TOWARDS THE DEVELOPMENT OF A SYSTEM-WIDE TOTAL LOGISTICS COST INDEX

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Introduction

Transportation performance measurement and benchmarking has a long history and a variety of applications. Performance measures include price and productivity performance of transportation carriers and infrastructure over time, on-time metrics and safety performance measures. These measures have been used in order to provide insight into improving transportation performance, for public information, planning purposes and for regulatory purposes, among others.

Performance measurement of the transportation and logistics sector in Canada, particularly at a system-wide level, has largely been disjointed or incomplete. Previous attempts at collecting transportation and logistics performance information have generally been at a highly aggregated level or based on soft, rather than hard quantitative measures. An example of the former was Industry Canada's estimate of Canada's logistics costs as a percent of GDP. An example of the latter was the National Transportation Agency's survey program. Furthermore, these measurements have suffered from frequency or consistency problems when it comes to establishing a time-series of significant length.

This paper describes recent efforts to develop and populate a Total Logistics Cost (TLC) model for the purpose of developing a system-

[1] The views presented in this paper do not necessarily reflect the views of Transport Canada.

wide transportation logistics cost performance indicator in Canada (Chow 2010). Some background is provided regarding current transportation system performance measurement, followed by a description of TLC models from a single shipper's perspective. The adaptation and application for the purpose of measuring performance on an aggregate level follows. Finally, some specific data and methodological challenges are described along with some example output of the model itself.

Background

Transport Canada (TC) has developed a number of transportation-related performance metrics for Canadian transportation carriers. For example, TC has maintains a time-series of Total Factor Productivity (TFP) performance for the air, rail, trucking and public transit modes beginning in the year 1981. In addition, unit costs, output prices and total price performance (TPP) metrics have been developed.

In terms of freight transportation, output prices and price performance are important indicators of performance from the shipper's perspective. Better TPP indicates that carriers have been able to offset price increases to customers due to increased input prices (such as capital, labour and fuel inputs). The extent to which carriers have offset price increases to customers (better TPP) depends mainly on two factors: productivity growth and carrier profits.

Since 1986 Class I railways in Canada have passed on approximately half of their productivity gains in price offsets to customers. On the other-hand, for-hire trucking carriers have passed on approximately 90 percent of their productivity gains in the form of price offsets.[2] These indicators provide some insight into the extent to which productivity gains in transportation have benefited buyers and sellers of physical goods in the marketplace.

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[2] Gill, Vijay (2008) Canadian Transportation Price and Productivity Performance, 1981-2005

While the above-mentioned indicators are useful, they do not provide a complete picture of freight transportation over time. For example, quality change is only to some extent factored into the indictors, largely due to methodological and data issues. In addition, a great deal of goods movement is multi-modal in nature; existing performance metrics are based on specific transportation modes.

For these reasons an approach utilizing a TLC model has many desirable properties. The approach explicitly takes into account the trade-off between the quality/reliability of the transportation service and inventory or stock out costs. Furthermore, it can represent the multi-modal nature of intermodal movements, basing performance on the transportation supply chain rather than focusing on a single segment of a larger trip. The following will describe the TLC model and how it could be adapted to an aggregate level with the purpose of tracking transportation logistics performance over a period of time.

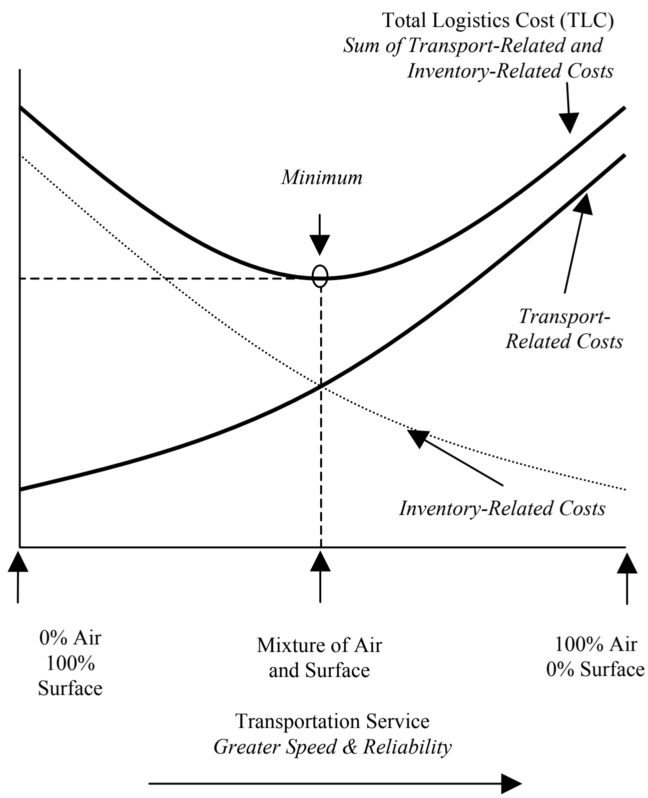
The Total Logistics Cost Concept

The TLC approach recognizes the importance of transport service quality in addition to direct transport cost. The TLC approach is the basis for a system-wide performance measure that recognizes the value of total delivery time and total delivery time variability as well as the direct costs for shipping goods between any two origin-destination pairs. This approach can assign dollar values to the logistics activities associated with freight shipments, which are important to business competitiveness and to the Government of Canada as part of its evaluation of the results of its investments.

The demand for freight transportation is a derived demand based on the need for firms (shippers) to move products. That movement can be accomplished over different routes, by different modes of transport, different service providers or by different services. A route is characterized by the intermediate nodes or locations through which freight passes between the origin and destination. Thus freight from Shanghai to Toronto can be routed through competing ports of entry into North America, each representing a different and potentially competing route. These alternative routes often offer shippers different price-service options. A Shanghai to Toronto route via Vancouver may be faster and have lower direct transportation cost than the Shanghai to Toronto route via Halifax. However, Halifax may be more reliable. Likewise, competing modes of transportation have inherent capabilities to provide different levels of service at different costs. Rail transport is inherently lower cost but slower and less reliable than truck transport. Similarly marine transport is inherently lower in cost but slower and less reliable than air transport on international routes. Carriers within the same mode might offer identical service if they compete on the same routes but often compete on the basis of service and price. Finally, the price-service offering of a specific carrier over a specific route may change over time.

Transportation alternatives can be characterized by price, speed, reliability, damage, information and minimum shipment size. Typically price is inversely related to the level of the service. Thus slower, less reliable transportation alternatives are typically correlated with lower transportation rates. Lower cost transportation is also associated with higher shipment size minimums and with transport alternatives that are more susceptible to damage. Figure 1 illustrates this cost tradeoff for international freight movements. The x-axis represents speed and reliability that is achieved with faster and more expensive modes or transport service. Speed reduces inventory-in-transit and reliability reduces the need for safety stock. These two cost factors, transportation and inventory, move in opposite directions as speed and reliability increases, resulting in a cost tradeoff. When cost tradeoffs exist, the pattern of total logistics cost is U shaped with a minimum total cost at the bottom of the U shaped cost curve.

Figure 1 Total Logistics Cost Tradeoffs



Source: Adapted from Clancy and Hoppin, 2007.

TLC Model Components and Structure

The cost variables that are relevant in a TLC model depend on the industry, inventory control systems and type of supply chains (push vs. pull). Typical costs in a TLC model may include:

• **Direct transportation costs (DTC)** charged by the transportation service providers and paid by transportation users.

• **In-transit inventory costs (ITIC)** are the opportunity cost incurred by ownership of goods while in-transit.
• **Cost of holding cycle stock inventories (CSCC)** which are held to meet anticipated demand.
• **Cost of holding safety stock inventories (SSCC)** required to meet stock availability objectives and which result from uncertainty of demand and of supply.
• **Cost of ordering (OC)** or production set up costs which are the transaction costs associated with each replenishment order.
• **Stock out costs (SOC)** or penalties for shortages are incurred when there is insufficient inventory to meet customer demand due to delayed delivery.
• **Cost of loss/damage** and claims processing of lost/damaged freight.

These are all costs that are impacted by the choice and quality of the transportation route, mode, carrier and service.

The importance or impact of each characteristic of transportation service on each cost component of the TLC is dependent on the characteristics of the freight being moved. Relevant commodity and shipment characteristics include: Origin and Destination of the movement; Demand Variability for the product; Shipment Size; Annual Volume or usage of product; Seasonality; Freight Density; Value of the Product; Shelf Life of the product; Fragility of the product; Profitability of product; Labour Costs in production; Service Level desired for product; Storage requirements; Unit Ordering Costs; Opportunity Cost of Capital; Physical Costs of storage space; Inventory Carrying Cost.

Some of these freight characteristics are directly reflected in the price of the transport alternative or direct transportation cost (DTC). For example, the origin and destination reflects distance and backhaul characteristics which are reflected in the carrier pricing; shipment size requires more consolidation so small shipments are charged higher prices; high annual volume may result in negotiated transportation rate reductions. The distance between origin and destination also impacts other logistic costs. Longer distances increase transit time and the amount of inventory held in transit.

Similarly, the fragility of the product is in part reflected in the price charged and in the probability (and subsequently the cost) of loss and damage.

Other freight characteristics have a greater impact on the Non Transportation Logistics Costs (NTLC). The value of the product increases the value of the inventory held in-transit as well as for cycle and safety stock, influencing the level of costs associated with each of these inventories. Shorter shelf life increases the cost of obsolescence which is embedded in the cost of holding any inventory type. Storage requirements and freight density together determine the space and therefore the physical costs of holding inventory. The profitability of a product is what is typically lost if a delivery delay results in a lost sale, thus more profitable products may incur higher stock out costs. In the production environment, labour costs are a major component of downtime costs resulting from delivery delays. Finally, firms seek a level of stock availability for each of its products. However this level is determined, it ultimately determines the amount of safety stock required with the speed and reliability of delivery.

The importance of each characteristic of transportation service on each cost component of the TLC is also dependent on firm wide (or firm specific) ordering costs, opportunity cost of capital, physical costs of storing inventory and ultimately inventory carrying cost. These unit costs are generally applicable to all products moved and stored by the firm. For example ordering costs (or production set up costs) are the costs of processing an order for a product. This cost is fixed per order and the same process and therefore the same cost per order is applicable across ordering situations in a specific firm. The ordering cost per order depends on the firm's effectiveness in order processing which is in part dependent on the degree of order processing automation rather than the commodity. The opportunity cost of capital is the forgone opportunity the firm incurs whether the product is in-transit or stored as cycle stock or safety stock. In all cases, the inventory investment ties up capital which could be used elsewhere to earn revenue and return on investment. The opportunity cost is firm specific, depending on the market conditions that the firm competes in, and competitive advantages and opportunities that each firm has. The physical cost of storing cycle and safety stock inventory per unit of space utilized is dependent on the efficiency of the warehousing systems utilized but the physical cost for a unit of specific product is dependent as well as the space taken up by the product. Inventory carrying cost is the sum of opportunity cost and unit warehousing and storage costs along with risk and obsolescence costs which are specific to freight types. In practice it is common to express inventory carrying cost as a percentage of the value of the product and for many firms, a single inventory holding cost percentage is used across the firm since the largest component of this cost is opportunity cost, which is firm wide.

As an example of how these variables come together to determine a component of total logistics cost, consider the SSCC:

- **Transit time and reliability** characterizes the transportation service for a commodity between a specific origin and destination at a particular time.
- Transit time and reliability along with the **average and variability of demand for the product**; determine the **variability of demand during lead time** where transit time represents lead time.
- Safety stock is determined by the variability of demand during lead time and **customer service level required** for the product.
- The **value of the safety stock** required is the safety stock multiplied by the **value of the product**.
- The **annual cost of the safety stock** is calculated as the product of the value of the safety stock and the **inventory carrying cost percentage**.

A similar process occurs for each logistics cost component, some with more and some with less complexity, and summed into a single metric reflecting the DTC and NTLC, the Total Logistics Cost metric. The TLC approach has the benefit of being able to isolate changes in logistics costs due to the level and price of transportation rather then to changes in the characteristics of the commodities or firms by holding those factors constant while transportation performance varies over time. For example, inventory costs may increase due to volatility in customer demand or increases in the value of the products.

Indexing Versus Absolute TLC

Total logistics costs for a specified commodity between specified origins and destinations by specific transportation alternatives can be estimated per the process described above. However, the focus of the TLC aggregate model is not on the absolute costs but to capture changes in total logistics cost performance and its components over time. For this reason, an indexing approach is useful in highlighting relative changes. Base period costs are indexed to 100 and subsequent period costs are reflected in relative terms to the base period.

Demonstration Example

A major food products producer provided actual traffic data for each shipment of a relatively homogeneous food product over a six month period during the first half of 2009. The observations were for shipments originating from multiple plants to approximately 100 destinations. In this example only the data for a single trade-lane is used. The data were compiled to produce monthly TLC performance. On an ongoing basis, it is more likely that the results be compiled on a quarterly or annual basis, as shorter periods raise the risk of insufficient observations to calculate transport reliability accurately. All of the logistics cost components were deemed significant for this movement and shipper except the cost of loss and damage which to some extent is reflected in the freight costs as the freight is generally insured. Commodity and firm-wide characteristics were collected or estimated. For example, both the cost of capital and depreciation rates was assumed to be 10 percent on an annual basis.

Each logistics cost component as well as TLC were calculated for each month and indexed to the first month. The indices for each of the individual components of the total logistics cost as well as the TLC and subtotal of NTLC are displayed in Table 1. The indices are calculated as a percentage of total sales volume.

Table 1: Total Logistics Cost Indices (as percent of sales) – Food Products/Single Trade Lane

Month	Sales	DTC	ITIC	OC	CSCC	SSCC	SOC	NTLC	TLC
Jan-09	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Feb-09	106.4	95.8	68.6	95.1	100.0	9.0	100.0	70.4	89.6
Mar-09	156.3	116.9	68.8	91.1	100.0	5.9	100.0	69.6	105.3
Apr-09	104.3	109.6	72.0	97.6	100.0	40.4	100.0	78.4	102.0
May-09	105.8	103.8	68.3	102.5	100.0	31.2	100.0	75.4	96.9
Jun-09	102.1	108.1	66.7	123.5	100.0	13.6	100.0	71.7	99.2

Sales – Inventory value in $, DTC – Direct Transportation Costs, ITIC – In-Transit Inventory Cost, OC – Ordering Cost, CSCC – Cycle Stock Carrying Cost, SSCC – Safety Stock Carrying Cost, SOC – Stock Out Cost, NTLC – Non Transportation Logistic Costs (total of all above except for DTC), TLC – Total Logistics Cost

There is considerable variance in the SSCC. This component is far higher in the first month (January) than in all other months due to the fact that transit time and transit time variability were much higher in that month. Because the temporal TLC model assumes that shippers have good forecasts of transit times and variability, the increased costs associated with these factors are linked to the safety stock calculation (the buyer carries more inventory) rather than the stock out calculation. In this particular case, the increased transit times and variability can be attributed to weather-related problems that impacted shipments through West coast ports during that time.

The CSCC grows as a same rate as the sales volume. The reason for this is the assumption in the data that each shipment in each month is for a unique customer. As a result, the CSCC is directly proportional to the sale volume (one half of the shipment value multiplied by the cost of capital and depreciation, both of which are held constant over the period). This issue is currently under examination.

These ratios clearly show that TLC performance has improved from January to June 2009 as logistics costs are a smaller percent of sales at the end of the period. However, the DTC index consistently exceeds the NTLC index, indicating that improved transportation service is the source of improvement in TLC. This is consistent with the improvement in transit time performance from Table 2.

The percentage contribution to the TLC by each component in each period for the same shipper and trade lane are displayed in Table 2. The average transit time and transit time deviation are also provided.

Table 2 - Single Shipper/Trade Lane – Percent Contributions to TLC

Month	Transit Time		DTC	ITIC	OC	CSCC	SSCC	SOC	NTLC	TLC
	Average	Deviation								
Jan-09	14.7	6.8	75.6	7.2	0.8	7.4	5.4	3.6	24.4	100
Feb-09	10.1	0.6	80.8	5.5	0.8	8.3	0.5	4.0	19.2	100
Mar-09	10.1	0.4	83.9	4.7	0.7	7.1	0.3	3.4	16.1	100
Apr-09	10.6	2.7	81.2	5.1	0.8	7.3	2.2	3.5	18.8	100
May-09	10.0	2.1	81.0	5.1	0.8	7.7	1.8	3.7	19.0	100
Jun-09	9.8	0.9	82.3	4.8	1.0	7.5	0.7	3.6	17.7	100

As mentioned, transit times were longer and more volatile in the month of January. For this reason, NTLC were nearly one-quarter of the TLC during that month, whereas they made up less than 20 percent of the TLC in all other months.

Figure 2 – Logistics Costs as a Percentage of Sales

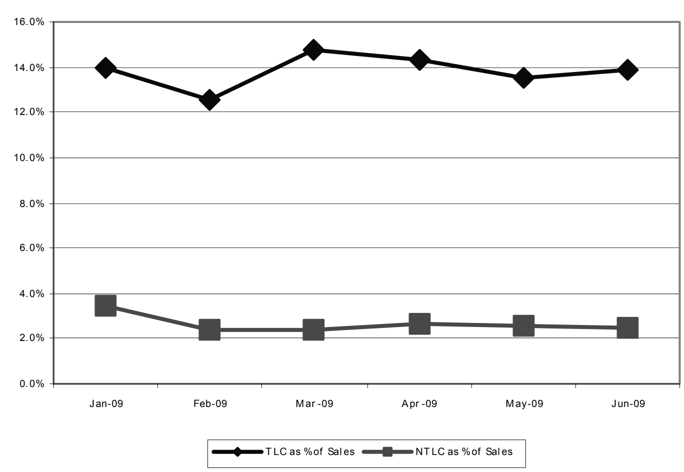


Figure 2 is a graphical representation of the TLC vs. the NTLC as a percentage of sales for all of the shipper's trade lanes over the same period of time. The spike in the NTLC in January is also apparent here. The increase in TLC in March can be attributed largely to the increase in freight costs from the previous month.

Aggregation Issues

In order to apply the model on an ongoing, aggregate level, two interrelated challenges need to be addressed. First, a relevant level of aggregation must be defined. There is an infinite combination of commodities, freight lanes and transport alternatives for which TLC could be measured. A TLC index could be estimated for a particular commodity or commodity group, a particular traffic lane or corridor, a particular carrier(s) or mode, particular service, or some combination. The greater the degree of aggregation, the greater the heterogeneity of the transportation service used and the characteristics of the commodities shipped. With higher levels of aggregation, a TLC trend is influenced by shifts in the relative importance of a more heterogeneous mix of observations. For example this is minimized in Transport Canada's annual transportation rate indices by weighting each commodity group price by their traffic volume.

Indices can be created by trade lane and possibly trade lanes through alternate routes. In order to create a single TLC index, trade lanes may be weighted by volume or total commodity value. However, it is quite likely that data would not be available at this level. Furthermore, it is not clear that a single TLC index would be meaningful as a performance indicator or tool for policy analysis.

The second challenge is thus the availability of data. For the purposes of this application, various shippers have been contacted and have been asked to supply data on a voluntary basis. The extent to which shippers have been able to participate has depended not only on the level of resources available, but on the availability of the data within their organization as well. Shippers are the ideal source of both transportation data (what they paid and what service they received) and the commodity/firm specific data. Whether or not the data are available depends on the breadth of the shippers' transportation management systems. The data example that was utilized in this paper is based on shipper data, the source of which is conditioned on confidentiality. The need for confidentiality is another reason for utilizing indices instead of actual or estimated logistics costs.

While the shipper may often be the best source of the product and firm-specific data, clearly it is not possible to get a "comprehensive" view of logistics cost performance relying only on volunteered shipper data. As a result, efforts are being made in order to obtain larger volumes of data across a greater number of trade lanes from transportation carriers. TC is in the process of collecting these data from a number of carriers for a related but distinct transportation fluidity/reliability study. These data will be leveraged, along with more general, aggregate commodity and industry data in order to populate the TLC model.

Other Methodological Challenges

In addition to the aggregation challenges, a number of methodological issues still have to be addressed before an effective and useful transportation measurement system based on TLC can be developed. One challenge is how to effectively measure performance for movement over multiple modes or segments. This is particularly relevant for intermodal and international shipments where the total movement involves multiple modes that seek to work seamlessly together. An ideal approach is to collect and measure service for the total movement from origin to destination from one source which inherently matches the transportation service data with commodity specific data. This is only possible when either a shipper or where a logistics service provider (such as a Third Party Logistics company) controls the total movement and therefore has the appropriate information. Another approach is to measure performance for each segment of the movement including the interchange processes at intermodal terminals and other cargo or vehicle exchange points in the transportation chain. Total service performance is the sum of the segments plus an adjustment for extra time and greater uncertainty inherent in freight or vehicle interchange. This modular approach has the advantage of leveraging multiple sources of data to estimate transportation performance over multiple routes sharing common network components. The pros and cons of each approach is currently being investigated. Other methodological issues include:

- Ex Ante or Ex Post Estimation of Transit Time Variability
- Applicability of the TLC approach to bulk commodity and non-repetitive movements.
- The relevance of normal distributions versus non normal distributions in estimating transportation performance.
- The impact of different inventory ordering systems on the estimation of TLC.
- The relevance of cargo loss and damage performance as key transportation performance characteristics.
- The ability of shippers to estimate or provide critical inputs required in the calculation of TLC such as stock out costs.

Future Research

The firm which provided the data for the demonstration example above is one of multiple firms selected for testing the applicability of the TLC approach for measuring transportation performance. Participating firms represent a broad cross section of industry from forest products to automotive parts to bulk movements and geographic markets from international to cross border to domestic. Valuable lessons are being learned from each firm on the applicability of TLC approach, adjustments required and data requirements and availability. These case studies are providing valuable insights on the aggregation and other methodological issues.

Conclusion

There is a need for an aggregate level performance metric that is capable of tracking transportation logistics performance over time. A Total Logistics Cost methodology is being developed to meet this need by assigning dollar values to the multiple dimensions of transportation performance and summing into a single metric. The TLC approach explicitly takes into account the trade-off between the quality/reliability of the transportation service and direct price. This is achieved by quantifying the impact of service quality on other logistics costs, in particular inventory and stock out costs. The methodology can be adapted to measure total logistics cost performance by route or trade lane, by mode or carrier and by type of service. Depending on the degree of aggregation, the performance may be measured for a single commodity or group of similar commodities, a single shipper or group of shippers. Furthermore, the TLC approach can represent the multi-modal nature of intermodal movements, basing performance on the transportation supply chain rather than focusing on single segments of larger trips. The estimated costs can be represented by indices for easier interpretation of performance and identification of trends over time.

Currently the model has been applied to selected firms that have voluntarily provided data as demonstrated by the case study of the movement of processed food product by one of the participating firms. The sample results illustrate the significance of non-transport logistics costs and how they are impacted by the speed and reliability of the transport service. The case studies are providing valuable insights on the aggregation and other methodological challenges and data issues that need to be considered in the development of an effective transportation performance measurement system.

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