Multiobjective Model of Empty Container Repositioning of Sea Carriage

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ABSTRACT

An multiobjective model for empty container repositioning of sea carriage is established. The first objective is to minimize the cost of empty container repositioning including shipping, renting and shortage cost. The second objective is to minimize the shortage number of empty containers. In the model, shipping cost is decided by the number of ship used for empty container repositioning. The constraints to the model include meeting the need of empty containers, limit to the ability of empty containers provided and the capacity of shipping. Lingo9.0 is used to solve the model and simulation is done under varied parameters to get a good shipping strategy. The results show that the model can provide an effective program of empty container repositioning for a shipping company and it is a good way to raise shipping efficiency.1

KEYWORDS

Empty container; line; stochastic programming; simulation.

INTRODUCTION

Container shipping of sea carriage plays a very important role in international trade, especially with China’s entry into WTO and the development of world trade. But empty container repositioning which produce only cost has increased rapidly with the development of container shipping.

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Many scholars did much research in the subject. Shi X used integer programming to study empty container repositioning on sea-bound, and he did simulation to analyse the influence of cost and income on Strategy of repositioning in [1]. Liu H.J and Shi X built the model of empty container repositioning based on Petri net and did simulation by the use of EXSPECT in [2]. Zhao D.Z and Huang J constructed model of empty container repositioning of sea-carriage and land-carriage with aim of cost minimized in [3]. Wu Z.Y, Song T.S and Zhao K discussed the optimization of container of sea-carriage in [4].

MATHEMATICAL MODEL

Parameters

\[ T : \text{Set of planning period. } T = \{1,2,\cdots,t,\cdots\}\text{. That is to say, } T \text{ is composed of all time periods.} \]
\[ L : \text{Set of lines.} \]
\[ OL : \text{The origination of line } l \text{. } (l \in L) \]
\[ S_t : \text{The set of ports supplying empty containers during } t \text{. } (t \in T) \]
\[ S^t_i : \text{The number of empty containers provided from port } i \text{ during } t \text{. } (i \in S_t, t \in T) \]
\[ D_t : \text{The set of ports requiring empty containers during } t \text{. } (t \in T) \]
\[ D^t_j : \text{The number of empty containers required from port } j \text{ during } t \text{. } (j \in D_t, t \in T) \]
\[ Slt : \text{The set of ships which can be used in empty container repositioning of line } l \text{ during } t \text{. Every ship } P^{slt} : \text{The load capacity of empty containers of ship } s \text{. } (slt \in Slt) \]
\[ P^{slt} : \text{The load capacity of empty containers of ship } s \text{. } (slt \in Slt) \]
\[ t^l_{ij} : \text{The shipping time from port } i \text{ to port } j \text{ by line } l \text{. } (i, j \in T, l \in L) \]
\[ C : \text{Cost of a ship used for empty containers repositioning.} \]
\[ C^rt_j : \text{Cost caused by an empty container rented from port } j \text{ during } t \text{.} \]
\[ C^{st}_j : \text{Cost caused by shortage of an empty container from port } j \text{ during } t \text{.} \]
Variables

\( y_{st}^{il} = 1 \) means that ship \( s \) is used in empty container repositioning by line \( l \) during \( t \). Otherwise \( y_{st}^{il} = 0. \)

\( x_{ij}^{lt} \): The number of empty containers shipped from port \( i \) to port \( j \) by ship \( s \) during \( t \). The empty containers are started from port \( i \) during \( t_1 \) and arrive at port \( j \) no later than port \( j \). Ship \( s \) sets off from \( O_l \) during \( t \) by line \( l \) and arrive at \( j \) during \( t_1 \) and \( t_2 \) respectively. \( (i \in S_i, j \in D_j, s \in Slt, l \in L, t_1, t_2, t \in T) \)

\( x_{jt}^{rt} \): The number of empty containers rented from port \( j \) during \( t \). \( (j \in D_j, t \in T) \)

\( x_{jt}^{jt} \): The number of shortage of empty containers in port \( j \) during \( t \). \( (j \in D_j, t \in T) \)

Objective Function

\[
\begin{align*}
\text{Min} & \quad \sum_{t \in T} \sum_{j \in D_j} x_{jt}^{jt} \\
\text{Min} & \quad \sum_{i \in T} \sum_{l \in L} \sum_{s \in Slt} C_{yi}^{ils} + \sum_{l \in L} \sum_{j \in D_j} C_{jt}^{rt} x_{jt}^{jt} + \sum_{i \in T} \sum_{j \in D_j} C_{ij}^{st} x_{ij}^{st} 
\end{align*}
\]

Turn multiobjective function into a linear programming.

\[
\begin{align*}
\text{Max} & \quad \lambda_1(1) + \lambda_2(2)
\end{align*}
\]

Constraints

\[
\begin{align*}
\sum_{t \in T} \sum_{l \in L} \sum_{s \in Slt} \sum_{i \in S_i} x_{ij}^{lt} + \sum_{t \in T} \sum_{j \in D_j} x_{jt}^{jt} = D_j^{t_2} \\
\sum_{t \in T} \sum_{l \in L} \sum_{s \in Slt} \sum_{i \in S_i} x_{ij}^{lt} + \sum_{t \in T} \sum_{j \in D_j} x_{jt}^{jt} = D_j^{t_2} \\
\sum_{t \in T} \sum_{l \in L} \sum_{s \in Slt} \sum_{i \in S_i} x_{ij}^{lt} \leq S_i^{t_2} + W_i^{t_2} \\
S_i^{t_2+1} = S_i^{t_2} - \sum_{t \in T} \sum_{l \in L} \sum_{s \in Slt} \sum_{j \in D_j} \sum_{t_3 \in T} x_{ij}^{lt} + W_i^{t_2+1}
\end{align*}
\]
\[
\sum_{t_i \in I} \sum_{t_j \in T} \sum_{t \in S_{lt}} \sum_{t \in D_{t_2}} x^{slt}_{i j} t_2 \leq y^{slt} \cdot p^{slt} \tag{7}
\]

\[
l \in L, t \in T, \sum_{t \in S_{lt}} y^{slt} \leq |S_{lt}| \tag{8}
\]

\[x^{slt}_{i j}, x^{R_{j} \ast}, x^{S_{j}} \] are non-negative integers and \[y^{slt} \] is 0-1 negative integers.

**NUMERICAL EXAMPLES**

The net of lines is described in Fig. 1.

![Figure 1. Net of lines.](image)

Line \[l_1: 1-3-5-7, l_2: 2-4-5-7, l_3: 2-4-5-6-8, l_4: 2-4-5-6-7 \] and \[l_5: 1-3-5-7-6-8. \] \[P^{slt} = 4 (slt \in S_{lt}), T = \{t_1, \ldots, t_5\} \] Every time period has 3 days , That is to say, \[t_1 = \{1,2,3\}, t_2 = \{4,5,6\}, t_3 = \{7,8,9\}, t_4 = \{10,11,12\}, t_5 = \{13,14,15\}, |S_{lt}| = 2, (l = 1, \ldots, 5, t = t_1, \ldots, t_5) \] \[P^{slt_1} = 230\text{TEU}, P^{slt_2} = 220\text{TEU}, P^{slt_3} = 231\text{TEU}, P^{slt_4} = 200\text{TEU}, P^{slt_5} = 195\text{TEU}, P^{slt_6} = 230\text{TEU}, P^{slt_7} = 205\text{TEU}, P^{slt_8} = 210\text{TEU}, P^{slt_9} = 209\text{TEU}. \] The renting cost and shortage cost of ports that need empty containers are shown below.

\[C^{R_{l_1}} = 5, C^{R_{l_2}} = 6, C^{R_{l_3}} = 9, C^{R_{l_4}} = 7, C^{R_{l_5}} = 18, C^{S_{l_1}} = 22, C^{S_{l_2}} = 23, C^{S_{l_3}} = 13, i = 1,2,3,4 S_{l_i} = 500, i = 1,2,3,4,5 w_{l_i} = 20, \lambda_1 = 0.7, \lambda_2 = 0.3. \]

The solving result are below: \[y^{slt_1} = 1, y^{slt_2} = 0, y^{slt_3} = 1, y^{slt_4} = 0, \] others is zero. The first objective function is 1750yuan, The second objective function is 23TEU.
REFERENCES