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Outsourcing and Optimization of Logistics Services for Chemical Companies

Mukta Bansal, Iftekhar A. Karimi, Rajagopalan Srinivasan

Department of Chemical and Biomolecular Engineering, National University of Singapore. 4 Engineering Drive 4, Singapore 117576.
Email: mukta@nus.edu.sg; cheiak@nus.edu.sg; chergs@nus.edu.sg

Abstract

Logistics plays a crucial role in chemical supply chains. In today's global trade environment, companies are looking for ways to lower costs in order to remain competitive. To this end, many chemical companies are increasingly outsourcing a variety of their logistics services to third-party logistics (3PL) firms in the same or other countries. This has resulted in a steady increase in the use of 3PL service-providers in the chemical sector. The objective of this paper is to model the outsourcing of various logistics services in terms of contracts offered by various 3PLs for various individual and bundled tasks. Our goal is to obtain the optimal contracts, and thus the 3PLs, that serve the total needs of the company in an integrated manner. The problem is formulated as a multi-period mixed integer linear programming (MILP) problem.

Keywords: Logistics; 3PLs; contracts; supply chain; chemical

1. Introduction

Companies are looking for ways to lower costs in order to remain competitive. In chemical companies, around 20% of the supply chain costs comes from logistics. To reduce this cost and to focus on core competency of chemical manufacturing, companies are increasingly outsourcing a variety of their logistics services to third-party logistics (3PL) firms in the same or other countries. However, outsourcing of services differs from the outsourcing of manufacturing, since the services are (Zeithaml et al. [3]): intangible, heterogeneous, inseparable and perishable. Some examples of the services provided by the 3PL firms to chemical companies are transport, terminaling, and storage of chemicals (feed, intermediate, products), blending, mixing, drumming, containerization, order management (documentation, customs clearance, etc.), marking, labeling, sampling, packaging, distribution, etc. Fig. 1. shows the schematic representation of demand sites, production sites, and packaging sites with different alternatives for shipping.

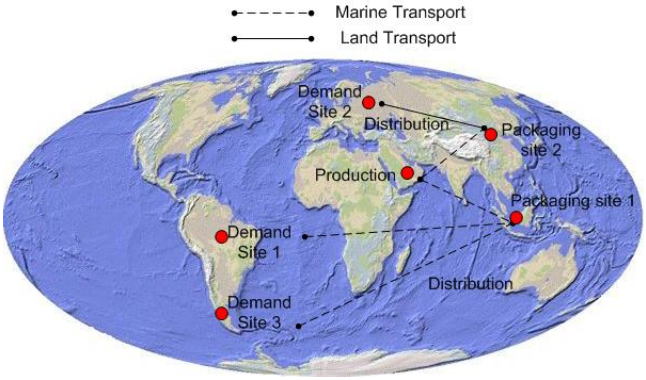

Fig. 1. Schematic representation of demand, production, and packaging sites

Many chemical companies prefer long term contracts with their logistics provider. A logistics service contract is an agreement between a company and a 3PL for a fixed duration which comprises certain terms and conditions. Contracts differ in features such as services, carrier, mode of transportation, equipment, reputation, speed, freight, pricing, flexibility, lead time, terms, conditions, durations, etc. In such a scenario, selecting logistics contracts and 3PLs is a complex problem that has received little attention in the literature. Therefore, it is very important to develop a method to critically evaluate and select contracts for 3PLs. The objective of this paper is to model the outsourcing of various logistics services in terms of contracts offered by various 3PLs for various individual and bundled tasks. The logistics contracts are designed to fulfill partial or full bundles of various logistics needs, tasks, and services, which can be performed at globally distributed places by various 3PLs. In this paper, we address the contract selection problem from the perspectives of a chemical company that signs one/multiple contracts with Logistics Company to fulfill their logistics needs.

Tay et al. [2] has divided the services provided by the 3PL firms to chemical companies into three broad categories: Tank Storage, Land Logistics and Integrated Logistics. They have solved the problem of selecting contracts and allocating tanks to contracts in a storage terminal to maximize profit. However, the problem of selecting contracts for Land and Integrated Logistics still remains unsolved.

2. Problem Description

Consider a chemical MNC with plant sites ($s = 1, 2, 3, \ldots, S$) located all around the world. Plant Site may be a production site (j), hub (l) or it may be a demand site (i). The logistics department of the company is responsible for contracting 3PLs for the logistics services that the company needs. The logistics department collects the demands of all materials ($m = 1, 2, \ldots, M$) and the list of tasks ($k = 1, 2, \ldots, K$) that are required for all materials.

The logistics department invites 3PLs to propose contracts. The logistics contracts are designed to fulfil partial or full bundles of various logistics needs, tasks, and services, which can be performed at globally distributed places by various 3PLs. 3PL firms propose contracts and each contract (c) has the following attributes

- Length of contract (CL_c)
- List of tasks provided by contract (k_c)
- Cost associated with each task. If the task is of site-to-site category then contracts will specify transportation cost ($TC_{mcss'}$) for material m in contract c from site s to site s'. If the task is of single site category then cost associated with k task for material m in contract c at site l is expressed as OC_{kcsl}

Various options are available and logistics department analyzes these options and hence, contracts and select the optimal options (contracts).

3. Methodology

We replace each 3PL by all the contracts that it offers. Thus, the problem of selecting 3PLs becomes that of selecting individual contracts. As discussed earlier, each contract has a fixed length, but its exact start/end times are variable. Because logistics decisions are generally long-term, we assume that all contract lengths are multiples of one or more months or quarters, as a finer time resolution is unnecessary. This enables us to use a uniform discrete-time representation and define the planning horizon to comprise T periods (t = 1, 2, …, T) of equal lengths. The horizon begins with time zero.

3.1. MILP Formulation

With the above simplifications, the primary decision for the MNC is to select the best contracts from the pool of all contracts of various durations and from various 3PLs, and determine their start times for doing the task. To model these decisions, we define the following binary variables

$$ys_{ct} = \begin{cases} 1 & \text{if contract } c \text{ begins at the start of period } t \\ 0 & \text{otherwise} \end{cases}$$

$$z_c = \begin{cases} 1 & \text{if contract } c \text{ is selected} \\ 0 & \text{otherwise} \end{cases}$$

The above two variables are related by,

$$z_c = \sum_t ys_{ct} \tag{1}$$

Because a contract can begin at most once during the planning horizon, and if selected, it must begin some time. Eq. 1a allows us to treat z_c as a continuous 0-1 variable. We impose an upper bound of 1.0 on z_c.
Knowing the length of each contract, the above binary variable allows us to see if a given contract is in effect during a period using the following 0-1 continuous variable.

$$y_{ct} = \begin{cases} 1 & \text{if contract } c \text{ is in effect during period } t \\ 0 & \text{otherwise} \end{cases} = \sum_{t-CL_c+1}^{t} ys_{ct} \tag{2}$$

The MNC must decide which task is to be done through which contract on which material. Let $F1_{mcss't}$ denote the amount of material m shipped under contract c from site s to destination site s' in time period t and FF_{kmclt} denote k task is done on material m under contract c at hub site l in time period t.
Clearly, if the contract c is not in effect in time period t, then the amount on which any task is done under that contract will be zero. Hence,

$$F1_{mcss't} \le F^U y_{ct} \tag{3a}$$

$$FF_{kmclt} \le F^U y_{ct} \tag{3b}$$

A contract c specifies minimum amount on which task is done (Q^L) if a contract is selected. Hence,

$$F1_{mcss't} \ge Q^L y_{ct} \tag{4a}$$

$$FF_{kmclt} \ge Q^L y_{ct} \tag{4b}$$

The Logistics Department collects the demands of all materials at all plant sites. D_{mit} represents the demand of material m at demand site i in time period t. Thus, the amount of material m shipped through all contracts from various hub sites to demand site i in time period t plus the remaining inventory from the last time period must exceed demand. Hence,

$$D_{mit} \le \sum_{c,l} F1_{mclit} + I_{mit-1} \tag{5a}$$

Also, amount on which task k is done on material m under all contracts at all hub sites l in time period t plus the remaining inventory from the previous time period must exceed demand of material m at site i in time period t. Hence,

$$D_{mit} \le \sum_{c,l} FF_{kmclt} + I_{mit-1} \tag{5b}$$

Note that the above eq. 5b will be written for all the tasks (services) required on material m.
Amount of material m shipped from production site (j) to all hub sites (l) through any contract cannot exceed the amount produced at site (j) in any time period. Let V_{mjt} is the amount of material m produced at production site j in time period t.

$$V_{mjt} \ge \sum_{c,l} F1_{mcjlt} \tag{6}$$

Amount of material m shipped in under all contracts from all site to hub site l in any time period t is equal to the amount of material m shipped out under all contracts from that site to all sites. Hence,

$$\sum_{c,s} F1_{mcslt} = \sum_{c,s} F1_{mclst} \tag{7}$$

Also, the amount of material m on which task k is done under all contracts at site l in time period t cannot exceed the amount of material m shipped to that site l. Hence,

$$\sum_{c} FF_{kmclt} \le \sum_{c,s} F1_{mcslt} \tag{8}$$

Finally, we compute the total logistics cost as,

$$Cost = \sum_{m,c,s,s',t} F1_{mcss't} TC_{mcss'} + \sum_{k,m,c,l,t} FF_{kmclt} OC_{kmcl} + \sum_{m,i,t} I_{mit} h_m$$

This completes the formulation.

3.2. Example

A plant in Belgium produces two products, A and B. The demand is in Thailand. Product A requires packaging and labeling, while B requires containerization. Thirteen contracts have been offered to the companies by several 3PLs for packaging, labelling, shipping, and containerization at five locations. First contract offers shipping, labeling and packaging for A. Second contract offers only packaging at site 2. Third contract offers only labelling at site 3. Similarly other contracts offers one or bundled tasks and locations for those tasks. The company wishes to select a set of contracts that fulfill its total logistics needs at the minimum cost. The schematic representation of the example for contract selection and location selection for A is shown in Fig. 2.

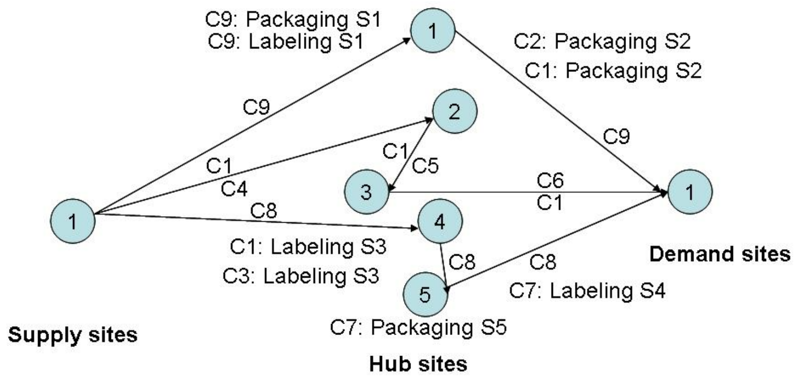

Fig. 2. Schematic representation of the example

Our MILP model for this problem has 23 binary variables, 514 constraints, and 279 continous variables, and it required 0.2 s of CPU time on 3 GHz Pentium® PC with 1.99 GB of RAM using GAMS 22.2 (Brooke et al. [1]) / Cplex 10.0 solver. Admittedly, this is a very small problem, so the solution is very fast. However, as we know, solution time can grow very rapidly for an MILP. In fact, it is good that this deterministic model is computationally fast, a stochastic model to address real-life uncertain data and scenarios will embed many such models, and a fast deterministic model will be of great help.

4. Conclusion and Future work

We have presented a MILP model for min-cost outsourcing plan for integrated logistics. Currently we are working on larger problems, whose results will be reported during the presentation. We plan to extend this model to stochastic environment where various business and economic data could be uncertain. We will report our experience during the presentation. We also plan to incorporate inventory at production sites and hub sites.

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