OPR 620 Final Project

Logistic strategy: FCL or LCL in sea freight

Abstract

Sea freight is one of the most important delivery approaches in the global logistic industry. There are many shipments loaded with different kinds of commodities and over the sea each day. For clients who want to sell the products to other countries via sea freight, it is important to plan a sea freight approach to save the cost, assigning the items between different containers and delivery methods is the most important part in planning. This paper demonstrates a model in planning the items assignment in the case of sea freight, to minimize the cost in oversea logistic.

Keyword: Sea freight, assignment problem, optimization

I Introduction

Background and Motivation

A Chinese manufacturer near Shanghai is thinking about how to deliver commodities that are produced to US to minimize the cost. For a commercial company that needs to deliver different kinds of items oversea, it is necessary to carefully consider how to assign and distribute various goods in different ways of sea freight. The manufacturer located in the east China and, thus this case the route is from Shanghai, China to Long Beach, CA USA. The aim of this project is to help this manufacturer to plan the assignment of sea freight to minimize the cost. Also, the project may also be applied in other cases about sea fright assignment in containers and delivery.

Literature Review

Generally, there are two ways in the sea freight, FCL and LCL. The FCL is full-container load. There are many kinds of containers in sea freight. In general, we only have two types of containers: 20-foot container or 1 TEU (Twenty-foot equivalent unit), 40-foot container or 1 FFE (Forty-foot equivalent unit). The table below is the detailed information on the containers:

	20-foot Standard	40-foot Standard
Exterior Dimensions	20 ft (L) x 8 ft (W) x 8.5 ft (H)	40 ft (L) x 8 ft (W) x 8.5 ft (H)
Interior dimensions	19.4 ft (L) x 7.8 ft (W) x 7.10 ft (H)	39.5 ft (L) x 7.8 ft (W) x 7.10 ft (H)

Load Weight capacity	approximately 33,000 lbs. (14,969 kg)	approximately 67,200 lbs. (30,480 kg)
Capacity	33 Cubic Meter	67 Cubic Meter
Cost	$3,500	$5,600

FCL (Full Container Load) and LCL (Less Than Container Load) are two forms of sea freight. The FCL is when cargo load can fill with a full container in the 20 feet or 40 feet. The LCL (Less Container Load) is cargo load that cannot fill with a full container, then share container space with other users. According to freightos.com, the cost of LCL is $778 per CBM (Cubic Meter), the unit price of LCL is much more expensive than FCL. Also, LCL generally requires longer delivery time, and it is uncertain since logistic company will not deliver LCL container until fill it up. As for FCL, the manufacturer can fill and seal the container in their own factory or storehouse, which ensures to avoid damage and theft during shipment. The table below is the delivery time and risk list in FCL and LCL:

	FCL (Full Container Load)	LCL (Less Container Load)
Delivery time	19 – 22 days	25-31 days
Risk List	1. Weather Delay 2. Low Security Risk	1. Weather Delay 2. High Security Risk

In this project, we focus on the situation when the manufacturers are only considered to purchase new containers if select FCL, and the price of the whole container in FCL is more expensive than only use part of container in LCL if goods to be delivered is small enough. Therefore, the problem is how to assign different commodities into FCL or LCL to minimize the cost by maximizing usage of the space usage in FCL container. The shipment's volume, weight, cost, transit time, delivery window, security requirements are the factors that are considered in the assigned procedures.

II Model Construction

Decision Variables

Before introducing the decision variables, we need specify the distribution result of each item Row represents the commodity type; the column represents the delivery approach (FCL or LCL) or container type, the sample of matrix table is below:

	LCL (Less Container	FCL (Full Container Load)

	Load)	20-foot container (FCL20)	40-foot container (FCL40)
Item 1			
Item 2			
……			
Item n			

Each item is the package with the same or multiple kinds of commodity with same delivery requirement and maximum risk. Thus, the blank area is the binary that needs to fill with 0 or 1; for filling 1 means that item n uses the corresponding method in shipment. Therefore, each item only has one blank to fill with 1. The table is the result of model, and it may change after each attempt in model running since some constraints and coefficients vary, this will be explained in the Randomness part.

The thing that needs to be awarded is that the table above does not directly impact on overall cost, it just represents where each item is assigned. Each container of FCL has its own maximum weight and volume capacity as shown earlier, the new container will be added if one container is filled. Thus, the cost of FCL is determined by the number of containers used, the cost of LCL is determined by the overall volume capacity used in LCL.

Therefore, the decision variables are the number of 20-foot containers (FCL20) and the number 40-foot containers (FCL40), and the volume of using LCL, these three decision variables may determine the overall cost.

Objective Function

The objective function is the overall cost of sea freight. The objective of this project is to minimize the overall cost. Therefore, the objective function is the sum up of cost of container cost and random cost. The random cost is the delayed penalty based on random variables. To be specific, the mathematical formula can be presented below:

Deterministic cost

The minimum deterministic cost *(min D)* is the container cost, which is the overall cost of FCL and LCL. The cost of FCL is the number of FCL40 *(N_40)* times the unit price of FCL40 *(C_40)* plus the cost of FCL is the number of FCL20 *(N_20)* times the unit price of FCL20 *(C_20)*, and the cost of LCL is the overall volume *(V_LCL)* of items times the unit price of LCL *(C_ LCL)*. The formula as follow:

$$\min D = C_{40} \cdot N_{40} + C_{20} \cdot N_{20} + C_{LCL} \cdot V_{LCL} \quad (1)$$

Random cost

The random cost is the total delayed penalty of all items, which use the delivery time *(T_Di)* minus required time of each item *(Ri)*, then times the delayed penalty of each item *(Pi)*. If the result is less than 0, return 0; or return the value that applies to penalty. The formula is following:

$$R = \sum_{i=1}^{n} \max(T_{D_i} - R_i, 0) \cdot P_i \tag{2}$$

Overall cost

The overall cost can be presented as follow:

$$O = \min D + R \tag{3}$$

To be specific, it can also be shown as following form:

$$O = \min \left(C_{40} \cdot N_{40} + C_{20} \cdot N_{20} + C_{LCL} \cdot V_{LCL}\right) + \sum_{i=1}^{n} \max(T_{D_i} - R_i, 0) \cdot P_i \tag{4}$$

In this case, the decision variables are the number of FCL40 *(N40)* and the number of FCL20 *(N20)*.

Constraints

There are many constraints (or factor) that may impact on decision making process:

Load Weight Capacity: The maximum weight capacity for each container, this constraint is only available for FCL. We assume that logistic company will not receive the package or dissemble the package into multiple small packages if it is too heavy in LCL. The item will be assigned into the next container if overall weight exceeds the maximum load capacity after adding the item. The constraint formula of load weight capacity is following:

$$\sum_{j \in I_i} W_j \leq WC_i, \quad \forall i \in \text{Containers} \tag{5}$$

Where:

- W_j: The weight of each item.
- WC_i: The maximum weight of the container.

Size of Container: The maximum space capacity for each container, this constraint is only available for FCL. We assume that logistic company will not receive the package or dissemble the package into multiple small packages if volume is too high in LCL. The constraint formula of space weight capacity is following:

$$\sum_{j \in I_i} V_j \leq VC_i, \quad \forall i \in \text{Containers} \tag{6}$$

Where:

- V_j: The volume of each item.
- VC_i: The maximum space of the container.

Delivery Time and Requirement: Delivery time for FCL and LCL are different, LCL generally requires longer time to destination, also with higher variance. For time requirement, each item has its own requirements. The penalty may be applied if delivery is delayed, the penalty is added into overall cost.

Risk: Damaged risk and theft may happen; it will cause double cost of this item if occur. The risk of LCL is significantly higher than FCL. In this project, the risk level of FCL is 1, the risk level of LCL is 2.

Randomness

The first randomness is delivery time. Based on market research, the delivery time from Shanghai to Los Angeles vary, this is because there is not daily shipment in this routine. The second randomness is weather randomness, it is a special event that may occur during the shipment, terrible weather may cause delayed shipment.

In the project, for random variables, it may create a specific value based on random program, then use these values to the coefficients of linear programming function. There are two random variables that affect the overall cost:

Delivery Time

As shown in the table in the earlier chapter, the delivery time of FCL and LCL vary. In coding experiment, I randomize the delivery day of FCL and LCL within range respectively.

Weather Delay

I set the probability in weather delay situation, which there is 97% not any weather delay, and 3% with extreme weather that may cause 3-5 more delayed days. These delayed days will be added to the delivery time for each kind of container. We use sigma to denote the delay time caused by extreme weather. The delayed time of weather can be expressed as:

$$P(\sigma = 0) = 0.97, \quad P(\sigma = 3) = 0.01, \quad P(\sigma = 4) = 0.01, \quad P(\sigma = 5) = 0.01 \tag{7}$$

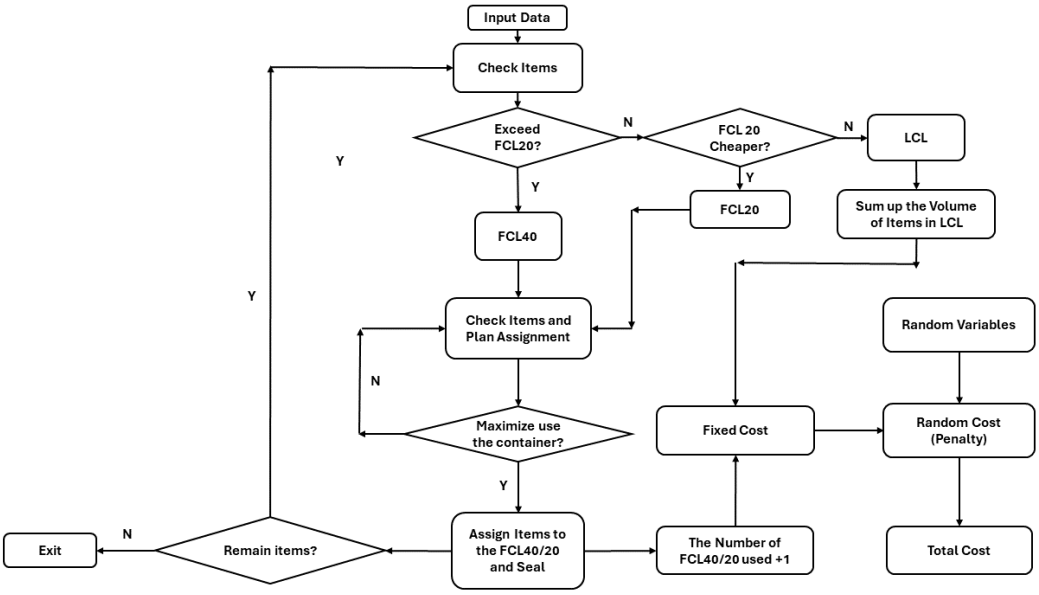
For the overall delivery time, the formula is below:

$$T_{D_i} = T_{R_i} + \sigma \tag{8}$$

Where:

T_Ri: The random delivery time in FCL and LCL.

III Operation Workflow



The workflow shows how the model works to output the minimum overall cost.

The first step is inputting the dataset of item list and generating the random variables simultaneously.

The second step is checking all items, compare the overall capacity and weight with the maximum capacity of FCL20, if the one of the weight and volumes of all items exceed the maximum capacity of FCL20, select the FCL40; if not exceed, comparing the cost of FCL20 and LCL, selecting the cheaper one as the container or delivery way. Since the FCL40 is far more cost-effective than FCL20 and LCL, it is impossible that there are remaining items after using FCL20 and LCL. The third to X step will be executed if FCL40 or FCL20 are selected.

The third step is re-checking all items, try to find all potential assigned combinations that does not exceed the maximum limitations of FCL40 (As mentioned before, all items can be included if select FCL20), then calculate the space or weight used of all combinations, then use the combination that fill the most load or space of container. This step is to find the assigned strategy that maximizes using the FCL40 container space and load.

The fourth step is processing remaining items by the second and third steps until all items are packaged into the container or assigned with LCL.

The fifth step is calculating the random cost, delayed penalty for each item, this is based on delivery method, time requirement and the value of random variable. This step will output the delayed penalty of each item. Then sum up the delayed penalty of

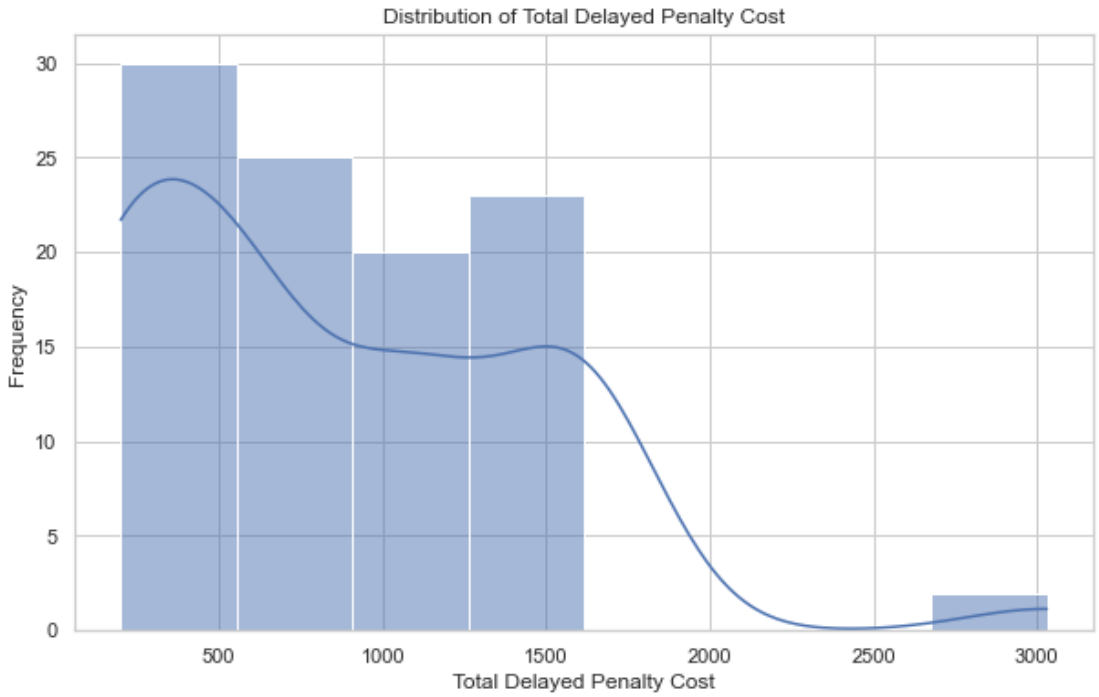
all items as overall random cost.

The sixth step is calculating the fixed cost, or container cost, based on the number of FCL40/20 used and the total volume of items in LCL. Then add the fixed cost and random cost as total cost.

The random cost can not be controlled because of stochastic process. The optimization is focusing on the part of fixed cost.

IV Numerical and Coding Experiments

Since the dataset is synched by the real-world situation, I added, deleted, and modified the dataset many times, then got different optimal solution with cost and assigned strategies after re-running. I also re-run the model with the same dataset many times to find the distribution of random cost.



The random cost, or total delayed penalty cost vary in each time of running the model. As the figure shown above, almost all the total delayed costs were less than $1,600, which resulted from the normal fluctuates in the delivery time of shipment. Also, the delayed cost only accounted for a small part of overall cost, which is acceptable. In very rare cases, the delayed cost may be around $3,000, the extreme weather occurs in this situation. The simulation of model reflects some random events in real-world situations, especially in the sea freight industry.

V Conclusion

For sampled data, I found the optimal solution of assigned strategy and got the minimum cost. After validating and calculating the space and load used, I cannot find a better solution than model's outcome in this case. Although the model returns different total cost that is resulted by random variables, the fixed cost and optimal solution from assignment is certain. Consequently, this model can help manufacturers to find the optimal solutions in assigning items in different containers and delivery methods, to ensure the minimum cost.

Application

This model provides a strategy to solve a simplified situation of Knapsack problem, which is also one of the forms of the combinatorial problem.

The FCL and LCL are two major methods to deliver commodities in sea freight, for business owners or decision makers who want export products by shipment, this model and project practice can help them on the assignment of products delivery. In real-world situations, the item information, delivery time, and anything else may vary, but it can be updated in codebook and get the solution after running. The model can also help to make decisions in other fields that may be related to the plan assignment.

Limitation

There are multiple kinds of containers in the sea freight, rather than only FCL20 and FCL40. Also, I only consider the CBM as the volume, rather than consider the length, width, and height like real-world situation, the latter needs to the space planning software and more complicated algorithm to solve the problem.

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