Container Shipping Routes Optimisation and Internal Packing Solutions from a Sustainable View

Liangyong Chu*, Shuo Dang

[1]Modern Research of Logistics,Jimei University,Xiamen, China

[2]Management School,The University of Liverpool,Liverpool, UK

*chuliangyong@163.com, S.Dang@liv.ac.uk

Keywords:sustainable container management, container operation performance, container shipping packages, container transport solution

Abstract. This paper chooses rice container transportation as the case, studies on the relationship between container packing and container shipping, analyse the main operation players, such as packaging provider, cargo owners, port & shipping company, to find its impact on container supply chain's KPI, identify the environmental impact and business benefits, under optimising container packing and shipping solutions. Then, according to the business case and container transport scenarios, it will build a mathematical Model to each scenario, in order to calculate and compare their container supply chain's KPI with different container shipping packages. After analysing the business cost, environment impact and lead time in each model, a decision-making framework will be given for container packing and shipping solutions by optimising the combination structure of different container supply chain and container shipping packages.

Introduction

In past years, a lot of study looked into supply chain efficiency in container operations. They aim to improve the container operation performance by simulation, mathematics and empirical. But, these studies did not look into delay factors of operation. Therefore, this study intended to overcome the shortcoming by analysing the sources of negative factors that affected container operations in container supply chain, such as delay caused by unreasonable packing and shipping solutions. And, in this paper, under the principle of sustainable container management (Dang & Chu, 2014), to improve the service quality, we will optimise container operation activities by improving the secondary packaging design. Then, according to the operation features of different container supply chain, it will propose a decision-making framework of container shipping packages.

If we can appropriately select container shipping packages for different container supply chain, we can significantly reduce the lead time, carbon emission and business costs, and improve the service quality for container operations, since several unnecessary processes will be cancelled. In the other word, it could help to improve container supply chain performance. From a sustainable view, it meets the economic (business costs reduction), environmental (transport routes optimisation), social (lead time reduction & service quality improvement) requirements (Adams, 2006; Song,2012).

BUSINESS CASE

This project chooses rice container transportation as the case. Rice is the basic grain consumed as a food in UK which is found in almost every supermarket. UK is a big consumer of rice in Europe. As the population increases, the import demand for rice is also increasing. These characteristics increase the burden of container transportation, making logistics complex and expensive, also improving the environment costs. So, it's necessary to find a way to improve the container operation performance for the rice, and achieve a sustainable development.

The case company – Weir & Carmichael is a typical packaging company which located in Liverpool. In addition, as another two important container operations player, the port and the shipping company will also be analysed by the case of Liverpool & Felixstowe port and Evergreen

Line, in order to optimise operations and reduce environment costs throughout the whole supply chain.

A. Container transport scenarios

In this study, three container transport scenarios can be analysed: devanning at CY, devanning at cargo owner's warehouse and integrated intermodal transport discharging at Felixstowe Port. The first scenario (figure 2.1) belongs to multimodal transport, and the last two scenarios (figure 2.2, 2.3 & 2.4) can be considered as the integrated intermodal transport.

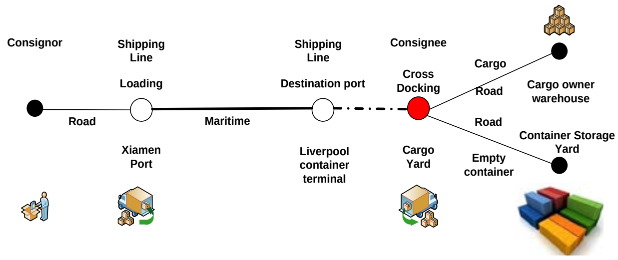

Figure 2.1 the scenario 1: devanning at CY

In scenario 1, the operations of devanning will be happened at CY (Cargo Yard). Then, the container will be directly returned to the container storage yard appointed by the shipping line (Generally, shipping line will appointed the container storage yard which is the nearest to the destination port. Clearly, in this model, the container storage yard is also in Liverpool).

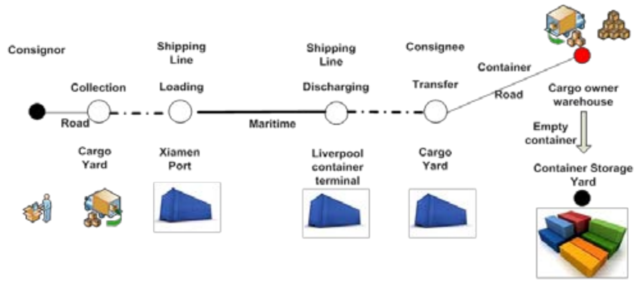

Figure 2.2 the scenario 2: devanning at cargo owner's warehouse

In scenario 2, it represents the container transport mode of CY to Door. In this supply chain, before the node of cargo yard (in Liverpool), shipping line is responsible for the transport. Even though, the cargo owner will pick up the container at CY, it won't be devanning until it arrive cargo owner's warehouse. Then, the container will be directly returned to the container storage yard appointed by the shipping line.

According to the empty container routes, scenario 3 (integrated intermodal transport) can be divided into 2 different modes (figure 2.3 & 2.4).

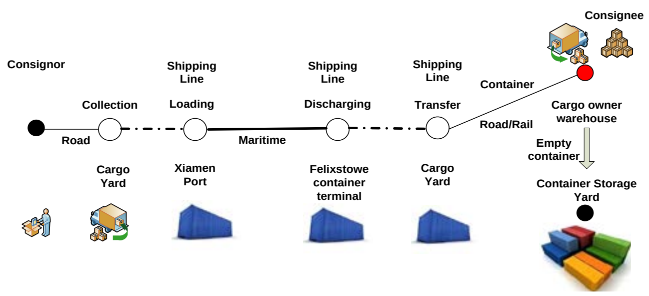

Figure 2.3 the scenario 3: integrated intermodal transport (F-F)

In scenario 3, since transport operators are responsible for the whole delivery, they will organise all the transport. Except to waiting at the destination, cargo owners need to do nothing. In fact, the shipping lines always have several fixed transport routes for selection. And, according to customers' destination, they will select the best one in consideration of the cost and lead time. In this case, Evergreen Line operates the business of intermodal transport from Xiamen (consignors' factory or warehouse) to Manchester (consignee's plant or warehouse). And, the discharging port is Felixstowe, not Liverpool. In figure 2.3, the empty container will be returned to Felixstowe. In figure 2.4, it's distinguished with figure 2.3 in scenario 3 that the empty container will be back to the CY in Liverpool port. For other information, it's same with figure 2.3.

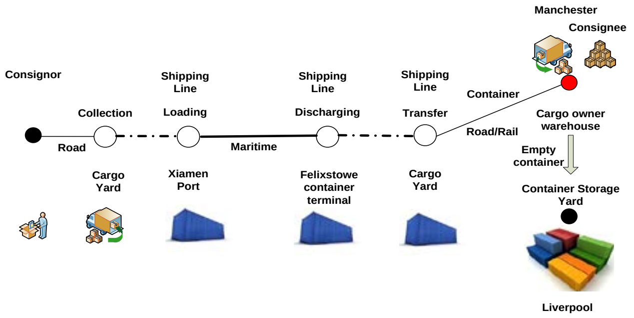

Figure 2.4 the scenario 3: integrated intermodal transport (F-L)

B. *Container shipping packages*

In this case, generally, rice liner and bulk bag (also known as FIBC or ton bag) are used as the container shipping packages.

According to Rice liner is one of the general packaging methods for a wide range of industries. It offers three key applications which is protection, transport or shelf ready packaging. Its construction means that it is one of the most effective methods of protection whilst being easy to use. The Rice liner is usually placed in 20 "or 40" container, which can be used to load and transport a large shipment of solid granular products or powdered products. But, since it needs a special machine to fill and suck out, perhaps, it's time consuming to wait the machine schedule.

International standards bulk bags (also known as FIBC / Space Bag / ton bag / Picture Bag): is a flexible transport container. And, it's the flexible intermediate bulk containers, which is helpful to achieve the unit of transport. This flexible freight bag is shown in figure 2.5.

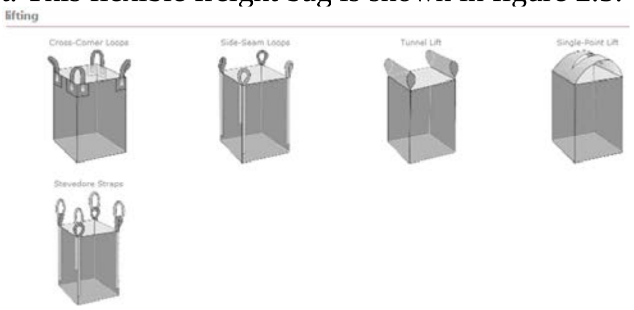

Figure 2.5 Bulk bag

Models and functions

According to the evaluation framework of container sustainable management (Dang & Chu, 2014) and measurement framework of container operation (Lai, 2002), to optimise different container operation design, container operations' value can be considered as the efficiency and effectiveness measured from 4 criteria: the business costs, environment costs, lead time and service quality. Thus, following models and functions will be built based on these 4 criteria.

Scenario	Route			
	Discharging Port		Container devanning place	Container return place
1	Model 1	Liverpool	CY (Liverpool port)	CY (Liverpool port)
2	Model 2	Liverpool	CFC (Manchester)	CY (Liverpool port)
3	Model 3	Felixstowe	CFC (Manchester)	CY (Felixstowe port)
	Model 4	Felixstowe	CFC (Manchester)	CY (Liverpool port)

Figure 3.1 Models structure

Model 1 and Model 2 are built for scenario 1 & 2, representatively. Meanwhile, for scenario 3, according to the empty container routes, Model 3 and 4 are also built in this paper (figure 3.1). $\mathbf{C_F}$ = Freight cost, $\mathbf{C_{LD}}$ = Loading or Discharging cost, $\mathbf{C_f}$ = Fixed cost, $\mathbf{C_I}$ = Inland delivery cost, $\mathbf{C_E}$ = Environment cost, $\mathbf{C_P}$ = Container internal package cost, $\mathbf{C_L}$ = Container leasing cost, $\mathbf{P_F}$ = Freight rate (£ / TEU), $\mathbf{P_{LD}}$ = Loading or discharging rate (£ / TEU), $\mathbf{P_I}$ = Inland haulage rate (£ / TEU), $\mathbf{P_E}$ = Carbon tax price (£ / TEU), $\mathbf{P_L}$ = Container leasing price (£/ day*TEU).

- Model 1: $C_{Total} = C_F + C_{LD} + C_L + C_P + C_E + C_f$
  Model 1A (Rice liner): $C_{Total} = D_G \cdot P_F + D_G \cdot T \cdot P_L + D_P \cdot P_R$
  $+D_G \cdot P_{LD} + C_E + C_f$
  Model 1B (Bulk bags): $C_{Total} = D_G \cdot P_F + D_G \cdot T \cdot P_L + D_P \cdot P_B$
  $+D_G \cdot P_{LD} + C_E + C_f$
- Model 2: $C_{Total} = C_F + C_{LD} + C_L + C_P + C_E + C_f$
  Model 2A (Rice liner): $C_{Total} = D_G \cdot P_F + D_G \cdot T \cdot P_L + D_P \cdot P_R$
  $+D_G \cdot P_{LD} + C_E + C_f$
  Model 2B (Bulk bags): $C_{Total} = D_G \cdot P_F + D_G \cdot T \cdot P_L + D_P \cdot P_B$
  $+D_G \cdot P_{LD} + C_E + C_f$
- Model 3: $C_{Total} = C_F + C_I + C_{LD} + C_L + C_P + C_E + C_f$
  Model 3A: $C_{Total} = D_G \cdot P_F + D_G \cdot P_I + D_G \cdot T \cdot P_L$
  $+D_P \cdot P_R + D_G \cdot P_{LD} + C_E + C_f$
  Model 3B: $C_{Total} = D_G \cdot P_F + D_G \cdot P_I + D_G \cdot T \cdot P_L$
  $+D_P \cdot P_B + D_G \cdot P_{LD} + C_E + C_f$
- Model 4: $C_{Total} = C_F + C_I + C_{LD} + C_L + C_P + C_E + C_f$
  Model 4A: $C_{Total} = D_G \cdot P_F + D_G \cdot P_I + D_G \cdot T \cdot P_L$
  $+D_P \cdot P_R + D_G \cdot P_{LD} + C_E + C_f$
  Model 4B: $C_{Total} = D_G \cdot P_F + D_G \cdot P_I + D_G \cdot T \cdot P_L$
  $+D_P \cdot P_B + D_G \cdot P_{LD} + C_E + C_f$

In the modeling, some values should be nonnegative number, total cost (CTotal), freight rate (PF), loading or discharging rate (PLD), inland haulage rate (PI), carbon cap and trading price (PE), container leasing price (PL), demand of container (Dc) and container shipping packages (DP). Furthermore, the standard container has 3 sizes, 20 feet (1 TEU) and 40 feet (2 TEU). Thus, the container demand should be integer, $D_C \geq 0$ & integer. And, the demand of container shipping package is limited by the demand of container. So they should meet the following formula: $D_P \geq D_C$.

Based on IPCC (2007), the basic Carbon emission calculation formula is: $C_t = \sum_{i=1}^{n}(W_i \times D_i \times EF_i)$, Carbon emissions of energies in transportation activity, kg; Consignment weight, tone; Distance of transportation mode i, km; Emission factor of energy i, kgCO_2per kg.km.

Data

In this case, the primary data are collected from the company's website and actual investigation (Evergreen Line & Liverpool Port), and the secondary data comes from current published research results.

Primary data include: Freight consignment information (Transport conditions, cargo specification, shipping processes); Container and container shipping packages information (Company information, container specification, container leasing rate and container shipping packages specification); Transport information (Ocean freight rates, inland delivery rate, fix cost, container loading/discharging cost); Average container inland turnaround time, ocean shipping time, and transport route.

Container inland travel distance – Model 1, 0 mile; Model 2, 86 mile; Model 3, 490 mile; Model 4, 288 mile.

	Model	Ocean time	Waiting in CY	Lead time	Container inland turnaround time
Scenario 1	Model 1A	43days	3days	46days	0
	Model 1B	43days	2days	45days	0
Scenario 2	Model 2A	43days	2days	45days	3days
	Model 2B	43days	2days	45days	3days
Scenario 3 (F-F)	Model 3A	35days	2days	40days	6days
	Model 3B	35days	2days	40days	6days
Scenario 3 (F-L)	Model 4A	35days	2days	40days	4days
	Model 4B	35days	2days	40days	4days

Figure 4.2 Time data

Container Size	Ocean freight rate	Inland haulage rate	Fixed cost (ENS, ship owner's security fee and document fee)	Loading & Discharging rate
20'	897.15GBP (Liverpool) 687.47GBP (Felixstowe)	534GBP	94.145GBP	80.33GBP
	Container leasing rate (in CY over 1-7days)	Container leasing rate (in CY over 8 days)	Container leasing rate (out CY over 1-3days)	Container leasing rate (out CY over 4 days)
	25GBP	40GBP	10GBP	24GBP
	Internal volume	Maximum net load (General container)	Maximum net load (Overweight container)	Bulk bag packing amount
	26.42m³	21670kg	28280kg	18

Figure 4.3 Cost data and container information

All carbon emission factors are from secondary data. The carbon emissions for the transport figures are from a sheet of conversion factors – 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting – which produced by AEA for the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (DEFRA). The Charge rate for the carbon emission is from a policy paper in UK that was published on the government website (www.GOV.UK.com, 17/08/2014) – Carbon price floor: reform and other technical amendments et al. The carbon emission factor is 0.12168 kgCO_2per tone. Km, and the carbon charge rate is £30 t/CO_2.

Results and Analysis

C. Result data

The following two figures indicate the calculate results for previous 4 models in 3 different scenarios. Scenario 1 (Rice liner packaging) is the most time consuming solution, but its cost is the lowest among all scenarios. In contrast, Scenario 3 uses the shortest time, but with a higher cost than others. For the carbon emission, Scenario 1 (Bulk bag packaging) is the most environmental friendly one among all of the 4 models. To find a container transport solution for our case study, it needs a further analyse.

	Model	Cost	Carbon Emission	Lead time
Scenario 1	Model 1A	1208.305GBP	196.46kg	46days
	Model 1B	1232.115GBP	190.26kg	45days
Scenario 2	Model 2A	1216.825GBP	392.92kg	45days
	Model 2B	1240.825GBP	380.52kg	45days
Scenario 3 (F-F)	Model 3A	1535.945GBP	2238.71kg	40days
	Model 3B	1559.945GBP	2168.10kg	40days
Scenario 3 (F-L)	Model 4A	1515.945GBP	1315.81kg	40days
	Model 4B	1539.945GBP	1274.31kg	40days

Figure 5.1 Result data

D. *Data analysis*

It's so hard to directly make a decision according to the result data in figure 5.1. In this part, Multi Criteria Decision Making methods (MCDM) can be useful for decision making, combined with AHP and normalised analyse. AHP is used for identifying the importance of each criterion and calculate their weights, when selecting a container transport solution. Then, the calculation steps of AHP are presented according to Saaty (1980).

- AHP calculation

Step 1: Establish the pair-wise comparison matrix A: (1) 3 Criteria: c_1 , cost ; c_2 , time ; c_3 : carbon emission; (2) Criteria score (1-9 score)from case study, academic researcher and academic articles (Song, 2010, Sarfaraz &Jurgita, 2012, Harilaos & Christos, 2010 & Saaty, 1990): Compare c_1 and c_2 , c_1 is important, so a_{12} = 5 ; Compare c_1 and c_3 , c_1 is much more important, so a_{13} = 7 ; Compare c_2 and c_3 , c_2 is a little more important, so a_{23} = 3; (3) Paired comparison matrix: A=$\begin{bmatrix} 1 & 5 & 7 \\ 1/5 & 1 & 3 \\ 1/7 & 1/3 & 1 \end{bmatrix}$

Step 2: Calculate the weight of each criteria: (1) Normalised by columns: $\overline{a_{ij}} = a_{ij}/\sum_{i=1}^{n} a_{ij}$ i,j = 1,2,…,n; (2) Calculate the summation of each line: $\overline{W_i} = \sum_{j=1}^{n} \overline{a_{ij}}$; (3) Normalized again, and get the eigenvectors (namely, weight coefficient): W=$(0.7235,\ 0.1932,\ 0.0833)^T$

Step 3: Estimate average consistency: (1) Calculate the largest eigenvalue: $\lambda_{max} = \sum_{i=1}^{n} \frac{[AW]_i}{nw_i}, n = 3$ $\lambda_{max} = 3.0658$; (2) Average consistency:$CI = \frac{\lambda_{max}-n}{n-1} = \frac{3.0658-1}{3-1} = 0.033$; Average consistency values of these matrices are given by Saaty and Vargas (1991) as provided in figure 6.1. If the CI<0.10, the estimate is accepted; otherwise, a new comparison matrix is solicited until CI<0.10. When n = 3, RI is 0.58. So, $CR = CI/RI = 0.033/0.58 = 0.057 < 0.1$. It meets the average consistency. And, the weight for each criteria is acceptable, $W_i = (0.7235,\ 0.1932,\ 0.0833)$.

n	3	4	5	6	7	8	9	1	0	1	1
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51		

Figure 5.2 RI value (Saaty & Vargas,1991)

- Normalise Analysis

The normalised decision-making matrix with value of each criterion expressed at intervals is presented in figure 6.16. As all criteria are min-max normalised, all the result data will be mapped between 0 and 1 (Podvezko, 2011). The conversion function is as follows:

To be specific, the normalisation is calculated under the weights (0.7235, 0.1932, 0.0833). It means cost is the most important factor, and much more important than the other two. And, the carbon emission factor is the most unimportant factor. From figure 5.3, we can see that, under this weight, the solution of Model 1A (namely, Scenario 1 with rice liner packaging) has the lowest score. Meanwhile, the solution of Model 3B (namely, Scenario 3 with bulk bag packaging, container return to Filexstowe) has the highest score. It indicates that, under the weight (0.7235, 0.1932, 0.0833), Model 1A is the best solution for the rice container transport.

Model	Cost	Lead time	Carbon emission	
Weighting	0.7235	0.1932	0.0833	Final score
1A	0	1	0.096	0.201
1B	0.068	0.833	0	0.216
2A	0.024	0.833	0.099	0.262
2B	0.092	0.833	0.093	0.308
3A	0.932	0	1	0.72
3B	1	0	0.966	0.768
4A	0.875	0	0.549	0.633
4B	0.943	0	0.529	0.682

In fact, at different business background, cargo owner will pay much more attention on different factors. Thus, it needs a further discussion. In the following analysis, we will change the weight to different ratios, which will represent different business requirements.

- Further normalise analysis

Weight 2 (0.5, 0.4, 0.1), it means that cost is the most important factor, but it's just a little more important than the time factor. And, carbon emission is the most unimportant one, however, just a little lighter than the time factor. This weight can be used to reflect the business with a rapid market, such as seasonal goods. It also can be used to reflect the business of perishable food, such as soybean, potato.

From figure 5.3, we can see that, under this weight, the solution of Model 2A (namely, Scenario 2 with rice liner packaging) has the lowest score. Meanwhile, the solution of Model 3B (namely, Scenario 3 with bulk bag packaging, container return to Filexstowe) has the highest score. It indicates that, under the weight (0.5, 0.4, 0.1), Model 2A is the best solution for the rice container transport.

	Cost	Lead time	Carbon emission	
Weighting	0.5	0.4	0.1	Final score
1A	0	1	0.096	0.41
1B	0.068	0.833	0	0.367
2A	0.024	0.833	0.099	**0.355**
2B	0.092	0.833	0.093	0.389
3A	0.932	0	1	0.566
3B	1	0	0.966	**0.597**
4A	0.875	0	0.549	0.492
4B	0.943	0	0.529	0.524

Figure 5.3 the normalised decision-making matrix for weight 2

Weight 3 (0.4, 0.4, 0.2), it means cost and time are the same important factor. And, carbon emission factor is a little lighter than the first two factors. This weight can be used to reflect the business of perishable food, such as soybean, potato. This weight can be used to reflect the business with a new product when face many competitors in the same market, such as the computer components or mobile phone components.

From figure 5.4, we can see that, under this weight, the solution of Model 1B (namely, Scenario 1 with bulk bag packaging) has the lowest score. At the same time, the solution of Model 3B (namely, Scenario 3 with bulk bag packaging, container return to Filexstowe) has the highest score. It indicates that, under the weight (0.4, 0.42, 0.2), Model 1B is the best solution for the rice container transport.

	Cost	Lead time	Carbon emission	
Weighting	0.4	0.4	0.2	Final score
1A	0	1	0.096	0.419
1B	0.068	0.833	0	**0.36**
2A	0.024	0.833	0.099	0.362
2B	0.092	0.833	0.093	0.389
3A	0.932	0	1	0.573
3B	1	0	0.966	**0.593**
4A	0.875	0	0.549	0.46
4B	0.943	0	0.529	0.483

Figure 5.4 matrix for weight 3

Weight 4 (0.3, 0.5, 0.2), time is the most important factor; cost factor is a little lighter than the time factor. And carbon emission is the most unimportant one, but a little lighter than the cost factor. This weight can be used to reflect the business of hot products in an emergency replenishment. In this situation, in order to maintain the market share, the cargo owner attaches great importance to the transport speed.

According to the score (figure 5.5), we can find that the result is quite different from previous matrixes. The lowest score is the model 4A, and the highest one is 1A. It means scenario 3, model 4 with rice liner packaging is the best solution for this weight.

	Cost	Lead time	Carbon emission	
Weighting	0.3	0.5	0.2	Final score
1A	0	1	0.096	0.5192
1B	0.068	0.833	0	0.4369
2A	0.024	0.833	0.099	0.4435
2B	0.092	0.833	0.093	0.4627
3A	0.932	0	1	0.4796
3B	1	0	0.966	0.4932
4A	0.875	0	0.549	0.3723
4B	0.943	0	0.529	0.3887

Figure 5.5 the normalised decision-making matrix for weight 4

	Cost	Lead time	Carbon emission	
Weighting	0.4	0.2	0.4	Final score
1A	0	1	0.096	0.3288
1B	0.068	0.833	0	0.2771
2A	0.024	0.833	0.099	0.2892
2B	0.092	0.833	0.093	0.3146
3A	0.932	0	1	0.6728
3B	1	0	0.966	0.6898
4A	0.875	0	0.549	0.5147
4B	0.943	0	0.529	0.5359

Figure 5.6 matrix for weight 5

Weight 5: (0.4, 0.3, 0.3), similarly, the normalised decision-making matrix is shown in figure 5.6. This weight can be used to reflect the business in a high carbon tax area. From figure 47, we can see that, under this weight, the solution of Model 1B (namely, Scenario 1 with bulk bag packaging) has the lowest score. At the same time, the solution of Model 3B (namely, Scenario 3 with bulk bag packaging, container return to Filexstowe) has the highest score. It indicates that, under these 3 different weights, Model 1B is the best solution for the rice container transport.

E. Solution framework

Comprehensively considering above different weights, on the basis of sustainable container management, a container packing and shipping solution framework is given for the rice case (figure 5.7), under two different container transport modes.

Multimodal transport	Scenario 1	Model 1	Model 1B (Bulk Bag)
Integrated intermodal transport	Scenario 2	Model 2	Model 2A (Rice Liner)
	Scenario 3 (F-L)	Model 4	Model 4A (Rice Liner)

Figure 5.7 Container Packing and Shipping Solution Framework

- **Business requirements:** (1) cost is the most important factor, a little or much more important than the time factor. And, carbon emission is the most unimportant one, however, just a little lighter than the time factor. (2) Carbon emission is as important as the time factor. And, cost is the most important one.
  Decision: multimodal transport, model 1B, bulk bag packaging.
- **Business requirements:** time factor is as important as the cost factor, they have the same weight. And, carbon emission is the most unimportant factor.

Decision: integrated intermodal transport, model 2A, rice liner packaging.

- **Business requirements:** time is the most important factor, and much more important than other two factors. In another words, the weight rates for carbon emission and cost are small. **Decision:** integrated intermodal transport, model 4A, rice liner packaging.

Discussion

In this case, the discharging ports are selected as Liverpool and Felixstowe. As we have introduced, the CFC for company A is in Manchester, the central part of UK. If the DC is located in the southern or northern, what the container packing and shipping solution should be?

If the cargo owner's warehouse is in the northern, the decision-making framework can also be applied to it. Because, except the transport distance, all the other factors are same with the case we have discussed.

If the DC is in the south part, such as Birmingham, the scenario in the solution framework will be less than the case we have discussed in previous chapters. The reason is easy. Comparing with Liverpool port, Felixstowe, as the biggest container port in UK, is much closer to Birmingham. Except to the geographical location feature, Felixstowe port also has its transport advantages. Thus, it's unnecessary to choice Liverpool port as the discharging port. And, the decision can be just made between model 3 and 4 under the Scenario 3, and Scenario 1.

Conclusion and limitation

This study focuses on the sustainable container management when selecting the container packing and shipping solutions. Based on the case of rice container transport in UK, and its main players – Liverpool & Felixstowe port, Evergreen Line and the cargo owner (Company A), AHP and numerical analyse was used to access the container operation performance from three main aspects, namely, lead time, business costs and environment impact. After calculating and analysing the above KPI's data when using different container packing and shipping solutions, some conclusions are brought.

For this case, from a sustainable view, scenario 1 (multimodal transport, Liverpool port, devanning at CY) has more advantages than other scenarios.

Appropriately using container shipping packages can help improve container operation performance. The bulk bag is a sub-packaging in container. And, it's helpful to achieve a unit handling operation. Compared with the rice liner, it can effectively improve the handling efficiency. For example, short the cross-docking time in cargo yard. It's suitable for the container supply chain with transfers in transit, especially for the multimodal transport. The rice liner is a holistic container packaging, with a cheaper packaging cost than the bulk bag solution. For a 20 ft. container, it needs 17 bulk bags with a packaging cost in 144 GBP, or one rice liner with a 120 GBP packaging cost. The rice liner also can provide a bigger container capacity utilisation than the bulk bag solution. From the analysis data, we can find that the container utilisation for rice liner solution is over 95%, but the bulk bag solution is around 90%. Under the integrated intermodal transport mode, the container won't be devanning until it reach cargo owner's warehouse. Thus, it's a good idea to select the rice liner packaging.

Appropriately selecting container packing and shipping solutions can help improve sustainable container management throughout the whole supply chain. According to our generalised analysis, for the business which has a cost or environmental tendency, it's better to choose scenario 1 (devanning at CY, multimodal transport mode) and use the bulk bag as its container shipping packages. And, it should try to use more water transport than road. For the time tendency business, if the CFC is in the south part, it's better to choice scenario 3 (integrated intermodal transport, Felixstowe port, container back to Liverpool port), with a rice liner packaging. If the CFC is in the north or central part, it's better to choice scenario 2 (integrated intermodal transport, Liverpool port), with a rice liner packaging.

In addition, this work also has some limitation. It's worthy to note that the case was too detailed to be able to draw general conclusions. The analysis of this study is restricted to one certain type of product within one sector. All assumptions and analysis was based on the specific case, so the results are right under the case's condition – container packing and shipping for the cargo in the types of powder, granular, massive objects, such as grain, forage, chemicals, building materials, plastics and others. That doesn't mean that these conclusions are applicable to all cargos' container packing and shipping. If some conditions in the case are changed, such as different consignment, packaging, or emission factors, there will be a possibility that the results may be different more or less.

For future study, measurement and analysis will be done among different companies and sectors, to develop the sustainable container packing and shipping framework in different supply chain.

Acknowledgment

The project was financially supported by the Natural Foundation of Fujian Province of China (NO. 2012J01302), supported by the Science and technology projects of Xiamen (No.3502Z2113032), supported by Department of Education of Fujian Province (NO. JA10195), also supported by the Scientific Research Foundation of Jimei University.

References

[1] Adams, W. M. (2006) The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century. Reportofthe IUCN Renowned Thinkers Meeting, January, 29 – 31.

[2] AEA. (2012) Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting.

[3] Carbon price floor: reform and other technical amendments et al, a policy paper on the government website in UK- www.GOV.UK.com, 17/08/2014.

[4] Dang, S. & Chu, L.Y. (2014), 'Evaluation Framework and Verification for Container Sustainable Management as Reusable Packaging', ICMEIM 2015 Conference, January, 30-31.

[5] IPCC. 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

[6] Lai, K.-H., Ngai, E. and Cheng, T. (2002) 'Measures for evaluating supply chain performance in transport logistics', Transport Research Part E, 7 38, pp. 439-456.

[7] Packaging Council of Australia. (2010). The Donald Richardson Packaging Collection—Thatwasthen, This is Now.http://www.pca.org.au/site/index.php/articles/article/1/546/The%20Donald%20Richardson%20Packaging%20Collection (cited 29 June 2014).

[8] Podvezko, V. (2011). 'The Comparative Analysis of MCDA Methods SAW and COPRAS'.InzinerineEkonomika-Engineering Economics, 22(2), 134-146.

[9] Sarfaraz, Z.H. & Jurgita, A. (2012) 'Team Member Selecting Based on AHP and TOPSIS Grey', Inzinerine Ekouomika-Engineering Economics, 4 (23), pp. 425-434.

[10] Saaty, T. L. (1980). The Analytic Hierarchy Process.Mcgraw-Hill, New York.

[11] Saaty, T. L. (1990). How To Make A Decision: the Analytic Hierarchy Process. European Journal of Operation Research, 48(1), 9-26. http://Dx.Doi.Org/10.1016/0377-2217(90)90057-l

[12] Saaty, T. L., & Vargas, L. G. (1991). Prediction, Projection and Forecasting. Dordrecht: Kluwer Academic Publishers.

[13] Song, D.-W. (2012) Maritime Logistics:A complete guide to effective shipping and port management, London: Kogan Page Limited.