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SOLVING DISTRIBUTION PROBLEMS IN SUPPLY CHAIN WITH TAX IMPLICATIONS

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ABSTRACT

Companies are becoming increasingly aware of the importance of improving their supply chains. The coordination and integration of production (supply), inventory, and distribution (demand) operations is widely perceived to be a route to obtain a competitive advantage. Solutions will be presented for the class of models:1) Single Supply Location and Multiple Demand location with Deterministic Models, 2) Multiple Supply locations and Multiple Demand location through Distributors or Dealers, 3) Problem 1) and 2) with (Capacitated) vehicle routing and 4) All the above with Tax implications. As in most NP-hard problems, three approaches are typically employed to solve these types of problems: heuristics, approximation methods and exact methods. Computational experience of solving illustrative cases is presented.

Introduction

Traditionally, firms have focused their energies on three main functions: purchasing, manufacturing, and distribution. Transport and storage activities within individual functions and across functions have not received adequate attention, and have usually been handled by the department managing the logistical aspects of the company. Challenges in product distribution, which is the downstream activity of the Supply Chain of a company, are becoming more and more complex due to increase in product variety, shorter product life cycle, demand fluctuations, excessive transport cost, and Tax levied across the distribution channels. In this paper, the Tax implication in the distribution system is considered. The problem is mathematically formulated for a variety of cases and solved. Computational experiences are reported.

Lei Lei, et al. (2006), Fabio Nanino and Roberto Panizzolo (2007), and Rosenfield and Little (2007) have reported a different versions of the distribution problems and solution methods. However, no literature addressed the distribution problem with Tax implications.

Problem statement

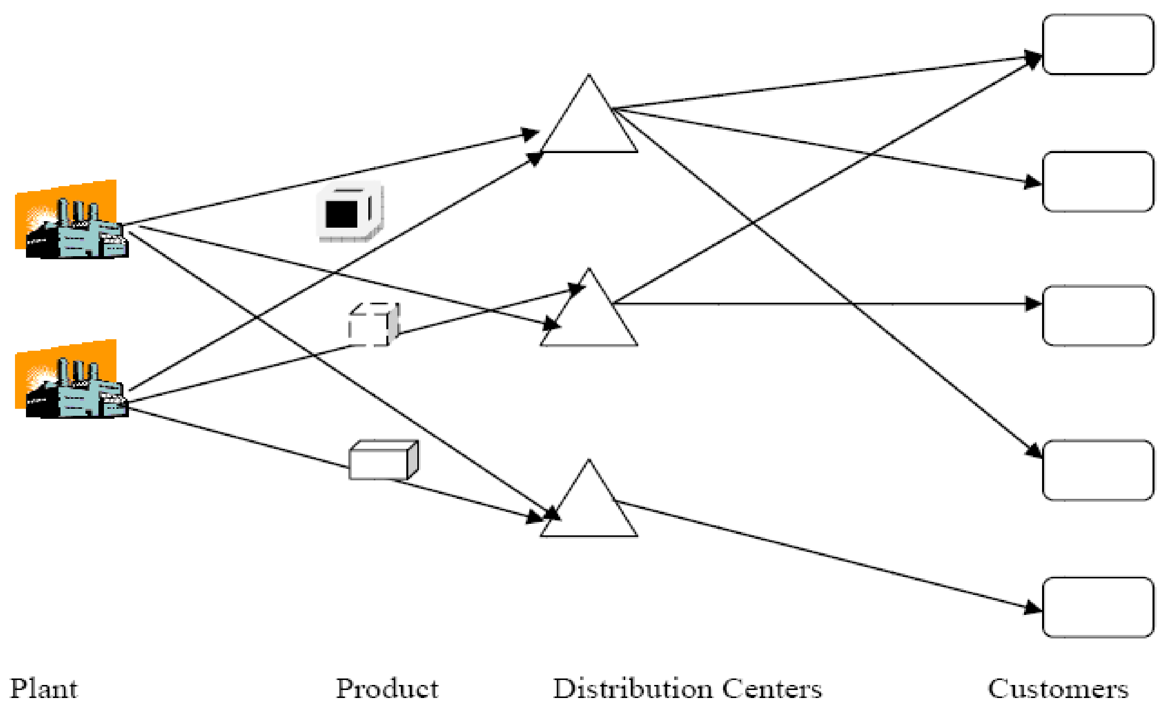
Consider a variety of products manufactured at plants located at various sites. These products will be supplied to stores through the distributors. The number of plants, distributors and the stores are assumed to be a known constant. The locations of these facilities are also known.

While the products are being transferred within the state and interstate transfer, certain Tax will be levied. Given the production capacity of each plant and the demand for each product, it is required to optimize the sum of primary and secondary transport cost and the Tax levied. Whenever there is change in Tax policy then the problem turns to optimizing the number and location of the distributors to make the business competitive.

Mathematical Model

Two models are presented: one without Tax implication and the other with Tax implication.

The following network diagram shows the supply chain with plants, distribution centers and stores that deals with production and distribution of multi products (SKUs).



Notations:

m=No. of plants
n=No. of DCs
a=No. of stores
k=No. of SKUs
d_{ij}=distance from i^{th} plant to j^{th} DC
d^1_{ij}=distance from i^{th} DC to j^{th} store
A_{ik}=production capacity of k^{th} SKU at i^{th} plant
B_{jk}=demand of k^{th} SKU at j^{th} DC
C_{jk}=demand of k^{th} SKU at j^{th} store
p=cost of transportation from plant to DC per ton per km
s=cost of transportation from DC to store per ton per km
t_{ijk}=monthly tonnage of k^{th} SKU delivered from i^{th} plant to j^{th} DC
t^1_{ijk}=monthly tonnage of k^{th} SKU delivered from i^{th} DC to jth store

Mathematical Formulation without Tax

$$\text{Min } Z = \sum\sum\sum d_{ij}t_{ijk}p + \sum\sum\sum d^1_{ij}t^1_{ijk}s$$

St.

$\sum\sum t_{ijk} \leq A_{ik}$, for k=1, 2, ….. ,b (Plant capacity constraint)

$\sum\sum t_{ijk} \geq B_{jk}$, for k=1,2,…..,b (DCs demand constraint)

$\sum\sum t^1_{ijk} \geq C_{jk}$, for k=1,2,….,b (Stores demand constraint)

All variables are ≥ 0

Illustration

Given that,

No. of Plants = 5
No. of DCs = 4
No. of SKUs = 7
Supply from plants for each SKUs
Demand at DCs for SKUs
Demand at Stores for SKUs
Distance in km between plant and DC
Distance in km between DC and store
Cost of transportation per ton per km between plant and DC
Cost of transportation per ton per km between DC and store

Solution,

Mixed integer LP may be generated in GAMS and solution may be obtained.

Approximate Solution,

The problem is simplified by considering the aggregation of the supply and demand into a single aggregate (pseudo) product instead of multi products. Then, the problem is formulated in to a

primary transportation model as shown in the table below. The aggregate supply and demand for the above mentioned illustration are:

Supply from Plants: 12.7, 449.0, 3973, 3.6, 978.3 (from plant 1 to 5 respectively).
Demand for DCs: 901.6, 1522.1, 1616.1, 1376.6 (to DC 1 to 4 respectively).

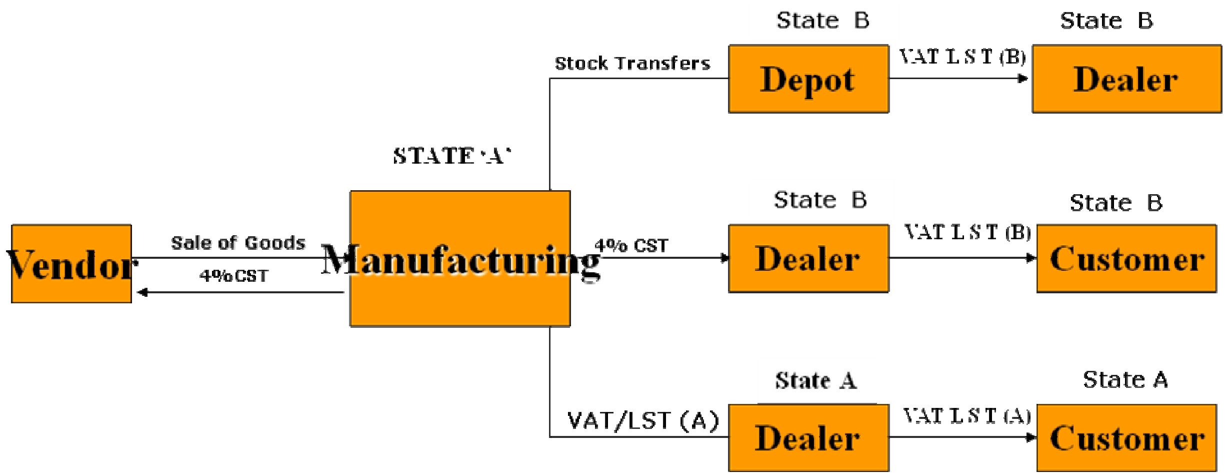
The Transportation problem was solved both optimally and near optimally. VAM is selected for non-optimal solution as it gives closer to optimal solution and takes less computation time.

Primary Transportation Model

		COST PER UNIT DISTRIBUTED				SUPPLY
		DESTINATION				
		1	2	…..	N	
SOURCE	1	C_{11}	C_{12}	…..	C_{1n}	S_1
	2	C_{21}	C_{22}	……	C_{2n}	S_2
	.					|
	.	……	……	……	…….	|
	.					|
	.					|
	m	C_{m1}	C_{m2}	……	C_{mn}	S_m
DEMAND		d_1	d_2	…..	d_n	

Mathematical Formulation with Tax

The diagram shown below is a sample Tax levy system when distribution is for interstate and state transfer.



The problem with Tax implication is formulated after defining the notations and is presented below:

$$\textbf{Minimize Z} = \sum_{l_c} Fc_{l_c} * Y_{l_c} + \sum_{t} \sum_{l_c} Vc_{l_c} * \sum_{l_d} \left(\sum_{j} \sum_{k} Dc_{jkl_dt} \right) * Y_{l_dl_ct} +$$

$$\sum_{t} \sum_{lc} \left(\sum_{l_d} \left(\sum_{j} \sum_{k} Dc_{jkl_dt} \right) * TCw_{l_cl_d} * Y_{l_dl_ct} \right) + \sum_{t} \sum_{l_c} \sum_{l_p} TCp_{l_pl_c} \left(\sum_{l_d} \left(\sum_{j} \sum_{k} Dc_{jkl_dt} \right) * Y_{l_dl_ct} \right) +$$

$$\sum_{t} \sum_{l_c} \sum_{l_d} \sum_{j} \left(\sum_{k} Dc_{jkl_dt} * Cp_{jk} \right) \left\{ \left(Lt_{l_cj} * \sum_{l_s} WH_{l_cl_s} * St_{l_dl_s} \right) + \left(Ct_j + Lt_{l_cj} \right) * \neg \left(\sum_{l_s} WH_{l_cl_s} * St_{l_dl_s} \right) \right\} * Y_{l_dl_ct}$$

Subject to,

$$Y_{l_c} \geq Y_{l_dl_ct}$$

$$\sum_{l_c} Y_{l_dl_ct} = 1$$

$$Y_{l_c}, Y_{l_dl_c} t \in (0,1)$$

In the above model, the first term in the objective function represents the fixed cost, second term for variable operation cost, third term for primary distribution cost, fourth term for secondary distribution cost and the fifth term for Tax levied for interstate and state transfer.

The first constraint is to make sure that warehouse which has been allocated is functional. Second constraint is to make sure only one warehouse is allocated to client. Third constraint is the binary constraint. The problem is solved near optimally by repetitive application of VAM and the final result is arrived by comparing and selecting all the solutions generated.

Conclusion

The Integrated analysis of production – distribution systems has proven to be of significant benefits, like savings and efficiency improvements. Researchers applied two phase solutions: Phase 1 solved a mixed – integer program, assuming direct supply to customers. Phase 2 applied heuristic method to optimize the transportation schedule. However, gap has been noticed that the production – distribution system has not been studied when the Tax implications are significant. In this paper, production – distribution models are presented with and without Tax implications and solution methods along with computation experience are discussed.

References

- Mitsuo Gen, Lin Lin and Jungbok Jo, Logistics Network Models and Optimizations: Evolutionary Algorithm Approaches, Intl. Jl. Of Logistics & Transport, Vol. 2, #1, 91 – 133, April 2008.
- Lei Lei, Shuguang Liu, Andrzej Ruszczynski and Sunju Park, On the Integrated Production, Inventory, and Distribution Routing Problem, IIE Transactions, Vol. 38, 955-970, 2006.
- Fabio Nonino and Roberto Panizzolo, Integrated Production/Distribution Planning in the Supply Chain: The Febal Case Study, Supply Chain Management: An International Journal, Vol. 12, #2, 150-163, 2007.
- Donald B. Rosenfield, The Retailer Facility Location Problem: A Case Study, Journal of Business Logistics, Vol. 8, #2, 2007.
- Nanthi Suthikarnnarunai, An Algorithm for the Mixed Fleet Vehicle Routing Decision Problem, Intl. Jl. Of Logistics & Transport, Vol. 2, #1, 209- 217, April 2008.

Biography

Dr. N. Sambandam is Professor & Dean (Research) at the National Institute of Industrial Engineering, Mumbai (India). He has been nominated as Chairman of All India Board of Management Studies for three years from December 2009. His areas of interest include Operations Management, Logistics & Supply Chain Management, Lean Enterprise, Combinatorial Optimization and Simulation. He has published 60 papers in National & International Journals and Conferences. He has organized many conferences including GLOGIFT 09. He is the life member of GIFT Society and many other professional bodies.

S. Rajapriya is a Computer Engineering graduate from University of Mumbai, India. Her current subject of interest is Operations Management and Optimization Theory. She is also interested in Financial Engineering and Management for research.