Importance of Intermodal Connectivity and Bottleneck Elimination

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Introduction

Intermodal transport refers to the shipment of goods that involves two, or more, modes of transport in a single journey. Ideally, each mode of transport is used for the length of haul that minimizes the line haul cost for the maximum distance moved. The best attributes of each mode of transport are combined in a system that yields the lowest cost of transportation for the supply chain.

Efficiency is the prime rationale for intermodal transport, but accessibility is a further reason for using two or more modes of transport. Most exports require trucks, or railcars, for pick-up and delivery at some point in the supply chain.

Intermodal transportation systems compete in terms of costs and time. A rail-barge intermodal system should be lower cost than an all rail movement, but normally it will be slower. Shippers of value-added goods regularly identify reliability and transit time as attributes equal to the importance of freight rates in modal choice decisions (Coyle, et al., 2003). Hence, potential time savings in intermodal are a key competitive issue.

The level of connectivity can affect reliability and transit time. Any impediment that slows or halts the flow of traffic is a bottleneck. The symptoms of bottlenecks are usually congestion slowdowns, queue formation or shipping delays. Maximum connectivity of intermodal transport demands an absence of bottlenecks.

Bottlenecks can have infrastructure or regulatory causes, and in some cases dysfunctions in the supply chain can also create bottlenecks. The purpose of this paper is to explore the causes of bottlenecks, and to illustrate how this conceptual framework might be used as a means of examining the competitiveness of intermodal systems. A taxonomy of bottleneck causes is set out in the next section. Subsequently, the framework is used to compare the intermodal handling of gain in bulk versus containers.

Bottleneck Elimination

The elimination of bottlenecks may appear to be futile. “Clearing up a single bottleneck only causes another bottleneck to appear.” (Manheim, 1979) A system may never be free of bottlenecks, but the value of their elimination should not be underestimated. As bottlenecks are reduced or removed, the average velocity of the traffic increases. With greater utilization, average logistics costs fall and the supply chain network becomes more competitive.

Figure 1 presents an economic model of the impacts of bottlenecks on transport and logistic costs. Utilization has a direct impact on line-haul and terminal costs because transportation systems have large fixed costs. With greater utilization, the ratio of fixed to variable costs falls and average transportation costs decline.
Bottlenecks cause the average total costs (including logistics costs) to rise well before the economies of size are exhausted. As queues form and congestion begins to emerge the rate of throughput slows and rising indirect costs offset the economies of size.

![Graph showing economic model of bottleneck costs](image)

**Figure 1 Economic Model of Bottleneck Costs**

Figure 2 presents a framework for the analysis of bottleneck causes associated with infrastructure, regulations and supply chain conduct. Infrastructure bottlenecks are divided into temporary constraints, which last six months or less, and chronic constraints that can be present for years or decades. Regulatory bottlenecks are discussed in terms of direct and indirect effects. The supply chain dysfunctions are dealt with individually.

**Infrastructure Bottlenecks**

In Figure 3, climate and physical barriers are classified as chronic infrastructure problems. Climate limits the Port of Thunder Bay to about 10 months of operation, and the Port of Churchill to a 3 to 4 month shipping window. These bottlenecks might be avoided with ice breaking, and other measures, but this has not been shown to be economic. Mountain passes are an example of physical barriers that can cause bottlenecks that limit the number of train transits. Again, investment can overcome this limitation as was demonstrated in the 1980s when the CP Railway built its new tunnel at Rogers Pass.
Infrastructure under-investment is a third cause of chronic bottlenecks. Under-investment can occur when a system is growing very rapidly. Over the past decade intermodal container traffic has been expanding faster than the terminals of the railways have been able to accommodate. Although they have invested significantly in terminal expansion, some rail terminals remain a chronic bottleneck.

Weather disruptions, construction and accidents cause temporary bottlenecks and need no further explanation. These events are very difficult to predict or prepare for, but are not long-lived. A more regular form of bottleneck is caused by market perturbations. These are cases when the system is stressed by a temporary surge of demand. An example is a bumper harvest that leads to a shortage of covered hopper cars. The railways cannot afford to supply enough cars to meet every eventuality, and hence, temporary bottlenecks arise whenever the demand is well above average. Peak-load pricing is a means of managing such bottlenecks, but is not necessarily popular with shippers. If the railways are in charge of determining the car supply and operating a peak-load pricing system, they could set the car supply at a level that always generates a shortage and maximizes their peak revenues (Prentice and Thomson, 2001).
A shift in demand can also cause bottlenecks. After the mid-1970s, Asia became the principal market for Canadian grain exports. The terminals on the west coast became unable to handle the surge in demand. This bottleneck became alleviated technically when additional capacity was added at Prince Rupert. The residual congestion at Vancouver illustrates that infrastructure alone may not eliminate bottlenecks.

Disinvestments occur when parts of infrastructure are abandoned, or maintained at a lower level of efficiency. Temporary bottlenecks can emerge as shippers search for alternative routes. An example of this occurred in Minnesota with the abandonment of local grain elevators. Instead of driving to the next closest elevator, many truckers decided to go all the way to the Minneapolis barge transfer sites. This has resulted in congestion of the suburban neighbourhood and longer truck queues at the transfer points.

**Regulatory Bottlenecks**

Regulatory bottlenecks are usually the unintended consequences of some other policy objective. Government has a legitimate role in ensuring safety and guaranteeing security. Inspection protocols do not necessarily lead to bottlenecks, but if the authorities under-staff positions, or become over-zealous in enforcement, queues and delays are a typical result. In Figure 4, these inspection-related bottlenecks are classified as the direct effects of regulation. The other types of bottlenecks are associated with indirect effects of policy.
Figure 4  Forms of Regulatory Bottleneck Causes

The indirect effects are associated with policies that are imposed to protect a local industry, raise government revenues, or influence market conduct. Cabotage restrictions that limit foreign competition might not lead to bottlenecks directly, but bottlenecks in the domestic market might be alleviated if foreign carriers or ports were accessible.

Competition policy is seldom associated with bottlenecks per se, but the Canadian grain industry is rife with anecdotes of how the Canadian Wheat Board and the private grain trade congest and interfere with each other’s shipments. In fairness, some bottlenecks could have occurred in any case, but the lack of coordination and differing agendas under this competitive arrangement makes bottlenecks more likely.

Fiscal policies can work indirectly through market forces. Prior to the end of the Statutory Freight Rates (1897-1982), the Canadian railways found the carriage of grain to be non-remunerative. As a result they ceased to invest in the system. Consequently, when demand surged in the mid-1970s, bottlenecks appeared throughout their network. Like a price control, a tax system that takes more out of transportation, than the government puts back in spending, is likely to experience infrastructure gaps. These bottlenecks are not directly traceable to fiscal policy, but are clearly the result thereof.

**Dysfunctional Supply Chains**

Figure 5 presents the bottlenecks associated with the failure of participants in the supply chain to act in a common interest.
Dysfunctional Supply Chain Bottlenecks

- Labour
- Work Rules
- Competing Corporate Agendas
- Information Incompatibility

Figure 5 Bottlenecks Caused by Supply Chain Dysfunctions

Work stoppages were a constant source of grain shipping delays at the ports until the government finally forced these groups to adopt the same hours of operation. The recent strike on the US west coast is another example of job protection among a small group of unionized workers that makes the whole supply chain weaker. It is interesting to note that the unions actually gain their power from the bottleneck. When such a bottleneck works in one group’s favour, their incentive to remove it can also disappear.

Competing corporate agendas are not an obvious bottleneck source. An example is the operations of the two railways that deliver rail cars to the various grain terminals at Thunder Bay. The competing terminals refuse to dedicate their operations to single grains, so ships often call at more than one berth to load. In addition, the turn around time to Winnipeg on the railcars sent to Thunder Bay is worse than that of similar trains going all the way by rail to Montreal. If the grain terminals were to develop a common supply chain objective this bottleneck could be diminished.

Interoperability of communications systems requires all parties in the supply chain to adopt common information standards. International bulk ocean shipping has many partners to link with, and thus far no universal ship-to-shore communications system has been accepted. Paper-based information bottlenecks have been eliminated by electronic communication systems in container shipping where the industry is more vertically integrated.

Application of Bottleneck Framework: Bulk versus Containers

Two intermodal systems are serving the grain marketing supply chain. The bulk system is the over 150 years old and handles the majority of the grain exports. However, ISO container shipping is growing rapidly and threatens to take a much larger share of the grain market. The traditional bulk handling system has its strengths, but the introduction of genetically modified (GMO) grains and the demands for Identity Preservation (IP) are challenging the incumbent system. This section examines the competing intermodal systems for grain transportation through the lens of the bottleneck framework.

Bulk
The key advantages of bulk handling grain stems from its economies of size and specialized material handling systems. Every time a new generation of facilities has been built, they have grown larger. At the same time, labour input has been maintained constant or reduced. Consequently, the labour cost per tonne of handling grain in bulk has fallen continuously.

The newest country elevators in Western Canada are giant terminals that can load multiple railcars simultaneously. For speed alone, the loading and unloading in the bulk system is impressive. This leads to faster car turns and associated savings in the use of railcars. The railways have also kept pace, moving from boxcars to 100 tonne hopper cars to newer “286” hopper cars that can carrying even larger volumes of grain.

With greater size and speed, the bulk handling system has managed to drive the unit costs of handling grain down to very economical levels. Of course, size can also have diseconomies. If the crop is short, or seasonal fluctuation in shipping lowers utilization, the unit costs of these systems can rise sharply. In addition, the system is designed for one way flows. The entire burden of handling costs and the round-trip of transportation is borne by the export commodity.

An appealing feature of bulk handling is the savings in packaging costs. No packages are required to hold the grain and the weight of the packaging does not add to the transport costs. Finally, the bulk handling system provides blending opportunities to the industry. Grades of lower quality grain can be raised to a higher standard through blending, while buyers receive a more consistent product than would be the case without blending.

ISO Containers

Containerization is a specialized case of unitized intermodal transport in which a standardized box is lifted from one vehicle directly to another. Economies of scope are a key advantage of containerized shipping. Containers can be used to transport a wide array of manufactured and semi-processed goods as well as commodities like grain. As a result, the costs of equipment, ships, and terminals are shared with these higher value goods. Typically, more valuable goods pay higher freight rates, and determine the traffic patterns. In the case of grain exports from North America, container shipping to Europe and Asia enjoys backhaul rates. Currently two full containers from Asia arrive at North America for every one that returns full.

Containerization also enjoys economies of size, and this has been particularly evident in the past decade. Trains that once carried single containers, now carry containers stacked two high. In 1990, a 3,000 TEU (twenty-foot equivalent unit) ship was common, this has doubled to 6,000 TEU ships, and 9,000+ TEU ships are in the shipyards (Kosior et al, 2002). Significant advances have also been made at the terminals, and the opportunity for more efficiency exists and will likely soon be implemented. These technical changes have led to a steady fall in the costs of container shipping.

The container is the storage medium as well as the unit of transport. This makes it very easy to track and trace shipments of products. It also enables a shipper to set up a Just In Time (JIT) inventory delivery system for his customer that lowers the in-transit inventories and reduces the customers inventory carrying cost.

Container supply chains have been designed to improve connectivity and eliminate transshipping bottlenecks by reducing material handling of the product. Minimum product handling is a significant advantage for delicate crops, like lentils, that could be destroyed in the bulk handling system. While this is still the mainstay of the industry, bulk grains are beginning to find a home in containers, and the requirements for IP grain shipments is providing further impetus. The contents of a container are only loaded and unloaded once during its intermodal movement.
Consequently, contamination is impossible and the exact origin and route of the product can be traced if for any reason the quality or variety differs from the contract agreement.

Figure 6 presents a subjective scorecard of the advantages of bulk versus containers in regard to bottlenecks. Space does not permit an elaboration of this ranking, and readers may disagree with the distribution of advantages. The containerization of grain appears to have more advantages than bulk, but it is not the number of bottlenecks alone that matters. The question is how binding or severe are the bottlenecks that remain.

![Bottleneck Scorecard for Bulk and Containerized Grain Handling](image)

The most important bottlenecks affecting containers are cabotage restrictions and infrastructure under investment. These are not insurmountable issues. Cabotage restrictions would be relatively costless to government to change because no revenues would be given up, and no domestic industry would have any significant dislocation (Vido et al, 2001). Giving foreign containers better access to Canada would lower re-positioning charges and encourage loading inland. The under investment in terminals and handling equipment (e.g. chassis, loading facilities, etc) are really a function of volume. As more grain moves in containers, the revenues to relieve these bottlenecks will be drawn forth from the private operators.

The most important bottlenecks affecting the bulk system are information incompatibility and safety/quality regulations. This has only recently become an issue as GMO crops have been introduced, and demands for IP grain has grown. The grain handlers have proposed a system of documentation and testing to maintain the identity of grain and to prevent accidental blending.

The testing method of maintaining IP grain quality is neither a proven, nor an inexpensive system. Kosior et al, (2002) discuss the costs of testing and the time required. In addition, each grain has to be binned separately. The attitude of the grain industry has been that if buyers want IP grain, they will have to pay higher prices. This view however, was countered by the observation that in other resource industries, failure to meet buyer specifications has led to discounts rather than premiums (Prentice et al, 2001).
In a normal year, the bulk handling system handles about 29 million tonnes, while about 1 million tonnes of grain are shipped in containers. The bulk handling system is covering its full costs (at least in a year of normal volumes), but the container system operates on the basis of backhaul rates. Consequently, the fixed costs of container shipping that are not presently covered. The total market operates at the costs determined by the marginal costs of the dominant bulk handling system.

The widespread introduction of IP grains and testing measures in the bulk system are going to create bottlenecks. The time delays for test results, testing costs and lower utilization of bin space will drive the marginal and average costs of the bulk handling system. This should encourage more grain to move in containers that the ability of containers to handle the bottlenecks posed by IP grain.

Economic theory is unable to forecast the magnitudes of market share changes with accuracy, but is usually reliable in predict the direction of change. This is all that is attempted here. The actual volume changes will depend on the cost relationships.

Observations

Congestion and queues are symptoms of bottlenecks and should not be treated exclusively as an infrastructure problem. An expansion of the infrastructure will not cure a problem that is regulatory in nature.

Any infrastructure bottleneck can be relieved, at least temporarily, if enough money and time is invested. Just because a bottleneck exists however, removal may not be economically justified. In some cases, it may be more economic to manage a temporary bottleneck through peak-load pricing than to attempt to alleviate it permanently.

Removal of any bottleneck is likely to improve the efficiency of an intermodal supply chain. But some parties may benefit from bottlenecks, and not want them removed. Careful analysis of bottlenecks is necessary to ensure that infrastructure solutions are not proposed to solve “gatekeeper” problems.

Governments may not appreciate the costs of bottlenecks resulting from their policy and regulations. The new security measures at the ports to counter terrorist threats could provide a useful case to assess the economic impact of inspection-related bottlenecks.

The costs of bottlenecks caused by supply chain dysfunctions could be a fruitful area for research. It is frequently observed that supply chain members can join together to obtain mutual benefits, but more often they do not. It would be interesting to study the role that bottlenecks and gatekeepers play in dysfunctional supply chains.

References


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i The carrying cost of inventory is an indirect cost that increases because bottlenecks increase the average inventories in transit.

ii Source: Dr. Richard Stewart, University of Wisconsin-Superior

iii Some farmers maintain that competition guarantees that the benefits of blending return to the farmers in higher selling prices. Others are skeptical. Mathematically, all farmers with above average grain quality must be subsidizing those with lower quality grain.