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An Optimization Model for Cargo Container Loading Plan Problem for Seafood Products

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Abstract— Recently Indonesian Government is focusing in marine fishery industry to be one of the key component for developing the economic of the country. Seafood products belong to this industry. In order to distribute rapidly the seafood products around Indonesia the fish industries need air express carrier service. These carrier flights are one-stop, from an origin, to the hub, then to destination. Airport operations include those at the origins, at the destinations and at the hub. In this paper we consider logistics supply chain decision problem which arises in marine fisheries industry in Indonesia. The loading planning problem is to deliver seafood products using air carriers. The objective of the model is to minimize the total container operation costs, subject to the related operating constraints. Due to the perishability of the products, if overflow occurred they should be transported by third party. The model is formulated as a mixed integer programs. We develop a neighborhood search approach for solving the model.

Keywords- *Stochastic optimization, air express carriers, cargo container loading plan, neighborhood search.*

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I. INTRODUCTION

Indonesia consists of more than thirty thousand islands. In order to distribute and to allocate products it is necessary to have a well planned logistic system. Logistics plays an important role in connecting each and every participant of the supply chain effectively. In today's global fast business environment much pressure has to be imposed on the supply chain system to be very competitive and efficient. Air logistic plays a vital role in ensuring the efficient flow of supply of goods in the complex supply chain and wide dispersed location. Air-logistics systems provide an effective solution for the faster and secure delivery of goods across the country. Nevertheles, they tend to deal with more expensive and time-sensitive goods, such as seafood products. In some way, air transport could help to keep down several costs, related to inventory, warehousing and maintenance. Designing a cost effective air-logistics system is always a challenging and difficult task.

In the process of the air-transport, the loading of package is an important step in estimating the transportation cost. The inefficient loading or packing the packages can result in unnecessary extra labour cost and extra delays in terms of unpacking and reloading of air cargos, with the implication that the transportation costs would increase.

In real application, there are two type of operations occur. The first one is to deliver packages to the same direction, called pure containers. In this type containers are transferred directly (called trans-loaded) to the hub from aircraft to aircraft. The second type is called mixed containers. In this type packages are shipped to different destinations. Therefore a sorting process is necessary at the hub to separate the enclosed These two types of container loading have a different impact at the origins and at the hub. Many factors need to be considered to determine optimally the container loading plan, such as the cargo OD demands, the container configurations, the number of containers that need to be loaded for each OD demand, the aircraft capacity, the time needed to sort packages, the handling capacity of each gateway and of the hub, the flight schedule, the available airport time window in operations which is affected by the flight schedule, and many related operating constraints. The loading plan comes under the heading of optimization, due to the fact that the objective of the plan whether to minimize the number of containers loaded or to maximize the efficiency of the packed volume inside the containers [31].

Research related to the air cargo loading problem, [10] proposed a two-stage decision support system for a two stage air cargo loading plan. They considered the problem as a three-dimensional bin packing problem as the air pallets have different shape and size specifications. The first stage involved the use of linear planning to determine the lower limit for the overall cost of the pallet relative to weight and quantity. The second stage involved the creation of a loading plan for each pallet. [12] proposed an integer programming model with a branch and bound approach for solving the pallet loading problem, in which the objective is to maximize the number of copies of the small rectangle that can be fitted without overlap into a larger rectangle. For heuristic approach, [15] addressed an application of simulated annealing to three dimensional packing. However, it can only be used on small problem sets. [19] use genetic approach for solving heuristically three-dimensional container loading problem. They significantly improve the search efficiently and to load most of heterogeneous boxes into a container along with the optimal position of loaded boxes. Review on cargo loading optimization can be found in ([14], [31]).

Other related research on air cargo has been devoted to such things as the characteristics of air express carriers [6], network planning for international air cargo carriers ([11], [16], [23], [24]), flight scheduling for air cargo carriers ([1], [24], [39]), competition analysis and configuration analysis for air cargo carriers ([22], [41], [42]), air freight strategies [32], hub location selection ([29], [2], [7], [30], [21], [3], [18], [35], [36], [28]), vessel loading problem [34], cargo loading plans for forwarders [37], and network revenue management problem of air cargo [17]. All these, however, have a different focus than this research and, therefore, do not provide efficient container loading plan solutions for air express carriers. Researches on planning problems concerning stochastic disturbances that occur in operations have been studied in other fields ([27], [13], [38], [20], [26]), but have not been found (to the best of the authors' knowledge) to resolving air cargo container loading plan problems for perishable products.

In this paper we consider logistics supply chain decision problem which arises in marine fisheries industry in Indonesia. The management of fish processed industry is still dominated by the local small traditional business, using conventional management strategy. They need supply chain management to distribute the fish productions to cities in Indonesia which are located in several islands. The expired date of fish processed products is short. This type of product, called perishable product, can be consumed whether they are top fresh or a few days old, but after their expiry date, they are usually deemed unfit for sale by the retailers.

Perishable products, such as fish processed, would impose additional difficulties to the logistics supply chain management due to their limited shelf-life. These difficulties include the duration of delivering the products due to the expired date. Hence, quantities delivered to retailers are limited by the shelf-life of goods as well as the retailer's holding capacity.

II. PROBLEM FORMULATION

Although generally cargo airlines plan flight schedules with multi-stop flights, for express carriers too many stops is not practical due to the time-definite constraint of the next-day delivery commitment. Most of Carrier flights are one-stop, i.e., from an origin, to the hub, then to a destination. Airport operations include those at the origins, at the destinations and at the hub..

The main functions of a gateway (an airport) are to collect outgoing (export) packages and to distribute incoming (import) packages. The export process starts from package pickup at an origin by an on-road courier. At the end of a day, all export packages are carried back to a station, and then transported to the gateway by shuttle. The gateway is responsible for sorting packages and assigning them to pure or mixed containers, which are then loaded into aircraft

In terms of whether pure or mixed containers are used, pure containers require more effort at an origin to be assembled owing to the time-consuming package sorting process, but less time is required at the hub for transloading from aircraft to aircraft. On the other hand, mixed containers require less effort at the gateway where there are limited resources, but require more manpower and longer package sorting time at the hub. If the container handling capacity at the hub is unlimited and the marginal operating cost is constant and lower than that at each origin, then obviously packages should be loaded into mixed containers at all origins, in order to reach the minimum total operating cost. However, usually the handling capacity at the hub is limited and the marginal operating cost is not constant. Indeed, the operating cost for handling packages is negatively related to the available operating time window, determined by the flight schedule. That is, the larger the available operating time window in the flight schedule, the lower the handling cost. For instance, for late arrival flights from origins to the hub it is necessary to build pure containers, so that the associated packages can arrive in time to catch early connecting flights. Obviously, the cargo container loading plan will be affected by the flight schedule. In this paper, the problem is mainly focused on the cargo container loading plan for a given flight schedule. The integration of a cargo container loading plan and flight scheduling can be researched in the future.

It is a common practice that flight cargo company relies on experienced staff with a fixed and projected demand to design its container loading plan. However it should be noted that, the container loading plan should be designed separately and independently at every gateway and at the hub. For conveniece the interrelations among all gateways and the hub are omitted from the system perspective., Normally, each volume (at an origin) is simply classified as split (i.e., to be loaded into pure containers) or not (i.e., to be loaded into mixed containers). This common method can only be applied for small deliveries case. For large service networks, such a method is neither efficient nor effective, and consequently, would result in sub-optimal solutions.

In this paper, we encounter a loading optimization problem for delivery seafood product from an origin city i to destination city j. It is assumed that the parameters of the problem are given, such as the cargo demands, the flight schedule, the aircraft loading capacity, the container handling capacities at each origin and at the hub, the container handling cost function at each gateway and at the hub, the cost for transporting the overflow volume by a third party, and other parameters. Then we develop a mixed integer programming model for the loading plan problem. We develop a solution method using neighbourhood search approach..

III. MODEL

As the logistics problem involve perishable product, then the problem would include time period T in which it contains $\sigma_{\max}$ the maximum shelf-life (expired date of products)

We use integer programming techniques to formulate the problem.

Notations used.

Sets.

I	Set of all origins,
J	Set of all destinations,
K	Set of all kind of containers,
T	Time period

Decision variables

x_{ijt}^{b}	The fraction of the demand from *i* to *j* to be loaded into the *b*th kind (AMJ or AKE)'s pure containers in time period $T-\sigma_{\max}$;
y_{ijt}	The fraction of the demand from *i* to *j* to be loaded into the mixed containers in time period $T-\sigma_{\max}$;
z_{ij}^{b}	The number of *b*th kind (AMJ or AKE)'s pure containers transported from *i* to *j*
w_{ij}	The container volume (in AMJ equivalents) transported by a third party from *i* to *j*;

The parameters are defined as follows:

d_{ijt}	The demand volume (in AMJ equivalents) from *i* to *j* in time period $T-\sigma_{\max}$
λ_i	The fully pure container equivalent for handling a mixed container at origin *i*;

μ_i	The fully pure container equivalent at the hub for handling a mixed container that is shipped from origin i;
b	The bth kind of container. b = 1 for AMJ and b = 2 for AKE;
u_i	The handling capacity (fully pure AMJ equivalents) at origin i;
s	The handling capacity (fully pure AMJ equivalents) at the hub;
LC_b	The aircraft loading capacity for the bth kind of containers;
v_b	The AMJ equivalent for the bth kind of container;
A_i	Cost for handling pure container at origin i;
B_i	Cost for handling mixed container at origin i
C_i	Cost for handling mixed containers transferred from gateway i
c_b	The marginal cost for handling a fully/partially pure bth kind container at the hub;
c_{ij}	The cost of transporting an AMJ's container volume by a third party from i to j;

The logistic problem is formulated as a mixed integer program as follows

Minimize

$$\sum_{i\in I} A_i \sum_{j\in J}\sum_{t\in T-\sigma_{Max}}\sum_{b\in K} d_{ijt} x_{ijt}^b + \sum_{i\in I} B_i \sum_{j\in J}\sum_{t\in T-\sigma_{Max}}\sum_{b\in K} d_{ijt} y_{ijt}^b + \sum_{i\in I}\sum_{j\in J}\sum_{b\in K} c_b z_{ij}^b + \sum_{i\in I} C_i \sum_{j\in J}\sum_{t\in T-\sigma_{Max}} d_{ijt} y_{ijt} + \sum_{i\in I}\sum_{j\in J} c_{ij} w_{ij} \quad (1)$$

The objective (Eq. 1) is to minimize the overall container handling cost in the system. If the overflow occurs, then it is necessary to use third party to tackle the delivery as the seafood product has a restricted time window. The cost for this case is expressed in the fifth term of the objective function (1).

There are several operational constraints that must be met.

$$\sum_b x_{ijt}^b d_{ijt} + y_{ij} d_{ijt} + w_{ij} = d_{ijt}, \quad \forall i, j \in I, J, \forall t \in T-\sigma_{Max}; \quad (2)$$

Constraints (2) are to make sure that each demand volume from i to j is completely loaded into pure/mixed AMJ/AKE containers in time period T while considering the shelf-life of the products. The constraints also consider if an overflow volume occur. It should be noted that all mixed containers and the overflow volume are represented as AMJ equivalents for ease of modeling. The next step would be the obtained amount of mixed containers are sorted into detailed AMJ and AKE containers, according to the aircraft loading capacity, after the number of both fully and partially pure containers, and the overflow volume, at each gateway have been determined.

$$\sum_j \sum_b x_{ijt}^b d_{ijt} + \lambda_i \sum_{j\in J} y_{ijt} d_{ijt} \le u_i, \ \forall i \in I, \forall t \in T-\sigma_{Max}; \quad (3)$$

Constraints (3) give the container handling capacity constraint in fully pure AMJ equivalents for each gateway in time period within shelf-life time windows. Note that the mixed containers have been transformed to pure AMJ equivalents. The pure AKE containers have also been converted to pure AMJ equivalents.

$$\sum_{i\in I} \mu_i \sum_{j\in J} \gamma_{ijt}^b d_{ijt} \le s, \quad \forall t \in T-\sigma_{Max}, b \in K; \quad (4)$$

Condition to address the mixed container handling capacity in fully pure AMJ equivalents at the hub is expressed in Eq. (4). However, it should be noted that this constraint excludes the handling of pure containers, for less effort is needed than for handling mixed containers using other types of equipment. This expression should be modified if pure containers are incorporated.

$$(x_{ijt}^b / v_b) d_{ijt} \le z_{ij}^b, \ \forall i, j \in I, J, \ \forall b \in K, \forall t \in T\text{-}\sigma_{Max}; \quad (5)$$

The number of pure containers needed for holding the pure container volume, is formulated in (5).

$$\sum_{j\in J} z_{ij}^b \le p_b, \ \forall i \in I, \ \forall b \in K; \quad (6)$$

In Eq. (6), it is shown that the number of pure AMJ and AKE containers to be moved (if any) from each origin to the hub cannot exceed the AMJ and AKE container aircraft loading capacity

$$\sum_{j\in J}\sum_{b\in K} v_b z_{ij}^b + \sum_{j\in J} y_{ijt} d_{ijt} \le \sum_{b\in K} v_b p_b, \ \forall i \in I, \forall t \in T\text{-}\sigma_{Max}; \quad (7)$$

The requirement to meet the aircraft loading capacity, particularly in AMJ equivalent, due to the movement of container from each origin to the hub, is expressed in (7)

$$\sum_{i\in I} z_{ij}^b \le p_b, \ \forall j \in J, \ \forall b \in K; \quad (8)$$

Constraints (8) present the aircraft capacity constraint for pure AMJ and AKE containers, respectively, from the hub to each destination gateway. It should be noted that any remaining capacity on the upper/lower deck of the aircraft can be filled with mixed AMJ/AKE containers.

$$\sum_{i\in I}\sum_{b\in K} v_b z_{ij}^b + \sum_{i\in I} y_{ijt} d_{ijt} \le \sum_b v_b p_b, \ \forall j \in J, \forall t \in T\text{-}\sigma_{Max}; \quad (9)$$

Another requirement for aircraft loading capacity, due to the movement of a number of containers (in AMJ equivalents) from the hub to each destination.

$$\sum_{b\in K} x_{ijt}^b + y_{ijt} \le 1, \ \forall i, j \in I, J, \forall t \in T\text{-}\sigma_{Max}; \quad (10)$$

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Constraints (10) present the fraction of each node's demand to be loaded into pure and mixed containers is less than or equal to one in time period T-σ_{Max}.

$$0 \le x_{ijt}^{b} \le 1,\ \forall i, j \in I, J,\ \ \forall b \in K, \forall t \in T\text{-}\sigma_{Max}; \qquad (11)$$

Constraints (11) are needed to make sure that the fraction of each node's demand in time period T-σ_{Max} to be loaded into pure AMJ or AKE containers is non-negative.

$$0 \le y_{ijt} \le 1,\ \forall i, j \in I, J; \forall t \in T\text{-}\sigma_{Max}; \qquad (12)$$

Constraints (12) states that the fraction of each demand from node I to node j in time period T-σ_{Max} to be loaded into mixed containers should be real numbers between 0 and 1..

$$w_{ij} \ge 0,\ \forall i \in I, \forall j \in J; \qquad (13)$$

The AMJ equivalent container volume transported by a third party for each node demand should be non-negative.

$$z_{ij}^{b} \ge 0,\ z_{ij}^{b} \in Z,\ \forall i \in I, \forall j \in J,\ \ \forall b \in k; \qquad (14)$$

Constraints (14) ensure that, the number of pure AMJ or AKE containers transported for each demand's node is a non-negative integer.

IV. THE ALGORITHM

Stage 1.

Step 1. Get row i^* the smallest integer infeasibility, such that $\delta_{i^*} = \min\{f_i, 1 - f_i\}$ This step is to obtain minimum deteriroation of the objective function.

Step 2. Do a pricing operation

$$v_{i^*}^T = e_{i^*}^T B^{-1}$$

Step 3. Calculate $\sigma_{ij} = v_{i^*}^T a_j$

With j corresponds to

$$\min_j \left\{ \left| \frac{d_j}{\sigma_{ij}} \right| \right\}$$

I. *For nonbasic j at lower bound*

If $\sigma_{ij} < 0$ and $\delta_{i^*} = f_i$ calculate $\Delta = \frac{(1-\delta_{i^*})}{-\sigma_{ij}}$

If $\sigma_{ij} > 0$ and $\delta_{i^*} = 1 - f_i$ calculate $\Delta = \frac{(1-\delta_{i^*})}{\sigma_{ij}}$

If $\sigma_{ij} < 0$ and $\delta_{i^*} = 1 - f_i$ calculate $\Delta = \frac{\delta_{i^*}}{-\sigma_{ij}}$

If $\sigma_{ij} > 0$ and $\delta_{i^*} = f_i$ calculate $\Delta = \frac{\delta_{i^*}}{\sigma_{ij}}$

II. *For nonbasic j at upper bound*

If $\sigma_{ij} < 0$ and $\delta_{i^*} = 1 - f_i$ calculate $\Delta = \frac{(1-\delta_{i^*})}{-\sigma_{ij}}$

If $\sigma_{ij} > 0$ and $\delta_{i^*} = f_i$ calculate $\Delta = \frac{(1-\delta_{i^*})}{\sigma_{ij}}$

If $\sigma_{ij} > 0$ and $\delta_{i^*} = 1 - f_i$ calculate $\Delta = \frac{\delta_{i^*}}{\sigma_{ij}}$

If $\sigma_{ij} < 0$ and $\delta_{i^*} = f_i$ calculate $\Delta = \frac{\delta_{i^*}}{-\sigma_{ij}}$

Otherwise go to next non-integer nonbasic or superbasic j (if available). Eventually the column j^* is to be increased form LB or decreased from UB. If none go to next i^*.

Step 4. Calculate

$$\alpha_{j^*} = B^{-1} \alpha_{j^*}$$

i.e. solve $B\alpha_{j^*} = \alpha_{j^*}$ for α_{j^*}

Step 5. Ratio test; there would be three possibilities for the basic variables in order to stay feasible due to the releasing of nonbasic j^* from its bounds.

If j^* lower bound

Let

$$A = \min_{i' \neq i^* | \alpha_{ij^*} > 0} \left\{ \frac{x_{B_{i'}} - l_{i'}}{\alpha_{ij^*}} \right\}$$

$$B = \min_{i' \neq i^* | \alpha_{ij^*} < 0} \left\{ \frac{u_{i'} - x_{B_{i'}}}{-\alpha_{ij^*}} \right\}$$

$$C = \Delta$$

the maximum movement of j^* depends on: $\theta^* = \min(A, B, C)$

If j^* upper bound

Let

$$A' = \min_{i' \neq i^* | \alpha_{ij^*} < 0} \left\{ \frac{x_{B_{i'}} - l_{i'}}{\alpha_{ij^*}} \right\}$$

$$B' = \min_{i' \neq i^* | \alpha_{ij^*} > 0} \left\{ \frac{u_{i'} - x_{B_{i'}}}{-\alpha_{ij^*}} \right\}$$

$$C' = \Delta$$

The maximum movement of j^* depends on: $\theta^* = \min(A', B', C')$

Step 6. Exchanging basis for the three possibilities

1. If A or A'
   - $x_{B_{i'}}$ becomes nonbasic at lower bound $l_{i'}$
   - x_{j^*} becomes basic (replaces $x_{B_{i'}}$)
   - x_{i^*} stays basic (non-integer)
2. If B or B'
   - $x_{B_{i'}}$ becomes nonbasic at upper bound $u_{i'}$
   - x_{j^*} becomes basic (replaces $x_{B_{i'}}$)
   - x_{i^*} stays basic (non-integer)
3. If C or C'
   - x_{j^*} becomes basic (replaces x_{i^*})
   - x_{i^*} becomes superbasic at integer-valued

Step 7. If row $i^* = \{\emptyset\}$ go to Stage 2, otherwise

Repeat from step 1.

Stage 2. Do integer lines search to improve the integer feasible solution

V. CONCLUSIONS

In order to be competitive globally an international air express carrier should have a good cargo container loading plan.To design a good cargo container loading plan, a carrier has to consider not only the airport operating cost, but also the market demand in actual operations. In this paper we develop a deterministic-demand cargo container loading plan model that can resolve daily demands occurring in practice. The objective is to minimize the total handling cost, subject to the related operating constraints. The model is formulated as a mixed integer program that is characterized as NP-hard in terms of optimization. We use a feasible direct search approach to solve the problem. The model and the solution method are expected to be useful planning tools for air express carriers to decide on their container loading plans, in order to lower their operating costs, enhancing profits and market competitiveness.

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