Optimization of the ratio of transport mode for international transportation

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Abstract. With the globalization of production, international transportation becomes more important. When me think about transport of goods crossing the border, we may find the problem of choosing transport modes. In general, clients combine some transport modes depending on their characteristics, especially cost and time. In addition, in one transport mode, there are some types of contracts between clients and transporters based on their term. Thus, clients should make contracts considering these two aspects. This problem of combination is crucial. However, in most reports, one particular transport mode is determined for one goods and the problem of contract term is not treated. The aim of this study is to determine the best ratio of contracts for each transport mode from the perspective of cost. To achieve this goal, first, we made a time series simulation to reproduce international transportation in reality. Then, we conducted a case study about transport from China to Europe. The result was that clients should use air transport based on a spot contract more than ever. This shows the effectiveness of air transport and a spot contract.

Keywords: international transportation, transport mode, contract term, demand fluctuation, time series simulation

1. INTRODUCTION

Globalization is a key trend in the industry world today. Many industrial companies have their factories all over the world, and they transport their parts and goods over great distance. This raises the cost of transportation. Now transportation cost is critical problem for global industrial companies.

To minimize transportation cost, they should solve two types of combination problem. The first is the combination problem of transport mode. Long distance transportation caused the expansion of transportation lead times and brought about the risk of shortage or oversupply of goods. To manage this risk, companies should keep more stocks and it takes more costs. These costs are called time-related costs [1]. When we think only about this cost, faster transport modes, like planes, are preferred. However, these modes also have weakness. They cost more for transportation because of their high fuel costs and low capacities. These costs are called non-time related costs [1]. When we think about this cost, later transport modes, like ships, are preferred. Theses two types of costs makes it difficult for companies to choose which transport mode they use. International industrial companies should combine some transport modes taking into account these costs.

The second combination problem is that of contracts. Most industrial companies don't transport their goods by themselves. They make contracts with logistics companies and consign them to transport. There are some types of contracts based on their terms. Longer term contracts cost less for transportation of one unit but have more risks of shortage or oversupply of capacity. International industrial companies should combine some contracts from this background.

The common point of these two problems is the risk of shortage and oversupply. Even today, exact prediction has not come true. Then companies should deal with the risk. In general, the more companies take care about the risk, the more costs it takes. However, if they do not take care, they may be damaged. Therefore, what is important for them is to determine the best point and minimize the total amount of costs. This is the very optimization problem, and many papers about transportation costs have been written from this point of view. Litman analyzed transport costs in detail and categorized them by various attributes [2]. Suzuki defined the external costs like CO2 emission cost in addition to internal costs like fuel cost [3]. Tsuboi formulated transport cost and developed the modal split model between marine and air transport [4]. They provide useful method to solve cost minimization problem but they do not take into account of demand fluctuation and variety of contracts.

The aim of this study is to determine the best combination of transport mode and contracts under fluctuating demand. To achieve this goal, we first make some combination of contracts. Then we performed a time series simulation and calculated the total cost. Repeating this process, we defined the best combination.

2. Model

Fig.1 shows the flow of our model. We will introduce each process in detail in this seccion.

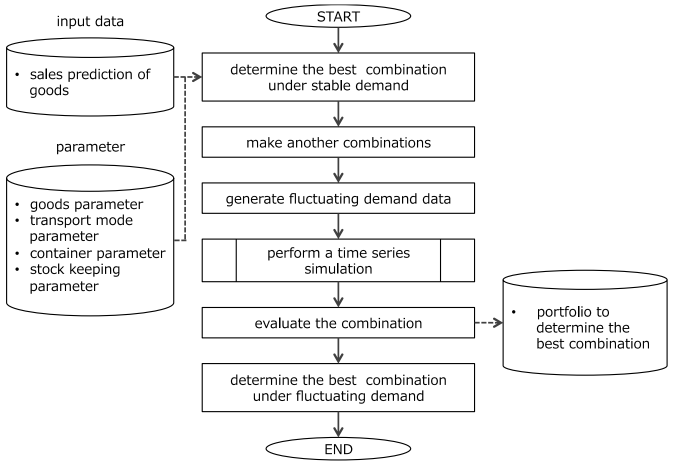

Fig. 1 The flow of the model

2.1 Input data

First we input data. The data are classified into two groups: input data and parameter.

Input data contains sales prediction of goods. In general, international industrial companies make contracts with transporters at the beginning of the year. At this time, they make decision by referencing the prediction of sales for the next year. We use this as input data.

Parameter contains four types of parameter data. Today, most goods crossing the border are transported by containers. Therefore we assume use of containers. Containers are globally standardized by International Organization for Standardization (ISO) [5]. In this study, ISO standard is used for container parameter. To calculate the capacity of one container we need to know the volume and the weight of goods. In the process of evaluation of the combination, we also need the production cost ratio, the stock loss cost ratio and chance loss cost ratio in the sales price of goods. These are goods parameters. Transport mode parameters contain lead time and transport cost of one container.

2.2 Determine the best combination under stable demand

Long term contracts offer transport service at low cost. However, once contracts are made, clients can't cancel them without any penalties. Therefor they have some risks of shortage and oversupply. In this point of view, short term contracts contains lower risks but transport cost is higher. Thus, the combination of these contracts is very important. In this process, we assume that the sales prediction is exact. Minimizing transport cost under this situation is the aim of this process.

First, we determine the term and amount of contract for each transport mode. Then, we calculate the whole cost for the combination with function (1). By repeating this process, we calculate the cost for all possible combinations and determine the best one that minimize the transport cost under stable demand.

$$C_{trans} = \sum\sum c_i \cdot n_{\square,\square} \quad (1)$$

C_{trans} : total cost of transport(yen)
i : types of contracts
t : simulation term
k : number of types of contracts
t_end : end term of simulation
$c_{\square}$: transport cost per one container of each contract (yen/TEU)
$n_{i,t}$: number of container on the term(TEU)

2.3 Make another combinations

In this process, we make new combinations of contracts by refering to the combination that we made in the previous process. In detail, we increased or decreased the amount of long term contracts by fixed rates. These new combinations are candidates of the best combinations under fluctuating demand and evaluated in the following processes.

2.4 Generate fluctuating demand data

In the previous processes, we assumed the stable demand but in the real world, the demand is fluctuating. Therefore the exact prediction is difficult and there are some deviations between the real demand and the demand prediction. To reproduce this deviation, we need to generate the fluctuating demand. This is the aim of this process.

The cause of the deviation is divided into two types. The first is the miss-prediction. In general, industrial companies dislike for risks of loss of sales chance caused by the shortage of stocks. Therefore, they overestimate the demand. This reads to the deviation. The second cause is the randomness of this world. Purchasing behavior of customers depends on economic trend. However predicting the trend is not easy for industrial companies and this is not their business. This also reads to the deviation.

Fig2. shows the outline of generating steps of the demand. To reproduce these two causes we take two steps. In the first step, we generate the average data of the fluctuating demand based on the sales prediction data with function (2). We reproduce the first cause in this process. In the second step, we generate the fluctuating demand data assuming that the distribution of the demand is a normal distribution. The average of the normal distribution is calculated in the previous step. The standard deviation is calculated based on the deviation between the real prediction data and the real demand data. Under this assumption, the fluctuating demand is calculated.

$$\mu_t = p_t \cdot (1 + k_{prediction}) \quad (2)$$

μ_t : average of demand in term t
p_t : sales prediction in term t
$k_{prediction}$: coefficient of mis-prediction

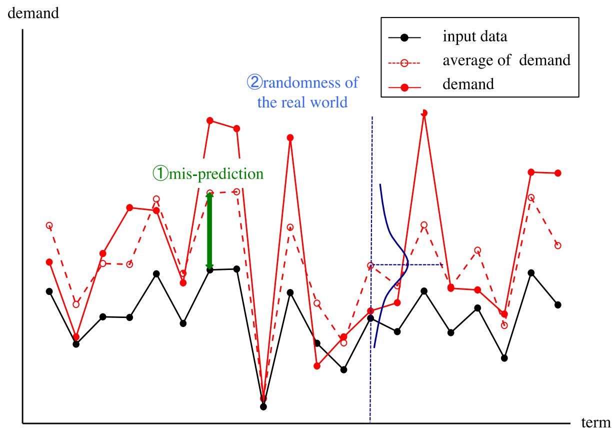

Fig. 2 The outline of generating fluctuating demand

2.5 Perform a time series simulation

Fig.3 shows the flow of the simulation. The aim of this simulation is to reproduce real flow from ordering to marketing.

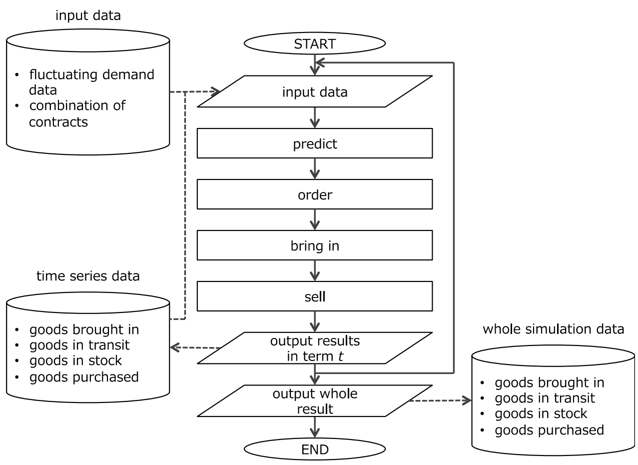

Fig. 3 The flow of the time series simulation

In the predict step, we predict the demand in the next term. We predict demand by the exponential smoothing method. This simple and powerful method is generally used. It was proposed in the late 1950s and given by formula (4).

$$s_0 = d_0$$
$$s_t = s_{t-1} + \alpha(d_{t-1} - s_{t-1}) \quad (t>1) \quad (4)$$

s_t : predicted value for term t
d_t : actual demand in term t
α : smoothing factor $(0<\alpha<1)$

Based on this prediction, we place an order in the next step. In ordering, there are two types of strategies: Push and Pull. Push production is based on forecast demand and pull production is based on actual demand. This study aims at global industrial companies and there are long lead times. Therefore, global industrial companies need to predict the demand and place an order in advance. Then, we select push strategy.

In the push strategy, the quantity of order is determined by formulas (5) and (6). This is also generally

$$OQ_t = \overline{d}(FT + L) + SS - IS_{t-1} - IT_{t-1} \quad (5)$$

OQ_t	:	order quantity on term t
$\overline{d}$	:	average demand rate
FT	:	fixed term between orders
L	:	lead time
SS	:	safety stock
IS_t	:	inventory in shops
IT_t	:	inventory on transit

$$SS = Z \cdot \sigma \cdot \sqrt{FT + L} \quad (6)$$

Z	:	the Z-score
σ	:	standard deviation of demand per term

After order step, we go into bring in and sell steps. In the bring in step, goods are carried in and increase the stock. In the sell step, goods are sold and decrease the stock. If we don't have enough stock, the quantity of shortage is counted as sales opportunity loss.

These steps from predict step to sell step are one series for each term. We repeat this series during the whole simulation term. In the end, the data related to sales, stocks, and opportunity loss in each term is output.

2.6 Evaluate combinations

To evaluate each combination candidate, we calculate the total cost throughout the simulation terms. Function (7) shows components of total cost and we will show details of each component below.

$$C_{total} = C_{trans} + C_{stock} + C_{disposal} + C_{oppotunity\_losss} \quad (7)$$

C_{total}	:	total cost
C_{stock}	:	stock keeping cost
$C_{disposal}$	:	stock disposal cost
$C_{oppotunity}$	:	opportunity loss cost

- **Stock keeping cost**

When stores keep stock, they have to pay some costs. We define the cost as stock keeping cost. In this study, we assume that the cost is proportion to the volume of goods. Function (8) shows the definition of this cost.

$$C_{stock} = \sum k_{stock} \cdot v \cdot n_{stock,t} \quad (8)$$

k_{stock}	:	stock keeping cost per m^3 (yen/m^3)
v	:	volume of each goods (m^3)
$n_{stock.t}$	:	Number of stocks in term t

- **Stock disposal cost**

If stores order excessive amount of goods and can't sell all of them, goods are left unsold. In the end of each year, stores dispose these unsold goods. In this process, they pay some costs. We define the cost as stock disposal cost. When goods are oversupplied, this cost increases. Therefore, this is one of the indexes to evaluate the effect of fluctuating demand on combination candidates. The definition of the cost is shown in function (9). We assume that stock disposal cost is proportion to the price of the goods.

$$C_{disposal} = r_{disposal} \cdot p \cdot n_{stock,end} \quad (9)$$

$r_{disposal}$	:	ratio of stock disposal cost to the price of goods
p	:	price of each goods(yen)
$n_{stock,end}$	:	number of stocks in the end of the simulation

- **Opportunity loss cost**

If stores doesn't order enough amount of goods, it causes the shortage of goods supply. This means the decrease of profit they could get with appropriate management. We define this as opportunity loss cost. Under fluctuating demand, if stores keep little stocks to decrease stock disposal cost, this cost increases. Therefore, this is also one of the indexes to evaluate the effect of fluctuating demand on combination candidates. Function (10) shows the definition. We assume that this cost is also proportion to the price of the goods.

$$C_{oppotunity} = \sum r_{oppotunity_{loss}} \cdot p \cdot n_{oppotunity_{loss},t} \quad (10)$$

$r_{disposal}$	:	ratio of opportunity loss cost to the price of goods
$n_{oppotunity}$	:	number of stocks in term t

2.7 Determine the best combination under fluctuating demand

In the previous step, we showed the total cost function. By using this, we evaluate each combination candidate.

Then, the combination that minimizes the total cost is selected as the best one.

3. Case study

We will carry out case study in this section. We cooperated with a global industrial company (company A). They gave us the data related to goods demand and transportation of them.

3.1 Background

Company A is a global industrial company. It has factories in 29 countries and stores in 64 countries. The main products are home appliances. Many of them are produced in China is and transported to all over the world. Based on this fact, we deal with the case that home appliances are produced in Chongqing in China and transported to Amsterdam in Netherland.

3.2 Input data

We will use real demand data as input data. Fig.4 shows the data. Each M means the model of goods and all goods are home appliances. Therefore, Fig.4 includes real demand data of five kinds of home appliances. From this figure, we can find that the demand is concentrated on from October to December. The demand during this term accounts for almost all of demand through a year.

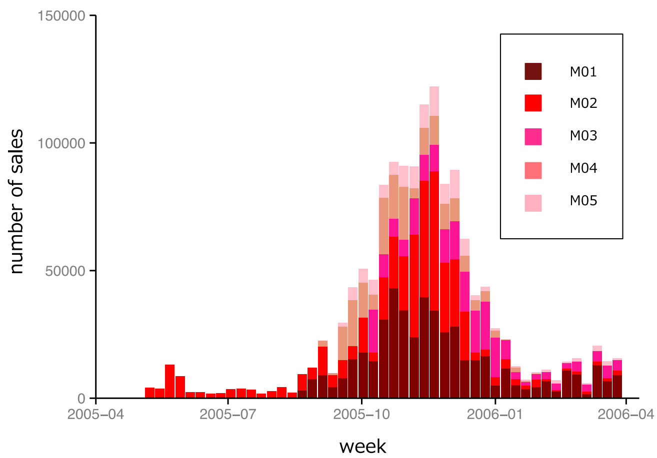

Fig. 4 Real demand for goods

3.3 Parameters

Here we show the parameters in this case study.

- **Goods parameter**

We think about the transportation of home appliances. To simplify the simulation, we assume that five home appliances have same parameters (Table.1).

Table. 1 Goods parameter

name	value	unit
price	20000	yen
volume	0.3	m^3
weight	12	kg
production cost ratio	55	%
stock loss cost ratio	55	%
chance loss cost ratio	20	%

- **Transport mode parameter**

In this case study, products are transported from Chongqing to Amsterdam. Now, company A uses sea and air transportation in this section (Fig.5). Therefore, we also use these transportation modes. In addition, in this case study, air transportation is used based on spot contract, and sea transportation is used based on three types of contracts: yearly, half-year, quarter- year. The shorter the contract term is, the lower the transportation cost is. Each parameter is shown in Table2-5.

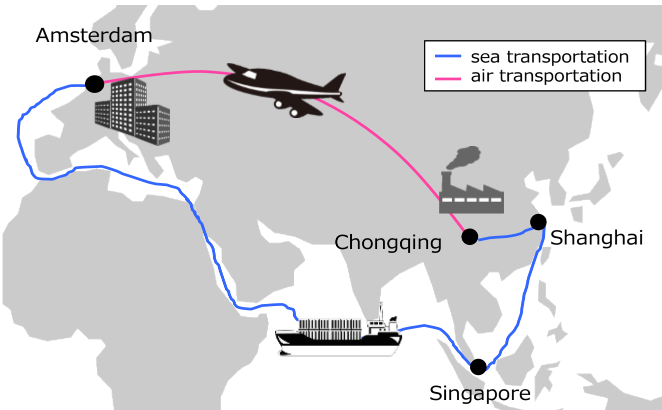

Fig. 5 Transport mode

Table. 2 Air transport parameter

name	value	unit
Price	800000	yen/FEU
Lead time	1	week
Contract term	1	week

Table. 3 yearly sea transport parameter

name	value	unit
Price	100000	yen/FEU
Lead time	5	week
Contract term	12	month

Table. 4:half-year sea transport parameter

name	value	unit
Price	150000	yen/FEU
Lead time	5	week
Contract term	12	month

Table. 5:quarter-year sea transport parameter

name	value	unit
Price	200000	yen/FEU
Lead time	5	week
Contract term	12	month

- **Container parameter**

Containers are globally standardized by ISO depending on its size. We select 40 feet container for transportation in this case study (Table6).

Table. 6:Container parameter

name	value	unit
inner volume	67.7×0.9	m^3
maximum payload	26670	kg

- **Stock keeping parameter**

Nomura calculated stock keeping cost in the previous study and we refer to that parameter. In this case study, we select safety factor as 95% and Z-score is determined (Table.7).

Table. 7:Stock keeping parameter

name	value	unit
stock keeping cost	1000	yen/m^3
Z-score	1.65	-
smoothing factor	0.26	-

3.4 Result

We will show the result of case study in this section. First, Fig.5 shows the best combination under stable demand. Matching the peak of the demand, short term contracts are made. Especially, quarter-term contracts are concentrated on from October to December.

Table. 8:Result of best combination under stable demand

name	container [FTU]	start week	expire week
yearly sea	78	2005/4/3	2006/3/26
half-year sea	68	2005/7/31	2006/1/22
quarter-year sea	302	2005/08/28	2006/11/20

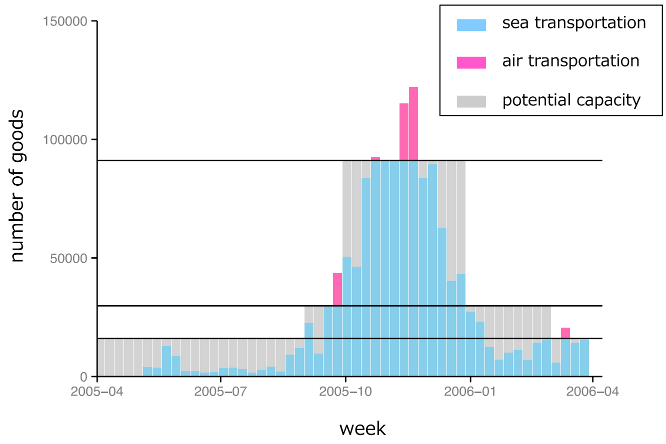

Fig. 5 Best combination under stable demand

Based on this combination, we made combination candidates and evaluated them. In this case study, we increased or decreased the capacity of all of sea transport contracts by 10 percent. Fig.7 shows the result of evaluation of all candidates. From this figure, we can understand 20 percent decrease of sea transportation capacity is the best combination under fluctuating demand. Table.8 shows the combination. With this combination, total cost decreased by 1.7 percent.

Table. 9 best combination under fluctuating demand

name	container [FTU]	start week	expire week
yearly sea	70	2005/4/3	2006/3/26
half-year sea	61	2005/7/31	2006/1/22
quarter-year sea	272	2005/08/28	2006/11/20

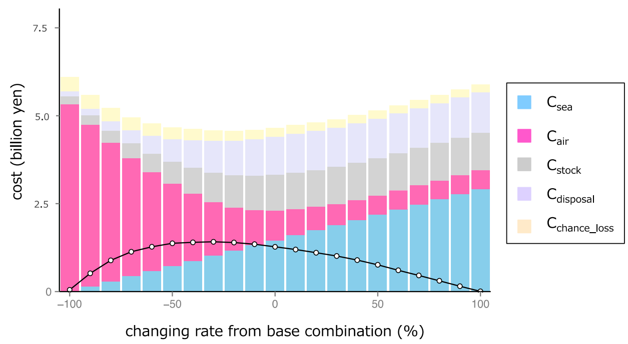

Fig. 6 portfolio of cost

4 Conclusion

In this study, we made best combination of contracts under fluctuating demand. Taking account of the effect of demand fluctuation, the capacity of each sea transportation contract decreased by 20 percent. As a result, total cost decreased by 1.7 percent.

This result shows the superiority of air transportation based on spot contract. In general, transport lead time of air is shorter than that of sea. Thus, air transportation is superior in the case of exponential increase of demand. In addition, spot contract is better under fluctuating demand. Long term contracts tend to generate the excessive capacity that dose not used. On the other hand, spot contract dose not generate these wasted capacity. These two features caused the result. Under today's unstable world economy, demand will fluctuate more, and the importance of air transportation based on spot contract will increase more.

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