A Total Logistics Cost Approach to Measuring Collateral Benefits of Security and Supply Chain Improvements At International Gateways

Garland Chow

Associate Professor, Operations and Logistics
Director, Bureau of Intelligent Transportation Systems and Freight Security
Sauder School of Business, University of British Columbia

Calgary Asia Pacific Gateway and Corridor Round Table
March 28-29, 2007

garland.chow@freightsecurity.ubc.ca

Abstract
Freight security initiatives do not necessarily result in cost increase or reduced service. Security improvements can also reduce logistics and supply chain costs by improving supply chain visibility and enhancing transit reliability, resulting in collateral benefits to efficiency and effectiveness of the supply chain. Conversely, supply chain and logistics improvements may improve security, producing collateral benefits to security in the supply chain. Previous studies have examined the impact of security ex ante, typically through surveys. We develop a Total Logistics Cost model to simulate alternative logistics scenarios and security strategies to determine the influence of security initiatives on the total logistics cost. The application of the model to the Asia-Pacific Gateway is used to demonstrate the usefulness of such a model in evaluating how security impacts the total logistics cost of using this gateway and subsequently the gateway's competitive advantage.

The assistance of Amy Yeung and Kelly Loke is gratefully acknowledged.

1. Freight Security in North America

Since 9/11, the necessity of improving security in the supply chain has been a mandate for both the Canadian and U.S. governments. Shortly after the World Trade Centre terrorist attack, the Canada-US Smart Border Accord was introduced and signed by December 2001. The Accord reflected the reactionary security-focused climate after 9/11, but 5 years later, the underlying principles of the Accord are embedded in the security policies of both countries as confirmed by the Security and Prosperity Partnership of North America signed by all three NAFTA countries in 2006.

U.S. initiatives included:

- Advanced Manifest Rule (AMR) - Advanced Cargo Information (ACI US) requiring detailed data for all modes to be submitted to the U.S. Customs and Border Patrol (CBP) prior to arrival within certain time windows to allow pre-screening of incoming containers and vehicles.
- Container Security Initiative (CSI) which pushes inspection and screening of overseas containers to originating ports.
- Customs-Trade Partnership Against Terrorism (C-TPAT) which encourages the implementation of best practices and procedures in freight security in return for reduce inspections, expedited processing and other benefits such as “front of line” inspections.
- The Free and Secure Trade (FAST) initiative which allows low risk goods transported by trusted drivers and trusted carriers to pass rapidly through border crossings.
- The Smart and Secure Trade Lanes (SST) program to develop tests and deploy infrastructure that provides visibility, alerts and physical security for containers throughout the journey. These “secure” containers can then pass through borders in “green” lanes which require no inspection except for random checks.[1i]

Since the U.S. continues to be Canada’s single largest trading partner, U.S. security initiatives directly influence freight moving from Canada to the U.S. including freight in transit to the U.S. from other countries. Canada has also implemented many security initiatives for freight traffic entering Canada from the U.S. and other foreign countries. These include Partners in Protection (PIP) and Advance Commercial Information (ACI Canada), the Canadian equivalents to C-TPAT and ACE respectively, as well as Canada’s version of FAST.

2. The Asia-Pacific Supply Chain and the Asia-Pacific Gateway/Corridor

Trade in the Asia Pacific region is important to both North America and Asia. Asia and in particular China is one of the most important trading partners to both the U.S. and Canada for both exports and imports. At the same time, the U.S. continues to be Canada’s single largest

[1] An extensive review of security and other border regulations is found in Chow, Frank and Gados (2006).

trading partner. This trade and the integrated production-distribution networks that underlie this trade are highly dependent on an efficient and effective supply chain. The Asia Pacific Supply Chain is the integrated network of trading organizations supported by logistics, financial and information service providers on all sides of the Pacific. Together they manage the raw material sourcing, manufacturing, and delivery of goods from the source of the commodities to the ultimate users. Trading organizations include raw material providers, manufacturers, wholesalers, distributors and retailers. Logistics service providers include transportation carriers, forwarders, airport and seaport or port terminal operators, warehousing and distribution service providers, customs brokers and third party logistics providers. Other stakeholders involved in supply chain operations include governments, consultants, information service and software providers, financial institutions and insurance providers.

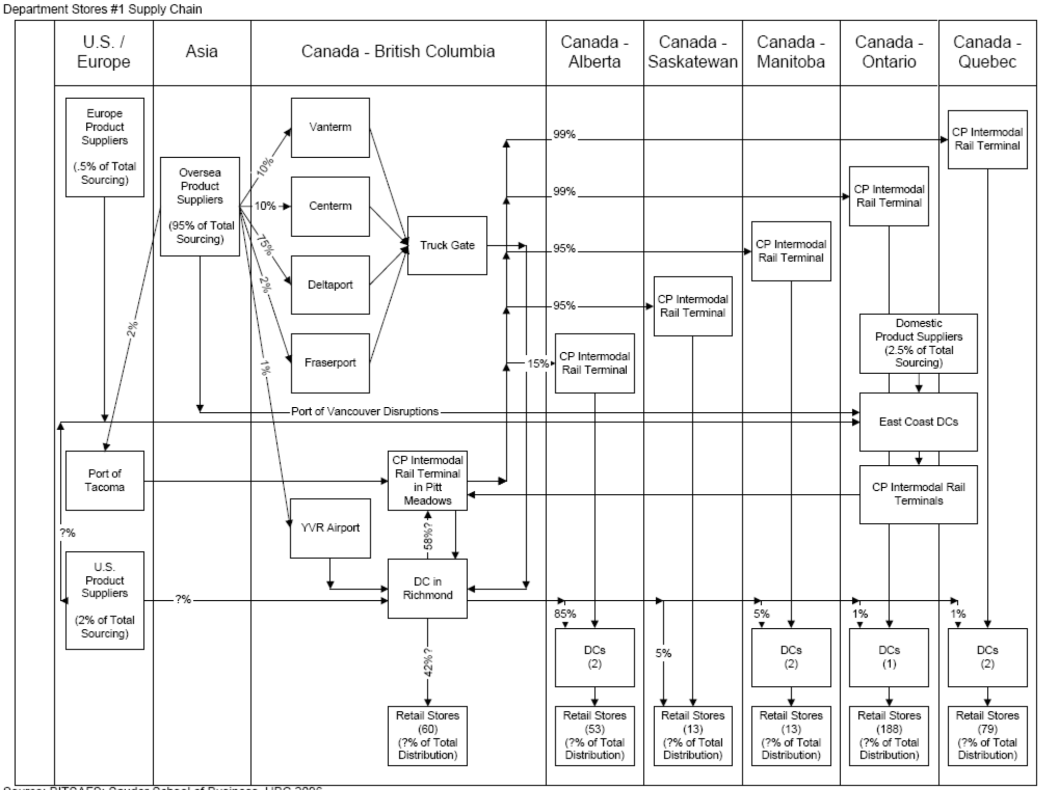
The efficiency and effectiveness of the Asia Pacific Supply Chain is dependent on the physical, information and financial connections in the Asia Pacific Region. Transportation or freight corridors are links that physically connect the spatially separated economic activity centers or markets in the Asia Pacific region, while gateways are important zones that facilitate transportation and freight flow to or within a corridor. The Asia-Pacific Gateway and Corridor (APGC) is one such gateway and corridor which includes the British Columbia Lower Mainland and Prince Rupert ports, their principle road connections stretching across Western Canada and south to the U.S., via key border crossings and major Canadian airports (Transport Canada, 2006). For freight moving by rail and sea, this gateway would include the rail connections both East-West and North-South, and short sea links along the Pacific coast.

For most international shipments, there are multiple logistics service providers involved. An example of the supply chain network of a major Canadian retailer and how it utilizes the Asia-Pacific Gateway is shown in Figure 1 (Chow, 2007).

Deleted: Figure 1

Figure 1

Department Stores #1 Supply Chain



Source: BITSAFS; Sauder School of Business, UBC 2006

The APGC is but one of many gateways and corridors, some of which are interconnected and some of which are competitive. The Cascadia Gateway region connects B.C. with Washington state and includes all of the border crossings for all modes on the western side of both B.C. and Washington state. The Cascadia Corridor connects B.C and the Pacific Northwest, and the West Coast corridor extends the Cascadia Corridor into the Baja peninsula of Mexico.

All major seaports in North America represent competing gateways and corridors to the APGC. Freight movements between North America and Asia have the alternative to move via the ports of Seattle - Tacoma, Oakland and Los Angeles - Long Beach. These ports and their inland transportation connections can reach destinations in Canada just as the APGC extends into the U.S. This port competition extends to shipments which can be routed through Mexico, via the Panama Canal to ports in the Gulf of Mexico (e.g. Houston) and the east coast. East coast ports can receive from or send freight to Asia via the Suez Canal. For Canada - Asia traffic, the Port of Halifax is potentially a competitor as well.

Each of these gateways/corridors is characterized by cost and service characteristics which determine the relative cost, speed and reliability of using an alternative gateway. These performance characteristics are dependent on the quality and capacity of the logistics infrastructure and the private sector users of the logistics infrastructure. In this paper, we focus on the impact of security on logistics costs. We posit that security can have differential impacts on different shippers, in different directions, on different modes of transportation and on different gateways/corridors, so as to change the competitive advantages or disadvantages of using different forms of transport or different gateways.

3. The Impact of Security on Supply Chains

9/11 heightens security concerns of both government and commercial enterprises. Both are cognizant of the higher probability of substantial disruption. Governments have increased regulations, intensified inspections resulting in higher transportation and shipping costs, greater shipping delays and less certainty in transit times. In addition, participants in the supply chain must invest and modify operating processes in order to comply with new regulations.

Numerous studies and anecdotal evidence exists on the impact of security initiatives on different performance aspects of global supply chains. At the trade level Panayides (2006) concludes "Security issues are not just important for higher security per se, but also because additional measures may hinder the supply chain and adversely affect the effectiveness of supply chains and ultimately global competitiveness." Wilson et al (2003) argued that burdensome customs and regulatory/security measures may hinder port and maritime security supply chain efficiencies, which in turn leads to a contraction in trade and overall efficiency. There is some evidence of the differential impact from examining U.S.-Canada trade patterns and correlating this pattern with land border delays. Globerman and Storer (2006) examined import and export trade for the U.S. with Canada before and after 9/11 to explore how security requirements and border congestion impacted trade. They observed that there was no significant export (U.S. to Canada) trade shortfall at the Blaine commercial crossing but there was a significant import (Canada to U.S.) shortfall of around 13 percent for that crossing and that a significant shortfall for U.S. imports from Canada continued to persist through mid-2005. The authors conclude "...Canadian exporters have been relatively disadvantaged compared to U.S. exporters by post-9/11 security related developments. This is supported by an examination of delay data at the Blaine (Pacific Highway) border crossing (Halcrow 2006). Average and maximum delays, primary inspection time and probability of secondary inspection were significantly higher going south than going north (Yuk and Chow, 2007).

Dame et al (2005) estimated the post-9/11 costs to the Canadian trucking industry due to the changes in U.S. border security measures ranges to be from \$179 million to \$406 million per annum. A number of issues were raised by carriers and shippers in the study that are contributing to this problem and these included: the lack of FAST lanes at certain border crossings; having to wait in a general queue to order to get access to FAST lanes; the uncertainty of wait times at the border that causes some truckers to build in a delay factor in the planning of their operations; restricted hours of operation at the border or number or customs booths open at the border, particularly for FDA inspections; and, the unpredictability and time required by customs brokers to process commercial invoices and then communicate with carriers once the shipment is in compliance. In some cases, this has resulted in trucks departing earlier in the day or even the day before to allow for, or avoid, delay at the border.

Similar impacts were found in the ITS - CVO Border Crossing Deployment Evaluation (IMTC, 2003) which estimated that waiting times approaching the border cost the trucking industry $13.8 million and at the booth another $0.8 million or $14.6 million annually. Customs broker related costs added $7.4 billion for a total of $22 billion.

Carriers have quantified the direct costs that can be attributed to regulatory changes. A large, regional Less than Truckload motor carrier (LTL) indicated that it incurred the additional costs listed in Table 1 to meet and exceed C-TPAT requirements (Miller, 2006). These can represent a substantial barrier to entry for many trucking companies.

Deleted: Table 1

Table 1: Costs and Investments to Secure Operations – Regional LTL Trucker

Additional Expense and Investment Items	Estimated Cost
Increase Security Officers from 6 to 18	n/a
IT Manifest Employees	$120,000/year
Customs Support	$300,000/year
Drivers application fees for FAST	n/a
IT Systems Development	In Excess of $1 million
IT Systems Maintenance	$1 million/year

Similar impacts on costs and investments and operating effectiveness, due to security regulations and requirements can be found in the maritime and air sectors (see Chow, Frank and Gados, 2006). The above costs are costs incurred by the carriers and other logistics service providers (e.g. shipping lines and port terminal security). These costs are eventually passed on to the shippers or absorbed by the logistics service providers.

Security improvements come at a cost. A private-sector analysis conducted by the International Monetary Fund (IMF) estimated the increase to business costs due to higher security costs at $1.6 billion per year, the extra financing burden of carrying 10% higher inventories at $7.5 billion per year. Another study estimated an increase in commercial insurance premiums of 20 percent at about $30 billion a year (Peleg-Gillai et al, 2003).

Willis, H.H. and Ortiz, D.S. (2004) recognize that supply chain security and efficiency are inseparable. Improving the supply chains efficiency may or may not improve supply chain security. For example, labour reductions for the sake of efficiency may decrease security.

Proponents of increased supply chain security often cite efficiency as an auxiliary benefit, although the two properties are often independent. Increased inspections could create delays that would lead to losses of perishable cargo or to negative economic effects on consignees. "The interconnected nature of supply-chain capabilities suggests that security measures that reduce efficiency could have unintended negative consequences because stakeholders will look for ways to compensate for or circumvent the security requirements."

It is well recognized that the additional costs are incurred by shippers due to longer and less certain transit times. These are primarily in the form of in transit and safety stock inventory costs. The owners of the freight incur opportunity costs for inventory in transit and additional safety stocks are required to compensate for variability in supply of which transit time is an important component. Transit time reliability has become more important as supply chains have become extended by off shore sourcing and as integrated production-distribution networks depend on just-in-time supply for satisfying goods requirements. However these costs, except anecdotally, are seldom estimated.

The new security reality is that all stakeholders have to take responsibility for the security of their own supply chains plus those of their trading partners (Chow, Frank, Gados, 2006, 2007). Both the public and private sectors must make decisions on the implementation of new security initiatives and invest in enabling information technologies, human resources, infrastructure and organization changes. The necessary benefit-cost and return on investment calculations depend very much on the accurate estimation of how process changes impact security, productivity, service and cost. We propose a Total Logistics Cost approach to effectively measure those impacts. To fully recognize all of the relevant logistics costs that are impacted by a security investment or program implementation, the collateral benefits of security investment must be recognized.

4. Collateral Benefits of Security and Supply Chain Improvements

A secure supply chain ensures the integrity of the shipment throughout the supply chain. This includes:

- Not allowing any biological or chemical agent to be introduced to the product.
- Not allowing any illegal commodity to be intermingled with the shipment.
- Not allowing the replacement of the product with an illegal commodity or person.
- Not allowing the shipment to be used as a weapon.

A comprehensive compendium of supply chain security initiatives can be found in U.S. CBP's Supply Chain Security Best Practices Catalog (2006). Security investments by their nature do not directly increase revenues but are intended to reduce or contain costs (Rice and Spayd, 2005). In most cases, other than theft reduction where there is tangible evidence of improvements when loss levels are reduced, it is difficult to measure the cost of a security breach or disruption that did not occur. The benefits are therefore difficult to measure if the avoided costs did not incur. As such, organizations have been facing challenges and limited success in securing the necessary funds for supply chain security initiatives.

Just as quality investments provide collateral benefits that offset the investments in quality, security investments can have a positive impact on the productivity and efficiency of the supply chain. Rice and Spayd (2005) provide a comprehensive review of these collateral benefits. The commonly mentioned collateral benefits mentioned in their study were:

- Enhanced Asset Utilization Through Greater Supply Chain Visibility. Greater supply chain visibility provides greater access to products and assets along the supply chain. It allows organizations to better anticipate material flows, plan operations in ways that maximize their operations' asset utilization.
- Improved Lead Times. Greater visibility coupled with the level of security confidence means that the probability that an organization's shipment will be delayed will be greatly reduced through the reduction in the potential of foul play and also the chances of inspections at ports and customs.
- Reduction in Safety Inventory. Greater visibility of shipment status and a reduction in lead times means organizations can now afford to hold less just-in-case inventory. And this frees up valuable working capital for the organization.
- Increased Efficiency and Productivity. By keeping an organization's system factors (i.e. processes, technology and assets, physical environment and human resource safe and secure, the organization can increase the effective capacity of inputs (e.g. better personnel morale, more productive hours due to less absenteeism and injuries) and reduce wasted outputs (e.g. less wastes in the form of damages). This will allow the organization to improve its productivity and efficiency.
- Improved Reliability and Service. The investments in ensuring personnel safety and security will let employees believe in the company's concern for the employee and develop a greater sense of loyalty and commitment. And the collateral benefits from this include improved customer service (in terms of service and reliability), leading to improved customer loyalty, increased sales revenues and higher market share.
- Enhanced Shipment Integrity Resulting In Reduction In Inspection Costs.

Numerous examples can be cited for the benefits of security programs. For example, Toymaker Hasbro spent just under $200,000 on its up-front C-TPAT compliance and spends an additional $112,500 a year maintaining it. Since it became C-TPAT-certified in November 2002, its inspections have dropped from 7.6 percent of containers coming into the U.S. in 2001 to 0.66 percent in 2003. Given that in 2003 the company imported about 8,000 containers, and that port authorities charge about $1,000 per inspection, Hasbro is saving about $550,000 a year in inspection costs alone, approximately a 5 to 1 return rate (Worthen, 2006).

Peleg-Gillai et al (2006) provide evidence that these collateral benefits are real from multiple case studies. They quantified collateral benefits for shippers with the following average results:

- higher supply chain visibility by 50 %

- improved supply chain efficiency including increased automated handling of their imports by 43%
- better customer satisfaction through improved on time shipping to customers by 30%
- improved inventory management reducing excess inventory by 14%
- reduced cycle time and shipping time, they saw a 29% reduction in transit times
- cost reduction following above improvements such as:
    - reduced customs inspections by 48%
    - reduced time to identify problems by 21%
    - reduced theft in inventory management by 38%

Dow Chemical, one of the case study firms cited the following benefits from its supply chain security initiatives (Allemang, A., 2006):

- 50% improvement in response time to identify and resolve in-transit problems
- 20% reduction in excess product/safety stock inventory
- 20% container fleet reduction
- Up to 90% improvement in reliability of delivery time windows
- Elimination/early detection of product theft
- Elimination of historical 10-to 15% human error rate associated with manual work processes to capture and enter data

The Peleg-Gillai et al (2006) research "...clearly demonstrates that security investments can be beneficial, and that these benefits can be quantified." However this was done by shippers after the fact. A total cost model would assist in estimating certain benefits prior to implementation and be used in the justification of investments in security.

5. A Total Logistics Cost Model Approach

The total cost approach has been a core principle in transportation and logistics decision making from the beginning of distribution management (the antecedent to logistics and subsequently supply chain management) in the mid 1950s. The recognition that generalized costs were but one factor in carrier selection and mode choice has been recognized in the carrier and modal choice literature (Chow and Waters, 1993). Jeffs and Hills (1990) for example found that generalized cost is less important than level of "control" in modal choice. Control in their study was determined by factor analysis to be composed of: reliability of transport mode, control over dispatch, control over delivery time, avoidance of damage to product when in transit, security of product in transit, transit time and ready availability of transport when required.

The concept of total logistics cost is conceptually simple; there are tradeoffs between the costs of different logistics processes, particularly between transportation and inventory. Transportation alternatives can be characterized by price, speed, reliability, damage, information and minimum shipment size. Typically price is inversely related to the service dimensions. Thus slower, less reliable forms of transportation typically charge lower transportation rates. Lower cost transportation is also associated with higher shipment size minimums and with transport alternatives which are more susceptible to damage

The concept of total logistics costs has a long history in the analysis of transportation choice problems:

- Baumol and Vinod (1970) modeled the tradeoff between transportation and inventory costs in the freight mode choice process. They labeled this the inventory-theoretic framework.
- Clancy and Hoppin (2007) analyzed the total logistics costs of alternative ocean transport services for products imported from Asia to inland U.S. destinations.
- Swan and Tyworth (2001) used a logistics cost model framework to analyze shipper sensitivity to unreliable service in rail carload markets.
- Tyworth and Zeng (1998) estimated the effects of carrier transit-time performance on logistics cost and service.
- Blauwens et al (2006) analyzed the effectiveness of policy measures at triggering shift in the freight transport market using the inventory-theoretic framework.
- Dullaert et al (2007) used the inventory-theoretic framework to show the impact of different transport modes on inventory levels and service.
- Roberts (Transmode, 1994) developed a truck-rail, rail-truck diversion model based on a total logistics cost model.
- HLB Decision Sciences (2001a, 2001b) use the logistics cost tradeoffs between transportation, inventory, warehousing and information costs to quantify the indirect benefits of transport improvements.

More detailed reviews of the total logistics cost application to transportation modeling can be found in Tyworth (1991), Chow and Waters (1993) and Blauwens et al (2006).

Studies using a total logistics cost approach typically account for:

- direct transportation costs
- in transit inventory costs
- cost of holding cycle stock inventories
- cost of holding safety stock inventories
- cost of ordering
- stock out costs (penalties for shortages)

Other costs accounted for in some of the studies include:

- loading and unloading costs (usually embedded in direct transportation costs)
- shelf life loss (usually included in cost of holding cycle and safety stock costs)
- loss and damage claims and losses
- emergency shipping costs (usually included in stock out costs)

The discussion in Section 4 on Collateral Benefits of Security Initiatives identifies numerous impacts of security improvement on the cost components of a total logistics cost model. A large number of the initiatives that can be taken by shipper, carriers or government reduce transit time or increase the consistency of the transit time and therefore have an impact on inventory costs. Therefore, linking transportation security levels to a traditional total logistics cost models is a fairly easy first step in measuring the benefits of security investment. A simple model is developed for that purpose in the next section.

6. A Total Cost Model for Transportation Selection

Transport choice can be the selection among alternative services, alternative carriers, alternative modes or alternative routes. A generalized total logistics cost model for any movement by any transportation alternative can be defined by commodity and shipment characteristics, firm characteristics and the characteristics of the transportation alternatives.

Commodity and shipment characteristics can include:

- origin and destination
- shipment size
- annual volume
- demand per period of time
- unit value
- required service level (product availability)
- density
- perishability (shelf life)
- fragility
- packaging and handling characteristics
- stock out cost
- obsolescence cost

Firm characteristics primarily include inventory carrying costs which account for the opportunity cost of capital, warehousing and storage costs unique to the firm.

Transportation alternative characteristics include:

- rate per unit for transportation between a unique origin and destination
- transit time between a unique origin and destination
- variability of transit times
- minimum shipping quantity for rate and service levels defined
- damage rates
- other charges

The shipment/commodity characteristics and firm characteristics are constant. However the transportation alternatives are different when choosing a different service (e.g. LCL versus FCL), different carrier, different modes or different routes with a specific point of entry.

A simple total cost model which computes annual costs and assumes a form of fixed order quantity ordering system would have the following components[2]:

$$TLC(Q, r : T, S_T) = RD + (UCTD/365) + (SD/Q) + (QCI/2) + rIC + K(D/Q)\ N(Z)S^{1}$$

Where:

R	=	Transportation Cost per Unit between Origin and Destination
D	=	Annual Demand
U	=	Carrying Cost of In-transit Inventory
C	=	Value per Unit
T	=	Transit Time of Transportation Alternative
S	=	Fixed Ordering Cost per Order
Q	=	Order Quantity
I	=	Carrying Cost of Warehoused Inventory
r	=	Safety Stock
K	=	Stockout Cost per Unit
N(Z)	=	Unit Loss Integral
S^{1}	=	Standard Deviation of Demand During Transit Time
S_T	=	Standard Deviation of Demand During Lead Time

Direct Transportation Cost: TC = RD

Direct transportation or shipping cost is the transportation cost inclusive of all charges involved with transportation. For example, a marine shipment may incur fuel bunker charges or bunker adjustment factor. There may be terminal receiving and handling charges and post inspection blocking and bracing. If the shipment is normally handled by a forwarder, there may be freight forwarder charges. Most international shipments are multimodal and involve freight charges from several modes although they may be quoted as a single rate. The value of T is normally correlated positively with service levels. In this model, we use a single transportation cost per unit R, recognizing that in reality the value of R is the summation of many subcomponents. Let D equal annual demand in units. Direct transportation costs is RD.

In Transit Inventory Carrying Cost: ITIC = UCTD/365

In transit inventory carrying cost is the opportunity cost of holding inventory in transit. Each unit of product has a valued C while in transit, is in transit for T days and incurs a carrying cost while in transit of U/365, where U is the annual opportunity cost of capital expressed as a percentage of

[2] Variations of this model can found in Swan and Tyworth (2001) and Blauwens et al (2006).

the value of the product. ITIC is thus UCTD/365. ITIC is dependent on the transit time service level of the transportation alternative.

Ordering Cost: OC = SD/Q
Ordering cost is S, the fixed cost incurred with each order or purchase transaction which does not vary with the size of the shipment. Q is the order quantity (EOQ or minimum ship quantity whichever is higher) and S is the ordering cost per order. Lower transportation rates are typically lower for larger shipments and are quoted for movements with minimum weight requirements. Thus in order to obtain a lower rate, the shipper may have to ship a quantity larger than its optimal order quantity (the EOQ), incurring higher inventory related costs.

Cycle Stock Carrying Cost: CSCC = (Q/2)CI = QCI/2
Cycle stock is the base inventory that a shipper would hold based on the EOQ or Q quantity ordered on a regular basis. The average inventory is Q/2, with each unit valued at C and the cost of holding each unit annually being I, the total cost of carrying inventory expressed as a percentage of inventory value. The value of I includes the opportunity cost of capital (U) plus the physical costs of holding inventory, risk and obsolescence costs which are a function of the size and duration of inventory.

Safety Stock Carrying Cost: SSCC = rIC
Safety stock carrying cost is the cost of holding safety stocks which compensate for variability in demand and supply. There are two methods of determining safety stocks. One method is to optimize the tradeoff between safety stock carrying costs and the cost of stocking out. The other method is to set a desired customer service level which reflects a customer service goal (and implies a valuation of the cost of stockouts). We use the later approach in this paper.

We define r to be the safety stock required to satisfy customer service level L, which is the probability that a stockout would occur during the order replenishment lead time[3]. L can be defined as a stockout level probability or a fill rate. In this paper, we choose the stockout level alternative. Then: $r = Z*S^{1}{}_{d}$ where Z is the service level multiplier expressed as the number of standard deviations of demand during lead time that need to be held to achieve the desired service level L. S_d is the standard deviation of demand during lead time[4].

---

[3] The lead time is the time between the need to order and the receipt of the order. In this paper, transit time assumed to be equal to lead time but in reality it is one (albeit a large component) of the total lead time.

[4] The standard deviation of demand during lead time, S can be directly determined but is more often determined by combining the distribution of daily demand with the distribution of lead time measured in days.

This demand distribution is in turn a function of the distribution (length and standard deviation) of the lead time for reordering and the distribution of demand per unit of time during the lead time. Using days as the unit of time, then:

LT	=	Lead Time
S_{LT}	=	Standard Deviation of Lead Time
d	=	Daily Demand
S^{1}	=	Standard Deviation of Daily Demand

And

$S^{1} = \surd\ LT * S_d^{2} * S_{LT}^{2}$

In our examples below, the variables of interest describe the transportation performance of alternative transportation routes. Therefore, we assume that T = LT although there are additional components to total LT such as order transmittal and order processing time. We also abstract from uncertainty in daily demand and assume that $S_d = 0$. Equation (2) thus reduces to:

$S^{1} = \surd\ d^{2} * S_{LT}^{2}$

Stockout Cost: $SC = K(D/Q)N(Z)S^{1}$
Stockout cost is the product of the stockout cost per unit stocked out, (K) times the number units stocked out per year. N(Z) is the unit loss integral that is a function of Z (which reflects the service level required) and S, the standard deviation of demand during lead time. The product of N(Z) and S^{1} yields the number of units expected to be out of stock per order cycle. The number of order cycles during the year is D/Q.

This model is hypothetically applied to comparing the total logistics costs of using different modes for a specific origin destination scenario defined in Table 2. The resulting calculations are shown in Table 3. In this particular example, rail transportation is the lowest total cost mode.

Deleted: Table 2

Deleted: Table 3

Table 2: Total Logistics Costs of Alternative Modes

		Mode		
Variables	**Descriptions**	**Air**	**Truck**	**Rail**
C	Value of Commodity ($/cwt)	20.00	20.00	20.00
U	Carrying Cost of In-transit Inventory (% of value)	15	15	15
I	Carrying Cost of Standing Inventory (% of value)	25	25	25
K	Stockout Cost ($/cwt)	10.00	10.00	10.00
S	Order Processing Cost ($/order)	10.00	10.00	10.00
D	Annual Demand (cwt)	10,000	10,000	10,000
L	Customer Service Level (max. % stockouts)	5	5	5
R	Transportation Rate ($/cwt)	2.00	0.70	0.50

T	Transit Time (days)	2	4	7
V	Delivery Time Variability (days)	0.5	1	2
Q	Minimum Shipment Size required to use Rate R (lbs.)	1,000	15,000	30,000

Table 3: Total Logistics Costs of Alternative Modes

		Mode		
Variables	**Descriptions**	**Air**	**Truck**	**Rail**
EOQ	Economic Order Quantity (cwt)	190.6925	196.5893	197.5459
Q(cwt)	Minimum Shipment Size (cwt)	10	150	300
Qa	Actual Order Quantity (cwt)	190.6925	196.5893	300.0000
Ds	Standard Deviation of Demand Over Transit Time (cwt)	13.6986	27.3973	54.7945
Z	Z-Value For Customer Service Level (# of Standard Deviations)	1.65	1.65	1.65
N(Z)	Unit Loss (from Unit Loss Integrals Table)	0.02064	0.02064	0.02064
Ta	Annual Transportation Cost ($)	20,000.00	7,000.00	5,000.00
Ua	Annual Carrying Cost of In-transit Inventory ($)	164.38	328.77	575.34
Sa	Annual Order Processing Cost ($)	524.40	508.67	333.33
Ia	Annual Carrying Cost of Standing Inventory ($)	524.40	508.67	768.75
SS	Annual Cost of Holding Safety Stock ($)	124.32	233.94	463.36
Ka	Annual Stockout Cost ($)	148.27	287.65	376.99
TC	Total Annual Relevant Cost ($)	21,485.78	8,867.70	7,517.77

7. Simulation of Alternative Gateway Costs[5]

The Total Logistics Cost model can be used to compare the cost of using alternative gateways to move a product from Asia to North America. We select the trade route Shanghai to Toronto and analyze three alternative routings distinguished by the gateway or port of entry into North America:

- Vancouver: Shanghai-Vancouver (Transpacific Sea) + Vancouver-Toronto (Long haul domestic trucking)
- Los Angeles: Shanghai-Los Angeles (Transpacific Sea) + Los Angeles-Toronto (Cross-Border trucking)
- Halifax: Shanghai-Halifax (Transatlantic Sea via Suez Canal) + Halifax-Toronto (Regional trucking)

[5] All figures are approximations and not intended to support specific policy conclusions.

Table 4 summarizes the characteristics of a fictitious shipment transported through the three international gateways.

Deleted: Table 4

All figures are fictitious but reflect relative comparative advantages perceived by the author. The shipment characteristics are based on Wood or Wood Articles valued at $400 per cwt. or about $8,000 per ton[6]. Average demand is assumed to be one 20' container per month at 45,000 pounds per container or 540,000 pounds or 5,400 cwt. per year.

The characteristics of the alternative routing alternatives were based on APL quotes, transit times from online websites and reasonable local intermodal transit time.

The transportation rate is estimated based on the author's experience that assuming relatively similar demand and supply, the freight rate for a dry 20' container from Asia to most of the ports in North America on average is about $3,000 to $4,000. Using the lower end of the range, the ocean freight rate used is about $6 (rounded down) per dry 20' container, assuming minimum shipment size of 45,000 lbs. The unit trucking rate is then added on top of this unit ocean rate and the unit rate is assumed to be positively correlated with distance traveled. Therefore the unit trucking rate is highest for Longest Beach to Toronto and the lowest for Halifax to Toronto.

There are more than one service routings calling at each of these ports. The ocean transit time used is that of the service routing that most frequently call at each of these ports. Delivery time variability was approximated by the average difference in transit time between 2 consecutive sailings over a 9-week sailing schedule period. It is assumed that containers that cannot load on a sailing will be rolled to the next available one. The variability for land transportation for the base case scenario is assumed to be negligible.

Based on real life schedules, Vancouver and Halifax are estimated to have higher average delivery variability (10 days) than Long Beach (4 days).

These and additional characteristics of the shipper are summarized in Table 4. The results of calculating the total logistics costs and the components of that cost are shown in Table 5.

Deleted: Table 4

Deleted: Table 5

Table 4: Total Logistics Costs of Alternative Shipment Routes

		Gateway		
Variables	**Descriptions**	**VC**	**LB**	**HF**
C	Value of Commodity ($/cwt)	400.00	400.00	400.00
U	Carrying Cost of In-transit Inventory (% of value)	15	15	15
I	Carrying Cost of Standing Inventory (% of value)	25	25	25
K	Stockout Cost ($/cwt)	10.00	10.00	10.00
S	Order Processing Cost ($/order)	50.00	50.00	50.00

[6] Unit value for containerized Wood and Wood article imports through Los Angeles/Long Beach was $7.8 thousand per ton.

D	Annual Demand (cwt)	5,400	5,400	5,400
L	Customer Service Level (max. % stockouts)	5	5	5
R	Transportation Rate ($/cwt)	7.00	8.00	6.50
T	Transit Time (days)	23	26	25
V	Delivery Time Variability (days)	10	4	9
Q	Minimum Shipment Size required to use Rate R (lbs.)	45,000	45,000	45,000

Legend:
VC = Vancouver LB = Long Beach HF = Halifax

Table 5: Total Logistics Costs of Alternative Shipment Routes

			Gateway	
Variables	**Descriptions**	**VC**	**LB**	**HF**
EOQ	Economic Order Quantity (cwt)	72.85	72.76	72.89
Q(cwt)	Minimum Shipment Size (cwt)	450.00	450.00	450.00
Qa	Actual Order Quantity (cwt)	450.00	450.00	450.00
Ds	Standard Deviation of Demand Over Transit Time (cwt)	147.95	59.18	133.15
Z	Z-Value For Customer Service Level (# of Standard Deviations)	1.65	1.65	1.65
N(Z)	Unit Loss (from Unit Loss Integrals Table)	0.02	0.02	0.02
Ta	Annual Transportation Cost ($)	37,800.00	43,200.00	35,100.00
Ua	Annual Carrying Cost of In-transit Inventory ($)	20,416.44	23,079.45	22,191.78
Sa	Annual Order Processing Cost ($)	600.00	600.00	600.00
Ia	Annual Carrying Cost of Standing Inventory ($)	22,893.75	22,950.00	22,865.63
SS	Annual Cost of Holding Safety Stock ($)	24,838.15	9,959.67	22,326.87
Ka	Annual Stockout Cost ($)	366.43	146.57	329.79
TC	Total Annual Relevant Cost ($)	106,914.77	99,935.70	103,414.07

Legend:
VC = Vancouver LB = Long Beach HF = Halifax

In Table 6, we show the sensitivity of the total logistics costs to a hypothetical change in the relative transit time performance through each of the three gateways. Assume that both transit time and the variability of that transit time are improved for this product moving through the Asia-Pacific Gateway by a combination of the shipper initiating supply chain security measures and/or one of the stakeholders in the transport chain making improvements. For example this

Deleted: Table 6

could be the shipper participating in PIP and a SCI, the port providing a "green" lane and the ocean carrier providing last on, first out positioning of the container on the ship. In this demonstration, the transit time and variability for routing through Vancouver are reduced to 22 and 7 days respectively while the transit time and variability for routing through Long Beach and Halifax are assumed to stay the same. The revised components of the total logistics cost model are shown in Table 7.

Deleted: Table 7

Table 6: Total Logistics Costs of Alternative Shipment Routes

		Gateway		
Variables	**Descriptions**	**VC**	**LB**	**HF**
C	Value of Commodity ($/cwt) - Electronics	400.00	400.00	400.00
U	Carrying Cost of In-transit Inventory (% of value)	15	15	15
I	Carrying Cost of Standing Inventory (% of value)	25	25	25
K	Stockout Cost ($/cwt)	10.00	10.00	10.00
S	Order Processing Cost ($/order)	50.00	50.00	50.00
D	Annual Demand (cwt)	540,000	540,000	540,000
L	Customer Service Level (max. % stockouts)	5	5	5
R	Transportation Rate ($/cwt)	7.00	8.00	6.50
T	Transit Time (days)	22	26	25
V	Delivery Time Variability (days)	6	4	9
Q	Minimum Shipment Size required to use Rate R (lbs.)	45,000	45,000	45,000

Legend:
VC = Vancouver LB = Long Beach HF = Halifax

The results in Table 7 show that security initiatives that improve delivery lead time and variability can positively impact the total logistics costs especially in terms of annual carrying cost of in-transit inventory, safety stock and stock-out cost.

Deleted: Table 7

Table 7: Total Logistics Costs of Alternative Shipment Routes Under Differing Levels of Security Measures

		Gateway		
Variables	**Descriptions**	**VC**	**LB**	**HF**
EOQ	Economic Order Quantity (cwt)	72.85	72.76	72.89
Q(cwt)	Minimum Shipment Size (cwt)	450.00	450.00	450.00
Qa	Actual Order Quantity (cwt)	450.00	450.00	450.00
Ds	Standard Deviation of Demand Over Transit Time (cwt)	88.77	59.18	133.15
Z	Z-Value For Customer Service Level (# of Standard Deviations)	1.65	1.65	1.65
N(Z)	Unit Loss (from Unit Loss Integrals	0.02	0.02	0.02

	Table)			
Ta	Annual Transportation Cost ($)	37,800.00	43,200.00	35,100.00
Ua	Annual Carrying Cost of In-transit Inventory ($)	19,528.77	23,079.45	22,191.78
Sa	Annual Order Processing Cost ($)	600.00	600.00	600.00
Ia	Annual Carrying Cost of Standing Inventory ($)	22,893.75	22,950.00	22,865.63
SS	Annual Cost of Holding Safety Stock ($)	14,902.89	9,959.67	22,326.87
Ka	Annual Stockout Cost ($)	219.86	146.57	329.79
TC	Total Annual Relevant Cost ($)	95,945.27	99,935.70	103,414.07

Legend:
VC = Vancouver LB = Long Beach HF = Halifax

In Table 8, the total logistics costs for the base case using the Vancouver gateway is summarized with the case of reducing transit time by 1 day and variability by 4 (Table 4 and Table 6) and two additional cases, no reduction in transit time but 4 days reduction in variability, and 4 days reduction in transit time but no reduction in variability.

Deleted: Table 8
Deleted: Table 4
Deleted: Table 6

Table 8: Sensitivity of Vancouver Total Logistics Costs to Service Components

Scenario	Transit Time	Transit Time Variability	Total Logistics Costs
Base Case	23	10	$106,915
Combination of improvements	22	6	$95,945
Reduce variability only	23	6	$96,833
Reduce transit time only	19	10	$103,364

It is observed that while a combination of improvements in both transit time and variability reduce the Total Logistics Costs substantially, the reduction in transit time variability has the greatest impact. It is difficult to improve on the length of the transit times as the transit times are based on the ships making each port their first port of call. Thus for reasons of feasibility and impact, improving transit time reliability would seem to be the direction for improvement in order to increase the competitiveness of a gateway. Of course competing ports may seek to increase their reliability as well.

8. Conclusions and Recommendations for Future Research

Security initiatives made by the U.S. and Canadian governments have increased the cost, time and variability of the time it takes to move products across borders. Gateway zones and corridors such as the Asia-Pacific Gateway and Corridor have been impacted by new regulatory requirements, and increased and intensified inspections. While there are many mandated investments and operational changes required to meet the security mandates of the U.S. and Canadian governments, both the public and the private sectors have substantial discretion in investing in security.

Investment in security beyond that mandated by government needs to meet benefit-cost or return on investment criteria of these stakeholders. The collateral benefits of such improvements should not be ignored and applying the total logistics cost principle is one method for measuring the logistics cost reductions or service improvements. The total logistics cost approach recognizes the impact of a decision on all of the relevant logistics costs that are affected and in particular, measures the tradeoff between these costs. The total logistics cost approach and related concepts such as the inventory-theoretic model have long been used in transportation demand and modal choice modeling. We have adapted this approach to estimate the logistic cost impact of improvements in the supply chain that improve the speed or reliability of service in a particular routing of a movement. The routing of a shipment is simultaneously the choice of a gateway and corridor in international movements. Thus investments in security by both the public and private sector could have an impact on the competitiveness (or the lack of investment could have an impact on the lack of competitiveness) of the gateway. The paper cites emerging evidence that differences in security enforcement between inbound and outbound movements between the U.S. and Canada have changed the balance of north-south trade at some border crossings and therefore on the competitiveness of U.S. routed products versus Canadian routed products.

A generalize Total Logistics Cost model is developed to analyze the potential impact of security or other improvements to a particular routing and gateway alternative. The model recognizes inventory related as well as transportation costs and is applied to a scenario which reflects relative values for values rather than exact values. Simulations demonstrate how improvements in transit time and reliability through a particular gateway can make that gateway more competitive. In addition, it is demonstrated that improvement in the reliability of transport has a greater impact on total cost than improvements in transit time.

The Total Logistics Cost model would be useful in analyzing the competitiveness of gateways which are hubs for container movement. Containerized products tend to have higher value than bulk or break bulk traffic and be more sensitive to service aspects of the transportation service. Containerized traffic is the fastest growing form of international transport and susceptible to undetected security breeches (relative to bulk and break bulk movements) due to the inherent loss of visibility of the contents of containers. As noted by Flynn (2004), “Much of the critical infrastructures that underpin our prosperity and way of life remain largely unprotected. This situation is especially true when it comes to the in the intermodal transportation systems that is the backbone of the global supply chains that support our manufacturing and retailing sectors.” For these reasons, it is recommended that the modeling of gateway competitiveness using the total logistics cost model focus on containerized traffic.

The Total Cost Logistics Model presented in this paper makes a number of assumptions that can be relaxed in a more detailed application. They include:

- Transit time is used in lieu of lead time.
- Demand variability was ignored.
- A fixed order quantity, continuous review inventory control system is used by shippers.
- Distributions of lead time (transit time) and demand are normally distributed.

All of these can be accounted for but require additional data or additional computations. A tradeoff needs to be made between realism and the cost and ability in obtaining data. For example, total lead time may include other shippers and shipment specific processes which are unique to each shipper and even each shipment type. A good compromise is to identify the range of values that are observed in the real world and simulate a reasonable set of values within that range.

The Total Logistics Cost model is primarily focused on the transportation and inventory cost elements of logistics costs. Elements that could be considered for an expanded model include loss and damage costs, reduced insurance costs and packaging costs. The former is especially relevant due to the commonality between the initiatives which would impact both. In addition, security initiatives that impact visibility of freight movement along the supply chain can impact the ability of logistics managers to make improved decisions. For example, with advanced information required for security, improved advanced planning may result in increased consolidation opportunities, the ability to cross dock freight, and advanced capacity planning. These shift the cost curves facing logistics managers, rather than move along a given cost curve! Further research is needed to determine how the traditional Total Logistics Cost model can be expanded to incorporate such benefits.

In section 4, the collateral benefits of security improvements and investments, on logistics and supply chain performance was discussed. In this paper, it was assume that some unknown set of private and public initiatives in security would result in decreased transit time and reduced variability in transit times. The linkage between the security initiatives and supply chain improvements needs to improved quantification. Peleg-Gillai et al (2006) provide survey evidence of these linkages. We suggest a process mapping approach as suggested by Rice and Spayd (2005). It provides a better logical structure that links security improvements with collateral supply chain benefits. Process mapping of the Asia-Pacific Gateway transport chain may provide the platform for such an effort (see Chow and Liu, 2006).

References

Allemang, A. (2006). “Supply Chain Security and the Business Benefits” Panelist remarks, Innovators in Supply Chain Security: Better Security Drives Business Value. The Manufacturing Institute (Aug. 1).

Blauwens, G., N. Vandaele, E.V. Voorde and F. Witlox (2006) “Towards a Modal Shift in Freight Transport? A Business Logistics Analysis of Some Policy Measures” Transport Reviews (March), 26,2, pp. 239 - 251.

Chow, G. and W.G. Waters (1993) Intermodal Transportation and Freight Mode Choice Models: Review and Directions for Research, Report prepared for Economic Analysis Branch, Transport Canada (Dec.)

Chow, G., D. Frank, and A. Gados. (2006). Regulations and Initiatives Affecting Secure, Efficient and Safe Cross-Border Freight Movements. Report 1.1 Bureau of Intelligent Transportation Systems and Freight Security.

Chow, G. and J. Liu (2006). Inter-Modal Freight Process Mapping of Cross Border and International Freight Flows. Report 1.3, Bureau of Intelligent Transportation Systems and Freight Security.

Chow, G., D. Frank, and A. Gados. (2007). "The Regulatory Environment for Cross-Border Freight in a Security Focused Era." Paper submitted to the ITS Canada, 2007 Annual Meeting.

Clancy, B.P. and D.F. Hoppin (2007) Coping with Uncertainty. Merge Global.

Closs, D.J. and McGarrell, E.F. (2004). “Enhancing Security Throughout the Supply Chain.” *IBM Center for The Business of Government*, Special Report Series.

DAMF Consultants Inc. and LP Tardiff & Associates Inc. (2005). The Cumulative Impact of US Import Compliance Programs at the Canada/US Land Border on the Canadian Trucking Industry: Final Report. Transport Canada: TP14402E.

Dullaert, W., B. Vernimmen, E. Aghezzaf and B. Raa (2007) “Revisiting Service-level Measurement for an Inventory System with Different Transport Modes” Transport Reviews, 1 - 11.

Flynn S. (2004) Testimony to the Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, U.S. House of Representatives, March 31.

Globerman, S. and P. Storer (2006) The Impacts of 9/11 on Canada-U.S. Trade, Research Report

No. 1, Border Policy Research Institute, Western Washington University (July).
HLB Decision Economics (2001a) Cost-benefit analysis of highway improvements in relation to freight transportation: microeconomic framework. Federal Highway Administration White Paper, Final Report (March).

HLB Decision Economics (2001b) Relationship between e-business, Advanced Transportation Logistics, and Canadian Industrial Performance. Final Report to Canada Transportation Act Review (May).

Halcrow Consulting Inc. (2006) Pacific Crossing Commercial Vehicle Border Delay Survey. Final Report to Whatcom Council of Governments (Nov.)

IMTC (2003). "ITS – CVO Border Crossing Deployment Evaluation Final Report." (Prepared for US DOT and FHWA).

Miller, D. L. (2006). Border Shipping Challenges: Security Versus Delay. Orals remarks recorded at the 2006 Annual Conference of the Transportation Research Board.

Jeffs, V and P. Hills (1990) "Determinants of modal choice in freight transport: A case study" Transportation 17, Jan. 29 - 47.

Panayides, P.S.M. (2006) "Maritime Logistics and Global Supply Chains:
Towards a Research Agenda" Maritime Economics & Logistics, 8, 3–18.

Peleg-Gillai, B., Bhat, G. and Sept, L. (2006). "Innovators in Supply Chain Security: Better Security Drives Business Value." The Manufacturing Institute (July).

Rice, J.B. Jr. and Spayd, P.W. (2005). Investing in Supply Chain Security : Collateral Benefits. *IBM Center for The Business of Government*. Special Report Series.

Security and Prosperity Partnership of North America
http ://www.pm.gc.ca/eng/media.asp?category=1&id=1085

Smart Border Accord, 32 Point Action Plan
http://geo.international.gc.ca/can-am/main/border/32_point_action-en.asp

Swan P. and J. Tyworth (2001) "Shipper Sensitivity To Unreliable Service in Carload Markets" Transportation Journal, Spring; 40, 3, 16 - 25.

Transmode Consultants Inc. (1994) Truck-Rail, Rail-Truck Diversion Model Users Manual. Report prepared for the U.S. Department of Transportation (December).

Transport Canada (2006) Canada's Asia-Pacific Gateway and Corridor Initiative, TP14605.

Tyworth, J.E. (1991) "The Inventory Theoretic Approach in Transportation Selection Models: A Critical Review" The Logistics and Transportation Review, 299 - 318.

Tyworth, John E. and Amy Zhaohui Zeng. "Estimating the Effects of Carrier Transit-Time Performance on Logistics Cost and Service." *Transportation Research Part A (Policy)*, 32A, no. 2 (February 1998): 89-97.

Tyworth, John E. and Amy Zhaohui Zeng. "Estimating the Effects of Carrier Transit-Time Performance on Logistics Cost and Service." *Transportation Research Part A (Policy)*, 32A, no. 2 (February 1998): 89-97.

.
US Customs and Border Protection (2005a). "ACE: Why Should my Company Participate?"

US Customs and Border Protection (2005b). "FAST Reference Guide." 1-24.

US Customs and Border Protection (2006). Supply Chain Security Best Practices Catalog: C-TPAT.

Willis, H.H. and Ortiz, D.S. (2004). "Evaluating the Security of the Global Containerized Supply Chain." *RAND Technical Report Series.*

Wilson, JS, Mann, CL and Otsuki, T. 2003: Trade facilitation and economic development: measuring the impact. World Bank Policy Research working paper, vol. 2988, March.

Yuk, W. and G. Chow (2007) Analysis of Border Delay Survey for Commercial Vehicles at the Pacific Highway Border Crossing. Bureau of Intelligent Transportation Systems.