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Optimization of Bakery Production at Fresh Options Limited Using Goal Programming

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ABSTRACT: This paper examines and adopts the Goal Programming (GP) optimization technique as an approach to improve output performance at Fresh Options Limited. Obtained data from the company's sales, purchases and bakery production records were analyzed using the LINGO 20.0 optimization software. The result of the analysis revealed that the company could meet both targeted profit and cost objectives producing less than the volume of output earlier set by management and still achieve the same profit goal. The outcome of this study demonstrates that the GP is a viable tool in the production decision of the small and medium enterprises. The developed method will equally be of value to those interested in the goal programming model as tool to solving complex planning issues involving uncertain parameters.

KEYWORDS: Optimization, Goal Programming, Production, Small and Medium Enterprise, SMEs

I. INTRODUCTION

Firms exist in an increasingly complex business environment that demands competitiveness in the face of limited resources, cutthroat competition, and a growing insatiable consumer expectation; fuelled especially, by an increasingly digitized global economy (Kering, et al., 2020; Alomar & Pasek, 2014; Gröger, et al., 2013). In order to survive and grow, firms, irrespective of type and location, must make decisions that lead to the production of goods in the right quality, quantity, time, and at minimum cost, but maximum profits (Kumar, 2019; Chukwuluzie, et al., 2010). This need is even of increasing importance for the small and medium enterprises, given their highly constrained resource base and the magnitude of the effect of poor decisions on their operations and survival. Typical is the case scenario at Fresh Options Limited, a small and medium enterprise located in Makurdi, Nigeria. Achieving customer satisfaction at a profit has remained a major challenge threatening the very existence of the company. While the cost of inputs have sky rocketed, the company has faced increasing challenges at achieving consistency in product quality and volume of output that meets its market demand, especially given its limited resources base,. The increasing challenge confronting management is the determination of product types and output volume that yield targeted profit objective. The company's inability to achieve consistency in products output have amounted to significant loss of (over 35%) company revenue and (25%) market share the past six months. This presents an optimization problem and, hence the need for this study. This study undertakes to explore the optimization technique as an approach to improve output performance at Fresh Options Limited. The theoretical framework to this study is built majorly around the Resource Based Theory (RBT), and the Optimization Theory (OT), which leads further to the Goal Programming Theory and Technique. a need to develop a mathematical model to aid management production decision at Fresh Options Limited,

II. LITERATURE REVIEW

2.1. The Resource-Based Theory

The Resource-Based Theory (RBT), is crucial to understanding how an SME improves its current production to satisfy its market demand and achieve its business goal – profitability (Ali, 2023). The RBT is an internally-driven method, concentrating primarily on internal organisational resources, as opposed to externally driven ways to comprehend the efficacy or failures associated with leveraging organisational activities (Kozlenkova, Samaha & Palmatier, in Utami & Alamanos, 2023). Traced to the works of Birger Wernerfelt (1984), Jay B. Barney (1991), Penrose (2009) and others (Utami & Alamanos, 2023; Madhani, 2014), the RBT conceives the firm as a bundle of resources and the firm's heterogeneous resource base as a condition for competitiveness in the market place (Madhani, 2014). Barney (1991) the proposed categorization divides a company's resources under the following primary groups: tangible capital resources, human resources, and organisational capital resources. Physical capital resources include company equipment, buildings, access to raw materials, geographical position, and technical infrastructure that is employed by the business. Similarly human capital resources include traits such as expertise, intellect, training, judgement, connections, and insights provided by employees, including managers as well as employees inside the organisation. It defined a firm’s organizational capital resources as the company’s formal structure, the company’s formal and informal system, comprising basically of planning, managing, and coordinating systems. Organizational resources also include informal relations amongst divisions within a company and the relationships between a company and its business environments (Utami & Alamanos, 2023) According to the RBT, company resources can either be classified as physical or intangible (Barney, 1991). Tangible resources refer to all assets, both economic advantages and visible business contributions like products and commodities. Intangible resources are competencies and expertise, in addition to organisational, strategic, including societal benefits. Keränen & Jalkala, 2013). This study conceives organizational resources as physical capital resources, human capital resources and organizational capital resources (Barney, 1991).

. A major proposition of RBT is in the four conditions of assessing the potential of a resource to become and generate a sustainable competitive advantage. The four conditions are (1) value, (2) being rare, (3) immobility and (4) sustainability (Barney, 1991). These four terms are known as the VRIS framework and are a strategic planning reference quality that according to this theory holds the prospect for sustained competitive advantage (Utami & Alamanos, 2023). These four conditions of RBT suggest that poor organizational policies, processes, and procedures may weaken a resource’s potential competitive advantage of the firm (Barney, 2007 in Utami & Alamanos). The ability of the organization to make quality decisions, as regards the use of its resources, acts as the adjustment factor to fully realizing the advantages of the firm's embodied resources (in terms of its value, rareness, and costliness or complexity to imitate) (p. 4). This is in agreement with Kraaijenbrink (2011), which argues that resources are not in their self responsible for the observable differences in firms’ performance, but rather, what makes the difference is their deployment, the nature of use the firm makes of these resources; to generate economic benefits for the firm. This suggests the relatedness of the quality of the firm’s decisions as regards resource availability, with the firm’s ability to achieve targeted goals. Agreeably, Barney and Frikan (2017), argue that resources become more valuable when they are used to reduce a firm's cost and to increase the firm's revenue. Here again, the choice of resource use, and in effect the quality of managerial decision, is linked with the possible increase in the firm’s revenue. The above arguments depict a point of connection between the resource-based theory and the theory of optimization, and indeed, the usefulness of the two theories in understanding and proffering solutions to the research question of this study. The following section explores the theory of optimization and its application to managerial decision-making.

2.2 The Optimization Theory

The Optimization Theory (OT) is concerned basically with mathematical structure, methods, properties, and implementation of optimization problems (Marchal, Ortega & García, 2019; Setiawati, & Arisya, 2018). As a defined area of theorizing, optimization theory had its origin in the 1940s, when it was increasingly realized that many problems in different fields have common mathematical elements and could be solved using a unified set of ideas and methods (Snyman, & Wilke 2005). The main disposition of this theory is that firms can achieve their business goal by finding the optimal allocations of limited resources required to meet a given objective (Greenwald, Crane, Krakowski & Barber, 2020; Setiawati & Arisya, 2018; Priyanka, et al., 2016). Essentially, this theory sets the practical stage for resource identification and usage in a certain order that leads to the achievement of maximum benefit to the firm at minimum discomfort (Amiens & Adedoyin 2020; Snyman, Jan & Wilke 2018; Sofi, et al., 2014). By implication, a proper match of important input raw materials with organizational resources typically, machines and labor hour, will necessarily produce that product that maximizes profit at minimum cost. Suggestible, the degree of the success or failure of a firm is a function of the ability of the organization’s ability to make appropriate decisions, as far as resource availability and usage is concerned (Kering, Kilika, & Njuguna, 2020; Setiawati & Arisya, 2018; Sharma 2016; Ajibode & Fagoyinbo 2010).

2.3 Goal programming

Goal programming (GP) is traced to a single-objective linear programming problem, developed by Charnes, Cooper, & Ferguson (1955) and to the later improvements by Ignizio, 1976, 1978 and Clayton et al. 1982 (Lotfi, A., et al., 2014; Deb, K., 1999). The principal argument here is that the firm's economics is a multivariate and multi-objective network system, the process in their production includes various factors and characteristics of non-deterministic, and at any point in time enterprises decisions are multi-objective oriented (Kumar, 2019; Priyanka, et al., 2016; Valunjkar, 2015; Okafor, 2010). By extending linear programming to problems that involve multiple objectives, goal programming allows the Decision Makers (DM) to specify a target for each objective function (Alam, T., 2022; Neelavathi, 2015; Lotfi, A., et al., 2014; Valunjkar, S.S.V., 2010). Here, the deviation between the desired goals is minimized according to the assigned priorities instead of maximizing or minimizing the objective function (Deb, 1999). Certain variables comprise important components in the designing of a goal programming model. These include: deviation variables, objective function, hard and soft constraints, goal priorities and desirable/undesirable outcomes. Below is a brief insight into these terms:

1) *Deviation variable:* Both upward (Positive) and downward (negative) deviations are used to explain the disparity within making decision and target values
   a. Positive deviation variables (d_i^+): represent that part of the decision value that exceeds the target, set $d_i^+ \geq 0$.
   b. Negative deviation variables (d_i^-): representing that part of the decision value that does not reach the target, set $d_i^- \geq 0$

Three possibilities exist in the determination of the targeted goal, namely: (i) Decision value above the target value, presented as $d_i^+ \geq 0$, $d_i^- = 0$; (ii) Decision value is below the target value, presented as $d_i^+ = 0$, $d_i^- \geq 0$. (iii) Decision value equals the target value, presented as $d_i^+ = 0$, $d_i^- = 0$.

2) *Absolute constraints and Goal constraints* absolute constraint are constraints that are required to meet strict equality constraints and inequality constraints. Target constraint is unique in the goal programming to determine a target value to make decisions, allowing the existence of positive or negative deviation with the target value.
3) *Objective function:* The objective function in a GP is a set of negative and positive deviations that must be minimize to achieve the target goals of the decision maker. Mathematical expression for the objective function of the goal programming model is: Min z = f (d_i^+, d_i^-) This has the following three basic forms:
   a. Exactly achieve the target: obtained positive and negative deviation variables are as small as possible, the objective function is: Min z= di+ + di–
   b. Does not exceed the target: obtained positive deviation variable is as small as possible, the objective function is: Min z = di+
   c. Exceed the target, namely the negative deviation variable is as small as possible, the objective function is: Min z = di– , di+ , di– + di+

Empirically, several studies have validated the GP as a viable optimization technique. Priyanka et al. (2016) applied a goal programming technique using the LINDO 11.0 software to analyze the daily sales profits, machine operational efficacy review and found that the goal programming model was not only useful in the production planning of the company, but that the DM could increase the number of goals to be considered based on the desirability in relation to their aspired objectives. This is in agreement with the findings by Kanakana-Katumba & Makinde (2018) of the effectiveness of the GP in the operation planning of a Small and Medium Bottled Water Production Enterprise. The study analyzed customer order, inventory, production timeframe and production expenses data using the LINDO software, and found that the organisations could achieve some of their objectives but could not achieve others, In an earlier research, Hassan, Nasruddin & Ayop (2012) developed a three objectives pre-emptive goal programming to optimize customers' demands in an SME producing five frozen foods, and distributing at three different locations, using LINDO 6.1. The study demonstrated also the relevance of the pre-emptive

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GP in the determination of the production planning of a firm's competitiveness in its market. The same results were established by Hasbiyati, Desri, & Gamal (2023) from their analysis of the Rotte Bakery Company using the LINGO 11.0 application, the study established that the GP method offers a more efficient outcome than the application of manual production planning by firms. Mahat, et al. (2022) and Ezra, et al. (2020) both produced similar reports. The former studies all used the LINGO solver, except for Ezra, et al (2020) who used Tora software, and further compared the preemptive GP with the weighted GP, and came up with the conclusion that their no issues of the superiority between the two methods but rather each approach is devised to meet decision maker's preferences.

Emerging from the literature above, the optimization technique, involving the use of the Goal Programming (GP), is especially useful in achieving precision at important decision variables in the production planning of firms. In addition to its multi-objective capacity to give the best possible solutions that yield not only the highest benefit/profit but the lowest distress/cost, the applicability of GP to the operational challenges of SME renders it useful to the problem situation at Fresh Options Limited. It must be mentioned that most GP usage has so far been restricted to clearly defined decidable problems and to the persistence of ideal results that optimize goal achievement to the possible extent within specified barriers. These limitations do not, however, pose any threat to the decision analysis of the current study. The use of the GP here is justified based on the deterministic multi-objective nature of the problem situation at Fresh Options Limited.

III. METHOD AND MATERIAL

This paper examines and adopts the Goal Programming (GP) optimization technique as an approach to improve output performance at Fresh Options Limited. The preemptive GP is employed here particularly as it prioritizes goals, focusing on achieving the vital goal as precisely as possible, in anticipation of going on to the subsequent higher goal, to the minimal goal. Some key steps to the GP model formulation are illustrated in Figure 3.1.

The data used for this study are collected from the company's day to day productions and sales record as presented Tables 3.1, 3.2, 3.3 and 3.4.

The various data were categorized into:
1) Units of product produced per day.
2) Available raw materials.
3) Available machines for the production.
4) Time for producing each product.
5) The profit contribution per each product.

Figure 3.1: Steps to Formulation of a Goal Programming Model

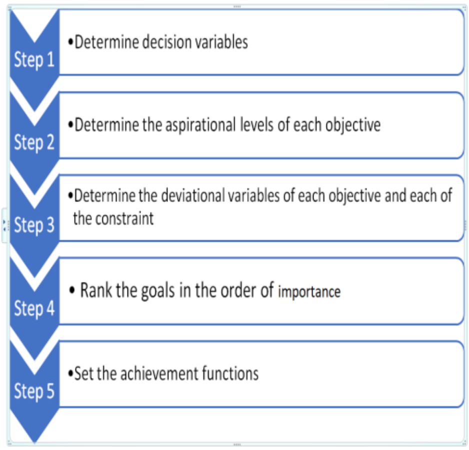

Table 3.1: : Products and units per day

S/N	Items	Notation	No. of units per day
1	Large sized Bread	X1	650
2	Fruitee Cakes	X2	440
3	Meat pie	X3	350
4	Sausage Rolls	X4	380
5	Cupcakes	X5	400

Table 3.2: Major Ingredients per unit Product in Grams

S/N	Ingredients for each product	Bread (X_1)	Fruitee Cake (X_2)	Meat Pie (X_3)	Sausage Roll (X_5)	Cupcake (X_4)	Availability per day/grams
1	Flour	333.3	60	60	70	40	300,000
2	Sugar	16	10	0.0	0.0	20	20,000

3	Margarine	5.0	10	30	10	20	150,000
4	Yeast	50.0	0.0	0.0	10	0.0	10,500
5	Baking powder	0.0	5.0	0.5	0.0	0.5	2,000
6	Salt	0.7	0.8	0.2	0.7	0.1	1,000
7	Egg	10	5,6	10.5	5.0	30	12,000
8	Milk	10	5.0	15	10	5.0	12,000
9	Meat pie filling	0.0	0.0	30	0.0	0.0	150,000
10	Mixed fruits	0.0	5.0	0/0	0.0	0.0	15,000

Table 3.3; Time required producing each product in minutes

	Resources available	**Bread (X_1)**	**Meat Pie (X_2)**	**Cupcake (X_3)**	**Fruitee Cake (X_4)**	**Sausage Roll (X_5)**	**Availability per day**
11	Machine	0.75	0.25	1.5	1.0	0.75	900
12	Labour	1.5	1.25	1.25	2.5	0.5	12000

Table 3.4: The Cost, Price and Profit for Each Product in Nigerian Naira (N)

Products	Costs (N)	Prices (N)	Profits (N)
Large sized Bread	280.886	600	319.114
Fruitee Cakes	103.189	100	96.8103
Meat pie	193.188	400	206.811
Sausage Rolls	143.264	200	56.736
Cupcakes	120.909	350	279.092

3.1. Preemptive Goal Programming Model Minimize:

$$z = \sum_{i=1}^{m} (d_i^+ + d_i^-); i = 1, 2, 3, \dots, m \qquad (1)$$

Subject to Linear Constraints:

A) Goal constraints:

$$\sum_{j=1}^{n} a_{ij} x_j - d_i^+ + d_i^- = b_i ; i = 1, 2, 3, \dots, n \quad (2)$$

B) System constraints:

$$\sum_{j=1}^{n} a_{ij} x_j \begin{vmatrix} \geq \\ = \\ \leq \end{vmatrix} b_i ; i = m+1, \dots m, +P \qquad (3)$$

Where:

Equation (1) is the objective function, a summation of all deviational variables. Equations (2) and (3) are the goal and system constraint functions respectively; and are both referred to as linear constraint functions. Equation (4) is a non-negativity constraint. m = the number of goals; p = number of system constraints, n = number of decision variables; z = the objective function expressed as the summation of all the deviational variables; x_j = the jth decision variables; $a_{i,j}$ = the coefficient of the jth decision variables in the ith goal; a_i is the aspiration level; d^+_i and d_i^- are degree of variance below and above the target level in succession; bj's are the targets or goals associated with the constraints. This means that the GP model has two variables: decision and deviational.

The use of the pre-emptive goal programming entails that the objectives can be split into numerous priority classes. The assumption here is individual goals have no similar priority. These goals are given a sequential placement, called pre-emptive priority factors. These priority factors have a link depicted by ranking according to the priority given to a goal. Both surpassing expectations and falling short cannot of a goal cannot occur concurrently. Hence, either one or both of these variables must have a zero value; that is,

$$p_1 >>> \rho_2 >>> \rho_i >>> \rho_{i+1} >>> \rho_m$$

With P_1, P_2, ..., P_n as the priority level for every goal arranged according to its priority, that is G_1, G_2 ... $G_1 \geq G_2 \geq \dots \geq G_n$.

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3.2. Conditions for solution

The main function in a goal programming model is to reduce the variance from goals in order of the goal priority. The success or otherwise of the goal is determined by the

Table 3.5: Procedure for Achieving a Goal

Minimize	Goal	If goal is achieved
d_i^-	Minimize the underachievement	$d_i^- = 0, \quad d_i^+ \geq 0$
d_i^+	Minimize the overachievement	$d_i^+ = 0, \quad d_i^- \geq 0$
$d_i^+ + d_i^-$	Minimize both under- and overachievement	$d_i^+ = 0, \quad d_i^- = 0$

3.3. Aspiration Levels: The priority structures

The following goal programming algorithm approach assumes that the priority ranking is exact. i.e., P1 goals are more important than P2 goals and P2 goal will not be achieved until P1 goals are all achieved; same applies to P3, and P4 goals according to their rating. values of deviation variables. Table 3.5 provides a procedure for achieving a goal.

1) First priority (P1) depending on the primary goal, this will result in the realisation of the
2) achievement function, which can be attained in the following way: Minimum P1 = d1-
3) Third priority (P_3) is determined by the third objective, and the fulfilment of the mechanism will follow from this. It is obtainable as: Minimum $P_3 = d_3+$
4) Fourth priority (P_4) is based on the fourth goal and this will result in the achievement function. It can be obtained as: Minimum $P_4 = d_4^-$

Goals

The major aims were to:

1) Minimize the underachievement of the profit goal (d_1^-),
2) overachievement of the production cost goal (d_2^+),
3) overachievement of the labor goal (d_3^+), and
4) underachievement of machine capacity goal (d_4^-)

3.4. Data Analysis

To reach the goal of this study, the straightforward technique as mentioned previously were used to the data provided in Tables 3.1, 3.2, 3.3 and 3.4. The analyses were carried out using LINGO Software (Version 20.0). The models consist of the objective functions, consisting of the specific deviation variables to be minimized as shown in (1); and the goal constraints and the system constraints as indicated by (2) and (3); where each model is formulated using the decision and deviational variables. The required models for different preemptive goals are formulated as follows:

Minimize z = $P_1 d_1^- + P_2 d_2^+ + P_3 d_3^+ + P_4 d_4^-$

Subject to:

A) Goal Constraints

$$320x_1 + 64x_2 + 207x_3 + 57x_4 + 279x_5 + d_1^- = 383\,600\ (profit\ goal)$$

$$281.00x_1 + 36x_2 + 193.19x_3 + 143.264x_4 + 121.00\,x_5 - d_2^- = 150000\ (Cost\ goal)$$

$$0.75x_1 + 0.25x_2 + 1.5x_3 + 1.0\,x_4 + 0.75x_5 - d_2^- = 12000\ (Machine\ goal)$$

$$1.5x_1 + 1.25x_2 + 1.25\,x_3 + 2.5\,x_4 + 0.5x_5 - d_3^+ = 900\ (Labour\ goal)$$

B) System Constraints:

$$333.3x_1 + 60.1x_2 + 60x_3 + 70x_4 + 40x_5 = 300{,}000\ (Flourgoal)$$

$$16x_1 + 10.x_2 + 0x_3 + 0x_4 + 20x_5 = 20{,}000\ (Sugargoal)$$

$$5x_1 + .10x_2 + 30x_3 + 10x_4 + 20x_5 = 150{,}000\ (Margarinegoal)$$

$$50x_1 + 0.0x_2 + 0.0x_3 + 10x_4 + 0x_5 = 10500\ (Yeastgoal)$$

$$0.0x_1 + 5x_2 + 0.5 + 0.0x_4 + 0.5x_5 = 2000\ (Baking\ powdergoal)$$

$$0.7x_1 + 0.8x_2 + 0.0x_3 + 0.7x_4 + 0.1x_5 = 1000\ (Salt\ goal)$$

$$10x_1 + 5.6x_2 + 10.5x_3 + 5x_4 + 30x_5 = 12000 (Egg\ goal)$$

$$10x_1 + 5x_2 + 15x_3 + 10x_4 + 5x_5 = 12000 (Milkgoal)$$

$$0.0x_1 + 0.0x_2 + 30.0x_3 + 0.0x_4 + 0.0x_5 = 150000\ (Meat\ pie\ filling\ goal)$$

$$0.0x_1 + 5.0x_2 + 0.0x_3 + 0.0x_4 + 0.0x_5 = 15000\ (Mixed\ fruits\ goal)$$

$$x_{1.} \geq 0, i = 1 \ldots 5, d_j^+ \geq 0, d_j^- \geq 0, j = 1 \ldots$$

IV. RESULTS AND DISCUSSION

Studying the results from the analyzed data using the LINGO 20.0 Optimization software is presented in Table 4.1. Table 4.2 presents a comparison between projected values and optimum values of decision variables.

4.1. Results

Table 3.6: Result of the analysis from preemptive GP

S/N	Variables	Values	Reduced Cost
1	X1	84.48	0.00
2	X2	0.00	0.00
3	X3	141.09	0.00
4	X4	0.00	0.00
5	X5	811.5	0.00
6	d^-_1	0.00	1.00
7	d^-_2	0.00	1.00
8	d^-_3	0.00	1.00
9	d^-_4	0.00	1.00

Table 3.6: Projections and Result Comparison

S/N	Items	Notation	Projected	Optimum value	Reduced cost
1	Large sized Bread	X1	650	84.48	0.00
2	Fruitee Cakes	X2	440	00	0.00
3	Meat pie	X3	350	141.09	0.00
4	Sausage Rolls	X4	380	0.00	0.00
5	Cupcakes	X5	400	811.48	0.00

4.2. Discussion

In this study, a Goal Programming model is solved using LINGO version 20.0 software The main goals were to minimise inadequate performance of the profit objective (d1-) and accomplishment of the manufacturing cost goal. (d_2^+), the overachievement of the labor goal (d_3^-), and the underachievement of machine capacity goal (d_4^-). From the results in Table 3.1, it is discovered that all of these goals were fully achieved ($d_1^- = 0$; $d_2^+ = 0$; $d_3^- = 0$; and $d_4^- = 0$). These suggest that the company can:

1. meet its profit goal of N283 600.00 profit from its daily sales;
2. achieve its minimum cost target of N150 000.00 per day;
3. achieve minimum labor hour use of 900 hours; and as well
4. Maximize the use of its machine capacity.

The lowered cost amounts to zero for all the factors indicates that the company will not incur additional cost by one unit improvement achievement in targeted goals. This is further backed by the values of the slack variable and the dual prices. The slack variables in row 1, 2, 3 and 11 are equal to zero, with all the others rows bearing positive values, indicating too that the constraints are satisfied only for the former rows (1, 2, 3, and 11), all others indicate resource allowance for higher achievements (Appendix 2).

The result reveal too that with just a total of 1037.05 units of products, (comprising of 84.48 breads; 141.09 meat pies and 81.48 cup cakes), the company will meet its targeted profit of 283 600 naira per day, without the need to stretch its resources producing the 2000 products as projected by the management. Producing beyond the available capacity is a evidently the explanation to the company's current experiences of inconsistencies in product quality, volume of output and failure in meeting its targeted profit objective. The result of the analysis indicates that the company is able to maximize profit producing just the three products using the same resources.

V. CONCLUSIONS AND RECOMMENDATIONS

The result from the analysis showed that the company could reach its targeted profit and cost goals producing less than the volume of output stipulated by management. This goes without saying the value of the quality of decision to the outcome of production resources. Clearly, the challenges the company has encountered in the inability to meet its profit goal, given its available resources were largely due a wrong combination of products and volume of output.The outcome of this study demonstrates therefore that the GP is a viable tool in the production decision of the small and medium enterprise.

This study recommends therefore, the use of the designed goal programming model by management the at Fresh Options to aid its production decision The established procedure will equally be of value to those intrigued in the goal programming model as tool to solution to difficult planning challenges with unclear parameters and multiple objectives

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