CIRRELT

Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport

Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation

Proactive Order Consolidation in the Retail Supply Chain

Teodor Gabriel Crainic
Suzanne Marcotte
Walter Rei
Pawoumodom L. Takouda

September 2009

CIRRELT-2009-37

Bureaux de Montréal :
Université de Montréal
C.P. 6128, succ. Centre-ville
Montréal (Québec)
Canada H3C 3J7
Téléphone : 514 343-7575
Télécopie : 514 343-7121

Bureaux de Québec :
Université Laval
2325, de la Terrasse, bureau 2642
Québec (Québec)
Canada G1V 0A6
Téléphone : 418 656-2073
Télécopie : 418 656-2624

www.cirrelt.ca

Proactive Order Consolidation in the Retail Supply Chain

Teodor Gabriel Crainic[1], Suzanne Marcotte[1], Walter Rei[1], Matthias Pawoumodom L. Takouda[1,*]

[1] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) and Department of Management and Technology, Université du Québec à Montréal, C.P. 8888, succursale Centre-Ville, Montréal, Canada H3C 3P8

Abstract. The objective of this paper is to present a proactive order consolidation strategy and to illustrate its worth within the replenishment process of imported finished goods. The strategy is based on a Bin Packing model that consolidates orders into groups that may be efficiently shipped in maritime containers. Simulation studies based on real-world data show that an order-consolidation strategy achieves profitable trade-offs among procurement, transportation, and inventory management with a significant decrease in inventory-holding costs compared to more traditional full-container load ordering processes.

Keywords. Order consolidation, procurement, bin packing, transportation and inventory management.

Acknowledgements. The research has been financially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), through its Industrial Research Chair and Discovery Grants programs, as well as through the contributions of the partners of the Chair: CN, Rona, Alimentation Couche-Tard and the Ministry of Transportation of Québec.

---

* Corresponding author: Matthias.Takouda@cirrelt.ca

Dépôt légal – Bibliothèque nationale du Québec,
Bibliothèque nationale du Canada, 2009

1 Introduction

In the current context of procurement of goods overseas and high transportation (fuel) prices, efficiency of operations and economy of scale in the costs of the supply chain are often achieved through full-container-load shipping strategies, purchase-order quantities being determined to fill up the containers. In the retail industry, this practice generally results in inventories too large relative to demand and, consequently, high financing and storage requirements. Indeed, retail firms end up paying more in immobilization than the amount saved via the economies of scale is shipping. Moreover, large inventories also reduce the agility of the firm in responding to changes in customer preferences.

To really achieve efficiency in overseas purchasing, one has to achieve a trade-off between carrying stocks and efficiently buying and transporting items. The order-consolidation strategy we propose aims to contribute in achieving this goal (Béliveau, 2009). Instead of ordering full containers, order quantities are determined according to inventory-management principles and the company's customer-service policies. These orders, smaller in volume, are then coordinated through a consolidation process so that they are shipped together using a minimum number of containers. *Consolidation*, a well-known business practice (e.g. Jackson 1981, 1985; Min and Cooper, 1990; Fangruo *et al*., 2001; Çetinkaya and Bookbinder, 2003), is used here in a proactive manner directly on the information flow.

The contribution of this paper is to present and illustrate this strategy approach through a case study where Bin Packing models, implemented in an order-consolidation process, lead to significant cost reduction. The remaining of this paper is organized as follows. The next section describes the case study. Section 3 introduces the methodology of integrating global procurement and inventory management through order consolidation. Section 4 provides numerical results and analysis before the perspectives and conclusive remarks of Section 5.

2 The Case Study

We consider a North-American hardware and renovation products wholesaler and retailer. The company operates a distribution network covering a wide geographical area, from coast to coast. The network is comprised of owned large and medium-size retail stores, as well as independent small-size neighborhood shops for which the company plays the role of wholesaler. The company maintains stocks for a very large variety of products to serve a numerous and diversified set of customers, including the neighborhood stores, which it does not fully control. Forced by the highly competitive retail market in North America, the company has become more and more involved in trade relations with overseas suppliers. An increasing number of Asian manufactured goods are being offered on their shelves or their partners'. Going global is well-known to be risky and to require meticulous preparation. This is even more the case when one has to import from Asia where proper technological infrastructure for order processing, EDI-type communications for example, is often lacking.

The major issue then becomes: how can one efficiently manage and coordinate the business relations between a technologically-advanced company, which evolves in a highly competitive market, and suppliers from emerging countries where technology is still being deployed? We aim to address this question in the case study presented in this paper.

We analyzed the procurement process for a group of products imported from South-East Asia. The various stakeholders involved and their relationships are illustrated in Figure 1. Going into the details of purchasing processes is beyond the scope of this paper (see, e.g., Simchi-Levi *et al*., 2002 or Bowersox *et al.*, 2005), and we only briefly explain it. The process involves the company, its suppliers, and a third-party logistics provider. Inside the company, three internal functions are mainly involved: merchandising, purchasing, and logistics.

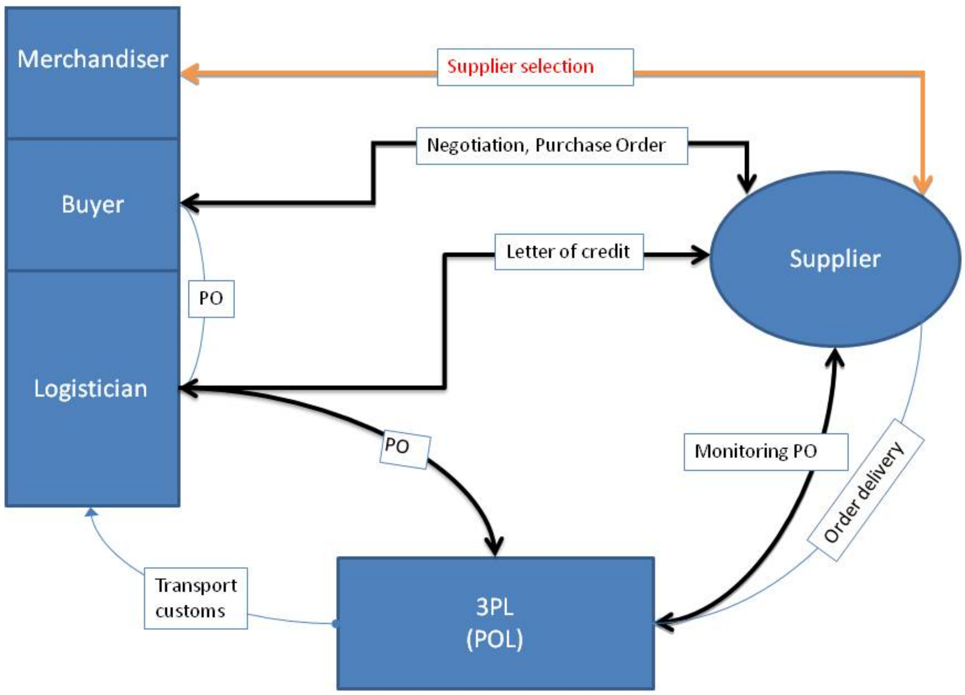


Figure 1. **Procurement process: Mapping of operations**

Part of the job of a merchandiser is to be aware of the products that are available and have a good selling potential in the market coveted by the company, as well as identify appropriate suppliers in terms of the company's cost, product-quality, and service-reliability criteria. Selecting suppliers involves appropriate agreements on a certain number of terms including the buying conditions (*incoterms*), port-of-loading (*POL*), prices, order quantities, and so on.

Buyers are primarily in charge of maintaining the planned level of inventory for given groups of products. A replenishment software warns the buyer when the inventory level of an item is low. The buyer then negotiates a purchase with a pre-determined supplier. Since little technology is available besides email or fax, the bargaining process can be particularly lengthy. To seal the deal, decisions are made on the order quantity, delivery date, price, incoterms, and POL, the last three being generally only a confirmation of the original contract established by the merchandiser. A purchase order (*PO*) is then issued, verified and approved by the appropriate services, and transferred to all concerned parties.

The company's logistician is responsible for the payment aspects and for properly processing and monitoring the order to ensure that the purchased items are delivered on time to the company's warehouses. This activity is performed in partnership with a third-party logistics (*3PL*) services provider, which will also take care of receiving the items and shipping them according to the company's instructions. The monitoring work is critical to ensure timely delivery. The payment step is also critical since, in most cases, suppliers wait for the letter of credit before starting production. A delay here directly impacts the lead time. The logistician has also to decide the transportation modes that will be used. For trans-oceanic shipments, items are typically moved in containers. Two options are generally available: Public/Shared and Private Transportation. In the former case, usually referred to as *LCL (less-than-container-load) service*, the pricing is defined per unit of volume, while in the latter a container is booked and filled at will, a fixed price being paid for the container, depending on its type.

The purchasing practice implements a full-container-load (*FCL*) strategy illustrated in Figure 2 displaying the physical flows generated by the orders. Typically, following a Free-On-Board (FOB) incoterm agreement (Bowersox *et al.*, 2005), the supplier fills a container with the order, seals the container, performs the export duties with the local authorities, and delivers it to the departure yard of the POL so that it can be shipped to the client.

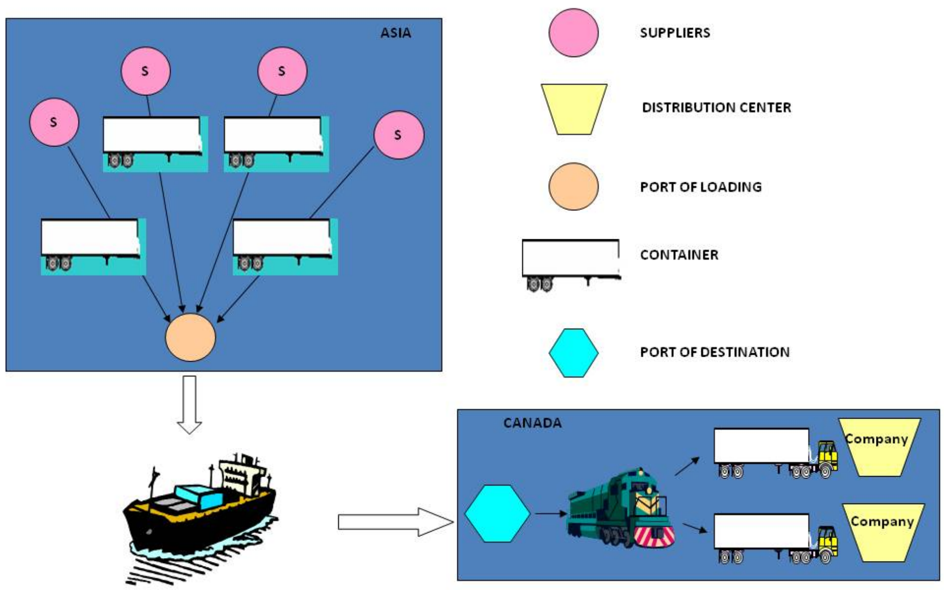


Figure 2. **Full-container-load physical process**

According to this strategy, whenever an item is needed, it is purchased by the full container, with the objective of achieving economies of scale in transportation, with minimal coordination efforts. Consider the example of a lamp with annual sales of 2642 units. The replenishment software takes into account the buying pattern and suggests an order-quantity of 432 units, which represents a volume of 2.1 cubic-meters (cbm) and an average demand of about 8.5 weeks. The buyer will boost this quantity to fill a container. The smallest container available, a twenty-foot box, has a maximum capacity of approximately 33 cbm and, thus, a purchase order will be issued for some 6788 units. The resulting per-unit shipping cost will doubtlessly be low.

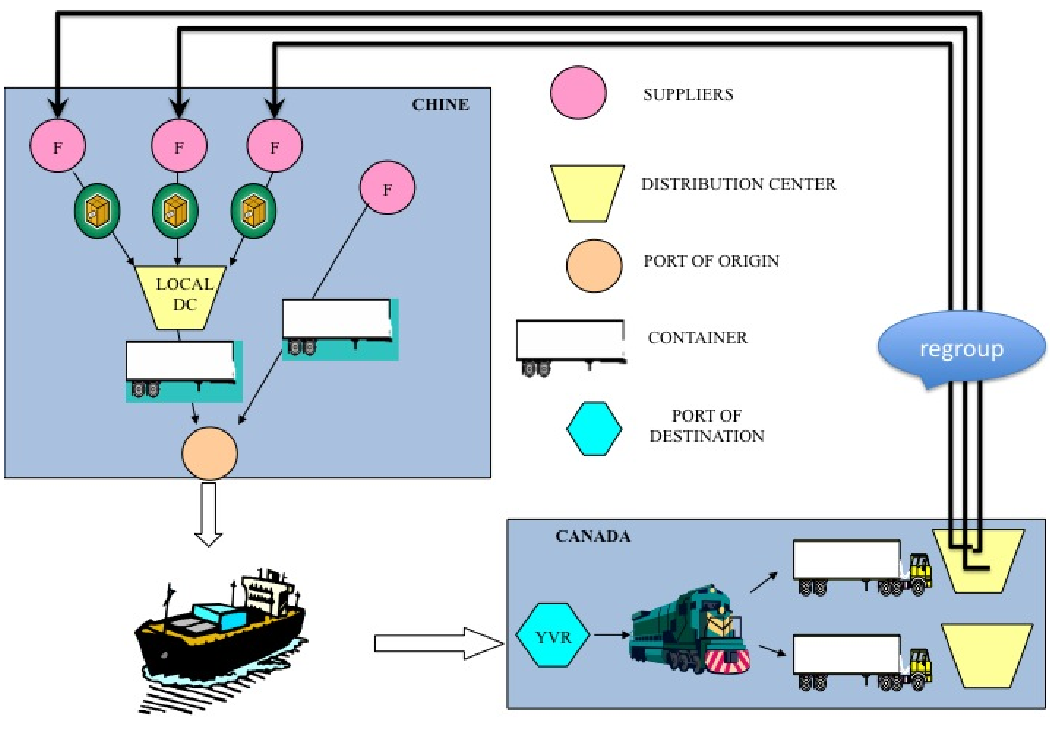
This strategy suffers of several drawbacks, however, the most important one being related to inventories. In the previous example, the FCL practice leads to ordering a quantity more than 10 times larger than the one suggested by the company inventory policy embedded into the replenishment software. In fact, this FCL order-quantity represents the equivalent of more than 2 years of sales. This has huge consequences on the annual inventory holding costs which are evaluated to 20% to 30% of the value of the goods in this industry. Moreover, more than half of the items will become obsolete in less than a year. Such practices thus not only go against best inventory-management principles, but they also end up setting the supplier as the driver of the supply chain. Indeed, the supplier is able to push its product via low-pricing strategies, leaving the retail chain to deal with inventories. Our objective is to provide an alternative practice that avoids these inconveniences.

3 Methodology

We first describe the order-consolidation approach we propose, followed by the operations research model at the core of the methodology.

3.1 Order consolidation process

In order to address the issues identified in the previous section, we propose a new purchasing practice called *order consolidation,* illustrated in Figure 3 through the new physical flow of the order. The supplier prepares the order, which now represents a small package in volume, and delivers it to a local distribution center of the 3PL. The 3PL then regroups the small-volume orders that have been delivered to fill a minimum number of containers. A container is thus shared between different orders coming from different suppliers, as oppose to the previous case where only products from the same supplier could share the same container.



- Figure 3 **Order consolidation physical process**

A decision support system (DSS) is inserted into the process to capture purchase orders as they are being released. The DSS first sorts the orders according to their POL. It then performs a consolidation of these sorted orders according to an operations research model described below, and provides the decision maker with consolidated groups of orders that may be shipped together in the same container.

Consolidation is a well-known concept generally defined (e.g., Bowersox *et al.,* 2005) as the accumulation of several small orders to be grouped into a vehicle - truck, plane, ship, train, pallet, box, wagon, container - or location (warehouse). Under the name “freight consolidation”, this idea has been extensively studied in the logistics literature (e.g., Jackson, 1981, 1985; Min and Cooper, 1990; Fangruo *et al*., 2001; Çetinkaya and Bookbinder, 2003; Tyan *et al.,* 2003). This is the point of view of the manufacturer or shipper, the consolidation processes focusing on managing the actual physical flows, once the orders have been processed and the corresponding goods have been produced and are ready to be distributed.

The method we propose is different. It is based on the application of the consolidation idea proactively, on the information flow, as soon as the orders are known. This means starting the consolidation process as early as possible in the supply chain, when decisions on delivery dates and the transportation mode to be used are made. Order processing and monitoring operations are then performed to ensure that grouped orders are properly coordinated. Order consolidation performed this way corresponds to viewing consolidation through the eyes of the person who places the orders. To the best of our knowledge, the idea of using consolidation in such a proactive manner has been hardly studied. To date, we have found no reference to such a work.

Proactive order consolidation also introduces a measure of cost-effective flexibility in the procurement process. One should thus achieve the economies of scale that justified the FCL strategy in the first place, without the drawbacks associated to large stocks. Moreover, it creates the agility necessary to adapt efficiently to quickly changing environments and hedge against some of the risks related to the introduction of new products or exploring new market segments.

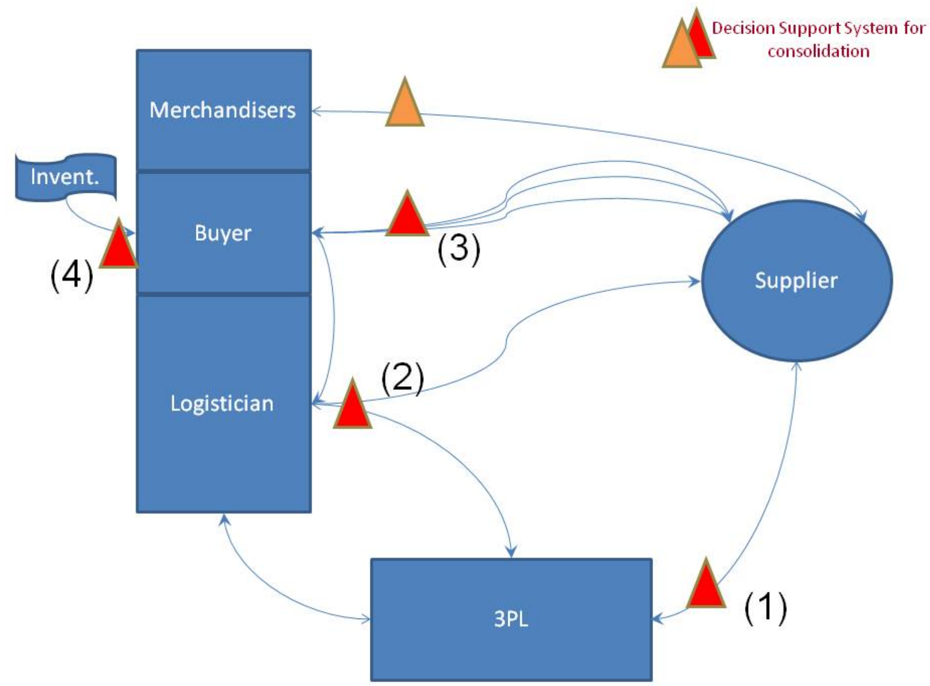


Figure 4 **Order consolidation: locating the DSS**

Two main issues must be addressed relative to the DSS. The one relative to how to construct consolidated orders is addressed in the next subsection. The second refers to the location of the DSS in the procurement process and its main operation principles: how it captures orders, at fixed interval or continuously, how often it provides groups of consolidated orders, and whether it may undo some already-consolidated groups. Several answers exist leading to various designs for the order-consolidation process. To illustrate, Figure 4 shows four possible locations for the DSS. It can appear as late as possible in the information and decision flow (Case 1), when one knows exactly which orders are late. This strategy is similar to freight consolidation. It could also be literally coupled (Case 4) with the replenishment software, leading to the latter providing the buyer with groups of orders to be executed together instead of just expressing a need for replenishment. Not all companies are ready to go to such an extreme in automatic decision-making, and the firm in the case study is no different. Between these two "extremes", Cases (2) and (3) correspond to the situations where the consolidation process is driven by the logistician or the buyer, respectively (see Béliveau, 2009 for detailed descriptions of these approaches). The logistician-driven approach corresponds to the case study and is analyzed in Section 4.

3.2 Bin Packing models

The decision to be made by the DSS, to group efficiently orders of relatively small volumes into lots with total volumes close to the available container capacity, corresponds to the well-known *Bin Packing* (*BP*) problem, quite extensively studied in the operations research literature (Martello and Toth, 1990, Wäscher *et al*., 2007).

The general BP problem is defined as follows: given a set of bins of finite capacity and a set of items to be packed into these bins, allocate a subset of items to each bin such that a measure of bin utilization, their number, usually, is minimized and the packing of items in each bin is feasible. Different BP problems are defined in the literature according to a number of criteria, including the dimensions of bins and items, how items are placed within bins, the particular sets of bins and items available, the shape of items, the optimization criteria, and so on.

In the case considered in this paper, containers (bins) and orders (items) are characterized by a single attribute, the volume (usable for the former and actual for the latter). An assignment of a group of orders to a container is then feasible if the sum of their volumes is less than the usable container capacity (volume). Moreover, given the type of application, one may assume a sufficient supply of containers and, thus, the goal of the process is to minimize the number of containers used. Finally, the orders are rather heterogeneous in their volumes but these are all smaller than the container capacity (anything larger will be split into a number of full containers and a residue to be considered by the order-consolidation process). The packing model used in the present study to consolidate orders into containers therefore is the classic one-dimensional BP problem, and we follow the optimization formulation of Martello and Toth (1990).

Consider N orders, each order $i \in N$ with a volume V_i. Let M represent the number of available containers, each of usable capacity $\mathcal{V}$. Actually, in most practical situations, this number is not a constraint. We introduce M, however, to tighten the formulation, and compute it as an estimation (upper bound) on the number of containers required to ship the N orders (at worst, $M = N$). Define the decisions variables:

- x_{ij}, loading-decision variables defined for each pair (order i, container j), equal to 1 if order $i \in N$ is loaded into container $j = 1, ..., M$, and 0 otherwise;
- y_j, container-selection variables equal to 1 if container $j = 1, ..., M$ is used, and 0 otherwise.

The *Order Consolidation* Bin Packing model (OCM) used to group orders into dedicated containers may then be written as:

$$\text{Minimize} \quad z = \sum_{j=1}^{M} y_j \tag{1}$$

$$\text{s.t.} \quad \sum_{j=1}^{M} x_{ij} = 1 \qquad \text{for all } i = 1, \dots, N, \tag{2}$$

$$\sum_{i=1}^{N} V_i x_{ij} \leq \mathcal{V} \cdot y_j \qquad \text{for all } j = 1, \dots, M, \tag{3}$$

$$y_j \in \{0, 1\} \qquad \text{for all } j = 1, \dots, M, \tag{4}$$

$$x_{ij} \in \{0, 1\} \qquad \text{for all } i = 1, \dots, N; \; j = 1, \dots, M, \tag{5}$$

where the objective is to minimize the number of containers used, while equations (2) make sure each order is transported (assigned to a container) and constraints (3) enforce container-capacity limits. Constraints (4) and (5) enforce the integrality of the decision variables.

It is known that several equivalent optimal solutions to this model may exist. All such solutions have the same minimum number of bins but with different packing of the items. Considering the residual capacity of each bin and the volumes of the items, a post-optimization procedure may be used to obtain the optimal solution with most bins packed close to capacity.

4 Experimentation and result analysis

We now present the application of the previous concepts and model to the case study described in Section 2. We first present the proposed process, then the data used and the simulations performed for the case study, and, finally, the analysis of the numerical results of these simulations.

4.1 Procurement processes with order consolidation

We propose a new procurement process with order consolidation for the case when the logistician controls the consolidation process, as described in Section 3.1. The DSS is located in position (2) in Figure 2 and orders are assigned to containers using the OCM model defined at the previous section. This process is appropriate for the reference organization, where the logistician is in charge of transportation-mode decisions.

According to the policies of the reference organization, the process assumes that orders are addressed according to their port of loading and, thus, orders admissible for consolidation must share the same POL. A particular shipping day is also defined for each POL and the supplier delivery dates are fixed accordingly when the order is passed. Orders are periodically monitored for delays or other disruptions, but the system cannot undo the consolidated groups. Orders arriving late to their POL, respective to the delivery due date, are shipped at the first possible departure date following their arrival at the port.

The proposed procurement process proceeds as follows. When needed, and following negotiations with the supplier, the buyer issues a purchase order for a quantity determined according to the internal policies of the company, the actual demand, and the cost. If the quantity fills one or several containers, the order is processed as before. It is marked for consolidation, otherwise. A marked order is forwarded to the DSS and the logistician. On request, the DSS provides suggestions for order consolidation for specific shipping dates. Final order handling instructions are transmitted to the 3PL, for monitoring of suppliers and carriers and efficient shipment according to schedule.

4.2 Data and simulations

The goal of the experimentation phase is to evaluate the order consolidation process described in the previous subsection by comparing it to the two other options: 1) ordering full container loads; 2) shipping each order using LCL services. The objective is to assess the cost efficiency of the order-consolidation process that we propose measured through the estimated cost reductions it would allow the company to achieve. To achieve this goal, we run simulations on real-world data provided by the company.

The data corresponded to one port of loading and its hinterland. We retained the products (SKUs) that originate from this port and display regular selling patterns (promotional activities were not taken into account, for example). Based on the expertise of the 3PL, we also made sure the selected products may be packed together.

The selection process yielded a sample of 109 products sharing the same port of loading. The data available for these products included the monthly historical sales for a 13-month span, the packaging information, and the selling prices. The forty-foot container was chosen as the consolidation container, as it is the most profitable one among maritime containers with respect to the per-unit transportation cost. We also obtained the cost of a forty-foot container used in a

FCL way and the cost per cubic-meter of an order shipped using LCL services. Based on these figures, it was then straightforward to compute the transportation-mode *breakeven point* corresponding to the quantity for which using a full container or shipping LCL yields the same transportation cost.

The annual and the average monthly demand for each product were computed from the historical data. We then used the product packaging information to compute the order quantity that corresponds to a full forty-foot container. Monte-Carlo simulations were then run for the order consolidation and the LCL processes.

Procurement policies and order quantities have to be specified for the simulations. The 109 products were thus divided into three classes according to their annual demand volumes: the first class contains item having the highest annual volume, and so on. The first class has 64 SKUs with a monthly procurement policy, i.e., the order quantity equals the average monthly demand for the product and an order has to be placed each month. The second group has 30 SKUs with a two-month procurement policy and a fixed-order quantity twice the average monthly demand. Among these 30 items, 15 are ordered every odd month (first, third, etc.) and the other 15 every even month. The remaining 15 SKUs have a three month procurement policy. The ordered quantity thus covers the average demand of 3 months, 5 of them every first, fourth, seventh, etc. month, 5 other every second, fifth month, etc., and the last 5 every third, sixth month, etc. Finally, we assume that the number of orders placed every week follows a triangular distribution, with parameters 10, 25, and 30 representing the lowest, most-likely (mode), and highest number of orders, respectively. The resulting orders are all of volumes inferior to the capacity of the container. By policy, orders cannot be split and shipped in several containers.

The simulations apply a replenishment policy similar to that of the company: each time the inventory level of a product goes below a given reorder point, an order is released, with the appropriate quantity. Deterministic order lead times were assumed, which means the monitoring process is performing well enough to avoid significant delays. Each run of a Monte-Carlo simulation consisted in developing a procurement plan to satisfy the demand for a year, selecting the transportation mode for each order or consolidated group of orders. The simulation worked as follows:

1. Determine, for every month of the simulated time horizon, a list of products to be ordered according to the 1, 2 and 3-month policies defined above. This yielded 84 orders for each month.
2. For every week of the month,
    a. Determine k, the number of orders to be released that week, according to the Triangular(10, 25, 30) distribution;
    b. Pick k orders randomly from the updated monthly list (except for the last week that ships all the remaining ones); Update the list;
    c. Solve the OCM model to determine the minimum number of containers needed to ship all the orders of the week, as well as the orders packed into each container;

d. Review each container to compare its load, the total volume of the orders it contains, to the breakeven point:
    i. Send as is when the container is filled over the breakeven point;
    ii. Send the orders in the container using LCL services, otherwise.

4.3 Numerical results and analyses

Results are provided for three processes: all orders increased to a full-containers volume (identified as FCL in the following), all orders shipped by LCL services (LCL in the following tables and figures), and the order-consolidation strategy indicated above (includes LCL services when loads are less than the breakeven point – identified OC in the following).

The *total annual cost* of the respective procurement plan, defined as the sum of the costs of purchasing, ordering, transportation, and inventory holding, is used to compare and asses performances. We compute these costs according to the actual practice of the firm as follows. The purchasing cost is obtained by multiplying the average total quantity ordered for a product by its unit cost and summing over products. Unit costs are negotiated by the merchandiser for the year and are thus fixed. The annual purchasing cost is therefore computed once and is the same for the three processes. The ordering cost is defined as the average annual number of orders placed multiplied by the cost of placing an order. The annual transportation cost is the sum of the prices paid to ship all the orders of the year according to the transportation mode selection. Finally, the inventory-holding cost for a given product is computed multiplying its annual inventory unit cost (viewed as a percentage of the purchasing price) and its average inventory level over the year; the total inventory cost being the sum over all products considered.

We run the simulation over 52 scenarios for each consolidation process. Each scenario corresponds to one year of operations. The bin packing problems were solved with CPLEX 10.0 on a 2.2 GHz dual processor AMD Opteron PC running under Linux. Numerical results are reported below as averages over all repetitions.

The annual costs are reported in Table 1. Ordering costs are lower for the FCL strategy because larger volumes (up to the container volume) are ordered less often. On the other hand, however, the corresponding inventory cost is significantly higher than for the other two strategies that ship smaller orders more often. The number and quantities of the orders being the same for the LCL and OC strategies, the corresponding ordering and inventory costs are also the same. Transportation costs are lower for the OC strategy, which makes it the most cost efficient of the three.

	FCL	**LCL**	**OC**
Purchasing	**9,517,245.73**	**9,517,245.73**	**9,517,245.73**
Ordering	**6,359.32**	**36,288.00**	**36,288.00**
Transportation	**616,500.54**	**1,282,248.00**	**782,325.14**
Inventory	**1,181,231.83**	**140,437.56**	**140,437.56**
Total	**11,321,337.42**	**10,976,219.30**	**10,476,296.44**

Table 1. Average annual costs for the tree processes

Table 2 displays a two-by-two comparison of the performances of the three processes. Each column identified X vs. Y displays the increase or decrease in the cost associated to procedure X relative to that of procedure Y. Thus, reducing the order volumes to the quantities needed increases the ordering cost significantly, but also reduces in a significant manner the inventory-related costs.

	LCL vs. FCL	OC vs. FCL	OC vs. LCL
Purchasing	**0 %**	**0 %**	**0 %**
Ordering	**470.6 %**	**470.6%**	**0 %**
Transportation	**108.0 %**	**26.9%**	**-39.0%**
Inventory	**-88.1%**	**-88.1%**	**0 %**
Total	**-3.0 %**	**-7.5 %**	**-4.6 %**

Table 2. Annual cost comparisons

Figure 5 illustrates the reduction of the inventory holding cost for the products considered. Products are displayed on the horizontal axis in increasing order of their average monthly demands (in volume). Hence, the products at the left of the axis exhibits the lowest demands and the one at the right the highest. The reduction is at least of 40%, the highest reductions being obtained for the products with low average demands, which confirms the interest of the OC and LCL strategies in this respect.

Concerning transportation costs (see in Table 2), not surprisingly, the highest transportation cost comes from using the LCL strategy where single-shipment costs are paid for each order. One observes also that order consolidation compared to full-container ordering yields a higher cost per cbm (Figure 6).

Despite the increases mentioned above, Table 2 shows that the total annual cost for OC is smallest of the three. Indeed, even though ordering and transportation costs raise, the actual amount of the augmentation (≈195,753$) is not significant when compared to the huge reduction (≈1,040,794$) of the inventory cost induced by the order consolidation. The order-consolidation strategy is winning in this respect.

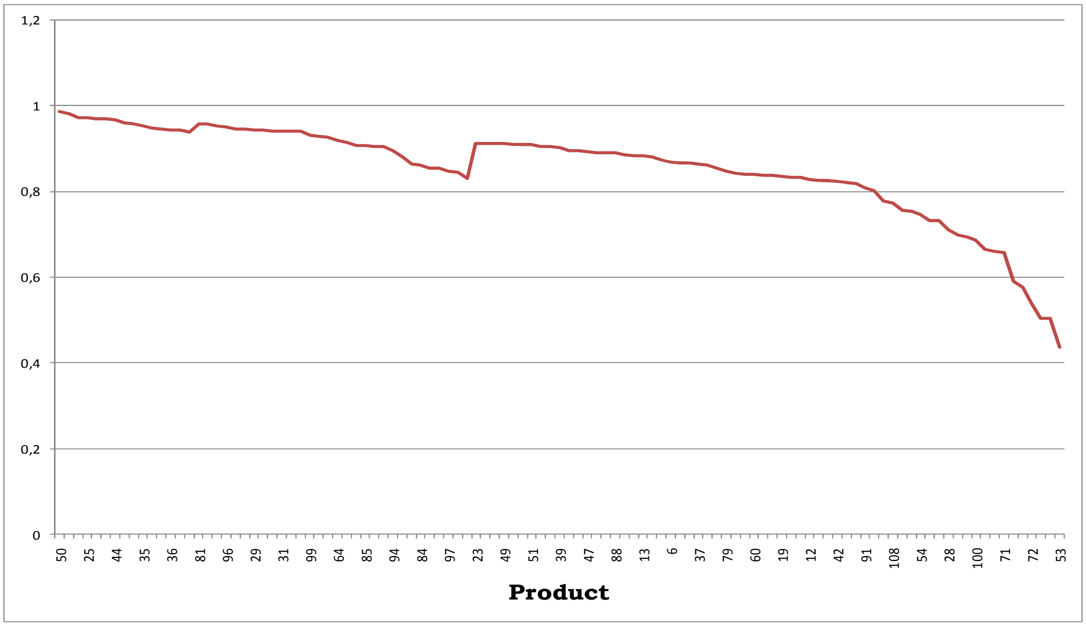


Figure 5 **Inventory cost reduction ratio from FCL to LCL/OC**

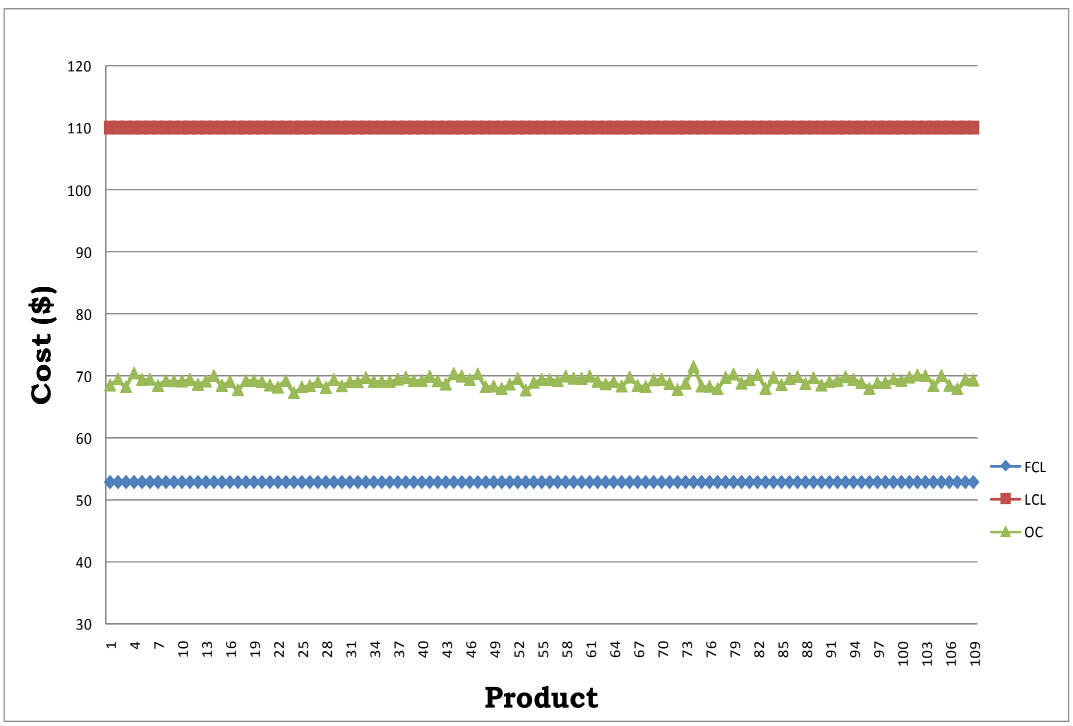


Figure 6 **Cost per cbm shipped for each product**

To sum up, our experiments show that both LCL and order consolidation strategies are better than FCL. Even though they induce an increase in ordering costs, this increase is largely compensated by large savings in inventory cost. In particular, FCL clearly appears as a bad choice for slow moving products. Furthermore, the order consolidation process is cheaper than LCL and appears as the strategy of choice.

In other words, for the procurement of items with low demand volumes compared to the capacity of trans-oceanic containers, the results of the simulations show that order consolidation provides the means to achieve profitable trade-offs between procurement, transportation, and inventory management. Indeed, demand is satisfied while keeping inventory at low levels, while ship small orders may be shipped at "low" transportation cost.

5 Conclusions and perspectives

We have presented a proactive order consolidation strategy and have illustrated its worth when integrated within the replenishment process of imported finished goods. The strategy is based on using a Bin Packing model to consolidate orders into groups that may be efficiently shipped in maritime containers. Simulation studies based on real-world data have shown that an order-consolidation strategy achieves profitable trade-offs among procurement, transportation, and inventory management with a significant decrease in inventory-holding costs compared to more traditional full-container load ordering processes.

There are several perspectives on this work. First, incorporate more dimensions in the bin packing models in order to optimize further the container packing. Second, improve the models to handle heterogeneous fleets of containers. Third, enlarge the scope of the models to encompass several regions and ports-of-call to assist in strategic procurement decisions and contract negotiations with suppliers and partners (e.g., 3PLOs).

Acknowledgements

While undertaking this project, Teodor Gabriel Crainic was the NSERC Industrial Research Chair on Logistics Management, École des sciences de la gestion, UQAM, and Adjunct Professor with the departments of Computer Science and Operations Research, Université de Montréal, and Economics and Business Administration, Molde University College, Norway, while Pawoumodom L. Takouda was Postdoctoral Fellow with the Chair and CIRRELT.

The research has been financially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) through its Industrial Research Chairs and Discovery grant programs, as well as through the contributions of the partners of the Chair: CN, RONA, Couche-tard, and the Québec Ministry of Transportation. The authors gratefully acknowledge the collaboration of RONA. The authors wish to express special thanks to MM. Pierre Pelletier and Richard Brouillette, past and current Vice-President Logistics at RONA, Mrs. Kelly Dimitropoulos, Import Team Manager at RONA and her team for the intensity of their collaboration and their welcome of our students and researchers in their offices. Finally, the authors thank M. Martin Béliveau, MBA candidate at UQÀM and research assistant within the Chair for all his help and assistance.

References

Béliveau, M. (2009), *Consolidation de commandes dans la grande distribution*, Master Thesis, Departement de management et technologie, École des sciences de la gestion, UQÀM, Montréal, Canada.

Bowersox, D.J., Closs, D.J., and Cooper, B.M. (2005), *Supply Chain Logistics Management,* McGraw-Hill.

Çetinkaya, S. and Bookbinder, J. (2003), Stochastic Models for the Dispatch of Consolidated Shipments, *Transportation Research Part B,* 38(8), 747-768.

Fangruo, C., Federgruen, A., and Yu-Sheng, Z. (2001), Coordination Mechanisms for a Distribution System with one Supplier and Multiple Retailers, *Management Science* 47(5), 74-76.

Jackson, G. C. (1981), Evaluating Order Consolidation Strategies Using Simulation, *Journal of Business Logistics* 2(2), 110-138.

Jackson, G. C. (1985), A Survey of Freight Consolidation Practices, *Journal of Business Logistics* 6(1), 13-34.

Martello, S. and Toth, P. (1990), *Knapsack Problems: Algorithms and Computer Implementations,* John Wiley & Sons, New York.

Min, H. and Cooper, M. (1990), A Comparative Review of Analytical Studies on Freight Consolidation and Backhauling, *Logistics and Transportation Review* 26(2), 149--169.

Simchi-Levi, D., Kaminsky, P., and Simchi-Levi, E. (2002), *Designing and Managing the Supply Chain,* McGraw-Hill.

Tyan, J.C., Wang, F.-K., and Du, T.C. (2003), An evaluation of freight consolidation policies in global third party logistics, *Omega* 31, 55-62.

Wäscher, G., Hauβner, H. and Schumann, H. (2007), "An improved typology of cutting and packing problems", *European Journal of Operational Research* 183(3), 1109-1130.