A Model for Optimizing Production by Goal Programming Approach and TOPSIS Method

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Abstract: This paper is regarded as an applied research in terms of objective and a library research in terms of data collection. To gather data required for the research, literature library research method has been adopted, and data pertaining to the research variables have been attained by referring to the production annual reports existing in different departments of a manufacturing plant. This paper aims at offering a model for optimizing production with a linear programming approach through using goal programming model (multi- objective) in which TOPSIS method has been applied to determine importance coefficient of each goal. The main objective of this paper is to determine values of each goal and to convert them into an identical (monetary) unit so as to compare and target large- scale management in manufacturing complexes.

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1. Introduction

Nowadays the general definition of management ranged from personal life management to organizational large scale management is restricted to decision making; because all the activities we undertake in our daily lives pass through the decision making process. While humans are deciding in all aspects of life, many times happen that decision making does not lead to full success. It is evident that so many factors influence decision making ability. Researches carried out on decision making reveal that the main effective factor on accurate decision making is related to the methods that one adopts in evaluating existing options. Except for some cases in which the person is certain about what he is doing, decision making is associated with probabilities due to rapidly changing environment conditions. That is, there is always likelihood of success or failure. Thus improvement of decision making skill means that everybody must increase differences among decision making options (Larry E. et al., 1987). Bad decisions are sometimes related to some parts of decision making process. For example, good solutions have not been defined, accurate data have not been gathered and/or cost- benefit analysis has not been precisely undertaken. Yet sometimes failure is not related to its process rather it relates to the mind of decision maker and its defects in an accurate selection.

The main matter in decision making is that there may be a mathematical solution for a problem, yet sometimes the mathematical model is so complicated that solution is not achievable by our knowledge. Here we choose intuitive solutions. In the early 20th century, decision making theories were firstly a part of economics. Mathematical models could not occasionally solve managers problems; and if we defined the problem quite accurately, the obtained equations would be too long, non linear and complicated. On the other hand, if we wanted to simplify the mathematical equation, this concern might be raised that the designed model would have substantial differences with the real life problem and might not indicate the problem facts. In the decision making process, managers require resources and facilities which enable them to optimize the decision efficiency in realizing individual, group, organizational and societal goals. Required resources include financial affairs, budget, time, facilities and opportunities, efficient human forces, and information. Due to the fact that decisions are mostly related to the future, managers need to gather more information so as to decrease uncertainty and consequently decision risk percentage (Sharifzadeh, Fattah, 1999). With respect to the importance of decision making activities in management, they are increasingly underscored in MIS environments and Decision Support System (DSS), in particular (Ahituv N. et al., 1994). Activities that involve decision making are considered as a major part of managers tasks. For two decades, management science will be focused on decision making perception. This prediction was somehow consistent with reality. All of the attentions were drawn to quantitative decision making models and computer information environment.

Combination of quantitative and computer method with decision making is due to understand that changes happen so rapidly that it is not possible for decision makers to evaluate effectively all the factors involved in decision making process (Murdick R. G.

et al., 1990). Computer allows managers to solve problems stated in statistical or mathematical language within several minutes or hours rather using manual methods that take several days, weeks or months.

2. Literature Review

To further understand decision making modeling process, we refer to Simon works. From Simon point of view, decision making process comprises three separate phases: information, design and selection (Simon, H., 1977). Implementation was later added to these three phases. There is a cycle of activities from information to design and then selection, yet in each phase we may return to the previous phase. In the phase of information, the environment reality is examined and the problem is specified and defined. In the phase of design, a model is made that indicates the system. It is possible via simplifying reality and writing the relations among variables. Then model is approved by evaluation criteria (Awad, A. M., 1994). Phase of selection consists of model solution. It must be noted that it is not the solution of our main problem; rather it is a solution for a problem that has been redefined in our model. This solution is tested in the model. Once the proposed solution seems justified, it is ready for implementation. Successful implementation means solving the main problem. Failure leads us again towards modeling process.

2.1 Theoretical Principles

Goal programming is a branch of multi objective optimization which is regarded as a branch of multi criteria decision making analysis (MCDA). It is also known as one of multi criteria decision making models (MCDM). Goal programming may be deemed as a format or generalization of linear programming that is responsible for multiple measures that may have conflicting goals. The objective is to prevent unwanted deviations from desired values and then to achieve minimal function. In this method, a vector or a set of weights attached to the goals for programming is used. One of the satisfactory goals in this method is fulfilling demands of the decision makers. In this kind of mathematical programming, three types of analyses are undertaken.

1. Determining resources required for achieving a desired set of objectives.
2. Specifying the amount of achieving goals by available resources.
3. Offering the best satisfactory solution by different quantities of resources and priorities.

Goal programming was firstly applied by Charnes, Cooper, and Ferguson in 1995. The main capability of goal programming is its simplicity. This is regarded as an advantage for many goal programming applications in various fields. Thus goal programming may calculate a relatively large number of variables, constraints and objectives all at once.

2.2 Research Background

(Yu-Cheng, T, et al., 2012), Multi-criteria decision-making based on goal programming and fuzzy analytic hierarchy process, (Masatoshi, S. et al., 2009), Interactive fuzzy programs for random fuzzy two-level programming problems through possibility-based fractal model, (Burcu, Y., et al., 2011), combined approach for equipment selection: F-PROMETHEE method and zero–one goal programming, (Lotfi, M.M., et al., 2011), A fuzzy goal programming approach for mid-term assortment planning in supermarkets, (Ballarin, A., et al., 2011), Biomass energy production in agriculture: A weighted goal programming analysis, (Shih-Jieh, H., et al., 2011), Activity-based divergent supply chain planning for competitive advantage in the risky global environment: A DEMATEL-ANP fuzzy goal programming approach, (Joonhoon, K., et al., 2011), Microbial Strain Design for Biochemical Production Using Mixed-integer Programming Techniques, (Ersin, K., et al., 2011), A multi-stage stochastic programming approach in master production scheduling, (Bilge, B., 2011), Application of fuzzy mathematical programming approach to the production allocation and distribution supply chain network problem, (Zeballos, L.J., 2010), A constraint programming approach to tool allocation and production scheduling in flexible manufacturing systems, Robotics and Computer-Integrated Manufacturing, (Josefa, M., et al., 2010), Mathematical programming models for supply chain production and transport planning, (Abouzar, J., et al., 2009), A hybrid fuzzy goal programming approach with different goal priorities to aggregate production planning, (Stephen, C.H., et al., 2009), A goal programming model for aggregate production planning with resource utilization constraint, (Marc, Z., et al., 2008), Close-optimal production and procurement policy for a X-network of added value using lexicographic linear goal programming, (Araz, I.O., 2008), production–distribution planning in supply chain: A fuzzy goal programming approach, (Stephen, C.H., et al., 2007), A goal programming model for production planning of perishable products with postponement, (Lei, L., et al., 2006), Earliness–tardiness production planning for just-in-time manufacturing: A unifying approach by goal programming, (Reay-Chen, W., et al., 2005), Applying possibility linear programming to aggregate production planning.

This paper aims at optimizing production in one of steel pipes and profiles manufacturing companies through pre determined goals of management. Optimization of pre determined goals consists of minimum and maximum objectives, and in the present paper a coefficient is considered for each goal via TOPSIS method in order to convert goal programming into linear programming.

3. Research Methodology

In the present paper, first we formulate production program objectives in the target functions based on goal programming principles. Then we determine importance coefficient of each goal by TOPSIS method, and finally we offer the main model by determining the constraints governing production and market of suppliers and vendors. So general constraints divided into constraints governing manufacturing and constraints governing modeling are presented in the following.

Constraints governing manufacturing identified in this paper are namely demand limitations, minimum acceptable inventory limitation, maximum acceptable inventory limitation, capacity limitation, minimum purchase quantity from each supplier which is generalized for each product or manufacturing system.

In modeling, we also encounter with constraints in objective functions as conflict with other objectives when gathering and tabulating data. These kinds of constraints are introduced as structural constraints of the model due to data nature. These constraints are likely to be seen in variables and parameters marks when forming objective function and model constraints (model structure).

3.1 Modeling

– Determining model goals or objective functions presented in the following. To identify model traits, table 1 presents model indices, variables, and parameters.

Table 1- Marks of Goal Programming Model

Indexes	i: product j: plant (production line) m: part n: supplier t: programming time span r: objective function
Variables	S_{mnt} = supplying mth part in tth time span S_{mtj} = supplying mth part in tth time span for jth plant S_{mntj} = supplying mth part from nth supplier in tth time span for jth plant IS_{mt} = inventory of mth part in tth time span IS_{mtj} = inventory of mth part in tth time span in jth plant (production line) IS_{mnjt} = inventory of mth part of nth supplier in tth time span in jth plant (production line) d_i^+ = deviation variable from goal (positive deviation) d_i^- = deviation variable from goal (negative deviation)
Parameters	P_{ijt} = ith production in jth plant in tth time span CS_{mn} = Cost of purchasing each part Ch_{mn} = Cost of maintaining each part in production site $TSPL_{mn}$ = Total suspended production line NDP_{mn} = Total suspended production line due to supplier performance LRS_{mn} = Minimizing losses from sale VC_{mi} = Consumption coefficient of mth part in jth product Wu = Importance coefficient of rth objective function LT_m = Time of supplying mth part α = Confidence coefficient determining permissible levels of inventory β = Coefficient determining minimum purchase from each supplier $\widetilde{Ct}_{mnj}$ = cost of transportation of mth part from nth supplier to the plant site $\widetilde{C}_{mn}$ = capacity of nth supplier for supplying mth part

1) Reduction of suspension in the production line due to a set of factors that for simplifying calculations all factors have been defined as suspension time. So reduction considered in this paper

is implemented by heads of each department via optimization programs based on determined objective.

$$Min\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}TSPL_{mn}S_{mnt}$$

2) Minimizing returned products and customers complaints.

$$Min\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}NDP_{mn}S_{mnt}$$

3) Maximizing profit of sale (minimizing losses from sale)

$$Min\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}LRS_{mn}S_{mnt}$$

4) Reduction of manufacturing overhead costs for purchasing steel sheets and consumable parts of production lines (total costs), cost of transportation of parts (from supplier to the warehouse location along with internal transportation, and cost of maintaining raw material and parts in the warehouse.

$$Min\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T}CS_{mn}S_{mntj}$$
$$+\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T}\tilde{C}t_{mnj}S_{mntj}$$
$$+\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T}Ch_{mn}IS_{mntj}$$

– determining model coefficients by TOPSIS method after passing below stages.

1) Scales existing in the decision matrix are بدون by formula $r_{ij} = x_{ij} \div \sqrt{\sum x_{ij}^{2}}$, x = (1 ... m).

2) Determining positive and negative ideal solutions

3) Obtaining distance of each option to positive and negative ideal by,

$$d_i^+ = \sqrt{\sum(v_{ij}-v_{ij}^+)^2}\ ,\ d_i^- = \sqrt{\sum(v_{ij}-v_{ij}^-)^2}\ ,\ i=(1\ldots n)$$

Determining the relative closeness of each option to the ideal solution by formula $CL_i^* = d_i^- \div (d_i^- + d_i^+)$

The results of calculating each goal coefficient for objective functions are presented in table 2.

Table 2- Coefficient of each goal in the model

Goal	Coefficient
Reducing total suspended production line	0.15
Minimizing returned products	0.10
Maximizing profit	0.43
Reducing production overhead costs	0.22

– Determining problem constraints that constitute the model main structure.

1. Demand limitation

$$S_{mtj} = \sum_{n=1}^{n}S_{mntj} = \sum_{i=1}^{i}VC_{im}P_{ijt}$$
$$-\sum_{n=1}^{n}IS_{mjt-1} + \sum_{n=1}^{i}IS_{mjt} \qquad \forall j,m,t$$

2) Optimal amount of inventory and ordering stock. The amount of inventory in a period is a coefficient of production volume in that period, part consumption coefficient, time of supplying part and confidence coefficient that is represented by α. So permissible minimum and maximum limit of inventory are presented in the following.

$$\sum_{i=1}^{n}IS_{mtj} \geq VC_{im}\times X_{ijt}\times\alpha\times LT_m$$
$$\forall j,m,t$$
$$\sum_{i=1}^{n}IS_{mtj} \leq VC_{im}\times X_{ijt}\times(1+\alpha)\times LT_m$$
$$\forall j,m,t$$

3) Capacity of suppliers of raw materials and consumable parts in production lines. J^{th} supplier can only estimate a limited number of demands for m^{th} part in each period. So the amount of supplying materials and part during the year must be equal to or less than Ci (supply limitation). It is presented in below.

$$\sum_{j=1}^{J}S_{mnjt} \leq \tilde{C}_{mn} \qquad \forall m,n,t$$

– Main model of the paper for steel pipe and profile manufacturing company.

The main model is presented with regard to the determined goals by management and computational coefficients for each goal and problem constraints.

$$MinZ = \sum_{u=1}^{u}w_u(d_u^+,d_u^-) = w_1d_1^+ + w_2d_2^+ + w_3d_3^+ + w_4d_4^- \qquad (1)$$

$$\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}TSPL_{mn}S_{mnt} + d_1^- - d_1^+ \qquad (2)$$

$$\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}NDP_{mn}S_{mnt} + d_2^- - d_2^+ \qquad (3)$$

$$\sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{t=1}^{T}LRS_{mn}S_{mnt} + d_3^- - d_3^+ \qquad (4)$$

$$\sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T} CS_{mn} S_{mntj} + \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T} \tilde{C}t_{mnj} S_{mntj} + \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{t=1}^{T} Ch_{mn} IS_{mntj} + d_4^- - d_4^+ \quad (5)$$

$$S_{mjt} = \sum_{i=1}^{n} S_{mnjt} = \sum_{i=1}^{n} VC_{mi} P_{ijt} - \sum_{i=1}^{n} IS_{mnjt-1} + \sum_{i=1}^{n} IS_{mt} \quad \forall j, m, t \quad (6)$$

$$\sum_{i=1}^{n} IS_{mtj} \geq VC_{mi} * p_{ijt} * \alpha * LT_m \quad \forall j, m, t \quad (7)$$

$$\sum_{i=1}^{n} IS_{mtj} \leq VC_{mi} * p_{ijt} * (1+\alpha) * LT_m \quad \forall j, m, t \quad (8)$$

$$\sum_{j=1}^{J} S_{mnt} \leq \tilde{C}_{mn} \quad \forall m, n, t \quad (9)$$

$$\sum_{j=1}^{J} S_{mnt} \geq \beta * \sum_{n=1}^{N}\sum_{j=1}^{J} S_{mnjt} \quad \forall m, n, t \quad (10)$$

$$S_{mnjt}, IS_{mtj} \geq 0, \text{integer} \quad \forall m, n, j, t \quad (11)$$

Due to high complication of the model in terms of number of variables, constraints and data, the model was designed and implemented in Lingo software. During programming, innovative techniques were applied to prevent model high volume. The results obtained for goal registered in the objective function are presented in table 3. For easy comparison, all units have been converted into an identical currency.

Table 3- The objective function goals values

Goal	Value
Reducing total suspended production lines	913,345,325
Minimizing returned products	645,484,568
Maximizing profit	32,456,542,985
Reducing production overhead costs	20,954,645,547

4. Conclusions

The proposed goal programming model has been presented based on data of a steel pipe and profile manufacturing company. This paper focused on determining importance coefficients of each goal by TOPSIS method. The first line of model presents objective function and the amount of distance from each goal, and last line provides the requirement of positive and integer variables of consumable parts limitations. Second to fifth lines introduce model goals and note that since objective function has been minimized; maximizing profit limitation has been converted into minimizing loss. Sixth to tenth lines indicate constraints governing production, supplying materials, parts, and transportation costs.

- Suggestions

1. Using similar studies, analyze other methods of determining coefficients in equal states including entropy, SAW, ELECTRE in calculating compared coefficients and the results of comparing coefficients.
2. Solve goal programming model for an industry by integrating goals (converting into linear programming) and compare the results with goal programming method.
3. Consider limitation for coefficients based on instruction of manufacturing firm management, design and solve the model as per fuzzy constraints.

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