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Empty Container Dispatching Inventory Model in Fuzzy Environment

Sheng-Long Kao, Chien-Min Su, Meng-Ru Tu, Cheng-Hao Lin

ABSTRACT – As the development of global trade becomes saturated, the income of enterprises gradually changes from open source to throttling. In this paper, we use a method to calculate the cost of dispatching containers for each port due to trade inequality, and add a fuzzy theory that is more in line with the actual situation. Generally, when estimating costs, it is assumed that the cost is fixed, but in fact we cannot guarantee the stability of the cost. In the model building, there are three main costs: holding cost, ordering cost and leasing cost. By assuming fuzzy holding cost and leasing cost, then defuzzifying, estimating the total cost under fuzzy semantics, and using Matlab R2014b to calculate the results of the hypothesis model.

Index Terms—Fuzzy theory, trade inequality, empty container dispatching

I. INTRODUCTION

Affected by globalization, the prevalence of international trade, container transportation has become an indispensable part of the logistics system. Trade inequality is a problem caused by the difference in import and export. A huge trade surplus will lead to the lack of port in the port. In order to effectively save the cost of container scheduling, Won Young Yun et al. (2011) considered the peak season. The difference, and according to the status of different inventory levels, judge whether to order or lease the container, and based on the difference between the cost and the lead time, establish a complete cost estimation model, and finally use the program to analyze and discuss the value.

Yang M.F. (2006) calculates the integrated inventory model and makes fuzzy assumptions about demand and productivity respectively. In the process of fuzzification and defuzzification, it describes each step in detail and uses the reduced distance method to estimate the total cost. Numerical analysis explores the relationship of variables. Yang M.F. et al. (2010) built a two-echelon inventory model for fuzzy demand in a supply chain, while at the same time took approach with mutual beneficial pricing. According to previous researches, fuzzy is often used in the calculation of demand in order to generate results that fit better to the reality. Pranab Biswas and Surapati Pramanik (2011) propose a multi-objective allocation problem with fuzzy costs, in which all targets are simultaneously minimized. Here each fuzzy cost is assumed to be a trapezoidal fuzzy number. Yager's ranking has been used to transform the newly formed single-objective fuzzy assignment problem into a clear assignment problem in the form of linear programming problems. Gomathi, M. and G. Rajendran (2012) proposed the selection of best paths in Mobile Ad Hoc Network (MANET) based on multipath routing with fuzzy cost in respect of the Fuzzy Cost Enabled Cluster based Routing (FCECR), it is shown PK De et al. (2012) discusses the conventional and fuzzy allocation problems, and proposes a method to solve the fuzzy allocation problem, in which the cost is inaccurate. digital. The element of the cost matrix of the assignment problem is a triangular fuzzy number whose triangle membership function is defined. Using this method, the optimal solution of the fuzzy assignment problem is successfully obtained.

Ali Ebrahimnejad (2013) prove that in the absence of degeneracy these frizzy methods stop in a finite numbers of iterations and the fundamental theorem of linear programming in a crisp environment to a fuzzy one. Finally, illustrated the proof by use of a numerical example. G. Santhi and Alamelu Nachiappan (2013) proposed a QoS (Quality of Service) route algorithm that uses fuzzy logic to consider multiple independent QoS metrics to select the optimal path. All available resources of the path are converted into a single metric. Blur costs and explore the performance comparison of different approaches to network routes. P. Parvathi and D. Chitra (2013) consider the interests of buyers and sellers and the combined total profit to find the optimal order quantity, sales price and shipping policy. The productivity of the buyers and sellers, the quantity of orders, the shortage and the cost of holding are regarded as triangles. Fuzzy numbers and defuzzification for numerical analysis. Y. Long et al. (2013) developed a tool that takes into account the actual conditions and limitations of the operator and helps to effectively manage the repositioning of the empty containers at sea. Lin Xudong et al. (2014) based on the principle of activity cost accounting, studied the problem of economic order quantity under quantity discount, proposed an inventory cost control model with loss rate and quantity discount and fuzzy

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parameters, and finally solved the inventory problem by numerical analysis. feasibility.

JK Dash and Anuradha Sahoo (2015) introduced the optimization of the single-period inventory problem (SPIP), considering the demand as a fuzzy random variable, the purchase cost is regarded as a fuzzy number, and the optimal order quantity is obtained through the concept of Buckley fuzzy number minimization. And expected profits. Ali Bozorgi et al. (2015) found that the Unit Maintenance Program (UMS) has a significant impact on company profitability. Based on the fuzzy framework, the uncertainty of load and production cost factors is modeled. The data analysis shows the effectiveness of UMS. S.Vimala and S.Krishna Prabha (2015) minimize the cost of fuzzy allocation problems by using fuzzy numbers. Each fuzzy cost is considered as a triangular fuzzy number, and the fuzzy assignment problem is transformed into a clear value by using semantic variables. The optimistic index is used to reflect the optimistic attitude of the decision maker and the modal index indicating the neutrality of the decision maker. David A. Wood (2016) provides deterministic, fuzzy and stochastic analysis of the cost-term schedule of complex projects under high-level, uncertain conditions, enabling decision makers to plan and monitor infrastructure and other complex projects. Sang-Wha Seo (2017) proposed a T-S fuzzy method to select the finite control set model to predict the cost function weight of the DC-DC converter control algorithm. The state or input variable with an excessively large value can be penalized by increasing the weight corresponding to the variable; the optimal control input is determined by online optimization of the T-S fuzzy cost function for all possible control input sequences.

Through the addition of fuzzy theory, the container dispatching model added the changes occurred in fuzzy cost. The decision makers set the cost range by considering the actual environment and current situation in order for the estimation model to calculate the total cost more accurately. To discuss how upper and lower bound affects the total cost, software is used to calculate results and perform sensitive analyses.

II. Model Formulation

With reference to the empty container dispatching model, depending on the differences in different periods, the demand changes and the difference between the inventory limit and the reorder point will be generated. Using the previous data, the inventory at the beginning of the current period can be calculated, and the current inventory level can be got through the addition of the ordering and leasing policies in this model, which is used to calculate the current order cost. Finally, the lease method is used to make up the lacking container quantity. In the cost of holding and the cost of leasing, the change of the triangular fuzzy number is added, which allows the decision maker to set the value in line with the current situation and add up the three costs to get the estimated total cost.

A. Ordering and leasing policy

When the inventory level of the container is below the low bound (reorder point), the container is dispatched by ordering, but the goods have a lead time from order to delivery. In this paper, it is assumed that in order to order containers in the i^{th} period, four periods of lead time are required, and the goods will be delivered in the i+4 period.

In the case of urgently needed containers, it is not possible to order containers to meet our immediate needs. Therefore, through the way of container leasing, the number of containers missing can be fully compensated, but the cost is higher than that of the ordering containers. Since it is a rental container, there is also the problem that the container needs to be returned. In this paper, it is assumed that in the i^{th} term lease of containers, the required quantity can be obtained immediately, but after the fourth period, the goods need to be returned in the i+4 period.

B. Assumption

(1) Only consider the same type of container.
(2) Demand increases or decreases according to the season.
(3) After (i+4) periods, leasing containers need to be returned.
(4) The lead time of the leasing container is 0.
(5) The lead time of ordering containers is stable for 4 periods.

C. Notation

S_1 Highest inventory level in low demand season.
s_1 Reorder point in low demand season.
S_2 Highest inventory level in high demand season.
s_2 Reorder point in high demand season.
D_i Customer demand in the i^{th} period.
V_i The amount of containers returned from customer in the i^{th} period.
N_i Net inventory at the beginning of the i^{th} period.
H_i Inventory level in the i^{th} period.
I_i Inventory level in the lead time of i^{th} period.
O_i Order quantity in the i^{th} period.
L_i Lease in the i^{th} period.
C_n Inventory holding cost per unit.
C_f Fixed-ordering per unit.
C_o Ordering cost per unit.
C_l Leasing cost per unit.
TC_i Total cost of the i^{th} period

$\tilde{C}_n$ is a unit holding cost triangular fuzzy number, $\tilde{C}_n = (C_n - \Delta_1, C_n, C_n + \Delta_2), 0 < \Delta_1 < C_n, 0 < \Delta_2$, while Δ_1, Δ_2 is determined by the decision maker.

$\tilde{C}_l$ is a unit leasing cost triangular fuzzy number, $\tilde{C}_l = (C_l - \Delta_3, C_l, C_l + \Delta_4), 0 < \Delta_3 < C_l, 0 < \Delta_4$, while Δ_3, Δ_4 is determined by the decision maker.

D. Model process

The following figure demonstrates the model flow chart. From this diagram, the complete model flow can be understood clearly, including the judgment of the off-peak season, the statistics of the inventory level, the calculation of various costs, and the estimation of the total cost. At the same time, it's also the main reference for the establishment of the model.

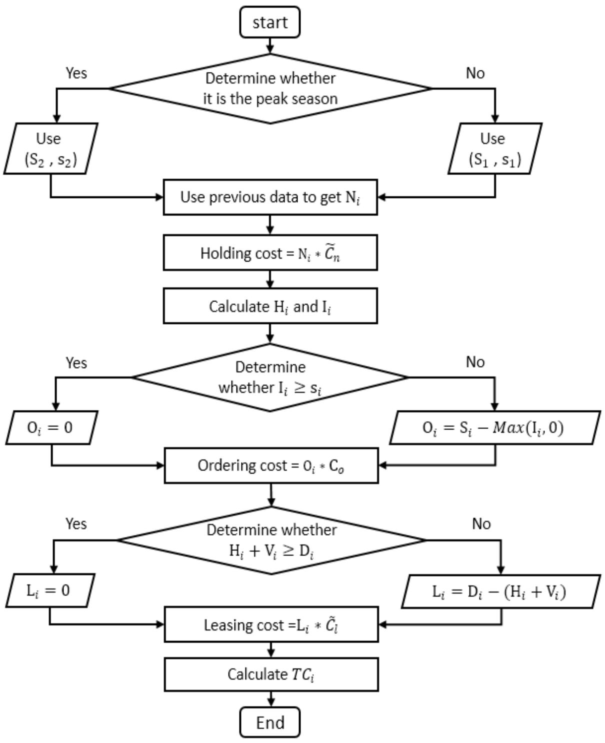

Fig.1. Flow chart for container dispatching model with fuzzy costs.

E. Model building

Choose (S_1,s_1) or (S_2,s_2) depending on the differences between peak-off season, according to the previous remaining stock as, the net stock at the beginning of the present period can be got:

$$N_i = H_{i-1} + V_{i-1} - D_{i-1} + L_{i-1} \tag{1}$$

Through the net stock at the beginning of the present period, the holding cost will be calculated:

$$NC_i = N_i * \tilde{C}_n \tag{2}$$

Through adding the order amount in period $(i-4)$(lead time) and subtracting the lease amount in period $(i-4)$(lead time), the current inventory level can be obtained:

$$H_i = N_i + O_{i-4} - L_{i-4} \tag{3}$$

Then,

$$I_i = H_i + \sum_{t=-3}^{0} O_{i+1} + \sum_{i=0}^{3} E[V_i] - \sum_{i=0}^{3} E[D_i] \tag{4}$$

Determine $(I_i \geq s)$, if $(I_i \geq s)$, ordering is not in need; if $(I_i < s)$, ordering will be replaced by $[S - MX(0,I_i)]$:

$$\begin{cases} O_i = 0 & while(I_i \geq s) \\ O_i = S - MX(0,I_i) & while(I_i < s) \end{cases} \tag{5}$$

Then,

$$OC_i = O_i * C_o \tag{6}$$

Determine $(H_i + V_i \geq D_i)$, if $(H_i + V_i \geq D_i)$, leasing is not in need; if $(H_i + V_i < D_i)$, leasing will be replaced by $[(D_i - (H_i + V_i)]$:

$$\begin{cases} L_i = 0 & while(H_i + V_i \geq D_i) \\ L_i = D_i - (H_i + V_i) & while(H_i + V_i < D_i) \end{cases} \tag{7}$$

Then,

$$LC_i = L_i * \tilde{C}_l \tag{8}$$

Finally, the total cost of the dispatching container can be obtained by taking NC_i, OC_i, and LC_i and add them together:

$$TC_i = NC_i + OC_i + LC_i \tag{9}$$

Definition 1. According to George and Yuan (1995), for a fuzzy set $\tilde{C} \in \Omega$ and $\alpha \in [0,1]$, α-cut of this $\tilde{C}$ set is $B(\alpha) = \{x \in \Omega \mid \mu_B(x) \geq \alpha\} = [B_L(\alpha), B_U(\alpha)]$, where $B_L(\alpha) = a + (b-a)$ and $B_U(\alpha) = c - (c-b)a$.

$$\tilde{C} = \frac{\int_{-\infty}^{0} x\mu_B(x)dx}{\int_{-\infty}^{0} \mu_B(x)dx} = \frac{1}{3}(2b + a + c) \tag{10}$$

Gravity method is used to the defuzzication of TC_i

$$\begin{aligned} \tilde{C} = d(\tilde{C},\tilde{0}_1) &= \frac{1}{3}[(C - \Delta_1) + 2C + (C + \Delta_2)] \\ &= C + \frac{1}{3}(\Delta_2 - \Delta_1) \end{aligned} \tag{11}$$

Then,

$$\begin{cases} \tilde{C}_n = C_n + \frac{1}{3}(\Delta_2 - \Delta_1) \\ \tilde{C}_l = C_l + \frac{1}{3}(\Delta_4 - \Delta_3) \end{cases} \tag{12}$$

Use the above formula to replace the original equation：

$$NC_i = N_i * \left[C_1 + \frac{1}{3}(\Delta_2 - \Delta_1)\right] \tag{13}$$

Then,

$$LC_i = L_i * [C_l + \frac{1}{3}(\Delta_4 - \Delta_3)] \tag{14}$$

Then,

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$$TC_i = N_i * \left[C_1 + \frac{1}{3}(\Delta_2 - \Delta_1)\right] + OC_i$$

$$+L_i * [C_i + \frac{1}{3}(\Delta_4 - \Delta_3)] \quad (15)$$

III. Numerical Analysis

The calculation for the numerical analysis uses Matlab R2014b; the 500[th] period is used as a reference for analyzing. Data assumptions for D_i, V_i, S_i, s_i and various costs factors (holding costs per unit, ordering cost per unit, fixed-ordering costs and leasing costs) in the off-peak season are made in TABLE I and TABLE II; while TABLE III does sensitivity analysis for changes in Δ.

TABLE I
D_i AND V_i IN HIGH OR LOW DEMAND

D_i in high demand season	D_i in low demand season	V_i in high demand season	V_i in high demand season
300	200	220	150

TABLE II
S_i, s_i AND VARIOUS COSTS FACTORS

S_1	s_1	S_2	s_2	Holding costs per unit	Ordering costs per unit	Fixed-ordering costs	Leasing costs per unit
90	40	130	60	2000	4000	50000	12000

TABLE III
NUMERICAL EXAMPLE RESULTS

Δ_1	Δ_2	Δ_3	Δ_4	$\tilde{D}_{i-1}$	$\tilde{D}_i$	TC_i
200	400	1000	500	2066.7	11833.3	576677.8
			1000	2066.7	12000	583333.3
			1500	2066.7	12167.8	590000
		2000	1000	2066.7	11667.8	570000
			2000	2066.7	12000	583333.3
			3000	2066.7	12333.3	596677.8
		4000	2500	2066.7	11500	563333.3
			4000	2066.7	12000	583333.3
			5500	2066.7	12500	603333.3
400	400	1000	500	2000	11833.3	573333.3
			1000	2000	12000	580000
			1500	2000	12167.8	586666.7
		2000	1000	2000	11667.8	566666.7
			2000	2000	12000	580000
			3000	2000	12333.3	593333.3
		4000	2500	2000	11500	560000
			4000	2000	12000	580000
			5500	2000	12500	600000
400	200	1000	500	1933.3	11833.3	570000
			1000	1933.3	12000	576677.8
			1500	1933.3	12167.8	583333.3
		2000	1000	1933.3	11667.8	563333.3
			2000	1933.3	12000	576677.8
			3000	1933.3	12333.3	590000
		4000	2500	1933.3	11500	556677.8
			4000	1933.3	12000	576677.8
			5500	1933.3	12500	596677.8

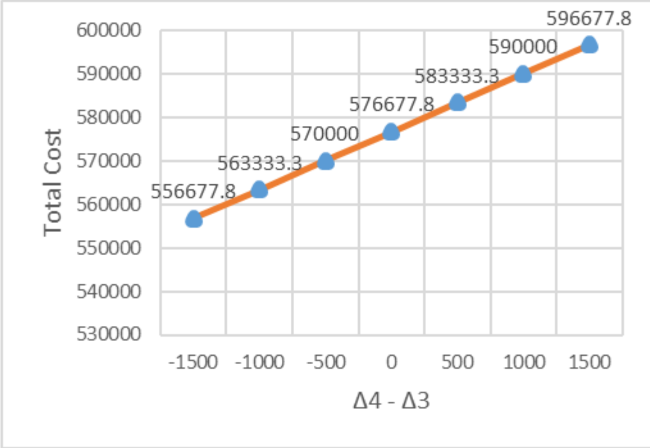

Fig.2. The effect on TC while $\Delta_4 - \Delta_3$ increases.

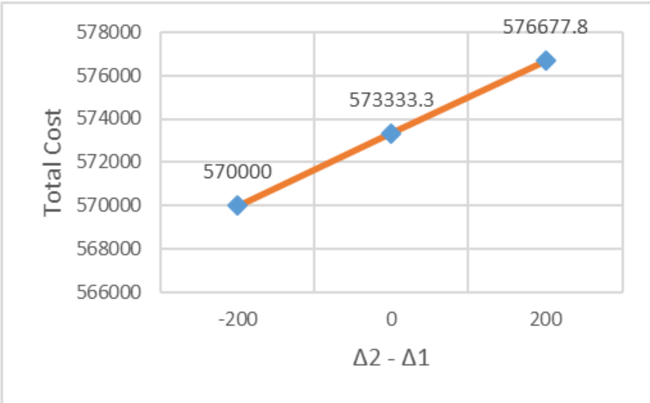

Fig.3. The effect on TC while $\Delta_2 - \Delta_1$ increases.

(1) While Δ_1,Δ_2,Δ_3 is stable; when Δ_4 increases, $\tilde{D}_i$ will increase along with Total Cost.
(2) While Δ_3 and Δ_4 is the same; when $\Delta_2 - \Delta_1$ decreases, $\tilde{D}_{i-1}$ will decrease along with Total Cost.
(3) The minimum of Total Cost will be obtain while $\Delta_1 > \Delta_2$ and $\Delta_3 > \Delta_4$ according to the numerical results.

IV. Conclusion

In the maritime market approaching saturation, the vicious price-cutting competition between the two sides has led to the deteriorating development of the maritime industry. How to effectively control the cost of expenditure is one of the keys to truly help the current maritime industry. In this research, by simulating the model of container dispatching cost, the cost triangle fuzzy number is added; and the cost can be changed by the decision maker according to the current situation, which allow the result to be more in line with the actual changes.

In the numerical analysis, software is used to calculate the expected cost value, and the sensitivity analysis is performed by the example data. The results indicated that the lower the lower limit (Δ_1, Δ_3), the lower the overhead cost. Future research is aiming to add more real-world situations and conditions in order to create a model that will be more suitable for use in the system.

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