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Optimizing Centralized Supply Chain Based on Purchasing and an Application on Pharmaceutical Field

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Merkezi Tedarik Zincirinde Satın Alma Fonksiyonuna Dayalı Optimizasyon ve Farmasötik Alanda Bir Uygulama

Abstract

The purpose of this study is to optimize the total cost of the supply chain, based on the purchasing function in the enterprises which have the structure of centralized supply chain. The company operates in the pharmaceutical field, which makes its own production and has its own purchaser and suppliers in its own structure. An application is done on the optimization of the annual supply chain total cost with the different combinations of suppliers. The literature of the supply chain and the supplier relationships and purchasing have been reviewed as a result of purchasing functions emerging for the suppliers, buyer and supply chain, annual total costs are calculated, as a result minimum total cost in terms of the company is found. In this study, Excel Solver, and 11.0 Lingo programs are used.

Key words: Centralized Supply Chain, Optimizing, Purchasing.

Jel Codes: C61

Introduction

Enterprises should make an effort to adapt to rapidly changing market conditions, to increase their competition power as well as to decrease their costs. Therefore, while performing the purchasing activities, maintaining high quality in products and services

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and decreasing the total cost of the supply chain are quite important. In increasing production quality and in effective and efficient product and service provision of enterprises making a decision on appropriate supplier is doubtlessly quite important. If an enterprise works with appropriate suppliers, risk of making mistakes for enterprise will be lowered, cost decreases will be observed and customer satisfaction will be increased. Along with increased product and service qualities and enhanced product range the market has enlarged and competition environment has become stiffer. In such a compelling market working with a single supplier has turned out to be an inadequate and undesired situation for enterprises. For an enterprise, in order not to have a problem in production, to maintain low costs and to procure products in the desired quality it should have an effectively established supply chain. In order for the enterprise to be one step further in the field in which it successfully operates only its own performance does not suffice, performances of the supply chain members belonging to the enterprise also take an important place in this achievement. Therefore, if the enterprises want to high perform in their sectors and carry on their operations with success they should give necessary importance to supply chain and manage their supply chain effectively. In this study the objective is to decide on suppliers which -in line with the objectives of the enterprise- are chosen among the many alternative suppliers, which provide cost advantage and which have the desired criteria and with the help of these suppliers to optimize total cost of the supply chain. Within this context firstly elaborations have been made to make the definition, explanation of the structure and the operation of the supply chain, supply chain management and the selection of the suppliers then the purchasing function has been touched upon. Studies in the literature have been analyzed and past studies about supply chain optimization have been given a place. Finally an application in an enterprise in the pharmaceutical field and solutions to alternative situations emerging from different supplier combinations as well as optimization studies of supply chain total costs have been touched upon. Excel Solver and Lingo 11.0 programs were used in the process. Firstly; physical features, quality and price criterias for the materials to be used in the production were taken into consideration by Excel Solver. Later by targeting to minimize the total cost in case of procuring materials from different suppliers the decision was made to determine appropriate suppliers. Subsequently, purchasing activities were realized through the suppliers found to be suitable, different supplier combinations were used and with the help of Lingo 11.0 program supply chain annual total cost was optimized. Finally, evaluation results of the application were brought to fore.

1.Literature Review

C.A. Silva et all. (2009) worked on supply chain management using ant colony optimization. In their work, they introduced a new supply chain management technique, based on modeling a generic supply chain with suppliers, logistics and distributers, as a distributed optimization problem. The different operational activities are solved by the meta-heuristic optimization called ant colony which allows the exchange of information between different optimization problems by means of a pheromone matrix. The simulation results show that the new methodology is more efficient than a simple decentralized methodology for different instances of a supply chain. Yoo, Cho and Yücesan (2010) used hybrid algorithm for discrete event simulation based supply chain optimization. The objective of their work is to propose hybrid algorithm with the

application of the nested partitioning (NP) method and the optimal computing budget allocation (OCBA) method to reduce the computational load, hence, to improve the efficiency of the supply chain optimization via discrete event simulation. The NP method is a global sampling strategy that is continuously adapted via a partitioning of the feasible solution region. The number of candidate alternatives to be evaluated can be reduced by the application of NP. The OCBA method minimizes the number of samples (simulation replications) required to evaluate a particular alternative by allocating computing resources to potentially critical alternative. Carefully designed experiments show extensive numerical result to illustrate the benefits of the proposed approach

Papageorgiou (2009) worked on the supply chain optimisation for the process industries. Supply chain management and optimisation is a critical aspect of modern enterprises and a flourishing research area. In his work, a critical review of methodologies for enhancing the decision-making for process industry supply chains towards the development of optimal infrastructures (assets and network) is presented. The presence of uncertainty within the supply chains is discussed as an important issue for efficient capacity utilisation and robust infrastructure decisions. The incorporation of business/financial and sustainability aspects is also considered and future challenges were identified.

Moncayo, Martínez and Zhang (2011) proposed a new approach to determine the supply chain (SC) design for a family of products comprising complex hierarchies of subassemblies and components. Their work proposed an algorithm based on Pareto Ant Colony Optimisation as an effective meta-heuristic method for solving multi-objective supply chain design problems. An experimental example and a number of variations of the example are used to test the algorithm and the results reported using a number of comparative metrics. Parameters affecting the performance of the algorithm are investigated. Kastsian and Mönnigmann (2011) addressed the steady state optimization of a supply chain model that belongs to the class of vendor managed inventory, automatic pipeline, inventory and order based production control systems (VMI-APIOBPCS). The supply chain was optimized with the so-called normal vector method, which has specifically been developed for the economic optimization of uncertain dynamical systems with constraints on dynamics. They demonstrated that the normal vector method provides robust optimal points of operation for a number of scenarios. Since the method strictly distinguishes economic optimality, which is treated as the optimization objective, from dynamical requirements, which were incorporate by appropriate constraints, it provides a measure for the cost of stability and robustness as a desired side-effect.

Paksoy, Pehlivan and Özceylan (2012) applied fuzzy sets to integrate the supply chain network of an edible vegetable oils manufacturer. The proposed fuzzy multi-objective linear programming model attempts to simultaneously minimize the total transportation costs. The first part of the total transportation costs was between suppliers and silos; and the other one was between manufacturer and warehouses. The approach incorporates all operating realities and actual flow patterns at production/distribution network with reference to demands of warehouses, capacities of tin and pet packaging lines. The model has been formulated as a multi objective linear programming model where data are modeled by triangular fuzzy numbers. Finally, the developed fuzzy

model was applied to the case study, compiled the results and discussed. Davis and Doyle (2011) introduced the optimization of the supply chain a framework for decision making that drives fiscally responsible decisions in their works. The cost-effective supply chain was driven by implementing a value analysis process for product selection, being mindful of product sourcing decisions to reduce supply expense, creating logistical efficiency that will eliminate redundant processes, and managing inventory to ensure product availability. The value analysis approach was an analytical methodology for product selection that involves product evaluation and recommendation based on consideration of clinical benefit, overall financial impact, and revenue implications.

Wan et all. (2003) made a simulation based optimization framework is presented to analyze complex supply chains under uncertainties, which includes three high level modules: deterministic optimization module, simulation module, stochastic optimization module. These modules coordinated to address challenging difficulties faced by supply chain management. This framework was applied to optimize the safety stocks of a three-stage divergent supply chain. The effect of supply chain network configurations on safety stocks is also examined.

Dal Mas et all. (2010) made a capacity planning and financial optimization of the bioethanol supply chain under price uncertainty. This work addresses the development of a dynamic spatially explicit MILP (Mixed Integer Linear Programming) modeling framework devised to optimize the design and planning of biomass-based fuel supply networks according to financial criteria and accounting for uncertainty on market conditions. The model capabilities in steering strategic decisions are assessed through a real-world case study related to the emerging corn-based bioethanol production system in Northern Italy. Two optimization criteria are considered, based on a risk-seeking or, alternatively, on a risk-adverse-approach. Zhou, Cheng and Hu (2000), supply chain optimization of continuous process industries with sustainability considerations. In this study, goal programming (GP) model was proposed to address this multi-objective problem with the integration of non-relaxable constraints and relaxable constraints. The analytic hierarchy process (AHP), a multi-objective decision making method, is used to evaluate the priorities of goals and weights of deviation variables. The application of this approach was illustrated through a case study on sustainable supply chain optimization and scheduling of a petrochemical complex. The results obtained show that this approach is a viable tool and offers good communication with decision-maker.

Kheljani, Ghodsypour and O'Brien (2009) in their work the issue of coordination between one buyer and multiple potential suppliers in the supplier selection process has been considered. On the other hand, in the objective function of the model, the total cost of the supply chain is minimized rather than only the buyer's cost. The total cost of the supply chain includes the buyer's cost and suppliers' costs. The model has been solved by applying mixed-integer nonlinear programming.

2. Supply Chain Management and Purchasing Functions

The supply chain has been defined as "the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" (Vrijhoef and Koskela, 2010). Supply chains exist to overcome the

separation between suppliers and customers; they allow for operations that are best done, or can only be done at locations that are distant from customers or sources of materials (Donald and Waters, 2007). As in organizations, supply chain participants are brought together in the pursuit of goals. Entities in a supply chain accept a specific role to perform functions and activities that target common goals. Each participant's role in the chain is based on the belief that they will be better off because of the collaborative efforts of the supply chain participants. Similar to the division of labor in a traditional organization, each supply chain participant generally specializes in the activity that best aligns with its distinctive competencies (Ketchen Jr and Giunipero, 2004). It involves planning, design and control of flow of material, information and finance along the supply chain to deliver superior value to the end customer in an effective and efficient manner (Shah, 2009).

Supply chain management (SCM) is the integration of key business processes from end-user through original suppliers that provides products, services and information that add value for customers and other stakeholders (M.Lambert, 2008). SCM; design, maintenance and operation of supply chain processes for satisfaction of end user needs (B.Ayers, 2006). SCM is the process of planning, implementing and controlling the operations of the supply chain with the purpose of satisfying the customer's requirement as efficiently as possible. Supply chain spans all movement and storage of raw material, work in process, inventory and finished goods from the point of origin to the point of consumption (Sinha, 2009). SCM is a key means of differentiation for a firm and a critical component in marketing and corporate strategy. Supply chain oriented companies commonly report lower invetory, transportation, warehousing and packaging costs; greater supply chain flexibility; improved customer service and higher revenues (Lamb, Hair and McDaniel, 2010). Supplier relationship management provides the structure for how relationships with suppliers will be developed and maintained. Close relationships are developed with a small subset of suppliers based on the value that they provide to the organization and more traditional relationships are maintained with others. (Mendes,2011)

A well designed supply chain shall provide the following benefits: (Sinha, 2009)

-Operations can be located in the best locations irrespective of customers locations.

-Bigger facilities can be created and hence economies of scale can be throught of.

-Large stocks need not be kept at the producer's end as the same can be kept with wholesalers near the customers.

-Retailers carry less stocks as whole sellers provide them the materials whenever needed.

-Lead times for retailers are short.

-Uninterrupted availability to customers.

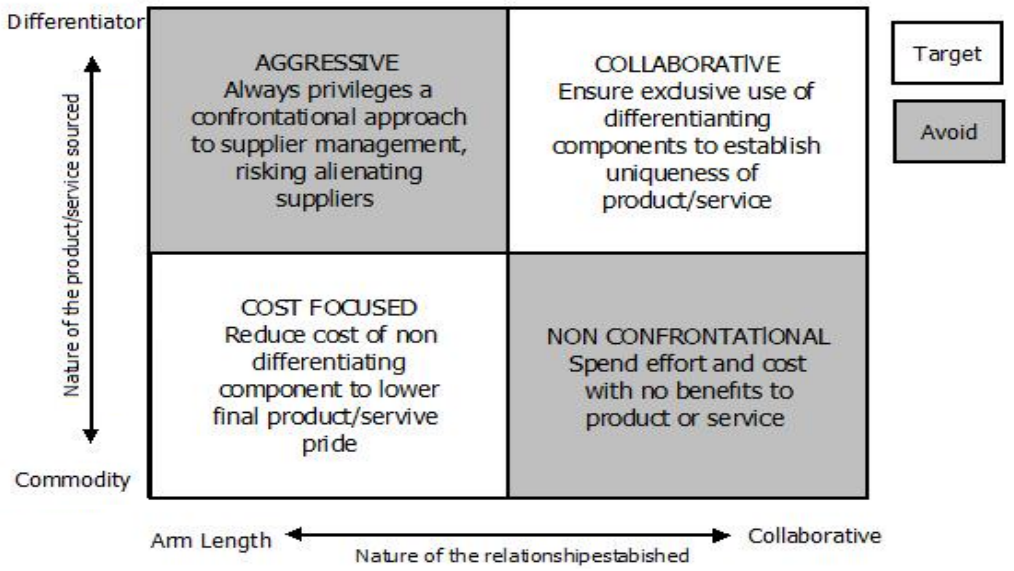
-Transport is simpler and routine.

Supplier relationship management is the supply chain management process that provides the structure for how relationships with suppliers are developed and maintained (M.Lambert, 2008). Activities germane to the supplier relationship management process typically include identifying and selecting suppliers; creating

supplier scoring criteria and applying scorecard tools to supplier groups; conducting periodic supplier reviews and visits and identifying ways that suppliers could provide greater service levels at similar costs, among many others. (Lamb, Hair and McDaniel, 2008)

The following diagram describes objectives that drive particular procurement team behaviors and supplier relationships (Philippart, Verstraete and Wynen, 2005).

Figure 1: **Supplier Relationship Management** (Philippart et all.,2005)



The evolution of relationships among companies within the supply chain has been an interesting and important issue for researchers and managers is the last years and will continue to be important in the future (Ronchi, 2003). The achievement of these benefits is not without effort by both parties. From the buyer organisation's point of view, the realisation of the benefits requires the supplier to act in the interests of the buyer (Cuganesan, Briers and Chua, 1999). Good supplier relations can provide many benefits such as flexibility in terms of delivery, better quality, better information and better material flows between buyers and suppliers. Many companies believe strongly that better supplier partnerships are important in achieving competitive corporate performance (Wisner, Tan and Leong, 2012). Strategic supplier management can increase productivity, eliminate ineffective processes and substantially boost your company's bottom line. Profit-Focused Supplier Management gives you the means to uncover valuable information about your suppliers, letting you make better supply chain decisions while limiting risks and improving your company's operational and financial health (Östring, 2004). Purchasing, is the management of the company's external resources in such a way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining and managing the company's primary and support activities is secured under the most favourable conditions (Van Weele, 2005). Purchasing is one of the basic functions common to all organizations. It is the process of

acquiring goods, services and equipment from another organization in a legal and ethical manner. Professional purchasing addresses five rights: purchase of the right item or service, in the right quality, at the right price, at the right time. Purchasing provides the foundation of supply management (Burt, Petcavage and Pinkerton, 2011). Purchasing establishes and maintains the supplier base, seeing to it that adequate capacity and quality are available and that the level of service and price are optimal (Lu Harding, 2001).

Procurement includes all activities required in order to get the product from the supplier to its final destination. It encompasses the purchasing function, stores, traffic and transportation, incoming inspection and quality control and assurance, allowing companies to make supplier selection decisions based on total cost of ownership (TCO) rather than price (Van Weele, 2005). Purchasing is a simple transaction process, Procurement includes transactions related to purchase and supplier settlement (Ray, 2010). The role of purchasing is to obtain raw material, components, parts, as well as information that are needed for the production of goods or providing services. The purchasing process includes many aspects, such as request for quotation (RFQ), supplier market analysis, supplier selection, contract negotiations and purchase plan implementation (Ling Li, 2007). The quality of finished product depends on the quality of the raw materials used. Purchasing also contributes to profitable operations by ensuring that goods are delivered when they are needed (Longenecker, Moore, Palich and Petty, 2006). This leads to the second argument for the importance of purchasing, which says that it affects broader organizational performance. If purchasing is done badly, materials do not arrive or the wrong materials are delivered in the wrong quantities at the wrong time with poor quality at too high price, low customer service and so on (Monczka, 2009).

Make or buy issues sit firmly at the centre of the manufacturing strategy of a company. (Probert, 1997) Make or buy decisions involve determining whether it's more cost-effective for the organization to make or buy the products or services of the project (Heldman, 2011). Make or buy decisions to determine how much of each of several components parts a company should manufacture and how much it should purchase from an outside supplier. Such a decision is referred to as a make or buy decision (Anderson, Sweeney, Williams and Martin, 2008). The quantity of items needed is one consideration. If a part is used in only one of many products, buying the part may be more cost-effective than making it. Buying standard items, such as screws, bolts, rivets and nails, is usually cheaper and easier than producing them internally. Purchasing larger components from another manufacturer can be cost-effective as well (Gitman and McDaniel, 2009). When a manufacturer assembles component parts in producing finished product, management must decide whether to make or buy the components. The decision to buy parts or services is often referred to as outsourcing (Weygandt, Kimmel and Kieso, 2010). The supply chain encompasses all organizations and activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flows. Material and information flows both up and down the supply chain (Nichols and Handfield, 2002). Supply chain management is the implementation of a supply chain orientation across suppliers and customers. Supply chain management is the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term

performance of the individual companies and the supply chain as a whole (Mentzer, 2001).

The purchasing function serves as the critical interface with the upstream supplier. Purchasing managers are responsible for ensuring that: 1) the right suppliers are selected; 2) suppliers are meeting performance expectations; 3) appropriate contractual mechanisms are employed and 4) an appropriate relationship is maintained with all suppliers (Nichols and Handfield, 2002). Supply chain management activities are following; (Mentzer, 2001)

-Integrated behavior.

-Mutually sharing information.

- Mutually sharing channel risks and rewards.

-Cooperation.

-The same goal and the same focus of serving customers.

-Integration of processes.

-Partners to build and maintain long-term relationships.

The purchasing department has been responsible for the price, delivery and quality of purchased goods (Harding, 2001). The key reasons for evaluating internal purchasing performance are the following (David Frederick Ross, 2004):

-To direct attention to main purchasing performance areas and objectives so that performance continually improves while objectives are being met.

-To improve purchasing department organizational structure, policies and procedures.

-To identify those areas where additional training and educational efforts may be required.

-To provide data so that corrective action can be taken where necessary.

-To improve interrelations within purchasing, between purchasing and other business functions and between purchasing and the firm's suppliers.

-To evaluate departmental staffing requirements.

3.Numerical Example

The company is operating in a pharmaceutical sector. It has 25.000 sqauare meter covered area, totally making 40.000 square meter with its four manufacturing facility, and with 3.000 employees. cGMP is applied in the facilities with the 100 milion box production capacity, making 300 milion $/year. For the purpose of material procurement it is worked with five different suppliers among which are local and international firms. In the beginning of the study, physical features and prices of the material to be procured from the suppliers were evaluated by the help of Excel Solver and suppliers to work with were determined. Later, the combination of the suppliers that previously decided on which would provide the minimum total cost was determined by

the help of Lingo. At this stage, the benefits of the quantity discount and its effects on supply chain total cost was analyzed.

In this study supply chain total optimization was evaluated at a manufacturing enterprise where single purchasing department works coordinated with more than one supplier. In this application each supplier has a limited production quantity, purchasing team want to buy one product from these suppliers and objective function is to minimize the total cost of the supply chain including purchasing agents' and suppliers' annual costs.

3.1. Selection of the suppliers

Features and unit prices of the stoppers that could be supplied by the five different suppliers are presented below.

Table 1: **The Properties of the Stoppers**

Suppliers	Moisture Content (%)	Desiccant Filling Quality (g)	Inner Diameter (mm)	External Diameter (mm)	Total Height (mm)	Unit Price (TL)
Supplier A	3,10	1,80	27,88	34,80	32,25	0,08
Supplier B	2,56	2,08	27,84	34,63	32,28	0,12
Supplier C	3,00	1,85	27,93	34,81	32,95	0,10
Supplier D	2,24	2,15	27,98	34,85	32,02	0,13
Supplier E	2,80	1,94	27,69	34,60	32,10	0,15

Percentages of stoppers to be purchased from the five different suppliers are stated as below:

X_1 : The percentage of stopper for first supplier

X_2 : The percentage of stopper for second supplier

X_3 : The percentage of stopper for third supplier

X_4 : The percentage of stopper for fourth supplier,

X_5 : The percentage of stopper for fifth supplier.

The objective function is to minimize the costs of stopper used in the production. Accordingly, the objective function should be expressed as follows:

$$\text{Min } Z = 0{,}08 * X_1 + 0{,}12 * X_2 + 0{,}10 * X_3 + 0{,}13 * X_4 + 0{,}15 * X_5 \quad \ldots \text{ equation (1)}$$

Table 2: **Values Need To Be Used in The Production of Polyethylene Stoppers**

Moisture Content (%)	max = 2,97
	min = 2,23
Desiccant Filling Quality (g)	max = 2,18
	min = 1,99
Inner Diameter (mm)	max = 27,96
	min = 27,69
External Diameter (mm)	max = 34,82
	min = 34,49
Total Height (mm)	max = 32,99
	min = 32,02

-Minimum and Maximum Quantity Constraints……..equation set(2)

$2{,}97 \geq 3{,}10 * X_1 + 2{,}56 * X_2 + 3{,}00 * X_3 + 2{,}24 * X_4 + 2{,}80 * X_5 \geq 2{,}23$

$2{,}18 \geq 1{,}80 * X_1 + 2{,}08 * X_2 + 1{,}85 * X_3 + 2{,}15 * X_4 + 1{,}94 * X_5 \geq 1{,}99$

$27{,}96 \geq 27{,}88 * X_1 + 27{,}84 * X_2 + 27{,}93 * X_3 + 27{,}98 * X_4 + 27{,}69 * X_5 \geq 27{,}69..$

$34{,}82 \geq 34{,}80 * X_1 + 34{,}63 * X_2 + 34{,}81 * X_3 + 34{,}85 * X_4 + 34{,}60 * X_5 \geq 34{,}49$

$32{,}99 \geq 32{,}25 * X_1 + 32{,}28 * X_2 + 32{,}95 * X_3 + 32{,}02 * X_4 + 32{,}10 * X_5 \geq 32{,}02$

In order to the total rate of stoppers to be purchased from all the suppliers to be 100 % ;

$X_1 + X_2 + X_3 + X_4 + X_5 = 1$……..equation (3)

In order to the decision variables not to be negative the following constraints should be included in the constructed model:

$X_1 , X_2 , X_3 , X_4 , X_5 \geq 0$……equation (4)

By taking all these constraints into account, the constructed model developed to achieve the objective function was solved by Excel Solver and the results found are presented in the table below:

Calculations showed that the objective function = 0,107 and x values which are the percentages that should be purchased from five different suppliers are as follows:

Table 3: **Suppliers and The Percentages of Use**

Suppliers	(Xi)
A	0,43
B	0,16
C	0
D	0,41
E	0

If 43% of polyethylene stoppers the enterprise needs is bought from supplier A, 16% is bought from supplier B and 41% is bought from supplier D "minimizing the stopper costs used in the production", namely the objective function, is achieved. In this case, from the perspective of cost, procuring stoppers from C and E suppliers is not a favorable situation for the enterprise.

3.2. Optimization of The Total Supply Chain

In the second section, by taking into account the annual production quantities, order costs, set up costs, variable costs of the suppliers that had been found appropriate by Excel Solver and by also considering the annual demand amount and stock keeping costs of the enterprise; the supply chain total cost was optimized by the help of LINGO. For the optimization purpose Lingo (Language for Interactive General Optimization) program is used, it is advanced version of the Lindo (Linear Interactive Discrete Optimizer) program, used for big problem types of lineer and nonlineer programming which promises optimum results, excell solver is also used in this study which has genetic algrithms embeded in the tool, promising near optimum results. By the help of Lingo suppliers were assessed and assuming that central model structure was applied at the enterprise, in a purchaser-supplier coordinated system, by showing decrease of supply chain total cost despite increase of purchasing total cost –which is not frequently encountered, it was shown that the enterprise should keep its supplier within its body and that the advantages could be attained if it produces the polyethylene stoppers it needs by itself. The enterprise intends to manufacture the polypropylene tubes and polyethylene stoppers that it uses in the production within itself.

Quantity discount is not actively being used in the enterprise. The order sizes are not arranged with respect to this reduction scale and the production is determined according to results of needs of production planning. Quantity discounts that the suppliers had provided at the beginning of the year were taken into consideration in this study and the reduction in the supply chain total cost arising from quantity discount was presented to the attention of the enterprise. Also in order for the enterprise to arrange its order sizes with respect to quantity discounts that the suppliers provide, a case study was prepared.

Annual Supply Chain Total Cost = Buyer's Annual Cost + Supplier's Annual Cost

Buyer's Annual Cost = Annual Purchasing Cost + Annual Fixed/Order Cost + Annual Inventory Holding Cost

Annual Cost for supplier = Annual Production Cost +Annual Setup Cost + Annual Inventory Holding Cost

can be considered.

3.2.1. Model Parameters

D: Buyer's annual demand rate.

Dí: Quantity purchased per year from the i th supplier.

Q: Order quantity per period.

Qí: Order quantity per period from the i th supplier.

Aí: Fixed/order cost for the i th supplier.

Xí: Percent of Q assigned to the i th supplier.

Sí: i th supplier's set up cost.

Pí: Annual production rate of the i th supplier.

Zí: Variable cost for each product of the i th supplier.

Cí: Purchasing price of each product from the i th supplier.

m: Number of suppliers.

r: Annual inventory holding cost rate.

T: Time of a buyer's period.

Tí: Time of consuming an ordered quantity of the i th supplier.

3.2.2. Model Assumptions

-Inventory shortage for buyer and suppliers is not allowed.

-Inventory surplus is not acceptable.

-In each period, after all i th supplier order quantities are consumed, i+1 th supplier's order quantity can be entered.

In the second section of the application; for the sake of optimizing the supply chain annual total cost, firstly annual costs that would occur for purchasing agent and supplier were calculated. Here it was assumed that "Central System" was in use. Therefore, both suppliers and purchasing agents are within the enterprise and both have worked towards to minimize supply chain annual cost.

Table 4: **Supplier's Data**

	Unit Price (TL/unit)	Production Rate (unit/year)	Order Cost (TL/year)	Set Up Cost (TL/year)	Production Variable Cost (TL/year)
Supplier A (X_1)	0,08	1.500.000	1.100	11.000	300
Supplier B (X_2)	0,12	1.000.000	1.000	10.000	270
Supplier D (X_2)	0,13	2.000.000	1.300	9.000	250

3.2.3. Solution With Lingo

Demand Rate for stoppers: 3.000.000 unit/year

Inventory Holding Cost: 0,25

According to the calculation of three different suppliers are available 2^n combination of $2^3 = 8$ different supplier's combination occurs.

These conditions are following:

Table 5: **Conditions of Suppliers Used for the Production of Different Combinations**

Cases	Y_1	Y_2	Y_3	Production Quantity	Feasibility
1	1	1	1	4.500.000	Yes
2	1	1	0	2.500.000	No
3	1	0	1	3.500.000	Yes
4	1	0	0	1.500.000	No
5	0	1	1	3.000.000	Yes
6	0	1	0	1.000.000	No
7	0	0	1	2.000.000	No
8	0	0	0	0	No

As it can be understood from the table above, because in the first, third and fifth supplier combination situations the total production quantity is greater than annual demand amount of 3.000.000, it was accepted. In the other combination situations the production quantity was not taken into assessment as it was not adequate to meet the annual demand. For the accepted first, third and fifth combination situations; stopper quantity percentages that should be bought from the suppliers (x), order quantity per period (Q), buyer's annual cost (BAC), annual cost of the i th supplier (SSAC) and annual supply chain total cost (ASCT) were calculated by the help of LINGO.

First Combination

The first combination situation is the situation where stoppers are bought from existing three suppliers. Firstly, stopper quantity percentages that should be purchased from suppliers and supply chain annual total cost are calculated by the help of Lingo:

Min (ASCT) = Min [D * $\sum_{i=1}^{n} Xi * (Ci + Zi)$ + √(2 *r * D * $\sum_{i=1}^{n} Ri$) * √{$\sum_{i=1}^{n} Xi^2 * \left(Ci + D * \frac{Zi}{Pi}\right)$}] ……..equation (5)

Min (TZYM) = 3.000.000 * (300,08 * X_1 + 270,12 * X_2 + 250,13 * X_3) + 223.830,2929 * √ (600,08 * X_1^2 + 810,12 * X_2^2 + 375,13 * X_3^2) ; .equation (6)

$X_1 + X_2 + X_3 = 1$;

If $X_1 \leq 1.500.000 / 3.000.000$; $X_1 \leq 0,50$;

If $X_2 \leq 1.000.000 / 3.000.000$; $X_2 \leq 0,33$;

If $X_3 \leq 2.000.000 / 3.000.000$; $X_3 \leq 0,67$;

Xí ≥ 0; The total annual cost of the above-mentioned formula and supply chain constraints are solved using Lingo:

Solution Report - LINGO1

```
Local optimal solution found.
Objective value:                              0.7737666E+09
Infeasibilities:                              0.1110223E-15
Extended solver steps:                                    0
Total solver iterations:                                  9

                     Variable           Value        Reduced Cost
                           X1      0.1000000E-04        0.000000
                           X2      0.3299900            0.000000
                           X3      0.6700000            0.000000

                          Row    Slack or Surplus      Dual Price
                            1      0.7737666E+09       -1.000000
                            2       0.000000          -0.8140953E+09
                            3      0.4999900            0.000000
                            4      0.1000000E-04        0.000000
                            5       0.000000           0.6019348E+08
                            6      0.1000000E-04        0.000000
                            7      0.3299900            0.000000
                            8      0.6700000            0.000000
                            9       0.000000          -0.8614474E+08
                           10      0.3299800            0.000000
                           11      0.6699900            0.000000
```

X_1 = 0,00001 X_2 = 0,32999 X_3 = 0,67 Accordingly, stoppers should be purchased from supplier A at a rate of 0,001%, from supplier B at a rate of 32,999% and from supplier D at a rate of 67%.

The same calculations were performed for the third and fifth combination cases and results found are presented in Table 6:

Table 6: **Values of Variables Calculated by Lingo for All Combination Cases Accepted**

Case	X_1	X_2	X_3	Q	BAC	SSAC	ASCT
1	0,00001	0,32999	0,67	55.890,74	563.096,72	773.203.503	773.766.600
3	0,33	0	0,67	47.957,76	491.034,18	802.151.965	802.643.000
5	0	0,33	0,67	44.632,57	535.094,09	772.508.405	773.043.500

3.3. Quantity Discount Model

According to the contracts signed at the beginning of the year with the potential suppliers with which the enterprise plans to work, quantity discounts are applied. Accordingly, certain rates of quantity discount are received from suppliers with respect to the quantity of stoppers to be purchased.

Table 7: **Quantity Discount Model Values**

Cases	Quantity Discount	% Discount	Reduced Cost		
			supplier A	supplier B	supplier D
1	0-499.999	No discount	0,08	0,12	0,13
2	500.000-999.999	4	0,077	0,115	0,125
3	1.000.000-1.999.999	6	0,075	0,113	0,122
4	2.000.000 and higher	8	0,074	0,11	0,12

Applying Lingo, in the case of fifth possibility that is accepted for the enterprise, the quantity discount to be applied with respect to stopper quantities to be purchased from the suppliers B and D. Accordingly, supply chain total cost was calculated as 773.018.400. With the unit price lowered as a result of quantity discount the total cost was decreased by 25.100.

Conclusion and Suggestions

In order to stand out against stiff competition conditions that exist among the enterprises and that is increasingly on the rise, decreasing the supply chain total cost has gained importance. In order for the enterprises to continue with their operations they should be able to procure the right material, from the right source, at the right time, with the right quantity and most importantly at a minimum cost. All these objectives can be attained through an effective supply chain. Therefore an enterprise having an effective

supply chain and minimizing the supply chain total cost takes an advantage compared to its competitors.

In this study suppliers were assessed based on quality and price criteria and best supplier selection was performed for the enterprise. Later, by using the suppliers that were found to be appropriate supply chain total cost optimization was performed. In this study Excel Solver and Lingo 11.0 package programs were utilized. Since, based on the values calculated for the three different suppliers combination case in the fifth combination case, supply chain total cost is smaller compared to the other two combination cases, the case to be preferred is the fifth case. The point that should be paid attention to is that despite a decrease in supply chain total cost, there is an increase in the total cost of purchasing agent. This situation is not generally accepted by procurement.

Two models are talked about in the problems with purchasing – supplier coordination; Central and Distributed Supply Chain Models. In the Central model the supplier and the buyer can use their own data for each other. In the Central models the enterprise has its own supplier and buyer.

The both units work for e good of the enterprise. Although total annual cost increase for the supplier or buyer they are interested in total cost of the enterprise. In the distributed models however, the supplier and the purchasing team are within different enterprises. Kheljani, Ghodsypour and O'Brien's work in 2009 has been developed in this study. The central supply chain models are not that commonly used in the enterprises. In an enterprise that uses distributed model the cost incurred for the supplier is ignored, therefore enterprises mostly act on their purchasing costs.

In this study it has been assumed that the enterprise has central supply chain structure therefore as the supply chain total cost decreases in the fifth case cost increase for the purchasing team has been an acceptable situation. In general while the enterprises take into account only the purchasing cost, in this study both the purchasing and supplier costs were analyzed and supply chain total cost was optimized. Decision making problem of purchasing agent and supplier is integrated and ordered. In this study the supply chain costs are optimized based on purchasing function. In the central models where purchasing team and supplier which are within the same enterprise, the annual supply cost and annual purchasing cost should not be considered and assessed separately. The supply chain annual cost which is comprised of total of the two costs should be predicated on.

In the last section quantity discounts received from suppliers were evaluated as well. With the quantity discount received from supplier B and D a decrease in the supply chain total cost was attained. As a conclusion, if the suppliers are considered within the enterprise, in the fifth combination case calculated with Lingo, the total cost for the enterprise was the minimum. According to this combination situation, 990.000 stoppers from supplier B and 2.010.000 stoppers from supplier D are procured the annual demand amount is met and the supply chain total cost is minimized.

Although the studies about optimization in the literature are done more on the companies which have decentralized supply chain, in this article centralized supply chain in companies is explained. The company in the article is a pharmacutical manufacturing company which believes in continuous improvement and the coordinated work of the

supplier and purchasing teams are encoraged on the polietilen taps used on the pharmacutical products. In this study the emphasis is on the diminishing of the total supply chain cost even though the purchasing cost increases. In the application part the benefits of the centralized supply chain is found.

Since the minimization of the total cost is the one of the primary goals of a company, there should be efforts for dimishing of the cost for both sides, the suppliers and the purchasing depatments of the companies in a supply chain. This could be considered as a different perspective of the coordinated and combined efforts of a companies purchasing teams.

This coordinated models are formulated to able to syncronize and optimize all the supply chain decisions. This article could guide the researchers and the companies who would move in the centralized supply chain direction.

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MERKEZİ TEDARİK ZİNCİRİNDE SATIN ALMA FONKSİYONUNA DAYALI OPTİMİZASYON VE FARMASÖTİK ALANDA BİR UYGULAMA

Özlem AKÇAY KASAPOĞLU •

Çağlar ONAÇ YAKUT ••

Özet

Bu çalışmanın amacı, merkezi tedarik zinciri yapısına sahip işletmelerde satın alma fonksiyonuna dayalı tedarik zinciri toplam maliyetini optimize etmektir. Bu amaçla farmasötik alanda faaliyet gösteren, kendi üretimini yapan, satın almacı ve tedarikçisini kendi bünyesinde bulunduran bir işletmede tedarik zinciri yıllık toplam maliyetini optimize etmek adına uygulama yapılmış ve farklı tedarikçi kombinasyonlarında satın alma faaliyetleri sonucu oluşan tedarikçi, satın almacı ve tedarik zinciri için ortaya çıkan yıllık toplam maliyetler değerlendirilerek işletme açısından minimum maliyetli durum seçilmiştir. Bu çalışmada, Excel Solver ve Lingo 11.0 programları kullanılmıştır.

Anahtar kelimeler: Merkezi Tedarik Zinciri, Optimizasyon, Satın alma

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