Profits comparison between alliance mode and non-alliance mode of empty containers repositioning of liner companies

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ABSTRACT

Alliance and non-alliance modes are the typical decision-making problem of strategy layer. Upper layer decision will have direct impact on the lower two layers: tactical layer and operational layer. Empty container repositioning mechanism must be keep synchronous operation according to the upper two layers. To quantitative analyse the impact of two modes of strategy layer, we have built the optimization models of empty containers repositioning according to the actual business flow. Two simulation cases have been designed to solve the models. The experimental data show that under alliance it can reduce various costs dramatically and improve the profits contrast to the non-alliance. The results validate the proposed standpoint: alliance mode is feasible for different company sizes. All companies in consolidation can obtain win–win. Furthermore, the reduced various costs such as transportation cost also mean lower greenhouse gas emissions, which is importance to keep sustainable development for the earth.

1. Introduction

As the high handling efficiency, high safety and reducing costs, the container transportation mode is always popular from its emergence (Drewry, 2016). Containerization has been a key driver of modern economic globalization (Bernhofen, El-Sahli, & Kneller, 2016). For historical reasons, national policies and other complex factors, the world trades are not balanced in recent several decade years, especially in the mainline shipping routes which include the Trans-Pacific, Asia-Europe and transatlantic. According to the statistics of UNCTAD (2018) and UNCTAD (2017), take the Trans-Pacific as an example. It has shown that the containerized trade is about 18.7\% of whole sea trade in eastbound (East Asia-North American). But the reverse one (Westbound: North America-East Asia) only has 7.9\%. The UNCTAD forecasts that the containerized trades on this mainline shipping route are 19.5\% and 8.1\%, respectively, in 2018. The same situation has existed in other two mainline shipping routes. One of results caused by these is the unbalanced distribution of empty containers among the ports. Namely, it leads to some ports have backlogged many surplus empty containers meanwhile other ports need a lot of empty containers to meet the customers’ demands. Where the former, we call it as surplus ports, may incur the storage costs. The latter, deficit ports, may lost the sales. As we have known, the empty containers only transport the air and do not generate any profit at all in actual business. So, it has to involve the repositioning with the laden containers transportation because of its role in order to reduce the corresponding fees of empty containers. So how to solve this imbalanced distribution of empty containers and reduce the cost are always the challenge problem.

In general, constrained with the scarce resources consisted of containers, vessels and other capital assets, it is not easy to efficiently and effectively dispatch the empty containers within one company. In addition, it is difficult to dealing with the fierce competition of the shipping industry for some certain company. The alliance or consolidation activity in liner shipping have evolved in recent years. Alliances of global carriers were restructured in 2017 to form three larger ones: 2M, the Ocean Alliance and ‘The’ Alliance. The details can refer to the (UNCTAD, 2018). It may release one signal that the alliance, which has become an important strategy to fortify the competitive market, is the general trend in shipping industry.

There has been many literatures related to empty containers repositioning (ECR) problem. Cheung and Chen (1998) model the ECR as a two-stage stochastic optimization model. Braeckers, Janssens, and Caris (2011) are focused on the empty container management problem at a regional level, where the details and opportunities...
for reducing empty container movements are also discussed. Dong, Xu, and Song (2013) classify the existing ECR policies into two aspects: origin-destination (OD)-based solutions and state-based dynamic rule. Aiming at different situations, they choose appropriate repositioning policies to tackle this problem. From inventory control-based model, there are many researches to give the solutions for ECR, such as Lee, Chew, and Luo (2011), Yun, Lee, and Choi (2011), and Song (2007b).

In addition, network flow models are also the important research streams. It often adopts mathematical programming to generate a set of arc-based matrices. The representative works mainly include as follows. To incorporate uncertainties in the operations model, Long, Lee, and Chew (2012) et al. adopt sample average approximation-based linear programming and formulate a two-stage stochastic programming model with random demand, supply, ship weight capacity, and ship space capacity. In view of disruption, DiFrancesco, Lai, and Zuddas (2013) et al. build the multi-scenario mixed-integer programming to solve the ECR. Comprehensive consideration of multiple factors consisting of multiple service routes, multiple deployed vessels, and multiple regular voyages, Song and Dong (2012) deal with the problem of joint cargo routing and ECR at the operational level for a shipping network. Khakbaz and Bhattacherjya (2014) review the maritime ECR literature in the fields of engineering, management, transport and logistics. Zhang, Ng, and Cheng (2014) analyse multi-period ECR with stochastic demand and lost sales. From supply chain perspective, Song and Dong (2015) published a survey on ECR. Chao and Chen (2015) build a time-space network to reposition reefer containers among major Asian ports. Zheng, Sun, and Gao (2015) construct a two-stage empty container coordination model among shipping carriers. Kuzmicz and Pesch (2018) consider the ECR optimization models of Eurasian intermodal transportation in the light of the Chinese One Belt One Road.

In recent decades years, the alliance or consolidation, through mergers and acquisitions has been gradually appear until it is formed in the container industry. The alliance mode can tackle the negative environment and losses experienced for the shipping trade. The main container shipping lines are estimated operating loss of $3.5 billion in 2016 (Lloyd’s Loading List, 2017). Key alliance in 2018 is the merge of several Japanese container ship operator groups to form Ocean Network Express and the planned merger of Orient Overseas Container Line with The China Ocean Shipping Company. Up to now, three shipping alliances: 2M, the Ocean Alliance, and ‘The’ Alliance, were formed in 2018. The more details can refer to UNCTAD (2018).

Because the alliance belongs to the adjustment of strategic layout, they will directly affect the various aspects of tactical layer and operation layer. The plan of ECR is one of the most immediate matter of the impact. The study of Notteboom, Parola, Satta, and Pallis (2017) presents the interplay between changes in the organizational routines of shipping lines as part of alliances, changes at the level of terminal operations and changes in port calling pattern. The literature of Parola, Satta, and Panayides (2015) focuses on the complex relationship between the terminal involvement of these alliance members and actual port calls, which is caused by the formation of strategy. Yang, Liu, and Shi (2011) have verified the stability of liner shipping alliances by applying core theory. They have draw a conclusion: the alliance’s stability is significantly related to the structure of member’s demands and joint-ships capacity. Moreover they also give many examples to describe the preference of different shipping companies in merge and acquisitions. Many works (Ryoo & Thanopoulou, 1999; Slack, Comtois, & Mccalla, 2002; Song & Panayides, 2002) research on the rationale for shipping lines to organize the alliances.

Although many studies exist, there is less research on the quantitative analysis of ECR under alliance and non-alliance modes. This study makes a good attempt to analyse the rationality for both two modes from this view. The main contributions include the following aspects:

1. To solve the ECR of shipping alliance, we have defined the collaboration degree of the alliance on the level of empty containers sharing. Comparing the optimization model of ECR based on alliance mode and non-alliance mode, it can be easy to obverse that for ECR the former has a great advantage than the latter from the experimental section in the paper.

2. This article is considered with the ECR coupled with the laden containers transportation simultaneously. The demands of these two typical containers must be met. The shipping space capacity first is used to load the laden containers. If the additional shipping space capacity still exists, the empty containers are loaded. Furthermore, we have set the vessel capacity to match the actual business.

3. For the previous research, they only consider the ECR on operational level. Here, we have broken through this boundary and extended it to the top level (namely, the strategic level). Dealing with the ECR problem based on strategy level and operational level, it can make the decision more reasonably and feasibly. Meanwhile it can also give the feedbacks to the strategic level decision. It quantitatively analyses and compares with the revenue and various costs.
under alliance and non-alliance modes. These can support the standpoint which the alliance mode can obtain win–win for all shipping companies.

The rest of this paper is given as follows. Problem description is given in Section 2. The detailed design of the proposed model is discussed in Section 3. Experimental results and analysis are demonstrated in Section 4. Conclusions and future work are presented in Section 5.

2. Problem description

In recent several years, through mergers & acquisitions and global alliance restructuring, the liner shipping industry experienced further consolidation. The basic situation has begun to emerge. At present, there are mainly three alliances consisting of 2M, the Ocean Alliance and ‘The’ Alliance. The alliance mode is the strategic layout, which will directly affect the tactical and operational mechanism. So the mechanism of ECR should be made accordingly to the actual requirements.

The fundamental reason of ECR problem is due to the trade imbalance. The imbalance exists in mainline shipping routes, such as Asia-Europe (A-E), Asia to North America (A-N) and Europe-North America (E-N). Besides the trade imbalance, there are other various factors to result in the empty containers movement including the repair costs in some certain ports, uncertainty demands or handling, etc. Since the factors influencing the ECR strategy are rather complex, here, we suppose that all models are subject to the following assumptions. For the liners shipping, the schedules of services are given and fixed. The liners, which affiliates to different liner companies are call at the same ports and about the same time. Regardless of the repair and scrap of containers, i.e. all of the containers are available. There is no limit on the number of leasing containers for each port in any moment. All the containers and demands are measured in TEUs. The inventory spaces of empty containers are unrestricted for each port in any moment. The transportation task of laden containers among ports should be met for all ports always. The demand empty containers must be satisfied for each port. Transportation costs among ports are proportional to their distances. In this paper we only solve the imbalance empty containers caused by the trade since other factors are not the root reasons.

Take Figure 1 as example, we describes the problem further. Suppose there are three companies: A, B and C in alliance. Before alliance, each shipping company has its laden transportation and ECR strategies, respectively. For company A, it has surplus empty containers in port1 and port3. The corresponding numbers are 10 and 30. But in port2 A needs to import or lease 10 empty containers. The leasing cost may be involved. Here, we use negative value to represent the deficit empty containers. The positive value the surplus ones. The surplus ports have to generate the stock cost. Basically, the whole cost will be high. After forming a alliance for these three companies, in the same ports for all the members, such as in port2, the total exporting empty containers only has 20 (80 – 50 – 10). The same thing exists in other two ports. Not only will they reduce the various costs and enhance the overall competition, but also it can decrease the emission of greenhouse gas and ensure sustainable development. It will have profound significance.

3. Optimization model of containers repositioning based on alliance and non-alliance

3.1. Parameters

To succinctly describe the models, the following notations are given to formulate the laden containers transportation and ECR problems.

- $ij$: port.
- $surP$: surplus port which can export the redundant empty containers to other deficit ports.
- $defP$: deficit port which needs to import the empty containers to meet the demands of customers.
- $k$: company belonging to the alliance, $k \in A, B, C$.
- $K$: the alliance company.
- $M$: the profit coefficient of laden containers.
- $N$: the cost coefficient of ECR.
- $Q$: the cost coefficient of laden containers transportation.
- $empty_{ik}$: number of empty container in port $i$ for company $k$.
- $empty_i$: number of empty container in port $i$ after alliance. Note: $empty_i = \sum_k empty_{ik}$.
- $lease_{ik}$: the leasing cost of each containers in port $i$ for company $k$.
- $lease_i$: the leasing cost of each containers in port $i$ for alliance $K$.
- $load_{ik}$: the loading cost of each containers in port $i$ for company $k$.
- $load_i$: the loading cost of unit containers in port $i$ for alliance $K$.
- $unload_{ik}$: the unloading cost of unit containers in port $i$ for company $k$.
- $unload_i$: the unloading cost of unit containers in port $i$ for alliance $K$.
- $stock_{ik}$: the inventory cost of unit containers in port $i$ for company $k$.
- $stock_i$: the inventory cost of unit containers in port $i$ for alliance $K$. 
laden_{ijk}: the number of transporting laden containers from \(i\) to \(j\) for company \(k\).

dis_{ij}: the distance between port \(i\) and \(j\).

In the following, according to two different situations: non-alliance and alliance modes, we construct the containers reposition optimization models as well as solving them.

### 3.2. Containers repositing optimization model under non-alliance mode

Based on the business flow of laden and empty containers transportation, it can be easy to give the decision variables and objective function as follows.

**decision variables:**

- \(\text{TransNum}_{ijk}\): the number of transport empty containers from \(i\) to \(j\) for company \(k\);
- \(s_{ik}\): the number of inventory empty containers in port \(i\) for company \(k\);
- \(l_{ik}\): the number of leasing empty containers in port \(i\) for company \(k\);

**objective function:**

\[
\text{maximize} \sum_{k} \sum_{i} \sum_{j} \text{laden}_{ijk} \times \text{dis}_{ij} \times M \\
- \sum_{k} \sum_{i} \sum_{j} \text{TransNum}_{ijk} \times (\text{dis}_{ij} \times N + \text{load}_{Cik}) \\
+ \text{unload}_{Cjk} - \sum_{k} \sum_{i} \sum_{j} \text{laden}_{ijk} \\
\times (\text{dis}_{ij} \times Q + \text{load}_{Cik} + \text{unload}_{Cjk}) \\
- \sum_{k} \sum_{i} s_{ik} \times \text{stock}_{Cik} - \sum_{k} l_{ik} \times \text{lease}_{Cik}; \quad (1)
\]

subject to

\[
\sum_{j} \text{TransNum}_{ijk} \leq \text{empty}_{ik}, \text{ for } i \in \text{surP}; \quad (2)
\]

\[
\sum_{j} \text{TransNum}_{ijk} \leq |\text{empty}_{ij}|, \text{ for } j \in \text{defP}; \quad (3)
\]

\[
\sum_{j} \text{TransNum}_{ijk} \leq 0, \text{ for } j \in \text{defP}; \quad (4)
\]

\[
\sum_{j} \text{TransNum}_{ij} + s_{i} = \text{empty}_{i}, \text{ for } i \in \text{surP}; \quad (5)
\]

\[
\sum_{i} \text{TransNum}_{ijk} + l_{ik} = |\text{empty}_{ij}|, \text{ for } j \in \text{defP}; \quad (6)
\]

The objective function describe the net profit which is equal to the whole profit minus the total costs. The former is the laden container fees. The latter consists of transportation cost of laden and empty containers, leasing cost and inventory cost. Where the first constraint (2) represents that the exporting number of empty containers of each surplus port does not exceed it supply ones. The left-hand side of less-than sign indicates the total exporting empty containers of port \(i\). The right-hand side describes...
the surplus empty containers of port \( i \). The second constraint \((3)\) describes that the importing number of empty containers of each deficit port should be less than or equal to its requested ones. The left-hand side of less-than sign gives the total importing empty containers of port \( j \). The right-hand side declares the demand empty containers of port \( j \). Since we use the negative value to represent the deficit state, here the right part should include the absolute sign. The constraint \((4)\) ensures that the deficit ports cannot transport the empty containers to other ports. The left-hand side of less-than sign explains that for port \( i \) exporting empty containers should be less than and equal to zero because it is deficit port. Otherwise it may make against the actual business. The fourth constraint \((5)\) indicates that for one certain surplus port its exporting number plus stock number equals to its additional empty containers. The first item of left-hand side gives the total exporting empty containers. The second item of left-hand side is the number of stock empty containers. The right-hand side of less-than sign is surplus empty containers of port \( i \). Basically, the constraints under alliance mode have the same function like constraints \((2)–(6)\). The minor distinguish is to integrate the empty container of all companies in the same port. As shown in Figure 1, after organizing the alliance, the state of port 1 is deficit port because the final number result of empty containers is \(-60\) \((10 - 20 - 50)\). The corresponding various costs are the same as non-alliance mode.

4. Experimental results and analysis

To evaluate above two models, some simulated experiments are designed to conduct in this section. To distinguish the different cases, balance factor (BF) has been defined.

**Definition 1. Balance factor (BF):** it represents the factor between deficit empty container and surplus empty containers of port.

### 4.1. Dataset1

Aiming at the different cases of empty containers distribution for alliance and non-alliance, simulated data are employed to analyse the corresponding strategies using the BF. When BF is larger, small and equal to 1 for alliance mode, three datasets have been randomly generated as Table 1.

### 4.2. The whole profit and various costs under two modes

The profits, whole costs and various costs under different datasets have been shown in Tables 2 and 3. Shown as Table 2, for three datasets the whole costs are decreased substantially for alliance mode. The profits of alliance

\[
\text{maximize} \quad \sum_i \sum_j \text{laden}_{ij} \times \text{dis}_{ij} \times M - \sum_i \sum_j \text{TransNum}_{ij} \times (\text{dis}_{ij} \times N + \text{load}_{Ci}) + \sum_i \sum_j \text{laden}_{ij} - \sum_i \sum_j \text{stock}_{Ci} - \sum_i \text{lease}_{Ci};
\]

\[
\begin{align*}
\sum_j \text{TransNum}_{ij} & \leq \text{empty}_i, \text{for } i \in \text{surP}; \\
\sum_i \text{TransNum}_{ij} & \leq \text{|empty}_j|, \text{for } j \in \text{defP}; \\
\sum_j \text{TransNum}_{ij} & \leq 0, \text{for } i \in \text{defP}; \\
\sum_i \text{TransNum}_{ij} + s_i & = \text{empty}_i, \text{for } i \in \text{surP}; \\
\sum_i \text{TransNum}_{ij} + l_i & = |\text{empty}_j|, \text{for } j \in \text{defP};
\end{align*}
\]
mode always greatly stay ahead of the ones of non-alliance. For example, the whole cost only has 178,120 under alliance mode for DS11, while the corresponding one of non-alliance is up to 734,440. Specially, it is easy to find that for company B, its profit is negative value. If it keeps going, it will be very dangerous in fierce competition of shipping industry. But the profit is positive value for alliance mode. The B may be get some profit according to its contribution to the alliance. So it is necessary to consolidate with other companies for this kind of company just like B.

In Table 3, the details of various cost are given. For DS11, the inventory cost of non-alliance are about 15,000. But for alliance it is zero. The primary cause dues to that this case belongs to the \( BF = 1 \). For each company of non-alliance, it has to dispatch its empty containers needs to be stocked than other two cases: \( BF = 1 \).

Although this cost of alliance is larger than the one of non-alliance, the other costs of former are lower than the ones of latter. And it makes the total cost is much less than the others. It also expounds the importance of the alliance from another angle.

### 4.3. Dataset2

To assess the impact of company size on the alliance or non-alliance, we have designed the dataset2 as Table 4. Generally speaking, suppose that the company size of A is larger than other two. The various unit cost of Dataset2 has the same value with Dataset1.

### 4.4. The whole profit and various costs under two modes

For dataset2, the profits, whole costs and various costs have been shown in Tables 5 and 6. From Table 5, keeping out of the dataset it can easy to say the whole costs are decreased substantially for alliance mode. Their profits always greatly stay ahead of the corresponding ones of non-alliance. For example, the whole cost only has 166,200 under alliance mode for DS21, while the corresponding one is 662,130 for non-alliance. The reduced number can add up to 495,930.

Basically, it can find that for company B based on DS21 and DS22, its profits are negative values. But the whole profits are positive ones for alliance mode. So it is necessary to consolidate with other companies for this kind of company just like B to hedge against the risk. However, for company A, although it has profits both alliance and non-alliance, it can reduce the various costs through the consolidation. For example, for DS21 before alliance, its whole costs is about 199,600. After alliance, the whole costs of three companies only has 166,200, which is far less than the one of company A. So it can draw a conclusion that the alliance mode fits different company whatever the size of company.

See Table 6 for details on various costs. For DS23, the inventory cost of non-alliance are about 25,000. But for alliance it only has 17,000. The essential reason is \( BF < 1 \). As it has known, for such case surplus empty containers needs to be stocked than other two cases: \( BF > 1 \).
Table 4. Three datasets under three cases for non-alliance and alliance.

|          | DS21: BF = 1 |          | DS22: BF > 1 |          | DS23: BF < 1 |
|----------|--------------|----------|--------------|----------|--------------|
| emptyA   | [120 – 80 90 – 80] | emptyA   | [–70 150 – 80 40] | emptyA   | [180 – 80 90 – 100] |
| emptyB   | [–30 – 20 – 45 30] | emptyB   | [20 – 30 – 20 – 50] | emptyB   | [40 – 30 – 10 30] |
| emptyC   | [10 – 30 – 30 – 40] | emptyC   | [–40 90 – 130 – 50] | emptyC   | [20 30 – 20 40] |
| emptyall | [100 – 800 – 20] | emptyall | [–40 90 – 130 – 50] | emptyall | [160 – 80 60 – 30] |

Note: BF, balance factor.

Table 5. Profits and whole cost under different datasets.

|          | DS21 |          | DS22 |          | DS23 |          |
|----------|------|----------|------|----------|------|----------|
| A        | 99,900 | 199,600 | 83,880 | 215,620 | 85,100 | 214,400 |
| B        | –15,640 | 315,140 | –19,900 | 319,400 | 47,320 | 252,180 |
| C        | 152,110 | 147,390 | –75,900 | 375,400 | 152,940 | 146,560 |
| non-alliance | 236,370 | 662,130 | –11,920 | 910,420 | 285,360 | 613,140 |
| alliance | 732,300 | 166,200 | 342,600 | 555,900 | 714,900 | 183,600 |

Table 6. Profits and various costs under different datasets.

|          | stockC | leasingC | transC and (un)loadC |
|----------|--------|----------|----------------------|
| DS21 non-alliance | 10,000 | 180,000 | 107,930 |
| alliance | 0      | 0        | 44,800 |
| DS22 non-alliance | 8000   | 440,000 | 98,220 |
| alliance | 0      | 340,000 | 94,500 |
| DS23 non-alliance | 25,000 | 110,000 | 113,940 |
| alliance | 17,000 | 0        | 45,200 |

Notes: StockC, inventory cost; leasingC, leasing cost; transC, transport cost; (un)loadC, unload cost or load cost.

and BF = 1. For each company of non-alliance, it has to dispatch its empty containers within it. It will have to incur various costs, such as loading costs, unloading costs, stocking cost, ECR cost, etc. However, for alliance, every company can share its resources of empty containers, which can greatly reduce the leasing cost. Each company in alliance can seek healthy development together. Take the DS21 as example in Table 6, the inventory costs of non-alliance and alliance are 10,000 and 0, respectively. Each company can decrease its stock cost. Another example, for DS22, the stock costs are zero and 34,000 for two modes. Their corresponding leasing costs are 340,000 and 440,000. The above data support the importance of the alliance further.

5. Conclusion and future works

In general, we have classified alliance or non-alliance to strategic level in shipping industry. Once the decision of strategic level has been adjusted, it will have huge influence for the lower two layers. From such angle, in quantitative analysis this paper has described the various impacts of ECR under two modes. To compare with the results, the optimization models and two datasets have been constructed according to the actual business flow. The simulations show that each company in alliance mode can win together regardless of the ratio of empty and laden containers distributions. At the same time, the total costs can be cut dramatically. These data described in this paper provide the support for alliance mode of companies. It can be considered as effective mechanisms for various company size to fend off a sluggish shipping industry.

In addition, many research directions can be considered as interesting extensions of this work. This paper mainly focuses on the non-alliance&alliance modes and ignore the profits distribution of each individual in alliance. It is a challenge problem because the trade-off between responsibilities and interests is the permanent topic. In the next work, since different consolidation modes may turn all the things on shipping industry, some researches on route planning and liner deployment, which belong to the problem of tactical layer, can be studied more. The future works have not limited to above aspects.

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