IMPLEMENTING A VIRTUAL CONTAINER YARD TO THE VAUGHAN CP INTERMODAL TERMINAL

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Abstract

Transportation of empty containers by trucks moving to and from container terminals is a source of inefficiency in intermodal freight transportation. Reducing unnecessary movement of empty containers by facilitating collaboration between shippers of outbound containers (exporters) and receivers of inbound containers (importers) could help improve efficiency. A Virtual Container Yard is an internet based system containing information on container movements for the purpose of matching container importing and exporting needs and minimizing unnecessary empty container kilometers travelled.

In this paper, the Virtual Container Yard concept, applied to the Vaughan CP intermodal terminal, is analyzed to demonstrate the potential effect on vehicle kilometers travelled. Container movement data were obtained from the Ministry of Transportation of Ontario's Commercial Vehicle Survey, and a linear program was formulated and solved to determine optimal matching of inbound and outbound containers to minimize empty container movements. It was determined that implementing a Virtual Container Yard could reduce the vehicle kilometers travelled to and from the Vaughan CP rail terminal by almost 40% assuming full collaboration between all importers and exporters. While the prospect of full collaboration may be optimistic, there is potential for significant decreases in vehicle kilometers travelled, and the practicality of implementing the virtual container yard concept at rail intermodal terminals should be further explored.

Introduction

Transportation of empty containers by trucks moving to and from container terminals is a source of inefficiency in intermodal freight transportation. Trucks transporting loaded containers to an importing company generally return the empty containers to the container terminal. On the other hand, trucks with empty containers drive from the container terminal to exporting companies, and return to the terminal with a full cargo. If it is possible to reduce the truck trips with empty containers to and from container terminals, it would help reduce logistics cost as well as externalities of truck movements, such as emissions, noise and pavement damage.

One solution that addresses the transportation of empty containers is the Virtual Container Yard (VCY). The VCY is an internet-based system that stores and disseminates information on the location and status of containers, and acts as a computerized dispatching system. Using this information, empty containers can be matched with the needs of shipping companies. This means the containers can be "street turned", or interchanged, without returning empty to the container terminal. Using a VCY, the total number of vehicle kilometers travelled by trucks can be reduced. Without a VCY, a truck would travel with a full container to the importing company, then travel with an empty container back to the container terminal. A second truck would travel with an empty container to the exporting company, and travel back with a full container. With a VCY, a truck would travel with a full container to the importing company, then travel with an empty container to the exporting company. The container could be street turned to pick up the goods at the exporter, and the truck would then return to the container terminal with a full container (Figure 1). As a result, one trip with an empty container is made instead of two. Also, if the two shipping companies are matched based on proximity to each other, the one empty trip will be much shorter than the trips to and from the intermodal terminal.
Traditionally, VCYs have only been applied to marine ports. In this paper, the application of a VCY for the Vaughan CP rail-truck intermodal terminal in the north of Toronto is considered. This paper

explores the effect a VCY system could have on trucking drayage movements to and from the Vaughan CP intermodal terminal.

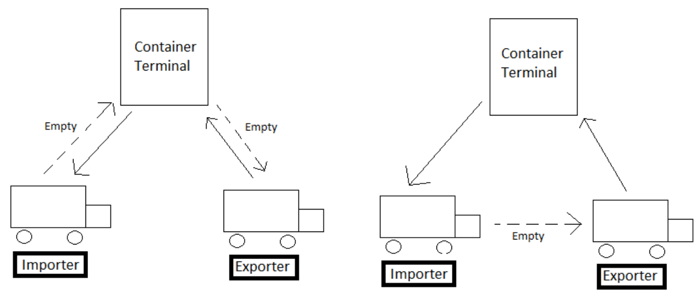

Figure 1: Truck path with and without a VCY

Literature Review

The issue of empty containers is prominent in transportation supply chain research. Boile[1] notes that the movement of empty containers can occur on a global, regional or local level, and VCYs can increase efficiency on a local level. However, local policies can be ineffective in addressing the problem of excessive empty containers that accumulate in North America because of the imbalance of trade favouring goods movement from east to western nations. The paper suggests dealing with empty containers by 1) implementing VCYs, 2) modeling behaviors between key players, and 3) determining key locations for depots.

Rodrigue et al. [2] also discuss the growing issue of empty containers, caused by trade imbalances, repositioning costs, revenue generation, manufacturing and leasing costs, and usage preferences. Since the cost to produce a container is rising more ocean carriers are repositioning empty containers (about 10% of transported containers and 20.5% of global port handling) [2]. The book discusses VCYs as a possible solution to reduce the movement of empty containers. The main goals of a VCY are 1) to display status of containers, 2) to improve information exchange between actors in the supply chain, 3) provide an easy method to transfer lease, and 4) help users make decisions on usage of container assets, namely returns and exchanges. Theofanis and Boile [3] discuss marine ports that use internet based systems to help improve port efficiency. The Port of Vancouver uses a website called Pacific Gateway Portal (PGP) that contains information about the port. It has a truck assignment system by which shipping companies pre-reserve loading times to avoid long truck line ups to the terminal. A significant hurdle of a VCY system is getting all parties to share information, and the PGP is an example where the relevant parties are sharing their information. The Port of Los Angeles has successfully implemented a VCY through a system called eModel, which contains information for 3 ports. eModel is run by a private company, who charges a fee to customers, and it is another example where all parties have agreed to share information. The Port of Oakland is another example of a port that has implemented a VCY, called SynchroMet. The Port of Rotterdam in Europe has an internet-based information system that has very similar functions to a VCY. These current examples demonstrate that installing an internet-based dispatching system, such as a VCY, can be successful.

According to the paper, the main players involved in a VCY system at a port are 1) Ocean carriers, 2) Truckers/Motor companies, 3) Container Leasing Companies, 4) Shippers, 5) Terminal Operators and 6) Port Authorities. A VCY can help coordinate and improve communication between all of these players. To determine the affect of implementing a VCY in the NY/NJ region, a model of the reduction in vehicle travel miles was developed. Mathematical programming was used to find the shortest path available when using a VCY. The final results of the paper demonstrated that collaboration of the players through a VCY helped reduce the vehicle travel miles. Crainic et al. [4] also used linear programming to optimize the movement of empty containers. The model used in this case was dynamic and stochastic. Although the paper did not specifically reference basing the optimization on a VCY system, it used similar principals of matching importers and exporters. The article put more of an emphasis on the time factor than does Boile(2). The paper dealt with time by limiting the transportation of imported goods with the arrival of the ship, and the transportation of exported goods with the departure of the ship. The paper also used vehicle miles traveled to demonstrate the efficiency of street turns and sharing of containers between importers and exporters.

Jula et al., [5] investigate optimizing empty container reuse in Los Angeles and Long Beach port region. They use an analytical method, in a deterministic and stochastic model that considers both time and distance. It examines the empty container movement's impact on cost and congestion. The data used was taken from case studies in the LA/LB region. The article considers two methods for container reuse; street-turns with a VCY, or depot-direct. In both cases it was concluded that reusing empty containers decreased cost and congestion. If time is a greater factor, then depot-direct is the best method. If cost and congestion are the greatest factor, then street turns using a VCY is the best method.

Method

The analysis compares the vehicle kilometers traveled (vkt) with and without a Virtual Container Yard in place. To model the effect of a VCY, a linear program is developed to match importers and exporters to form tours that minimize empty container movements. The method is based on that of Boile [3]. Boile incorporated full, partial and no collaboration situations into her model, whereas this model only considers full and no collaboration.

Based on the reduction or increase in vkt, the affect of a VCY for the CP rail terminal in the GTA can be determined. The following are the variables used in the optimization:

d_{io} → distance between importer i and the intermodal terminal
d_{jo} → distance between exporter j and the intermodal terminal
d_{ij} → distance between importer i and exporter j
w_i → number of loaded containers destined for importer i
w_j → number of loaded containers originating at exporter j
x_i → number of containers travelling from the terminal, to importer i, then straight back to the terminal

$y_j \rightarrow$ number of containers travelling from the terminal, to exporter j, then straight back to the terminal
$s_{ij} \rightarrow$ the number of containers travelling from importer i, to exporter j then returning to the terminal.
$I \rightarrow$ the set of all importers i
$J \rightarrow$ the set of all exporters j

The objective is to minimize the total km travelled, where the decision variables are x_i, y_j and s_{ij}.

$$\sum_{i=1}^{I}(d_{io}*w_i)+\sum_{i=1}^{I}(d_{io}*x_i)+\sum_{i=1}^{I}\sum_{j=1}^{J}(d_{ij}*s_{ij})+2*\sum_{j=1}^{J}(d_{jo}*y_j)+\sum_{j=1}^{J}((\sum_{i=1}^{I}s_{ij})*d_{jo})$$

The first term in this equation demonstrates the distance travelled by containers moved from the intermodal terminal to the importer, the second term is the distance travelled by containers from the importer to the intermodal terminal, the third term is the distance travelled by containers moved from the importer to exporter, the fourth term is the distance from intermodal terminal to exporter and back, and the last term is the distance from exporter to intermodal terminal. Figure 3 shows the path that each term represents, where the center of the circle is the intermodal terminal, i's are importing locations, and j's are exporting locations.

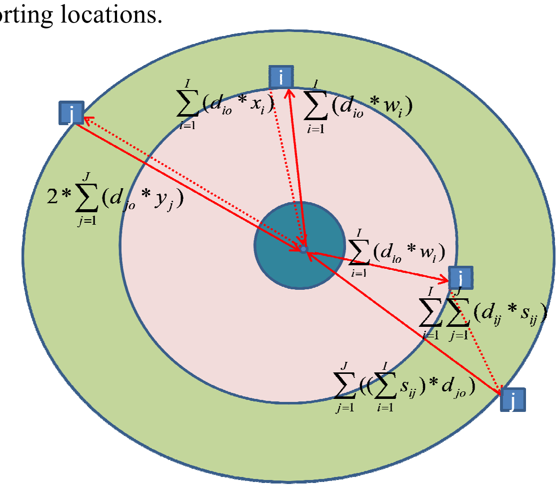

Figure 3: Path each term of the optimization equation represents

The optimization is subject to the following constraints:

1. Conservation of flow at export site

$$\sum_{i=1}^{I}(s_{ij} + x_i) = w_j$$

2. Conservation of flow at import site

$$\sum_{j=1}^{J}(s_{ij} + y_j) = w_i$$

3. s_{ij}, x_i and y_j must be positive and integers

$$s_{ij}, x_i, y_j >= 0$$

$$s_{ij}, x_i, y_j = \text{int}$$

The assumption made in this analysis is that street turns can be made anytime within the same day. On average, Vaughan CP rail intermodal terminal has 5 trains arriving, and 5 trains leaving every day. However, shipping companies are not assigned a specific train beforehand, they have a destination and are assigned a train upon arrival at the terminal. As well, goods being received at the intermodal terminal take at least 12 hours to prepare for truckers, and can be in the terminal up to 2 days before CP charges for storage of a container [6]. Due to these factors, there do not appear to be strong time window constraints within one day. However, a further area of research would be to incorporate a time variable within the optimization, based on the daily train schedule and tendency of trucking movement.

Data

The Commercial Vehicle Survey (CVS) is an Ontario roadside survey conducted in coordination with the National Roadside Study conducted by Transport Canada every five years. The CVS involves a roadside driver intercept survey to gather more detailed information on trucking movement, and 7 day truck counts for survey expansion. For this analysis, data from the 1999-2001 implementation of the

CVS was used. The dates for which the CVS conducted surveys at the CP rail intermodal terminal are October 23 to October 26, 2001 and the data collection site was the intersection of Rutherford Rd and Highway 50. Table 1 shows the total number of trucks counted, and how many were stopped to be surveyed.

Table 1: Total truck volumes and volumes surveyed for CVS in 2001

DOW	Total	Total Surveyed
Sunday	165	0
Monday	2096	88
Tuesday	2385	70
Wednesday	2443	72
Thursday	2312	49
Friday	2178	0
Saturday	288	0

In each survey, the driver classified the trip as a “pedal-run”trip or a “linehaul” trip. A pedal run trip is a trip where stops for cargo pick-up and delivery are made between its first cargo pick-up point and last cargo delivery point. A linehaul trip transports the entire cargo load from one point to another. Only linehaul trips were considered for this analysis, since the Virtual Container Yard only matches up containers that are going directly to and from the intermodal terminal. The majority of the data was linehaul trips, therefore the assumption that most trucks are going to and from the intermodal terminal is accurate.

Origins and Destinations outside of a 100 km radius were not included in the model. This assumption implies trucks that are traveling greater than 100km will not perform a street turn at another location because they are too far away. The Virtual Container Yard examined in this paper only considers truck movement within the 100km radius.

The remaining locations were used to create a map of importers and exporters throughout the GTA using the longitude and latitude points from the CVS.

Estimating Import and Export Demand (w_i and w_j)

To apply the optimization model, a volume matrix for importers and exporters for a typical day was estimated based on CVS data. To determine which locations were importers and which destinations were exporters, the data category giving the direction of the truck, and whether the truck had a full cargo, were considered. If the truck was headed towards the CP intermodal terminal (direction N), and had a full cargo, the origin was considered an exporter. If a truck was leaving (direction S) with an empty container, the destination was also considered to be an exporter. Otherwise the location was considered an importer.

The CVS data collection spanned 4 days, October 23 to October 26 (Monday to Thursday), and all 4 days were used to estimate container demand for a typical day. The volume for each day was added up at each import/export site and multiplied by an expansion factor. To develop this factor, the ratio of total to surveyed trucks on Day X is multiplied by the percent the day represents in the 4 day total.

$$\text{Exp Factor Day x} = \frac{\text{Trucks Counted on Day x}}{\text{Trucks Surveyed on Day x}} * \frac{\text{Trucks Counted on Day x}}{\text{Trucks counted over 4 days}}$$

The volumes demonstrate that there are slightly more imports than exports, as was expected. Although Toronto has a large manufacturing industry, the city still imports from other provinces, particularly from the west, more than it exports. This imbalance limits the number of street turns between importers and exporters. The largest importer and the largest exporter is Mississauga. Other significant importers and exporters include Brampton and Etobicoke.

Creating a Distance Matrix

To create a distance matrix between importers and exporters, the longitude and latitude points were used with the Haversine function. The Haversine function returns the spherical distance between two points on the Earth's surface. This distance is an approximation, because the trucks will be moving in a grid pattern along the streets.

Only aggregate information about the location of importers/exporters was available. Locations were generally aggregated to the municipal or neighbourhood districts, represented by a central point within each district. An intrazonal average distance of 5km was assumed based on the overall size of the area considered and the average size of zones.

Dividing Data into Quadrants

The number of decision variables (s_{ij}) in this linear programming problem is 780, which creates a very large problem to solve computationally. To simplify the problem, the locations were first divided into four quadrants. The assumption is made that trucks only make street turns at locations within the same quadrant. The quadrants were selected to balance the demand within each quadrant. The quadrant boundaries were -79.6184 longitude and 43.73362 latitude.

Results

The linear program was solved using IBM Ilog Cplex [7]. In quadrant 1 (NE), a frequent path is to drop off a container at an importer in Scarborough, then street turn at an exporter in Scarborough before returning to the intermodal terminal. This occurs frequenty because Scarborough is distant from the terminal, and has the highest volumes.

In quadrant 2 (NW), the locations that are both importers and exporters have a street turn within the same zone. Driving to another location within the same zone is the shortest distance between importers and exporters, so it is logical that a large portion of the trucks would conduct an intrazonal path. The Honda-SPSS plant is only an importer, and is on the same tour with Bolton exporters since Bolton is on the way back to the intermodal terminal. The Bramalea CN rail yard is only an exporter, and trucks visiting that yard make street turns with Brampton importers. Containers going to and from

Vaughan generally do not make street turns because Vaughan is so close to the Vaughan CP intermodal terminal.

Quadrant 3 (SW) has a diverse set of paths because this quadrant has the most distinct locations, and the locations are spread out compared to the other quadrants.

Quadrant 4 (SE) mostly has intrazonal street turns, because for that quadrant all the import locations also have exporters, and there are similar volumes for imports and exports.

For quadrants 1 and 3, all y_js are zero, which indicates all the exporting demand has been meet, and the maximum possible number of street turns has been reached. This occurs because there are more imports than exports, leaving no demand for empty containers at an exporting location. For quadrant 4, all x_is are zero, which means the maximum possible number of street turns has been reached, and exports exceed imports.

Table 2: Reduction in vehicle kilometers travelled with a VCY system

Quadrant	Original Distance	Optimized Distance	% Reduction
1	16080	10555	-34.4%
2	9133	5686	-37.7%
3	31519	20070	-36.3%
4	29640	15782	-46.8%
Total	86372	52093	-39.7%

Table 2 shows the vehicle kilometers travelled for the original distance, and the optimized distance. The total reduction with a VCY was 39.7%, which is a very significant reduction in kilometers travelled. The maximum possible reduction is 50%, which would occur if all the containers that were imported had a demand for an export at exactly the same location. However, 39.7% is the theoretical optimum for the GTA, and in reality the reduction of vehicle kilometers travelled would be less significant.

As seen in Table 2, the quadrant with the greatest reduction is quadrant 4. This is because the majority of the paths taken involved intrazonal street turns, which result in the shortest possible distance between importers and exporters. Quadrants 1 and 3 have a slightly less significant reduction because these quadrants have the locations furthest away from Vaughan CP intermodal terminal, and have fewer intrazonal street turns compared to the other quadrants.

Challenges in Implementing a VCY at Vaughan CP Rail Yard

Implementing a VCY at Vaughan CP intermodal terminal shows potential to reduce the vehicle kilometers travelled. The major advantage of reducing vehicle kilometers travelled is that it would reduce the cost and time required to transport empty containers around the GTA. It would also help to reduce the environmental impact of trucks, since they would be travelling smaller distances. However, there are certain barriers to implementing a VCY at Vaughan CP intermodal terminal.

The major challenge is convincing all stakeholders involved to share information. CP, trucking companies, importing and exporting companies would need to be willing to share information on where and when they are shipping their goods. Companies may be unwilling to share the necessary information in highly competitive business environments.

VCY's have mostly been explored as an option for large ports, such as the New Jersey/New York port, and the Vancouver port. The Vaughan CP intermodal terminal is a much smaller operation than these ports. It is questionable whether there is a business case for implementing a VCY at this small scale. CP could operate simply using human dispatchers to try and match importers and exporters for a street turn. The down side of human dispatchers is that they may not find the optimal a path.

Information technology could take CP Rail to the next level of transportation safety and efficiency, and they have been exploring different option. Digital information sharing is not a new concept in the railway industry. One example is the industry fleet of automobile carrying rail cars. Each railway contributes rail cars to this fleet based on the amount of business they do in this sector. Distribution of this fleet back to the various North American railways for loading is controlled by a central office. Information gathering, processing, and sharing amongst the equipment is becoming more common in the rail industry.

Future Research

Additional research should be conducted to further refine the analysis. First, travel time could be minimized, rather than spherical straight-line distance. Travel time should take into account congestion delays at the time of day the trucks are travelling, which would require solving a more computationally challenging VRP with time varying demand [8].

Second, incorporating constraints imposed by the train schedule may influence the solution. Imposing such constraints would help to decide what time of day the trucks are travelling, in order to calculate travel time.

Third, more accurate intrazonal distances are needed. In absence of better data, calculating intrazonal distances based on the area of the zone would improve the result.

Another constraint not considered in the analysis is container type. There are different sized and special purpose (e.g. refrigerated) containers that may not be interchangeable as the model in this paper assumes.

Finally, further research into the costs and practicality of implementing a VCY at Vaughan CP intermodal terminal should be explored. More detail about how a VCY would work, how it would be build, and what types of contracts would be needed between players would help demonstrate the real world practicality of implementing a VCY. A monetary value for the costs saved by reducing the vehicle kilometers travelled could be estimated and compared to the cost of developing and maintaining a VCY.

Conclusion

Moving empty containers to and from the Vaughan CP intermodal terminal is inefficient and the distances empty containers are moved should be minimized. A Virtual Container Yard for trucks moving to and from the Vaughan CP intermodal terminal within the GTA is a possible solution to reduce the vehicle kilometers travelled. Using data from the Commercial Vehicle Survey, and linear optimization of vehicle kilometers travelled, it is concluded that a VCY could reduce the vehicle kilometers travelled by up to 39.7%. This would help reduce the cost and environmental impact of moving empty containers. Theoretically, a VCY appears to have strong potential to reduce the number of vehicle kilometers travelled. The practicality of implementing a VCY for Vaughan CP should be further explored.

Acknowledgements

The authors wish to express their gratitude to CP Rail and the Ministry of Transportation of Ontario for providing the data necessary to conduct this research. Also we wish to thank Paul Kerry for providing helpful comments on a first draft of the paper.

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