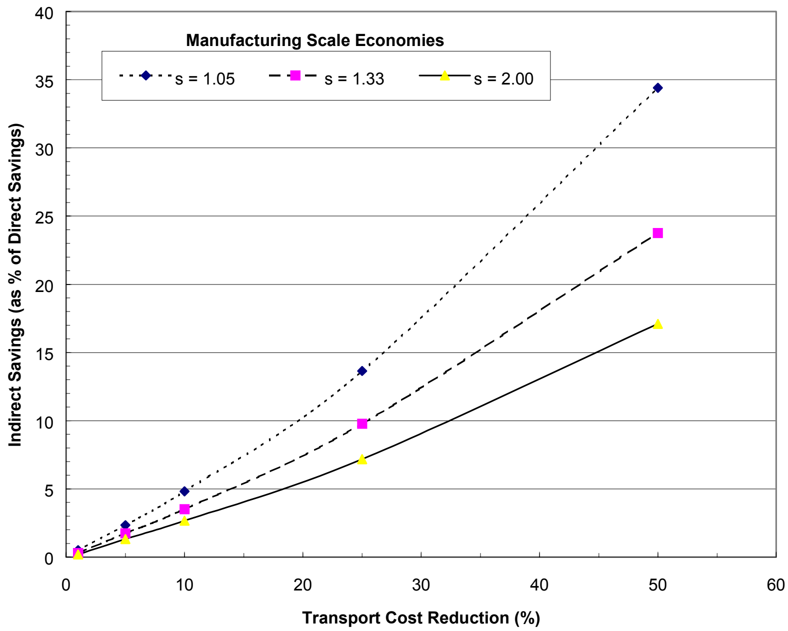

Exhibit 1: Indirect savings as a fraction of direct savings for given transport cost reductions and manufacturing scale economies.

The studies reviewed on policy and trends provide the context for benefit cost analysis of transportation improvements. With increasing demand for transportation, it is ever more important to have a sound framework for evaluating all costs and benefits and to be able to rank initiatives in terms of their value generation.

Research on theoretical approaches to cost benefit analysis (micro, and macro-economic) and logistics are complementary to what had already been examined as part of the white paper. The framework should be able to account for, at a high level, the impact of a wide number of initiatives, whether they are infrastructure related or of a technological nature.

A number of studies have been identified as relevant for the meta-analysis. Oum, and Oum et al. provide the most comprehensive review of both methods and actual elasticity estimates. For truck freight, demand elasticities are given by estimation method used and some by individual commodity. Having reviewed over 60 empirical studies of transport demand, Oum notes a wide range of values across different commodity groups, but also for the same group using different functional forms. The preliminary meta-analysis reveals that the BCA framework will need to work with elasticity ranges and uncertainty in the estimates.

Although not directly applicable here, a number of studies cover demand elasticities for other modes of transport. Goodwin examines elasticities of transport demand with respect to petrol price and transport price for bus, rail and metro using a micro-cost function; Rolle compares the elasticity of railway and car demand with respect to price. Using a bootstrap procedure, he obtains a distribution of these estimates. This procedure could be investigated for the present study.

Related data on external costs of inter-city trucking are given in Forkenbrock based on various sources. Blanchard reports illustrative logistics cost elasticities with respect to service levels, changes in reliability and lead time as part of his logistics analysis and review. Tyworth estimates the effects of carrier transit-time performance (mean delivery time and variation) on total logistics cost and service using an enhanced single-echelon continuous review inventory model. Finally, the so-called Mohring theorem allows the estimation of direct and indirect benefits for various scale economies as a function of transport cost reduction.

3.7 Concluding Remarks

Overall, this body of literature has confirmed the basis for the micro-economic framework had been identified and reviewed as part of the White Paper and initial developments. Complementing previous work, a number of papers have been found as key works for the meta-analysis, allowing the extraction and estimation of parameters for the BCA model. A variety of alternate approaches to elasticity estimation have also been found and will form the basis for the next phase of the project.

4. LITERATURE ON INDUSTRY EXPERIENCES AND CASE STUDIES

As discussed in the White Paper that presents the proposed framework for FHWA's Freight BCA Study, we will rely on revealed and stated preference surveys of industry to enhance the robustness of the methodology. This Section provides a review of literature on how industries react to improvements in freight transportation.

4.1 Introduction

There is a very small compendium of "industry case studies" which attempt to directly relate improvements in transport infrastructure in general or highways in particular to industry restructuring of distribution (logistics) functions. The general absence of literature directly linking infrastructure improvements to logistics changes does not suggest lack of interest or unimportance of the topic. The infrastructure improvement logistics productivity relationship is a distinct subset of the overall prevailing logistics literature which focuses on least total cost tradeoffs within customer service objectives for a network of diverse inputs (transportation, warehousing, inventory control, order processing, etc.), processes and ensuing technological changes in each of the logistics inputs. To the extent that there have been changes in transport infrastructure the logistics literature has indirectly incorporated these changes in process, such as decreases in average and/or variability of transit time for existing modes, or technology, such as changes in speed or reliability of new transport services, for example air freight, or electronic shipment tracking.

The relationship between infrastructure improvements and logistical restructuring that is addressed by the literature has an approach similar to the early studies of changes in railroad and intercity truck market shares for transportation (tons and ton-miles) of manufactured products. A number of studies demonstrated the obvious: there was a distinct shift of market share from rail to truck for most manufactured goods particularly during the 1960's and 1970's. The rail truck market share studies took two basic forms: macro, reflecting changes in total shares of industrial output between the modes for commodities based on SIC or STCC industry or commodity codes, respectively, and; micro, reflecting "case studies" of shifts in mode split of a firm or industry. The macro studies tended to be in the public domain often as part of policy debates while the micro studies tended to be proprietary often related to carrier market research.

Both macro and micro approaches to measuring rail truck market shares were useful to explain trends in intercity freight competition. However, neither approach was particularly useful to explicitly identify the causal variables for the shift from rail to truck, among which were improvements in cost and service because of new road infrastructure. This situation seems analogous to the "industry" case studies pertaining to the relationship between highway improvements and logistics restructuring. The macro studies, exemplified by statistical relationships between public investment and productivity, do not provide understanding of the logistics process responses to infrastructure. The micro studies, exemplified by industry logistical changes nominally associated with changes in highway infrastructure, do not provide the logistical supply elasticities that reflect shifts in the quality of transportation as a function of improvements in highways.

The issues, problems and needs of the industry "case studies" can be expressed in macro or micro perspective. From a macro perspective the case studies could reflect any transportation improvement with respect to changes in transit time and variability. Rail truck competition would be an example where modal substitution typically results in changes in transit time and variability with ensuing logistics responses. From a micro perspective the case studies would reflect changes in truck transit time and variability based on highway improvements.

There is an extensive body of logistics literature on mode split that reflects least total cost tradeoffs. Although conceptually relevant to the issue of defining logistics restructuring to reflect improvements in transit time and variability, much of the changes in mode split have already occurred as firms shifted from rail to truck for most high value time sensitive goods. Attempts to replicate rail and truck based logistics systems to define responses to changes in transit time and variability are likely to be mostly conjectural. Moreover, the substantial differences between carload rail and truck service, particularly transit time variability, are likely to inflate logistics restructuring relative to changes in truck service from highway improvements unless assumptions are made about non-linear elasticities of logistics inputs.

However, comparisons of shipper logistics restructuring based on cargo shifts to or from rail intermodal to truck is a distinct possibility in strategic long haul rail double stack intermodal corridors which have service quality performances similar to truck. Similarly, changes in shipper logistics restructuring between the use of truck service providers who use (rail) intermodal (for example J.B. Hunt) and those who do not use rail intermodal (for example Werner Enterprises) offers another alternative for investigation. The public domain literature is silent about these recent rail-truck mode split logistics. Both avenues of potential investigation would have to control for more than service changes because of differences in loss and damage, freight rates, packaging, etc. This tends to detract from "intermodal" case studies to the extent that they exist or can be undertaken.

There is a very limited body of literature on the narrow issue of logistics restructuring in response to improvements in truck transit time and variability. Although the literature identifies many changes in truck services based on revisions of processes and applications of new technology, most relate to information and communications which only relate tangentially to improvements in transit time and variability. The literature suggests that the bulk of truck service improvements have more to do with the speed and quality of shipment related information, including advance notification of expected delay and delivery. Therefore attempts to relate changes in transit time and variability must include the existence of information substitution effects for impacts on transit time and variability changes on logistics restructuring. Improvements in information technology (IT) and different applications in shipping and trucking enterprises is another element that confounds attempts to use pre IT literature for possible logistics restructuring benchmarks other than to depict that a causal relationship exists between transit time improvements and restructuring. Indeed, it appears possible to deduce from the literature that recent and emerging IT applications to transportation, particularly trucking, could decrease the impact of transit time variability within distribution networks that have dynamic substitution possibilities, for example closely located networks of affiliated retail stores handling consumer durable goods such as tires, appliances, etc.

4.2 Review of the Literature and Summary of Results

The results of the literature indicate that there are causal relationships between changes in average and variation of transit time and logistics inputs, for example faster more reliable truck transport effects on inventory safety stocks. However, the nature of the causal relationships with regard to logistics elasticities for substituting strategic inputs such as increased use of transportation and reduced number of stocking locations, partly as a function of changes in safety stock, cannot be a-priori defined. For example, for a particular situation defined in terms of average and variation of sales demand during the lead time, and average and variation in transit time, inventory safety stock can be empirically determined to provide a level of inventory availability during the reorder cycle affected by transit time. Other things equal, changes in transit time (average and or variability) will affect the required amount of safety stock. How the transit time changes affect the number of stocking locations because of increased transportation from highway improvements is not evident from algorithms commonly used to estimate safety stock.

Masking the situational nature of the logistics substitutions (restructuring) in response to transportation improvements is the indirect nature and relevance of highway improvements to logistics managers (shippers) compared to carriers (truckers). The literature seems to have focused on extracting changes in processes used by logistics providers who are only indirectly influenced by changes in infrastructure that affect transit time and variability. As a result there is a paucity of explicit causality between highway improvements, truck service (transit time and variability) and logistics responses. Attempts to make explicit linkages are characterized by assumptions or hypothetical situations. Robust linkages and statistics are notably absent.

The literature directly relevant to the relationship between transit time service improvements (mean and variability) ostensibly related to highway improvements and logistics restructuring is exclusively qualitative or incidental in nature such that empirical generalizations do not exist. The principle of dynamic changes in logistics inputs and some examples of logistics restructuring exist but this phenomenon generally has not been related to one variable such as transit time improvements other than in a conjectural sense. Moreover, attempts to relate logistics restructuring in a quantitative manner as an explicit function of transit time improvements have not been possible based on the limited industry case studies available. Consider the results reported in Faucett:

> *In the initial stages of the research we hoped to obtain estimates of cost savings due to highway system improvements in the various operations of the plants of the firms interviewed in the sample industries. As it turned out, we were able to obtain many fragmentary estimates but these were not in sufficient detail nor comprehensive enough to warrant a quantification of cost savings in each of the sample industries.*
>
> *There are a number of reasons why the desired measures of cost savings are difficult to obtain. First and foremost are the complicated interrelationships among the operations within the plant and between these operations and the logistics operations. For example, savings in inventory costs due to faster delivery time and reliability affect not only the costs of holding inventories (storage, insurance, pilferage, and interest costs) but also handling costs (labor and equipment). ----It was difficult for firms to estimate the effects on these interrelated costs, and the tradeoffs in costs, except in a very approximate fashion.*
>
> *Second, the impacts of improvements to the highway system on industry cost savings take place over time as firms and plants structure their operations to take advantage of the potential savings. Some of the major cost savings occurred as the interstate system was put in place years ago. Current officials take this system for granted and are hard pressed to estimate what it meant to their operations. Finally, the major impacts of deregulation and advances in communication and computer technologies over the past decades are intertwined with the impacts of highway improvements and are difficult to separate in the cost savings estimates that current officials have witnessed (Faucett).*

The research in Faucett reportedly covered 27 companies in six different industries. While the research resulted in a great deal of descriptive information, there was a virtual absence of empirical results by which a direct relationship could be distinguished between highway investments and productivity. The results of the investigation suggested that there were three principal sources of cost (productivity) savings from highway improvements: 1) reduced inventory costs resulting from faster and more reliable replenishment delivery times; 2) economies of scale in larger volumes of output per plant due to access to wider distribution markets; and 3) reductions in regional warehouse operations due to more direct deliveries from plants to retailers, wholesales, and final users as a result of more reliable delivery times direct from manufacturers (Faucett).

The difficulty of the task of linking highway improvements to changes in logistics costs (other than directly related to vehicles) manifested by Faucett was nevertheless urged by Quarmby as a necessity to fully reflect the benefits of road improvements:

> *Benefits to commercial vehicles of road improvements, calculated as straight time savings, will tend to underestimate the true "business potential". It could be shown that, in a typical operation of retail distribution of food, the benefits from restructuring the distribution and depot network could exceed the benefits of straight time savings by 30 – 50 per cent (sic). It is important that the "business potential" released in this and other industries by network improvements should be better understood (Quarmby).*

Quarmby uses the example of a hypothetical retail chain store food distribution warehouse network to construct a conceptual model of "business potential" (logistics restructuring) cost savings that are understated when major highway improvements are evaluated by traditional benefit cost models. The retail food industry example is perhaps among the more obvious instances wherein changes induced in warehouse location through highway improvements increasing vehicle driver productivity have visible effects on the number and location of retail stores served, including new markets. The results suggested as comprising unaccounted business potential seem obvious: 1) it is feasible to serve branches located further away; this opens up new market potential for the company; and 2) the number of warehouses serving a total geographical territory can be reduced (Quarmby).

The author "quantifies" the restructuring benefits as distinct from cost benefit vehicle operating cost savings by presuming savings from warehouse reductions (denoted as economies of scale) and reductions of safety stock from centralization of inventory at fewer stocking locations. Warehouse reduction cost savings are based on assuming marginal costs for warehouse throughput per case handled and inventory savings are based on an assumed annual carrying cost expressed as a percentage (twelve percent) of product investment applied to the estimated average value of the safety stock savings.

The assumed cost of extra transport because of fewer warehouses in response to highway improvements is deducted from the total gross savings of fewer warehouses and reduced inventory safety stock to arrive at estimated net restructuring savings. The estimated net savings of restructuring (reduction in number of warehouse and safety stock) are about 23% greater than that reduction of direct transport savings without restructuring based on hypothetical linear costs assumed by the author. It is important to note that the author does explicitly indicate that, "*This section can do no more than illustrate the means by which this 'business potential' can be unlocked in retail physical distribution* (emphasis added)."

The results of a series of industry case studies on highway improvements and logistics restructuring were reported in 1990 (Apogee, 1990) and 1991 (Apogee, 1991). The case study methodology was used to find examples of how transportation improvements affect the productivity of specific firms or industries. The focus of the research was to determine through interviews the corporate logistics executives how firms respond with changes in their internal operations to transportation improvements. Productivity changes from transportation improvements were adduced to reflect the following phenomenon: 1) reduce bottlenecks in production and management; 2) increase flexibility in production sourcing and scheduling; 3) improve assess to labor; 4) permit increased specialization of corporate functions; and 5) increase access to near or larger markets.

The results of the case study of approximately fourteen firms revealed three major findings: (1) there is a clear interaction between high technology and transportation; (2) there is a chain-reaction effect that links transport improvements to a series of productivity gains that can effect the structure of how firms do business; and (3) there are clear examples of a relationship between transportation and productivity across a wide range of industries surveyed.

The research was largely exploratory in nature, leading to generalizations that the productivity gains that are occurring in logistics systems are the result of integrating high technology communications and location of vehicles. The preliminary implications were that the transportation improvement linkage with (logistics) productivity was quite different from tangible measures of inputs or outputs such as lane miles built or ton miles of goods moved. The emphasis appeared to be on transportation improvements related to reliability and coordination with attendant impacts on inventories and spatial location within changing distribution networks.

The research suggested that beyond the general finding of increased productivity there was no systematic study of transportation improvements on productivity gains in a cross-section of industries. Few examples were found where any real attempt has been made to quantify potential productivity gains. Attempts to quantify micro-productivity effects are rare. Most managers focus on their immediate problems and departments while transportation induced productivity improvements typically cut across a series of departments. Moreover, the direct measurement of gain is difficult since many of the most significant effects of transportation improvements relate to customer service (Apogee 1991).

A fruitful series of research reports on trucking operators' responses to congestion and used of advanced information technologies were produced from a 1998 survey of California-based trucking fleets (for-hire and private carriage) and larger national carriers with operations in California. An overview of the research plan describes the survey and summarizes the results of the research with respect to traffic congestion, use of information technologies, and use of intermodal facilities in California (Regan and Golob, 1999). The survey reflects a comprehensive knowledge of different operational aspects of sectors within the trucking industries such that it was possible to relate operator profiles to responses to congestion, use of information technology and California intermodal terminals. Subsequently, the authors parsed the data to produce research publications that reflect these topics.

A structural equations model is estimated on the survey data to determine how five aspects of congestion differ across sectors of the trucking industry with respect to: (1) slow average speeds; (2) unreliable travel times; (3) increased driver frustration and morale; (4) higher fuel and maintenance costs; and (5) higher costs of accidents and insurance. For both for-hire and private carriers, scheduling problems due to unreliable travel times is the most important component of the congestion problem. Unreliable travel times are a significantly more serious problem for intermodal air operations and less of a problem for specialized bulk operators. Although much of the findings are common sense, the research does empirically identify sectors of the trucking industry that are most likely to benefit from and support different types of congestion improvements (Golob and Regan, 1999).

Further results of truck freight operator responses to congestion include attitudes towards policies to reduce congestion (Golob and Regan, 1999) and perceptions of congestion problems and potential solutions in maritime intermodal operations in California (Regan and Golob, 1999). The authors used conformity factor analysis with regressor variables to classify twelve hypothetical congestion relief policies: 1) more freeway lanes; 2) electronic clearance stations; 3) special truck freeway lanes; 4) longer hours of operation at ports and distribution centers; 5) congestion tolls; 6) traffic signal optimization; 7) truck only lanes on some surface streets; 8) truck only access to intermodal terminals; 9) real time HAZMAT load information system; 10) electronic international border clearance; 11) traffic signal preemption for trucks; and 12) on street parking bans. The authors arrived at six distinct classes or natural groupings of congestion mitigation policies denoted as factors. The factors (and associate congestion relief policy numbers in parenthesis) are as follows: 1) Dedicated truck facilities (3, 7 and 8); 2) Improvements in operational efficiency (2, 4, 8, 9, 10, and 11); 3) Improvements in traffic management (2, 3, 6, 8 and 9); 4) Truck urban arterial priority (3, 7, 11 and 12); 5) Increased road capacity (1, 4, 6, 7 and 12); and (6) Congestion pricing (1, 5 and 10). The authors conclude that:

From a transportation planning perspective, implementation of the policies included in classes three and four, improved traffic management and truck urban arterial priority, appear to be the most cost effective. Moreover, industry spokespersons who are in favor or either of these two classes of policies tend not to favor the policy of dedicating a single freeway lane to truck traffic, a policy that would be controversial, have potentially severe consequences for other road users, and lead to increased taxation of trucking operations. The addition of a third class, improved operational efficiency, would effectively guarantee a set of policies that appeal in some way to all industry segments. The other advantage of these three sets of policies is that they each encompass a set of policies that can be implemented in small pieces and targeted to severely congested regions (Golob and Regan, April 1999).

Similar research was reported for a subset of trucking companies that serve California marine terminals. The research concluded that:

- Information technologies hold particular promise for reducing delays inside and outside ports. Increased use and reliability of container status inquiry systems which supply carriers with information about what has been unloaded, and where on the port property containers are stored, could go a long way in preventing the problem of drivers arriving at the port before their loads are ready to be moved. Additionally, information about when carriers have scheduled their pickups at the port could help port operators make more appropriate decisions about short, medium and long term staging areas for unloaded containers.
- It seems likely that further improvements in marine international operations will be the result of creative public/private sector collaboration. Goods movement, once primarily a private sector concern is of increasing interest to local, regional and state governing agencies determined to support "sustainable" growth (Regan and Golob, June 1999).

The final set of research reports from the California based truck operator survey concerned perspectives on the usefulness of various sources of traffic information (Golob and Regan, 2000) and trucking industry adoption of information technology (Golob and Regan, 2000). Both reports suggest that the trucking sectors vary by reliance on congestion information and use of different information technologies.

The Golob and Regan literature is of value primarily because it attempts to draw relationships between different operational sectors of the trucking industries and issues related to congestion and responses thereto. A different approach taken by Nagarajan, et. al. emphasizes that innovations in the trucking industry have addressed two basic issues: the enhancement of value to customers at an affordable price and the utilization of information to improve business practices through the application of technology. The non-technological factors influencing the trucking industry are identified as: 1) globalization; 2) intermodalism; 3) changing distribution practices; 4) competitive pressures on price and service; 5) labor productivity and workforce skills; and 6) environmental and safety factors. Technological factors influencing the trucking industry are identified as: 1) telecommunications; 2) computer hardware and software; 3) navigation and positioning systems; 4) surveillance, sensing and tagging technologies; and 5) data exchange and blending. The paper presents an overview of the non-technological and technological factors as well as a conceptual model of the influence of these elements on innovation and firm performance. Although the paper concludes with some obvious effects of technology on the trucking industry, it primarily depicts how different the trucking industry is today from a decade ago.

An attempt to formulate logistics restructuring from hypothetical reductions in average transit time and variability for a sample of fifty shippers along the Interstate 5 corridor in Oregon is quite divorced from the esoteric content of much of the trucking industry literature related to transit time. This "case study" seems to exist to demonstrate that something (logistics restructuring) changes based on shipper responses to degradations of transit time and/or reliability. The theoretical approach to estimate the benefits to industry from a network of infrastructure improvements is succinctly presented as a step-wise procedure:

1. Assess the improvements in travel times and travel time reliability throughout the affected region. Divide the region into sub-regions with distinct transport characteristic impact.
2. Survey the sources of business activity in the region that depends on freight transport. The identified firms need to be categorized according to 1) sub-regions with unique characteristics; and 2) type of industry.
3. For each category of firms the following information needs to be obtained: 1) total sales; 2) logistics costs as a percentage of sales; and 3) relevant elasticities of logistical costs.

However, rather than proceeding with this methodology a "short-form" approach was utilized for a sample of fifty firms to estimate the two types of cost reductions, cost reductions due to logistics restructuring and conventional cost reductions (related to vehicle operating cost time savings). A survey instrument addressed "small," hypothetical degradations in average transit time and variability of transit time that would not prompt logistics restructuring and larger changes that would prompt logistics restructuring. A critical assumption is that the willingness to pay for an improvement in the transportation conditions is the same as the willingness to accept compensation for a decline in these conditions.

The findings reflect the limitations of the survey: only three out of fifty firms would restructure their logistics if the predictability in travel time improved (note assumption of similar elasticities for service degradations and improvements in average transit time and variations of transit time) by twenty percent or the average transportation time is decreased by seventeen percent. Not surprisingly, the three firms that would restructure their logistics in response to changes in transit time reflected the food industry (two respondents) and a manufacturer of office supplies. Otherwise the study notes that:

> *It is interesting that other 10 firms claim that they would restructure their logistics in response to a sufficient change in travel time reliability or travel time, but they do not provide cost information. It is assumed that all the 47 firms, for which cost information is not available or does not respond to the question, would not restructure. The above result suggests the value of the industry restructuring benefits is quite probable to be of magnitude several times higher than the estimates obtained in this report.*

The case study attempts to arrive at a quantitative estimate of the benefits from logistics restructuring using three pivotal assumptions:

1. all industries in the manufacturing sector, on average, experience the same benefit from restructuring, expressed as a cost margin;
2. the sample is considered representative for the industry; and
3. the transportation improvements are big enough to prompt logistics restructuring. Progressing from these laudable assumptions the study indicates that the vague answers to some questions requires the data to be interpreted by assuming a reasonable range of logistics restructuring benefits.

It was noted that on average a twenty- percent change in travel predictability or a seventeen- percent change in travel time would prompt restructuring. The study also notes that:

> *An interesting finding is that 10 firms say, in answering question A, that they would restructure in response to some degradation in predictability, travel time or both, but these firms did not provide any information in Question C about their current and expected logistics costs after a restructuring (DKS Associates).*

The study concludes with upper and lower bound estimates of industry benefit from logistics restructuring, expressed as a markup from unit costs, assuming that all surveyed firms have the same relative weight, of 0.45 and 0.25 percent respectively. The range of restructuring benefits would be between $62 and $111 million (1997 dollars) a year for the region of Oregon affected by Interstate 5 corridor improvements. The present value of the stream of potential logistics restructuring benefits would be $584 to $1046 million (1997 dollars).

The study concludes that:

> *The benefit from logistics restructuring should not be neglected, though probably it is not enough on its own to justify an infrastructure investment. It is worth remembered that this benefit comes in addition to the conventional benefit stemming from transportation time and cost savings, and may, in some cases change the balance of benefits and costs in favor of the former (DKS Associates).*

Although of recent vintage, the work by Nagarajan, et. al. fails to address the integration of trucking into supply chains through emerging IT systems. The rapid growth in electronic business for both industrial distribution (business to business or B2B) and consumer distribution (business to customer or B2C) is reviewed by Chow to define impacts on transportation industrial organization, particularly trucking. Chow identifies emerging forces that are affecting the role of truck service providers such as supply chain disintermediation, supply chain integration, and the state of the art of e-business maturity reflecting the development and utilization of the Internet by transportation companies.

According to Chow there are different business models of carrier participation in emerging electronic freight exchanges that affect shipper and truck service provider relationships:

1. Virtual Third Party Logistics (TPL) dot.coms, representing one stop access to multiple transportation and logistics services from multiple suppliers and extensive decision support offered through an intermediary;
2. sites representing multiple transport carriers and logistics expertise offered as a consulting service in place of an extensive decision support from an affiliated intermediary; and
3. transportation for a specific industry sector.

At this time in the very early stages of electronic logistics networks it is premature to accurately predict whether these information networks will supplement traditional business relationships by concentrating only on spot market movements such as backhauls or the medium will rise to a role of dominating freight service selection. Regardless of the future of different forms of Internet logistics service providers it seems clear that there are fundamental implications for the business model of transportation firms, particularly trucking. Trucking will increasingly become an integral part of electronic logistics because of IT linkages based on speed and reliable processing of information. While some of the trends are evident, such as supply chain disintermediation leading to increased number of small shipments, other elements of the IT service provider organization are less understood, particularly with regard to traditional market structures of transportation service providers such as trucking.

4.3 Relevance of this Body of Literature to the Freight BCA Study

The literature pertinent to "logistics restructuring" benefits of highway improvements suggests that past efforts to empirically relate transportation improvements to logistics cost savings have seriously underestimated the analytical complexities and paucity of non-proprietary information that could be obtained to sustain causal relationships. Indeed, it is by no means clear that the full logistics complexities are sufficiently understood and/or sufficient resources are provided for their identification as witnessed by the DKS short form methodology.

There appear to be three components and applications of the literature germane to highway improvements and logistics restructuring.

- First, the effect of highway improvements on truck service providers with regard to decreased transit time performance (average and variability). It seems reasonable that logistics managers would not normally be able to directly associate highway improvements with transit time changes unless they had responsibility for a private truck fleet which had comparable operating circumstances to typical for-hire sector general freight less than truckload (LTL) and truckload (TL) service providers.

  The impacts of highway improvements on truck service capabilities (transit time) should best be determined from relevant sectors of the trucking industries. Work done for the Port Authority of New York and New Jersey on truck sensitivity to congestion toll incentives supports the work of Regan and Golob that trucker perceptions of congestion and improvements vary by sector (Berger). Highway improvements that reduce congestion, whether through additional capacity or changes in the use of existing infrastructure will be perceived differently by various truck sectors as having relevance to transit time average and variability and resulting impacts on vehicle productivity measured in trips or stops.[17]

- Second, the effect of <u>transit time</u> improvements on logistics system inputs can most likely be empirically addressed by logistics managers in relatively controlled environments where there is a similarity of product characteristics from the standpoint of logistics inputs and requirements. Ideally, the firms to utilize would have multiple production and/or distribution warehouse locations such that network effects of changes in transit time could be heuristically simulated and network costs compiled. Firms, which have recently conducted warehouse location analysis, would

[17] Typically local truck general freight service provider response to changes in congestion is oriented to the effect on cost of operation (time) and vehicle opportunity costs (trips or stops) rather than a logistics shipment perspective of measures of average and variable transit times.

appear to be more likely to be able to empirically address the logistics restructuring cost savings compared to asking hypothetical questions to a senior manager of a multi-product enterprise.

- Third, IT has brought about radical changes in the integration of trucking companies into supply chains. There are obvious substitution effects between transit time performance (mean and variability) and the speed and accuracy of order processing and fulfillment. To some degree the capability of real time monitoring of shipments enables potential late shipments to be subject to early warning tests and possible corrective action taken to minimize lateness by expediting, substituting or rescheduling shipment or production. These actions should reduce the level and importance of safety stock relative to probabilistic occurrences of late shipments. Real time shipment tracking would appear to diminish the importance of safety stock to reduce potential lost sales (or disrupted production) to the extent that potentially late shipments can be corrected. Similarly, JIT systems would appear to reduce the impact of highway improvements on finished goods warehousing for affected product sectors.

Alternatively, to the degree that highway congestion affecting truck transit time reliability is non-reoccurring, and alternatives for shipment expediting or substitution are very limited, for example retail deliveries in Manhattan from a warehouse in New Jersey, IT offers less opportunity than highway improvements that reduce these delays such as improved information. In the retail sector the reliance on imports and seasonal merchandise interfacing with local marine terminal highway connector congestion may affect the demand for number of warehouses.

The literature pertinent to the impacts of highway improvements on transit time as well as technological changes in the trucking industries suggest that distinguishing causal relationships of highway improvements on logistics has become more complex due to the IT integration of trucking in supply chain commercial relationships. Although web based supply chain IT linkages between shippers and intermediaries, including trucking, are still evolving, the new organizational relationships should be more fully understood to identify whether there are distinctions between supply chain organization of truck service providers and the importance of transit time performance as an independent variable that can be linked to logistics restructuring.

4.4 Concluding Remarks

The public domain literature that contains empirical relationships of the impacts of transit time improvements on logistics system restructuring is for all practical purposes non-existent. The reasons are obvious since this is a highly specialized avenue of inquiry that has different applications within and between distribution networks, for example inbound versus outbound logistics and JIT demand pull versus traditional production push systems. As least total cost logistics systems evolved IT has made transportation service primarily a commodity that is bought at a minimum price in conformity to a set of shipment service specifications, including transit time.

Deregulation of trucking has allowed a wide menu of competitive services and contractual relationships to integrate transportation into supply chain networks wherein the motor carrier has become an extension of the shipper logistics organization. In some instances shipper selection of motor carriers is entirely contracted to third party logistics service providers (3PL). For all possible practices motor carriers have lost their ability to discriminate or differentiate other than by integrating themselves into shipper logistics systems and supply chains through value added services (warehousing, assembly, etc.) or value added information capabilities (shipment tracing, status, etc.).

Distribution networks have become more complex over the last decade since the topic of logistics restructuring in response to transit time improvements was initiated. There has been a shift from seller or buyer logistics systems to integrated supply chain vertical relationships, typified by retailing, and substitution of electronic real time information for traditional elements of logistics such as forecasting and carrier delivery notifications in JIT systems. There is abundant evidence that logistics system productivity with respect to key drivers such as inventory performance measures have been maximized.

This suggests two diametrical possibilities for research into transit time improvements on logistics restructuring:

1. that sweeping productivity improvements have or are anticipated to be achieved through the integration of IT and fully integrated supply chains so that improvements in transit time would generally be regarded as insignificant relative to restructuring unless order of magnitude changes were achieved; or

2. supply chains that are at maximum productivity under full application of existing technology and organizational integration are awaiting transit time improvements for the next wave of logistics restructuring in the absence of further IT innovations. The likely reality is somewhere in between these scenarios, depending on the measures to define the logistics restructuring impacts of transit time improvements.

APPENDIX A - REFERENCES

1. American Petroleum Institute, The Benefits of Road Travel and Transport, American Petroleum Institute, 1998.
2. American Public Transit Association, Transit Performance and Productivity 1975-1980: Improvements through the Intergovernmental Partnership, American Public Transit Association, 1985.
3. Antle, John M., Infrastructure and Aggregate Agricultural Productivity: International Evidence, The Pakistan Development Review, Spring 1982.
4. Apffel, C. et al., Freight Components in Louisiana's Statewide Intermodal Transportation Plan, Transportation Research Record, No. 1552 (Planning and Administration), National Academy Press, 1996.
5. Apogee Research, Inc., Case Studies of the Link Between Transportation and Economic Productivity, U.S. DOT, FHWA, January 1991.
6. Apogee Research, Inc., Transportation: Key to a Better Future. The Relationship of Transportation Investments to Economic Growth: A Special Committee Report, American Association of State Highway and Transportation Officials, 1990.
7. Aschauer, David, Is Public Expenditure Productive, Journal of Monetary Economics 23, (pp. 177-200), 1989.
8. Aschauer, David, Genuine Economics Returns to Infrastructure Investment, Policy Studies Journal, Vol. 21, No. 2, (pp. 380-390), 1993.
9. Aschauer, David Alan, Highway Capacity and Economic Growth, Economic Perspectives, Vol. 14 (September/October), (pp. 14-24), 1990.
10. Aschauer, David Alan, Is Public Expenditure Productive?, Journal of Monetary Economics, Vol. 23, (pp. 177-200), 1989.
11. Aschauer, David Alan, Transportation Spending and Economic Growth: The Effects of Transit and Highway Expenditures, American Public Transit Association, September 1991.
12. Aschauer, David Alan, Why is Infrastructure Important?, Is There a Shortfall in Public Capital Investment? Proceedings of a Conference Held at Harwich Port, Massachusetts, June 1990.
13. Strauss-Wieder, Inc., The Role of the National Highway Collectors: Industry Context and Issues, U.S. Department of Transportation, Federal Highway Administration, April 1999.
14. Babcock, Michael; Bratsberg, Bernt, Economic Impacts of the Kansas Comprehensive Highway Program, Kansas Department of Transportation, June 1997.

15. Banister, D.; Capello, R.; Nijkamp, P. (eds.), European Transport and Communications Networks: Policy Evolution and Change, John Wiley & Sons, 1995.
16. Banister, D., Berechman, P. (eds.), Transport in a unified Europe: Policy Evolution and Change, Elsevier Science, 1993.
17. Baumol, W.J., Vinod, H.D., An Inventory Theoretic Model of Freight Transport Demand, Management Science, Vol. 16, No.7, pp.413-421, 1970.
18. Bell, Michael; McGuire, Therese, Macroeconomic Analysis of the Linkages Between Transportation Investments and Economic Performance, U.S. DOT, 1994.
19. Berndt, Ernst; Hansson, Bengt, Measuring the Contribution of Public Infrastructure Capital in Sweden, Scandinavian Journal of Economics Vol. 94, Supplement, (pp. 151-168), 1992.
20. Beshers, Eric, Effects of Highway Investment on the Competitiveness of US Firms, Transportation Quarterly, Vol 53 No. 3, 1999.
21. Binswanger, Hans; Khandker, Shahidur; Rosenzweig, Mark, How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India, The World Bank, Working paper, No. WPS 163, March 1989.
22. Bjorner, T.B., Environmental Benefits from Better Freight Transport Management: Freight Traffic in a VAR Model, Transportation Research, Part D: Transport and Environment, Elsevier Science, Ltd. (England), 1999.
23. Blanchard, Ghislain, Highway Benefit-Cost Analysis: A Review of Evidence, Transport Canada – Economic Analysis, June 1996.
24. Blanchard, Ghislain, Highways and Logistics and Production Performance, Transport Canada – Economic Analysis, June 1996.
25. Blum, Ulrich, Positive Externalities and the Public Provision of Transportation Infrastructure: an Evolutionary Perspective, Journal of Transportation and Statistics, October 1998.
26. Boarnet, Marlon G., Highway and Economic Productivity: Interpreting Recent Evidence, Journal of Planning Literature, Vol. 11, No. 4, (pp. 476-486), May 1997.
27. Boarnet, Marlon G., Infrastructure Services and the Productivity of Public Capital: the Case of Streets and Highways, National Tax Journal, Vol. 50, No. 1, (pp. 39-57) 1997.
28. Boarnet, Marlon, G., Road Infrastructure, Economic Productivity, and the Need for Highway Finance Reform, Public Works Management and Policy, 1998.
29. Boarnet, Marlon G., Spillovers and the Locational Effects of Public Infrastructure, Journal of Regional Science, Vol. 38, No. 3, 1998.
30. Borcherding, Thomas; Deacon, Robert, The Demand for the Services of Non-Federal Governments, The American Economic Review, (pp. 891-901), 1972.

31. Buechner, W.R., The Federal Highway Program and Highway Safety: An Economic Analysis, American Road and Transportation Builders Association (ARTBA), 1998.

32. Buechner, W.R., The Road to Prosperity: The Importance of the Federal Highway Program to the Economic Prosperity of Individual States, American Road and Transportation Builders Association (ARTBA), 1997.

33. Button, Kenneth, Freight Transport, Transport in a Unified Europe: Policies and Challenges, Banister, D. and J. Berechman (eds.), Elsevier, 1993.

34. Button, K.; Nijkamp, P.; Priemus, H. (eds.), Transport Networks in Europe: Concepts, Analysis and Policies, Edward Elgar, 1998.

35. Byrne, P.B.; Markham, W.J., Improving Quality and Productivity in the Logistics Process: Achieving Customer Satisfaction Breakthroughs, Council of Logistics Management, 1991

36. Cabago, J.; Fries, Steven, Restructuring Infrastructure in Transition Economies, Working Paper 21, Office of the Chief Economists, EBRD, May 1997.

37. Chow, Garland, E-business and the Future of the Canadian Transport Industry, CTA Review Working Paper, Sept 2000. (unpublished – not for citation)

38. Cisic, D.; Kesic, B.; Komadina, P., Investigation the Power in Freight Transport Communication Network Infrastructure, Promet Traffic – Traffico, Sveuciliste U Zagrebu (Croatia), 1999.

39. Clifford, W.; Corsi, T.; Grimm, C.; Evans, C., The Economic Effects of Surface Freight Deregulation, The Brookings Institute, 1990.

40. Conrad, Klaus; Seitz, Helmut, The Economic Benefits of Public Infrastructure, Applied Economics, Vol. 23, (pp. 303-311), 1994.

41. Cox, Wendell, Love, Jean, The Best Investment a Nation Ever Made: A Tribute to the Dwight D. Eisenhower System of Interstate and Defense Highways, American Highway Users Alliance, June 1996.

42. Crihfield, John; Panggabean, Martin, Is Public Infrastructure Productive? A Metropolitan Perspective Using New Capital Stock Estimates, Regional Science and Urban Economics, Vol. 25, (pp. 607-630), 1995.

43. Davis, H.W.; Drumm, W.H., Logistics Cost and Service 1999, Annual Conference Proceedings 1999, Council of Logistics Management, 1999.

44. De Brucker, K.; De Winne, N.; Peeters, C.; Verbeke, A.; Winkelmans, W., The Economic Evaluation of Public Investments in Transportation Infrastructure: The Use of Multicriteria Analysis, International Journal of Transport Economics, (pp. 261-281).

45. Delaney, R.A. A look back in anger at logistics productivity, 10th Annual State of Logistics Report, Cass Information Systems and ProLogis, 1999.

46. Delaney, R.A. Logistics and the internet, 11th Annual State of Logistics Report, Cass Information Systems and ProLogis, 2000.
47. DKS Associates in association with Gene Leverton and Associates, Hickling Lewis Brod, Inc., and Willamette Traffic Bureau, Inc., Freight Users/Shippers Logistics Interviews Interstate 5 Corridor, Oregon DOT, 1999.
48. DRI/McGraw-Hill, The Contribution of Transportation to Aggregate and Sectoral Productivity, U.S. DOT, FHWA, May 1994.
49. Duffy-Deno, Kevin; Eberts, Randall, Public Infrastructure and Regional Economic Development: A Simultaneous Equations Approach, Journal of Urban Economics, Vol. 30 (pp. 329-343), 1991.
50. European Commission – DG VII (NEI, et al), REDFINE: Relationship Between Demand for Freight Transport and Industrial Effects, 1999.
51. European Conference of Ministers of Transport (ECMT), Efficient Transport for Europe: Policies for Internalization of External Costs, OECD Publishing Service, 1998.
52. Fawaz, Youssef Mohamad, Alternative Truck/Highway Combinations: An Exploration of Opportunities for Major Productivity Gains in the Truck-Highway System, University of California at Berkeley, 1993.
53. Felton, J.R.; Anderson, D.G., Regulation and Deregulation of the Motor Carrier Industry, Iowa State University Press, 1989.
54. Fernald, John, Roads to prosperity? Assessing the Link Between Public Capital and Productivity, The American Economic Review, June 1999.
55. Ford, Robert; Poret, Pierre, Infrastructure and Private-Sector Productivity, Economic Studies, No. 17, Autumn, 1991.
56. Forkenbrock, D.J., External Costs of Inter-City Truck Freight Transportation, Transportation Research Part A, Vol. 33, pp 505-526, 1999.
57. Forkenbrock, David J.; Foster, Norman S.J., Accident Cost Savings and Highway Attributes, Transportation (24), (pp. 79-100), 1997.
58. Forkenbrock, David J.; Foster, Norman S.J.; Pogue, Thomas F., Safety and Highway Investment, Midwest Transportation Center, University of Iowa, June 1994.
59. Forkenbrock, D.; Pogue, T.; Foster, N.; Finnegan, D., Road Investment to Foster Local Economic Development, The Public Policy Center the University of Iowa, May 1990.
60. Forkenbrock, D.J., Foster, N.S.J., Economic Benefits of a Corridor Highway Investment, Transpn. Res.-A, Vol. 24A, No.4, pp 303-312, 1990.
61. Fraumeni, Barbara, Productive Highway Capital Stock Measures, U.S. DOT, FHWA, January 1999.

62. Frazier, C. et al., Analysis of Intermodal Terminal Highway Access to Economic Activity Centers, Transportation Research Circular, No. 459, Transportation Research Board, June 1996.
63. Gallamore, E.G., Regulation and Innovation: Lessons from the American Railroad Industry, Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer, Brookings Institution Press (pp. 493-529), 1999.
64. Garcia-Mila, Teresa; McGuire, Therese J., The Contribution of Publicly Provided Inputs to States' Economies, Regional Science and Urban Economics 22, (pp. 229-241), 1992.
65. Garland, C., North American Trucking Policy, Transport Economics: Selected Readings, Korea Research Foundation, 1995.
66. Gerondeau, C., The Road Network: Only the Road Can Relieve the Road, Transport in Europe, (pp. 65-93), 1997.
67. Gillen, David W., Transportation and Economic Development: A Review of the Recent Literature, Logistics and Transportation Review, (pp. 63-76), 1996.
68. Goodwin, P.B., A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes, Journal of Transport Economics and Policy, May 1992.
69. Golob, T.F., Regan, A.C., Freight Industry Attitudes Towards Policies to Reduce Congestion, Transportation Research-E, Vol. 36, pp. 55-57, 2000.
70. Golob, T.F.; Regan, A.C., Freight Operators' Perceptions of Congestion Problems and the Application of Advanced Technologies: Results from a 1998 Survey of 1200 Companies Operating in California, Transportation Journal, 1999.
71. Hancock, K.L., Freight Transportation Data, Transportation in the New Millenium, Transportation Research Board, 2000.
72. Hauser, Edd; Breese, Amy, Partnerships for Multimodal Transportation Planning, Transportation Research Board, No. 1552 (Planning and Administration), National Academy Press, 1996.
73. Hertz, Susanne, The Internalization Processes of Freight Transport Companies: Towards a Dynamic Network Model of Internalization, Stockholm School of Economics, 1993.
74. Hickling Corporation, Measuring the Relationship Between Freight Transportation Services and Industry Productivity, National Cooperative Highway Research Program, Transportation Research Board, 1994.
75. Hickling Corporation, Methodologies for Evaluating the Effects of Transportation Policies on the Economy, Transportation Research Board, National Research Council, March 1991.

76. Hickling Corpation, National Cooperative Highway Research Program Report 342: Primer on Transportation, Productivity and Economic Development, Transportation Research Board, National Research Council, September 1991.
77. HLB Inc., Social Cost Pricing and the External Benefits of Trucking, American Trucking Association Foundation, December 1997
78. Holleyman, Chris, Industry Studies of the Relationship Between Highway Infrastructure Investment and Productivity, Logistics and Transportation Review, (pp. 93-117), 1996.
79. Hooper, P.G., Productive Change in Transport: a Survey, Transport Reviews, Vol. 7, No. 4, (pp. 341-367), 1987.
80. Hulten, Charles; Schwab, Robert M., Regional Productivity Growth in US Manufacturing: 1951-78, American Economic Review, Vol. 74 No. 1 (pp. 152-162), March 1984.
81. Hulten, Charles, Schwab, Robert M., Public Capital Formation and the Growth of Regional Manufacturing Industries, National Tax Journal, Vol. XLIV No. 4, (pp.121-134), 1992.
82. Husak, Volodymyr; Glenn, Thomas, The Impact of Transportation Investment on Factor Productivity in Texas, Texas Transportation Institute, May 1998.
83. Jack Faucett Associates, Report of the Private Sector Panel of the Federal Infrastructure Strategy Program, U.S. Corps of Engineers, 1995.
84. Jack Faucett Associates, Industry Studies of the Relationship Between Highway Transportation and Productivity, U.S. DOT, FHWA, 1994.
85. Jack, William, Some Guidelines for the Appraisal of Large Projects, Internal Discussion Paper: South Asia Region, The World Bank, (pp. 1-62), February 1993.
86. Jacoby, Arthur, Recent Advances in Understanding the Effects of Highway Investment on the U.S. Economy, Transportation Quarterly, Vol. 53, No. 3, (pp. 27-34), 1999.
87. Jansson, Owen Jan, Government and Transport Infrastructure–Pricing, Polak J. and A. Heertje (eds.), European Transport Economics, (pp. 188-219), 1993.
88. Keeler, Theodore; Ying, John, Measuring the Benefit of a Large Public investment–The Case of the US Federal-Aid Highway System, Journal of Public Economics, Vol. 36, (pp. 69-85), 1988.
89. Kessides, Christine, A Review of Infrastructure's Impact on Economic Development, Infrastructure and the Complexity of Economic Development, 1996
90. Kessides, Christine, The Contributions of Infrastructure to Economic Development: A Review of Experience and Policy Implications, World Bank Discussion Paper #213, (48 pages including bibliography), 1993.

91. Khanam, Bilkis, Macroeconomic Performance and Public Highway Infrastructure, Transport Canada – Economic Analysis, June 1996.
92. Kiriazidis, Theo, European Transport: Problems and Policies, Avebury, 1994.
93. Kuehn, John A.; West, Jerry G., Highways and Regional Development, Growth and Change, (pp. 23-28), 1971.
94. Lakshmanan, T.R., Review of International Studies of the Productivity Effects of Highway Infrastructure, Economic Returns from Transportation Investments, Eno Transportation Foundation, 1996.
95. Lewis, David, Ensuring Productive Investment in Transportation Infrastructure, Policy Study No. 159, Reason Foundation, June 1993.
96. Lichter, Daniel T.; Fuguitt, Glenn V., Demographic Response to Transportation Innovation: The Case of the Interstate Highway, Social Forces, Vol. 59:2 (pp. 492-511).
97. Lombard, Paulus Cornelius, The Relationship Between Highway Infrastructure and Regional Economic Development, University Thesis (UMI Dissertation Services), 1991.
98. Luker, Bill, Public Investment and U.S. Productivity Change: An Evaluation of Recent Research, Texas Transportation Institute, June 1992.
99. Mackie, Peter, Induced Traffic and Economic Appraisal, Transportation 23, (pp. 103-119), 1996
100. Marks, D.; Sutton, W.L., Highways and the New Wave of Economic Growth, Public Roads, Federal Highway Administration, July 1999.
101. McKinnon, Alan and Allan Woodburn, Logistical Restructuring and Road Freight Traffic Growth: An empirical Assessment, Transportation 23 No. 2 (pp 141-161).
102. Mendoza et al., Analysis of Vehicles for International Motor Transport of Freight Between Mexico and other NAFTA Countries, Transportation Research Record, No. 1602: Freight Transportation (Multimodal), National Academy Press, 1977.
103. Middendorf, D.P.; Bronzini, M.S., The Productivity Effects of Truck Size and Weight Policies, U.S. Dot, FHWA, November 1994.
104. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Spain, Capitulo II: Infraestructuras y Actividad Economica, Plan Director de Infrastructuras: 1993-2007, 2nd edución. 1994.
105. Ministerie van Verkeer en Waterstaat, Adviesdient Verkeer en Vervoer, Economic Benefits of Intermodal Transport, 1997
106. Herbert Mohring and Harold Williamson, Jr., Scale Economies of Transport Improvements, Journal of Transport Economics and Policy, Volume 3, Number 3, September 1969.

107. Herbert Mohring, Transportation Economics, (especially chapters 8 and 11), 1977.

108. Morrison, Catherine; Schwartz, Amy, State Infrastructure and Productive Performance, The American Economic Review, Vol. 86, No. 5, (pp. 1095-1109), 1996.

109. Morrison, S.A.; Winston, C., Regulatory Reform of U.S. Intercity Transportation, Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer, Brookings Institution Press (pp. 469-492), 1999.

110. Muller, Gerhardt, Intermodal Freight Transportation, 3rd edition, Intermodal Association of North America, Eno Transportation Foundation, Inc., 1995.

111. Munnell, Alicia H., How Does Public Infrastructure Affect Regional Economic Performance?, New England Economic Review, (pp. 11-32), 1990.

112. Munnell, Alicia, How Does Public Infrastructure Affect Regional Economic Performance?, Is There a Shortfall in Public Capital Investment?, Proceedings of a Conference Held at Harwich Port, Massachusetts, June 1990.

113. Munnell, Alicia H., Infrastructure Investment and Economic Growth, Journal of Economic Perspectivies, Vol. 6, no. 4, (pp. 189-198), Fall 1992.

114. Nadiri, Ishaq M., Contribution of Highway Capital to Industry and National Productivity, Research Report prepared for US Federal Highway Administration (US DOT), March 1996.

115. Nadiri, M.I.; Mamuneas, T.P., Contribution of Highway Capital to Output and Productivity Growth in the US Economic and Industries, Research Report prepared for the US Federal Highway Administration (US DOT), August 1998.

116. Nadiri, Ishaq; Mamuneas, Theofanis, The Effect of Public Infrastructure and R&D capital on the Cost Structure and Performance of U.S. Manufacturing Industries, Review of Economics and Statistics, Vol. 76, No. 1, (pp. 22-37), 1994.

117. Nagarajan, Anuradha; Bander, James; White, Chelsea C., Trucking--US Industry in 2000: Studies in Competitive Performance, The National Academy Press, 199?.

118. National Highway Traffic Safety Administration, The Economic Cost of Motor Vehicle Crashes, 1994, NHTSA, 1994.

119. Nijkamp, P.; Vleugel, J.; Maggi, R.; Masser, I. (eds.), Missing Transport Networks in Europe, Avebury, 1994.

120. Norris, Bahar; Haines, Marsha, Implications of Intermodal Freight Movements for Infrastructure Access, Capacity, and Productivity, U.S. DOT, 1996.

121. Organization for Economic Co-operation and Development (OECD), Advanced Logistics and Road Freight Transport, OECD, 1990.

122. Oum, T.H., Alternative Demand Models and their Elasticity Estimates, Journal of Transport Economics and Policy 23 (2), 163-87, 1989.

123. Oum, T.H., Waters, W.G., Yong, J-S., Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates, Journal of Transport Economics and Policy, May 1992.
124. Peterson, George, Is Public Infrastructure Undersupplied?, Is There a Shortfall in Public Capital Investment? Proceedings of a Conference Held at Harwich Port, Massachusetts, June 1990.
125. Pinnoi, Nat, Transportation and Manufacturing Productivity, Texas Transportation Institute, October 1993.
126. Prud'homme, Remy, Assessing the Role of Infrastructure in France by Means of Regionally Estimated Production Functions, Infrastructure and the Complexity of Economic Development, 1996.
127. Queiroz, Cesar and Surhid Gautam, Road Infrastructure and Economic Development: Some Diagnostic Indicators, Policy Research Working Paper, Western African Department and Infrastructure and Urban Development Department, the World Bank, 1992.
128. Quarmby, D.A., Developments in the Retail Market and their Effect on Freight Distribution, Journal of Transport Economics and Policy, Jan 1989.
129. Queiroz, Cesar; Haas, Raplh; Cai, Yinyin, National Economic Development and Prosperity Related to Paved Road Infrastructure, Transportation Research Record 1455, (pp. 147-152), 1994.
130. Regan, A.; Holgun-Veras, J.; Chow, G.; Sonstegaard, M.H., Freight Transportation Planning and Logistics, Transportation in the New Millenium, Transportation Research Board, 2000.
131. Rephann, Terance James, A Study of the Relationship Between Highways and Regional Economic Growth and Development Using Quasi-Experimental Control Group Methods, Ph. D dissertation, University of West Virginia (381 pages), 1993.
132. Robert, P.O.; Fauth, G., The Outlook for Commercial Freight, Special Report 220: A Look Ahead – Year 2020, Transportation Research Board, 1988.
133. Roeseler, W.G.; Smithson, C.W., The Impact of Technological Change in Transportation Networks on Regional Productivity and Development, U.S. DOT, August 1980.
134. Rolle, J.-D., Estimation of Swiss Railway Demand with Computation of Elasticities, Transportation Research-E, Vol. 33, No. 2, pp. 117-127, 1997.
135. Rothengatter, Wener, Do External Benefits Compensate for External Costs of Transport?, Transportation Research, Part A, Vol. 28A No. 4, (pp. 321-328), 1984.
136. Savage, I., The Economics of Commercial Transportation Safety, Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer, Brookings Institution Press, (pp. 531-562), 1999.

137. Shah, Anwar, Dynamics of Public Infrastructure, Industrial Productivity and Profitability, The Review of Economics and Statistics, (pp. 28-36), 1992.

138. Shah, Anwar, Public Infrastructure and Private Sector Profitability and Productivity in Mexico, The World Bank, Working Papers, Country Economics Department, WPS 100, (41 pages), September 1988.

139. Stephanedes, Yorgos, Transportation and Economic Development: Final Report–Executive Sumary, Submitted to Research Administration and Development Section Office of Materials and Research, Minnesota Department of Transportation, (11 pages), May 1989.

140. Stephanedes, Yorgos J.; Eagle, David, Highway Impacts on Regional Employment, Journal of Advanced Transportation, Vol. 21, (pp. 67-79), Spring 1987.

141. Stephanedes, Yorgos J.; Eagle, David, Highway Expenditures and Non-Metropolitan Employment, Journal of Advanced Transportation, 20:1 (pp. 43-61), 1986.

142. Szostak, Rick, The Role of Transportation in the Industrial Revolution, McGill-Queen's University Press, 1991.

143. Talley, Wayne, Linkages Between Transportation Infrastructure Investment and Economic Production, Logistics and Transportation Review, (pp. 145-154), 1996.

144. Taylor, Richard; Casavant, Kenneth, Lenzi, J.C., Rail Line Abandonment and Public Acquisition Impacts on Economic Development, Transportation Research Record, No. 1274, 1990.

145. Tone-Gout, M, M.; van Sinderen, J., The Impact of Investment in Infrastructure on Economic Growth, Erasmus University Rotterdam, 1994.

146. Transportation Research Board, National Research Council, New Trucks for Greater Productivity and Less Road Wear, Transportation Research Board, 1990.

147. Transportation Research Board, Paying Our Way: Estimating Marginal Social Costs of Freight Transportation, Transportation Research Board, 1996.

148. Transportation Research Board, Committee for Study of Policy Options to Address Intermodal Freight Transportation, Policy Options for Intermodal Freight Transportation, Transportation Research Board, 1998.

149. Transportation Research Board [consultants: Hickling Corporation], NCHRP Report 342, A Primer on Transportation and Economic Development (pp. i-xvi, 1-79), 1991.

150. Transportation Research Board (Louis Berger Group), NCHRP Report 421: Economic Trends and Multimodal Transportation Requirements, 1999.

151. Transportation Systems Center, Cambridge, MA, Highways and the Economy, Prepared for the Federal Highway Administration, (118 pages), 1983.

152. Trowbridge, Amity et al., The Potential for Freight Productivity Improvement Along Urban Corridors, Washington State Transportation Center, December 1996.

153. Tyworth, J.E., Zeng, A.Z., Estimating the Effects of Carrier Transit-time Performance on Logistics Cost and Service, Transportation Research-A, Vol. 32, No.2, pp. 89-97, 1998.

154. U.K. Department of the Environment, Transport and the Regions (DETR), Transport and the Economy, UK DETR, 1999.

155. U.S. Department of Transportation, FHWA, Assessing the Relationship Between Transportation Infrastructure and Productivity, Search for Solutions: A Policy Discussion Series, U.S. DOT, August 1992.

156. U.S. Department of Transportation, Federal Highway Administration, Office of Program and Policy Planning, Benefits of Interstate Highways, 1983.

157. U.S. Department of Transportation, Office of Intermodalism, The Impacts of Changes in Ship Design on Transportation Infrastructure and Operations, U.S. Department of Transportation.

158. U.S. Department of Transportation, Federal Highway Administration, Office of Program and Policy Planning, Highway Infrastructure Investment and Job Generation: A Look at the Positive Employment Impacts of Highway Investment, 1996.

159. U.S. Department of Transportation, Productivity and the Highway Network: A Look at the Economic Benefits in the Highway Network, Federal Highway Administration, 1996.

160. U.S. Department of Transportation, Rebuilding America: Partnership for Investment, U.S. DOT, FHWA, 1994.

161. U.S. Department of Transportation–FHWA, FTA, MA, 1995 Status of the Nation's Surface Transportation System: Conditions and Performances, Report to Congress, U.S. DOT, 1995.

162. U.S. Department of Transportation, FHWA, 1997 Federal Highway Cost Allocation Study: Final Report, U.S. DOT, 1997.

163. U.S. General Accounting Office, Longer Combination Trucks: Potential Infrastructure Impacts, Productivity Benefits, and Safety Concerns, GAO, August 1994.

164. Weisbrod, G. and Treyz, F., Productivity and Accessibility: Bridging Project-Specific and Macro- Economic Analyses of Transportation Investments, Journal of Transportation and Statistics, October 1998.

165. Williams, A.W., Transport, Rights-of-Way and Compensation: Injurious Affection from an Economic Perspective and Some Australian Evidence of Freeway Impacts (Part II), International Journal of Transport Economics, October 1993.

166. Wilson, Frank R.; Stevens, Albert M.; Holyoke, Timothy R., Impact of Transportation on Regional Development, Transportation Research Record 851, (13-16), 1982.
167. Wilson, F.R.; Graham, G.M.; Aboul-Ela, Mohamed, Highway Investment as a Regional Development Policy Tool, Transportation Research Record, (pp. 10-14), 1985.
168. Xin, Yang, Study of Regional Economic Benefit Model of Transportation System Projects, International Journal of Transport Economics, (pp. 89-105), 1996.
169. Zavatero et al., Mainstreaming Intermodal Freight Into The Metropolitan Transportation Planning Process, Transportation Research Record, No. 1613: Freight Transportation, 1998.
170. Zingales, Luigi, Survival of the Fittest or the Fattest? Exit and Financing in the Trucking Industry, NBER, November 1997.
171. Zegeye, Aklilu A., U.S. Public Infrastructure and Its Contribution to Private Sector Productivity, Bureau of Labor Statistics Economics Research Paper-WP 320, 2000.