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Research Article

# Application of goal programming for target setting in Irans auto industry

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**Abstract**

One of the main challenges in Irans auto industry is goal setting in various functional domains. Managing costs of supply chains requires recognition of cost drivers and mathematical modeling for target setting. Realization of the main elements of supply chains and setting logical relations among variables and parameters in the form of a mathematical model are of the main purposes of this research paper. The main question is how it is possible to bring conflict goals of a supply chain together in a mathematical model with the help of goal programming. The relations among 10 au (1)1to part suppliers, 1 warehouse, 3 auto manufacturing plants and 3 agencies are investigated in this study. After collecting data of model parameters, model is solved through application of LINGO software and the following results are revealed. The positive goal deviation of the first objective is equal to 2500 million Rials. The negative goal deviation of the second objective is equal to 1750 million Rials. The positive goal deviation of the third objective is 1250 million Rials.

*Keywords* : Goal programming; Target Setting; Conflict Objectives; Managing Supply Chain; mathematical modeling.

## 1 Introduction

Supply Chain Management (SCM) is concerned with material and information flows between facilities and the final consumers [6]. As of the beginning of 1990s the concept of Supply Chain began to emerge as one of the most popular field of research and study until today[8]. Supply Chain Management has developed into a major conceptual approach inside management and business administration. Over the past two decades, Supply Chain Management has come to be seen as a key component of organizational competitiveness and effectiveness [12]. Peter Drucker believes that in order to progress in the increasingly competitive global market, which is the dominant, companies should know total cost of their Supply Chain and help with the other members of the Chain to manage costs and deliver maximum efficiency [7]. Such Supply Chain strategies focus on how both internal and external business processes can be integrated and coordinated throughout the Supply Chain to better serve ultimate customers and consumers while enhancing the performance of the individual Supply Chain members [5]. Chopra and Meindl (2004) describe the Supply Chain as a dynamic network of collaboration that consists of many parties such as suppliers, manufacturers, transporters, warehouses, distribution centers, retailers, customers, etc., and its objective is to maximize the overall value generated for all the members of Supply Chain [4]. Therefore, companies have started

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changing from estimating the cost of what is happening within their own organizations to estimate the total cost of Supply Chain network, in which the largest companies are only one loop of the Chain. Over and over again in business history, unknown firms in several years have gone a head of established industry pioneers.They argued about having the best strategy, new technology, better marketing or cheaper manufacturing. But the fact is that in all these cases, entered new companies have benefited the extraordinary advantage of the cost which was usually about 30 percent. All these entered new companies know not just their own costs but the total costs of Supply Chain to users and run them. Perhaps the Toyota automotive company is the best example of a company which knows about parts suppliers' and its own distributors' costs and runs them . Of course, all of these companies are members of Toyota Supply Chain network .Toyota Company through the network runs all of its own costs from supply costs and construction/production to marketing and selling expenses as a series of stimulating cost activities.

## 2 Problem Setting

A Supply Chain may be considered an integrated process in which a group of several organizations, such as suppliers, producers, distributors and retailers, work together to acquire raw materials with a view to converting them into end products which they distribute to retailers. Design and optimization of strategic production-distribution models for SCM is one of the most popular problems in this research field. Operational research, with its rich mathematical fundamentals has a very vast application in supply chain modeling. However, the conflicts of resources and the incompleteness of available information make it almost impossible for decision makers (DMs) to build a reliable mathematical model for representation of their preferences [17].

In industrial cases there are always different but related goals. Especially, we can see this situation in supply chain management. The supply chain starts with suppliers, warehouse, plants, and finishes with end-customers. Minimizing the transportation, inventory, backorder, fixed costs and maximizing the profit, customer satisfaction, recycling ratio etc. are generally aimed in supply chains. Although there just are usually general objectives such as mentioned above, sometimes decision makers determine upper and lower targets to achieve the goal. Budget, time, human resources constraints or something else cause this situation [17]. In sciences and industries such as signal optimization, traffic assignment, economic market and etc, many problems have been modeled by bilevel programming (BLP) problems, where in each level one must optimize some objective functions [2]. Manufacturing process and product features in auto industry requires several connections and links before and after the manufacturing process. Before manufacturing, these connections include links to suppliers (raw materials and parts) and after production comprise end-users and society. Studies show that the most prominent costs which companies undergo in the supply chain mostly include that of raw materials, parts, transportation (from supplier to manufacturer and from manufacturer to distributer and user, in general), establishing agencies and inventories.

Likewise, the main focus of our research is on finding answers for the following questions:

1. Can a goal programming model be formulated to demonstrate the relations among various elements of supply chain of Irans auto industry in the figure of a mathematical programming model by the use of operational research techniques?
2. What are the features and characteristics of such a goal programming model, if it is possible to do so?
3. How is it possible to recognize deviation of goals?
4. How is it possible to make a logical target setting?

### 2.1 Verifying Elements of a Supply Chain

Supply chain management has become one of the most frequently discussed topics in the business literature. According to Simchi-Levi et al. (2003), supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements. Supply chain is defined as a combinatorial system consisting of four processes namely plan, source, make and deliver, whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed forward flow of materials and the feedback flow of information. Effective management of an organizations supply chains has proven to be a very effective mechanism for providing prompt and reliable delivery of high-quality products and services at the least cost.

Determination of the target setting becomes difficult in problems with multiple inputs and multiple outputs. In this case, a set of weights has to be determined to aggregate the outputs and inputs [13] and it is clear that models should be formulated in order to have a better performance [13].

Despite the importance of the topic, supply chain modeling methodology often is lacking in literature of a comprehensive taxonomy that aid researchers to evaluate various models when analyzing the supply chain. Also, there is no systematic way of defining the scope of a specific supply chain problem. This may stem from nature of supply chain, which includes different functions that need to be modeled and/or overlap among different sets of models [11].

Various orientations lead to various targets. The question is which of these points is the suitable target? A variety of studies on the target setting can be considered in literature [10].

### *2.2* Models Concerning Distribution Costs

A common objective in designing a distribution network is to determine the least cost system design such that the retailers demand is satisfied without exceeding the capacities of the warehouses and plants. This usually involves making tradeoffs inherent among the cost components of the system that include cost of opening and operating the plants and warehouses and the inbound and outbound transportation costs [20].

Hasan Selim et al. (2006), developed a supply chain (SC) distribution network design model is developed in their paper. In their paper, they dealt with a SC distribution network comprised of a set of manufacturing plants, warehouses and retailers. In the design option considered, inventory is stored locally at retail stores and distributor warehouses. The main advantage of such a network structure is that it can lower the delivery cost and provide a faster response than other networks [20].

### *2.3* Models Concerning Transportation Costs

In general, distribution of product from depot to customer is called Transportation Problem (TP) which first developed by F. L. Hitchcock since 1941. It usually aims to minimize the total transportation cost. Other objectives that can be set are a minimization of the total delivery time, a maximization of the profit, etc. [15].

The fuzzy mapping function was introduced by Chang and Zadeh. Later, Dubois and Prade presented an elementary fuzzy calculus, based on the extension principle. The concept of integration of fuzzy functions was first introduced by Dubois and Prade. Alternative approaches were later suggested by Goetschel and Voxman, Kaleva, Nanda and others [9].

Waiel F. et al (2004) presented an interactive fuzzy goal programming approach to determine the preferred compromise solution for the multi-objective transportation problem. The proposed approach considered the imprecise nature of the input data by implementing the minimum operator and also assumed that each objective function has a fuzzy goal. The approach focused on minimizing the worst upper bound to obtain an efficient solution which was close to the best lower bound of each objective function [1].

Wuttinan Nunkaew et al. (2009) proposed a multi-objective programming for transportation model with the consideration of both depot to customer and customer to customer relationships. The objectives are to minimize the total transportation cost which is the baseline objective and to minimize the overall independence value. A Lexicographic Goal Programming (LGP) is applied to the proposed model. A minimization of the total transportation cost is set to the first goal and a minimization of the overall independence value is set to the second goal of the proposed model [16].

Morteza Shafiee et al. (2011) presented a new model and solution for multi-objective vehicle routing problem (VRP).Their paper, using goal programming with specific constraints and this model solved with genetic algorithm, that in which decision maker specifies optimistic aspiration levels to the objectives and deviations from those aspirations are minimized. The proposed algorithms have been successfully implemented and deployed for the real life problems in National Iranian Oil Products Distribution Company. The objective was to minimize the distance in each travel and minimize the number of vehicle without being tardy or exceeding the capacity or travel time of the vehicles [21].

### *2.4* Models Concerning Production/Distribution Costs

T. Paksoy et al. (2010) presented an application of Fuzzy mathematical programming model to solve network design problems for supply chains via considering aggregate production planning (APP). APP goals to minimize all costs through optimal levels of production, subcontracting, inventory, backorder and work levels over a time period to meet the demand. Fuzzy logic was applied to solve the uncertain production/distribution/subcontracting costs and capacities. The proposed APP model attempts to minimize total costs which are, transportation costs, production costs, inventory and backorder costs, labor hiring and firing costs in terms of inventory and backorder levels, work force level, subcontract and manufacturer production levels, regular time and overtime production levels, labor hiring and firing levels, demands and transportation capacities. This model simultaneously minimizes the most possible value of the imprecise total costs, maximizes the possibility of obtaining lower total costs and minimizes the risk of obtaining higher total costs [18].

### *2.5* Models Concerning Multiple Costs

Mostefa Belmokaddem et al. (2009) presented an application of a fuzzy goal programming approach with different importance and priorities (FGPIP) developed by Chen and Tsai (2001) to aggregate production planning (APP), for the state-run enterprise of iron manufactures nonmetallic and useful substances. The proposed model attempted to minimize total production and work force costs, carrying inventory costs and rates of changes in work force [3].
Turan Paksoy et al. (2010) considered a supply chain network design problem with popup stores which can be opened for a few weeks or months before closing seasonally in a marketplace. The proposed model is multi-period and multi-stage with multi-choice goals under inventory management constraints and formulated by 01 mixed integer linear programming. The design tasks of the problem involve the choice of the popup stores to be opened and the distribution network design to satisfy the demand with three multichoice goals. The first goal is minimization of the sum of transportation costs in all stages; the second is to minimization of set up costs of popup stores; and the third goal is minimization of inventory holding and backordering costs. Revised multi-choice goal programming approach is applied to solve this mixed integer linear programming model [18].
Kambiz Shahroudi et al. (2005) tried to develop a model to design and explain cost leadership strategy in Irans Auto Industry. What the paper emphasized was to achieve cost leadership advantage through focusing on internal resources. In order to analyze the cost structure of companies and contribute to strategic decisions and internal analysis of organization, Michael Porters value chain model was applied. The aim of the study was to develop the traditional model introduced by Porter and adapt it with the current situation of Irans Auto Industry. To test the model, a multi-objective mathematical modeling was first developed based on the suggested model. Then, in order to assess the validity of the model, data of an auto industry was used. The result gained from solving the model indicate that making use of the proposed model reduces the cost of supplies, maintenance costs, optimized allocation of funds, cost of raw materials and transportation cost [22].
In another paper, Kambiz Shahroudi et al. (2011) introduced an integrated model for suppliers selection and order allocation in an automotive company. Therefore, the research was performed in two sections. In the first, concerning how to select best supplier(s), after reviewing the research literature, interview with the experts, and survey the managers, in a company custodian to automotive supply chain management group, decision-making criteria were identified using Delphi method including criteria and subcriteria affecting on suppliers selection. Then, in order to calculate the weight of each indices

and final ranking of desired parts suppliers, integrated AHP-TOPSIS techniques were used. After that, in order to find out allocation quantity of orders to each supplier, multi-objective linear programming model (MOLP) was used. Results show that applying a two phase AHP-TOPSIS methodology causes to select the best suppliers. Also Automotive Companys total costs will be minimized with using a MOLP model [23].

# 3 Methodology

In this research, the authors are to find a mathematical model to demonstrate the relations among various elements of supply chain of Irans auto industry by applying operational research techniques. Minimizing total cost of transportation, backordering, inventory holding and idle production capacity cost is the main objective of doing this research. The model will be presented in the figure of a goal programming model and will minimize the aforementioned costs simultaneously. In order to check the validity of the presented model, data from Saipa Industrial Group is used and Lingo Software is applied to solve the model.

## 3.1 Mathematical Modeling

To model this value chain, the relations between all the activities which create value in the chain should be displayed through mathematically. This model can be developed if objective data are available. According to the classification of organizational resources (from the viewpoint based on resources within organization), it was found that organizations have two classifications of resources which include the followings:
1. tangible resources
2. intangible resources.
Access to data on tangible resources such as machineries, capacities, human resource, finance, market share and etc. is achievable through investigating documents. However, collecting data on intangible resources is very complex and transforming them into mathematical models is too time- consuming. A review on literature of mathematical modeling confirms this fact, as well [22]. Therefore, this study will apply data on tangible resources for mathematical modeling.

## 3.2 Introducing decision variable / suggested model parameters

## 3.3 Decision variables and the goal model

# 4 Proposed multi-objective decision making model

## 4.1 Goal Objective

$$\min\ T_0 = w_1 d_1^+ + w_2 d_2^+ + w_3 d_3^+$$

## 4.2 Goal Constraints

$$\sum_{p=1}^{5}\sum_{i=1}^{10} C_{piw}.X_{piw} + \sum_{p=1}^{5}\sum_{i=1}^{10}\sum_{k=1}^{3} C'_{pik}.Y_{pik} + \sum_{p=1}^{5}\sum_{k=1}^{3} C''_{pwk}.Z_{pwk} + \sum_{k=1}^{3}\sum_{l=1}^{3} C'''_{ckl}.Q_{ckl} - d_1^+ + d_1^- = 350,000,000,000$$

$$\sum_{p=1}^{5}\sum_{i=1}^{10} \beta_{pwi}.G_{pwi} + \sum_{p=1}^{5}\sum_{k=1}^{3}\sum_{i=1}^{10} \beta'_{pki}.H_{pki} + \sum_{p=1}^{5} \alpha_p.I_p - d_2^+ + d_2^- = 175,000,000,000$$

$$\min\ Z_3 = P_{ip}\left(1 - \frac{X_{piw}}{\sum_{p=1}^{10}\sum_{p=a}^{e} CL_{ip}}\right) - d_3^+ + d_3^- = 225,000,000,000$$

## 4.3 System Constraints

$$X_{piw} + Y_{pik} \le CL_{ip} \qquad \forall\ i = 1,2,...,10, \quad p = 1,2,..,5.$$

$$\sum_{p=1}^{5} X_{piw} \le S_p \qquad \forall\ p = 1,2,..,5.$$

$$\sum_{i=1}^{10}\sum_{p=1}^{5} F_{kpi}.Y_{pik} \le F \qquad \forall\ k = 1,2,3.$$

$$\sum_{i=1}^{10}\sum_{p=1}^{5} X_{piw} \le TS \qquad \forall\ p = 1,2,..,5.$$

$$\sum_{i=1}^{10}\sum_{p=1}^{5} X_{piw} \le TW \qquad \forall\ p = 1,2,..,5.$$

$$\sum_{p=1}^{5} X_{piw} \ge D_p \qquad \forall\ p = 1,2,..,5.$$

$$\sum_{k=1}^{3}\sum_{p=1}^{5} Y_{pik} \ge D'_{pk} \qquad \forall\ k = 1,2,3, \quad p = 1,2,..,5.$$

$$Q_{ckl} \le CL'''_l \qquad \forall\ l = 1,2,3.$$

$$I \le CL'_p \qquad \forall\ p = 1,2,..,5.$$

$X_{piw} + Y_{pik} + \varpi.Q_{ckl} = 0 \; \forall \; i = 1, 2, ..., 10, \;\; p = 1, 2, .., 5, \;\; k = 1, 2, 3.$

$I \geq IS_p \qquad \forall \; p = 1, 2, .., 5.$

# 5 Describing the constraints and functions of the goal objective

## 5.1 Goal Objective

The aim of the goal objective is to minimize positive deviations from the goal which consequently minimizes the total cost of transporting auto parts from suppliers to warehouse, suppliers to manufacturing plants, warehouse to manufacturing plants as well as that of transporting autos from manufacturing plants to agencies, the total cost of backordering auto parts from warehouse and manufacturing plants to suppliers and the inventory holding cost of auto parts in warehouse, the total idle production cost of auto parts in suppliers. The weights of the goal objective are gained by AHP technique.

## 5.2 Goal Constraints

Equation 4.2 represents the goal constraint of the first goal.

Equation 4.2 represents the goal constraint of the second goal.

Equation 4.2 represents the goal constraint of the third goal

## 5.3 System Constraints

Equation 6.3 states that the total number of auto parts transported from suppliers to warehouse and suppliers to manufacturing plants should be less than or equal to the production constraint of the suppliers.

Equation 6.3 states that the number of auto parts transported from suppliers to warehouse should be less than or equal to capacity constraint of warehouse for auto parts.

Equation 6.3 states that the budget constraint of manufacturing plants for purchasing auto parts from suppliers should be less than or equal to the total budget constraint for purchasing auto parts.

Equation 6.3 states that the number of auto parts transported from suppliers to warehouse should be less than or equal to space constraint of transportation ($m^3$).

Equation 6.3 states that the number of auto parts transported from suppliers to warehouse should be less than or equal to weight constraint of transportation (kg).

Equation 6.3 states that the number of auto parts transported from suppliers to warehouse should be more than or equal to demand of warehouse for auto parts.

Equation 6.3 states that the number of auto parts transported from suppliers to manufacturing plants should be more than or equal to demand of manufacturing plants for auto parts.

Equation 6.3 states that the number of autos transported from manufacturing plants to agencies should be less than or equal to the capacity constraint of agencies.

Equation 6.3 states that the inventory level of warehouse should be less than or equal to the total capacity constraint of warehouse.

Equation 6.3 guarantees that the total number of auto parts which are transported from suppliers to manufacturing plants and from warehouse to manufacturing plants should be equal to the number of autos transported from manufacturing plants to agencies multiplied by the number of parts required to produce one auto.

Equation 6.3 ensures that the total inventory level in warehouse should be greater than or equal to safety stock.

# 6 Goal programming model with real parameters and variables

Data of Saipa Corporation is used to test the mathematical model presented in this paper. Due to comprehensiveness of the model and multiplicity of variables and parameters and because of diversification of products, resources, suppliers, manufacturing plants and sales centers of Saipa Co. and the limitations of the study, collecting all the information is not possible. As a result, the problem under study will be limited to fewer decision variables and parameters. After solving the new limited problem and analysis, the suggested model can be generalized to problems with more decision variables and parameters. The model is downsized to ten suppliers producing, five different auto parts, one warehouse, three manufacturing plants and three agencies.

## 6.1 Goal Objective

$\min T_0 = 0.4d_1^+ + 0.3d_2^+ + 0.25d_3^+$

## 6.2 Goal Constraints

1558*111+160*x121+130*x231+125*x241+

165*x351 +170*x361+150*x471+145*x481+

130*x591+130*x5101+155*y111+150*y112
+

150*y113+175*y121+170*y122+175*y123+

160 *y231+170*y232+165*y233+190*y241+

190*y242+180*y243+200*y351+190*y352+

195*y353 +185*y361+185*y362+180*y363+

195*y471+170*y472+180*y473+160*y481+

175*y482+170*y483+205*y591+200*y592+

195*y593+185*y5101+210*y5102+200*y5103+

85*z111+80*z112+75*z113 +90*z211+

85*z212+80*z213+75*z311+95*z312+

100*z313+105*z411+100*z412+95*z413+

110*z511+90*z512+85*z513+

135000*q111+130000*q112+140000*q113+

145000*q121+130000*q122+150000*q123 +

120000*q131+125000*q132+

130000*q133*$d_1^+ + d_1^-$=350,000,000,000

110*g111+105*g112+95*g213+70*g214+

60*g315+75*g316+80*g417+70*g418+

55*g519+50*g5110+145*h111+155*h121+

190*h131+175*h112+135*h122+120*h132+

150*h213+160*h223+145*h233+165*h214+

170*h224+130*h234+125*h315+140*h325+

185*h335+170*h316+180*h326+175*h336+

140*h417+145*h427+130*h437+150*h418+

155*h428+130*h438+125*h519+130*h529

+135*h539+170*h5110+180*h5210+

165*h5310+300*i1+350*i2+280*i3+220*i4+

250* i5-$d_2^+ + d_2^-$=175,000,000,000

1549000-1.8*x111-2.1*x121-1.2*x231-

1.6*x241-2.4*x351-2.3*x361-1.5*x471

-1.6*x481-1.6*x591-1.4*x5101-

$d_3^+ + d_3^-$=225,000,000,000

## 6.3 System Constraints

$X_{piw} + Y_{pik} \leq CL_{ip}$ $\forall i = 1, 2, ..., 10$,
p=1,2,..,5.

x111+y111+y112+y113≤75000;

x121+y121+y122+y123≤85000;

x231+y231+y232+y233≤90000;

x241+y241+y242+y243≤75000;

x351+y351+y352+y353≤85000;

x361+y361+y362+y363≤90000;

x471+y471+y472+y473≤75000;

x591+y591+y592+y593≤90000;

x5101+y5101+y5102+y5103≤90000;

$\sum_{p=1}^{5} X_{piw} \leq S_p,\ \forall\ p = 1, 2, .., 5.$

45*x111+45*x121≤320000000;

60*x231+60*x241≤400000000;

35*x351+35*x361≤370000000;

70*x471+70*x481≤450000000;

12*x591+12*x5101≤430000000;

$\sum_{i=1}^{10} \sum_{p=1}^{5} F_{kpi}.Y_{pik} \leq F\ \forall\ k = 1, 2, 3.$

80*x111+85*x121+85*x231+

82*x241+92*x351+100*x361+

120*x471+112*x481 +135*x591+
125*x5101≤ 100000000000;

$82 * x112 + 82 * x122 + 90 * x232 +$

$85 * x242 + 85 * x352 + 95 * x362 +$

$125 * x472 + 115 * x482 + 127 * x592 +$

$135 * x5102 \leq 100000000000;$

$75 * x113 + 75 * x123 + 85 * x233 +$

$85 * x243 + 90 * x353 + 105 * x363 +$

$120 * x473 + 135 * x483 + 125 * x593 +$

$130 * x5103 \leq 100000000000;$

$\sum_{i=1}^{10} \sum_{p=1}^{5} X_{piw} \leq TS\ \forall\ p = 1, 2, ..., 5.$

20*x111+20*x121≤115000; $(m^3)$

2*x231+2*x241≤110000; $(m^3)$

2.5*x351+2.5*x361≤135000; $(m^3)$

3*x471+3*x481≤140000; $(m^3)$

1.5*x591+1.5*x5101≤120000; $(m^3)$.

$\sum_{i=1}^{10} \sum_{p=1}^{5} X_{piw} \leq TW\ \forall p = 1, .., 5.$

1.5*x111+1.5*x121≤10000;

x231+x241≤10500;

2*x351+2*x361≤11000;

3*x471+3*x481≤12000;

2.5*x591+2.5*x5101≤10500;

$\sum_{p=1}^{5} X_{piw} \geq D_p\ \forall\ p = 1, ..., 5.$

x111+x121≥600;

x231+x241≥750;

x351+x361≥1150;

x471+x481≥1200;

x591+x5101≥1300;

$\sum_{k=1}^{3} \sum_{p=1}^{5} Y_{pik} \geq D'_{pk}\ \forall\ k = 1, 2, 3,\ p = 1, ..., 5.$

y111+y121≥750;

y231+y241≥850;

y351+y361≥950;

y471+y481≥660;

y591+y5101≥770;

y112+y122≥800;

y232+y242≥850;

y352+y362≥960;

y472+y482≥840;

y592+y5102≥730;

y113+y123≥910;

y233+y243≥850;

y353+y363≥750;

y473+y483≥680;

y593+y5103≥930;

$Q_{ckl} \leq CL_l''' \quad \forall\ l = 1, 2, 3.$

15*q111+2*q121+9*q131≤985000;

25*q112+3*q122+3.5*q132≤1040000;

6*q113+5.5*q123+2.5*q133≤1120000;
$I \leq CL_p' \quad \forall\ p = 1, 2, .., 5.$

i1<=950000;

i2<=800000;

i3<=1050000;

i4<=1000000;

i5<=1100000;

$X_{piw} + Y_{pik} + \varpi.Q_{ckl} = 0\ \forall\ i = 1, 2, ..., 10,\ p = 1, 2, .., 5,\ k = 1, 2, 3.$

x111+x121+x231+x241+x351+x361+

x471+x481+x591+x5101+y111

+y112+y113+y121+y122+

y123+y231+y232+y233+y241+

y242+y243 +y351+y352+

y353+y361+y362+y363+

y471+y472+y473+y481+y482

+y483+y591+y592+y593+

y5101+y5102+y5103-5*q111-5*q112-5

*q113-5*q121-5*q122-5*q123-

5*q131-5*q132-5*q133=0 $I \geq IS_p\ \forall\ p = 1, ..., 5.$

i1>=75;

i2>=90;

i3>=120;

i4>=80;

i5>=50;

## 7 Analyzing answers and evaluating research questions

The model was solved by LINGO software and the following results were obtained:

$d_1^+ = 2,500,000,000,\ d_1^- = 0,$

$d_2^+ = 0,\ d_2^- = 1,750,000,000,$

$d_3^+ = 0,\ d_3^- = 0.$

The above results reveal that 2,500,000,000 Rials should be added to the budget of transportation. This will minimize the total cost of transporting auto parts from suppliers to warehouse, suppliers to manufacturing plants, warehouse to manufacturing plants as well as that of transporting autos from manufacturing plants to agencies. 1,750,000,000 Rials is saved through applying this model and will minimize the total cost of backordering auto parts from warehouse and manufacturing plants to suppliers and the inventory holding cost of auto parts in warehouse.
1,250,000,000 Rials need to be added to the budget of idle capacity. This will minimize the total idle production cost of auto parts in suppliers.
These goals will be achievable only if the following values for the decision variables of the model are applied:

As expressed earlier,$G_{piw}$ present number of auto parts(p) transported from supplier(i) to warehouse(w); since 2 different suppliers manufacture one auto part (ten suppliers for five auto part), warehouse has the option to choose which supplier to buy from. In other words, for each auto part, it chooses the supplier and the amount of order based on demand, capacity, and inventory and more importantly cost. That is why the following decision variables can be analyzed as follows:

$X111 = 590$ means that 590 part a warehouse should be transported from supplier 1 to the warehouse. Similarly, $X121 = 10$ means that only 10 part a should be transported from supplier 2 to the warehouse.

The same analysis can be generalized to the remaining decision variables. For part b the decision variables include: $X231 = 0$ and $X241 = 750$. This means that no part b should be transported from supplier 3 to the warehouse; however, from supplier 4, 750 part $b$ should be transported to the warehouse. The same happens for part $c, d$ and $e$.

The next group of decision variables includes $Y_{pik}$ which shows number of auto parts (p) transported from supplier (i) to manufacturing plants (k). Since there are 3 auto manufacturing plants using 5 auto parts provided by 10 suppliers, 30 decision variables of this kind exist which are analyzed. Similarly, plants can choose to order from two different suppliers as 2 different suppliers manufacture one auto part based on cost and some other factors.

The other variables can be analyzed accordingly. With a closer look it can be clearly seen that suppliers 2, 4, 5, 10, and to some extent, 8 are not successfully managing their centers. The cost of transporting their auto parts to manufacturing plants is too high that makes it disadvantageous for manufacturing plants to order from them. Cost-cutting measures need to be taken to reduce costs of transportation to a great extent and to make it possible for those manufacturing plants to be able to work in the long run. Other suppliers (excluding, 2, 4, 5, 8 and 10) should remember creating other advantages for buyers; otherwise, it gives way to entering new rivals to the chain, according to Porters viewpoint. Moreover, it gives a bargaining power to suppliers 1, 3, 6, 7, 8 and 9. The results from solving the model, sensitivity analysis of the cost and right-hand ranges indicate that these suppliers can increase their prices to infinity. They can even reduce the quality, since theres no substitution for their products in the market. As a result, other suppliers of those parts need to drop their prices dramatically to get some of the market share. Otherwise, this situation creates interest for new comers as warehouse and manufacturing plants do not have other sources to provide their needed auto parts.

The other unexpected outcome of the model solution was that transporting and storing auto parts to warehouse is not cost effective. Manufacturing plants prefer to provide their needed parts right from suppliers and not from warehouse. Thus, the inventory holding cost of auto parts in the warehouse should be minimized. Cost of transporting auto parts to and from the warehouse need to be reduced significantly, as well. This can be done by transporting in huge amounts or replacing the transportation medium with a more cost effective one. However, these solutions should be evaluated based on thorough investigations.

# 8 Conclusion and Future Research

The managers of auto industry should make mathematical models with the help of operational research experts in order to set targets in functional domains of their company. The results of the study represents that these kinds of target settings will lead to considerable reduction of costs in their company. Furthermore, mathematical modeling will set logical basis for budgeting. According to the model results no car should be transported from auto plants to agencies (except from plant 3 to agency 1 to the number of 3456). In other words, transporting autos from plants to agencies does not have financial justification in terms of transportation costs.

One of the shortcomings of the model in this study is absence of demand for autos from agencies and customers. If demand for autos was brought into the model, this transportation cost could be expressed differently or might be rationalized financially. Moreover, since the data used in the model is not certain and in real situations they are parametric, solving the model based on fuzzy logic can make it one step closer to real world conditions.

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