Materials Procurement Order Development for Feed Manufacturing in a Teaching and Research Farm in Western Nigeria using Multi-objective Optimization Approach

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Abstract: Although an essential but scarce resource, money is constantly required for the purchase of raw materials necessary for a continued production of livestock feeds. Improper management of available capital can lead to stoppage of production activities, low productivity and loss of customers' good will. Therefore, there is the need to manage effectively the little capital available. This study was aimed at developing and solving a model that can determine the procurement order for raw materials considering the liquid capital constraint. An animal feed firm was investigated and data on materials (bill, quantity ratio, cost); products list; supplier's list; product demand; liquid capital available and the available lead time amongst others were collected by means of interviews, observations and existing records. These were thereafter analysed to form the required parameters. A multi-objective optimization model was developed using linear programming technique as a tool for procurement order of materials in the firm and solved using two different soft wares (Tora 1.0 and Lingo 14.0). Selection of suppliers was based on payment term. 6 products, 13 materials, 7 suppliers, 2 days and ₦138,856 were obtained from the bill of materials, suppliers list, available lead time and liquid capital available respectively. A total weekly demand of 22,600kg of product was also obtained from the product demand. A total of 205 parameters were obtained from the analysed data. The developed model exhibited 3 objective functions (maximize profit on all products, minimize waiting time for all raw materials and minimize the total cost of raw material), 32 variables (Q1...q1) and 78 constraints (t1 ≤ 0.28… t13 ≥ 0). Same optimal values (0, 0, … and 0.55) were obtained from the use of Lingo 14.0 and Tora 1.0. Moreover, 211.97₦kg was realised as the optimum value for the objective function. The supplier IBM, with the most flexible payment term was selected to supply nine out of the 13 materials. The developed model will be useful in ensuring effective management of the available liquid capital for material procurement, thereby eliminating the stoppage of production activities, improving productivity and ensuring customers' good will.

Key Words: Liquid capital, Materials, Multi-Objective Optimization, Procurement, Productivity

1. INTRODUCTION

Manufacturing, in simple terms involves the conversion of raw materials into a useful product of better value compared to the raw materials [5]. Manufacturing often requires the use of some other resources apart from the raw materials as all these work together, interacting with one another to ensure that useful product is produced. Some of these may include, labour, land, information and energy [2]. Manufacturing is one of the primary sources of income for a nation and a wealth creation aspect of a country's economy as it adds value to the raw materials being converted. Hence, it is important to ensure that high productivity is achieved.

In its own sense, Productivity is defined as a measure of quantifying the output against the amount of input [1]. Productivity also determines profitability because the higher the productivity, the higher the profitability of such a product [8]. Profitability is the measure of how much profit is made on a product relative to the market conditions and the cost of production [19]. It is important to note that profit making is one of the major concerns of most establishments, manufacturing industries inclusive [16].

Nevertheless, the productivity of a manufacturing firm can be affected by certain factors, such as: financial constraint, inadequate labour, lack of technical know-how, frequent break down of machines and equipment, as well as worker's attitude to mention a few [6]. The raw materials used for production have to be purchased with money. Then, availability of finance is one of the six major factors that affect productivity [6]. The significant effects of measures of financial factors on firms' total factor productivity on different firms (Italian, Estonian and Bulgarian firms was also found [3]. It was established that easing financial constraints in industries will increase the firm's level of productivity using the Chinese manufacturing data [10].

Materials constitute one of the most important input resources in any production process [4]. Non-availability of these materials when needed delays production even as the waiting time for the supply of materials becomes long. This leads to machine idleness, loss in useful man hour and energy wastage. All these eventually reduce productivity and lower the profit realisable on the product. Tackling financial constraint was the major focus of this research work.

An animal feed mill was used as a case study. It is an agriculture-based manufacturing firm with different products like vegetables, tubers and poultry products. This work was aimed at developing a model to help arrange sequentially in order of importance and relevance the materials to be purchased for animal feed production, considering the material needs of the farm and the amount of money available for purchase. Out of the many material needs of a manufacturing firm, it is imperative to decide on what and what to be procured first without interfering with smooth running of the manufacturing process.

There is a need to develop a mathematical model that will give a sequence for material procurement, considering the amount of money available, the importance of the materials, payment terms and delivery terms to ensure continuity in production.

Then, the aim of this was work to develop and solve a mathematical model that will give an order of materials procurement for a typical manufacturing industry, considering the importance of relevant materials, payment terms, and delivery terms to reduce or eliminate delay in production activities usually caused by non-availability of raw materials.

Therefore, the objectives of the project include:

1. Investigating the activities of typical manufacturing firm and collection of necessary data.
2. Using linear programming as a tool to developing a model for the procurement order problem.
3. Solving the problem using two different optimisation softwares (Lingo 14.0 and Tora 1.0) and deriving a procurement order.

2. METHODOLOGY

2.1 Data Collection

Data required for the study was collected from a farm in Ibadan, Oyo State, South-Western Nigeria majorly by interviews, observations and historical records. The animal feed manufacturing section of the farm was chosen as case study, to represent a typical manufacturing firm in Nigeria, in which there will usually be the need to purchase raw materials from their available working capital. Out of the three working staffs present at the feed mill section of the farm, two of them were interviewed differently to obtain data. The two staffs were selected purposively based on their experience in the business. The feed mill section was further observed closely for a week to validate the results of the interview.
The following data collected were bill of materials, list of products, quantity ratio of materials, product Demand, material Usage rate, procurement process, list of suppliers, payment and delivery terms and conditions, material cost, liquid capital available, profit margin on products and available lead time.

2.2 Experimental

The material needs of the firm and procurement activities were developed into a mathematical model using the multi-objective problem-solving model. Required objective functions, decision variables and constraints were obtained from the study. The linear aggregation of objectives technique for solving multi-objective optimization problem was thereafter adopted. The model was then solved using Lingo 14.0 and Tora 1.0 software.

2.3 Symbols, Abbreviations and Currency Conversion

$Q_i = quantity\ of\ product$
$q_k = quantity\ of\ raw\ materials$
$t_k = replensihment\ time\ for\ raw\ materials$
$i = product\ number$
$k = raw\ materials\ number$
$n = number\ of\ products$
$m = number\ of\ raw\ materials$
$P_i = profit\ on\ products$
$u_k = usage\ rate\ of\ raw\ materials$
$C_k = cost\ of\ raw\ materials$
$L = amount\ of\ liquid\ capital\ available$
$T_k = Maximum\ lead\ time\ for\ materials$
$D = product\ demand$
$d = raw\ materials\ demand$
$Z_1 = objective\ value\ for\ total\ profit\ on\ products$
$Z_2 = objective\ value\ for\ total\ replnishment\ time\ for\ raw\ materials$
$Z_3 = objective\ value\ for\ total\ cost\ of raw\ materials$
$Z_T = objective\ value\ for\ all\ objective\ functions$
$W_1 = weight\ assigned\ to\ Z_1$
$W_2 = weight\ assigned\ to\ Z_2$
$W_3 = weight\ assigned\ to\ Z_3$
$b_k = coefficient\ of\ q_k in\ the\ objecive\ function\ Z_2$
$v_i = coefficinets\ of\ Q_i$ in the objective function
$Z_1 y_k = coefficient\ of\ t_k in\ the\ objecive\ function\ Z_3$
Q1 = quantity of broilers' feed
Q2= quantity of growers' feed
Q3 = quantity of layers' feed
Q4 = quantity of cattle feed
Q5 = quantity of pigs' feed
Q6 = quantity of Rabbits' feed
q1 = quantity of Maize
q2 = quantity of Soya bean
q3 = quantity of wheat bran
q4 = quantity of Bone meal
q5 = quantity of Limestone
q6 = quantity of Premix
q7 = quantity of salt
q8 = quantity of Lysine
q9 = quantity of methionine
q10 = quantity of PKC
q11 = quantity of GNC
q12 = quantity of toxin binder
q13 = quantity of rice bran

t1 = replenishment time for maize
t2 = replenishment time for soy bean
t3 = replenishment time for wheat bran
t4 = replenishment time for bone meal
t5 = replenishment time for limestone
t6 = replenishment time for premix
t7 = replenishment time for salt
t8 = replenishment time for lysine
t9 = replenishment time for methionine
t10 = replenishment time for PKC
t11 = replenishment time for GNC
t12= replenishment time for toxin binder
t13 = replenishment time for rice bran
V= milling charge per unit
Sp = fixed selling price per unit
v= number of suppliers
Prf =price by supplier f
D1= first value of product demand
D2= second value of product demand

₦1= 0.0027855 US Dollars

2.4 Model Development

The variables of the model are the quantities of the materials (q) needed for production, the quantities of the products (Q) available and the replenishment time for the materials (t).

$variables = [Q_1 \ldots Q_i], [q_1 \ldots q_k]$ and [$t_1 \ldots t_k$]

The objective functions of the model are as follow:

1. Maximize total profit on all products

Max $Z_1 = P_1Q_1 + P_2Q_2 + \cdots + P_nQ_n$ 2.1

2. Minimize quantity of idle materials which implies minimizing the total replenishment time for materials

Min $Z_2 = u_1t_1 + u_2t_2 + \cdots + u_mt_m$ 2.2

3. Minimize the total cost of materials

Min $Z_3 = c_1q_1 + c_2q_2 + \cdots + c_mq_m$ 2.3

The constraints of the model are as follow

1. Lead time available for each product

$t_1, t_2, t_3 \ldots . t_n \leq T$ 2.4

2. Liquid capital available

$c_1q_1 + c_2q_2 + c_3q_3 + \cdots . + c_mq_m \leq L$ 2.5

3. Demand for each products and materials

$q_k \leq d_k$ 2.6

$Q_i \leq D_i$ 2.7

4. Material balance equation for each product

$Q_1q_{11} + Q_2q_{12} + \cdots + Q_iq_{1i} = q_1$

$Q_1q_{21} + Q_2q_{22} + \cdots + Q_iq_{2i} = q_2$

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$Q_nq_{mn} + Q_nq_{mn} + \cdots + Q_nq_{mn} = q_m$ 2.8

$\forall\ k = 1,2,3 \ldots m \ and \ i = 1,2\ 3, \ldots n$

5. Non- negativity constraint

$q_1, q_2, q_3 \ldots . q_m \geq 0$ 2.9

$Q_1, Q, Q_3 \ldots . Q_n \geq 0$ 2.10

$t_1, t_2, t_3 \ldots . t_m \geq 0$ 2.11

2.5. Problem solving technique

The adopted technique (linear combination of objectives) twas adopted. The technique entailed weight assignment to different objectives and bringing of conflicting objectives to same dimensions. To achieve this, the objectives were first brought to the same objective function goal, that is, minimize or maximize. The minimization problem was changed to a maximization objective function by multiplying by -1.

Each of the objective function, equations 2.1, 2.2 and 2.3 became equations 2.12, 2.13 and 2.14 respectively

Max $Z_1 = P_1Q_1 + P_2Q_2 + \cdots + P_nQ_n$ 2.12

Max $Z_2 = -1(u_1t_1 + u_2t_2 + \cdots + u_mt_m)$ 2.13

Max $-Z_3 = -1(c_1q_1 + c_2q_2 + \cdots + c_mq_m)$ 2.14

Units of each of the objective functions were also considered. Equations 2.12 and 2.14 are in $₦Kg$ while equation 2.13 is in kg. To achieve sameness in unit, equation 2.13 is multiplied by the cost which resulted to equation 2.15

Max $Z_2 = -1(c_1u_1t_1 + c_2u_2t_2 + \cdots + c_mu_mt_m)$ 2.15

The aggregate objective function therefore is

Max $Z_T = \left[\frac{w_1}{\sqrt{\sum_{i=1}^{n} v_i^2}}\right] Z_1 - \left[\frac{w_2}{\sqrt{\sum_{k=1}^{m} b_k^2}}\right] Z_2 - \left[\frac{w_3}{\sqrt{\sum_{i=1}^{m} y_k^2}}\right] Z_3$ 2.16

Where $w_1 + w_2 + w_3 = 1$ 2.17a

All weights ($w_1, w_2 and\ w_3$) were assigned values as follows (based on their assumed degree of importance)

$w_1 = 0.4$ 2.17b

$w_2 = 0.3$ 2.17c

$w_3 = 0.3$ 2.17d

w_1 was given the highest weight because it is believed that as much as possible, the firm would attach more importance to making profit no matter what the situation at hand is. However, the other two objective functions (minimize the replenishment time and cost of materials) were given the same degree of importance as appropriate.

Therefore, from equations 2.17b, 2.17c and 2.17d, equation 2.18 was derived

$$\text{Max} \quad Z_T = Z_T = \left[\frac{0.4}{\sqrt{\sum_{i=1}^{n} v_i^2}}\right] Z_1 - \left[\frac{0.3}{\sqrt{\sum_{k=1}^{m} b_k^2}}\right] Z_2 - \left[\frac{0.3}{\sqrt{\sum_{i=1}^{m} y_k^2}}\right] Z_3$$

2.18

2.6 Problem Solution

Lingo 14.0 programme and Tora 1.0 were used to solve the developed model. The model was programmed on both software using their individual commands and the solutions were derived, compared and discussed.

2.7 Procedure for Supplier Selection

The supplier selection procedure was in two stages.

For the first stage, the supplier with the lowest price was selected from the values obtained for the materials from the model since the amount available can be used to purchase these materials.

For the second stage, for the remaining quantities which cannot be purchased by the limited capital available, the unit price by the suppliers and the duration of payment term were used to determine which of the suppliers should be patronised to meet up with the maximum demand.

Weights were assigned to the two decision criteria (that is, the unit price and the duration allowed for payment). The weight for the payment term (w_{PT}) was given the highest weight because it was considered to be of higher importance since the problem at hand indicates that there is no sufficient cash available. The weight for the total price (w_{TP}) was lower because the prices are fixed and cannot be easily changed. Based on these reasons, a ratio of 6: 4 was used for w_{PT} and w_{TP} respectively.

$w_{PT} = 0.6$ 2.19a

$w_{TP} = 0.4$ 2.19b

Such that $w_{PT} + w_{TP} = 1$ 2.19c

Values for each of the suppliers of these two criteria were obtained and scored.

For the Payment Term (PT), the scores were given based on the advantage the payment term can serve the firm. The payment term with the highest advantage to the firm is one with a high credit limit while the payment term with the lowest advantage is one that requires payment before delivery. The payment term that requires payment on delivery is of no advantage to the firm and the payment term that requires payment after delivery is relatively better than the former.

Hence, equations 2.20a- 2.20d are the scores obtainable for each of the payment terms.

If $PT = credit\ limit\ , score = 3$ 2.20a

If $PT = \ after\ delivery\ , score = 2$ 2.20b

If $PT = on\ delivery, score = 0$ 2.20c

If $PT = before\ delivery, score = -1$ 2.20d

For the total price (TP),$\max(TP) = \max score$ 2.21

The weight and score were then multiplied and the results were ranked. The best rank is the best supplier to be patronized.

$SV = w_{TP}TP \times w_{PT}PT$ 2.22

$\max(SV) = best\ supplier$ 2.23

To allow for flexibility and effective suppliers selection, this procedure was done for each of the materials for corresponding suppliers.

2.8 Model assumptions

1. All products (feeds) are produced every week according to the weekly demand.
2. Profit calculated was based on only the cost prices of the products relative to their selling prices. Other associated costs were not considered since they are constant for all the product types.
3. There is no production to stock.
4. Goods are purchased on a weekly basis and it was assumed that the maximum amount of weekly demand is produced. Therefore, no inventory of raw materials.
5. There is a minimum cash deposit that can be remitted to the accounting department.

3. RESULTS AND DISCUSSION

3.1 Data Collection

On collecting data from the feed mill section of a teaching and research farm in Ibadan and analysing them appropriately, results obtained from the interviews, observations made, as well as past data are as reflected in the bill of materials, list of products, quantity ratio of materials, product demand, material usage rate, procurement process, list of suppliers, payment terms and conditions, delivery terms and conditions, material costs, liquid capital available, profit margin on products and available lead time shown in Tables 1-10

TABLE 1
CLASSIFIED BILL OF MATERIALS FOR PRODUCTION

S/N	Name of materials	
	Macro Ingredients	Micro Ingredients
1	Limestone	-
2	Rice Bran	-
3	Maize	-
4	Groundnut Cake (GNC)	-
5	Palm kernel Cake (PKC)	-
6	Soya bean	-
7	Wheat bran	-
8	-	Toxin binder
9	-	Premix
10	-	Methionine
11	-	Salt
12	-	Lysine
13	-	Bone meal

Table 1 is a list of all raw materials used for production. A total of 13 materials are listed in no definite order. Some materials are needed in large quantities and these are called the macro ingredients while others like Methionine, toxin binder, lysine, salts are not needed in large quantity are referred to as micro ingredients as shown on the table.

TABLE 2
LIST OF PRODUCTS

S/N	Names of products
1	Broiler feed
2	Grower feed
3	Layers feed
4	Cattle feed
5	Pig feed
6	Rabbit feed

Table 2 consists of the different products produced by the firm. A total of 6 products are produced and they are all feed products for different livestock's consumption. These feed types are produced normally from the materials already mentioned in Table 1, although in varying ratios.

Table 3 illustrates the quantity of each material that makes up each of the six products. The quantities of raw materials presented in the table are per one thousand kilogrammes (1 tonne) of feed. This table formed the result for the material balance constraint in the model formulated. The quantities are in kilogramme.

TABLE 3
QUANTITY OF MATERIALS REQUIRED FOR EACH PRODUCT

S/N		MATERIAL RATIO PER THOUSAND KG OF FEED (kg)												
	NAME OF PRODUCT	MAIZE	SOYA BEAN	WHEAT BRAN	RICE BRAN	BONE MEAL	LIMESTONE	PREMIX	SALT	LYCINE	METHIONINE	PALM KERNEL CAKE	GROUNDNUT CAKE	TOXIN BINDER
1	Broiler feed	600	300	50	0	25	25	5	3	1	2	0	0	0
2	Grower feed	500	150	200	0	30	30	3	3	1	1	100	0	0.5
3	Layers feed	470	180	200	0	30	86	3	3	0	2.5	26	0	0.5
4	cattle feed	500	200	200	0	30	20	3	3	0	0	50	0	0
5	pig feed	150	0	0	20	30	30	3	8	0.5	0	600	150	0
6	Rabbit feed	200	100	300	140	30	20	2.5	3	0	0	200	0	0

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TABLE 4
WEEKLY PRODUCT DEMAND

S/N	Name of product	D_1 (kg)	D_2(kg)	D (kg)
1	Broiler feed	6000	7000	7000
2	Grower feed	6000	7000	7000
3	Layers feed	6000	7000	7000
4	Cattle feed	1000	1000	1000
5	Rabbit feed	100	100	100
6	Pig feed	500	500	500

Table 4 shows the various weekly demands for the feeds produced by the firm. The broiler, grower and layers feeds were noticed to have high demands while pig and rabbit feeds have low demands.

TABLE 5
MATERIAL USAGE RATE

S/N	MATERIAL USAGE RATE (kg/ week)														
	NAMES OF PRODUCT	WEEKLY DEMAND (in thousand Kg)	MAIZE	WHEAT BRAN	PALM KERNEL CAKE	GROUNDNUT CAKE	SOYA BEAN	LIMESTONE	RICE BRAN	BONE MEAL	PREMIX	SALT	LYCINE	METHIONINE	TOXIN BINDER
1	Broiler feed	7	4200	350	0	0	2100	175	0	175	35	21	7	14	0
2	Grower feed	7	3500	1400	700	0	1050	210	0	210	21	21	7	7	3.5
3	Layers feed	7	3290	1400	182	0	1260	602	0	210	21	21	0	17.5	3.5
4	Cattle feed	1	500	200	50	0	200	20	0	30	3	3	0	0	0
5	Pig feed	0	15	0	60	15	0	3	2	3	0.3	0.8	0.05	0	0
6	Rabbit feed	1	100	150	100	0	50	10	70	15	1.25	1.5	0	0	0
	Sum of materials required per week (kg)		1160 5	3500	1092	15	4660	1020	72	643	81.6	68	14.1	38.5	7

Table 5 shows the quantity of materials used per week, as well as the total sum of each material required for a week's production. The material with the highest requirement rate is maize while toxin binder has the lowest requirement.

TABLE 6
LIST OF SUPPLIERS

S/N	LIST OF SUPPLIERS	NAMES OF MATERIALS												
		Maize	Soybean	Wheat bran	Bone Meal	Limestone	Premix	Salt	Lycine	Methioni	PKC	GNC	Toxin	Rice Bran
1	Supplier ANC	O	O	O	O	O	X	O	X	X	O	O	O	O
2	Supplier IBR	X	X	X	X	X	X	X	X	X	X	X	X	X
3	Supplier FMS	O	O	O	O	O	X	O	X	X	O	O	O	O
4	Supplier OGL	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Supplier MPS	O	O	O	O	O	X	O	X	X	O	O	O	O
6	Supplier ADM	X	X	X	X	X	X	X	X	X	X	X	X	O
7	Supplier ATF	X	X	X	X	X	X	X	X	X	X	X	X	O

Key:
X- Material is available
O- Material is not available

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Table 6 shows the different suppliers available to the firm for the supply of materials. Seven suppliers were recorded and each of the materials can be purchased from at least one of the suppliers. It also shows a checklist of the materials each of these suppliers can supply.

TABLE 7
PAYMENT TERMS OF SUPPLIERS

S/N	NAME OF SUPPLIER	PAYMENT TERM
1	Supplier ANC	2weeks after delivery
2	Supplier IBR	₦3 million credit limit
3	Supplier FMS	100% payment on delivery
4	Supplier OGL	100% payment on delivery
5	Supplier MPS	2 weeks after delivery
6	Supplier ADM	100% payment before delivery
7	Supplier ATF	100% payment on delivery

Table 7 shows the payment terms required by the suppliers for the supply of materials. 2 weeks after delivery implies that the payment is expected latest two weeks after the materials have been delivered while 100% down payment implies that a full price of the supply must have been paid before the materials can be delivered. All payments have to be made as soon as the materials are delivered by the suppliers for the 100% payment on delivery payment term. The ₦3 million credit limit as expected by supplier IBR means that once the credit amount of ₦3 million is reached, no materials can be supplied until the bill is paid.

TABLE 8
COST OF MATERIALS

S/N	NAME OF MATERIALS	COST OF MATERIALS PER Kg (₦)								
		Supplier ANC	Supplier IBR	Supplier FMS	Supplier OGL	Supplier MPS	Supplier ADM	Supplier AT F	AVERAGE PRICE (₦)	APPROXIMATE AVERAGE PRICE (₦)
1	Maize		128		130		129	130	129.25	129
2	Soybean		138		140		139	140	139.25	139
3	Wheat bran		64		66		65	66	65.25	65
4	Bone meal		52		55		53	55	53.75	54
5	Limestone		15		17		16	17	16.25	16
6	Premix	1100	1200	1100	1300	1100	1250	1300	1192.857	1195
7	Salt		40		42		41	42	41.25	41
8	Lycine	920	1000	920	1005	920	960	1005	961.4286	961
9	Methionine	2120	2200	2120	2205	2120	2160	2205	2161.429	2161
10	PKC		50		52		49	52	50.75	51
11	GNC		110		113		115	113	112.75	113
12	Toxin binder		1200		1300		1250	1300	1262.5	1263
13	Rice bran		15		17				16	16

Table 8 shows the cost presented by the different suppliers for each of the materials available in ₦ per kg of material. There is a slight variation in the prices of the materials as shown in the table. The supplier, IBR, has the lowest price while OGL has the highest price.

Also, the average prices were computed to select a representative for the different prices presented by the suppliers and an approximate (rounded up or off) value was also given for each of the raw materials.

TABLE 9
FINANCIAL RECORD FROM APRIL 3 TO MAY 19, 2017

S/N	DATE	INCOME (₦)	CUMULATIVE AMOUNT (₦)	REMARK
1	April 3 – April 7, 2017	23,213	23,213	₦ 23,213 available, it was not remitted.
2	April 10 – April 14, 2017	17,261	40,474	₦ 40,474 available, it was not remitted.
3	April 17- April21, 2017	455,295	495,769	₦495,769 available, thus remitted to Bursary.
4	April 24 – April 28, 2017	10,585	506,354	₦ 10,585 available. It was not remitted.
5	May 1-May5, 2017	10,119	516,473	₦ 20,704 available. It was not remitted.
6	May 8 – May 12, 2017	66,102	582,575	₦ 86,806 available. It was not remitted.
7	May 15 May 19, 2017	52,050	634,625	₦ 138,856 available. It was not remitted. This is the available liquid capital for the next week.

As shown in Table 9, the amount of liquid capital available is dependent on how much (on hand or at bank) has been received (income) by the firm at any given period of time. Usually, a cumulative amount of N200, 000 is remitted to the University bursary department but is sometimes held on to if need be. The cumulative amount, when available below N200, 000 would be regarded as the available liquid capital.

Table 9 shows the financial record of the firm for 7 weeks. The week date shown is from April 3, 2017 to May 19, 2017. The income is the residual amount available for the firms' use (that is, after all expenses for each week has been deducted), while the cumulative amount is the amount of income calculated in lump sum over the seven weeks.

The remarks explain the state of the cumulative amount and how much can be referred to as liquid capital available after every week. The last week (May 15-May 19, 2017), as shown in the table reveals that a sum of ₦138,856was available as liquid capital as at May 19, 2017 which is the period selected for the study (since this was not up ₦200,000).

TABLE 10
PROFIT ON PRODUCTS

S/N	PRODUCT NAME	COST PRICE/ KG (₦)	MILLING CHARGE/ KG (₦)	SELLING PRICE/ KG (₦)	PROFIT /KG (₦)
1	Broiler feed	135.481	2	142.700	9.219
2	Growers feed	113.012	2	119.54	8.529
3	Layers feed	112.714	2	119.778	9.064
4	cattle feed	113.498	2	119.06	7.562
5	Pig feed	73.7135	2	79.190	7.477
6	Rabbit feed	76.6905	2	82.360	7.670

Table 10 shows the profit on each of the products produced as computed by equation 3.5. For instance, for the every kg of cattle feed produced, a profit of ₦ 7.56 is made. Pig feed has the highest profit margin while Broiler feed has the lowest profit margin.

For the available lead time, the study considered two days to be the lead time available.

3.3 Model development

On developing the model, three categories of variables, with thirty two variables all together were obtained, so that the problem $variables = [Q_1 \dots Q_6], [q_1 \dots q_{13}]$ and $[t_1 \dots t_{13}]$
The resulting model is as follows

1. Max $Z_1 = 9.219Q_1 + 8.5285Q_2 + 9.064\ Q_3 + 7.562Q_4 + 7.4765Q_5 + 7.6695Q6$ (Maximize weekly profit on all products) 3.1
2. Min $Z_2 = 11605t_1 + 3500t_2 + 1092t_3 + 15t_4 + 4660t_5 + 1020t_6 + 72t_7 + 643t_8 + 81.6t_9 + 68t_{10} + 14.1t_{11} + 388.5t_{12} + 7t_{13}$ (Minimize quantity of idle materials which also implies minimizing the replenishment time of materials) 3.2
3. Min $Z_3 = 129q_1 + 139q_2 + 65q_3 + 54q_4 + 16q_5 + 1195q_6 + 41q_7 + 961_8 + 2161q_9 + 51q_{10} + 113q_{11} + 1263q_{12} + 16q_{13}$ (Minimize the cost of materials) 3.3

Subject to

$t_1, t_2, t_3 \dots . t_{13} \leq 0.28\, week(2days)$ (Lead time available for each material) 3.4

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$129q_1 + 65q_2 + 51q_3 + 113q_4 + 139q_5 + 165q_6 + 16q_7 + 54q_8 + 1195q_9 + 41q_{10} + 961q_{11} + 2161q_{12} + 1263q_{13} \leq$ ₦138856 (Liquid capital available) 3.5

$q_1 \leq 11605kg$ 3.6
$q_2 \leq 3500kg$ 3.7
$q_3 \leq 1092kg$ 3.8
$q_4 \leq 15kg$ 3.9
$q_5 \leq 46660kg$ 3.10
$q_6 \leq 1020kg$ 3.11
$q_7 \leq 72kg$ 3.12
$q_8 \leq 643kg$ 3.13
$q_9 \leq 81.6kg$ 3.14
$q_{10} \leq 68$kg 3.15
$q_{11} \leq 14.1kg$ 3.16
$q_{12} \leq 38.5kg$ 3.17
$q_{13} \leq 7kg$ 3.18
$Q_1 \leq 7000kg$ 3.19
$Q_2 \leq 7000kg$ 3.20
$Q_3 \leq 7000kg$ 3.21
$Q_4 \leq 1000kg$ 3.22
$Q_5 \leq 500kg$ 3.23
$Q_6 \leq 100kg$ (Demand for each of the product and materials) 3.24
$0.6Q_1 + 0.5Q_2 + 0.47Q_3 + 0.5Q_4 + 0.15Q_5 + 0.2Q_6 = q_1$ 3.25
$0.05Q_1 + 0.2Q_2 + 0.2Q_3 + 0.2Q_4 + 0.3Q_6 = q_2$ 3.26
$0.1Q2 + 0.026Q3 + 0.05Q4 + 0.6Q5 + 0.2Q6 = q3$ 3.27
$0.15Q5 = q4$ 3.28
$0.3Q1 + 0.15Q2 + 0.180Q3 + 0.2Q4 + 0.1Q6 = q5$ 3.29
$0.025Q1 + 0.03Q2 + 0.086Q3 + 0.02Q4 + 0.03Q5 + 0.02Q6 = q6$ 3.30
$0.02Q5 + 0.14Q6 = q7$ 3.31
$0.025Q1 + 0.03Q2 + 0.03Q3 + 0.03Q4 + 0.03Q5 + 0.03Q6 = q8$ 3.32
$0.005Q1 + 0.003Q2 + 0.003Q3 + 0.003Q4 + 0.003Q5 + 0.0025Q6 = q9$ 3.33
$0.003Q1 + 0.003Q2 + 0.003Q3 + 0.003Q4 + 0.008Q5 + 0.003Q6 = q10$ 3.34
$0.001Q1 + 0.001Q2 + 0.0005Q5 = q11$ 3.35
$0.002Q1 + 0.001Q2 + 0.0025Q3 = q12$ 3.36
$0.0005Q2 + 0.0005Q3 = q13$ (Material balance equation for each product) 3.37
$q_1, q_2, q_3 \dots q_{13} \geq 0$ 3.38
$Q_1, Q, Q_3 \dots Q6 \geq 0$ 3.39
$t_1, t_2, t_3 \dots t_{13} \geq 0$ (Non- negativity constraint) 3.40

There are three objective functions which are represented by equation 3.2- equation 3.4. The first objective function (Z_1) is to maximise the profit on all products. The objective function Z_2 minimises the replenishment time of materials while the last objective function Z_3 minimises the cost of materials.

There are four categories of constraints which altogether numbered up to thirty seven (non-negativity constraints were grouped together) identified as (equation 3.4 – equation 3.40). The first category is the lead time constraint for materials. This explains that the lead times should be less than or equal to the lead time expected for product delivery which is 2 days (0.28 weeks). The second category is for the liquid capital available which constrains the value for the quantity of raw materials multiplied by the cost to be exactly equal to the amount of liquid capital available. The third category is the demand constraint on each of the materials and products. Thereafter, a materials balance equation for each of the material for each product. This constraint ensures that the ratio of materials needed to produce a feed is kept. The last category is the non-negativity constraints which constrains all values to be greater or equal to zero (that is, non-negative value is obtainable)

3.4 Problem solving technique

The results of the linear aggregation method are given in equation 3.41.

The aggregate objective function is given as

Max Z_T= 0.019711742[9.219q1 + 8.5285q2 + 9.064q3 + 7.562q4 + 7.4765q5 + 7.6695q6]-0.000000181444[1497045t1+227500t2+55692t3+1695t4+647740t5 +16320t6+1152t7+34722t8+97512t9 +2788t10+13550.1t11+83198.5t12+8841t13]-0.000101842[129s1+65s2 +51s3 +113s4 +139s5 +16s6 +16s7 +54s8 +1195s9 +41s10 +961s11+2161s12 +1263s13] 3.41

3.5 Problem solution

The results of the problem are as given in Table 11

TABLE 11
SOLUTIONS TO VARIABLES BY LINGO 14.0 AND TORA 1.0

S/N	Variables	Values from LINGO 14.0	Values from Tora 1.0	Remark
1	Q_1	0	0	Same value was obtained
2	Q_2	0	0	Same value was obtained
3	Q_3	1098.49	1098.49	Same value was obtained
4	Q_4	0	0	Same value was obtained
5	Q_5	100	100	Same value was obtained
6	Q_6	100	100	Same value was obtained
7	t_1	0	0	Same value was obtained
8	t_2	0	0	Same value was obtained
9	t_3	0	0	Same value was obtained
10	t_4	0	0	Same value was obtained
11	t_5	0	0	Same value was obtained
12	t_6	0	0	Same value was obtained
13	t_7	0	0	Same value was obtained
14	t_8	0	0	Same value was obtained
15	t_9	0	0	Same value was obtained
16	t_{10}	0	0	Same value was obtained
17	t_{11}	0	0	Same value was obtained
18	t_{12}	0	0	Same value was obtained
19	t_{13}	0	0	Same value was obtained
20	q_1	551.29	551.29	Same value was obtained
21	q_2	249.69	249.69	Same value was obtained
22	q_3	108.56	108.56	Same value was obtained
23	q_4	15	15	Same value was obtained
24	q_5	207.73	207.73	Same value was obtained
25	q_6	99.47	99.47	Same value was obtained
26	q_7	16	16	Same value was obtained
27	q_8	38.95	38.95	Same value was obtained
28	q_9	3.85	3.85	Same value was obtained
29	q_{10}	4.40	4.40	Same value was obtained
30	q_{11}	0.05	0.05	Same value was obtained
31	q_{12}	2.75	2.75	Same value was obtained
32	q_{13}	0.55	0.55	Same value was obtained

Table 11 shows the solutions to the problem as complied by Lingo 14.0 and Tora 1.0. The values obtained by both compilers were all the same and there are no variations. The values of the variables (quantity of product, quantity of materials and lead time for materials) were obtained considering the liquid capital available.

The Lingo 14.0 and Tora 1.0 programmes both gave feasible solution for this model. This implies that the model is practicable and all the constraints could be met. Even though the liquid capital is not enough to produce for the weekly demand required, the optimal values obtainable based on this liquid capital available have been obtained.

However, the overall decision of what quantity, and when to place an order for material purchase is still dependent on the payment terms given by the suppliers even though the model as given a recommendation for these values. Table 7 provided information about the suppliers and their payment terms. The delivery terms of the suppliers are the same. The payment terms are compared and the Table 12 shows a comparison for these suppliers, considering the results obtained in Table 11. Decision with respect to supplier was made based on the payment term of the individual suppliers.

3.6 Procedure for supplier selection

From Tables 6, 7 and 9 which respectively show the list of suppliers, their payment terms and the cost of materials according to the different suppliers, and following the procedure described under section , obtained results are as shown in Table 12.

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TABLE 12
SUPPLIER SELECTION

S/N	Suppliers' cost (₦)										
	NAME OF MATERIALS	Quantity required (kg)	Supplier ANC	Supplier IBR	Supplier FMS	Suppler OGL	Supplier MPS	Supplier ADM	Supplier ATF	Minimum value of cost	Supplier selected
1	Maize	551.29	-	70565.12	-	71667.7	-	71116.41	71667.7	70565.12	IBR
2	Wheat bran	249.69	-	15980.16	-	16479.54	-	16229.85	16479.54	15980.16	IBR
3	PKC	108.56	-	5428	-	5645.12	-	5319.44	5645.12	5319.44	ADM
4	GNC	15	-	1650	-	1695	-	1725	1695	1650	IBR
5	Soybean	207.73	-	28666.74	-	29082.2	-	28874.47	29082.2	28666.74	IBR
6	Limestone	99.47	-	1492.05	-	1690.99	-	1591.52	1690.99	1492.05	IBR
7	Rice bran	16	-	240	-	272	-	-	-	240	IBR
8	Bone meal	38.95	-	2025.4	-	2142.25	-	2064.35	2142.25	2025.4	IBR
9	Premix	3.85	4235	4620	4235	5005	4235	4812.5	5005	4235	ANC, MPS, FMS
10	Salt	4.4	-	176	-	184.8	-	180.4	184.8	176	IBR
11	Lycine	0.05	46	50	46	50.25	46	48	50.25	46	ANC, MPS, FMS
12	Methionine	2.75	5830	6050	5830	6063.75	5830	5940	6063.75	5830	ANC, MPS, FMS
13	Toxin binder	0.55	-	660	-	715	-	687.5	715	660	IBR

As described in section 2.4.3, for the first stage of supplier selection, the values of the total cost obtained from the values in Table 8 and the selected suppliers were represented in Table 12. IBM has the highest number of low cost materials. Some of the materials (Lycine, methionine and premix) could be purchased from more than one supplier.

For the second stage of supplier selection, the obtained results are as shown in Table 13.

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TABLE 13
TOTAL PRICE SCORE FOR SUPPLIERS

S/N	Total Price (TP) Score for Suppliers							
	NAME OF MATERIALS	Supplier ANC	Supplier IBR	Supplier FMS	Supplier OGL	Supplier MPS	Supplier ADM	Supplier ATF
1	Maize	-	4	-	1	-	3	2
2	Wheat bran	-	4	-	2	-	3	2
3	PKC	-	3	-	2	-	4	2
4	GNC	-	-	-	-	-	-	-
5	Soybean	-	4	-	2	-	3	2
6	Limestone	-	4	-	2	-	3	2
7	Rice bran	-	2	-	1	-	-	-
8	Bone meal	-	4	-	2	-	3	2
9	Premix	6	3	6	1	6	2	1
10	Salt	-	4	-	2	-	3	2
11	Lycine	6	2	6	1	6	3	1
12	Methionine	6	2	6	1	6	3	1
13	Toxin binder	-	4	-	2	-	3	2

According to the procedure described in section 2.4.3 about scoring suppliers based on their total price for materials, Table 13 shows the scores obtained by this procedure. The column and rows without values indicate that the supplier cannot supply the corresponding materials. Some suppliers have the same values, hence, sameness in the scores obtained.

TABLE 14
PAYMENT TERM SCORE FOR SUPPLIERS

S/N	Payment term (PT) Score for suppliers							
	NAME OF MATERIALS	Supplier ANC	Supplier IBR	Supplier FMS	Supplier OGL	Supplier MPS	Supplier ADM	Supplier ATF
1	Maize	-	3	-	0	-	-1	0
2	Wheat bran	-	3	-	0	-	-1	0
3	PKC	-	3	-	0	-	-1	0
4	GNC	-	-	-	-	-	-	-
5	Soybean	-	3	-	0	-	-1	0
6	Limestone	-	3	-	0	-	-1	0
7	Rice bran	-	3	-	0	-	-	-
8	Bone meal	-	3	-	0	-	-1	0
9	Premix	2	3	0	0	2	-1	0
10	Salt	-	3	-	0	-	-1	0
11	Lycine	2	3	0	0	2	-1	0
12	Methionine	2	3	0	0	2	-1	0
13	Toxin binder	-	3	-	0	-	-1	0

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Table 14 shows the score given to the suppliers based on their payment term as described in section 2.4.3. The supplier with the highest score is IBR. The supplier offers a three million naira credit limit as the payment term. The supplier with the negative score (-1) is ADM, because full payment for all materials ordered for must be made prior to their supply. Due to the liquid capital constraint (inadequacy) being faced by the manufacturing firm, this is not advantageous to the feed firm in any way, considering the liquid capital constraint.

TABLE 15
SUM VALUE FOR SUPPLIERS

S/N	Sum Value (SV) for the suppliers									
	NAME OF MATERIALS	Supplier ANC	Supplier IBR	Supplier FMS	Supplier OGL	Supplier MPS	Supplier ADM	Supplier ATF	Max value	Selected supplier
1	Maize	-	3.4	-	0.4	-	0.6	0.8	3.4	IBR
2	Wheat bran	-	3.4	-	0.8	-	0.6	0.8	3.4	IBR
3	PKC	-	3	-	0.8	-	1	0.8	3	IBR
4	GNC	-	-	-	-	-	-	-	-	-
5	Soybean	-	3.4	-	0.8	-	0.6	0.8	3.4	IBR
6	Limestone	-	3.4	-	0.8	-	0.6	0.8	3.4	IBR
7	Rice bran	-	2.6	-	0.4	-	-	-	2.6	IBR
8	Bone meal	-	3.4	-	0.8	-	0.6	0.8	3.4	IBR
9	Premix	3.6	3	2.4	0.4	3.6	0.2	0.4	3.6	ANC, MPS
10	Salt	-	3.4	-	0.8	-	0.6	0.8	3.4	ANC
11	Lycine	3.6	2.6	2.4	0.4	3.6	0.6	0.4	3.6	ANC, MPS
12	Methionine	3.6	2.6	2.4	0.4	3.6	0.6	0.4	3.6	ANC, MPS
13	Toxin binder	-	3.4	-	0.8	-	0.6	0.8	3.4	IBR

Table 15 shows the values for the sum value (SV) for each of the suppliers from equation 2.29.The values obtained were an aggregate sum of the scores from the total price offered by the supplier and the payment term. The recommended suppliers based on these two criteria were also given in the table.

Most of the materials (about 61.54%) were recommended to be ordered from IBR. This is because the supplier offers both relatively low price and a payment term that can be used to the firm's advantage, especially when the liquid capital available is not sufficient.

TABLE 16

SUMMARY OF RESULTS FOR SELECTED SUPPLIERS, CORRESPONDING QUANTITY OF MATERIAL TO BE ORDERED, TIME TO MAKE PAYMENTS AND AVAILABLE TIME BEFORE PLACING ORDERS

S/N	Name of material	Quantity of material (kg)	Recommended supplier	Time to make payments	Time available before ordering (days)
1	Maize	551.29	IBR	Immediate payment	0
2	Wheat bran	249.69	IBR	Immediate payment	0
3	PKC	108.56	ADM	Immediate payment	0
4	GNC	15	IBR	Immediate payment	0
5	Soybean	207.73	IBR	Immediate payment	0
6	Limestone	99.47	IBR	Immediate payment	0
7	Rice bran	16	IBR	Immediate payment	0
8	Bone meal	38.95	IBR	Immediate payment	0
9	Premix	3.85	ANC, MPS, FMS	Immediate payment	0
10	Salt	4.4	IBR	Immediate payment	0
11	Lycine	0.05	ANC, MPS, FMS	Immediate payment	0
12	Methionine	2.75	ANC, MPS, FMS	Immediate payment	0
13	Toxin binder	0.55	IBR	Immediate payment	0
14	Maize	11053.71	IBR	Before ₦3 million credit limit is exceeded	0
15	Wheat bran	3250.31	IBR	Before ₦3 million credit limit is exceeded	0
16	PKC	983.44	IBR	Before ₦3 million credit limit is exceeded	0
17	GNC	0	-		0
19	Soybean	4452.27	IBR	Before ₦3 million credit limit is exceeded	0
20	Limestone	920.53	IBR	Before ₦3 million credit limit is exceeded	0
21	Rice bran	56	IBR	Before ₦3 million credit limit is exceeded	0
22	Bone meal	604.05	IBR	Before ₦3 million credit limit is exceeded	0
23	Premix	77.75	ANC, MPS	2 weeks after delivery	0
24	Salt	63.6	ANC	2 weeks after delivery	0
25	Lycine	14.05	ANC, MPS	2 weeks after delivery	0
26	Methionine	35.75	ANC, MPS	2 weeks after delivery	0
27	Toxin binder	6.45	IBR	Before ₦3 million credit limit is exceeded	0

Table 16 shows a summary of the recommended suppliers and the recommended quantity of materials to be ordered as well as when to place the order and when to make payments for the materials.

The total quantity of materials is the required amount to meet up with the firm's weekly demand. Therefore, even though the liquid capital available is not enough to purchase the raw materials needed to meet up with demand, the payment terms by suppliers have been used to manage this problem. All materials will be purchased; some will be paid for immediately while others will be paid for later in accordance to the terms given by the suppliers.

All materials, except the groundnut cake will not be paid for immediately as only a particular quantity can be paid for as shown in the table. Immediate payment means that the quantity of material can be paid for as soon as it is ordered for while some others can be paid for later without faulting the payment agreement by the suppliers.

The available time to place the order for all the material is zero because it is always preferable to have all materials ready for production to eliminate waiting time for materials.

4. CONCLUSIONS

A manufacturing firm has been studied and a multi-objective model has been developed and solved using Lingo 14.0 and Tora 1.0 Optimization software for computation. Necessary data and information about a typical manufacturing firm were obtained from the manufacturing firm that was studied and, using linear programming, these were used to develop and solve a model that addresses the problem of non-availability of materials due to limited available liquid capital to purchase materials.

The following conclusions were drawn:

1. Activities of a typical manufacturing firm were investigated and necessary data from the firm were collected.
2. Operations research method was used as a tool to develop a model for the procurement order problem.
3. The model was solved using two optimization soft wares (Lingo 14.0 and Tora 1.0)

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