Port Congestion and Drayage Efficiency

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Port congestion and drayage efficiency issues have re-emerged as major challenges for U.S. container ports with the recovery of container traffic to previous peaks. The deployment of ever larger container vessels results in “bunching” of traffic at marine terminals. Resolution of terminal and road congestion problems is complicated by the reluctance of terminal operators to extend truck gate hours. Changes in container chassis logistics have had a major impact on drayage efficiency.

Similar problems were encountered much earlier at the Port of Vancouver. Port Metro Vancouver’s container terminals currently achieve a throughput per acre approaching 8,000 TEU’s per acre, approximately 70% higher than the average for Southern California ports. Maintaining fluidity of terminal operations with these higher throughput levels required significant changes to terminal operations, including the displacement of non-essential activities to off-dock sites and implementation of technology including truck reservation systems.

These increased drayage costs provided the motivation for rationalization of container logistics in BC’s Lower Mainland. These efforts have included cooperation among import and export shippers to expand the use of “triangulation” to reduce empty truck trips; and deployment of container-handling equipment at both import distribution and export transload warehouses to increase the efficiency of chassis utilization and throughput on firms’ limited land base. This paper highlights research conducted by the authors on the impact of “densification” of port container terminals on the drayage sector and the short and long term responses of the logistics system to higher drayage costs.

Southern California Crisis

The Southern California container gateway is in a state of crisis. Overall, the LA/Long Beach market share of Pacific Rim containerized imports declined from 56.5% in 2003 to 48.4% in 2014. The long term decline is attributable to increased costs for the West Coast routing relative to East Coast options. More recently, port operations were disrupted during the negotiation and eventual signing of a new longshore labour agreement by the Pacific Maritime Association and ILWU.

A number of factors contribute to current congestion problems at the Ports of Los Angeles and Long Beach. The predominance of larger vessels and bunching of vessel arrivals have been cited as one of the major causes of port congestion. The increased prevalence of vessel-sharing alliances has also been cited, because it requires terminals to receive containers from multiple shipping lines, increasing the complexity of operations.

Regardless of the causes, congestion has resulted in inefficiency in drayage operations. The visible symptom has been a dramatic increase in turn times. Turn times (including queuing delays) at the Southern California terminals averaged 89 minutes in July 2015. This is as much as 48% higher than those recorded in early 2014, when turn times averaged 60 to 70 minutes. The Harbor Trucking Association of Southern California says turn times at marine terminals must get back down to 60 minutes if the harbor is to operate efficiently (Mongeluzzo, August 2015).

Evolution of Terminal Operations in Southern California

The operating model which evolved in the development of US container operations was unique in both terminal operating practices and drayage arrangements.

Southern California terminals were designed primarily to deliver and receive containers by truck. Transfers to rail were accomplished by drayage from the port terminals to near-dock or downtown intermodal yards. Containers were stored on chassis within the terminal, which enabled rapid pickup or drop off of containers by truck and reduced labour costs relative to ‘live loading” of trucks from stacks in the container yard. Chassis were provided by the shipping lines at the terminal free of charge for the trucking industry to use. This system requires a large terminal site to accommodate the relatively low density of terminal operations.

This model has broken down as a result of increases in container volumes and peaking of container movements due to larger vessels. Southern California terminals are being forced to stack containers higher and deliver them directly to trucks rather than transferring them to chassis for pickup. The decision of shipping lines to divest their chassis fleets has further complicated the situation, as the transition to fully "grounded" operations is incomplete and chassis are still required on dock to support terminal operations.

The congestion being experienced at the Southern California terminals is an inevitable consequence of handling increasing traffic volumes on a limited site footprint, exacerbated by the cargo surges resulting from the use of larger vessels. Experts suggest that to operate in this high-density environment, a terminal must handle at least 7,000 TEUs per acre (Mongeluzzo, July 2015). In 2013, average throughput was estimated at 4,500-4,800 TEU's per acre for Southern California terminals (Mongeluzzo, 2013).

Port Metro Vancouver

Port Metro Vancouver illustrates the impact of increases in terminal throughput on the drayage sector. The major container terminals at the Port achieved a throughput per acre exceeding 8,000 TEU's per acre by 2006. However, achieving this level of throughput required substantial changes in terminal operating practices and resulted in major disruptions in the drayage sector. While Vancouver's experience is influenced by unique local factors, it can provide some guidance on the challenges facing Southern California ports in avoiding congestion while coping with high throughput levels.

The evolution of container terminals at the Port of Vancouver differed substantially from the U.S. experience. Major differences include:

- Inbound and outbound cargo flows are relatively balanced.
- All terminals are "common user" terminals serving multiple shipping lines.
- All containers are stacked; there are no street chassis used for terminal operations and chassis are supplied by trucking companies.
- The terminals are highly dependent on rail. At the three major terminals, 65%-70% of loaded inbound containers are typically loaded direct to rail on-dock.
- In contrast, the largest share of export cargo is loaded into containers in the Lower Mainland and delivered to the port terminals by truck. To fill the need for empty containers for loading exports, empty containers returned by rail from Eastern markets must be trucked off of the docks.

There are four on-dock container terminals in the Lower Mainland. The terminals are geographically dispersed. Centerm and Vanterm are located in the Port of Vancouver's Inner Harbour. Deltaport is located on Roberts Bank around 20 miles from the Inner Harbour. Fraser Surrey Docks, located on the Fraser River, is primarily a breakbulk terminal but handles a small number of containers.

Expansion of terminal capacity has been complicated by a lack of available land adjacent to the terminals. Major expansions were completed at Vanterm and Centerm in 2005 on the existing terminal footprints. Deltaport was constructed on an artificial island or "pod"; an additional 20 acres for container storage was added by reclaiming land adjacent to the existing terminal as part of the Third Berth expansion project completed in 2010. Density reached approximately 8,000 TEU's per acre in 2006 and has averaged close to this level ever since, with a slight reduction from 2009 through 2011 related to completion of the Deltaport Third Berth project and traffic declines resulting from the global financial crisis. The Vancouver terminals exceeded the current Southern California throughput per acre by 2003.

Impact of Higher Density

The move to higher density operations rendered the terminals more vulnerable to congestion. In January 2005, TSI Terminals declared "Force Majeure" at Deltaport due to a backlog of rail shipments on CN Rail. Subsequently, TSI implemented a number of changes in terminal procedures to maintain fluidity:

- Free time for import and export containers was reduced from 7 days to 5 working days in early 2005. (TSI, 2005)
- In 2006, TSI's Fluidity Plan (TSI, 2006) eliminated empty container storage on the docks with the exception of empty containers scheduled for evacuation on the next vessel.
- Empty containers not scheduled for immediate evacuation, and empty containers repositioned for export loading, were subjected to a fee of $100 per TEU per day for any period beyond the free time of 2 days.
- Earliest Reporting Dates (ERD's) for loaded export containers were reduced from 5 days to 4.

- Acceptance of import containers for each shipping line was restricted to volumes agreed in capacity agreements between the line and the railways; any containers in excess of this volume were required to be trucked off the terminal immediately or faced substantial financial penalties.

These changes had far-reaching impacts on drayage efficiency. In late June 2005, operations at all of the container terminals were disrupted by a withdrawal of services by drayage drivers. The major factors leading to the strike included long turn times at the port terminals, changes in trip patterns due to the introduction of off-dock storage of empty containers, and low rates. The dispute was resolved through a federal government Order in Council which compelled trucking companies to pay owner-operators the rates contained in a Memorandum of Agreement negotiated between the drivers and trucking companies. The adoption of the MOA rates increased drayage rates in the Lower Mainland by approximately 40%. In addition, a fuel surcharge which varies with the price of diesel fuel was introduced.

In early 2014 port operations were again disrupted by a strike by drayage drivers. The major issues were lengthy turn times at the port terminals and low rates. Total turn times at the largest port terminals (Deltaport and Vanterm) increased by approximately 20% between 2007 and 2014, and the system for regulation of rates which was put into place following expiry of the two year agreement mandated in 2005 proved ineffective. The 2014 strike was ended following negotiation of a 14 point Action Plan by the provincial and federal governments which included the following provisions:

- An increase of 6% in the regulated rates implemented in 2006, and doubling of the fuel surcharge. At current diesel prices, the fuel surcharge doubled from 7% to 14%.
- Extension of GPS tracking to the entire port trucking fleet.
- A pilot project for extended truck gate hours at the port terminals.
- Penalties payable by the port terminals to truckers for turn times in excess of 90 minutes.
- Implementation of an enhanced common reservation system by January 2015.

The port terminals implemented regular night gates in July 2015. The terminal operators acted to ensure use of the night gates by reducing the availability of daytime reservations and implementing a $50 surcharge for daytime reservations.

The provincial government has passed legislation to create the office of the Port Trucking Commissioner with responsibility for overseeing licensing of trucks serving the port terminals and regulations of rates. Regulations under the Act specifying details of rates, etc. were finalized in May 2015.

Summary – Vancouver Impacts

The experience at the Port of Vancouver shows that a higher throughput density for container terminals is achievable through aggressive policies to limit dwell time for containers on the dock. However, the overall impact on the container logistics system has been extremely disruptive. In Vancouver, the actions taken by the terminal operators to achieve higher throughput and maintain the fluidity of operations contributed to the following outcomes:

- Lengthy port shutdowns due to drayage strikes in 2005 and 2014.
- Substantial increases in drayage rates. The rates specified in the most recent regulations are approximately 65% higher than those in effect prior to the 2005 strike, with additional costs in the form of a fuel surcharge.
- Implementation of mandatory truck appointment systems at the container terminals, which have impacts on the efficiency of drayage movements. For example, the reservation systems make it difficult to coordinate double moves (i.e. loaded both ways) on trips to the port terminals.
- Additional costs to shipping lines for dray-off of empty containers and off-dock container storage.
- Government regulation of drayage performance and driver remuneration, and monitoring and regulation of turn time performance by the port terminals (enforced by monetary penalties).

Efficiency Impacts Case Study – BC Lower Mainland Trucking Sector

Continuing concern over drayage efficiency led the Province of British Columbia to sponsor creation of a Container Lower Mainland Container Logistics Stakeholders' Forum to explore options for increasing efficiency in landside logistics. As part of this effort, the BC Ministry of Transportation engaged IBI Group to analyze and model container truck movements in the Lower Mainland (IBI Group, 2007). The scope of the project included integration and analysis of data on Lower Mainland container truck movements gathered through trip surveys, global positioning systems (GPS) tracking devices, radio frequency identification (RFID), and security access records. A simulation model was designed to estimate the impact of changes to basic system parameters including turn and travel times and trip distribution patterns. The model was used to estimate the impact of potential changes on driver revenue (based on the number of trips completed) and costs.

Analysis of the data generated the following findings:

- Drivers were achieving an average of seven one-way trips per day, but the trucks were loaded with a container for only five of these on average.

- More than half of drivers' trip time was spent waiting or being processed at terminals.

- Turn times (including queuing delays) were longest at the on-dock container terminals, followed by rail intermodal and off-dock terminals. All terminals have a high level of variation in their turn times.

- Turn times at on-dock container terminals averaged 52 minutes, and were almost identical among the three large terminals (Vanterm, Deltaport and Centerm). On average, these terminals processed 80% of trucks within 80 minutes.

- Travel times between origins and destinations exhibited less variation relative to the average than terminal turn times.

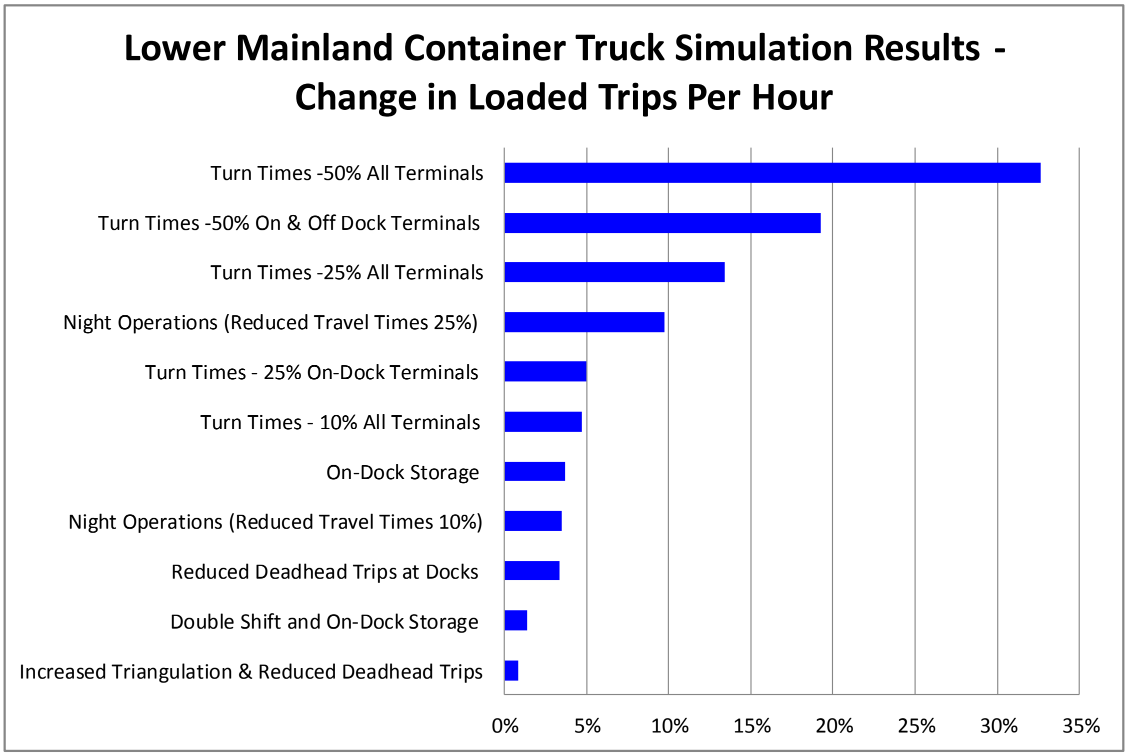
A simulation model was developed using Extend software to analyze the impact of changes in terminal operating practices (off-dock storage) and turn times on drayage efficiency. The model incorporates 12 distinct nodes representing origins and destinations for container trips in the Lower Mainland. The on-dock and major off-dock terminals are included as individual nodes because they are essential elements in the "common" user system (i.e. used by all parties) and account for the largest proportion of truck turn times. The model nodes include on-dock container terminals, off-dock terminals, transload warehouses classified as either export or import, rail intermodal terminals and a generic yard as a start and end point for daily itineraries. This allows analysis of system impacts using a compact 12x12 origin-destination matrix.

A probability distribution of turn times for each individual terminal was generated based on the results from the data surveys. For the aggregated nodes (import and export transload warehouses and rail intermodal terminals) the average turn time distribution was used. Travel times were assumed to be normally distributed with a mean and standard deviation estimated from the survey data for specific origin-destination pairs. For aggregate categories (transload warehouses, rail intermodal terminals) the aggregate mean and standard deviation is used.

Trip patterns are based on probability distributions for destinations for each node, based on their load status (i.e. loaded container, empty container, or no container (deadhead).

A large number of simulation scenarios were calculated to estimate the impact of changes in turn times, terminal operations and trip patterns on drayage efficiency. Two measures of efficiency were used: loaded trips per hour and loaded trips per day. From the drayage driver perspective, the most significant is loaded trips per hour; in the simulation cases exploring extended gate hours at the container terminals drivers achieve more trips per day at the expense of working longer hours. The simulation cases showing the largest increase in loaded trips per hour are shown in the figure below.

The results show the dominant influence of terminal turn times on drayage performance. This is not surprising, since the survey results showed that drivers spent 52% of their time at terminals. The model estimated that a reduction of 50% in the average and standard deviation of turn times at all terminals (on-dock container terminals, off-dock empty storage terminals, import and export transloads and rail intermodal terminals) would increase loaded trips per hour by almost 33%. A reduction of 50% at the on-dock and off-dock terminals alone would increase loaded trips per hour by 19%, and a reduction of 25% at all terminals would increase loaded trips per hour by 13%.



The simulation results indicate that the number of loaded trips achieved is relatively insensitive to small changes in turn times. A reduction of 10% in average turn times at all terminals resulted in an increase of less than 5% in loaded trips. This is not surprising given the average duration per trip of approximately 90 minutes; a reduction of 10% in turn times would not add up to enough time for an additional trip. In order to generate substantial changes in loaded trips, a large reduction in turn times throughout the system is required. If turn times at all terminals were reduced by 25%, average loaded trips per day would increase by 9.5%.

Several simulations were run to explore the impact of changes in travel times. These cases were based on assumptions regarding reductions in travel times due to night operations at the terminals i.e. shifting truck travel to off-peak hours. A reduction in travel times of 25% resulted in an increase in loaded trips per day of almost 10%; a reduction of 10% increased loaded trips per day by approximately 5%.

Changes in trip patterns resulted in relatively minor increases in drayage efficiency. A return to on-dock storage increased loaded trips per hour by approximately 4%. Increased triangulation and reduced deadhead trips (i.e. transfers of empty containers directly from import to export transload warehouses) increased loaded trips per hour by less than 1%.

Simulations of extended gate hours showed substantial increases in trips per day due to longer duty hours for trucks. Double shifts at the container terminals plus extension of duty hours from 8.7 hours per day to 13.6 hours per day (close to the 14 hour Hours of Service maximum) resulted in an increase of 50% in loaded trips per day but a reduction of almost 4% in loaded trips per hour.

Drayage costs were modelled on a unit cost basis for both fixed and variable costs to estimate financial impacts for each of the cases considered. The costs of a company fleet operation were used as the benchmark, under the assumption that this cost (including a 5% profit margin) would be the minimum required to induce firms to participate in the market. Costs for each scenario were based on turn times, travel times, and the number of loaded trips. Fuel costs were adjusted to account for total kilometers driven for each scenario.

The simulation model base case generated an average cost per loaded trip of $114.28 in 2006. Among the simulation cases, reducing system wide turn times had the largest impact, reducing trip costs by 16%; followed by double shift operations, which reduced costs by 11%. More efficient trip patterns through increasing the number of double-loaded moves at the container terminals, or reinstating on-dock storage of empty containers, reduced costs by 3%-4%. The major cost savings from reductions in turn times is due to reduced labour costs; the reduction in trip costs due to extended hours of operation results largely from reduced fixed costs and overhead; and the major impact of changes in trip patterns is a reduction in fuel costs.

The simulation analysis suggests that terminal turn times (including both service time and queueing time) is the key factor impacting the number of truck turns achieved in a day. In order to maximize the benefits of reduced terminal turn times, substantial improvements have to be made across the board – at on-dock terminals, off-dock terminals, rail terminals and transload warehouses. This does not necessarily require broad cooperation among stakeholders, because it can be undertaken on an individual basis by each terminal operator.

Note that these estimates applied only to efficiency of drayage operations, and did not address the impact of changes on BCO costs. In addition, the analysis does not include costs for chassis ownership and maintenance.

Efficiency Impacts Case Study – Southern California “Peel-Off” and “Dray-Off” Operations

The previous example showed the impact of key system parameters – turn times and trip patterns – on the efficiency of the trucking sector. The Ports of Los Angeles and Long Beach are pursuing one option for relieving port congestion which influences both of these: increased use of the “peel-off” and “dray-off” options for loaded import containers. In the “peel-off” option, containers from several pre-approved importers are discharged from the vessel and block-stored at the marine terminal. When a sufficient block is formed, truckers are given preferential gate access and the ILWU equipment operator “peels off” the containers without regard to consignee. In the “dray-off” option, truckers dray the containers to a near-dock site, drop the loaded chassis and then return to the terminal with another container. The loaded chassis is picked up by another trucker from the near-dock yard and transported to its destination. When these options are combined, turn times at the terminal are reduced and trucks hauling to the near-dock site make more trips per day. However, the impact on overall system costs is less clear.

To explore the impact of the “peel-off” and “dray-off” options on system efficiency, we have developed a model to analyze the impact of several options on terminal and drayage costs in Southern California. Four options were modelled:

1. Case A is represents traditional handling practices at Southern California terminals, modified slightly to take into account that the containers are now grounded. Containers are unloaded from the vessels, grounded in the container yard and then loaded onto trucks which have obtained a chassis from the terminal inventory. This container is then drayed to the BCO, and the driver returns to the terminal with an empty container on a different chassis. There is no additional complication to match containers to shipping lines (or terminals), or chassis to their proper pools.

2. Case B represents a variation to the simplified version by adding one bobtail leg to the drayage component. For example, this could involve the tractor and driver going from one BCO to another for an empty container. It may be considered as a surrogate for some of the real-life complications that are not reflected in Case A.

3. Case C introduces the Drop Yard feature, which includes use of both the “peel-off” option and the “dray-off” option. The journey from the dockside terminal to the

BCO is conducted in two drayage moves and one additional terminal process at an off-dock parking area not far from the dockside; the drop yard is a wheeled operation. This approach speeds up the in-terminal activity, reduces delay for the dray operator and it is more productive for the terminal. Total terminal handling costs (dockside plus drop yard) resulting from this change are not increased, and most likely reduced; this is a good result from the perspective of the terminal operator. The trip to the customer over the road is approximately the same distance from either the drop yard or the dockside terminal, because the off-dock parking area is close to the marine terminal.

4. Case D is a minor variation on Case C. In Case C, the drop yard is involved in both the import direction, and in the export direction. On the other hand, in Case D the drop yard is bypassed on the return journey and the empty container is delivered directly to the marine terminal.

To assess these options, we have developed a hypothetical economic-cost model which assumes that the control and ownership of each box from ship to door is all managed by a single agency that minimizes overall costs. This abstraction in necessary because the fragmentation of operational responsibility among system participants (shipping lines; terminal operators; drayage companies and drivers; container storage and warehousing facilities; and BCO's) may result in sub-optimal system outcomes as each tries to maximize their own profits.

In particular, our method of incorporating chassis costs ignores whether the chassis are owned by shipping lines, trucking companies or a leasing pool, and simply estimates the capital and operating costs of a chassis fleet that would be required to support one tractor operating one shift six days per week.

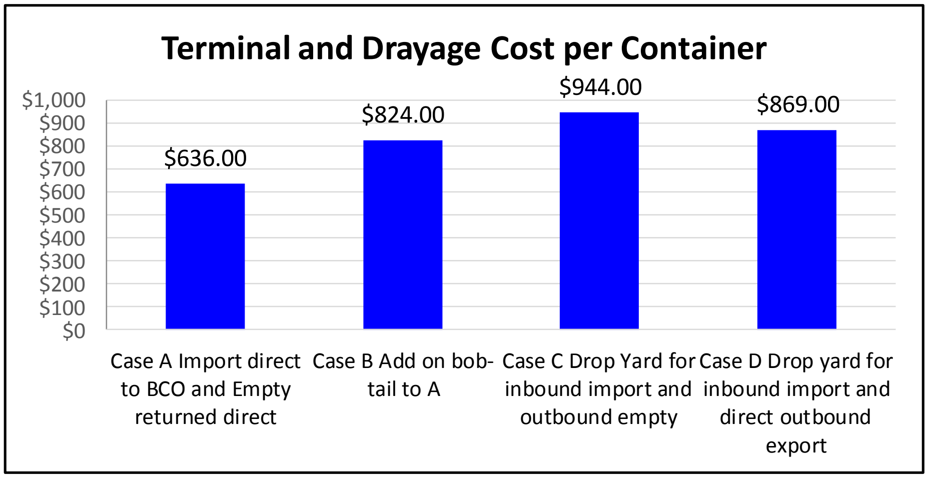
We have made a series of assumptions based on our understanding of the current situation in the ports of Los Angeles and Long Beach. Our costing model uses input unit factor costs for capital and operating elements, and productivity factors that can be specified by the analyst using the model. They are based on our judgment of typical costs applicable in Southern California based on our own experience and on numerous references in current media releases. The input costs can be easily modified to assess the impact of different unit cost data on the model's output.

The key assumptions that we have built into the model are summarized in the table below.

Economic Cost Elements between Vessel and Beneficial Cargo Owner Premises

Hypothetical Case Parameters			
	Traditional		**Drop Shuttle**
Drayage			
Tractor Capital Cost	$100,000		$90,000
Service Life	6	years	8
Chassis Cost	$12,000		$12,000
# Chassis per Tractor	6	#	3
Blended Cost of Capital	8.50%	% p.a.	8.50%
Driver Wages	$25	$/hr	$25
- plus social benefits		35%	
Avg. # one-way trips/day	4		10
Avg. trip length	60	miles	10
Avg. waiting & processing time/leg	0.75	hours	0.30
Annual Cost per tractor operated	$234,000		$171,000
Cost per Day (312 days/yr)	$750		$550
Cost per mile	$2.34		$4.08
Cost per leg	**$188**		**$55**
Handling Dockside			
Labor Average (incl. 35% fringes)	$88	$/hr	$88
Labor hours per container handled through the dockside terminal	0.84		0.56
Add equipment cost	60%	% labor	60%
Gen'l & Admin	10%	% +	10%
$ per container throughput one-way	**$130.00**		**$100.00**
Handling Drop Yard			
Labor hours per container handled through the dockside terminal			0.17
Add equipment cost		% labor	20%
Gen'l & Admin		% +	20%
$ per container throughput one-way			**$20.00**

The figure below shows the total of the terminal handling costs and drayage for each import container (20 feet, 40 feet or 45 feet in length) for each option.



The results suggest that simply focusing on turn times in the dockside terminal is a sub-optimal approach that actually results in higher costs.

Case A – the traditional trip pattern with containers drayed direct to destination with an empty container repositioned to the container terminal on the return leg – shows the lowest overall cost, at $636 per round trip (inbound vessel to outbound vessel per container). Adding an additional bob-tail leg increases costs by $188 or approximately 30%.

Case C – the Drop Yard case, incorporating the “peel-off” and “dray-off” options – results in increased costs in spite of reductions in terminal costs for container yard and gate operations. The use of the Drop Yard results in increased costs from the intermediate drayage trip (container terminal to Drop Yard) and direct Drop Yard costs. Costs are reduced slightly if the empty container is delivered directly from the BCO’s location to the container terminal, bypassing the Drop Yard.

In summary, the solutions focusing on only terminal congestion by shifting the problem to another location do not generate systemic solutions. Nevertheless, the drop yard approach is an effective short-term stopgap measure to buy some time to develop effective system solutions. Without complementary strategic change in the long run, this option could exacerbate market erosion as customers eventually shift their supply chain strategies in favour of other more efficient locations.

From a practical perspective, the availability of suitable industrial land in proximity to the Ports is a major constraint on expansion of the “dray-off” option as a long term solution. The 22 acre Pasha Drop Yard currently in operation has a capacity of 700 containers on chassis for a density of up to 64 TEU's per acre (Dupin, 2015). In comparison, the storage density for grounded container terminal operations using Rubber Tired Gantry cranes (RTG's) is up to 300 TEU's per acre (Smith, 2012). Consequently storage of containers at Drop Yards rather than a container terminal would require additional land at a ratio of almost 5 to 1 i.e. it would require almost 5 acres of Drop Yards to substitute for 1 acre of terminal land. It is highly unlikely that sufficient land will be available to support the "Dray-Off" option as a long term solution.

Efficiency Impacts Case Study – Shipper Costs in BC Lower Mainland

As detailed in previous sections of this report, the measures taken to achieve higher throughput levels at the container terminals at Port Metro Vancouver resulted in a substantial increase in trucking rates paid by shippers (commonly termed "Beneficial Cargo Owners" or "BCO"'s in Southern California). This section deals with strategies to enable BCO's to control their own costs in an environment of rising system costs.

The move to off-dock storage of containers altered drayage trip patterns and provided opportunities to negotiate lower rates based on actual trip patterns rather than the traditional "round-trip" rates. For example, importers with facilities in close proximity to an off-dock storage yard began to negotiate lower rates because the empty containers were being trucked across the street rather than back to the port terminals. This flexibility in rates enabled BCO's to develop strategies to capture potential cost savings from "triangulation" of containers (i.e. avoiding drayage trips by coordinating direct transfer of empty containers from an import distribution centre to an export transload facility for reloading prior to return to the port terminals). "Triangulation" is commonly referred to as a "street turn" in Southern California. Theoretically the use of triangulation to eliminate the need for repositioning of empty containers can reduce the cost of moving cargo to and from the container terminals by 50%.

This case study is based on a study conducted for a group of BCO's in Vancouver in 2007 to evaluate potential cost reductions from increased cooperation and coordination of container movements. Details of the case are confidential to protect the commercial privacy of the proponents.

The six different Beneficial Cargo Owners (BCO's) are more or less equally balanced between volumes imported and volumes exported in 40 foot containers. All have facilities in the lower

Mainland and together they represent a combined volume in the order of 100,000 FEU's per year.

Together, they investigated the benefits and costs of collaborating to enable inbound import containers to be unloaded and then reloaded with export cargo at the same facility or at a facility in close proximity. Essentially they were seeking optimal sourcing and allocation of empty marine containers on an average day based on the lowest total cost for handling and transportation of all loads and empties on that day. All containers had to be reloaded to the same terminal from which they were imported; there were no restrictions on chassis. Four different trans-load locations were involved.

The main point of the exercise was to determine if the benefits from optimal triangulation justified pursuit of this strategy. The results were impressively positive.

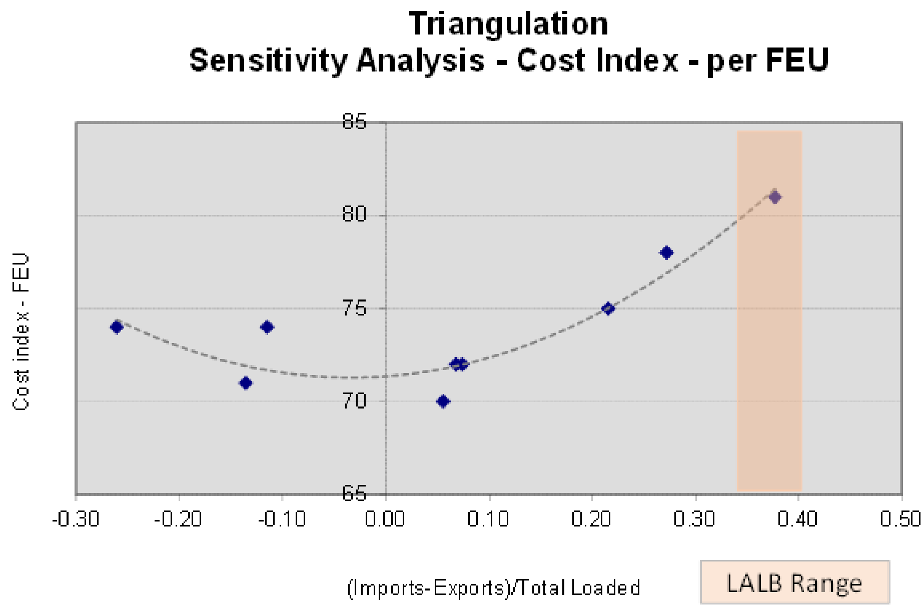
The results also proved the need for centralized coordination and management of both shipping schedules and the drayage operation in scheduling and routing vehicle movements. A dedicated fleet of drivers (unionized), tractors and chassis as well as the cost of central management and coordination was included in the evaluation.

A linear programming trip assignment was run with actual point-to-point demand for loaded movements, and empties were assigned to achieve the objective of lowest overall system cost. Sensitivity cases were carried out for a typical slow day and a typical busy day. Also a number of cases were examined to evaluate the impact of a shifting in balance between import and export volumes.

The optimal costs were compared both with the actual costs for drayage paid by the BCO's for those moves. Triangulation did not completely eliminate movement of empty containers because of the day-to-day dynamics of matching containers with terminals. Nevertheless, overall drayage savings in excess of 20% were shown to be realistic.

The potential additional savings from fleet management were not included in this scope. They were a source of additional encouragement because of the added savings that could be achieved in terms of fleet utilization, higher fluidity through even further scheduling improvements, and regular operations in low traffic periods.

Traffic imbalance between exports and imports was one area of concern. For the case of these BCOs, imbalance was not a major issue, mainly because the imbalance variations were expected to be within the range of +/- 15% on a daily basis. A reduction in costs of up to 30% was achievable, before allowing for discounts and two-way incentives that were in effect (in the range of 10% to 15%). The relative stability of optimal system cost within this range is illustrated in the graph below.



The sensitivity analyses that were carried out at the time cast some light on potential applicability to Southern California. Imports dominate over exports at San Pedro Bay Ports, with an import/export imbalance in the range of 40%. This reduces potential cost savings, but still results in significant savings.

The relationship is neither linear nor symmetrical. The best fit through the points shown is a quadratic equation that is much more progressive in the positive direction than the opposite. In other words the surplus of exports is less disruptive than the surplus of imports.

While the potential benefits of the project were impressive, it was not fully implemented due to its impact on existing commercial relationships between the BCO's and drayage companies, and concerns over inflexibility with regard to the potential use of breakbulk options for a portion of the cargo.

Long Term Adjustments

BCO's, drayage firms and logistics operators have had more than a decade to adjust to changes resulting from increased density of operations at the container terminals. The successful adjustments consist primarily of investments to capitalize on the potential benefits from more efficient trip patterns including triangulation. The adjustment has been made more difficult by a chronic shortage of suitable industrial land in the Lower Mainland, and the consequent high prices for industrial real estate.

Clustering of Container Facilities

One strategy for reducing drayage costs is the clustering of container facilities in close proximity. The prime example of this in the Lower Mainland is the development of Port Metro Vancouver's Richmond Logistics Centre on approximately 500 acres of land assembled by the Fraser River Port Authority from a former landfill site. The site is ideally suited for container logistics midway between Inner Harbour terminals (Centerm and Vanterm) to the north and Deltaport to the south. Development was kick-started by a joint venture called Modalink between the Fraser River Port Authority and the Vancouver Port Authority (amalgamated as Port Metro Vancouver in 2008) which resulted in the construction of the Coast 2000 combined export transload facility and empty container storage yard on the bank of the Fraser River in 2004. The site is almost completely built out now, with a mix of import, export and other logistics operators, rail service by CN Rail, and a barge ramp at Coast 2000 for handling pulp shipments. Port Metro Vancouver divested their interest in the Modalink joint venture to the private sector in 2012.

The availability of empty container storage at the site is the key to improving the efficiency of drayage trip patterns, because it facilitates the repositioning of empty containers among importers, exporters and storage without leaving the site. It will be difficult to replicate this development within the Lower Mainland due to the lack of sufficiently large industrial land parcels.

Densification of Warehouse Facilities

The move to off-dock storage initially resulted in rapid increases in traffic at off-dock storage yards. However over the longer term demand for dedicated storage yards has declined as both import and export transload facilities began to stack and store containers on-site. Some facilities have combined all three functions at a single site (transloading imports, transloading exports, and storing empty and loaded containers). This provides a number of benefits:

- Reduces truck trips, travel times, and drayage costs by reducing empty hauls.

• Enables more efficient use of the drayage chassis fleet.

• Increases logistics facility throughput capacity and flexibility for complying with the marine terminal reservation systems.

• Provides a cost effective alternative for shipping lines to meet their off-dock storage and equipment maintenance requirements and still provide the necessary level of customer service.

A prime example of this strategy is development of a cross-dock facility on Port Metro Vancouver land in the city of New Westminster. It was originally developed by Damco to accommodate Target's import traffic in their short-lived foray into the Canadian market, and is currently handling large quantities of import containers for Canadian Tire, a major Canadian retailer. The facility is designed to transload imports from international containers (primarily 40 foot containers) into 53 foot domestic containers for further shipment by rail. The facility achieves high throughput on a relatively small footprint by stacking marine containers onsite. The building is only 43,000 square feet on an 11 acre site for a Floor/Site Ratio (FSR) of only .11, compared to approximately .35 for more conventional import distribution centres in the Lower Mainland.

In the Lower Mainland, densification of port terminal operations in the Lower Mainland has resulted in the densification of operations at import and export transload facilities to offset additional drayage costs. This results in additional capital and operating costs for onsite container handling equipment, and potentially for strengthening of yard pavements to cope with the dynamic and static loads of equipment and container stacks.

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