Newsvendor Based Pricing Model for Liner Shipping With Sailing Speed Optimization

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Abstract

We study the problem of freight pricing using pricing break points with quantity discounts offered by liner shipping services to freight forwarders in maritime transportation. We propose a model that maximizes the liner shipping and the forwarders profits. The forwarders book slots on the vessels for every trip (usually weekly) in a quantity that is encouraged by a pricing scheme proposed by the liner services with a single breakpoint. The booking is done before the forwarders have an accurate idea about their transport demands, and therefore they model it using probabilistic representations. Since container transportation services cannot be stored and given the stochastic nature of demand, the studied problem can be considered as a newsvendor type problem. Moreover, we consider an accurate formulation of the cost function of the liner service in which the sailing speed is a decision variable. The model is an integrated decentralized two-stage optimization model where the forwarders constitute the first stage and the liner company the second, and in which the optimal decisions taken by one stage are taken into account in the optimization of the decisions of the other stage. A numerical application is provided to show the effectiveness of the model.

Keywords
Newsvendor model; Liner shipping; Freight forwarders; Maritime Transportation; Optimization;

1. Introduction
Maritime shipping has been exceedingly booming in the last few decades, due to its cheapness and the fact that increasingly numerous companies that are producing in overseas countries due to lower production costs and other tariff and tax incentives, in addition to the online shopping companies that are developing vastly especially in China (Clemes et al., 2014).

Liner shipping companies can improve their profits by using pricing techniques so that they may affect the number of containers forwarders are willing to ship using their services, especially that the service quality provided by different lines is more or less at the same level, which reduces the competition based on quality and makes freight rates the leading decision drive.

The name "forwarders" is given to the linkage party between the liner shipping companies and the real shippers that owns basically the goods needed to be shipped overseas. These container forwarders collect the shipments from the good owners, like industrial or commercial companies, and ship them through the liner services which are selected based on the offered freight rates and the transit times. The forwarders' profit is then the difference between the freight tariffs collected from real shippers (goods owner) and the freight tariffs paid to the liner companies indeed.

Considering the transport demand nature, it is important to highlight that in this study the demand is presumed to be stochastic. Since the container forwarders are booking the slots based on the goods they are aiming to collect from real shippers, the shipments at that moment are not truly known, so it is not guaranteed that the forwarders will consolidate the full container load (FCL) and may just exploit less than container load (LCL), or in other words, use several slots less than the originally booked number. This case raised the need for the liner companies to determine some penalty rates to preserve their profits in cases of unused booked slots and the setting of penalty rates has a considerable impact on the profit and the cost for the forwarders and the liner companies (Yin and Kim, 2012).

A new perspective in this study will be optimizing the vessels' speed, which is to the best of our knowledge not considered previously in such pricing schemes. Vessels sailing speed is a chief has a significant impact on the vessel's operating cost, ship routing and scheduling (Wang and Xu, 2015). Moreover, Papadakis and Perakis (1989) stated that the bunker fuel consumption of a vessel is very sensitive to its actual sailing speed, since the fuel consumption cost generally accounts for more than 50% of the total operating cost of a containership. Conversely, the sailing speed in its turn affects the sailing time of a vessel for a certain voyage.

Accordingly, it is now more explicit what are the parameters that affect the liner shipping companies' total profit. First, the quantities to be shipped by the forwarders along with number of slots to be reserved and utilized are the chief source of revenues for the liner shipping company. Moreover, to guarantee a minimum revenue gaining in case of forwarders' un-commitment to their promised order quantities, an agreed upon penalty rate should be paid for the liner shipping company. These revenue sources are linked to determined freight rates. On the other hand, the line's costs also should be calculated precisely to determine the actual total profit at the end. The cost would be a function of the operating costs that include the vessels cost operating on the cycle (chartering cost), the bunker cost which is related directly to the sailing speed and the daily fixed cost (Cheaitou and Cariou, 2012).

Thus, it is highlighted in this study different factors using the newsvendor model to obtain optimum quantities to be ordered, in other words slots to be reserved, to maximize the profits of the liner shipping company considering forwarders pricing options.

2. Literature Review and Contribution

Fundamentally, in this research, the newsvendor model will be used as a mean of pricing in the field of maritime shipping. However, since that multiple indirectly related aspects are being undertaking in this study, such as the vessels sailing speed, many different tracks were taken when reviewing the literature. These tracks are explored in the next sections.

2.1 Newsvendor or Newsboy Model

Actually, the newsvendor or newsboy problem, which also may be named as the single-period problem (SPP), is an inventory management model that intends to find an order quantity that maximizes the expected profit in a single period under probabilistic demand framework ((Khouja, 1999); (Qin et al., 2011)).

Interest in the newsvendor problem remains unabated and lots of extensions to it had been proposed in the last three decades. Such extensions include dealing with different suppliers' pricing policies, assorted newsvendor pricing policies and discounting structures, various objectives and utility functions, different states of information regarding the demand, multi-products under specific constrains, multiple-products with chances of substitution, random yields, and multi-location problems and models (Khouja ,1999).

However, Qin et al. (2011) extended Khouja's (1999) prior review by considering various specific extensions in their paper such as stock dependent demand, buyer risk profiles and integrating marketing effort and how they all affect determining the optimal newsvendor order quantity. Additionally, they also reviewed another twenty contributions since the review of Khouja (1999).

Generally, the newsvendor model is structured based on the assumption that at the beginning of a single-period, the buyer is interested in verifying an ''optimal'' stocking policy (Q) in order to satisfy the total customer demand for a particular product. This customer's demand is assumed to be stochastic and characterized by a random variable (D) with the probability density function (f(D)) and the cumulative distribution function (F(D)). The quantity (Q) is purchased by the buyer from a supplier for a fixed price per unit (Pc). In this model, the supplier is assumed to be operating with no capacity limits and with zero lead time of supply. Therefore, an order placed at the beginning of a period by the buyer with the supplier is immediately filled. The sales of the product occur during the single period. In this case, there are two possibilities: the quantity ordered is more than (or equal to) the actual demand or the quantity ordered is less than the actual demand. For the first case, which is expressed as Q ≥ D, there is a number of (Q – D) units that are left over at the end of that period. Similarly, for the second case, which is expressed as Q < D, there is a number of (D – Q) units which represent the lost sales. Consequently, the actual profit for the buyer at end

of the period is easily obtained by determining the actual sales with a defined market price (Pm) minus the losses due to surpluses and shortages (Qin et al., 2011).

Patil et al. (2010) stated that firms that sell considerably short life cycle products usually receive quantity discounts from their own suppliers and transporters for placing larger orders. Patil et al. (2010) studied in their research the impact of the quantity discounts and the transportation cost structures on procurement, shipment and clearance pricing decisions throughout a stochastic programming with recourse formulation. They proposed a solution procedure to efficiently solve the stochastic non-linear problem, then they suggested that it is not always compulsory to select the most complex action plan, and even under some businesses' environments, it is a better option to place and transport a single large order as a conventional strategy. Actually, their numerical experiments suggested that this strategy becomes dominant in case of the availability of low cost sourcing options. Moreover, in respect with these order sizes, in newsvendor problems, it is assumed that the initial business volume may vary between 60% and 100% of the total anticipated order (Subrahmanyan, 2000). A good example of that is that winter suit buyers acquire 80% before the winter season, keeping the remaining 20% of the budget back until after the season starts (Gellers, 1993).

From a similar point of view, Sayın et al. (2014) believe that inventory models, including single-item and the single-period newsvendor model, impel the decision makers to choose a fitting order quantity that maximizes the balance level between the cost of ordering too few against the cost of ordering too many items. However, they also stated that most models in the literature of the newsvendor model are not necessarily risk-neutral and just choose the order quantity that insures the maximum expected value and utility of the cash flow at the end of the period. Sayın et al. (2014) research paper took a utility-based approach to the single-item and single-period newsvendor model. Moreover, as a contribution, they supposed that there is uncertainty in demand in addition to supply and that both random demand and supply are possibly correlated with the surrounding financial markets. Their model exploits this correlation towards the buyer so that he can manage his risks by investing and being supplied in a portfolio of financial instruments. Therefore, this decision problem includes the determination of the optimal ordering size policy and at the same time the selection of the optimal portfolio. They used a minimum-variance approach headed for selecting the portfolio. Some numerical examples were presented to illustrate how the decision variables on the optimal order quantity were effected and the importance of financial hedging on the risk reduction.

2.2 Newsvendor Model in Maritime Shipping

In this research, it is considered the case of using the newsvendor model, discussed previously, in order to optimize the profits of liner shipping companies, and their forwarders. Yin and Kim (2012) discussed a method to optimize container freight rates/ tariffs in liner shipping in order to maximize the maritime company's expected profit by taking into consideration changes in order quantities made by the forwarders as these forwarders respond to the pricing schemes suggested by the liner company. The forwarders here are defined as the intermediaries, also may be identified as the non-vessel operating common carriers (NVOCCs) in some countries, they are typically collecting and arranging shipments from the real shippers (e.g. industrial or commercial companies), so their profit is granted from the price difference between the freight tariffs collected from real shippers and those paid to the liner companies. This indirect sales mode is common because shipping lines face numerous shippers that often exceed their direct sales capabilities. However, the liner companies' freight rates can be characterized by discount schemes, price-break points, and penalties for the unsold spaces. Yin and Kim (2012) designed an analytic model that addressed all-unit quantity discount schemes with single or multiple price-break points in addition to employing penalty rates as an innovative parameter which is not usually used by other researchers.

2.3 Quantity Discounts and Economic Order Quantity (EOQ) For Free Shipping

Free shipping offers, especially from e-retailers, are developing rapidly nowadays since e-commerce is becoming more popular and secured for international customers so the competition between the companies is increasing by providing such offers. For determining the minimum quantity to be ordered by the customers to get the free shipping offer or to decide on the shipping cost to be given to the customers for the quantities below the minimum one, usually the quantity discount of the economic order quantity model can be considered.

Kwon and Cheong (2014) studied the optimal policies of the retailers who operate their inventory by a single period model (i.e. a newsvendor model) under a free shipping offer where a fixed shipping fee is exempted if an order quantity size is greater than or equal to a certain minimum quantity. Zhou et al. (2009) had explored that model, while Kwon and Cheong (2014) further investigated Zhou et al. (2009) analysis for the optimal ordering quantity policies which they didn't adequately develop. So, Kwon and Cheong (2014) extended the basic model to deal with the practically vital aspect of inventory management when the particular distribution function of the demand isn't available. They combined this aspect into the basic model and then presented the optimal policies for the extended

model using a numerical example. They conducted then an extended numerical experiment in order to evaluate the performance of the modified model and analyzed the impacts of the fixed shipping fee and the minimum free shipping quantity on the performance, keeping in mind that the minimum free shipping ordering quantity or value possibly generates additional sales through encouraging customers to order more quantity to avoid the shipping fee. Similarly, Boone and Ganeshan (2011) investigated how to structure free shipping strategies from the perspective of the e-retailers. Among the several forms of free shipping offers, they concentrated on the value-based free shipping strategy. They suggested how the e-retailer can optimally determine the free shipping threshold level of a product for the customer and how to replenish the product from its supplier concurrently.

Hua et al. (2012) determined the retailer's optimal lot size to be ordered and the optimal retail price correspondingly, given that the supplier offers the customers a free shipping. They plainly combined the supplier's quantity discount with the transportation cost into their model, so that they could numerically and analytically examine the impacts of quantity discount, transportation cost and free shipping on the retailer's pricing and optimal lot sizing decisions. They found out that free shipping can benefit all of the supplier, the retailer and the customers. Moreover, free shipping can effectually encourage the retailer to order larger quantity of the good, to the extent of making orders a few times of the determined optimal order lot size without free shipping. The order lot size would increase while the retail price would decrease if the supplier properly offered free shipping.

2.4 Main Findings and Research Gap
Based on the papers reviewed in the previous sections, the following findings, that represent limitations in the existing works, can be listed:
1. There are few direct studies or researches considering optimizing the liner shipping companies profits or even other types of transportation means intended for shipping, through pricing and quantity discount techniques.
2. To the best of our knowledge, only one work, namely (Yin and Kim, 2012) used quantity discounts with stochastic demand and modeled a newsvendor problem to optimize the liner shipping profit and the forwarders cost. However, they did not consider the sailing speed as a decision variable and their shippers' demand was not sensitive to the sailing speed.
3. To the best of our knowledge, (Yin and Kim, 2012) is the only paper to consider the maritime supply chain with shippers, forwarders and liner shipping companies, in a profit maximization framework, but without speed optimization.

2.5 Contribution to the Literature
This study is mainly intended to improve the existing optimization mathematical models for liner shipping companies and to develop new models in order to ensure better efficiency. This aim could be fulfilled by:
1. Combining and improving the optimization models proposed by Yin and Kim (2012) and Cheaitou and Cariou (2012) for liner shipping companies in a perspective of being closer to reality.
2. Controlling pricing schemes in maritime supply chain with a realistic cost function of liner shipping company.
3. Including the fixed cost of vessels (chartering cost) in the model, which is directly proportional to the number of vessels and related to the vessels' sailing speed.
4. Including the vessels' sailing speed as a decision variable in the model, which affects in its turn the bunker fuel consumption and consequently the line costs.
5. Studying the effect of the sailing speed on the shippers and consequently the forwarders stochastic demand, and the optimal solutions.

3. Optimization Model
The aim of our model is to maximize the total profit of the liner shipping service companies, while considering maximizing the forwarders' profits too based on the approach proposed by (Yin and Kim, 2012). Considering an accurate cost function in term of vessel speed, in other words, fuel consumption. Moreover, a penalty rate is put to reduce the liner shipping company costs or losses when forwarders' does not commitment to their promised order quantities. Nevertheless, the total costs are divided equally on the pre-booked slots only, so no losses happen when some slots are not booked in the voyage.

3.1 Model Assumptions
In this study, it is assumed that:

1. The priority for customers to book the slots is based on First Come First Served rule.
2. The all-unit quantity discount system will be used because of its simplicity and popularity in the literature.
3. The quantity discount pricing scheme would offer a discount system with only a single price-break point.
4. The freight rate between the port of departure and the port of destination charged to all forwarders is the same.
5. The forwarders' demand is stochastic with known probability distribution, mean and standard deviation and depends on the freight rate.
6. The order quantities and discounted freight rates are both continuous parameters.
7. In a line, all the vessels are similar and have the same characteristics.
8. For the line's containerships, the cost function will be estimated based the model suggested by Cheaitou and Cariou (2012).

3.2 Model Parameters

Forwarders' parameters

N	The set of forwarder catalogues, $\{1, 2, 3, ..., n\}$, thus, (n) is the number of forwarders
R	Freight rate offered from forwarders to shippers (USD /TEU)
D_i^{AB}, D_i^{AB}	Demand faced by forwarder (i) from A to B and vice versa (TEU)
$f_i(.)$	Probability density function of the demand faced by forwarder (i)
$F_i(.)$	Cumulative distribution function of the demand faced by forwarder (i)
$F_i^{-1}(.)$	The inverse cumulative distribution function of the demand faced by forwarder (i)
Π_{Fi}	The expected profit of forwarder (i) (USD /cycle)

Line's parameters

W_0	The regular freight rate stated by the line to the forwarders when ordering a quantity below the price-break point (USD /TEU)
W_{d1}	The discounted freight rate stated by the line to the forwarders when ordering when ordering a quantity at the price-break point or more (USD /TEU)
P_0	The penalty rate stated by the line to the forwarders (USD /TEU)
Π_{Li}	The expected line profit from forwarder (i) (USD /cycle)
Π_{LT}	The total expected line profit from forwarder (i) (USD /cycle)

Cost function parameters

$C_T(V)$	Total cost of the cycle, which is the summation of all the costs associated with cycle with respect to a certain speed (USD/day)
$C_{TEU}(V)$	The unit carriage cost of the line, including both the fixed and variable costs with respect to a certain speed (USD /TEU)
CB_d^M	Average daily bunker cost for the main engine (USD/day)
CB_d^A	Average daily bunker cost for the auxiliary engine (USD/day)
C_b^M	IFO 380 cst (Intermediate Fuel Oil), used for the main engine, price (USD/ton)
C_b^A	MDO (Marine Diesel Oil), used for the auxiliary engine, price (USD/ton)
CV_d	Average daily fixed cost for the vessels operating on the cycle (USD/day)
C_v	Fixed daily cost of a vessel excluding port dues (USD/day)
V	The vessel intercontinental sailing speed (knots)
V^R	Vessel sailing speed within regional areas (knots)
D	Intercontinental distance per cycle (nautical miles)
D^R	Regional distance within regional areas per cycle (nautical miles)
S	Total intercontinental sailing time per cycle (day)
S^R	Total regional sailing time per cycle (day)

Vessel specifications

V^{DS}	Vessel design speed (knots)
F^M	Main engine average fuel consumption per intercontinental day at sea (tons/day)
F^{MR}	Main engine average fuel consumption per regional day at sea (tons/day)
F^A	Auxiliary engine average fuel consumption per day on the cycle (tons/day)

Decision variable

Q_i The order quantity forwarder (i) agreed upon with the line in their service contract

3.3 Model Formulation

3.3.1 Cost Estimation Function

We can express C_{TEU}, which is the ratio of the total cost per vessel per cycle by the total actual demand, as follows:

$$C_{TEU}(V) = \frac{C_T(V)}{\sum_{i=1}^{n} Qi}$$

Where, C_{Total} is obtained by summing the average daily cost for: the main engine cost at intercontinental and regional sailing plus the auxiliary engine cost plus the fixed cost of the vessel (Cheaitou and Cariou, 2012), expressed as follows:

$$C_T(V) = CB_d^M + CB_d^A + CV_d$$

Perceptively, CB_d^M is the average daily bunker cost for the main engine in the cycle. It is obtained by multiplying the bunker fuel price by the average daily bunker fuel consumption which in its turn consists of the main engine average fuel consumption in the intercontinental days and in the regional days at sea, considering sailing time. It is considered to be in term of USD per days, as follows:

$$CB_d^M = C_b^M (S F^M + S^R F^{MR})$$

While F^M and F^{MR} represent the fuel consumption (IFO 380 cst) per day at sea (ton/day) and the fuel consumption (IFO 380 cst) per day in the regional areas (ton/day). Both are calculated for the main engine as follow:

$$F^M = (SFOC^M \ El^M \ PS^M)(\frac{V_i}{V^{DS}})^3 \ (\frac{24}{10^6})$$
$$F^{MR} = (SFOC^M \ El^M \ PS^M)(\frac{V^R}{V^{DS}})^3 \ (\frac{24}{10^6})$$

Note that $SFOC^M$ represents the specific fuel oil consumption of the main engine (g/kWh), El^M the engine load of the main engine (%) and PS^M the power of the main engine (kW).

Similarly, CB_d^A is the average daily bunker cost for the auxiliary engine in the cycle. It is obtained by multiplying the bunker fuel price by the average daily bunker fuel consumption which in its turn consists of the auxiliary engine average fuel consumption, considering sailing time. It is considered to be in term of USD per days, as follows:

$$CB_d^A = C_b^A \ F_F^A \ S$$

Again, F_F^A is the auxiliary engine average fuel consumption per day on the cycle (ton/day). The fuel consumed is MDO (Marine Diesel Oil).

$$F_F^A = (SFOC^A \ El^A \ PS^A) \ (\frac{24}{10^6})$$

Note that $SFOC^A$ represents the specific fuel oil consumption of the main engine (g/kWh), El^A the engine load of the main engine (%) and PS^A the power of the main engine (kW).

Finally, the daily fixed operating cost is obtained by multiplying the daily fixed operating cost per sailing day in the cycle, as follows:

$$CV_d = C_V \, S$$

3.3.3 Total Demand Estimation

Again, C_{TEU} consists of the total costs divided by the total actual demand. The cost function was illustrated previously in this section. Here, we have to clarify that the summation of all of the quantities to be ordered in a price scheme ($\sum_{i=1}^n Qi$) is the total demand at that point. However, it'll be clearer how to apply that in the numerical application example in the next section.

3.3.2 Q_i Determination and Profit Models

Our principal objective is to maximize the liner shipping company total profit. Yin and Kim (2012) had expressed the expected line profit from forwarder (i) as follows:

$$\Pi_{Li}(Q_i) = \int_0^{Q_i} \big((W(Q_i) - C_{TEU}(V))D_i + P\,(Q_i - D_i)\big)f_i \, D_i \, dD_i + \int_{Q_i}^{\infty} (W(Q_i) - C_{TEU}(V))Q_i \, f_i \, D_i \, dD_i$$

As shown, the first part of the equation presents the case where Q_i is less than what was agreed on to be transported by forwarder (i), so, P (penalty) is applied on the difference between quantity agreed upon on and real demand. In contrast, the second part of the equation presents the case where Q_i exceeds what was agreed upon, therefore, the forwarder pays for what is transported only.

Correspondingly, the total profit, which is our concern to optimize in order to determine the quantity discount scheme, is the summation of the profit gained from all the forwarders. It was expressed as follows:

$$\Pi_{LT}(Q_i) = \sum_{i=1}^{n} \Pi_{Li}(Q_i)$$
$$= \sum_{i=1}^{n} \int_0^{Q_i} \big((W(Q_i) - C_{TEU}(V))D_i + P\,(Q_i - D_i)\big)f_i \, D_i \, dD_i + \int_{Q_i}^{\infty} (W(Q_i) - C_{TEU}(V))Q_i \, f_i \, D_i \, dD_i$$

Thus, the QD scheme is expressed as follows:

$$W\,(Q_i) = \begin{cases} W_0 & Q_i \in (0, Q_{d1}) \\ W_{d1} & Q_i \in [Q_{d1}, \infty) \end{cases} \quad \text{where } Q_{d1} > 0 \text{ and } W_0 > W_{d1} > C_{TEU}(V)$$

Subsequently, Q_{d1} is the price-break point and W_{d1} is its corresponding discounted freight rate.

Similarly, the quantity discount scheme tends also to maximize the forwarders' profits, by considering their decision when designing the scheme. However, they expressed the forwarder's (i) profit as follows:

$$\Pi_{Fi}(Q_i) = \int_0^{Q_i} \big((R - W(Q_i))D_i - P\,(Q_i - D_i)\big)f_i \, D_i \, dD_i + \int_{Q_i}^{\infty} (R - W(Q_i))Q_i \, f_i \, D_i \, dD_i$$

Nevertheless, they've proved in their research that for a given pricing scheme, the optimal order quantity (Q_i^*) for forwarder (i) is determined as:

$$Q_i^* = \begin{cases} Q_{i0} & for \ Q_i^{01} \le Q_{d1} & (Case\ 1) \\ Q_{d1} & for \ Q_{i0} < Q_{d1} < Q_i^{01} & (Case\ 2) \\ Q_{i1} & for \ Q_{d1} \le Q_{i1} & (Case\ 3) \end{cases}$$

Where:

$$Q_{i0} = F_i^{-1}\left(\frac{R - W_0}{R - W_0 + P}\right)$$

$$Q_{i1} = F_i^{-1}\left(\frac{R - W_{d1}}{R - W_{d1} + P}\right)$$

While Q_i^{01} is the value of Q_i which is greater than Q_{i1} and satisfies $\Pi_{Fi}(Q_i, W_{d1}) = \Pi_{Fi}(Q_{i0}, W_0)$

Furthermore, Q_{d1} has to be one of the Q_i^{01} from one of the forwarders that maximizes Π_{FT} .

Again, and as our contribution to this study, the total line profit from all forwarders (Π_{FT}) and the profit of the line from forwarder (i) (Π_{Fi}) will be changed from what Yin and Kim (2012) proposed after adding the cost function as follows:

$$\Pi_{Li}(Q_i) = \int_0^{Q_i}\left((W(Q_i) - C_{TEU}(V))D_i + P\,(Q_i - D_i)\right)f_i\,D_i\,dD_i + \int_{Q_i}^{\infty}(W(Q_i) - C_{TEU}(V))Q_i\,f_i\,D_i\,dD_i$$

$$\Pi_{LT}(Q_i) = \sum_{i=1}^{n}\int_0^{Q_i}\left((W(Q_i) - C_{TEU}(V))D_i + P\,(Q_i - D_i)\right)f_i\,D_i\,dD_i + \int_{Q_i}^{\infty}(W(Q_i) - C_{TEU}(V))Q_i\,f_i\,D_i\,dD_i$$

3.4 Model Resolution

The optimization model has been implemented and solved in Wolfram Mathematica, as follows:
  A- Define and import all input data

  B- For every value of the sailing speed: $V = V_j$ do the following
   1- Assume that $Q_i^{AB*} = \mu_i^{AB}$ and $Q_i^{BA*} = \mu_i^{BA}$ (the mean of the demand) for each forwarder

   2- Calculate the total cost of the line in the cycle in both directions (AB and BA):
       a. Calculate $C_{Total,1}^{AB}$ and $C_{Total,1}^{BA}$ using (Cheaitou and Cariou 2012)

   3- Calculate the cost per container in both directions ($C_{TEU,1}^{AB}$ and $C_{TEU,1}^{BA}$)
       a. Divide $C_{Total,1}^{AB}$ by $\sum_{i=1}^{n} Q_i^{*AB}$ to obtain $C_{TEU,1}^{AB}$
       b. Divide $C_{Total,1}^{BA}$ by $\sum_{i=1}^{n} Q_i^{*BA}$ to obtain $C_{TEU,1}^{BA}$

   4- Calculate Q_{i0}^{AB}, Q_{i0}^{BA}, Q_{i1}^{AB}, and Q_{i1}^{BA} for each forwarder i using (Yin and Kim, 2012)

   5- Calculate $Q_i^{01,AB}$ and $Q_i^{01,BA}$ for each forwarder i using (Yin and Kim, 2012)

   6- For each combination (Q_{d1}^{AB}, Q_{d1}^{BA}) so that $Q_{d1}^{AB} = Q_i^{01,AB}$ and $Q_{d1}^{BA} = Q_i^{01,BA}$ for every i do the following:
       a. Calculate Q_i^{AB*} and Q_i^{BA*} for both directions and all forwarders
       b. Calculate the profit of the line from each forwarder $\Pi_{Li} = \Pi_{Li}^{AB} + \Pi_{Li}^{BA}$
       c. Calculate $\Pi_{LT} = \sum_{i=1}^{n} \Pi_{Li}$
   7- Choose the combination (Q_{d1}^{AB}, Q_{d1}^{BA}) that provides the largest value for Π_{LT}

   8- Calculate the corresponding Q_i^{AB*} and Q_i^{BA*} for both directions and all forwarders

   9- Calculate again (update) the cost per container in both directions ($C_{TEU,2}^{AB}$ and $C_{TEU,2}^{BA}$)
       i. Divide $C_{Total,2}^{AB}$ by $\sum_{i=1}^{n} Q_i^{*AB}$ to obtain $C_{TEU,2}^{AB}$
       ii. Divide $C_{Total,2}^{BA}$ by $\sum_{i=1}^{n} Q_i^{*BA}$ to obtain $C_{TEU,2}^{BA}$

10- *Set m=2;*

11- If $C_{TEU,m}^{AB} \notin [C_{TEU,m-1}^{AB} - 10\%; C_{TEU,m-1}^{AB} + 10\%]$ OR $C_{TEU,m}^{BA} \notin [C_{TEU,m-m}^{BA} - 10\%; C_{TUE,m-1}^{BA} + 10\%]$ do the following:
   a. Use Q_{i0}^{AB}, Q_{i0}^{BA}, Q_{i1}^{AB}, Q_{i1}^{BA}, $Q_i^{01,AB}$, and $Q_i^{01,BA}$ that were calculated in steps (4) and (5) above
   b. For each combination $(Q_{d1}^{AB}, Q_{d1}^{BA})$ so that $Q_{d1}^{AB} = Q_i^{01,AB}$ and $Q_{d1}^{BA} = Q_i^{01,BA}$ for every i do the following:
      i. Use Q_i^{AB*} and Q_i^{BA*} that were calculated in step (6.a)
      ii. Use $C_{TEU,m}^{AB}$ and $C_{TEU,m}^{BA}$ to calculate the profit of the line from each forwarder $\Pi_{Li} = \Pi_{Li}^{AB} + \Pi_{Li}^{BA}$
      iii. Calculate $\Pi_{LT} = \sum_{i=1}^{n} \Pi_{Li}$
   c. Choose the combination $(Q_{d1}^{AB}, Q_{d1}^{BA})$ that provides the largest value for Π_{LT}
   d. Calculate the corresponding Q_i^{AB*} and Q_i^{BA*} for both directions and all forwarders
   e. Set *m=m+1*
   f. Calculate again (update) the cost per container in both directions ($C_{TEU,m}^{AB}$ and $C_{TEU,m}^{BA}$)
      i. Divide $C_{Total,m}^{AB}$ by $\sum_{i=1}^{n} Q_i^{*AB}$ to obtain $C_{TEU,m}^{AB}$
      ii. Divide $C_{Total,m}^{BA}$ by $\sum_{i=1}^{n} Q_i^{*BA}$ to obtain $C_{TEU,m}^{BA}$
   g. Go back to step 11
12- Calculate the total profit of the line without quantity discount Π_{LT}^0
13- Choose the highest profit between the latest Π_{LT} obtained in step 11 and Π_{LT}^0

C- Choose the value of the sailing speed V_j that provided the maximum profit.

D- Calculate the corresponding Π_{Fi} for each forwarder i.

E- Export the key outputs into a .txt file

4. Numerical Application

To show the efficiency of the proposed model, a numerical application using data obtained from other research works has been conducted. In this section, we provide the used values of the parameters as well as the optimization results.

4.1 Parameters and Values

The values of *P, R_i W_0* and W_{d1} were inspired by the values used in (Yin and Kim, 2012) while considering the ratio between the values used by these authors. For example, $C_{TEU}(V)$ in their paper is equal to 50 USD/TEU, but in our paper it reaches more than 400 USD/TEU for some cases, since in our model we considered the costs in a more precise way, thus we've applied fixed multiplications to keep the ratio between the parameters static. Whilst, the fuel prices, vessel specifications and sailing distances are got from (Cheaitou and Cariou, 2012). Table 1 shows the data values.

Table 1. Model parameters and their corresponding values used in the numerical application example

Parameter	Corresponding value	Parameter	Corresponding value
P	1200	$SFOC^M$	206
W_0	1500	El^M	0.8
W_{d1}	1320	PS^M	41186
R_i	2500	$SFOC^A$	221
S^R	19	El^A	0.5
V^R	16	PS^A	2433
C_v	25000	C_b^M	500
V^{DS}	23.3	C_b^A	750

For the demand, we used normal probability distributions for every forwarder using a mean and a standard deviation inspired from the work of (Yin and Kim, 2012)

4.2 Optimization Results
The optimal results obtained from the implementation of the model in Mathematica are as follows:

- There is a proportional relationship between the vessel speed (V) and the total cost ($C_T(V)$), thus, there is an inverse relationship between the vessel speed and total profit of the line (Π_{LT}). This is pretty expected and totally clear and logical. However, Table 2 shows the relation by the numbers we've got in our model.
- Q_{d1} which satisfies Max. Π_{LT} at all different vessel speeds (V) is equal to 3835.45.
- The absolute Max. Π_{LT} is at $Q_{d1\ optimal} = 3835.45$ and $V_{optimal} = 14\ knots$, which is the lowest speed in the M list
- The optimal cycle time *S= 36 days*
- However, after $V_{optimal}$, the next speed values at $Q_{d1\ optimal}$ are also leading to a successful QD scheme, with higher profits.
- The forwarders' profits are provided in Table 3. It shows that two forwarders benefit from the scheme; forwarder 2 and forwarder 5.

Table 2: The relationship between vessel speed (V), total cost ($C_T(V)$) and total profit of the line (Π_{LT}).

Vessel Speed (V)	Total Cost ($C_T(V)$)	Total Line Profit W_0 (Π_{LT} (W_0))	Total Line Profit W_{d1} (Π_{LT} (W_{d1}))
14	1,710,300	1,296,700	1,301,980
17	2,213,080	3,883,160	3,899,520
21	2,594,670	1,055,330	1,059,800
24	2,852,470	1,649,600	1,656,350
28	3,594,980	4,205,340	4,482,590

Table 3: The forwarders' profits at W_0 and W_{d1}.

Forwarder (i)	Π_{Fi} (W_0)	Π_{Fi} (W_{d1})
1	825,606 USD	825,606 USD
2	2,688,410 USD	3,194,640 USD
3	738,962 USD	738,962 USD
4	1,060,730 USD	1,060,730 USD
5	2,886,090 USD	3,000,110 USD

5. Conclusions
In conclusion, it was pointed out the importance of optimizing the profits for container transportation services provided by the liner shipping companies. The field of maritime shipping generally is not given the concern it deserves in the perspective of financial profitability, while many reviewers and researchers considered its environmental aspect. On the other hand, some studies considered mathematical optimization models for free shipping quantity orders determination for online businesses. However, it should be concerned the importance of optimizing the liner shipping services companies profits and costs. Indeed, under the QD scheme, the total optimal line profit (Π_{LT}) increased by 2.6 % which is 310,100 USD.
For other not non-optimal total line profits (Π_{LT}), under the QD scheme, when the vessel speeds (V) increase, the liner service achieved profits that reached 2.9%, which is 330,400 USD, this is at maximum vessel speed $V = 28\ knots$. Forwarders are benefiting from this scheme also, since any forwarder's optimal quantity to be ordered fits the condition: $Q_i \geq Q_{d1}$ will get a discount in the freight rate. Moreover, indirect forwarders benefit is when the line minimizes its total cost, which may have an effect on the line's freight rate W_0. In this study, more attention is paid to the decision variables that really affect the whole liner shipping services' profit, which are the freight rates and the sailing speed. It also considered the effect on the maritime supply chain partners, namely the forwarders and shippers. In other words, if a liner shipping company guarantees encouraging pricing schemes for its forwarders and shippers and suitable sailing speed, then this liner shipping company is winning the bid and getting the customers' loyalty, since that forwarders or shippers are frequent customers with frequent, or at least periodic, demand to ship

goods. This raises the real importance of structuring such mathematical optimization models to contribute to the literature and add value to the maritime shipping field and literature.

Nevertheless, a better addition to our model is to determine the optimal discounted freight rate (W_{d1}) to guarantee even more total line profit (Π_{LT}). Moreover, it would be great to integrate the demand sensitivity to speed, since that the vessel speed affects directly the total sailing cycle time S. these two additions are already our concerns in further developing this optimization model. A further dimension would add a great value, is considering the CO_2 emissions, which is a global environmental concern raising these years.

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Biography

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