INTRODUCING TRAMP AND LINER SHIPPING MODEL TO PRODUCTION PLANNING

Qian Huang[1], Shunichi Ohmori[2], Kazuho Yoshimoto[3]
[1)3)] Department of Industrial and Management Systems Engineering
[1)2)3)] Department of Business Design and Management, Graduate School of Creative Science and Engineering, Waseda University, Tokyo

ABSTRACT

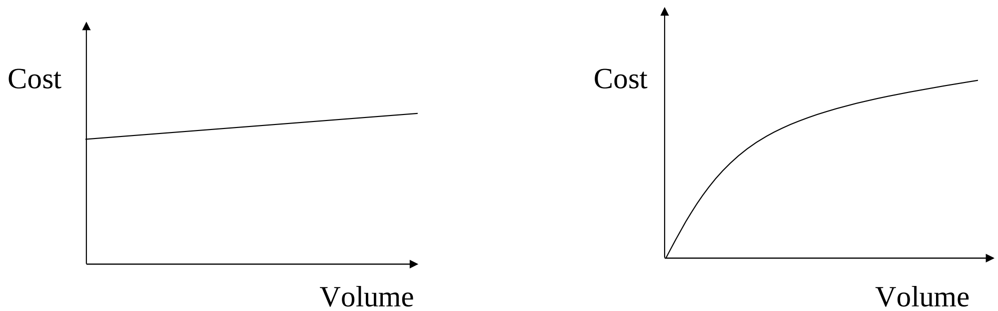
Since the complexity of globalization and the importance of the transportation process, global manufacturers need to consider production planning with complex transportation situation. The constant value of transportation process is not accurate and leads to total cost increasing. Corresponding to different supplying network, appropriate transportation modes with nonconstant value should be considered with production planning simultaneously. The proposed model aims to assist managers to make decisions about production allocation, transportation mode selection, shipping contracts by volume with carriers and vessel companies under a given network. This study develops a global production–shipping planning model that incorporates a decision on transportation mode after considering the cost function of different transportation modes from the shipper's point of view. We propose tramp shipping, liner shipping mode into production-shipping planning, considering transshipment and consolidation to exploit economies of scale under a given network. We present mathematical formulations of tramp, liner modes. In order to verify the effectiveness of the proposed modes, we present a practical case study that is motivated by a real-world example. The two modes are compared and discussed in numerical examples. The advantages and disadvantages of the two modes are discussed in different situations. The result is a decision aided system to support production– shipping planning in selecting the optimal transportation mode.

Keywords: production-shipping planning, maritime transportation, tramp shipping model, liner shipping model

1. INTRODUCTION

Since the complexity of globalization and importance of transportation process, the global manufacturers need to consider the production planning with complex transportation situation. The mode of marine transportation, whether *tramp*, *industrial*, or *liner*, significantly impacts the structure and efficiency of transportation planning (Christiansen et al. 2013). Ship routing and scheduling decisions in industrial and tramp operations are very similar; therefore, they will be discussed together. The shipments do not have fixed routes or predetermined schedules of departure. This is similar to a taxi cab service. Liner vessels follow a fixed route according to a published schedule—similar to a public bus service.

Typically, a shipping service offers volume, or quantity, discounts to their clients to encourage demand for larger, more profitable shipments. Figure 1 presents how economies of scale are considered in each transportation mode. In the tramp shipping mode, a shipper subcontracts the transportation from origin to destination over a specified period and pays a fixed fee to the subcontractor. The shipper's cost is proportional to the shipping volume. This can be modeled as a fixed and variable cost function as described in Figure 1(a). In a liner shipping mode, most commodities are shipped in less-than-full-shiploads. The shipment fee is predetermined by the shipping company, which considers volume discounts. The cost function can be modeled as a concave function as shown in Figure 1(b). Notably, in prior research on production–distribution systems, transportation cost is calculated by the unit cost times the distribution volume. In other words, the unit-price of distribution costs is constant whether the volume is high or low.



(a) Fixed and variable cost function shipping mode

(b) Concave cost function for tramp for liner shipping mode

Figure 1. Cost function in tramp and liner transportation modes

Another important issue is that when liner shipping is used, the route is predetermined, and the shipper must select the path from the origin to the destination from a given set of routes. Therefore, the shipper must simultaneously consider the interplay of economies of scale and routing problems in modeling production and distribution. Further, the shipper can select from among different transportation modes. When tramp and liner shipping are both used, the planner needs to decide which cargo should be transported by which transportation mode.

This study develops a global production–shipping planning model that incorporates a selection of transportation mode, considering the cost function of different transportation modes.

The remainder of this paper is organized as follows: Section 2 includes a review of the relevant literature on production–distribution problems, Section 3 describes the research problem and presents the model. Section 4 discusses the compared models and the results of the numerical experiments. Finally, Section 5 summarizes the conclusions.

2. LITERATURE REVIEW

There are two particular research streams on transportation modes: those on liner shipping and those on tramp shipping.

In liner shipping, one major research area is problems in network design. There is a vast amount of research on problems in transshipment at hub ports (Karlaftis et al. 2009), hub locations (Gelareh et al. 2010), empty container repositioning (Meng and Wang 2011), and fleet allocation (Reinhardt and Pisinger 2012). Another important planning problem in liner shipping is fleet deployment, which is the tactical planning problem of assigning ships to liner routes (Powell and Perakis 1997 and Gelareh and Meng 2010). Lei et al. (2008) studied various degrees of collaboration among container shipping companies. Meng and Wang (2011) developed a container flow simulation model for intermodal freight transportation systems. Boros et al. (2008) studied the problem of determining the optimal cycle time. Lagoudis et al.(2010) presented a model to be used to determine optimal vessel and container fleet size. Ng and Kee (2008) undertook an investigation to simulate the optimal containership sizes from the perspective of ship operators.

In tramp shipping, the major research vein is problems in routing cargo and scheduling. This includes determining the optimal set of routes for a fleet of ships to carry a particular set of cargo. Jetlund and Karimi (2004) presented a model for maximum-profit scheduling of a fleet of multi-parcel tankers engaged in shipping bulk liquid chemicals. Korsvik et al. (2010) proposed tabu-search heuristics. Malliappi et al. (2011) offered a variable neighborhood search. Another, more tactical decision-making problem, is fleet size and composition, which studies how to manage a fleet over time, including decisions about how many ships to buy, sell, charter-in, and charter-out, as well as the timing of these activities in order to meet demand. Recent studies have incorporated inventory decisions into routing, a process called maritime inventory routing, in which an actor has the responsibility for inventory management at one or both ends of the maritime transportation legs and for the ships' routing and scheduling.

This paper makes the following contributions to the above-mentioned research streams.

1. There is a substantial amount of research on ship routing and scheduling problems for liner and tramp shipment modes. These papers, however, plan and optimize shipping and routing from the carrier's point of view under a given transportation mode. They do not compare the linear and tramp shipping modes explicitly from the shipper's point of view. This research discusses the advantage and disadvantage of shipping modes and examines transportation modes under different situations, which is of great interest in practice.
2. While a typical shipment routing and scheduling model assume to serve a given set of cargo from an origin to a destination, our model includes productions decisions in the model; thus, there is flexibility in selecting the plant that will fulfill the demand. This may impact the choice of transportation, because there may be more opportunities to consolidate shipments. None of the prior research has considered this issue.

3. PROPOSED MODEL

3.2 Tramp Shipping Model

We let z_e be the binary variable to take one if the arc e is opened for subcontract and zero otherwise. There is fixed cost f_e and variable cost c_e^T that is proportional to the shipment volume. The cost for edge e is formulated by $f_e z_e + c_e^T x_e$.

The trump shipping model has the following input and decision variables.

Input
- f_e: Fixed shipping cost for arc e
- c_e^T: Unit variable shipping cost for arc e
- d_i: Demand of market e
- q_i: Shipping capacity of plant i
- P_{ei}: Incidence matrix
- Q: very large number

Decision variable
- x_e: Shipping volume for arc e
- y_i: Production volume for plant i
- z_e: Binary variable to take one if arc e is opened

The formulation is as follows:

minimize	$\sum_{e\in E_T}(f_e z_e + c_e^T x_e)$		(1a)
subject to	$\sum_{e\in E_T} P_{ei}x_e + y_i = 0 \;\forall i \in V_S$		(1b)
	$\sum_{e\in E_T} P_{ei}x_e - d_i = 0 \;\forall i \in V_C$		(1c)
	$x_e \le Q z_e$	$\forall e \in E_T$	(1d)
	$y_i \le q_i$	$\forall i \in V_S$	(1e)
	$x_e, y_i \ge 0$	$\forall i, \forall e$	(1f)
	$z_e \in \{0,1\}$	$\forall i, \forall e$	(1g)

Objective function (1a) is total shipping cost. Constraints (1b) requires the flow conservation for the plant node. Constraints (1c) requires the flow conservation for the market node. Constraints (1d) requires that the total shipping volume for each arc can be positive only if the arc is opened. Constraints (1e) requires the total shipping volume from each plant is less than or equals to its capacity. Constraints (1f) requires that shipping and production volume is nonnegative. Constraints (1g) requires that Z_e should be binary variable.

3.3 Liner Shipping Model

There is no fixed cost. Typically, liner shipping service offer volume, or quantity, discounts to their clients to encourage demand for larger, more profitable shipments. The cost can be modeled as the concave cost function $C_e^L \sqrt{x_e}$.

The liner shipping model has the following input and decision variables.

- Input
  - c_e^L: Unit shipping cost from supplier i to market j
  - d_i: Demand of market i
  - q_i: Shipping capacity of supplier i
  - P_{ei}: Incidence matrix
- Decision variable
  - x_e: Shipping volume for arc e
  - y_i: Production volume for supplier i

The formulation is as follows:

Minimize	$\sum_{e\in E_L} c_e^L \sqrt{x_e}$		(2a)
subject to	$\sum_{e\in E_L} P_{ei}x_e + y_i = 0 \;\forall i \in V_S$		(2b)
	$\sum_{e\in E_L} P_{ei}x_e - d_i = 0 \;\forall i \in V_C$		(2c)
	$y_i \le q_i$	$\forall i \in V_S$	(2d)
	$x_e, y_i \ge 0$	$\forall i, \forall e$	(2e)

The objective function (2a) is the total shipping cost. Constraint (2b) sets the flow conservation for the plant node. Constraint (2c) sets the flow conservation for the market node. Constraint (2d) requires that the total shipping volume to each market equals the requested demand. Constraints (2e) requires that shipping and production volume is nonnegative.

4. NUMERICAL EXAMPLES

4.1 Test Problem Description

We consider a test problem motivated by a real-world manufacturing company. The models are applied to a network consisting of five factories and twelve markets. The five factories are in Osaka, Shanghai, Hochimin, Bangkok, and Port Klang. The twelve markets are in Tokyo, Pusan, Qingdao, Hong Kong, Yangon, Mundra, Chennai, Singapore, Jakarta, Manila, Sydney, and Auckland. The plants are represented by boxes and the markets are represented by circles. The flow of a commodity via tramp shipping is represented by an arrow with a solid line, and the flow of a commodity via liner shipping is represented by an arrow with a dashed line.

4.2 Results of Numerical Experiments

Table 1 and Table 2 shows the total costs and production allocation of each scenario respectively. Figure 2, Figure 3 shows the supplying flows from plants to markets under liner and tramp shipping modes.

Table 1. Cost construction and total cost of each scenario ($100)

Cost Item	Tramp	Liner
Fixed Cost	53.7	0
Variable Cost	5.9	61.7
Total Cost	59.6	61.7

Table 2. Production allocation of each scenario (units)

Node	Name	Tramp	Liner
1	Osaka	33	45
2	Shanghai	53	53
3	Hochimin	24	12
4	Bangkok	49	43
5	Port Klang	24	30

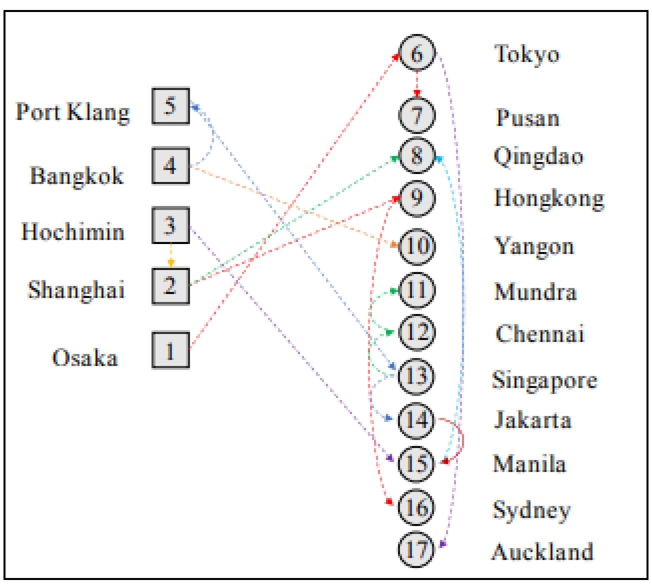


Figure 2. Result of liner shipping network

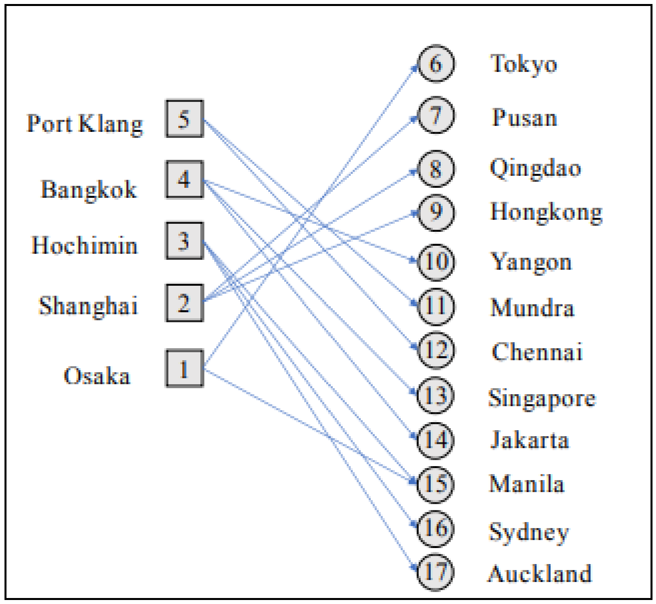


Figure 3. Result of tramp shipping network

Figures 2, 3 indicate that the plant from which the demand is sourced is also different among the scenarios. For example, Auckland (j =17) is sourced from the Hochimin plant (i =3) via arc e = 36 in the tramp mode; whereas, it is sourced from the Osaka plant (i =1) via arc e = 1 and e = 77 in the liner transportation modes.

The total product volume produced in plants changes with transportation modes, which also affects product supplying. The market demand is same for both the liner and tramp shipping network. However, the optimal supply flows change because different shipping modes have different cost functions.

Consequently, the total costs change with changes in transportation mode. The case presented indicates that as with all matters of logistics, a one-size-fits-all approach will end in failure in some situations. As shipping volume grows, the tramp shipping may be more appropriate and vice versa. The proposed mixed model can help select the correct shipping mode for each from–to cargo situation, considering transshipment and consolidation to exploit the economies of scale under a given network.

5. CONCLUSIONS

This paper has proposed a global production–shipping planning model that incorporates the selection of transportation mode that considers the cost function of different transportation modes. The formulation of the model addresses some of the complex issues related to the fixed and variable cost function of tramp shipping and the nonlinear cost function of liner shipping. The results put the focus on production planning that considers tramp, liner shipping modes from the shipper's point of view.

In the complexity of globalization and the importance of transportation processes, global manufacturers need to consider complex transportation networks in production planning. Estimating the costs of transportation can be inaccurate and can lead to higher total costs. Selecting a single transportation mode is not enough in the complex global environment. Therefore, this study considers multiple transportation modes and varying unit-transportation costs in production–shipping models. The results showed that tramp shipping is outstanding when the fixed and variable costs of tramp shipping are cheaper; liner shipping is outstanding when the fixed and variable costs of tramp shipping are higher; the fixed and variable costs of tramp shipping are not cheaper or higher. The proposed model aims to assist managers make decisions about production allocation, transportation mode selection, shipping contracts by volume with carriers and vessel companies under a given network.

For future work, inventory decision should be extended to simultaneously consider production planning in a multi-period model to acquire more economies of scale. Another extension of the model relates to a consideration of production costs. The rate of production and transportation cost would change the production allocation and transportation modes. Also, numerical examples could be expanded to land and air transportation in other practical case studies, which is an ongoing extension of this study.

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