CHOOSING A LOGISTICS SUPPLY CHAIN ON THE BASIS OF OPPORTUNITY COST

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Abstract

The total logistics cost (TLC) is the traditional expenditure-approach method of calculating the logistics cost of a supply chain as the goods are moved from the source to the end destination. This method uses the sum of all expenditure associated with the movement of goods (i.e. transport and handling), in-transit storage of goods and the generation of information to enable these movements to occur. As logistics chains become more complex and longer, calculating the TLC becomes increasingly difficult. The question that this paper answers is how to define and calculate the four logistics supply chain economic, or opportunity, cost factors of (1) physical movement (i.e. transport and handling); (2) in-transit cost of holding the stock while not available to the end customer; (3) the cost of the information needed to enable the movement; and (4) the effect of the reliability of the logistics chain on the safety stock. A practical method is developed whereby the TLC, incorporating these four aspects, is shown for a hypothetical movement. The costs highlight the total logistics opportunity cost (TLOC) for a multiple-leg voyage and the costs associated with all four aspects of the movement. The most attractive logistics supply chain would be the one with the lowest TLOC, and the choice can be made with confidence, as it incorporates the full economic logistics cost of the chain. ('Economic cost' and 'opportunity cost' are terms used synonymously in this work.)

Keywords: Reliability, Safety Stock, Supply Chain, Total Logistics Cost, Total Logistics Opportunity Cost

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Introduction

The total logistics cost (TLC) is the traditional expenditure-approach method of calculating the logistics cost of a supply chain as the goods are moved from the source to the end destination. It includes the sum of all financial expenditures associated with goods movement (i.e. transport and handling), in-transit storage of goods and the generation of information to enable these movements to occur. As logistics chains become more complex and longer, calculating the TLC becomes increasingly difficult. Consider the supply of goods to a manufacturing facility in Malaysia where raw materials and semi-finished goods may come from several countries, and the end product is distributed to consuming nations around the world. This is a difficult calculation to perform not just because of the sheer complexity of the parts, but also because of the need to incorporate all the customs duties, temporary import bonds, and so on.

The recognition of the logistics chain and its complexities came to the fore with the work of Lambert et al. (1998) and Saccomano (1999). As the outsourcing process became more prevalent, studies have shown that costs can range from 4 per cent to over 30 per cent of the sale value, as shown by Ballou (1999). More complex analysis of logistics costs were presented by Zeng and Rossetti (2003). In these calculations, the costs included all the costs associated with the movement, but did not extend the theory to the cost of the inventory that must be held in the final distribution warehouse to achieve a given service standard. The inventory quantity is influenced by the upstream logistics chain's speed and reliability, and is an integral cost of the total value delivered by logistics. To ignore this cost is to sub-optimise the logistics chain (Pienaar and Vogt, 2012).

There are many cases where companies have decided to move their source of production or procurement to another country, only to discover that the decision had to be reversed, as they encountered issues that they had not foreseen. These can be characterised by one or more of the following factors: longer supply chain lead times, greater in-transit inventory, and/or unreliable service and higher inventory in stock. The question is, could this have been prevented by professional logistics analysis of the movement and route? The answer is yes – if the company can perform a comprehensive total logistics opportunity cost (TLOC) assessment, which is described in this document. To address this, we need a method that incorporates all aspects of a logistics supply chain in the form of an economic analysis, which provides the true TLOC. The TLOC encompasses all the economic aspects as the goods move through the supply chain from the source to the final destination and into the stock location. It includes the impact of logistics speed, reliability and visibility on the stock holding, and is an added aspect to the traditional calculation of the TLC.

The question that this paper answers is how to define and calculate the four economic factors of (1) physical movement (transport and handling); (2) in-transit cost of holding the stock while it is not available to the end customer; (3) the cost of the information necessary to enable the movement; and (4) the effect of the reliability of the logistics chain on the safety stock. This method supersedes the traditional way of looking at a supply chain and calculating its direct physical in-transit expenses, or the old cost-savings focus, where the procurement organisation is rewarded for direct expenditure savings. If history is not to repeat itself, the correct method must be TLOC analysis encompassing all the aspects of moving, storing and handling the goods from source to the holding of final inventory.

Transport Routes

Any international movement of goods can be realised by land transport to and from the seaports or airports utilised for movement, and a choice or combination of land, ocean and air transport between the ports. Although this may sound complex, in reality the choice is usually restricted. Goods of lower value must be transported by ocean, as high air-freight charges make it air transport uneconomical. Similarly, high-value goods must be transported by air, and time-sensitive products may also warrant air transport. Economic logic reduces the number of appropriate transport methods, obviating the need to consider every potential route available.

On the other hand, utilising only known routes is wrong-headed. One of the problems is that obvious routes are chosen, and these are usually routes that have been utilised before and which are therefore deemed to be the cheapest. Arriving at a choice of the cheapest route solely by reviewing previous expenditure is not advisable, as there are potentially other routes that may offer better alternatives if one is to correctly apply the TLOC approach.

Consider the following example, and the options become far clearer. Goods need to be moved from China to Houston, Texas. The goods need to be transported by ocean and relatively cheaply. However, there are a number of routes available even if one excludes air transport:

- Road or rail transport from the source to a Chinese port; then either of –
  - Ocean movement to a US west coast port, then by rail to Houston and from the railhead by road to a destuffing location and by road to the end destination; or
  - Ocean movement via the Panama Canal to Houston, then by road to the destuffing location and by road to the end destination.

Although there are other options, these suffice to illustrate the point. There are two completely different routes, one via the west coast and one via the Panama Canal, which utilise different service providers, resulting in different times, costs and reliability. Once the most appropriate route is determined, then smaller improvements can be made by the choice of service providers and ports, and so on.

One has to take into account the viable alternatives of appropriate routes and modes, or combinations of these. An aspect that is invariably overlooked in these analyses is that the movement of sea vessels or aircraft does not necessarily entail going directly from one port to another. For example, in an ocean voyage schedule it will show a call at perhaps two consecutive ports. Hence there is always the potential for delays and unreliability at ports, so to utilise the first port of call is more reliable than a voyage that involves subsequent ports. So if it is feasible to remove the goods at the first port of call, all other downstream movements remaining the same, this will improve the speed and reliability of the goods movement.

In these choices of routes, there are four economic values to be considered:

- The cost of the movement, including packing and preparation of the goods
- The cost of the information flow, including customs and duties
- The cost of the working capital used to procure the goods while travelling to the end destination
- The reliability of the route and the chosen service providers, which influences the safety stock required.

These are explained in the following sections.

Economic Cost of the Physical Movement

The total economic cost for the movement is the sum of all the movement expenses to prepare the goods for movement and to move the goods from the source to the end destination. In this case, the customs costs are not part of the movement costs but are included in the information costs to enable movement for these goods. This cost element is perhaps the best understood, as it forms the major part of the traditional cost calculation. However, care must be taken to include all costs for physical movement from the start of the supply chain to the final consignment of the goods in a stock location.

Economic Cost For The Time Taken For Physical Movement

While goods are in the process of being transported they are not available to earn revenue or be sold. Therefore, there is an opportunity cost associated with having these goods moved, based on the time they remain in the logistics chain. The total time for the physical movement is the average time for each leg of the journey, including any known periods of transition. These periods of transition are times such as when vessels are in ports of call when the goods remain on the vessel, or when goods are being transhipped from one mode to another or the same mode. A shipping line that takes goods from, for example, the US to the Middle East may have a service to Europe, transhipment in a European port, and a second vessel and different service to move the goods to the Middle East. The vessel from the US arrives in the transhipment port and the goods wait until the onward service vessel is ready to load and depart. It is essential that these three distinct periods – inbound movement, transhipment and outbound movement – are taken into account in order to calculate the total time and reliability of the service.

Included in these times and economic costs are the preparation of the goods, the packaging and the acquisition of any transport. The delays in ordering a container, making a booking, and so on, are times that must be included in the total movement cycle time. The goods are also delivered to the port prior to the time the vessel stops accepting goods for loading – usually about a day before departure. If one adds these times, the following can be calculated:

Total preparation time preparation of goods for movement + delivery cut-off time before sailing + average time between sailings (this is equivalent to ½ x time between sailings).

This last factor is the probability that the arrival of the goods occurs in time for preparation and delivery to the vessel. In reality, some goods will make the vessel in time and some will arrive too late and will be delayed until the next available vessel. So for a sailing that occurs every seven days, the probability of the goods being loaded on a vessel = ½ x 7 days = 3.5 days.

The combination of all the times associated from the start of the preparation to the point where the goods are put into the stock location is known as the route total movement time.

The economic cost for this total time is calculated according to the working capital used for the goods while they are in transit, but not available to the end customer. This calculation is as follows:

Route total movement opportunity cost = cost of capital to the company x route total movement time (days) / 365 x value of the goods.

The cost of capital for the company is the composite percentage cost of money in the company for both its stock and its debt. In the US this is often in the 11–13 per cent range for larger companies and rises as the company size decreases or the creditworthiness of the company decreases.

Total Cost of Information Flow

To transport goods without delays, information is required and the time and effort to process this information. There are a number of issues in this category of costs, which include the cost to declare goods leaving the country of export, the cost of an order to make a booking and the customs cost to enter a country or transit a country en route to the end destination. Goods cannot be shipped from, for example, Mexico to Canada via the US without the US customs authorities being informed. Such information has a cost associated with it.

Care must be taken that customs duties are determined by the customs classification number (this is the Harmonized Schedule or Harmonized Tariff Schedule number, as defined by the World Customs Organization) and the country of origin. The same goods from different countries attract different duties when such aspects as anti-dumping, quotas, allocations and other measures are involved.

All costs associated with providing information – such as records and information required to facilitate movement – must be included from the source to the final placement into the stock location.

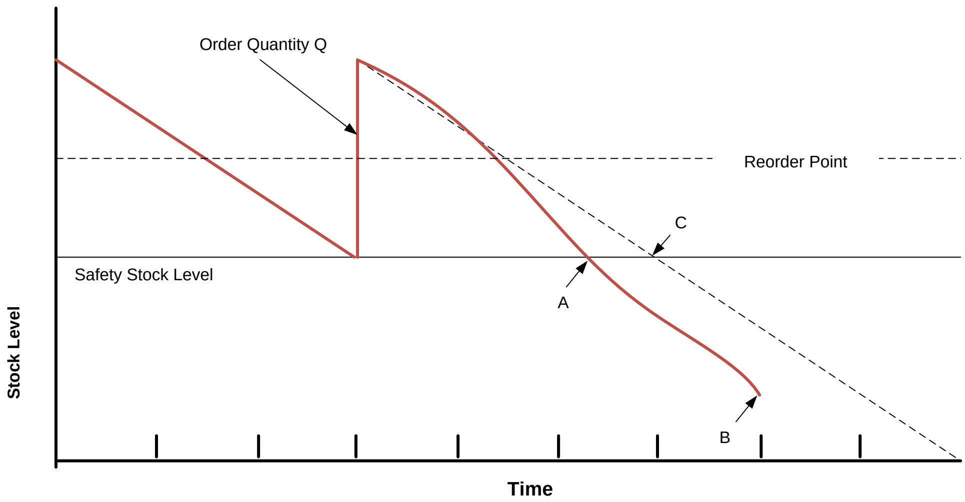
Reliability of Transport Method

A logistics chain that delivers goods with increasing reliability reduces uncertainty and will intuitively require less stock to be held in the final location. Improved reliability means that the safety stock required to cater for variations in the supply chain is less and the final location stock is reduced. Stock in a location comprises a mix of safety stock and the amount bought each time. The average inventory is then the safety stock + ½ x order amount. Safety stock caters for uncertainty in demand from the time the order is placed, plus the uncertainty of the delivery of the order. While the uncertainty of demand is not controllable, the logistics chain chosen can decrease the uncertainty of supply by means of improved reliability.

Figure 1 shows the safety stock and a set amount that is purchased (Q). As the stock is reduced by demand, the stock level falls below the reorder point and the next order is placed. In the left portion of the stock curve, the goods are ordered and arrive 1.5 time periods later, just as the stock reaches the safety stock level. This is the ideal, but the second portion of the curve shows the more practical reality. The goods are reordered as the stock crosses the reorder point. In this case, the demand is thereafter higher than expected and the stock falls below the safety stock at point A, which is earlier than the goods would be expected to arrive, as shown by the dotted line crossing the safety stock at point C. To compound this problem, the goods take one period longer after point C and are only delivered at point B. The result is that the stock quantity falls well below the safety stock level and approaches zero in this example. It is evident that if the safety stock is lower than is shown here, an out-of-stock situation might occur.

The challenge is to ensure the safety stock can cater for changes in demand and changes in the delivery cycle of the goods so out-of-stock situations are avoided. While demand is dependent on the business, delivery is directly influenced by the reliability of the supply chain.

Figure 1. Stock Management



Although this is intuitively logical, we need to be able to encapsulate the concept in a formula that can be applied to the logistics of moving goods while reviewing alternative logistics chains. We are fortunate to have a formula to calculate the inventory, as follows:

$$SS = Z \times \sqrt{(L \times \sigma_D^2) + (D^2 \times \sigma_L^2)}$$

Where:

SS = safety stock

Z = probability of having stock (at 95 per cent, this is a probability factor of 1.6449)

L = average lead time for an order to be received

D = average demand during the lead time

σ_L = standard deviation of the lead time

σ_D = standard deviation of the demand during the lead time

While this is a complex formula, the simple effect of lead time and its variability is evident and can be expressed as follows:

Safety stock ∝ (is proportional to :)

- ${\sigma^2}_L$ x D^2 (that is, the square of the standard deviation of the lead time [logistics reliability] multiplied by the average demand); and
- ${\sigma^2}_D$ x L (that is, the square of the standard deviation of the demand over the lead time, multiplied by the lead time)

The value of Z is a probability value that goods will be in stock when there is a demand. This is chosen as a 95 per cent probability and hence a factor of 1.6449. A higher stock availability figure will result in an exponentially larger requirement for safety stock, and for a 98 per cent probability the factor is 2.055, which is an exponential increase from the 95 per cent level. Obviously each industry has a different requirement for stock availability and hence a higher or lower value for the probability factor.

We can conclude from the mathematics presented here that the standard deviation of the lead time has a large influence on the safety stock. As standard deviation is a measure of reliability, it is evident that reliability is one of the major influences in the choice of the logistics chain if the total inventory value is added, as it must be, to the TLOC. This has been simplified into a spread sheet, shown in Appendix 1.

Choice of Logistics Chain Using Tloc

The key issues are how should a company choose to route its goods with all these issues to be considered, and is there a way that can be used to enable the company to make the right decision when one takes all these factors into account?

The choice of the correct logistics method is a comprehensive economic analysis from the source to a destination, which must take into account all of the following:

- Transport methods – different combinations of modes and routes – to achieve delivery to the final stock point
- The cost of the provision of information to enable the movement
- The opportunity cost of carrying inventory during the time that the logistics movement takes place
- The opportunity cost of carrying inventory due to the unreliability of delivery, in order to achieve the required in-stock probability

A practical method is shown in Appendix 1, where the TLOC incorporating these four aspects is shown for a hypothetical movement of goods. The costs highlight the true TLOC for a multiple-leg voyage, which incorporates the costs associated with all four aspects of the movement. By comparing the various options, such as the hypothetical transportation of a goods consignment from China to Houston, the different routes would be calculated according to this method. The most attractive would be the one that entails the lowest TLOC, and the choice can be made with confidence, as it incorporates the full economic cost of the chain.

There is one caveat, however, to this approach. The total opportunity cost for each option needs to be calculated with realistic data. The calculations are of no value if, for example, the quoted ocean voyage details of a third-class ocean carrier are ascertained from a website – such figures are often not representative of actual in-transit times, and their use would result in incorrect conclusions. Real data is required, and not sales data. The TLOC calculation takes the above factors into account and produces a cost for each logistics link in the supply chain. The supply chain with the lowest TLOC is the logistics route of choice.

Conclusion

As international logistics chains become more complex and longer, the traditional expenditure-approach (based on transaction cash flows only) method of calculating the logistics cost of a supply chain as the goods are moved from the source to the end destination becomes inaccurate and not representative of all the relevant cost sacrifices attached to supply chains. The choice of the correct logistics method should be based on a comprehensive economic analysis from source to destination, which takes into account:

- transport methods – different combinations of mode and routes – to achieve delivery to the final stock point;
- the cost of the provision of information to enable the movement;
- the opportunity cost of carrying inventory during the time that the logistics movement takes place; and
- the opportunity cost of carrying inventory due to the unreliability of delivery, in order to achieve the required in-stock probability.

The most attractive logistics supply chain would be the one with the lowest total logistics opportunity cost, and the choice can be made with confidence, as this method incorporates the full economic cost to the company of the chain.

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Appendix 1. Calculations

	Calculations		**Cost**	**Average Time**	**Maximum Deviation**	**Standard Deviation**	**Total SD**
Preparation							
	Packaging		$ 150	1	1	0.707107	0.5
	International Movement Document Preparation		$ 175	1	1	0.707107	0.5
	Marks		$ 25	0			0
	Special Preparation (Inspections / Fumigation)				0	0	0
							0
Booking							0
	Obtain booking for movement		$ 75	2	4	2.828427	8
							0
Transport							0
	Move freight to port - time before ship sails		$ 250	3	0		0
							0
Freight			$ 1,155				0
	Movement to next location			12	1	0.707107	0.5
	Delay at next location			2	2	1.414214	2
	Movement to next location			10	1	0.707107	0.5
	Delay at next location			2	2	1.414214	2
	Movement to next location			6	1	0.707107	0.5
							0
Arrival and Customs							0
	Customs Clearance submission fee		$ 200				0
	Duty Percentage on HS and country of origin	5%	$ 2,500				0
	Customs Clearance time from goods receipt to handover to transport			3	2	1.414214	2
							0
	Transport to end destination		$ 150	3	1	0.707107	0.5
Totals			$ 4,680	45	days		4.123106
Assumptions							
	WACC	11%					
	Holding cost of Inventory	21%					
	Value of the Goods moved	$ 50,000					
	Total Quantity ordered	90					
	Cost per item	$ 555.56					
	Demand variability standard deviation	1					
	Demand average (30 days draw down)	3	per day				
Total Costs							
	Movement		$ 2,180				
	Customs Duties		$ 2,500				
	Working Capital		$ 678.08				
	Value of Safety Stock						
	Quantity	20.4					
	Value		$ 2,381				
Total Logistics Cost			**$ 7,739**				