OMNI-CHANNEL DISTRIBUTION: A TRANSSHIPMENT MODELING PERSPECTIVE

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ABSTRACT

In our work, we develop a specialized optimization technique that adapts the general linear programming Transshipment model to the ever-growing needs of Omni-Channel distribution in Supply Chain Management. With the rapid adoption of "smart" mobile technologies, customers now acquire merchandise across multiple channels and devices. As a result, retailers are challenged with downstream operational complexities.

Fulfillment of customer orders now changes the placement and amount of independent demand inventory organizations may hold. Our research integrates the use of Hub or Fulfillment Centers, locations where sellers fill customer orders placed through e-commerce, as an additional segment of demand. This adaptation to the optimization of Transshipment can result in significant benefits to the firm's logistics presence, customer retention, and profit.

KEYWORDS

Supply chain management, Transshipment,Omni-Channel distribution, e-commerce, transportation, logistics, modelling

1. INTRODUCTION: WHAT IS OMNI-CHANNEL DISTRIBUTION?

The concept of Omni-Channel Distribution has been around for some time. However, its concept was magnified during the COVID pandemic of 2020 [1]. The ever-changing means by which customers procured goods was put to the test at that time and is becoming more and more of a challenge to Supply Chain and Logistics professionals moving forward.

Its definition can be considered fluid as many avenues for procurement are included and prioritized by the customer. One such logistics-sensitive definition of Omni-Channel Distribution is as follows:

> "Strategic customer care initiatives designed to deliver "*seamless*" customer experiences across multiple channels (e.g. phone, social media, web, mobile and e-mail) and devices (in-store, laptop and smartphone), where each of these possible channels may require a different or modified supply chain." [2, p. 137]

This definition suggested the need to modify current supply chains. In support of their assertion, we explore traditional Transshipmentmodeling and present a modified Omni-Channel Transshipment method as an enhancement to current research.

2. THE TRADITIONAL OPTIMIZATION TECHNIQUE

The Transshipment problem is an extension to the traditional general linear programming Transportation model where intermediate nodes, referred to Transshipment nodes, are introduced to account for locations such as warehouses, distribution centers, and/or hubs [3]. In this type of distribution problem, independent demand inventory may move between any pair of three general types of nodes: Production (or supply), shipment, and customer (or demand) nodes.

Like the Transportation problem, the supply available at each production facility is limited, and demand at each retail point is known. The objective of the Transshipment problem is to determine how much inventory should be shipped over each arc (arrow) in the network so that all customer demands are met with the minimum possible transportation cost. Figure 1 below provides a network representation of the traditional Transshipment model. In addition, Model 1 represents its generalized Transshipment optimization method.

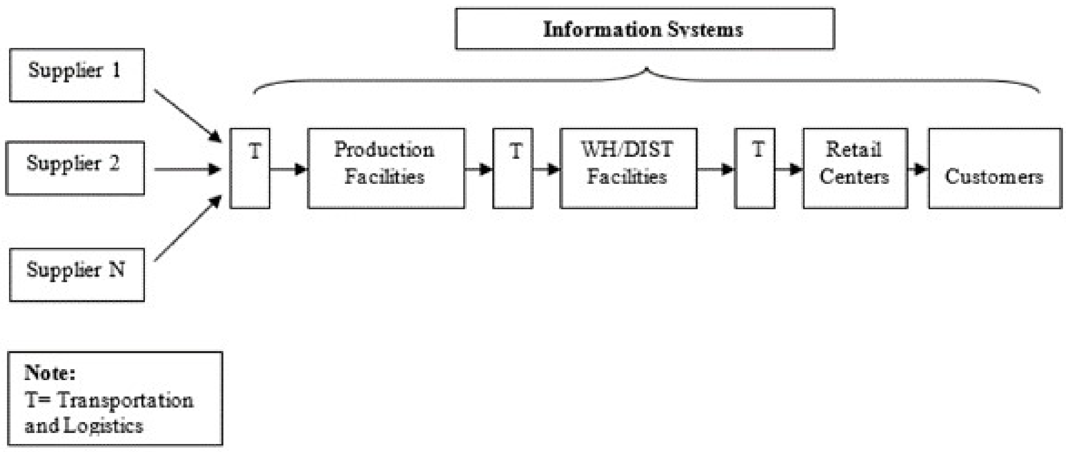

Figure 1. Traditional transshipment logistics model(Jones et al., 2009)[4]

Let x_{ij} denote the number of units shipped from node i to node j, and c_{ij} denote the cost associated with using that specific route.

$$\text{Min} \sum_{all\ arcs} c_{ij} * x_{ij}$$

Subject to:

$$\sum_{all\ out} x_{ij} - \sum_{all\ in} x_{ij} \leq s_i \text{ Manufacturing Capacity}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = 0 \text{ Warehouse/Distribution Conservation}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = d_j \text{ Retail Demand}$$

$x_{ij} \geq 0$ for all i and j
and where:
s_i – Capacity for each Manufacturing Facility
d_j – Independent Retail Customer Demand
Model 1.General Linear Programming Transshipment Model(Anderson et al., 2006) [3]

3. The Logistics Problem: Customer Choice

The idea of an Omni-Channel shopper is now the standard, made possible by the rapid adoption of "*smart*" mobile technologies by customers everywhere. The logistics problem associated with it is a classic one, where upstream and downstream strategies oppose one another. Upstream, manufacturing firms want to take advantage of economies of scale and produce as efficiently as possible (Min Cost). In opposition to this strategy, downstream firms seek a full line of products for customer choice, product placement and sales (Max Revenue, Max Profit).

Downstream consumers don't care about distribution channels, but they do care about finding solutions to their needs, and a retail center either satisfies that need or it doesn't. This brings the concept of "*service level*" into the problem. Downstream, retail centers strive for high service levels for goods at every retail point to increase revenue and profit. This approach leads to tying up capital and procuring unnecessary amounts of independent demand inventory.

Of course, upstream manufacturing firms call into question the concept of high service levels. They rely more heavily on forecasts for production in the short and medium terms, leading to stocking and service levels of less than 100% at the retail centers.

The situation that presents the most variance (and cost) to a logistics professional is Last Mile Delivery. While there continue to be traditional "walk-up" customers in Omni-Channel Distribution, the requirements for delivering goods to customers over the last mile can be quite expensive. For cost-conscious firms, the question becomes: Should all facilities have delivery capabilities for retail consumers?

4. Last Mile Delivery and the Hub/Fulfillment Center Concept

The focus of logistics for Omni-Channel Distribution has been to deliver products to customers as quickly as possible without a severe loss in profit. In densely populated areas, delivering huge volumes of packages rapidly is easier and faster. However, in outlying and less densely populated areas, this can be costly. Supply chain businesses must consider this and carefully plan new strategies to optimize efficiencies, reduce travel time and keep costs under control. Thus, logistics providers are interested in controlling the cost of their "*last mile*" deliveries.

Datex Corporation [5, n.p.] defines Last-Mile Delivery as "the movement of goods from a transportation hub to the final customer delivery destination." That final delivery destination is typically a personal residence, and this segment of the delivery route typically incurs the highest cost per item. Today, these hubs are better known as Fulfillment Centers, where a seller fills customer orders placed through an e-commerce store (direct-to-consumer) and/or business-to-retail, where the seller fulfills wholesale orders to retail centers.

Twenty-eight percent of total transportation costs are attributed to Last Mile Delivery, the least efficient leg of the supply chain [5]. Having warehouses, distribution centers, and fulfillment centers in optimal locations adjacent to population centers has been instrumental in the Last Mile Delivery logistics process to date. Some of the most important factors for consumers when considering delivery options include cost, speed, flexibility, reputation, and service.

5. OMNI-CHANNEL LOGISTICAL OPERATION ISSUES

Omni-Channel shopping by consumers breaks the traditional, Transshipment supply chain operational models moving from upstream to downstream. Customers routinely investigate and select products in non-store channels, even when they complete those purchases in the store. As a result, most logistics firms find that their operational models are challenged with downstream Omni-Channel distribution, which is much more complex. Krug [6] identified several of these challenges:

- Lack of Inventory Visibility and Metrics
- Poor Visibility into Inventory in Transit
- Segmented Supply Chain Processes
- Unreliable Order Fulfillment Processes
- Finding the Right Transportation
- Reverse Logistics
- Manual Processes
- Overlooking Physical Transformation
- Implementing 3PL Strategy

To offer solutions to many of these problems, a newly adapted network diagram containing hubs or fulfillment centers, retail centers (individually or in clusters) with accurately forecasted customer demand is needed.

6. AN ADAPTED OMNI-CHANNEL DISTRIBUTION NETWORK

Figure 2 below provides a network representation of the Transshipment model adapted for Omni-Channel Distribution. Figure 3 focuses on the choices customers have at the retail end of the supply chain: products sent to them via a hub or fulfillment center, products sent to them via retail stores, or retrieving products themselves from retail stores.

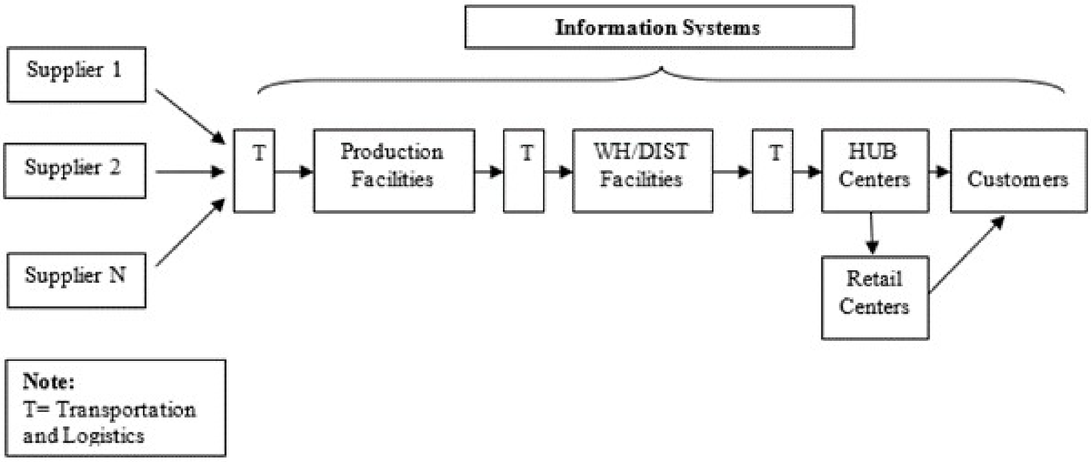

Figure 2. Transshipment logistics model modified for omni-channel distribution

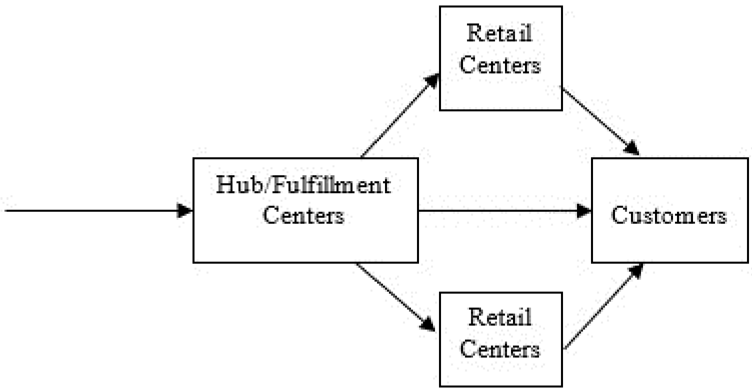

Figure 3. Transshipment logistics downstream model representation for omni-channel distribution

7. An Adapted Omni-Channel Distribution Optimization Technique

When modeling an Omni-Channel network, additional routes and nodes are required. From Figure 3, we see that the downstream portion of the supply chain must include Hubs/Fulfillment Centers and Regional Retail/Customer demand. Thus, shipments of goods are permitted from production facilities to Transshipment nodes (Warehouse/Distribution Centers, Hub/Fulfillment Centers, and Retail Centers), and to meet customer demand can happen from any origin to another origin, from any Transshipment location to another, and from any customer demand point to another. Using this logic, our modification creates a new set of nodes, Hub or Fulfillment Center nodes, which can supply consumers directly in addition to fulfilling demand at regional Retail Centers. Model 2 below represents the generalized Omni-Channel Transshipment optimization method.

Again, let x_{ij} denote the number of units shipped from node i to node j, and c_{ij} denote the cost associated with using that specific route.

$$\text{Min} \sum_{all\ arcs} c_{ij} * x_{ij}$$

Subject to:

$$\sum_{all\ out} x_{ij} - \sum_{all\ in} x_{ij} \leq s_i \text{ Manufacturing Capacity}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = 0 \text{ Warehouse/Distribution Conservation}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = 0 \text{ Hub/Fulfillment Center Conservation}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = 0 \text{ Retail Center Conservation}$$

$$\sum_{all\ in} x_{ij} - \sum_{all\ out} x_{ij} = rd_j \text{ Regional Demand: All Customers in Region}$$

$$\sum_{all\ in} x_{ij} \leq dd_j \text{ Retail Customer Demand: Independent or Clustered Demand}$$

$x_{ij} \geq 0$ for all i and j

and where:

s_i – Capacity for each Manufacturing Facility
rd_j – Demand for all Customers in the Region (Retail Stock and Customer Direct)
dd_j – Individual Retail Customer Demand or Cluster Demand for Retail Stock

for:

$rd_j = drd_j + wrd_j$
with drd_j equal to Demand sent directly to the customer from a Retail Center
with wrd_j equal to Demand for walk-up Retail Center customers

Model 2. Adapted omni-channel linear programming transshipment model

8. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Due to the growing need for speed in shipping, new and revised regulations, and network infrastructure limitations, logistics providers have begun to study and offer alternative delivery solutions. These solutions include improved tracking and alerts, Sunday deliveries, improved re-delivery options, delivery to safe place options, delivery to locker banks, click-to-collect, robots, Uber, drones, and local delivery services. Many of these topics go beyond the scope of this research but indicate the level of importance to logistics providers moving forward.

When Omni-Channel Distribution takes into consideration the tradeoffs between strategies of cost minimization associated with economies of scale in manufacturing in conjunction with high service levels desired by retail centers for maximizing profit or revenue, significant benefits should result. Those benefits may include:

- Improved customer retention
- Higher average profit margin per customer
- Greater customer lifetime value
- Future Applications to Procurement
- Centralized Purchasing
- Localized Purchasing
- Future Applications to Logistics
- Last Mile Delivery
- Fuel/Mileage Minimization
- Optimal Fleet Size

The high relevance of Last Mile Delivery has triggered researchers and practitioners to provide general solutions to the developments and challenges associated with increasing volume, sustainability, costs, time pressure, and an aging workforce. Not much interest has been given to network evaluation for Omni-Channel distribution. Given these challenges and the ongoing technological developments, it is anything but surprising that plenty of last-mile delivery concepts have been promoted in recent years [7].

Moving forward, we plan to exercise our model over several network representations. Those representations will include traditional manufacturing facilities and warehouse/distribution facilities. Hubs/fulfillment centers and retail centers will be included for Omni-Channel Distribution representation. Retail centers will be modeled in multiple ways. First, they will be included using forecasted, independent consumer demand. They will then be grouped into areas representing clustered consumer demand. Outcomes predicting the movement of inventory based on Last Mile Delivery costs will be evaluated based on varying service levels. We hypothesize outcomes where some retail centers are supported in the network while others are not. Preliminary runs of the model indicate that retail centers should not participate in Last Mile Delivery. That should only be performed by hubs/fulfillment centers.

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