CROSS-BORDER TRUCK-RAIL MODE CHOICE ANALYSIS: AN APPLICATION TO THE MANUFACTURING SECTOR IN ONTARIO

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Introduction

Cross-border transportation within North America is under-researched in comparison to Europe and eastern Asia. Large amounts of freight by weight and dollar value travel across borders as a result of the implementation of the North American Free Trade Agreement (NAFTA) between Canada, the United States of America (USA) and Mexico (Government of the United States of America, 2013). The USA including the District of Columbia and Puerto Rico is a substantial consumer of goods manufactured in Canada and Mexico (Government of the United States of America, 2013).

The manufacturing sector in Ontario is comprised of 14 major sectors including aerospace, automotive, clean energy, clean technology, digital gaming, financial services food manufacturing, information technology, life sciences, materials, medical technology, mining, nanotechnology, and tourism investment (Government of Ontario, 2013). Most of Ontario's manufacturing production is exported to the United States and furthermore most of Canada's manufacturing production is also exported to the United States (Anderson, 2012).

The purpose of this preliminary study is to examine the quantities of trade in terms of weight and dollar value that are destined for the USA via the two major and two intermediate Ports of Entry on the border with Ontario, Canada using four major commodity groups: Automotive (parts and assembled vehicles); Iron and Steel; Plastics; and Organic Chemicals. The following research questions are addressed in this paper: what commodities are moved by what mode; and what are the factors influencing the choice of a particular mode to move certain manufacturing commodities across the Ontario-USA border for consumption in USA destinations?

Background

The European Union

The European Union (EU) is a political and economic union of many European States that was created in 1993. The EU serves the economic purposes of a standardized market and quasi-borderless transportation of goods, people, services and capital between member states. One of the key benefits for member states in the EU has been the development of both national and inter-EU States road and rail transportation infrastructure serving both people and freight (Wikipedia, 2013). It is noted that the member states of the EU are also signatories to the Kyoto Protocol that is discussed later in the Results and Discussion section of this paper.

Based on the European research in the literature review it appears that logistics companies, transportation companies (Woodburn, 2003; Eng-Larsson and Kohn, 2012; Truschkin and Elbert, 2013) and state Governments are engaged in understanding how their cross-border freight transportation systems operate . The primary theme in European freight transportation mode choice research appears to be identifying opportunities to improve cost effectiveness of transportation (Janic and Vleugel, 2012) and the secondary theme is

exploring opportunities to reduce carbon dioxide and other greenhouse gas creation through making changes to the mode choices available and transportation network options available to industry and logistics companies (Iannone, 2012).

Research on North American Freight Mode Choice

In comparison to the European and Asian regions there appears to be very little published research on freight mode choice in North America. Total embodied energy and emissions modal freight requirements across the supply chain for each of over 400 sectors in the USA (Nealer et al., 2011) is a substantial study that was limited to the USA. North America's continued reliance on the trucking industry as the preferred mode choice has also been examined (Eom et al., 2012). The lack of international mode choice studies is somewhat surprising as the North American Free Trade Agreement (NAFTA) between Canada, the USA and Mexico has been in effect for over 20 years. As similar industries, logistics providers and transportation systems exist in North America in comparison to Europe and Asia, it begs the question has the research been prepared in the private sector and not become public?

The big difference between the North American transportation systems and the European and Asian systems is and has been for the past 50-60 years the public and private sector investment in freight rail infrastructure. In the 1950's the USA invested large sums of capital for the construction of the Interstate Highway System whereas European and Asian countries continued to invest in rail systems. Since the development of the Interstate Highway System most freight transportation in the USA has been dominated by the truck.

Efforts to Reduce Transportation Costs

The primary transportation cost center for truck and rail modes is operation and maintenance, broken down further the biggest individual expense item is fuel. In the European and Asian contexts, research has been prepared to look at lowering costs by encouraging modal shifts from truck to rail or intermodal truck-rail-truck shipping (Cook et al. 1999; Amano et al., 2003) and even as far as minimizing fossil fuels from the transportation costs equation by switching to electric powered rail with the subsidized electricity generated by nuclear power plants (Kadono et al., 2004). Mode choice behaviour analysis was investigated for policy assessment (Samimi, et al. 2011). In the North American context, the focus is on just-in-time delivery so that increased shipping costs by truck may be offset by reduced warehousing costs. This is a paradox that should be investigated further as the just-in-time delivery approach has numerous implications on transportation mode choice such as cost, location of origin and destination facilities, logistics and transportation system design.

Efforts to Reduce Environmental Impact of Freight Transportation

Research on transportation mode choice and mode shift for the benefit of the environment is well established in Asia and Europe (Li et al., 2007; Baker et al., 2009; Hanaoka and Regmi, 2011; Kim et al. 2011), noting that industrialized countries involved are all signatories to the Kyoto Protocol. Developed markets such as Japan have become leaders in this area in response to the impacts of greenhouse gases on populated areas of their countries (Masui and Yurimoto, 2000). Similar research has been prepared in the Netherlands, Germany and Italy.

While Canada and the USA are not signatories to the Kyoto Protocol, the USA Environmental Protection Agency (EPA) has taken steps to

limit diesel exhaust from rail locomotives with the implementation of Tier I, II, III and IV standards for concentration of greenhouse gases based on the year of construction of the locomotive. Additionally in response to state laws in California, stringent requirements have led industry to develop battery powered diesel locomotives that are now widely used for short-haul rail freight transportation in heavily populated areas across North America. In terms of environmental legislation, Canada has fallen behind the USA and does not place the similar environmental restrictions on diesel exhaust. It is noted that both major Canadian railways are currently purchasing locomotives from producers in the USA that meet the EPA standards. The curious situation in North America is why hasn't been more research to identify opportunities to reduce the environmental impacts of freight transportation?

Timeliness of Increased Levels of Research on Transportation Mode Choice

The two periods of increased levels of research on transportation mode choice coincide with two historically important periods for surface transportation in North America. The late 1960's through 1970's were a period of great decline for freight rail transportation in the USA. Mergers and acquisitions dominated the period along with numerous high profile railroad bankruptcies including the Penn Central, itself a product of the merger of eastern USA railroad giants the New York Central and Pennsylvania railroads, and later the New Haven railroad. Railroads were failing because they were not able to compete with the heavily subsidized road and Interstate transportation systems coupled with some questionable management decisions as was the case with Penn Central's bankruptcy. The Penn Central and predecessor New York Central situation is particularly relevant as the railroad served the cross-border Canada-USA market via the Canada Southern (CASO) route that operated from Detroit to Buffalo via Windsor and Niagara Falls/Fort Erie, Ontario and transported the

commodities that were examined in this study. The CASO route offered the shortest distance, fastest travel time between New York City/Boston, MA and Detroit, MI/Chicago, IL for many decades until the 1970's.

Another factor in the late 1960's through 1970's as well as the 1990's through early 2000's periods that may have contributed to research on mode choice was rising gas prices. The early 1990's brought North America the first wide-spread use of intermodal truck-rail and container-rail shipping. Intermodal rail freight transportation was a joint effort on the part of several trucking companies and the Class I railroads in the USA to compete for transportation business by offering lower rates for long distance shipments. Such partnerships proved to be beneficial for both the trucking companies involved and the railroads as they were able to sustain market share and fight off competition from other trucking companies by providing industry and logistics companies with preferable rates.

The Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change is an international treaty that set binding reductions in greenhouse gases for industrialized countries. The Kyoto Protocol was adopted by the Parties in 1997 and came into effect in 2005. Notably, Canada renounced the treaty in 2012 and the USA indicated that it had no intention of ratifying the treaty in 2011 (Wikipedia, 2013).

The relationship between transportation mode-choice implications and the Kyoto Protocol would be an interesting topic to explore in the context of cross-border freight transportation in North America considering the quantity of automobile commodities shipped between Canada, the USA and Mexico; and considering that the primary mode

choice for transporting this commodity group is diesel powered trucks.

The gap in North American cross-border research is particularly surprising in consideration of the long-standing trade relationships between Canada and the USA and NAFTA nations.

Methods of Analysis

Characteristics of Canada-USA Border Crossings in Ontario

Ontario's manufacturing exports to the United States are important because Ontario hosts 2 of the major international Ports of Entry between Canada and the USA: (1) **Windsor-Detroit crossings of the Detroit River between Ontario and Michigan** comprised of: the Ambassador Bridge, the Windsor-Detroit Tunnel, the Canadian Pacific Railway tunnel, and the Detroit River Truck Ferry, and (2) **Niagara River corridor crossings between Ontario and New York** comprised of: the Peace Bridge connecting Fort Erie and Buffalo, the International Rail Bridge between Fort Erie and Buffalo serving the Canadian National, Canadian Pacific and Norfolk Southern railroads, the Rainbow Bridge between Niagara Falls, Ontario and Niagara Falls, New York, the Whirlpool Bridge between Niagara Falls Ontario and New York serving automobiles on the lower deck and the Canadian National Railway, VIA Rail and Amtrak on the upper deck, the inactive Canada Southern rail bridge between Niagara Falls Ontario and New York, and the Queenston-Lewiston Bridge connecting Queenston, Ontario to Lewiston, New York.

Two intermediate Ports of Entry between Ontario, Canada and Michigan, USA also host multiple crossings: (1) **The St. Clair River crossings in the vicinity of Sarnia, Ontario and Port Huron Michigan** are comprised of: The Blue Water Bridge, The Canadian

National Railway tunnel; a rail ferry, and a vehicle ferry; and (2) **The crossing of the St. Mary's River between Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan** comprised of: The International Bridge (highway); and A Canadian National Railway bridge.

Additional smaller international Ports of Entry exist southwest of Thunder Bay, Ontario, road and rail crossings near Fort Frances, Ontario, and across the St. Lawrence River at the Thousand Islands and Cornwall, Ontario.

Data

Optimally, production, consumption, trade, logistics services, transportation services and network services data would be used to generate variables for the analyses in this type of research. A search of Canadian and American online data sources that were free and in the public domain was conducted and the result was that most of this data would not be available in the short 2-month time frame of this preliminary study.The Government of the United States of America Research and Innovative Technology Administration Bureau of Transportation Statistics (BTS) North American Transborder Freight Database was selected as the primary data source for this project. The database is accessible online at: http://transborder.bts.gov/programs/international/transborder/TBDR_QA.html The most recent complete calendar year data set available for use in this study is for 2012. The data used include:

1. 4 USA Ports of Entry: Detroit, MI; Port Huron, MI, Sault Ste. Marie, MI; and Buffalo-Niagara, NY;
2. 4 selected commodity types out of approximately 90 available: Automotive; Iron and Steel; Plastics; and Organic Chemicals;

3. The weight in metric tonnes of each commodity type imported through each Port of Entry by 1) truck and 2) rail modes – transported to each of the 52 USA states and districts;
4. The value in US dollars of each commodity type imported through each Port of Entry by 1) truck and 2) rail modes – transported to each of the 52 USA states and districts;
5. The estimated 2012 population of each USA destination state and district (Government of the United States of America Census Bureau, 2013); and.
6. The distance from each Port of Entry to the primary destination (i.e. port) within each of the 52 USA destination states and districts as measured by the primary author.

Descriptive statistics generated for the raw data demonstrate large standard errors, large sample variances, and highly leptokurtic distributions with large positive kurtosis. These observations indicate a large range in the values of the weight of the commodities with some destination states receiving large quantities and others receiving little or none of the commodities.

Modal Share Hypothesis Testing

Several hypotheses were tested by examining how certain factors affect the modal shares of the commodities crossing between Ontario and the United States either by Truck or Rail. A set of Binomial Logit models were estimated to test the formulated hypotheses. The model took the following form:

$$\Pr(Truck) = \frac{\exp(V_{truck})}{\exp(V_{truck}) + \exp(V_{rail})}$$

Modal share (truck and rail) was estimated for each Port of Entry and destination state pair in lieu of detailed logistics and transportation

services data. A set of utility functions V_{truck} and V_{rail} were specified and estimated in NLOGIT 5.0 to test the following hypotheses:

1. Shorter distance transportation is more likely to use truck mode;
2. Longer distance transportation is more likely to use rail mode;
3. Lighter weight commodities are more likely to use truck mode;
4. Heavier weight commodities are more likely to use rail mode; and
5. Greater quantities of commodities are more likely to be shipped to destinations with larger populations.

Results and Discussion

Results

Of the 64 scenarios tested, 16 generated significant results at the 1% level and 3 generated significant results at the 5% level. The coefficients generated for the Detroit and Buffalo-Niagara Ports of Entry yielded significant results for both truck and rail mode choices for the destination State/District population variable for all commodities except for automotive. The coefficients generated for the Port Huron and Sault Ste. Marie Ports of Entry did not yield significant results for neither truck nor rail mode choices nor for any of the variables examined.

Of the four commodity groups examined: Automotive, Iron and Steel, Plastics, and Organic Chemicals, the only commodity that did not yield coefficients with significant results was Automotive. A possible explanation for why the Automotive commodity group did not yield significant results is the large quantity of local cross-border trips between Metropolitan Detroit, MI plants and southwest Ontario plants. It is noted that commodity data specific to the parts plants and

Table 1: Scenarios yielding significant coefficients for commodities by type and measure

Mode	Type	Measure	Destination Variables	Port of Entry
Truck	P	W	Location & Population	Detroit
Truck	P	W	Location & Population	Buffalo
Truck	P	V	Location & Population	Buffalo-Niagara
Rail	I&S	W	Location & Population	Detroit
Truck	I&S	W	Location & Population	Detroit
Rail	OC	W	Location & Population	Detroit
Truck	OC	W	Location & Population	Detroit
Rail	I&S	W	Location & Population	Buffalo-Niagara
Truck	I&S	W	Location & Population	Buffalo-Niagara
Truck	P	W	Location & Population	Buffalo-Niagara
Rail	I&S	V	Location & Population	Detroit
Truck	I&S	V	Location & Population	Detroit
Truck	P	V	Location & Population	Detroit
Rail	OC	V	Location & Population	Detroit
Truck	OC	V	Location & Population	Detroit
Rail	I&S	V	Location & Population	Buffalo-Niagara
Truck	I&S	V	Location & Population	Buffalo-Niagara
Truck	P	V	Location & Population	Buffalo-Niagara
Rail	OC	V	Location & Population	Buffalo-Niagara

Key: Measure: W = Weight; V = Value
Type (of Commodity): P = Plastics; I&S = Iron & Steel; OC = Organic Chemicals

assembly plants in Ontario to the USA border is not available at the time of this study and may contribute to explaining the relationship for mode choice.

Coefficients generated for both truck and rail mode choices yielded significant results for all commodities and destination State/District population except for the automotive commodity. The coefficients generated for the Detroit and Buffalo-Niagara Ports of Entry yielded significant results for both truck and rail mode choices for the destination State/District population variable for all commodities except for automotive. The coefficients generated for the Port Huron and Sault Ste. Marie Ports of Entry did not yield significant results for neither truck nor rail mode choices nor for any of the variables examined. The coefficients for estimated travel distance from each Port of Entry to State/District destinations did not yield any significant results for mode choice, nor commodity in terms of weight transported nor value transported.

Discussion

This research involved a high-level preliminary examination using publicly available data. The descriptive statistics indicate a high level of variance within the data set. This suggests that additional research focusing on trade between Ontario and specific USA destinations using more detailed and complete data may better explain mode choice selections. The results indicate there are relationships between truck or rail mode choice for import of the commodities mentioned in Table 1 and Table 2 through the Detroit and Buffalo-Niagara Ports of Entry into to the USA at the State/District level. The fact that significant results were not obtained for most of the scenarios indicate that the variables used in this high-level exercise do not explain the mode choice selection in these cases. This further emphasizes the point that additional more detailed data about rail and truck trips is necessary to explain the mode choice selection.

Conclusions

This research project identified that there is a statistically significant relationship between truck and rail mode choices for shipping iron and steel, plastics and organic chemical commodity groups through the USA Ports of Entry of Detroit, MI and Buffalo-Niagara, NY to States/Districts in the USA based on their population. The research identified that there are many aspects of cross-border freight transportation mode choice that have not yet been explored in the North American context and that examples from the European and Asian regions should be examined to determine if they are relevant to the North American context.

The results do not tell us:

1. Where in Ontario the commodities originated;
2. The destinations of the commodities in the USA;
3. The cost to transport the commodities;
4. The duration of travel for the commodities;
5. Whether intermodal or multi-modal transportation was used;
6. The routing through the transportation network; and
7. Whether multiple logistics and transportation companies were involved in the transportation of the commodities.

These seven points are issues that should be examined in future research on mode-choice for cross-border freight transportation in the North American context.

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