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INTEGER WEIGHTED GOAL PROGRAMMING MODEL FOR A MULTI-PRODUCT COMPANY: A CASE STUDY IN THE NIGERIAN FOOD INDUSTRY

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ABSTRACT

Production planning is a complicated task that requires cooperation among multiple functional units in any organization. The management of production companies have several goals or target which they intend to achieve for their company. Henceforth, this research work presents a weighted Goal programming model for the production problem of a Nigerian food manufacturing company. The goals of the work include minimization of the underachievement of the profit goal, minimization of the underachievement of production target of the breads (burger, sardine, banana, hot dog roll, coconut, mixed fruit) and minimization of the overachievement of the machine production time. The data was collected from the production and sales department of the case company. The data included the quantity of each raw material (flour, sugar, salt, milk, nutmeg, water, butter, yeast, preserver, improver) used in producing one unit of each bread type (burger, sardine, banana, hot dog roll, coconut, mixed fruit), profit per unit of bread, time used in producing 1 unit of bread, quantity target of 1 unit of bread. The goals of this work are 8 goals which include profit goal, machine time goal, production goal of burger bread, sardine bread, banana bread, hot dog roll bread, coconut bread, mixed fruit bread. From the results obtained using LINGO optimization software, 6 goals out of 8 target goals were achieved. The achieved goals include production goal of burger, sardine, banana, hot dog roll, coconut, mixed fruit bread while the goals not achieved includes machine time goal and profit goal.

Keywords: Multi-product Company, Production planning, Integer Weighted Goal Programming Model, Goal Programming Model, Nigeria food industry.

INTRODUCTION

Organizing the production process is a challenging endeavor that demands collaboration among several operational divisions in any company. The planning phase results from a hierarchical chain of determinations addressing varied matters within the manufacturing domain, see [2]. In order to design an efficient production planning system, a good understanding of the environment in terms of customers, products and other variables involved in the manufacturing process is a must, see [9]. A proper production planning within these entities is a key condition to a manufacturing system success to deal with the limitations of efficiency and flexibility and to consider the real-world resources limitation (i.e. budget, time, labor, etc). Although such planning exists in the company, it is often incorrectly structured due to the presence of different multiple conflicting objectives whose unit can attain either continuous and integer values. Therefore, new tools for production planning are required that considers and accommodates this targeted goal. A classical approach to handle a multi –objective problem whereby the values of the targeted goals can take either continuous and integer values at the same time is the mixed integer goal programming model (MIGPM).

Multi-product systems, such as business entities, often face the challenge of achieving multiple target goals within a given timeframe. These goals are often conflicting and not measured in the same units, making it impossible to fully optimize all goals at once. As a result, businesses make an effort to minimize the deviation from the estimated target goals, with a given priority order of importance. While some goals may be more important than others, there is always a trade-off between the goals that can be achieved. Lexicographic Goal Programming technique is an appropriate method for solving such problems. see[6]. A multi-objective aggregate production planning model was developed to meet the needs of businesses that aim to optimize resource utilization in uncertain environments while maintaining acceptable levels of product quality and customer service. The proposed model was first converted from a fuzzy model into a crisp multi-objective model, and then goal programming was applied to the converted model. This approach enabled the model to handle the inherent uncertainty in production planning and incorporate multiple competing goals. see[12].

Challenges in decision-making within mathematical models arise from conflicts over limited resources and the lack of complete information. In real-world scenarios, decision-making problems necessitate the consideration of multiple objectives alongside different forms of uncertainties. Different methods are employed to address the diverse types of uncertainties encountered, [1]. The main idea in goal programming technique is to transform the original multiple objectives into a single goal. The resulting model yields what is usually termed as an efficient solution because it may not be optimum considering all the conflicting objectives of the problem. The technique uses simplex method for finding the near optimum solution of a single dimensional or multidimensional objective function subject to a set of linear constraints.

Quite often, most of these goals are competitive in terms of the need for scarce resources. In the presence of incompatible goal, the manager needs to exercise his judgment about the importance of the individual goals. Stated more simply, the most important goal must be achieved to the extent the management desires before the next goal is considered. Goal programming is one of the techniques for solving multiple objective decision problems. There have been many research works on the application of goal programming on different study areas.

[8]presented a mixed integer linear goal programming model for optimizing multiple constrained resources product-mix problem under the theory of constraints. In the paper, a mixed integer linear goal programming (MILGP) model was proposed to deal with

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product-mix problem when multiple constrained resources exist. The proposed MILGP model emphasized utilization of all bottle necks as the primary goal and maximization of throughput as the secondary goal. The proposed model was experimented on problems cited in literature and the randomly generated ones and the optimum results are reported by the proposed model. [10]presented a glorious literature on linear goal programming algorithms. In the paper, they presented a survey of current methods of LGP and limitations of LGP in general. Hence, the basic concept of goal programming is that whether goals are obtainable or not, an objective will be stated in which optimization gives a result which comes as close as possible to the desired goals. GP solution cannot be bounded since it has only minimum values. It has been proven that when the goals are not feasible remains an open problem. Major advantage of goal programming is that there always exists a solution to the problem, provided that it has feasible region and this is because of the inclusion of deviational variables. [5] presented a note on standard goal programming with Fuzzy Hierarchies: A sequential approach. In the paper, it has been assumed that the normalized deviations should lie between zero and one. In some cases, this assumption may not be valid. Therefore, the result showed that additional constraints must be incorporated into the model to ensure that the normalized deviations should not exceed one. [11]presented the application of integration of two-phase goal programming to examine the effectiveness of membership model. They introduced an alternative through two-phases of goal programming to overcome the existing membership model problem that does not have specific mathematical method to examine whether the receipt number of members is compatible with the criteria or characteristics that apply for membership through the Lexicographic goal programming (LGP) and multi choice goal programming with utility function. It is applied for membership artificial data. The results indicate that both goal programming methods could meet the retail loyalty program membership Modu Operandi. [4] presented a goal programming optimization model for the allocation of liquid steel production. In the paper, a goal programming was developed to determine the optimal allocation of steel production in EAF of a large steel company Indonesia. The results of the optimization showed that only maximizing production capacity goal could not achieve the target. However, the model developed in the paper can optimally allocate liquids steel so that the allocation of the production doesn’t exceed the maximum capacity of the machine work hours and maximum production capacity. [3] presented a goal programming model in time cost quality trade-off. In the paper, a goal programming model was developed to find suitable solutions to manage the cost, time and quality of the project, in order for the developed model to be examined, a case study was accomplished in the project implemented by Arak Machine Sazi company, computational results showed the applicability of the model and efficiency of proposed method. [7]presented a model for solving incompatible fuzzy goal programming: an application to portfolio selection. The paper presented a new approach that avoids infeasibility arising in FGP models when fuzzy targets cannot be jointly satisfied. They proposed an alternative algebraic formulation of the membership functions, which allowed them to formulate models capable of providing solutions although some tolerance thresholds were surpassed. The objective values that do not violate their corresponding thresholds were evaluated positively according to the degree of achievement to their fuzzy target, and in turn those who violate the thresholds are penalized according to their unwanted deviation with respect to the threshold. Thus, the model jointly used the fuzzy GP approach and the standard GP approach which also allowed incorporating fuzzy and crisp targets into the same problem. The proposed procedure is applied to socially responsible portfolio selection problem.

In the midst of this, our study will focus on achieving the primary objective of developing a mixed integer goal programming model that minimizes deviation from a Nigerian food manufacturing company target goals.

METHODOLOGY

Goal Programming Model for case company

$$\frac{w_1 U_{prod(B)}}{K_1} + \frac{w_2 U_{prod(S)}}{K_2} + \frac{w_3 U_{prod(Ba)}}{K_3} + \frac{w_4 U_{prod(H)}}{K_4} + \frac{w_5 U_{prod(C)}}{K_5} + \frac{w_6 U_{prod(M)}}{K_6} + \frac{w_7 U_{prof}}{K_7} + \frac{w_8 O_{MT}}{K_8}$$

subject to the constraint

$$T_1x_1 + T_2x_2 + T_3x_3 + T_4x_4 + T_5x_5 + T_6x_6 + U_{MT} - O_{MT} = AMT$$

$$p_1x_1 + p_2x_2 + p_3x_3 + p_4x_4 + p_5x_5 + p_6x_6 + U_{prof} - O_{prof} = EWPD$$

(weekly profit goal)

$$x_1 + U_{prod(B)} - O_{prod(B)} = T_{prod(B)}$$

(weekly production goal of burger bread)

$$x_2 + U_{prod(S)} - O_{prod(S)} = T_{prod(S)}$$

(weekly production goal of sardine bread)

$$x_3 + U_{prod(Ba)} - O_{prod(Ba)} = T_{prod(Ba)}$$

(weekly production goal of banana bread)

$$x_4 + U_{prod(H)} - O_{prod(H)} = T_{prod(H)}$$

(weekly production goal of hot dog roll bread)

$$x_5 + U_{prod(C)} - O_{prod(C)} = T_{prod(C)}$$

(weekly production goal of coconut bread)

$$x_6 + U_{prod(M)} - O_{prod(M)} = T_{prod(M)}$$

(weekly production goal of mix fruit bread)

$$f_1x_1 + f_2x_2 + f_3x_3 + f_4x_4 + f_5x_5 + f_6x_6 \leq F_q$$

{Flour constraint (kg)}

$$s_1x_1 + s_2x_2 + s_3x_3 + s_4x_4 + s_5x_5 + s_6x_6 \leq S_q$$

{Sugar constraint (kg)}

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$sa_1x_1 + sa_2x_2 + sa_3x_3 + sa_4x_4 + sa_5x_5 + sa_6x_6 \leq SA_q$

{Salt constraint (kg)}

$m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4 + m_5x_5 + m_6x_6 \leq M_q$

{Milk constraint (g)}

$n_1x_1 + n_2x_2 + n_3x_3 + n_4x_4 + n_5x_5 + n_6x_6 + \leq N_q$

{nutmeg constraint (g)}

$w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5 + w_6x_6 \leq W_q$

{water constraint(lt}

$b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 \leq Bq$

(Butter constraint)

$y_1x_1 + y_2x_2 + y_3x_3 + yx_4 + yx_5 + y_6x_6 \leq Y_q$

{yeast constraint (g)}

$p_1x_1 + p_2x_2 + p_3x_3 + p_4x_4 + p_5x_5 + p_6x_6 \leq P_q$

{preserver constraint (g)}

$I_1x_1 + I_2x_2 + I_3x_3 + Ix_4 + I_5x_5 + I_6x_6 \leq I_q$

{improver constraint (g)}

$U_{prod}, O_{prod}, U_{prof}, O_{prof}, EWPD, P_rT, Fq, S_q, Sa_q, M_{q,}N_{q,}W_q, B_qY_q, P_{q,}I_q \geq 0$

$and\ x_1, x_2, x_3, x_4, x_5, x_6 \geq 0\ and\ integer.$

Where:

$P_rx_1 + P_rx_2 + P_rx_3 + P_rx_4 + P_rx_5 + P_rx_6$

are the profits in naira associated with a loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively, in a week, while MP_T is the weekly profit target.

EWPD is the expected total weekly demand for all the bread.

$\rightarrow f_1x_1 + f_2x_2 + f_3x_3 + f_4x_4 + f_5x_5 + f_6x_6$

are the quantities of flour (kg) used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Fq is the total quantity of flour(kg) used in a week.

$\rightarrow s_1x_1 + s_2x_2 + s_3x_3 + s_4x_4 + s_5x_5 + s_6x_6$

are the quantities of sugar(kg) used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Sq is the total quantity of sugar(kg) used in a week.

$\rightarrow sa_1x_1 + sa_2x_2 + sa_3x_3 + sa_4x_4 + sa_5x_5 + sa_6x_6$

are the quantities of white salt (kg) used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while SAq is the total quantity of salt(kg) used in a week.

$\rightarrow m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4 + m_5x_5 + m_6x_6$

are the quantities of milk*(kg)* used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Mq is the total quantity of milk (kg) used in a week.

$\rightarrow n_1x_1 + n_2x_2 + n_3x_3 + n_4x_4 + n_5x_5 + n_6x_6$

are thequantities of nutmeg*(kg)* used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Nq is the total quantity of nutmeg (kg) used in a week.

$\rightarrow w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5 + w_6x_6$

are thequantities of water *(It)*used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Wq is the total quantity of water (kg) used in a week.

$\rightarrow y_1x_1 + y_2x_2 + y_3x_3 + yx_4 + yx_5 + y_6x_6$

are thequantities of yeast(g)used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Yq is the total quantity of yeast (g) used in a week.

$\rightarrow p_1x_1 + p_2x_2 + p_3x_3 + p_4x_4 + p_5x_5 + p_6x_6$

are the quantities of preserver(g) used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Pq is the total quantity of preserver(g) used in a week.

$\rightarrow I_1x_1 + I_2x_2 + I_3x_3 + Ix_4 + I_5x_5 + I_6x_6$

are the quantities of improver(g) used in producing one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Iq is the total quantity of improver(g) used in a week.

$b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6$

are the quantities of butter used in the production of one loaf of Burger, sardine, banana, hot dog roll, coconut, mix fruit bread respectively for a week, while Bq is the total quantity of butter used in a week.

Weighted Goal Programming Model for the case company

$$\text{Min}z = \frac{1U_{prod(B)}}{560} + \frac{1U_{prod(S)}}{350} + \frac{1U_{prod(Ba)}}{420} + \frac{1U_{prod(H)}}{70} + \frac{1U_{prod(C)}}{180} + \frac{1U_{prod(M)}}{210} + \frac{1U_{prof}}{650000} + \frac{1O_{MT}}{12960}$$

Subject to constraints

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70x1 + 100x2 + 80x3 + 90x4+ 110x5 + 105x6 + Uprof- Oprof = 650000

(profit goal)

X1 + Uprod(B) – Oprod(B) = 560

(weekly production goal of burger bread)

X2 + Uprod(S) – Oprod(S) = 350

(weekly production goal of sardine bread)

X3 + Uprod(Ba) – Oprod(Ba) = 420

(weekly production goal of banana bread)

X4 + Uprod(H) – Oprod(H) = 70

(weekly production goal of hot dog roll bread)

X5 + Uprod(C) – Oprod(C) = 180

(weekly production goal of coconut bread)

X6 + Uprod(M) – Oprod(M) = 210

(weekly production goal of mix fruit bread)

$1.4x_1 + 2.0x_2 + 1.5x_3 + 1.7x_4 + 6.0x_5 + 4.5x_6 + U_{mt} - O_{mt} = 12960$

(machine capacity goal)

$0.17x_1 + 0.83x_2 + 0.66x_3 + 0.62x_4 + 2.5x_5 + 2.0x_6 \leq 9200$

(flour constraint)

$17.37x_1 + 3.33x_2 + 66.66x_3 + 16.25x_4 + 25x_5 + 20x_6 \leq 200560$

(sugar constraint)

$2.08x_1 + 10x_2 + 8x_3 + 7.5x_4 + 30x_5 + 24x_6 \leq 149040$

(salt constraint)

$1.74x_1 + 8.33x_2 + 6.66x_3 + 6.25x_4 + 25x_5 + 20x_6 \leq 125120$

(milk constraint)

$0.05x_1 + 0.33x_2 + 0.26x_3 + 0.25x_4 + 1x_5 + 0.8x_6 \leq 4949.6$

(nutmeg constraint)

$0.03x_1 + 0.16x_2 + 0.13x_3 + 0.13x_4 + 0.5x_5 + 0.4x_6 \leq 2484$

(water constraint)

$2.43x_1 + 11.66x_2 + 9.33x_3 + 8.75x_4 + 35x_5 + 26x_6 \leq 1751496$

(butter constraint)

$1.04x_1 + 5.0x_2 + 4.0x_3 + 3.75x_4 + 5.0x_5 + 6.0x_6 \leq 75145.6$

(yeast constraint)

$$0.69x_1 + 3.33x_2 + 2.66x_3 + 2.5x_4 + 10x_5 + 8x_6 \leq 50011.2$$

(preserver constraint)

$$0.7x_1 + 3.33x_2 + 2.5x_3 + 2.5x_4 + 10x_5 + 8x_6 \leq 48576$$

(improver constraint)

$U_{Prod}, O_{Prod}, U_{Prof}, O_{Prof} U_{MT}, O_{MT} \geq 0$ and $x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$ and integer.

Data Illustration of the Case Company

The data of the case Nigerian food manufacturing company was analysed using the weighted goal programming technique with the LINGO optimization software. The summary of result obtained is summarized in the table below.

Table 3.1

Goals	Target level	Under achievement value, negative deviation(N)	Over achievement value, positive deviation(P)	Achieved Goal Value	Percentage deviation from target	Goal Achievement
Profit Goals	650000 (Naira) (min.)	40	0	649960	0.006%	Minimally under achieved
Burger bread production goal	560 (Loaves) (min.)	0	0	560	0	Achieved
sardine Bread production goal	350 (Loaves) (min.)	0	0	350	0	Achieved
Banana Bread production goal	420 (Loaves) (min.)	0	0	420	0	Achieved
hot dog roll Bread production goal	70 (Loaves) (min.)	0	5489.0	5559	98.7%	Over Achieved
coconut Bread production goal	180 (Loaves) (min.)	0	0	180	0	Achieved
mix fruit bread production goal	210 (Loaves) (min.)	0	0	210	0	Achieved

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Machine time production goal(mins)	12960 Minutes (max.)	0	629.30	13589.30	4.85%	Over Achieved
Total					103.556%	

Table 3.2 Quantity of Bread Produced (Decision Variables)

Decision Variable (Bread Quantity)	Quantity
X1 = Burger bread	560
X2 = Sardine Bread	350
X3 = Banana Bread	420
X4 = Hot Dog Roll Bread	5559
X5 = Coconut Bread	180
X6 = Mix Fruit Bread	210

From the summary of the solution shown in table 3.1 the sum of unwanted deviation was 4.856 which indicated a minimal unwanted deviation value. The profit target was underachieved by 0.006% while the production time target was overachieved by 4.85%. Meanwhile the production target of X4(Hot dog roll bread) was excessively overachieved with a positive deviation of 5489. So, the achievement goal value from the solution is a profit of 649960while the production quantity for burger bread, sardine bread, banana bread, hot dog roll bread, coconut bread, mix fruit bread were 560 loaves, 350 loaves, 420 loaves, 5559 loaves,180 loaves, 210 loaves.

CONCLUSION

The weighted mixed integer goal algorithm was used in achieving the targeted goals with weight on the underachievement of the profit target, overachievement of the machine time and the underachievement of the production target subject to the constraints of raw materials. The results obtained showed that the profit target was underachieved by N40 and the machine time was overachieved by 629.30(sec) and the production target of hot dog roll bread was overachieved by 5489 loaves and the production target of burger bread, sardine bread, banana bread, coconut bread, mixed fruit bread was fully achieved. The results suggested that the case company should produce 560 loaves of burger bread, 350 loaves of sardine bread 420 loaves of banana bread 5559 loaves of hot dog roll bread, 180 loaves of coconut bread, 210 loaves of mixed fruit bread per week in other to optimize their production goal. The weighted goal programming approach is useful for the multi-product company in achieving their goals subject to certain constraints, hence this model is appropriate to be used by this multi-product company. The mixed integer goal programming approach can also be used by other multi-product companies in Nigeria and other countries in Africa and the rest of the world with multiple conflicting objectives to achieve their goals.

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APPENDIX

Case company

INGREDIENTS = flour, sugar, salt, preserver, milk, nutmeg, water, butter, yeast, improver,

Ingredient	Burger bread	Sardine bread	Banana bread	Hot dog roll bread	Coconut bread	Mixed fruit bread
Flour	0.17 kg	0.83kg	0.66kg	0.62kg	2.5kg	2.0g
Sugar	17.37	83.33g	66.66g	16.25g	25.0g	20.0g
Salt	2.08g	10.0g	8.0g	7.5g	30.0g	24.0g
Milk	1.74g	8.33g	6.66g	6.25g	25.0g	20.0g
Nutmeg	0.05g	0.33g	0.26g	0.25g	1.0g	0.8g
Water	0.03It	0.16It	0.13It	0.13It	0.5It	0.4It
Butter	2.43g	11.66g	9.33g	8.75g	35.0g	26.0g
Yeast	1.04g	5.0g	4.0g	3.75g	15.0g	12.0g
Preserver	0.69g	3.33g	2.66g	2.5g	10.0g	8.0g
Improver	0.07g	3.33	2.5g	2.5g	10.0g	8.0g
Time used in production	0.42 min(25.2s)	2min(120s)	1.5min(90s)	1.5min(90s)	6min(360s)	4.8min(288s)
Estimated profit per loaf of bread	N70	N100	N80	N90	N110	N105
Quantity target of bread	560 Loaves	350 Loaves	420 Loaves	70 Loaves	180 Loaves	210 Loaves