NONPRE-EMPTIVE INTEGER NONLINEAR GOAL PROGRAMMING MODEL FOR MULTI-ITEM INVENTORY PROBLEM: (CASE OF A CAR RETAIL CENTRE IN LAGOS STATE)

ABSTRACT

In this paper, a Non-preemptive Integer Nonlinear Goal Programming (NINGP) model was developed for obtaining Economic Order Quantities (EOQ) of multi-item inventory problems that satisfy the multiple and conflicting objectives of the Decision Maker (DM). The particular case considered was that of a motor vehicle dealer who sells 10 brands of tokunbo vehicles and wants to determine the EOQ for each brand such that the deviations from the aspiration level is minimized. Using LINGO 17.0 Software to solve the NINGP model, the EOQ allocated to each brand types from 1 through 10 are 2, 2, 5, 2, 2, 3 3, 3, 3, and 3 cars respectively. The optimal number of cars was 28 with the associated cost of ₦53,825,915. Compared to the estimated budget of ₦60,000,000, the NINGP approach was able to achieve a 10% (₦6,174,085) below budget. With proper modifications considering associated constraints, related inventory problems can be solve using the NINGP model.

Keywords: Non-preemptive programming, Nonlinear programming, Goal Programming, Multi-Item Inventory, Economic Order Quantity.

INTRODUCTION

Non-preemptive integer nonlinear goal programming (NINGP) helps to solve problems associated with multi-item inventory decision-making problems. For the most part, real-world optimization issues in firms, businesses, merchants and commerce involve multiple objectives with constraint resources. According to Seyed *et al., (*2014), multi-item stock level are maintain in other to meet need of prospecting customers demand at one stop shop. Multiple items or products are stored in these shops to increase profitability, competition and attract sales from prospective customers with different choices. According to Nsikan *et al.*, (2015), ‘‘to maintain an optimal level of these inventories, some set of policies and control measures must be in place to monitor, replenish and order to sustain this level,’’. Venture in huge and numerous inventories can lead to an expanded running cost, low benefit and tall working capital prerequisites whereas investment in little inventory can lead to break-ups in organizational handle, loss of customers and a greatly reduced profit margin. In Amini, (2017), ‘‘the major concern in real-life decision-making situations, is that these problems involve multiple criteria (attributes or objectives) rather than single criteria,’’. These objectives are conflicting and are best-approached using goal programming analytical framework. Goal programming is an operation research technique useful for achieving simultaneously multiple goals with constrained resources (Ajayi-Daniels, 2019). The aim of goal programming (GP) is to find an optimum solution out of a set of feasible solutions that satisfy the real-life constraints and comes in a closed-form to the decision-makers stated target value (goals). The Goal Programming approach also analyzes how much a proposed optimal solution deviates from each target though there are deviation variables defined, for each pair of stated goals (Moumita and De, 2016).

Goal programming developed by Charnes and Cooper (1961) and improved by Ijiri, (1965), Lee, Clayton (1972) and Ignizio, (1976), among others in seminar works, was used to convert original multiple objectives into a single goal. The results achieved is satisfactory and efficient but the solutions are an optimal solution to the problems. This concept has enjoyed significant applications by many researchers over time, in solving different inventory problems with multiple constraints resources. According to Aouni and Kettani (2001), the increase in the use of goal programming was simply because it is exceptionally simple to comprehend and apply.

Till date, the application of goal programming cut across so many areas, such as the manufacturing, production, retail shops, transportation, medicine, agriculture, academic institutions, and construction companies alike. Ajayi-Daniels (2019) applied the goal-programming model to optimize resources in a fashion firm where goals, was prioritized according to importance. The result-achieved bases on priority level show a reduction in the overtime hours from 10hours to 8 hours, which is the optimum time, and a target profit margin was-achieved. Also with efficient use of resources the set goal of 3 garments per day was achieved. Kliestik *et al.* (2015), developed a unique GP model that management companies with numerous plans can use to implement a strategic goal. Yahia-Berrouiguet and Tissourassi (2015), tested the use of goal programming model for the allocation time and cost to three different projects with preemptive goals. They discussed the illogical allocation of zero (0) time to project planning and concluded that a project is bound to fail if the planning phase is not given a proper consideration with an allocation of time. This paper, presents the application of NINGP model to determine the EOQ required in a Car Retail Centre in other to achieve the Decision Maker’s competitive priorities with stated constraints.

2.0 MODEL DEVELOPMENT

The approach of the Non-pre-emptive goal programming involves establishing a specific numerical value (target) for the objectives of the Decision Maker (DM). Deviations from these targets are not desirable, therefore the DM seeks a compromise solution.

2.1 Brief Description of The Problem

A ‘‘Tokunbo’’ vehicle dealer in the metropolitan city of Lagos-state, wishes to determine the economic order quantity (EOQ), for the ten (10) different and affordable brand of vehicles with a yearly budget of ₦60million that will be needed to fill up the retail Centre, such as not to lose prospecting customers to the ever increasing competitors in the local business. The available retail space has the capacity for 30 Tokunbo vehicles and the dealer wishes to determine the optimal mix of these vehicles at a reduced cost.

2.2 Assumptions of Model

The model assumptions are:

i. The inventory system involves multiple items
ii. For every replenishment an order for a single delivery is made
iii. There is a constant Lead time
iv. Shortages are not allowed
v. Discount are not allowed for any item ordered
vi. Equal space are available for all items order
vii. Inventory cost (Carrying cost and ordering cost) are known
viii. Demand is known and constant.
ix. The inventory parameters are preset and constant
x. The goals are of equal weight as well as the deviations from the target
xi. The goals are of equal importance

TABLE 1: NOTATIONS WITH DECRIPTION

INDICES	DESCRIPTION

i	Integer index for items (i= 1, 2, 3 …n)
j	constraints Index (j = 1, 2 …m)
a_{ij}	Average investment per unit of item i
oq_i	The decision variable (ordered quantity of item i)
b_j	The right-hand side value associated with constraint j
d_i^-, d_j^-	The negative deviation variables of the NINLGP from the $item$ (i) and constraint (j) (underachievement)
d_i^+, d_j^+	Positive deviational variable of the INLGP from the ith goal and constraint j (over-achievement)
S_{oc_i}	Sum of ordering cost and holding cost for ith item
T_{ic}	Total inventory cost
S_{ci}	Setup cost for item i
G_i	Target value for the item i
S_c	Storage capacity

2.3 Mathematical Formulations

Model Formulation

The general model is of the form

$$\text{Minimize:} \qquad T_{ic} = \sum_{i=1}^{n} \left[S_{oc_i} O_{qi} + \frac{S_{ci}}{q_i} \right] \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \qquad (1)$$

Subject to:

$$\sum_{i=1}^{n} a_{ij} O_{qi} \leq b_j, \quad 1 \leq j \leq m \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. \dots \dots \dots \dots \dots \dots . (2)$$

$$\sum_{i=1}^{n} O_{qi} \leq S_c, \qquad 1 \leq i \leq n, \; q_i integer \; \forall i \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . (3)$$

Goal Formulation

The NINGP model objective and constraints are taken as the model goals with the introduction of deviational variables.

***i.* Total Inventory Cost Goal**

Deviational variables added to the inventory cost to give:

$$\sum_{i=1}^{n}\left[S_{oci}O_{qi} + \frac{S_{ci}}{O_{qi}}\right] + d_i^- - d_i^+ = G_i \ldots\ldots\ldots(4)$$

***ii.* Investment Goal**

With the deviational variables the targeted investment goal gives:

$$\sum_{i=1}^{n} a_{ij}O_{qi} + d_j^- - d_j^+ = b_j \ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

***iii.* Inventory Space Goal**

The targeted inventory space becomes;

$$\sum_{i=1}^{n} O_{qi} + d_i^- - d_i^+ = S_c \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(6)$$

***iv.* Weighted Average Structure**

Accordingly, the weighted average structure of the Non-preemptive Integer Nonlinear Goal Programming (NINGP) stated as;

Find $\overline{O_q}$ $(O_{q_1}, O_{q_2}, \ldots O_{q_i})$ to

Minimize: $$\left[w_i(d_i^- + d_i^+) + w_j\left(d_j^- + d_j^+\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Subjected to

$$\sum_{i=1}^{n}\left[S_{oci}q_i + \frac{S_{ci}}{O_{qi}}\right] + d_i^- - d_i^+ = G_i \qquad 1 \le i \le n \ldots\ldots\ldots\ldots\ldots(8)$$

$$\sum_{i=1}^{n} a_{ij} O_{qi} + d_j^- - d_j^+ = b_j \qquad 1 \leq j \leq m \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9)$$

$$\sum_{i=1}^{n} O_{qi} + d_i^- - d_i^+ = S_c \qquad O_{qi}(integer \; \forall \; i) \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (10)$$

Where, $d_i^-, d_j^-, d_i^+, d_j^+ (integer \; \forall \; i, j) w_i = w_j = 1$, since all goals are presumed to be of equal importance to the DM

3.0 MODEL APPLICATION

The cost detail for each brands of "Tokunbo" car is tabulated below.

TABLE 2: COST DETAILS FOR EACH BRAND OF CARS

Car Type	(C_i)(₦) '000	Setup cost (S_i)(₦) '000	Target value (G_i)(₦) '000	Average Investment (a_{ij})(₦) '000
Toyota Camry (2004)	3963	2600	10000	7613
Toyota Corolla (2006)	4325	2463	10000	8013
Toyota Corolla (2004)	1550	2325	8000	4225
Peugeot 307 (2002)	2688	2380	7000	5768
Peugeot 307 (2004)	3525	2500	9000	7163
Honda Accord (2004)	2550	2500x	8200	5750
Nissan Quest	2162	2225	8000	5000

Honda Accord (2003)	2505	2363	9000	5629
Honda Civic (2003)	2437	2363	9000	5509
Toyota sienna (2003)	2637	2325	9000	5645

Inventory Cost goals

The inventory cost goals for brands 1 through 10 respectively are presented in equations (11–20) below using the data in Table 3:

$$3963O_{q_1} + \frac{2600}{O_{q_1}} + d_1^- - d_1^+ = 10000; \quad \text{……(11)}$$

$$4325O_{q_2} + \frac{2463}{O_{q_2}} + d_2^- - d_2^+ = 10000; \quad \text{……(12)}$$

$$1550O_{q_3} + \frac{2325}{O_{q_3}} + d_3^- - d_3^+ = 8000; \quad \text{……(13)}$$

$$2688O_{q_4} + \frac{2380}{O_{q_4}} + d_4^- - d_4^+ = 7000; \quad \text{……(14)}$$

$$3525O_{q_5} + \frac{2500}{O_{q_5}} + d_5^- - d_5^+ = 9000; \quad \text{……(15)}$$

$$2550O_{q_6} + \frac{2500}{O_{q_6}} + d_6^- - d_6^+ = 8200; \quad \text{……(16)}$$

$$2162O_{q_7} + \frac{2225}{O_{q_7}} + d_7^- - d_7^+ = 8000; \quad \text{……(17)}$$

$$2505O_{q_8} + \frac{2363}{O_{q_8}} + d_8^- - d_8^+ = 9000; \quad \text{……(18)}$$

$$2437O_{q_9} + \frac{2363}{O_{q_9}} + d_9^- - d_9^+ = 9000; \quad \text{……(19)}$$

$$2637O_{q_{10}} + \frac{2325}{O_{q_{10}}} + d_{10}^- - d_{10}^+ = 9000 \quad \text{……(20)}$$

Investment constraint

Since the cost of each vehicle ordered are fixed the equation becomes:

$(76130_{q_1} + 80130_{q_2} + 52250_{q_3} + 57680_{q_4} + 71630_{q_5} + 57500_{q_6} + 50000_{q_7} +$

$56290_{q_8} + 55090_{q_9} + 56450_{q_{10}}) + d_{11}^{-} - d_{11}^{+} = 165062$ …………………...(21)

Inventory constraint

The total carrying capacity of the warehouse is 30 cars. Thus, the goal equation appears a

$(O_{q_1} + O_{q_2} + O_{q_3} + O_{q_4} + O_{q_5} + O_{q_6} + O_{q_7} + O_{q_8} + O_{q_9} + O_{q_{10}}) + d_{12}^{-} - d_{12}^{+} =$

30 ……………………………………………………………………………….(22)

4.0 RESULTS AND DISCUSSION

The NINGP model is solved, using an optimization tool in LINGO 17.0 software specifically because of its nonlinear functions and ability to handle large number of variables. The optimal mix for the various brands and their respective deviations is presented in Table 3 below.

Table 3: RESULTS SHOWING THE OPTIMAL MIX

Car type	Quantity (EOQ)	Positive (+)/Negative (-) Deviation (₦)
O_{q_1}	2	-1204275
O_{q_2}	2	-1348312
O_{q_3}	5	529619
O_{q_4}	2	-760805
O_{q_5}	2	-1054150
O_{q_6}	3	830042
O_{q_7}	3	-696021
O_{q_8}	3	-815128
O_{q_9}	3	-790410
$O_{q_{10}}$	3	-864645
TOTAL	**28**	**-6174085**

From the result shown in **Table 3**, the dealer needs to stock up the space with 10 different brands of cars occupying 93% of the inventory space. The solution saved the decision maker the sum of ₦6,174,085, which represent 10.3% of the decision maker's annual budget estimate. As shown in Table 4, the optimal cost of the cars is ₦53,825,915 as against the initial cost of ₦60,000,000.

5.0 CONCLUSION

This paper presents the application of Nonpre-emptive Integer Nonlinear Goal Programming (NINGP) model and the procedure to solving a multi-item inventory problem in other to obtain the EOQ required to achieve the aspirations of a local car dealer. All conflicting objectives and constraints was taken into consideration and with the use of an optimization tool in LINGO 17.0 software, an optimal solution was obtained. Thus, the NINGP model can be used efficiently to proffer solution to similar type of inventory problems where the desire is to minimizes cost and deviations from set goals.

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