

Transportation Planning by SBIDS : Optimal Assignment of Carriers to Lanes

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Abstract:

For product distribution, shippers often rely on carrier services. The goal of selecting right carrier services is to deliver the products in a prompt and most economical way. In this paper, we describe an optimization problem for shippers to select carrier services, and show a solution method to optimally assign delivery lanes to carriers. In particular, we introduce the carrier selection model and describe solution methodology based on a mixed integer program. We have implemented the proposed solution method as a software system, called SBIDS, and we show some case studies where SBIDS saved the substantial transportation costs.

1. Carrier Selection Problem

First, we describe the carrier selection problem. Suppose a manufacturing company manages a distribution network either internally, or with help from a 3PL (third party logistics, i.e. logistics consulting company). Its distribution network mainly consists of plants, distribution centers (DC) and customer sites. Sometimes it may involve raw material purchase locations as well. The company uses a number of vehicles owned and/or managed by different carriers to deliver the products throughout its distribution network.

Shippers, typically manufacturing and distribution companies, need to ship products from their plants to distribution centers, and from distribution centers to customer sites using carrier services. Contracts with carriers are typically negotiated by the headquarter department for the entire company. The process of such negotiation starts with creation of a demand profile for shipper's future shipment, and then gives rise to solicitation of bids for carrier services. Once the carrier bids are in, shippers can select the combination of carrier services to cover the entire transportation network at the best cost. The actual negotiation with carriers may take place subsequently and may be repeated until the right combination of services and prices are agreed.

Some carriers may serve customers in a relatively small region around selected plants (e.g., short line hauls by regional carriers), or others may cover the entire nation (e.g., long line hauls

by national carriers). For TL (truck load, i.e. the whole truck is used for one customer's shipment) cases, each carrier's price structure may depend on whether its service is dedicated (non-reloadable) to a particular plant, i.e. serving only that plant, or non-dedicated (reloadable); i.e. pick-ups and delivers may be mixed with other customers' loads. In each case, a price per mile for a truckload is quoted together with various accessorial charges. For LTL (less-than-truck load, i.e. a truck is shared by multiple customers in a mixed load) cases, the prices may be given for each weight bracket (i.e., a range of weight, such as less than 1000 lb. or between 1000 and 5000 lb., etc.) and class (i.e., a classification of loads to distinguish certain characteristics). Shippers need to take into account such carrier characteristics when they select carrier services. Once the decisions are finalized, shippers need to implement the new contracts at the plant and DC levels, since plant and DC managers are the ones who make daily shipment decisions based on the contracts.

Most shippers keep track of historical shipment records, which contain such information as dates and time, amounts of shipment, product description, origins and destinations, carrier names and the associated costs. By extracting what is essential for carrier selection problem from such historical records, we create so-called **transactions**. Below we show examples of transactions.

Lane_No	O_City	O_State	D_City	D_State	Class	Weight	Plant	density	Carrier_1	density	cost	Carrier_2	density	cost
1	AAASAW	AL	BBBTON	MN		55	10000	BBBTON_MN	1	RoadWay1	1			115
2	AAATUR	AL	RRRTON	GA		85	2000	RRRTON_GA	1	RedStar	1			100
3	AAATUR	AL	CCCROI	PA		60	2000	CCCROI_PA	1	CF	1			70
4	BBBILE	AL	CCCSAINT	IL		60	500	BBBILE_AL	5	RedStar	5			200
5	BBBILE	AL	CCCSAINT	IL		60	2000	BBBILE_AL	1	Central	1			83
6	BBBILE	AL	CCCSAINT	IL		60	5000	BBBILE_AL	2	Central	2			405
7	BBBILE	AL	CCCSAINT	IL		60	10000	BBBILE_AL	2	RedStar	2			469
8	BBBILE	AL	CCCSAINT	IL		70	500	BBBILE_AL	1	RedStar	1			40
9	BBBILE	AL	CCCSAINT	IL		70	5000	BBBILE_AL	1	CF	1			70
10	BBBILE	AL	RRRFORD	IL		60	500	BBBILE_AL	3	RedStar	3			120
11	BBBILE	AL	SAUGET	IL		60	500	BBBILE_AL	1	RedStar	1			40
12	BBBILE	AL	SAUGET	IL		60	5000	BBBILE_AL	39	Central	39			5595
13	BBBILE	AL	STERLING	IL		60	500	BBBILE_AL	3	RedStar	3			120
14	BBBILE	AL	STERLING	IL		60	1000	BBBILE_AL	7	RoadWay1	7			737
15	BBBILE	AL	UUUPARK	IL		60	500	BBBILE_AL	1	RedStar	1			40
16	BBBILE	AL	VVVYAYLORS	IL		60	2000	BBBILE_AL	1	RedStar	1			64
17	BBBILE	AL	VVVYAYLORS	IL		60	5000	BBBILE_AL	1	RoadWay1	1			185
18	BBBILE	AL	WESTVILLE	IL		60	500	BBBILE_AL	1	RedStar	1			40
19	BBBILE	AL	BBBTOWN	IN		60	5000	BBBILE_AL	3	RedStar	3			144
20	BBBILE	AL	BBBTOWN	IN		60	10000	BBBILE_AL	3	RedStar	3			1551
21	BBBILE	AL	BBBTOWN	IN		999	10000	BBBILE_AL	7	CF	7			542
22	BBBILE	AL	BBBTOWN	IN		999	20000	BBBILE_AL	5	CF	5			1139
23	BBBILE	AL	BOONVILLE	IN		60	500	BBBILE_AL	1	RedStar	1			40
24	CCAXIS	AL	RRRTON	GA		55	500	RRRTON_GA	1	RedStar	1			40

Figure 1: Sample for Transactions

Transactions can be further summarized into **lanes**, which can be defined as origin/destination pairs with additional information such as frequencies and shipment amounts. Given such lanes

as a potential profile for future transportation demands, shippers may request bids from carriers on the potential services for the lanes.

Shippers need to minimize the total line haul costs for a planning period (e.g. a year) based on bids from different carriers, while satisfying the constraints on outbound / inbound loads from / into plants. There are numerous such constraints, including

- Limiting total number of carriers per plants
- Maximum density percentage for carriers at plants
- Dedicating carriers to plants (TL only)
- Dedicating carriers to lanes (TL only)

The carrier selection problem is to find a best combination of carrier services to cover all the lanes, given the future transportation demands and operational constraints. To solve this problem, we developed an optimization model and a solution method. In the next section, we introduce a carrier selection model to further explain the basic elements and the operational constraints.

2. Carrier Selection Model Components

2.1 Plants, Lanes and Sites

Usually, as described above, shippers have historical shipment records for orders taken at each plant. The total number of orders is called an annual load or density. Monthly or daily breakdown of this number may also be available. Each distinct origin-destination (which may be plant-to-DC, plant-to-customer, or DC-to-customer) combination becomes a lane. Mode-specific features, such as equipment types, weight brackets, service classes, can be added further to define lanes. The origins of lanes are typically manufacturing plants or DC's, and the destinations of lanes are typically DC's and customer sites.

2.2 Carrier Bids

Once the lanes are generated, they are grouped by plants and submitted to a number of carriers for bidding. For TL cases, each carrier is required to provide three numbers: (1) Reloadable (non-dedicated) price per mile per load for each lane; (2) Non-Reloadable (dedicated) price per mile per load for each lane; and (3) maximum level of participation, i.e., percentage of annual load it is able/willing to handle. For LTL cases, each carrier may submit two numbers, a bid for a combination of weight bracket and class, and a transit time (i.e. elapsed time on each lane).

2.3 Carrier Selection by Plants

After the bids are collected, we need to optimally assign carriers to lanes, and display the number of loads covered and the line haul cost for each lane. While bids are optimized, we need to take into account additional assumptions on carrier selection. They include:

- Selecting and/or deselecting certain carriers for some plants
- Forcing maximum and/or minimum number of lanes and densities given to certain carriers
- Forcing regional consideration while selecting carriers
- Consideration for transit times (LTL only)
- Bundling certain lanes for specific carrier bids

Since carrier selection is a negotiation process, carriers often give various conditions and special offers to attract shipper's decision. In most cases, such conditions can be modeled mathematically. We call the above problem the lane assignment problem, and the solution to this problem is a key element of carrier selection process. Next, we describe our solution approach to the lane assignment problem.

3. Solution Methodology

The lane assignment problem can be formulated as a mixed integer program (often called MIP), which consists of numerous linear equations representing various operational constraints and an objective function (to be minimized) representing the total line haul cost of carrier assignment. In particular, the binary variables indicate if each carrier is selected for assignment. A set of linear equations are generated to handle such parameters as the maximum number of carriers for each plant, and their minimum or maximum percentage of assignment. In addition, we set the objective function by calculating the potential cost of assigning one carrier to each lane for the target plant. The developed mixed integer program can be solved by a mathematical programming package.

To manage the carrier selection process efficiently, the shippers and 3PL consultants need to handle significant amount of data, including transactions, lanes and carrier bids. In addition, once the necessary data are gathered, they need to solve the lane assignment problems quickly, and then show the results in an efficient manner to analyze various options. Furthermore, to facilitate shipper's decision, we need to provide a detailed solution breakdown for plants, such as the total cost per carrier per plant, the total plant cost and loads covered, and the total lane coverage. Based on such needs for an operational tool, we have developed a software system, named SBIDS (Smart Bids Optimization System).

SBIDS is an optimization-based decision support system for managing carrier selection

problems. It determines optimal assignment of carriers to lanes, originating (outbound) and/or terminating (inbound) in a set of plants (hubs). While optimizing the total transportation cost, SBIDS takes into account mode-specific bidding structures, such as reloadable vs. non-reloadable bids for TL, and per-weight brackets and classes for LTL, levels of participation (percentage of lanes carrier is willing to commit to), and other operational constraints. It performs “what-if” analyses on number of carriers to be used, prices per lane haul, and levels of carrier commitment to serving plants. It also demonstrates trade-offs between the total transportation costs and service levels.

4. Output Reports

The SBIDS’s optimization results can be viewed in various modes. Report files are created for displaying assignment of carriers to all the lanes sorted by plants. The cost information is also given in such a report.

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II. Lane - Carrier Assignment

Plant: BBBILE_AL

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Lane(Org)	Orign	Destin	Class	Wgt	Dens	Carr 1(dns)	Cost	Transit	
4	4	BBBILE, AL	CCCSAINT, IL	60.0	500	5	Central(5)	1	0
5	5	BBBILE, AL	CCCSAINT, IL	60.0	2000	1	Central(1)	83	0
6	6	BBBILE, AL	CCCSAINT, IL	60.0	5000	2	Central(2)	405	0
7	7	BBBILE, AL	CCCSAINT, IL	60.0	10000	2	TedStar(2)	469	1
8	8	BBBILE, AL	CCCSAINT, IL	70.0	500	1	PathWay(1)	5	0
9	9	BBBILE, AL	CCCSAINT, IL	70.0	5000	1	DF(1)	13	3
10	10	BBBILE, AL	RRRFORD, IL	60.0	500	3	PathWay(3)	12	0
11	11	BBBILE, AL	SAUGET, IL	60.0	500	1	TedStar(1)	0	1
12	12	BBBILE, AL	SAUGET, IL	60.0	5000	39	Central(39)	5595	1
13	13	BBBILE, AL	STERLING, IL	60.0	500	3	TedStar(3)	28	1
14	14	BBBILE, AL	STERLING, IL	60.0	1000	7	PathWay(7)	737	1
15	15	BBBILE, AL	UUUPARK, IL	60.0	500	1	PathWay(1)	2	1
16	16	BBBILE, AL	VVYTAYLORS, IL	60.0	2000	1	TedStar(1)	64	1
17	17	BBBILE, AL	VVYTAYLORS, IL	60.0	5000	1	PathWay(1)	185	2
18	18	BBBILE, AL	WESTVILLE, IL	60.0	500	1	Central(1)	1	1
19	19	BBBILE, AL	BBBTOWN, IN	60.0	5000	3	TedStar(3)	130	1
20	20	BBBILE, AL	BBBTOWN, IN	60.0	10000	3	TedStar(3)	1551	1
21	21	BBBILE, AL	BBBTOWN, IN	999.0	10000	7	DF(7)	524	3
22	22	BBBILE, AL	BBBTOWN, IN	999.0	20000	5	DF(5)	1139	3
23	23	BBBILE, AL	BOONVILLE, IN	60.0	500	1	TedStar(1)	1	2

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total cost = $ 10945

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Figure 2: Sample Carrier Assignment Report

The above shows detailed assignment results for lanes at a particular plant. All the assignment results can be summarized as well.

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**  SBIDS: Carrier Selection Optimization Results (ID: SIATECH on 10/14/02) **
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I. Carrier Assignment

no	name	asg_lane	asg_dens	cost
1	PathWay	8	16	\$ 1093
2	DF	6	16	\$ 1891
3	Orange	0	0	\$ 0
4	TedStar	12	19	\$ 2613
5	Central	6	49	\$ 6512
6	base_case	0	0	\$ 0

	- total -	32	100	\$ 12111

Figure 3: Sample Summary Report

The above result shows the total cost of \$ 12,111 by using four carriers (Pathway, DF, TedStar, Central). Please note that the above case is a hypothetical example, as the actual transportation costs are typically in the range of million dollars and may involve dozens of carriers.

In addition to the text reports, the lane assignment can be displayed on a mapping system (GIS). Below is an example, where we show the assigned lanes in different colors for different carriers at a selected plant:

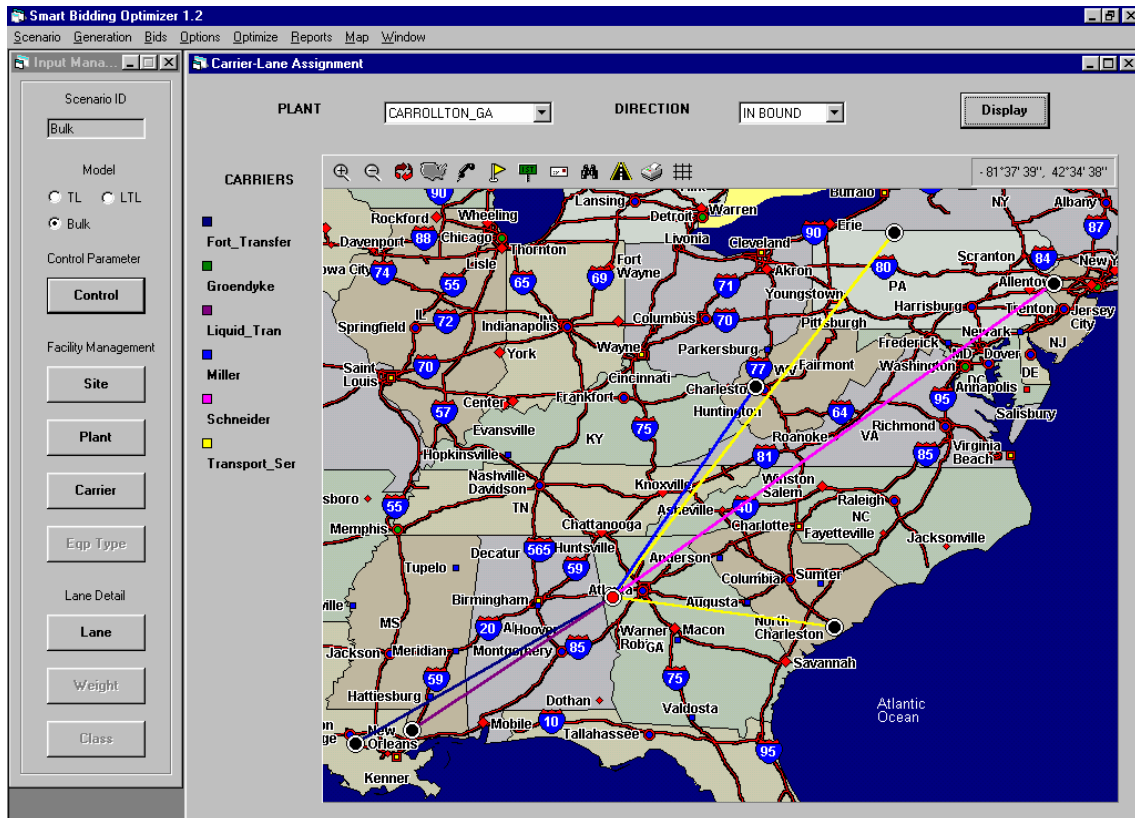


Figure2: Sample screen of SBIDS output

5. Case Studies

SBIDS has been applied to various real cases, and shippers have saved substantial amounts of transportation costs by using SBIDS's optimization capabilities. Here are some actual examples:

- 5.1 A large manufacturing company in mid-west makes paints and coatings at more than 80 locations in North America with the annual sales of more than \$ 1 billion. This company, with a help of 3PL consultants, used the SBIDS bulk model in 1999, and created a few thousand lanes. The bid solicitation was sent to more than 20 carriers. After the bid optimization by SBIDS, this company selected 3~4 (or less) carriers at each plant, and saved about 15 % of the total transportation cost.
- 5.2 Four shippers on the east coast combined their shipping demands and jointly solicited for LTL carrier bids. A 3PL consulting company coordinated the joint efforts, and generated close to ten thousand lanes by the SBIDS LTL module. After lengthy negotiations and many what-if analyses by SBIDS, the four companies saved between 5 and 10 % of the total transportation costs with new contracts with selected carriers.

5.3 A manufacturing company in a mid-Atlantic state had 10 plants and a few hundred customers to delivery the chemical products. The company was using dozens of carriers for product shipment before the carrier selection optimization. The company generated more than one thousand lanes using the SBIDS bulk module, and sent bid solicitation to thirty carriers. After careful analysis and negotiations, the company selected one carrier for all the transportation needs, and saved close to 20% of the total transportation cost.

6. Conclusion

In this paper, we described a carrier selection and lane assignment problem. An optimization model and a solution approach have been developed, and it has been implemented as a decision support system. Numerous companies benefited from the software and associated consulting services, and saved 5 to 20 % of the annual transportation costs.