SUPPLY CHAIN MANAGEMENT IN APPAREL INDUSTRY: A TRANSSHIPMENT PROBLEM WITH TIME CONSTRAINTS

HAZIR GİYİM ENDÜSTRİSİNDE TEDARİK ZİNCİRİ YÖNETİMİ: ZAMAN KISITLI BİR AKTARIM PROBLEMİ

Deniz Türsel ELIIYI
Izmir University of Economics
Department of Industrial Systems Engineering
e-mail: deniz.eliiyi@ieu.edu.tr

Emine Zehra YURTKULU
Izmir University of Economics
Department of Logistics Management

Dicle YURDAKUL ŞAHİN
Izmir University of Economics
Department of Business Administration

ABSTRACT

Supply chain management is one of the main sources of competitive advantage for companies. As a useful tool for inventory and transportation management in supply chains, transshipment points provide an effective mechanism for correcting discrepancies between demand and available inventory. This study aims to model the transshipment problem of a company in the apparel industry with multiple subcontractors and customers, and a transshipment depot in between. Unlike a typical transshipment problem that considers only the total cost of transportation, our model also considers the supplier lead times and the customer due dates in the system and it can be used for both supplier selection and timely distribution planning. The proposed model can also be adapted easily by other companies in the industry.

Keywords: Transshipment problem, Lead time constraints, Apparel industry.

ÖZET

Tedarik zinciri yönetimi şirketler için rekabet avantajı sağlamadaki temel kaynaklardan birini oluşturmaktadır. Tedarik zincirlerinde envanter ve ulaştırma yönetimi konusunda faydalı kullanımları olan aktarım noktaları özellikle talep ve envanter miktarı arasındaki farkı kapatma konusunda etkin bir mekanizma sunmaktadır. Bu çalışmanın amacı hazır giyim sektöründe birden çok fason imalatçı ve müşteri ile faaliyet gösteren ve aktarım deposuna sahip bir şirketin aktarım probleminin modellenmesidir. Yalnızca toplam maliyeti minimize etmeyi amaçlayan tipik aktarım modellerinden farklı olarak modelimiz tedarik sürelerini ve müşterilerin termin zamanlarını da dikkate almakta, bu sayede hem tedarikçi seçiminde hem de zamanında dağıtım planlamasında kullanılabilmektedir. Önerilen model sektördeki diğer firmalar için de kolaylıkla adapte edilebilir.

Anahtar Kelimeler: Aktarım problemi, Tedarik süresi kısıtları, Hazır giyim sektörü.

1. INTRODUCTION

Supply chain management is one of the main sources of competitive advantage for companies and its importance is increasing due to its effects on solving problems faced by many companies in terms of mismatches between customer demand and supply, which will lead to low levels of customer satisfaction and eventually decreasing sales and market share (1). Logistics is a critical part of supply chain management, and is used to control the flow of materials, services and information taking into account the cost of these activities on one side and the value created in

terms of both the customers and the organization on the other (2, 3).

Supply chain management entails effective replenishment and inventory policies. The use of transshipment points in supply chains renders monitored movement of stocks to intermediary storage locations between two echelon levels. Transshipments are effective policies for correcting discrepancies between demand and inventory available at specific locations, serving as a tool for effective management of stocks that are already procured and delivered into the system (4). By using transshipments as a tool for utilizing stocks, a company can

reduce its costs and improve the level of service without increasing the stock level and bearing additional costs (5).

Transshipment problems are variations of transportation problems in which goods and services are distributed between sources, storage points and destinations. Like in many cases, the objective function of transshipment problems is to minimize cost. Transshipments problems were first defined by Orden (6) as an extension of transportation problems with transshipment points between the sources and the destinations (7).

Transshipment models can be used to enhance cost efficient movement of

goods and improve the level of customer satisfaction. Dynamic transshipment problems involving inventory decisions have several locations, and in each of these locations companies have to bear fixed replenishment, per unit replenishment, and per unit holding costs. Transshipping inventories between locations also includes fixed and per unit costs. The objective in these kind of problems is to determine the replenishment quantities and how much to transfer in each demand process to ensure cost minimization. In the studies by Herer and Tzur (8, 9), the authors develop optimal and heuristic algorithms for dynamic transshipment problems incorporating fixed replenishment and transshipment costs. A dynamic and deterministic environment is considered, where the transshipments are not used as a tool for emergency source of supply, but instead they can be used to offset different replenishment and holding costs at different stock locations.

In this study, we use integer programming to solve the transshipment problem of an apparel company. One of the core aims of this study is to ensure that the offered model and the corresponding solution can be used practically by the company, leading to more efficient management of the supply chain. In Section 2, we define the problem in detail. Next, we develop the mathematical model in Section 3. Numerical results are presented in Section 4. Discussion and conclusion is presented in Section 5.

2. PROBLEM DEFINITION

We consider a real-life problem faced by an apparel company located in Izmir, Turkey. The company currently operates in the segment of ready-to-wear garments. The company has two basic branches of operations; namely, the casual wear branch and personnel garments branch. Personnel garments are manufactured partly in-house, but

most of the production is via contract manufacturing.

Competition is dense in the textile and apparel industry. The main competitors of the company are its own subcontractors, who are willing to sell their products directly to the customers. The company works under the pressure of strict due dates. High penalty fees apply in case the deliveries are untimely. The relationships with both suppliers and customers play key roles in the personnel garments industry, and trust is a key factor in these relationships. Therefore, conformity to quality standards and deadlines is crucial. There are mainly five key players in the transshipment process:

1. The customer: The source of the request or order.

2. The company: The decision maker. This represents our company, which receives the order from the customer and outsources the production via different suppliers and ateliers.

3. Suppliers/Subcontractors: Companies that provide raw materials, semi-finished and finished products used in the production process.

4. The workshop: The atelier in which the production activity is outsourced/ performed.

5. The transportation company: The firm that is responsible for the transportation of finished products to customers.

The process flow of the order fulfillment process is provided in Figure 1. The process begins with the receipt of a customer order. Then, the company communicates with its suppliers to discuss if required materials are already available at stocks or if they should be manufactured. Hence the lead time for each order is determined and the order is scheduled for production. The workshop starts

production right after receipt of the required materials. Upon completion of production at the workshop, the order is shipped via the transportation company.

The company has a depot used as a transshipment point. The products manufactured at various subcontracting facilities are supposed to be gathered at this depot for final arrangements and packaging. Different items of personnel uniforms such as hats, shirts and trousers may be produced by different subcontractors. The final packaging and labeling processes bring these items together. However, due to tight due dates of the customers, and as a result of working with many subcontractors, the company usually has to ship from the supplier directly to the customer at the last minute. This result stems from ineffective planning of the whole transshipment process. The transportation cost is considerably high for these last-minute shipments as the usual modes of transportation cannot be used. The decision makers in the company wish to use their depot and provide timely deliveries at the same time.

The problem is analyzed within the context of a transshipment scheme. Basic elements of the transshipment problem are the capacity of supply points, requirements of the demand points, and the costs associated with shipping of one unit of product from each supply point to each transshipment point, from each transshipment point to each demand point, and from each supply point to each demand point directly. The objective is to minimize the total transportation cost. We model the problem as a transshipment problem with due date restrictions. Unlike typical transshipment models, the due date of an order is also considered in our model since the company faces high penalty costs. We present our model in the following section.
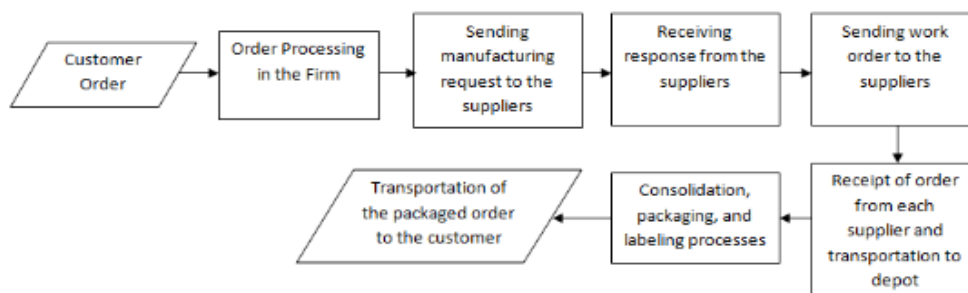

Figure 1. The order fulfillment process.

3. THE MATHEMATICAL MODEL

We define the indices and parameters used in the model as below:

s: supplier index

t: transshipment point index

c: customer index

p: product type index

D_{cp}: Demand quantity depending on customer and product type.

DD_{cp}: Deadline of order depending on customer and product type.

l_{sp}: Lead time of production depending on supplier and product type.

c_{st}: Cost of shipping one unit from supplier point to transshipment point.

c_{sc}: Cost of shipping one unit from supplier point to the customer.

c_{tc}: Cost of shipping one unit from transshipment point to the customer.

t_{st}: Shipping time from supplier point to transshipment point.

t_{sc}: Shipping time from supplier point to the customer.

t_{tc}: Shipping time from transshipment point to the customer.

pr_p: The percentage of volume a specific product *p* occupies in a package.

$$E_{ps} = \begin{cases} 1, & \text{if supplier } s \text{ is eligible for providing product } p \\ 0, & \text{otherwise} \end{cases}$$

We define our decision variables are given below.

Binary variables:

$$X_{scp} = \begin{cases} 1 \text{ if product p, which is produced by supplier s, is assigned to customer c on the route } S \rightarrow C \\ 0 \text{ otherwise} \end{cases}$$

$$Y_{cpst} = \begin{cases} 1 \text{ if product p, which is produced by supplier s, is assigned to customer c on the route } S \rightarrow T \\ 0 \text{ otherwise} \end{cases}$$

$$Z_{cpt} = \begin{cases} 1 \text{ if product p, which is produced by supplier s, is assigned to customer c on the route } T \rightarrow C \\ 0 \text{ otherwise} \end{cases}$$

Integer variables:

Xp_{cs}: Number of packages shipped from supplier *s* to customer *c*.

Yp_{st}: Number of packages shipped from supplier *s* to transshipment point *t*.

Zp_{tc}: Number of packages shipped from transshipment point *t* to customer *c*.

Our objective function in Equation 1 minimizes the sum of the batch-shipment-costs.

$$\text{Min} \sum_{s=1}^{n}\sum_{c=1}^{n} Xp_{sc} * c_{sc} + \sum_{s=1}^{n}\sum_{t=1}^{n} Yp_{st} * c_{st} + \sum_{t=1}^{n}\sum_{c=1}^{n} Zp_{tc} * c_{tc} \tag{1}$$

Batch-shipment-cost is represented by three different cost components: The total cost of sending packages directly, the total cost of sending packages from suppliers to transshipment points and the total cost of sending packages from transshipment points to customers.

Every customer must be served with each product either directly from a supply point or through the transshipment point. This constraint is reflected by the following equation:

$$\sum_{s=1}^{n} X_{scp} + \sum_{t=1}^{n} Z_{cpt} = 1, \ \forall c, p \tag{2}$$

Constraint set 3 below ensures time limits for direct shipments. The company works with strict deadlines for each order. These time constraints make our model different from the typical transshipment problems. Sum of the lead time and the shipping time from supplier to customer cannot exceed the deadline of an order. Note that, instead of including due dates and related penalty costs in the objective function, strict deadlines are included as constraints in the model. This is due to the fact that there are very high penalty costs for late orders, and the company decision makers never prefer this situation regarding future relationships with customers. So it can be said that the company actually has deadlines rather than due dates.

$$l_{sp} + t_{sc} \leq DD_{cp} + (M * (1 - X_{scp})), \ \forall c, p, s \tag{3}$$

Constraint set 4 ensures time limits for shipments via transshipment points. Sum of the lead time, the shipping time from supplier to transshipment point and the shipping time from transshipment point to the customer cannot exceed the deadline of an order.

$$l_{sp} + t_{st} + t_{tc} \leq DD_{cp} + (M * (1 - Y_{cpst})), \ \forall c, p, t, s \tag{4}$$

The next constraint set assures that, at every transshipment point, if a product p for customer c is sent from one of the possible suppliers to the transshipment point, then it must be sent out from the transshipment point to customer c. Hence, these constraints ensure the conservation of flow for the transshipment points.

$$\sum_{s=1}^{n} Y_{cpst} = Z_{cpt}, \ \forall c, p, t \tag{5}$$

Xp_{cs} denotes the number of packages shipped from the supplier to the customer directly. The next constraint set settles the total number of packages to be shipped, depending on the number of products to be shipped and their capacity usage in a package.

$$Xp_{sc} \geq \sum_{p=1}^{n} X_{scp} * D_{cp} * Pr_p, \ \forall s, c \tag{6}$$

Yp_{st} denotes the number of packages shipped from the supplier to the transshipment point, and Zp_{tc} denotes the number of packages shipped from the transshipment point to the customer. Constraint sets 7 and 8 compute the total number of packages to be shipped in a similar way similar as constraint set 6.

$$Yp_{st} \geq \sum_{c=1}^{n} \sum_{p=1}^{n} Y_{cpst} * D_{cp} * Pr_p, \ \forall s, t \tag{7}$$

$$Zp_{tc} \geq \sum_{p=1}^{n} Z_{cpt} * D_{cp} * Pr_p, \ \forall t, c \tag{8}$$

Not all suppliers can provide all product types. Product p can only be sent from a supplier s if that supplier is eligible to provide that product. There may be more than one eligible supplier for a product, and our model makes optimal supplier selections based on transportation cost, lead times and transshipment times. The following constraint sets ensure that only eligible suppliers are selected for each product in both direct shipments and shipments through the transshipment points.

$$X_{scp} \leq E_{ps}, \ \forall c, p, s \tag{9}$$

$$Y_{cpst} \leq E_{ps}, \ \forall c, p, s, t \tag{10}$$

Finally, types of variables in the model are defined.

$Xp_{cs}, Yp_{st}, Zp_{tc}, \geq 0$ and integer, $X_{scp}, Y_{cpst}, Z_{cpt}$ binary, $\forall c, p, s, t \tag{11}$

4. PROBLEM DATA

The data used is obtained from the company by taking a recent snapshot of the system involving many orders. In this problem instance with a 20-day planning horizon, there are 13 potential suppliers, 11 customers and 5 product types. The unit direct shipment cost from the suppliers to the customers changes between 25 and 31 monetary units and the shipping takes 2 to 3 days. The unit shipment costs from the suppliers to the transshipment point is between 3 to 7

monetary units depending on the location of the supplier. The unit shipment cost from the transshipment points to each customer changes between 6 and 12 monetary units. The shipment from the supplier to the transshipment point, and from the transshipment point to the customer takes approximately 1 day each. Table 1 shows the lead times of each potential supplier based on product type. The pr_p values, i.e. the percentage of volume that a specific product type p occupies in a package are estimated as 2% for product types 1, 2 and 3, and 8.3% for product types 4 and 5. The demand of each customer from each product is given in Table 2. The due date of each customer is 20 days for this instance. We provide the results of the computational study in the next section.

Table 1. Lead times of potential suppliers for each product type (in days).

	p1	p2	p3	p4	p5
s1	13	4	6	6	6
s2	5	7	6	6	6
s3	8	8	7	6	6
s4	5	5	5	6	6
s5	14	6	7	9	5
s6	12	7	8	5	6
s7	10	8	9	7	7
s8	4	9	5	6	6
s9	8	5	5	7	7
s10	9	6	6	7	6
s11	8	7	7	8	6
s12	8	6	7	6	6
s13	7	7	8	8	8

Table 2. Customer demand data (in unit of product).

	p1	p2	p3	p4	p5
c1	0	0	46	0	138
c2	48	0	0	0	16
c3	1136	852	35	0	101
c4	54	36	18	0	0
c5	42	32	15	0	0
c6	0	4	2	0	0
c7	21	14	8	0	0
c8	6	4	1	0	0
c9	21	8	14	0	0
c10	18	12	3	0	0
c11	0	0	0	5	0

5. COMPUTATIONAL RESULTS

The problem is modeled and solved using GAMS 22.5 optimization software. As it was stated in the previous section, the gathered real life data includes a planning horizon where the orders from 11 customers should be fulfilled using 13 supplier nodes

through 1 transshipment node. The supplier nodes are candidate supplier nodes, which provide different lead times for the incoming orders. The model therefore also performs supplier selection regarding the due dates of the orders at minimum total cost of transportation.

According to the optimal solution obtained from GAMS 22.5, only 4 suppliers are selected to serve the 11 customers. The optimal solution is depicted in Figure 2 in a network representation. The numbers on the arcs of the network represent the number of shipped packages between any two nodes. The reasons for selecting only 4 suppliers out of 13 supplier candidates are either the high costs of transportation from the other suppliers or the due date restrictions. The optimal solution suggests that all packages should be shipped through the transshipment point, which is an expected result of high direct shipment costs. The transshipment point also facilitates the distribution and transportation of the packages. For instance, 72 packages come from suppliers in our data set. Since these packages are consolidated in the transshipment point and then shipped to the customers, complete delivery to the customer is possible in one shot.
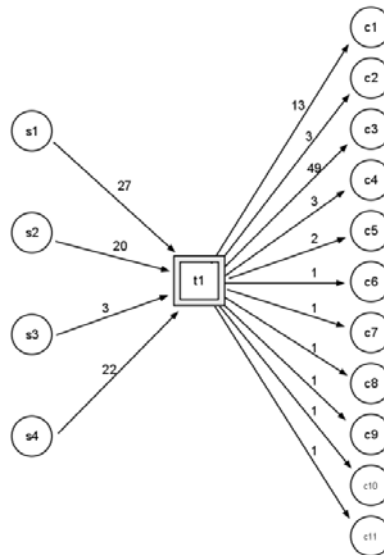

Figure 2. The optimal solution.

Next, we explain how the company actually proceeded in this specific problem instance and compare their intuitive solution with the optimal solution. Because of the tight due dates and since one of their most important accounts is among these 11 customers, the company actually did not use transshipment point and

shipped the products from the suppliers directly to the customers. In addition, the company had to make the consolidation of the packages in the suppliers' workshops, and the packages were transferred from one supplier to another for rearranging and reconsolidation, which lead to conflicts and higher labor and time costs. Labeling processes were delayed, interrupted or even cancelled, decreasing the quality of shipments. This is partly due to the fact that the company did not prefer the suppliers giving the best lead times, although the manufacturing prices were very similar among them. The total number of shipments in the optimal solution of our model is 15 for this instance while the company had to make more than double this amount, i.e. 30 direct shipments plus the inter-supplier travels. The number of packages shipped in the optimal solution is 76, while the company used 89 packages for shipments due to inefficient planning. The company's intuitive solution is depicted in Figure 3.
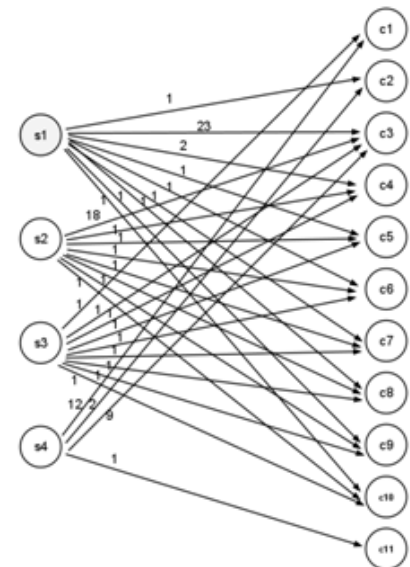

Figure 3. Solution of the company.

The solution time of the model in GAMS for this size of an instance with 334 variables is ignorable due to the simplistic network-type formulation of the problem. The optimization model provides a cost advantage to the company as well as improving customer satisfaction related with the timely shipments. When the actual cost of the company is compared to the results obtained from the optimization model, it can be observed that there is a reduction in the transportation costs almost by 35%. This means that using the transshipment point provides cost advantage and operational efficiency.

6. CONCLUSION

In this study, we consider a real-life problem of an apparel company regarding the transportation of goods. We propose a transshipment model for the problem that can be adapted practicably by other companies in the industry. According to the findings of the study, use of the transshipment point increases the overall efficiency and decreases the total transportation cost.

Our transshipment model differs from previously used models in the literature due to the addition of time constraints. The model also provides decision support to the supplier selection problem by selecting the optimal suppliers in terms of cost and time constraints. The simplicity and easy implementation are the advantages of the developed model. GAMS is a commercial optimization software, and may not be readily available in many companies. However, the proposed compact model can easily be handled in widely available spreadsheet software such as MSExcel and solved by built-in solvers. Introducing such optimization models into the everyday operations of small to medium size companies in the textile and apparel industry will greatly increase their efficiency of operations. However, many of such companies are either not aware that some optimization methods can be adapted to their systems, or they are not capable of using the proposed methods easily due to complex computational aspects. The simple optimization model in this study is proves useful in improving the shipment operations in both time and cost terms. Hence, we believe that our study contributes to the literature and industry by closing the gap between the theoreticians and practitioners.

REFERENCES

1. Reyes P.M., 2006, "A game theory approach for solving the transshipment problem: a supply chain management strategy teaching tool", *Supply Chain Management: An International Journal*, 11, 288–293.

2. Wu Y., 2008, "A mixed-integer programming model for global logistics transportation problems", *International Journal of Systems Science*, 39, 217–228.

3. Harrison T.P., 2003, "Principles for the strategic design of supply chains", *in: The Practice of Supply Chain Management: Where Theory and Application Converge*, T.P. Harrison, H.L. Lee and J.J. Neale (Eds), USA: Kluwer Academic Publishers, 3-12.

4. Herer Y.T., Rashit A., 1999, "Lateral Stock Transshipments in a Two-Location Inventory System with Fixed and Joint Replenishment Costs", *Naval Research Logistics*, 46, 525-547.

5. Ozdemir D., Yucesan E., Herer Y.T., 2006, "Multi-location transshipment problem with capacitated transportation", *European Journal of Operational Research*, 175, 602-621.

6. Orden A., 1956, "The transshipment problem", *Management Science*, 2, 276-286.

7. Hemaida R.S., Kwak N.K., 1994, "A Linear Goal Programming Model for Trans-Shipment Problems with Flexible Supply and Demand Constraints", *Journal of the Operational Research Society*, 45, 215-224.

8. Herer Y.T., Tzur M., 2001, "The Dynamic Transshipment Problem", *Naval Research Logistics*, 48, 386-408.

9. Herer Y.T., Tzur M., 2003, "Optimal and heuristic algorithms for the multi-location dynamic transshipment problem with fixed transshipment costs", *IIE Transactions*, 35, 419-432.