Supply Chain Benefits from Highway Investments

Conventional methods of cost/benefit analysis for evaluating the benefits of highway investments measure only a portion of the total benefits which may theoretically accrue. Some benefits which are theoretically possible are not included due to a lack of consensus on their actual existence and attribution. Others are excluded due to difficulties in measurement. Calculation of the benefits to commercial traffic from highway benefits have often been calculated as an afterthought, based on a simple percentage of truck traffic from traffic counts.

One of the most common tools used for cost/benefit analysis of highway projects is MicroBENCOST. MicroBENCOST was developed in the early 1990's through the U.S. Transportation Research Board's National Cooperative Highway Research Program (NCHRP)[1]. Categories of benefits assessed in MicroBENCOST are limited to user travel times, vehicle operating costs, and reductions in accidents.

A 1998 paper by Weisbrod and Treyz[2] identified three categories of benefits from highway investments:

1. reduced travel costs for serving existing trips;
2. reduced inventory/logistic costs; and
3. greater operating scale and accessibility economies.

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[1] http://www.dot.ca.gov/hq/tpp/offices/ote/Benefit_Cost/models/microbencost.html

[2] Productivity and Accessibility: Bridging Project-Specific and Macroeconomic Analyses of Transportation Investments Glen Weisbrod and Frederick Treyz, Journal of Transportation and Statistics, v.1, n.3, 1998.

Only the first category is captured in conventional evaluation methods such as those embodied in MicroBENCOST. For commercial traffic, the value of time is based on the operating costs of various truck classes, and aggregate benefits are calculated based on forecasts of truck traffic as a percentage of Annual Average Daily Traffic levels.

Multiple Criteria Evaluation techniques such as the Multiple Accounts Evaluation framework used by the BC Ministry of Transportation assess a broader selection of potential benefits in a qualitative fashion, but do not attempt to quantify them.

This study focuses on the second category identified by Weisbrod and Treyz: inventory and logistics costs. There have been numerous recent articles and studies focusing on estimation of the benefits to firms in terms of reduced inventory and logistics costs for firms. Two major examples are discussed below.

The U.S. Federal Highway Administration (FHWA) began a major study in 1994 examining potential impacts of changes in truck weights in dimensions regulations. This study was published in 2000 as the U.S. Department of Transportation Comprehensive Truck Size and Weight Study (CTSWS).[3] It explicitly analyzed inventory costs primarily due to the potential for shifts between truck and rail intermodal under various truck weights and dimensions scenarios:

> *A major part of the study involved developing and testing analytical tools to estimate potential diversion of traffic from one type of truck to another or between rail and truck if TS&W limits were changed. This study makes several significant improvements over previous studies by explicitly considering inventory and other logistics costs that shippers evaluate in making real-world transportation decisions and by analyzing*

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[3] Comprehensive Truck Size and Weight Study http://www.fhwa.dot.gov/reports/tswstudy/TSWfinal.htm

in detail large numbers of specific moves rather than a few typical moves.[4]

The CTSW identified major demand factors involved in mode selection including shipment size, frequency of delivery, speed (order cycle time), and reliability. The impact of changes in truck size and weights on shippers mode choice was analyzed using an Economic Order Quantity (EOQ) model to estimate the impact of regulatory changes based on commodity characteristics, particularly on product value and density.[5]

A major study was undertaken by Leachman et al in 2005 to estimate the impact of container fees on container traffic volumes at the Southern California ports of Los Angeles and Long Beach.[6] This study developed a long term elasticity model which allocates imports to ports and modes so as to minimize total inventory and transportation costs from the point of view of importers.[7]

Two major types of inventory cost were identified:

One is the cost of pipeline inventory for goods in transit from Asian factories to regional or national distribution centers that serve the importer's retail outlets in the United States. This cost is a linear function of the average transit time of the supply channel, the average declared value of the imports assigned to that channel, and the quantity routed via that channel. The other is the cost of safety stocks maintained at destination distribution centers. These stocks are established

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[4] Ibid., Executive Summary, http://www.fhwa.dot.gov/reports/tswstudy/EXECSUM4.htm

[5] Ibid., Working Paper 8: Logistics and Truck Size and Weight Regulations http://www.fhwa.dot.gov/reports/tswstudy/tswpaper.htm

[6] Final Report Port and Modal Elasticity Study Prepared for Southern California Association of Governments, Robert C. Leachman, in association with Theodore Prince, Thomas R. Brown and George R. Fetty; Sept. 8, 2005.

[7] Leachman, p. 6.

as a hedge against uncertainties in transit times and against potential errors in sales forecasts over the lead time from when the goods were ordered. This cost is a complex non-linear function of the variability in lead times and transit times of the shipping channels utilized, the volume assigned to each channel, and the statistical error in sales forecasts.[8]

Leachman found that "for many importers, the cost of their safety stocks is comparable to or even larger than the cost of their pipeline stocks. Moreover, the total cost of their pipeline and safety stock inventories is often larger than the total cost of transporting their goods from Asia to their destination distribution centers". [9]

Leachman found that both types of inventory costs are linear functions of the value of the goods imported. The average value per cubic foot for each commodity type was estimated from the World Trade Atlas, PIERS data, and Pacific Maritime Association data on the mix of marine container types (20ft, 40ft, 45ft) that are imported , supplemented by the consultant's estimates concerning the mix of standard and hi-cube 40-foot containers.

These studies illustrate the growing recognition of the impact of inventory costs on firms' logistics decisions, and the substantial role that reliability plays in determining the level of those costs.

The U.S. Federal Highway Administration (FHWA) has made available a modeling tool called the Intermodal Transportation and Inventory Cost State Tool (ITIC-ST) which was developed as part of the CTSWS, and further refined in the course of a major study on the impact of truck weights and dimensions in the Western U.S. States[10]. In addition to estimating changes in transportation costs, ITIC-ST

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[8] Leachman, p. 9.
[9] Leachman, p. 10.
[10] Western Uniformity Scenario Analysis. U.S. Federal Highway Administration, 2004
http://www.fhwa.dot.gov/policy/otps/truck/wusr/wusr.pdf

estimates the impact of the reliability of transportation on firms inventory and logistics costs.

This paper highlights a study done for the BC Ministry of Transportation which uses the ITIC-ST methodology to estimate the impact of increased highway reliability on inventory and warehousing costs for freight flows on the Highway 1 Corridor in B.C.

ITIC-ST is a disaggregate demand model which was developed to estimate the diversion potential generated by a change in the transportation levels of service or price that would likely be caused by improvements in transportation infrastructure, transportation operations, or government policy. It can also be used to calculate estimates of the economic benefits associated with such a change. The ITIC-ST model chooses the transportation alternative that minimizes total logistics costs. This process is repeated for a large number of disaggregate observations from a representative sample of shipper movements. The model summarizes the statistics on the analyzed sample to estimate mode share and travel demand.

The ITIC-ST model is not ideal for use in analyzing Canadian logistics behaviour, for a number of reasons:

1. Truck loadings are based on current U.S. federal and state weight limits, which in most cases are lower than those in Canada.
2. The model is calibrated specifically to U.S. highway infrastructure on a state by state basis.
3. Trucking and rail intermodal costs are based on a database of U.S. rates.

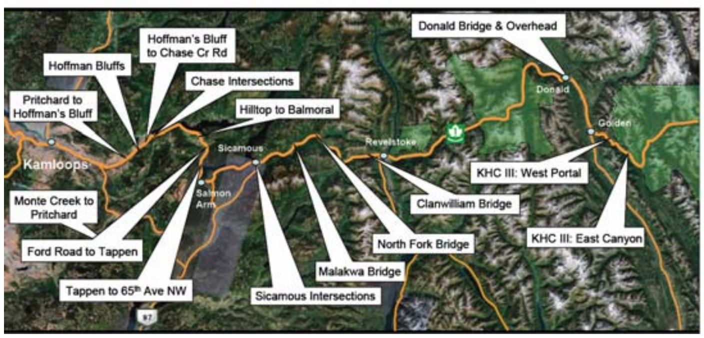
However, the model incorporates a calculation of the impact of transportation reliability on inventory and warehousing costs based on shipment volumes, density and value which is transferable to the Canadian situation.

<u>The Highway 1 Corridor in British Columbia</u>

Highway 1, the TransCanada Highway, is BC's major highway link with the rest of Canada. This study focuses on the section of Highway 1 between Kamloops and the Alberta border. The BC Ministry of

Transportation has developed a comprehensive plan for highway improvements in this section, with the objective of improving travel speed, reliability and other performance characteristics along the length of the corridor. Current project priorities under BC MOT's corridor plan are illustrated below:

HIGHWAY 1 KAMLOOPS TO GOLDEN



This highway segment carries a large portion of interprovincial truck traffic, including imports and exports associated with Asia-Pacific trade through the Lower Mainland ports.

<u>The ITIC Model and Transportation Reliability</u>

The ITIC model incorporates a calculation of the impact of transportation reliability on inventory and warehousing costs based on shipment volumes, density and value which is transferable to the Canadian situation. This calculation is incorporated through the use of probability functions related to transit time:

> *Special attention needs to be given to the reliability of the lead-time associated with the restocking of a product used on a continuous basis. Reliability has already been identified as one of the principal variables that affect the choice of mode and shipment size. Reliability as defined here is the variability in the ordering lead-time. Lead-time includes the time required for the shipper to receive the order from the user, pick the*

order from his inventory, arrange for carriage, wait for a vehicle to arrive at the shipping dock, load the shipment, and finally, to travel from the shipping point to the final destination. Reliability is important primarily because it impacts the amount of safety stock that needed to insure that the user does not run out of the item. Safety stock is typically a larger component of total logistics cost than many of the other costs (with the possible exception of transportation charges) because it must be carried continuously. If the user must break into the safety stock to avoid a stock-out, he must replace it immediately, or place the operation into jeopardy of a stock-out the next time he reorders.
At the time that the order is placed, there is uncertainty as to exactly when the shipment will arrive—more with some modes than with others. There is also variability in the use rate that may exacerbate the uncertainty that current stocks will last until the shipment arrives.[11]

This methodology relies on modeling of shipper behaviour in estimating the benefits of highway improvements. The benefits (in terms of inventory cost savings) are in addition to the benefits achieved through reductions in average travel time. Estimating these additional benefits requires data on the composition of freight traffic as well as information on the volume of truck traffic on the corridors. For purposes of this study, estimates of commodity flows from a study conducted by IBI Group in 2002 are used[12]. These are based on data collected in the National Roadside Survey conducted in the fall of 1999. These estimates were updated to take into account major economic changes since 1999, and to focus on the major traffic generators in each corridor.

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[11] ITIC-ST Version 1.0 Intermodal Transportation and Inventory Cost Model A Tool for States Technical Documentation pp. 12-13.
[12] British Columbia Trade Corridor Flow Study, Study prepared by IBI Group for Transport Canada, March 2002.

Traffic and Commodity Flow Estimates

An attempt was made to use the ITIC-ST model to generate commodity flow estimates based on truck volumes from the BC MOT permanent count station data and the data on the composition of traffic from the 2004 origin destination survey at Golden. However, this did not generate usable estimates. There are major discrepancies in the wood and paper products and petrochemical volumes relative to the 1999 Roadside Survey, and the overall volumes generated by the ITIC-ST model are significantly below those which would be expected. This may be due to the ITIC-ST truck loading parameters which are based on U.S. regulations, which generally limit Gross Vehicle Weights to levels below those permitted in Canada. For this reason, the ITIC-ST model was not used to estimate freight volumes in this study, only to generate estimates of inventory and warehouse cost savings based on enhanced reliability of the highway system.

Estimates of current freight volumes on this route were generated by applying a growth rate of 2.5% per year to all categories. The results are shown below:

Estimated Commodity Flows on the Trans Canada Highway At Golden (Tonnes)		
	BC Trade Flow Estimates (1999)	Estimated 2005 Volumes
Food and Beverage	1801100	2088724
General Freight (Incl. Mfd Goods, Machinery)	1726100	2001747
Wood and Paper products	713500	827441
Building Materials	72800	84426
Automotive	115600	134061
Metal Products	575600	667520
Petrochemical	300100	348024
Total	5304800	6151942

Reliability and the Highway Network

The ITIC model estimates firms' mode choice based on total costs. Inventory costs include holding costs and warehousing costs. Required inventory levels are defined as a function of mode choice (i.e. rail intermodal or specific truck configurations), commodity value and density, and transit time reliability over a three day order cycle.

For purposes of this study commodity density values were estimated from data on average import and export container loadings at the Port of Vancouver. Commodity values were estimated from Canada Customs data analyzed by Intervistas in the 2005 economic impact study done for the Vancouver Port Authority[13]. Values for forest products were based on industry specific data on lumber prices and volumes.

The resulting estimates of product these parameters for the major commodity groups transported by truck along the Highway 1 Corridor are shown below:

Commodity Density and Values	Density (Lbs/Cu. Ft.)	Value ($/Lb.)
Food and Beverage	13.3	$1.93
General Freight	5.2	$1.93
Wood and Paper	10.1	$0.43
Building Materials	23.8	$0.48
Automotive	7.9	$1.93
Metal Products	8.4	$0.48
Petrochemical	11.0	$0.14

The ITIC-ST model analyzes reliability as the probability of arrival of a shipment in a given time period. A Gamma probability distribution

[13] Vancouver Port Authority Economic Impact Update 2004 Intervistas Consulting, 2005.

is used to represent these probabilities, with the parameters of the distribution defined as functions of the mean and standard deviation of the travel time. These values are input into the model in the form of the coefficient of variation of travel times (the coefficient of variation equals the sample variance divided by the sample mean).

Estimates of highway corridor performance related to commercial vehicle movements have been collected by the BC Ministry of Transportation since 2004. These are based on travel times across segments of the highway system estimated from data generated by Global Positioning System (GPS) transponders used for tracking of trucks for fleet management purposes.

Performance of the highway corridor between the Vancouver Gateway and the Alberta Border via the Coquihalla Highway and Highway 1 for the August to October period in 2005 is shown below:

<u>Travel Time Performance Highway 1 Corridor Aug. – Oct, 2005</u>

CORRIDOR	**# OF OBS**	**AVG DIST (KM)**	**AVG SPEED (KPH)**	**STD DEV**	**COV**
Vancouver to Alberta	698	484	76	8.8	0.12
Alberta to Vancouver	819	483	76	8.3	0.11

For purposes of this analysis, estimates of changes in inventory and warehousing costs are generated based on a 20% reduction in standard deviation of trip times from the current average value of 12% recorded for this corridor by BC MOT’s performance measurement system

Model Results

The ITIC-ST model generates the following estimates of inventory and warehousing cost savings resulting from increased reliability of the highway system.

Estimated Reduction in Inventory and Warehousing Costs Due to Enhanced Reliability of Trans Canada Corridor

	Tonnes	Value ($ per lb)	Annual Cost Reduction
Food and Beverage	2088724	$1.93	$92,154
General Freight	2001747	$1.93	$136,891
Wood and Paper products	827441	$0.43	$40,157
Building Materials	84426	$0.48	$1,676
Automotive	134061	$1.93	$25,729
Metal Products	667520	$0.48	$45,649
Petrochemical	348024	$0.14	$9,981
Total	6151942		$352,238

Total benefits would include a one time saving in reduced inventory on completion, additional inventory savings based on inventory requirements for incremental traffic growth, and reductions in warehousing costs for the total volume for each year. On the basis of an annual growth rate of 2.5% per year and a discount rate of 10%, these benefits would total approximately $6.5 million as shown below:

Estimated Benefits - Increased Reliability of Highway 1 Corridor	
One Time Inventory Reduction	$4.4 Million
Ongoing Inventory and Warehouse Cost Reductions - Net Present Value	$2.1 Million
Total Benefits	$6.5 Million

Net Present Value over 25 Years with a discount rate of 10% per year.

At a truck traffic growth rate of 5% per year rather than 2.5%, the total benefits would be increased to $7.8 million.

Conclusions

This paper has demonstrated a method for estimating supply chain from increased reliability of the highway system. These benefits include a reduction in inventory holding and warehouse costs.

There is a solid case in economic theory for attributing these benefits to highway improvements. While this study is indicative rather than definitive in quantifying benefits because it relies on the assumption of reduced variability in travel times, the assumption could be readily tested through ongoing monitoring of travel time performance along highway corridors. The performance measurement system developed by the BC Ministry of Transportation accomplishes this, and can provide ongoing measurement of corridor performance as the Highway 1 Corridor Plan moves toward completion.

It may be useful to compare the status of supply chain benefits to the travel time benefits which typically account for the largest portion of highway user benefits resulting from investments in highway infrastructure. Travel time benefits are also logically attributable to highway improvements, and measurable in a similar fashion from ongoing monitoring of travel time performance. However, post-project evaluations of travel time benefits are not typically based on empirical data on travel times. The travel time reduction calculations are embedded in the highway benefit/cost models such as MicroBENCOST based on typical values for specified road configurations and traffic volumes.

If this method is deemed adequate for confirming the level of travel time benefits, a similar embedding of typical reductions in travel time variability could be embedded in the conventional benefit/cost models. If this could be accomplished, the only information which would be required in addition to the road data would be estimated of the composition and value of commodity traffic along the highway corridor.

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Appendix: ITIC Overview and Default Parameters

The Intermodal Transportation and Inventory Cost Model which forms the basis of the ITIC-ST Model was developed the U.S. Department of Transportation for a Comprehensive Truck Size and Weight Study undertaken in 2000.The U.S. Federal Highway Administration has made a version of the model available to assist state agencies and other interested parties in evaluating the impacts of policy changes including changes to truck size and weight regulations, heavy truck fees and infrastructure improvements. The model allocates traffic among these options based on cost and reliability parameters for specific commodity characteristics and origin-destination pairs.

The module of the model which is used in this study calculates the impact of mode choice on inventory and warehousing costs. The model calculates the values for these costs based on commodity density, value, and order cycle reliability. Order cycle reliability is a key variable because it determines the level of inventory firms require as safety stock to ensure product availability.

For this study, the model was used to calculate the potential impact of enhanced reliability resulting from improvements on major highway corridors on firms' inventory and warehousing costs. The default ITIC-ST parameters used to calculate inventory and storage costs include the following:

ITIC-ST Default Assumptions - Inventory and Handling Costs

GENERAL		
Operating Days per Year	365	days per year
Variation of Demand	40%	of average demand
Order Processing Cost	$100	per shipment
INVENTORY		
Cost of Capital	8.00%	per $/year
Marginal Tax Rate	40.00%	per $/year
Before Tax Cost of Capital	13.33%	per $/year

Non-Capital Holding Cost	5.75%	
Insurance	0.25%	per $/year
Taxes	0.50%	per $/year
Depreciation	5.00%	
Holding Factor for Whse Inventory	19.08%	per $/year
Holding Factor for In-Transit Inventory	13.33%	per $/year

TRANSPORTATION

Unitized Shipment Method	pallet	48" L x 40" W x 48" H
Unit Cubic Dimensions	53.3	cubic feet
Maximum Unit Weight	2,000	per pallet
Intermodal Management Company Fees	7%	of drayage & linehaul charges
TOFC or DS Ramp Handling Time	16	hrs per shipment
DS9 or TRIPLE Trailer Handling Time	4	hrs per shipment
Order-to-Ship Time	3	days

	Per Ton	Per Pallet	Per Ton	Per Pallet
HANDLING AND STORAGE	Bulk	Dry	Open	Temp Con
Handling Cost Per (Pallet or Ton)	$4.00	$6.00	$6.00	$12.00
Handling Minutes Per (Pallet or Ton)	$5.00	$10.00	$12.00	$12.00
Storage Cost Per (Pallet or Ton) Per Day	$0.05	$0.15	$0.10	$0.60