

# Shipment Consolidation Policy Project

## *A Case Study at the Integrated Logistics Product Area at the Case Company*

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Larger corporations which distribute products and goods globally face both internal and external demands from stakeholders. High service levels call for frequent shipments for goods to arrive in time. However, frequent shipping comes at a higher cost. Lately, this has become an issue for the case company. To reduce the shipping cost, the company's alternative would be to increase lead times and consolidate shipments into larger batches. This will reduce the number of shipments and hence reduce the transportation cost. The key is to find a balance between these two alternatives to satisfy all parties by implementing an appropriate consolidation policy.

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## 1. Introduction and literature review

Logistics is the part within supply chain management that handles the forward and reverse flow and storage of goods, services and related information between the point of origin and the point of final consumption. It can also be described as the doctrine of effective material flows. It is a term which describes all the activities which allows materials to be at the right place at the right time, with the purpose to maximize benefit, both in respect of time and place. These benefits are aligned with shareholder interest to increase economic advantages and gain competitive advantage.

The most traditional and simple transport pattern used in logistics is to ship individual orders directly from the distributor to the final customer. This allows for a great deal of transport flexibility and the order can be sent at any given point in time.

However, in most cases, it comes at a high cost. The necessity for flow coordination happens when an order has many order lines, i.e. one customer orders multiple goods. The goods can then be consolidated to make better use of transport vehicle space and reduce shipping cost.

Shipment consolidation allows the company to accumulate orders over a time period. This allows the distributor to reduce shipping cost by spreading the fixed cost over a larger number of items, thus benefiting from economies of scale. However, this implies that the customer is willing to wait an additional period before the goods are received. The purpose of the thesis, of which this article stems from, is to evaluate whether a new shipment consolidation policy could be implemented for selected test locations while maintaining a reasonable service level, i.e. the customers goods are dispatched within the specified timeframe (in this case two working days).

As the master thesis project behind this article is of abductive character, there are few articles with analytical methods which solves an identical problem. Thus, this report needs to utilize methods from articles with similar problems but make necessary adjustments to solve the problem at hand. There are mainly two articles which have been used to approach this problem: “An analytical model for computing the optimal time-and-quantity-based policy for consolidated shipments”, by Mutlu et al. and “Policy Recommendations for A Shipment-Consolidation Program” by Higginson and Bookbinder. The former is the first paper that develops a fully analytical model to evaluate how a Time and Quantity-based policy would perform given a set of parameters. This is of high relevance for this case study as the model becomes highly flexible and the result can be determined using both quantity and time as parameters.

## 2. Related Literature

Except the articles stated above, related consolidated shipment literature has been reviewed in this project, these include: (1) Stochastic models for the dispatch of consolidated shipments by Çetinkaya and Bookbinder, (2) A Tree-Structured Markovian Model of the Shipment Consolidation Process by Cai, He and Bookbinder, (3) Markovian Decision Processes in Shipment Consolidation by Higginson and Bookbinder and (4) Inventory Control in Divergent Supply Chains with Time-Based Dispatching and Shipment Consolidation by Marklund.

## 3. Problem Setting and Model Characteristics

This article will investigate whether it is possible to use an alternative shipping method to the immediate dispatch method in order to reduce costs while maintaining a similar service level. In this article, a consolidated shipping policy will be analysed, and an analytical model will be developed. Furthermore, the policy will be investigated for potential future implementation. As freight costs are closely correlated to total size and weight of carried goods, this could potentially lower the costs when the orders are shipped in larger batches. As the consolidated shipment policy has not yet been implemented, this article will focus on investigating on how such a distribution network would perform using empirical data.

To use and apply the related theory on consolidated shipping, a few adjustments of the characteristics presented in the article by Mutlu et al. needed to be made in order to make full use of the theoretical model and for the results to be viable. This is due to the difference in input and problem characteristics. These differences are listed below:

1. The case company setting is located at a cross-docking warehouse rather than a 3PL collection depot.
2. The case company units are not of equal size and there is no specific variable cost  $c$  associated with each order. This cost needs to be approximated.

3. There is no known waiting cost  $w$  associated with holding a unit for a period at the case company. This cost also needs to be approximated.

## 4. Problem Formulation and Solution

The objective of this analytical model is to find the decision variables  $q$  and  $T$  which minimizes the long-run average cost  $\check{G}(q, T)$ , i.e. the expected cost per consolidation cycle (Mutlu et al., 2010). In most cases however, there is some restriction and upper bound on at least one of these decision variables. For example, a customer may only be willing to wait for a certain timeframe, leading to a restriction on the decision variable  $T$  - in this case 2 days. Moreover, a fixed cost  $\tilde{K}$  and a variable per unit cost  $c$  is associated with each shipment.

As the distribution is conducted by a 3PL supplier, truck capacity is assumed to be infinite. Furthermore, a waiting cost parameter  $w$  incurred for delaying an order for a unit of time. This is one of the more difficult parameters to estimate, as it is computed differently in each case and requires further investigation.

### 4.1 The Expected Variable Cost $E[c]$

In this case study there is no obvious cost  $c$  associated with each order. Instead, the cost is associated with the weight of each order. To derive this, one must use statistics to estimate the expected cost per unit shipped

$E[c]$ . First, the distribution of the weights of each order must be obtained using distribution fitting. When the distribution fits at a satisfactory significance level, one can use Equation (1) to find  $E[c]$ .

$$E[c] = \int_0^{x_1} c_1 x \Phi_w(x) dx + \int_{x_1}^{x_2} c_2 x \Phi_w(x) dx \dots + \int_{x_{n-1}}^{x_n} c_n x \Phi_w(x) dx \quad (1)$$

Were  $c_i$  - the variable cost for adding a kg to the consolidated load - represents the cost in each weight bracket (it is assumed to be linear within each bracket) for  $i = 1, 2, 3 \dots n$ . Furthermore,  $x$  represents the weight and  $\Phi_w(x)$  represents the probability density function of the weight distribution function.

### 4.2 The Expected Waiting Cost $E[w]$

The waiting cost,  $w$ , occurs when consolidated shipments delay deliveries and require additional storage space. The waiting cost used in this report is described as a cost per unit of time. In particular, the storage space cost is used as the additional cost for storing a unit for a period. To obtain the storage space cost one must first calculate the expected volume of a packaged good. When this value is obtained, it can be multiplied with the storage holding cost ( $h$ ) of storing a volume unit for a unit of time. In this case study, the storage holding cost  $h$  has been calculated by taking the rental cost per  $m^2$  multiplied with the shelf length and

shelf depth and dividing this by the height of the storage shelf. This gives the cost of storing a unit (m<sup>3</sup>) for a month. This number is simply divided by 20 to get the cost per working day. In this study, the holding cost  $h$  is constant and Equation (2) can therefore be expressed as Equation (3).

$$E[w] = \int_0^{v_1} h_1 v \Phi_v(v) dv + \int_{v_1}^{v_2} h_2 v \Phi_v(v) dv + \dots + \int_{v_{n-1}}^{v_n} h_n v \Phi_v(v) dv \quad (2)$$

$$E[w] = E[v] * h \quad (3)$$

$$\check{G}(q, T) = \frac{E[C_c]}{E[L]} = \frac{\check{K} + E[w](q / \lambda \bar{F}(q, T)) + TF(q - 1, T) + ((q - 1)qE(qT) / 2\lambda) + (T / 2) \sum_{n=0}^{q-1} np(n, T)}{(1 / \lambda) + q\bar{F}(q, T) / \lambda + TF(q - 1, T)} + E[c]\lambda \quad (4)$$

## 5. Results

As this case study studied three locations at the case company the results for those will be presented in Table 1 below

Table 1: Results from the developed analytical model

	Location A	Location B	Location C
E[c]	274 SEK	259 SEK	154 SEK
E[w]	0.15 SEK	0.12 SEK	0.08 SEK
E[v]	0.09m <sup>3</sup>	0.07m <sup>3</sup>	0.05m <sup>3</sup>
$\check{G}(q, T) - Current$	576.81 SEK	247.14 SEK	101.07 SEK
$\check{G}(q, T) - Optimal$	463.67 SEK	195.18 SEK	72.5 SEK
$\check{G}(q, T) - T = 2$	485.37 SEK	214.09 SEK	86.41 SEK
Cost Savings - Optimal	20%	21%	28%
Cost Savings - T = 2	16%	13%	13%

## 4.3 The Long-Run Average Cost

When both the expected costs for shipment and waiting has been obtained, it is possible to present the long-run average cost using a modified version of the equation used in Mutlu et al, 2010 (see Equation (4)).

## 6. Analysis

To easier grasp the potential cost savings, the annual cost for each policy and location will be calculated in absolute numbers. These will then be analysed to evaluate if a consolidation policy is reasonable in terms of potential cost savings. If reasonable, it shall also be obvious if this also is true for the time constraints set by the case company. This cost will be compared to that of an optimal consolidation policy.

Figure 1 illustrates the potential cost savings in absolute numbers when implementing a consolidation policy for different restrictions in T, i.e. today's annual costs are compared to the restricted T (the time constraint given by the case company) and optimal TQ policy. Figure 1 also shows the potential percentage point cost savings for each location. The annual cost is obtained by multiplying the cost per cycle length with the number of cycles over a year.

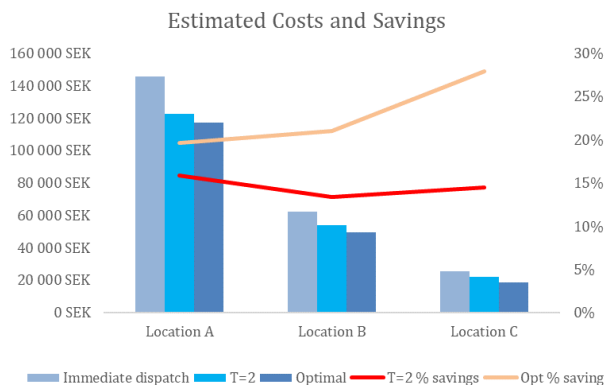


Figure 1: Annual costs for different policies in absolute numbers and potential cost savings.

Figure 1 shows a great cost saving potential for each location with an optimal policy with cost reduction ranging from 19 to 28 percent.

Furthermore, it shows that the potential cost savings with a restricted T policy also results in a significant cost saving potential ranging from 13 to 16 percent.

## 7. Conclusion

To conclude, it is the team's belief that the case company could implement a consolidation policy for all studied locations - based on company holding time constraints. Given these constraints, the result shows that a 13-16 percentage point annual cost reductions could be possible at the studied locations. However, when looking at this cost reduction in absolute numbers, it appears to be more reasonable to focus on the larger customers.

To summarize, the purpose of this study was to see if a consolidated shipping policy will reduce the total shipping costs while maintaining a reasonable service level. The team concludes that this is true for all studied locations but recommends the company to focus on evaluating high frequency locations for future policy implementations.

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