ENVIRONMENTAL IMPACT AND ECONOMIC BENEFITS OF CABOTAGE LIBERALIZATION: CONTAINER REGULATIONS AND LEAN SUPPLY CHAINS

Dr. Barry E. Prentice, UMTI and Dr. Jake Kosior, MB DI&T[i]

Introduction

Lean thinking has been popularized by the success of the Toyota Motor Company (Womack and Jones, 2003). Taiichi Ohno (1912-1990) originated a unique way of improving efficiency based on the identification of *muda*, or waste. Much in the way that engineers discovered that the strength of materials depended on cracks, lean thinking revealed why some supply chains are weaker than others. The key insight of lean thinking is to focus on the identification and elimination of waste. As soon as waste is eliminated, the supply chain grows more efficient and is likely to be more environmentally sustainable and robust.

The transport of empty international containers is a supply chain waste. Empty moves consume railway and port system capacity and generate greenhouse gas (GHG) emissions. Customs regulations that govern the repositioning of containers within Canada require containers to move empty except under some strict conditions. The waste created by the repositioning of two empty containers in opposite directions is the equivalent capacity of one full round trip.

Canada Customs regulations of international containers permit one incidental move of domestic freight en route to an export port. No backtracking off this route is allowed between domestic points. Speculative moves of empty containers are also prohibited.

Foreign containers are required to leave Canada 30 days after entry. In contrast, U.S. Customs allows international containers to carry domestic loads anywhere within their jurisdiction provided that the carrier is a U.S. truck, railway or barge. Moreover, foreign containers can remain in the country for 365 days (Vido and Kosior, 2001). The inflexible Canadian customs regulations prohibit efficient repositioning of containers to pick up loads in Canada, discourage the formation of Non-vehicle Operating Common Carriers (NVOCC), and segment the North American container market. Larger container lines treat Canada and the U.S. as separate markets rather than a unified whole.

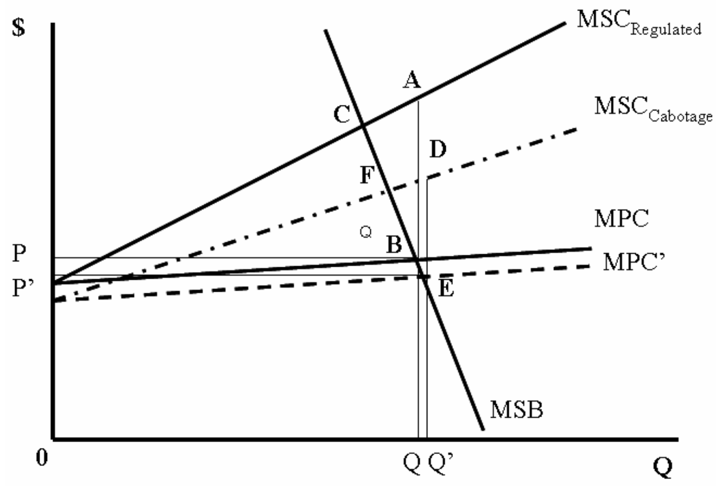
This paper examines the impact of adopting a more permissive cabotage regime on the movement of international containers in domestic service. The discussion begins with the presentation of an economic framework and the method of analysis. Subsequently, three cases are presented to illustrate the environmental and economic impact of a liberalized cabotage regime.

Economic Framework and Method of Analysis

Full capacity is always greater than effective capacity. A container train that is loaded with 400 containers has an effective capacity of 75 percent, if 100 of these containers are empty. Revenues increase for the railway if more of the containers are full, but the marginal cost increase is only the fuel consumed by the extra cargo weight. Of course if the entire freight demand could be carried on 75 trains instead of 100, then the Marginal Private Costs (MPC) of the railway are reduced. The cost reduction obtained through better utilization is illustrated in Figure 1 as the change from MPC to MPC'. Assuming that the saving is passed on to shippers, with a price change from P to P'; the total freight demand would increase form Q to Q'.

The negative externality associated with the current container cabotage restrictions is represented by the Marginal Social Costs ($MSC_{Regulated}$). The deadweight loss associated with the emissions of GHGs is ABC at the market determined equilibrium at Q containers movements at a cost of P. As empty moves are eliminated under a more relaxed cabotage regime, GHG emissions would be reduced and less energy would be wasted on the construction and maintenance extra network capacity. $MSC_{Regulated}$ would pivot down and shift lower. The new equilibrium at P'Q' would have a negative externality of $MSC_{Cabotage}$ and a deadweight loss of DEF.

Figure 1: Improved Social Welfare of Cabotage



The theoretical result can be tested using case studies of actual container shipments. Micro-level analysis provides only an indication of the potential benefits of eliminating waste in the system. Case studies cannot be aggregated to determine the holistic energy savings on a network scale. Nevertheless, case studies can illustrate the inefficiency inherent in the current system and provide a quantification of the general range of direct environmental benefits. The case studies described in this paper are based on the environmental impacts of utilizing backhaul opportunities for 40-foot reefer containers.

Three case studies are modeled in this analysis. The identities of the firms are hidden but the data are derived from actual shipping histories. The shipments are exports of meat products and seafood, the imports and domestic movements are those of a large merchandiser. Rail is the predominant mode for long haul transport in the first cases, but some short haul trucking is involved because the shipper is located in a city without an intermodal ramp. The third case involves long haul trucking from Toronto to St. John's Newfoundland. Rail could be used for part of this shipment, but for expediency the standard *modus operandi* is truck.

Railway fuel consumption is measured in average litres of diesel fuel consumed per metric tonne kilometer (L/T-KM)[ii]. The estimate for average fuel consumption in Canada is 0.0057 L/T-KM. The volume of fuel consumed by incremental railcars, containers or cargo consignments is calculated by multiplying the added tonnes by the distance hauled times the fuel consumption estimate. In economic terms, this is the marginal fuel cost for each additional tonne carried. Some subtle fuel consumption differences are observed between eastern and western train movements, but this calculation is suitable for the micro-analysis case studies of average train operations [iii].

For truck movements, the fuel consumption for each container carried by a tractor-trailer unit is fully allocated to the conveyance. In other words, each container has a dedicated power unit (the tractor-trailer) assigned to it for the trip[iv].

Figure 2: Truck Fuel Consumption (L/T-KM vs. GVW)
(for vehicle speed of 105 KPH)

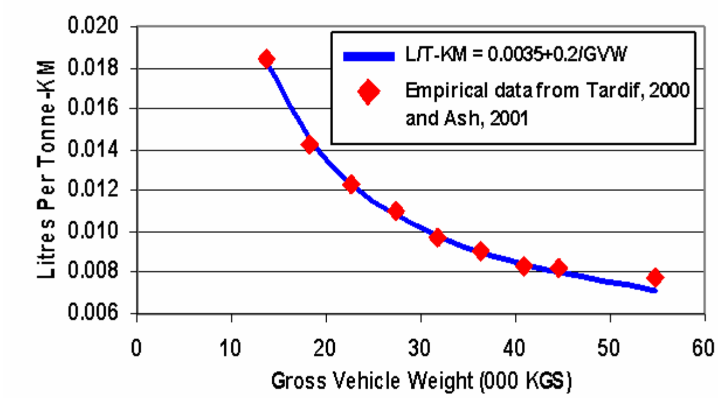
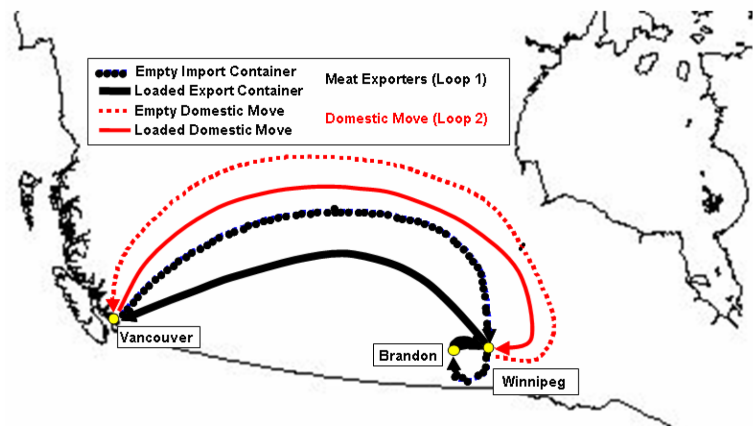


Figure 2 shows the fuel efficiency of trucking with respect to gross vehicle weight (GVW). The equation is standardized for a highway speed of 105 KMH. The corridors are assumed to have less than 10 percent idling in the data mix. The general equation that is derived from Tardif (2000) and Ash (2001) suggests a pronounced "fixed" cost relative to "variable" costs as GVW increases[v].

Case 1 - Meat Export and Generic Domestic Movement

The first case presents a 40-foot refrigerated container movement of frozen meat from Brandon, Manitoba to the Port of Vancouver. In order to ship a full container from Manitoba, an empty container must be positioned at the Brandon plant. The fronthaul shipment is represented as a solid heavy black line in Figure 3. The empty backhaul repositioning move is designated as the broken heavy line. Together, this fronthaul-backhaul combination completes the cycle which is designated as Loop 1 for the remainder of the analysis.

Figure 3: Meat Exports (Loop 1) and Domestic Move (Loop 2)



The round trip distance of Loop 1 includes transshipment at Winnipeg. The rail legs are 2,232 km between Vancouver and Winnipeg, and the truck haul is 200 km between Winnipeg and Brandon, for a total of 4,864 km. The rail legs take three days each way. The dwell period in the Winnipeg intermodal yard is a two days. The 200 km road trip from the intermodal yard to the Brandon plant dock and the administration of documents takes six hours complete. Wait times are minimized because the product is perishable. Loading the container with meat is estimated at 12 hours. Dwell time at the Port of Vancouver is estimated at three days. In summary, the transit time is 7 days and dwell periods equal 7.5 days for a total cycle time of 14.5 days. The transit and dwell estimations assume a 24/7 schedule with no weekend layover. The last actual loading time is Friday afternoon because the plant does not operate over the weekend.

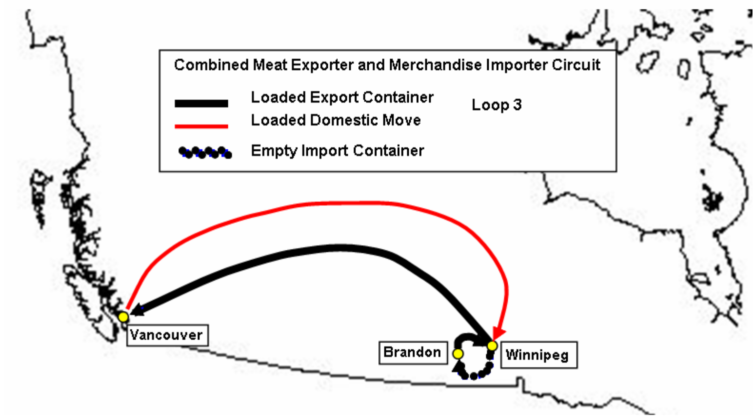
Only the marginal fuel required to move the empty container between Vancouver and Winnipeg is considered because the train is a scheduled run. The movement of an empty 40-foot reefer container between Vancouver and Winnipeg uses 50.6 liters of fuel. This is less than the fuel consumed on the short haul truck trip between Brandon and Winnipeg. The fuel required to move the tractor and container chassis is 49.2 liters with an additional 2.8 required to move the empty container for a total of 52.6 litres.

On the fronthaul trip, the fuel requires 69.5 liters to move the truck with 25 tonnes of cargo. The marginal fuel required to move the cargo is 17.5 liters. The rail fronthaul requires an additional 318.1 liters of fuel to move the cargo. In total Loop 1 consumes a total of 540.8 liters of diesel fuel.

Loop 2 in Figure 3 represents an unrelated domestic shipment between Vancouver and Winnipeg. Loop 2 is designated by the thinner lines, and the interpretation is the same. The solid line is a full movement, and the broken line is an empty return. There is no short haul truck trip to Brandon. The five day dwell time in Winnipeg represents 2 days in the rail yard, 1 day to a consignee's dock, unload and release of the container, then another two days waiting for a train. Loop 2 consumes 419.3 liters of fuel and takes 11 days to complete.

Loop 3 in figure 4 represents the merger of loop 1 and loop 2 in an ideal situation when the two shippers can co-ordinate movements. The distance for the total circuit is 4,864 kms – the same as for loop 1 with the difference that the inbound rail move from Vancouver to Winnipeg now includes the domestic cargo. The total time for the loop 3 circuit is 15.5 days, or one additional day longer than loop 1. The additional day is to unload the domestic cargo at the consignee's dock in Winnipeg. Fuel consumption is 858.9 liters for the complete circuit. The only empty movement is from Winnipeg to Brandon.

Figure 4: Combined Meat Exports and Domestic Moves (Loop 3)



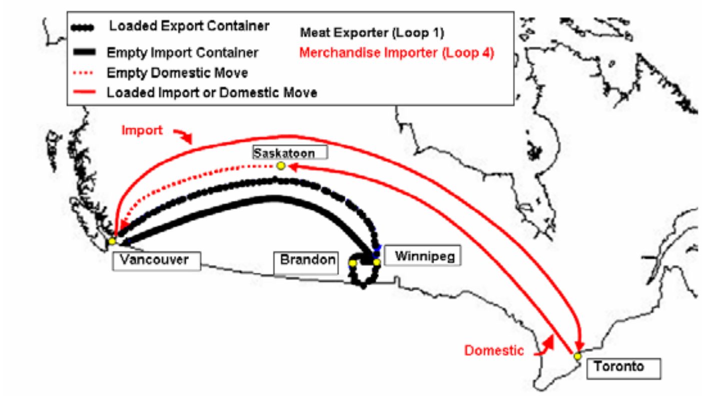
The cabotage movement eliminates 4,464 kilometers of empty container travel. Coordination of the circuit eliminates two long haul empty moves. The combined circuit frees up space to move another full cycle. The net time reduction in the merged Loop 3 is 10 days. Six days of transit time and 4 days of dwell time days are removed from the logistics pipeline.

Fuel consumption is calculated by dividing the total litres consumed for a circuit by the sum of the cargo-tonne-kilometers The environmental benefit is the reduction of 101.3 liters of fuel consumed.

Case 2 – Meat Export and Imported Merchandise Distribution

In this scenario, the meat export case designated Loop 1 is used in a merged circuit with the operations of an imported general merchandise distributor. In Figure 5 the import distributors operation is designated as Loop 4.

Figure 5: Meat Exporter (Loop 1) and Merchandise Import Distributor (Loop 4)



The imported merchandise distributor normally transloads 40-foot international containers into 53-foot domestic containers at Vancouver to gain extra volume for its light density import freight. It is assumed that the inbound freight is dense and "weighs out" before utilizing all available container volume, thereby negating the need for trans-loading. The analysis assumes that the distributor is able to separate heavy goods (pumps, rakes, shovels, etc.) from light goods (plastics, toys, household sundries) at the origin and use a 40-foot reefer container to bring their products to a Toronto warehouse.

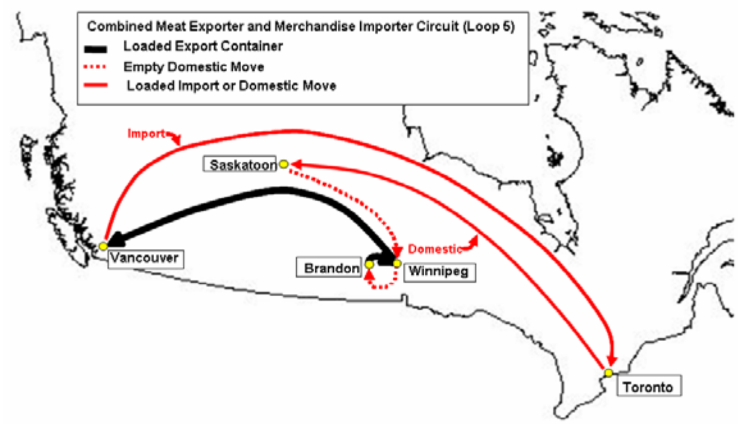
The inbound leg for the importer from Vancouver to Toronto by rail is 4,464 kilometers. It is estimated to take 7 days by rail and consume 737.4 liters of fuel. The Toronto dwell time of 5 days includes removing the container from the rail yard and transfer to a Toronto area warehouse where it is destuffed and reloaded with a domestic load for stores in Western Canada.

The second leg involves moving the domestic load to Saskatoon, which is a representative mid-Western Canadian point. Toronto to Saskatoon is 2,927 kilometers and the trip consumes 488.5 liters at an estimated 5 days by rail. The dwell time in Saskatoon is 5 days, similar to the dwell times for the previous loops. The empty leg to Vancouver from Saskatoon is 1,667 kilometers and takes an estimated 3 days by rail consuming about 37.8 liters of fuel. No dwell time is assigned to the container when it returns to Vancouver because it is placed back into the pool. The total circuit takes 25 days and uses nearly 1,264 liters of fuel.

Loop 5 in Figure 6 is the combined operation of the merchandise importer and the meat exporter. If the two shippers collaborated, the first half of merchandiser's logistics to Saskatoon is retained, and at that point the empty 40-foot reefer container is turned over to the meat exporter. An 829-kilometer leg from Saskatoon to Winnipeg, saving 838 empty kilometers, replaces the Saskatoon to Vancouver empty leg. This also eliminates the Vancouver to Winnipeg empty leg in Loop 1. The Saskatoon to Winnipeg leg takes about 2 days by rail with a dwell time of 2 days. Once the container is removed from the Winnipeg rail terminal, the latter portion of the Meat Exporter logistics pipeline prevails.

Loop 5 takes about 35.5 days to complete and consume nearly 1,735 liters of fuel. However the longer time to complete the combined operations exceeds the 30 day time limit currently stipulated in cabotage regulations. The combined circuit eliminates 3,070 empty kilometers of wasted rail capacity. Fuel savings amount to almost 70 liters with transit time rail capacity reduced by 4 days. The dwell times are nearly the same for the separate and combined loops and therefore no benefits are realized in terms of rail yard congestion savings.

Figure 6: Combined Meat Exporter and Merchandise Importer Circuits (Loop 5)



Case 3 – Sea Food Export and Import Merchandise Distribution

Trucking is the standard conveyance between Newfoundland and central Canada because the island has no railway. Figure 7 maps out the route from Toronto by truck to North Sydney, Nova Scotia and ferry to Newfoundland. The 2,013-kilometer truck journey takes 2 days and consumes 700 liters of fuel. If timed correctly, the truck has about a half day of wait time for the Marine Atlantic ferry to Argentia. The 518 kilometer ferry crossing takes 17 hours. This is the shortest time route to St. John's and uses 107 liters of fuel. The fuel calculation includes the tare weight of the truck and cargo carried by the ferry. At Argentia, the truck travels 131-kilometers to St. John's and uses 45.5 liters of fuel. The trip takes 12 hours and the container has a three day turnaround time in St. John's.

For Loop 6, it is assumed that no arrangements have been made to co-ordinate a backhaul load and the container returns empty. The truck to Argentia consumes 34.1 liters of fuel, the ferry to North Sydney uses 43.5 liters of fuel and truck to Toronto takes 523 liters of fuel. Return transit times are the same, with no dwell times. At Toronto, the container reenters the pool. No dwell time is assigned in the model.

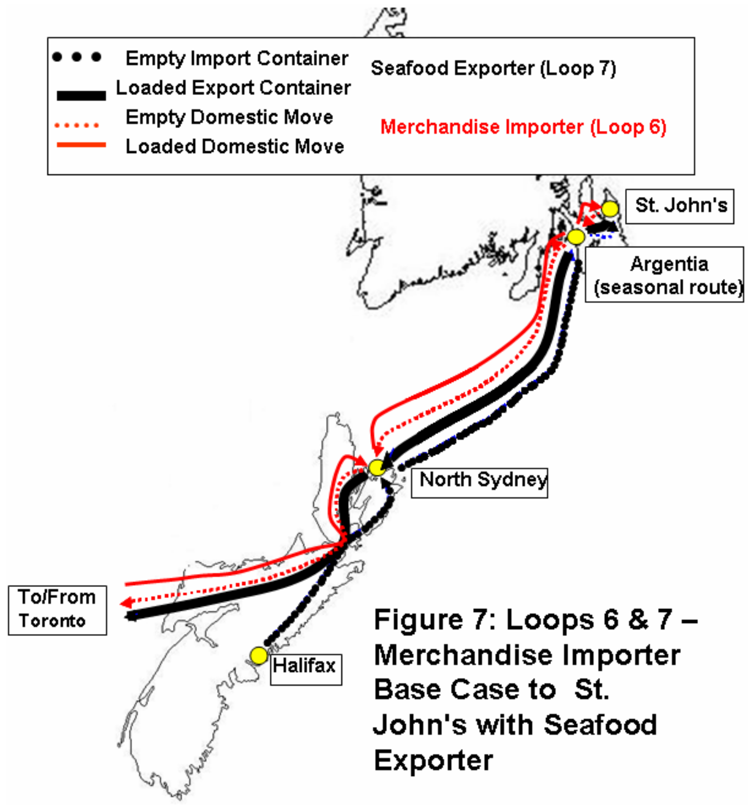


Figure 7: Loops 6 & 7 – Merchandise Importer Base Case to St. John's with Seafood Exporter

Loop 6 takes 10.5 days to complete (6.5 days in transit, 4 days dwell). The distance is 5,324 kilometers with 1,453 liters of fuel consumed.

Loop 7 is essentially the reverse of loop 6. The export move requires an empty container to be trucked from Halifax to St. John's where it is loaded with seafood. Loop 7 takes 11.5 days to complete with 5.5 days in transit and 6 days dwell time. Transit is one day less but two days of extra dwell time when compared to loop 6. The total distance is 3,740 kilometers and 1,041.2 liters of fuel are consumed.

Figure 8 shows loop 8 that utilizes a fully loaded two-way move from Toronto to St. John's and return. The total distance for this circuit is 5,324 kilometers that requires 13.5 days (6.5 intransit, 7 dwell) to complete and burns 1,704 litres of fuel.

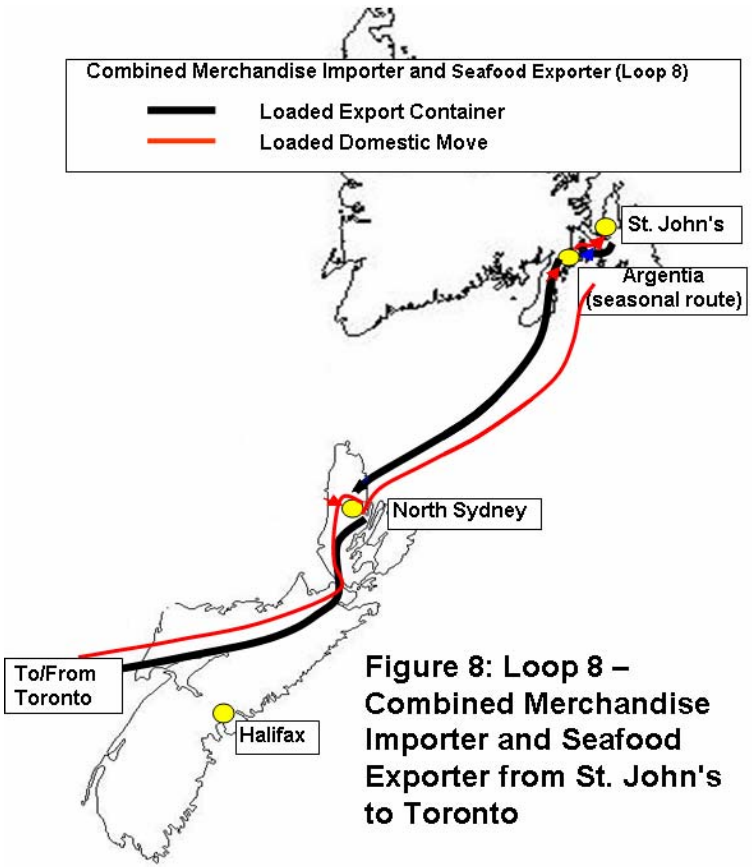


Figure 8: Loop 8 – Combined Merchandise Importer and Seafood Exporter from St. John's to Toronto

The waste eliminated in Case 3 is 3,740 empty container miles and GHG emissions from 790 litres of fuel. Trucking accounts of 80.5

percent of the GHG emissions. Additional utilization for the system is equal to 8 days (5 intransit, 3 dwell).

Summary

The data from the three case studies are summarized in Table 1. Amended container cabotage laws could increase transport system capacity and reduced fuel consumption. In all cases transport capacity is increased in terms of empty equipment days in transit and dwell times at terminals. The most dramatic fuel savings is Case 3 that combines merchandise imports from Toronto with St. John's seafood exports. The waste of fuel eliminated is 790 liters.

Table 1 Summary of Benefits of Container Cabotage

Loop	Round Trip (kilometers)	Supply Chain (days)	Fuel Use (litres)
Case 1 – Meat Exporter and Domestic Shipper			
1	4,864	15	541
2	4,464	11	419
3	4,864	16	859
Savings	-4,464	-10	-101
Case 2 – Meat Exporter and Import Distributor			
1	4,864	15	541
4	9,088	25	1,264
5	10,882	36	1,735
Savings	-3,070	-4	-70
Case 3 – Sea Food Exporter and Import Distributor			
6	5,324	11	1,453
7	3,740	11	1,041
8	5,324	14	1,704
Savings	-3,740	-8	-790

The least dramatic change is Case 2 in which only 70 litres of fuel are saved. Under existing law, this case violates the 30-day time limit for containers to remain duty-free and would require special dispensation. In Case 1 the additional efficiency gain is precluded because a second domestic move is not allowed in the regulations.

Conclusion

In every scenario empty backhauls can be eliminated and fuel consumption can be reduced. The modeling analysis corroborated statements by industry spokespersons that equipment cycle time for combined operations would be greater than the 30 day limit, thus precluding synergies from logistical partnerships. However, added capacity from reduced empty movements is an immediate, tangible reality from amended regulations. While the micro-analysis suggests that cabotage regulations would improve capacity and reduce fuel consumption, a broader national network modeling effort would provide further evidence on the full impacts of amended regulations.

Leaner supply chains are known to have economic benefits. The environmental benefits of lean thinking are less known. These examples show the harmful environmental effect of restrictions on cabotage. The modeling presented here does not represent the worst cases. The 30-day limit is not viewed as negatively as the inability to backtrack or restrictions on the repositioning of empty containers without confirmed loads. Space does not allow for these examples, but the results are generally the same. Greater flexibility in the use of international containers for domestic traffic increase rail network capacity and reduces GHG emissions.

It is clear that the Canadian Customs regulations are out of step with current transportation needs. A simple solution would be to mirror the more permissive U.S. Customs regulations that treat containers as if they are "re-usable packaging" rather than a foreign vehicle. In addition to the economic and environmental benefits of revising Canadian Customs regulations, trade between North America and external markets in Europe and Asia would become simplified. More research is needed to determine the long term impacts of freer cross-border movements.

References

Ash, L., *Operating Costs of Trucks in Canada 2001*, Prepared for Transport Canada, Economic Analysis Directorate, 2001.

Tardif, L., *Fuel Efficiency Benchmarking in Canada's Trucking Industry, Results of an Industry Survey*, Prepared for Office of Energy Efficiency, Natural Resources Canada, March 2000.

Vido, Erica and Kosior J. "An Assessment of North American Cabotage Laws: The Carriage of Goods in Marine Containers". *Canadian Transportation Research Forum, 36th Annual Proceedings,* May 2001.

Womack, James P. and Daniel T. Jones. *Lean Thinking - Banish Waste and Create Wealth in your Corporation.* New York, NY: Free Press, 2003.

Acknowledgement

This article is based on a report prepared for Transport Canada: *A Review of Regulations Governing Use of International Marine Containers in Canadian Domestic Cargo Carriage*. (2005) The opinions contained in this paper are the sole responsibility of the authors and do not necessarily reflect the views of Transport Canada.

---

[i] Transport Institute, Department of Supply Chain Management, University of Manitoba and Government of Manitoba, Department of Infrastructure and Transportation

[ii] Email correspondence with Marie Houde, Director of Network Strategies, CN Rail.

[iii] A network approach would require the use of the Davis railway propulsion formula for train operations.

[iv] In the case of rail operations, the train will still move between points in a corridor whether 300 or 400 containers are full.

[v] The Davis railway formula does follow an inverse relationship as well, but since modern trains are long and heavy, fuel consumption is "way down" the inverse curve and is can be considered linear for all intents and purposes.