A Deterministic Multi-Objective Optimization Process of Multi-Item Inventory Management in Fmcg Industry

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Abstract: The inventory management is the crucial part of any of the company's, and nowadays, they find challenging to perceive out the optimal quantity level needed to overcome from shortages problem and also to reduce the wastages.In this paper, we used a multi-criteria decision-making for formulating the inventory management problem without shortages with the aim of optimizing profit and holding cost of the company simultaneously. We have also considered both ordering cost and storage cost as a non-linear function of the rapid stock level. In addition we used linear goal programming to find out the minimum optimal quantity level to put in the inventory to reduce out of stock situation. Finally, a numerical illustration of FMCG Company has been taken to show the application of proposed work.

Keywords: Inventory Management; Linear Fractional Programming; Multi-Criteria Decision-Making; Goal Programming.

I. INTRODUCTION

Inventory is the terminology generally use for available goods for sale and for raw materials used to manufacture goods for sale. Inventory is a stock of items kept to meet future demand[1]. Various questions come in mind when top management has to decide how many units to order when to order. This question comes in mind because it is important to manage inventory properly. If the company is not able to manage the inventory properly. Company may have to suffer huge losses in the organization. So it is important that we need to keep inventory and to reduce bullwhip effect so that demand information do not distort as it moves away from end-use customer.so, some companies are making use of the direct interface those days between the customer and the company [2].

These days the use of information technology is helping the companies to reduce this effect, but many times the demand gets distorted because of the bullwhip effect. Higher safety stock inventories are stored to compensate for this. He has to meet the demand of their customers and with minimum cost and without shortages [3].

There is extensive research conducted by various researchers to solve the problems of inventory management and this research also helps in the decision makingof the higher management people [4,5].Researchers use multi-objective functions and optimization techniques to solve inventory problems. But in the best of my knowledge

researcher takes the hypothetical data to solve their model and valid on certain assumptions. In real-life examples of inventory models, we find various uncertainty in inventory.

This study based on multi objective function which use the real-time data of Indian FMCG Company and according to that, proposed model helps the operational managers in the manufacturing and where decision-maker can make a decision regarding inventory cost. This research also find out how company can optimize the different costs such as carrying cost, ordering cost, shortage cost etc.

II. LITERATURE REVIEW

In current situation, the holding cost of perishable product like milk, vegetables, ice-cream, flowers, food and fruit crease with each going day. The reduction in carrying cost with maintaining fresher product is very challenging task for company. Researchers are developed many model for minimizing inventory cost in uncertain and risk environment. The table 1 shows various inventory model which developed by researchers in past year. The summary of some related literature for inventory models are represented in Table 1. In spite of the above-mentioned developments, this study developed multi multi-objective model with fuzzyrough variables.

Table 1: Summary of Literature on Inventory Models

Garai et al. [1]	They formulated inventory model base on demand rate and carrying cost with fuzzy concept. The paper determined optimal order quantity and inventory level with minimize total inventory cost for retailer

Ali et al. [2]	They formulated multi-objective inventory optimization model to min. inventory cost and optimal order size under intuitionistic fuzziness.
Gharaei et al. [3]	The study is based on a bi-objective function, with conflicting goals, minimizing the chain inventory costs and maximizing the chain total profit aided to find optimum policy for integrated lot sizing under stochastic environment.
Dutta and Kumar [4,5]	They proposed multi criteria decision-making (MCDM) for multi-item inventory problem without shortage in system. They used goal programming under three factor budget constraint, space constraint and budgetary constraint on ordering cost.
Debnath et al. [6]	The study proposed an inventory model under trade credit policy with type-2 fuzzy parameters and solved through the use of generalized derivative approach. They used weighted sum method and global criteria method to determine the optimum time to minimize the total inventory cost of product.
Colapinto et al. [7]	They suggested various applications of goal programing in engineering, management and social sciences area.

III. METHODOLOGY

2.1 Linear Fractional Programming

The Hungarian mathematician Matros[8,9] was the first to develop the linear fractional programming (LFP) problem. A general linear programming problem (in matrix notation)'s is as follows:

Find $x_1, x_2, x_3, ..., x_n$, so as to optimize

Maximize (or Minimize) $Z = CX$

Subject to $\qquad AX(\leq, =, \geq)b$

$$X \geq 0; b \geq 0,$$

where $A = \begin{bmatrix} a_{ij} \end{bmatrix}_{m \times n}$ called the coefficient matrix, C is an $1 \times n$ row matrix, $\mathbf{b}$ is an $m \times 1$ column matrix, X is an $n \times 1$ column matrix and $\mathbf{0}$ is a null matrix of the type $n \times 1$.

A LFP problem occurs when a fractional function is to be optimizedand the problem can be formulated mathematically is as follows:

Maximize (or Minimize) $Q(X) = \dfrac{p(X)}{d(X)} = \dfrac{c^T X + \alpha}{D^T X + \beta}$

Subject to $\qquad A\underline{X}(\leq, =, \geq)b,$

$$\underline{X} \geq 0; b \geq 0,$$

where $A = \begin{bmatrix} a_{ij} \end{bmatrix}_{m \times n}$ called the coefficient matrix, C is an $1 \times n$ row matrix, $\mathbf{b}$ is an $m \times 1$ column matrix, X is an $n \times 1$ column matrix, $\mathbf{b} \in R^m$, $X, C, D \in R^n$, $\alpha, \beta \in R$.

2.2 Research Methodology

R₁. The data has been gathered through the interface and consultation with the division's managers.

R₂. Many important information has been collected from executive interviews with unstructured process.

R₃. Magazines and annual reports are also used to gather the desired information.

R₄. Different research articleshas been used for formulating the model.

1.3 Statement of the Problem

Inventory expenses have a huge impact on the company's productivity and performance. Inventory management and its automated decisions at the right time based on recognizing key performance factors and appropriate decisions.In a competitive market environment, to maximize the effects of inventory activity, it is important to concentrate on decision-making and the factors affecting decision-making.The present research focuses on the dimensions of identifying factors affecting stock management between businesses through a structured and unstructured system and grouping them into two sets as internal variables and external variables, and optimizing them by grouping the information for the correct decision.Increased stakeholder pressure has pushed businesses to consider methods that can be useful in achieving optimum order quantity of products.This manuscript consists of modeling without deficiencies of a multi-objective inventory problem.Through decreasing their deviational variables, the goal programming technique has been used to achieve the problem's compromise solution.

2.4 Sources of Data

The present study uses primary data that has been collected from the well know FMCG company through a structured questionnaire. In a few cases, for order to understand the nature of the problem and the complexity of the research variables, the researcher met professionally trained industry experts directly and had a personal interview.It helps to understand the topic in a broad perspective and examine the same from the point of view of studies.The secondary data has been collected from both print and electronic media that includes published research papers, thesis works, unpublished industry reports, and the other text books.

2.5 Objectives of the study

- To apply goal programming model to a reallife inventory situation to find a compromise solution among the different conflicting goals of the FMCG Company.

- To minimize the total deviations associated with meeting the profit and holding cost of the FMCG Company.

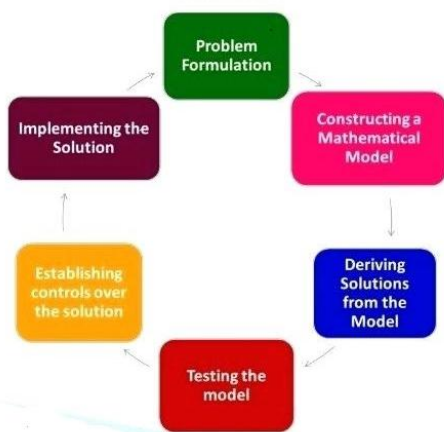The above defined research methodology can be presented in flow chart as:

Fig. 1: Methodology for Optimization Process

IV.   MATHEMATICAL MODEL

Inventories deal with the management of sufficient inventory of products to guarantee a smooth functioning of a production system. Business and industry have traditionally viewed stock as aindispensable measure.Too little stock can cause an expensive process failure, and excessively inventory can destroy the economical edge of the company.Recently, Ali et al. [2] proposed a multi-objective inventory model with in which they considered a theoretical process with deterministic parameters for the inventory model and used a fuzzy goal programming technique to achieve the optimum quantity.Dutta and Kumar [4,5] used LFP along with multi-criterion decision-making in inventory management.They consideredthe problemof without shortage, and formulated it as the multi-objective inventory problem of fractional objective function and extracting the ideal order quantity of commodities, respectively.Here, we discussed the modelling and optimization of a multi-objective inventory system with consideration of real set of data which has been collected from FMCG Company.The foregoing descriptions and premises used to develop the problem are as follows:

Nomenclature

n-Number of items $j=1,2,3,...,n$
SC-Stable cost per demand
TB-Over-all offered budget for all items
AP-Over-all accessible space for all items
Q_j-Ordering quantity of jth item
HC_j-Holding cost per item per unit time for j^{th} item
PC_j-Purchasing price of jth item
SP_j-Selling Price of jth item
D_j-Demand quantity per unit time of jth item
ap_j-Space required per unit for the jth item (/sq. m)
OC_j-Ordering cost of jth item

The following assumptions that are important for the question of stock are considered as follows:

1. A multi-item stock model.
2. Infinite duration in time for one cycle time   span.
3. Constant level of production.
4. There's no lead time.
5. Holding expenses and purchase price should be understood and enduring.
6. There is no discount.
7. There are no shortages required.
8. There is no sufficient decline.

The mathematical model of multi-objective inventory model for one cycle time period is formulated as follows on the basis of the above defined assumptions:

***MODEL* (1)**

$$\text{Maximize } Z_1 = \frac{\sum_{j=1}^{n}(SP_j - PC_j)Q_j}{\sum_{i=1}^{n}(D_j - Q_j)}$$

$$\text{Minimize } Z_2 = \frac{\sum_{j=1}^{n}\dfrac{HC_j * Q_j}{2}}{\sum_{j=1}^{n}Q_j}$$

Subject to the constraint

$$\sum_{j=1}^{n} PC_j * Q_j \leq TB$$

$$\sum_{j=1}^{n} ap_j * Q_j \leq AP$$

$$SC * D_n - (OC_n)Q_n \leq 0$$

$Q_n \geq 0 \; and \; OC_n > 0, \; \forall \; j=1,2,3,..,n$

where,

$\sum_{j=1}^{n}(SC_j - PC_j)Q_j$ denotes the quantity-related profit.

$\sum_{j=1}^{n}\dfrac{HC_j * Q_j}{2}$ denotes the holding cost

$\sum_{j=1}^{n}(D_j - Q_j)$ denotes the back ordered quantity

$\sum_{j=1}^{n}Q_j$ denotes the total ordering quantity

$\sum_{j=1}^{n}\dfrac{SC * D_n}{Q_n}$ denotes the ordering cost

Where,

Constraint I denotes the maximum investment's upper limit.
Constraint II applies to restricting the size of the store.

Constraint III applies to the budgetary constraint on the price of purchasing.

Ordering cost for the nth item can express as:

1st Item: $\frac{SC*D_1}{Q_1} \leq OC_1 => kD_1 - (OC_1)Q_1 \leq 0$

2nd Item: $\frac{SC*D_2}{Q_2} \leq OC_2 => kD_2 - (OC_2)Q_2 \leq 0$

Similarly, for the nth item

$$\frac{SC*D_n}{Q_n} \leq OC_n => SC*D_n - (OC_n)Q_n \leq 0$$

V. OPTIMIZATION METHOD

Linear programming methodology is only valid in a single objective situation such as cost minimization or profit maximization.Although, in practice, organizational goals can largely depend upon the principles and ideology of association, legal legislation, conservational conditions, etc, while profit optimization is considered to be the sole motivation of organization, but due to the financial strain of society and different types of statutory directives, organization will have different multiple objectives, such as work life balance, high quality of the product, social disbursements, industrial and labor relations, revenue optimization, etc.To optimize multiple goals and objectives, learning and understanding the management system requires a different kind of methodology.This technique is acknowledged as Goal Programming (GP) technique for decision making which is nothing but an extension of LPP.

GP model and its different types ofvariants have been applied to solve large-scale multi-criteria decision making problems. Charnes and Cooper [10] used the GP method for the first time in the 1960s.Lee (1972 [11] and others have expanded this GP method and gave a different types of methodology for solving GP.GP is one of the frameworks developed to tackle the decision-making challenges with multiple goals.This framework allows for multiple priorities to be taken into account at the same time as decision-making finds the best solution from among a collection of feasible alternatives.GP methodology is therefore an empirical method that can be used by a decision-maker to provide optimal solutions for various multiple or contradictory objectives.Throughout GP methodology, all management objectives, any or many of them, are integrated into the objective function and only the conservational conditions, i.e., those outside the influence of the organization are regarded as constraints.In particular, that goal is set at a satisfactory level that may not actually be the most achievable, but one that would please management to accomplish given multiple and sometimes contradictory goals. GP's mathematical technique is to choose a set of solutions that satisfy environmental restrictions and achieve a suitable goal by reducing deviational variables.GP is not only a strategy of reducing the total of all deviations, but also a technique for minimizing as much as necessary value of deviations.The decision-maker influences the outcomes of multi-objective problem solutions Nevertheless, there will be differences based on the decisions made when there is a difference between goals.In this type of problem, the path

and magnitude of these deviations play significant roles.In this type of problem, the path and magnitude of these deviations plays important roles.One of the technical advantages of multiple objective programming is that, although some goals are overlapping, there is always a solution to the problem, given the feasible area R is non-empty. In the other words, GP's methodology does not explicitly optimize or reduce the goal function as in Linear Programming, but aims to mitigate the differences (both positive and negative) between the desired goals and then the outcomes achieved by objectives.

GP is one of the oldest multi-criteria decision-making strategies to achieve multiple goals while reducing the divergence from the desired target for each of the objectives.As a consequence of unsolvable linear programming concerns and the emergence of the opposing multiple objective, the theory of GP emerged.There has been a lot of research in GP frameworks in various fields and Romero [12] has noted in his research that, GP is the most commonly employed method for decision-making multi-criteria. The structure for GP modeling is easy to understand and implement and can be solved using most commercial software for mathematical programming.The compromise criterion, used for achieving the goal can be modeled as follows:

MODEL **(1)**

Minimize $\sum_{j=1}^{n} \lambda_j$

Subject to the constraint

$$\frac{\sum_{j=1}^{n}(SP_j - PC_j)Q_j}{\sum_{i=1}^{n}(D_j - Q_j)} - \lambda_1 \leq Z_1^*$$

$$\frac{\sum_{j=1}^{n}\frac{HC_j * Q_j}{2}}{\sum_{j=1}^{n}Q_j} - \lambda_2 \leq Z_2^*$$

$$\sum_{j=1}^{n} PC_j * Q_j \leq TB$$

$$\sum_{j=1}^{n} ap_j * Q_j \leq AP$$

$$SC*D_n - (OC_n)Q_n \leq 0$$

$Q_n \geq 0 \text{ and } OC_n > 0, \ \forall \ j=1,2,3,..,n$

Where Z_1^* and Z_2^* are the individual optimum solution of the objective functions respectively. Using the LINGO software package which is developed by LINDO Systems Inc, the above described non-linear programming problem has been solved.

It is friendly to the user and requires little knowledge of computer programming or computer languages. You can have more information about the program by visiting the www.lindo.com website.

VI. ALGORTITHM

The following step by step procedure has been used for solving the formulated model:

1. Formulate the inventory problem with factors such as carrying costs, purchase price, selling price, demand, and ordering costs as a multi-objective problem.
2. Firstly, the formulated problem has been solved as a single objective problem using only one objective at a time.
3. The solutions thus obtained are considered the ideal solutions and these solutions also helped the decision maker set the level of aspiration for each objective function.
4. The aspiration level for each objective function has been defined in such a way that it should be substantially higher than (in the case of maximization) and/or lower than (in the case of minimization) to the amount of aspiration which should also be known as a goal value.
5. The formulated goal programming model has been solved after defining the goal value using the optimizing software LINGO 16.0.

VII. NUMERICAL ILLUSTRATION

The accompanying quantitative example illustrates the solution that has been suggested.Ali et al. [2] and Dutta and Kumar [4,5]have presented their inventory model with hypothetical information. Here we are considering the real case of inventory optimization in which the input information has been collected from the well-known FMCG Company.The information collected has been summarized in Table 2 below:

Table 2.Four Item Inventory Information

Item (j)	1	2	3	4
HC_j	13.44	8.88	7.60	91.60
PC_j	328.2	222.5	190.9	229.2
SP_j	383.2	242.01	267.00	305.00
D_j('00)	172	83	27	60
OC_j	0.443	0.767	2.398	0.255
ap_j	0.08	0.01	0.006	0.009

Stable cost per order =7

Maximum accessible space = 16,000 sq. m

Maximum inventory budget= Rs. 1500,000

By using the information of table 1, the problem of inventory management has been formulated as follows:

$$Max\ Z_1 = \frac{55Q_1 + 19.51Q_2 + 76.1Q_3 + 75.8Q_4}{(62000 - Q_1) + (30000 - Q_2) + (9600 - Q_3) + (90000 - Q_4)}$$

$$Min\ Z_2 = \frac{6.72Q_1 + 4.44Q_2 + 3.8Q_3 + 45.8Q_4}{Q_1 + Q_2 + Q_3 + Q_4}$$

Subject to the constraint

$$328.2Q_1 + 222.5Q_2 + 190.9Q_3 + 229.2Q_4 \leq 1500,000$$
$$0.08Q_1 + 0.01Q_2 + 0.006Q_3 + 0.009 \leq 16,000$$
$$7*(172) - 0.443Q_1 \leq 0$$
$$7*(83) - 0.767Q_2 \leq 0$$
$$7*(27) - 2.398Q_3 \leq 0$$
$$7*(60) - 0.255Q_4 \leq 0$$
$$All\ Q_j \geq 0, j = 1,2,3,4$$

The problem that has been formulated above cannot be solved instantly, so we must first figure out the individual optimum solution for each objective function.The obtained individual optimum value of each objective functions has been treated as their goal respectively. The problem further can be restated as:

$$Minimize\ \lambda_1 + \lambda_2$$

Subject to the constraint

$$\frac{55Q_1 + 19.51Q_2 + 76.1Q_3 + 75.8Q_4}{(172 - Q_1) + (83 - Q_2) + (27 - Q_3) + (60 - Q_4)} - \lambda_1 \leq 316219$$

$$\frac{6.72Q_1 + 4.44Q_2 + 3.8Q_3 + 45.8Q_4}{Q_1 + Q_2 + Q_3 + Q_4} - \lambda_2 \leq 5.55$$

$$328.2Q_1 + 222.5Q_2 + 190.9Q_3 + 229.2Q_4 \leq 1500,000$$
$$0.08Q_1 + 0.01Q_2 + 0.006Q_3 + 0.009 \leq 16,000$$
$$7*(172) - 0.443Q_1 \leq 0$$
$$7*(83) - 0.767Q_2 \leq 0$$
$$7*(27) - 2.398Q_3 \leq 0$$
$$7*(60) - 0.255Q_4 \leq 0$$
$$All\ Q_j \geq 0, j = 1,2,3,4$$

Using LINGO 16.0 software package, the solution of the above defined non-linear programming problem has been obtained as:

Q_1=2719; Q_2=757; Q_3= 329; Q4=1643 units with achieved value of inventory management problem is Z_1=316219; Z_2=5.557236 respectively.

The obtained result has been compared with the previous results:

Table 3. Previous Obtained Compromise Solution

Result	Z_1	Z_2	Q_1	Q_2	Q_3
Ali et al. [2]	7.5	8.6	22	1187	22
	7.5	8.6	22	1187	22
	7.5	8.5	22	1187	22
	7.6	8.4	22	1188	22
	7.6	8.4	21	1188	21
	7.6	8.3	21	1188	21
	7.6	8.2	21	1189	21
	7.7	8.2	21	1189	41
	7.7	8.1	21	1189	41
	7.7	8.1	21	1190	41
	7.8	8.0	21	1190	41
A — ·—	7.7	19.6	23	41	1935

	7.7	19.0	23	40	1938
	7.8	18.9	23	40	1940
	8.1	18.5	22	40	1942
	8.2	18.1	22	40	1945
	8.3	17.7	22	40	1948
	8.5	17.3	21	39	1950
	8.7	16.9	21	39	1953
	8.8	16.5	21	39	1955
	9.0	16.1	20	39	1958
	9.2	15.7	20	38	1960
Kumar and Dutta [4]	85.1	6.1	130	9	-
	17.1	3.2	40	9	7
Dutta and Kumar [5]	11.5	6.2	1364	40	42

It is unfair to compare the results with previous studies because models had been formulated under different environments and conditions.

VIII. CONCLUSION

Inventory control is concerned with maintaining accurate records of ready-to-ship finished goods.This often involves adding the value of newly completed products to the overall stock and subtracting the current finished goods deliveries to customers.Most of the previous inventory-related articles include hypothetical case studies, but here we used a case study from a well-known FMCG Company.In the formulated problem, different types of costs and other variables are addressed in order to capture real-life market scenarios.The inventory model presumed that there has been stock-dependent demand non-linear storage costs and no shortages etc.This paper shows how the GP techniquecan be used skillfully to solve the problem of inventory management.Furthermore, the suggested framework can be generalized further in a number of ways, such as fuzzified demand, vague production, variable quantity discount, time-dependent storage costs, etc.

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