Improving the productivity of small and medium scale industries using linear programming model

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ABSTRACT: Productivity improvement in small and medium scale enterprise will develop both the economic condition and the industry on its side. During these research operation research techniques where employed to Golden plastic industry limited (GPIL) and a linear programming technique was used in maximizing profit. Productivity therefore improve by applying the linear programming instead of the normal trial and error been employed by the managers of the industry.

Key words: Optimization, Linear Programming, Plastic, Productivity, Quantity and Decision Variables

Introduction

Golden Plastic Industry Limited, Emene produces eight different products. It has the necessary physical facilities to apply linear programming techniques in determining the quantity combination of the different types of products that maximize profit (optimal product mix). Computer facilities are adequate, yet the firm uses the trial-and-error method in determining its product mix.

Golden Plastic Industry Limited is chosen for this study for two main reasons. First, it uses the trial-and-error method in arriving at major management decisions even when the researchers feels that a linear programming approach would have given a better result and improve the productivity of the industry. Secondly, Golden Plastic Industry Limited produces eight different products which makes the determination of the quantity combinations of the products produced (product mix) an important and major management decision.

Researchers then applied linear programming to determine a new quantity combination. The total contribution to profit of each of the products for the month using the new quantity will now be compared with the total profit contribution made by the former product mix determined by the trial-and-error method. The problems encountered in the process will be noted and from personal interviews and relevant records, other peculiarities shall be established.

Objectives of Study: The objective of this study is to apply productivity improvement model (PIM) to improve productivity of small and medium scale industries.

Review of Relevance Study: Productivity improvement stimulates researchers to search for methods that can achieve the increase in the productivity which in turn supports business main objectives. In this field of research, many researchers focused on improving process rather than employee performance in order to get more gains in productivity. One of these researchers was Yung who developed a new method to improve the manufacturing process productivity based on rearranging the sequence of tools and techniques by considering the coordination of information flow and selecting only the suitable tools for the specialized problems. The goal of the method was achieved but still there are some factors affecting the workers performance. Radharamanan et al. and Huang et al. also, did not consider the factors affecting the workers performance. Radharamanan et al. applied Kaizen philosophy for continuous improvement and to develop the products with higher quality, lower cost, and higher productivity that meet the customer requirements whereas Huang et al. applied effectiveness metric and simulation analysis for improving manufacturing productivity.

In addition to these efforts, Andris and Benjamin used the intimate relationship between four techniques and they proposed an integrated model that shows significant improvement on both quality and productivity of the product and process. The techniques used are Statistical Process Control (SPC), the seven basic tools (histogram, check sheet, cause-and-effect diagram, control chart, Pareto Chart, flow process chart, scatter diagram), KAIZEN (Japanese term of continuous improvement), and Total Quality Management (TQM) principles. However, the main drawback of their model is that SPC, KAIZEN and TQM are very time-consuming and bulky methods.

According to Charles, Cooper and Henderson (1963), this is known as optimization problem, and can be approached using mathematical programming. They further refer to linear programming as a uni-objective constrained optimization technique. This is because, according to them, it seeks a single objective of either minimizing or maximizing unknown variables in a model. In line with this, Gupta and Hira (2009) argue that linear programming deals with linear optimization of a function of variables known as objective function subject to set of linear equations and /or inequalities known as constraints. The objective function may be profit, cost, production capacity or any other measure of effectiveness which is to be obtained in the best possible or optimal manner. The constraints may be imposed by different resources such as market demand, production process and equipment storage capacity, raw material available, and so on. They further posit that programming implies planning and by linearity is meant a mathematical expression in which the expressions among the variables are linear.

Dowing (1992) advocates that the Lagrangian method should be used for any optimization subject to a single inequality constraint, the Graphic approach for optimization subject to only two inequality constraints, and the linear programming model for optimization subject to many inequality constraints. Supporting this view, Dwivedi (2008) posits that linear programming is of great use in making business decision because it helps in measuring complex economic relations and thereby, provides an optimum solution to the problem of resource allocation. According to him, linear programming technique thus, bridges the gap between abstract economic theories and managerial decision-making. Furthermore, he stressed that any linear programming equation should have three specifications, namely: objective function specification, constraint equation specification, and non-negativity requirement. Corroborating this view, several authors (Dowling, 1992, Dwivedi, 2008, Koutsoyiannis, 1979, Henderson and Quandt, 2003, etc) have given the general specification of the linear programming model.

Adeyemo and Otiero (2009) also tried to demonstrate that the linear programming model can be extended beyond the realms of Management Sciences and organizational decision departments to other areas such as Physical and Environmental Sciences. They used the application of Differential Evolution (DE) and Linear Programming (LP) to maximize total income (in South African Rand ZAR) of 2500 ha planting area where 16 crops are planted and constrained by water availability (using only 10mm3 of irrigation water). It is found that a total income of ZAR 46,060,200 can be derived using linear programming. Ten strategies of DE are tested with this problem varying the population size (NP), crossover constant (CR) and weighing factor (F). It is found that strategy 1, DE/rand-1-bin, with values of NP, CR and F of 160, 0.95 and 0.5 respectively obtains the best solution most efficiently.

Kareem and Aderoba (2008) tried to show the effectiveness of adopting the linear programming model in maintenance and manpower planning using data from a cocoa processing industry in Akure, Ondo State of Nigeria. The result shows that only four maintenance crew out of the 19 employees are needed in that section to effectively carry out maintenance jobs in the industry. But in their own contributions, Nedim et al (2002) tried to demonstrate that risk analysis is necessary in order to maximize resources allocation efficiency and minimize the effects of risk environment. They used data from a sample of a company's products taking risk into account as the objective function. The result suggests that producing 5 units of X1 generates 36% loss possibility. If decision makers aim risk not to exceed certain limits, then, variances should be used as constraints. The model suggests that producing 3 units of X1 will decrease the objective function from $432 to $287.

This paper is a contribution in this field of research. It focuses on improving process productivity as well as worker performance. It proposes mathematical model that improves the productivity without increasing the risk and the fatigue that affects the worker performance by enabling the user to select the best technique that achieves this aim among set of candidate techniques.

Research Methods: For this study both Quantitative and Qualitative research method are employed to get an insight on the production system of the industries and device a means to improve productivity of the industries. The Qualitative method used will be basically industrial production improvement tools.

Research Design: In the design adopted for this research work, we made use of both Quantitative and Qualitative method of productivity improvement to model the production system of small and medium scale industries in eastern part of Nigeria. The Qualitative methods used are work study, method study and time measurement. These methods where used to carry out Qualitative analysis in order to device a model to improve productivity of the industries. Three industries around eastern Nigeria was used to carry out these research due to the complexity involve in getting small scale industries to carry out research work at these level. The sources of data collection used are both primary and secondary and it allows for necessary information to be collected from the appropriate and different departments of the industries which we use as the research case study.

Analyzing Techniques: These was based on developing a mathematical decision model that aims at improving the productivity of the production process by selecting the best techniques to perform significant operations without increasing the risk, the fatigue, cost and time associated with the implementation of the selected techniques.

Linear Programming: Linear programming is the name of a branch of applied mathematics that deals with solving optimization problems of a particular form. Linear programming problems consist of a linear cost function (consisting of a certain number of variables) which is to be minimized or maximized subject to a certain number of constraints. The constraints are linear inequalities of the variables used in the cost function. The cost function is also sometimes called the objective function. Linear programming is closely related to linear algebra; the most noticeable difference is that linear programming often uses inequalities in the problem statement rather than equalities.

The objective is to maximize or minimize a single objective function relative to a set of constraints.

A mathematical program is linear, if

F $(x_1, x_2,\ldots,x_n)$ and each G $(x_1, x_2,\ldots,x_n)$ (i =2,3,…,n) are linear in each of their argument.

That is,

$F(x_1,x_2,\ldots,x_n) = c_1x_1+c_2x_2+\ldots+c_nx_n$

$g(x_1,x_2,\ldots,x_n) = a_{11}x_1+a_{12}x_2+\ldots+a_{in}x_n$

c_i and a_{ij} (i = 1,2,…..n; j = 1,2,…,n) are known constants.

All linear programming problems have the following properties in common: all seek to optimize some quantity. This property is referred to as the objective function. There are constraints, which limit the degree to which the objective can be pursued; and there must be alternatives to choose from. The objectives and constraints in linear programming must be expressed in terms of linear equation or inequalities.

However, the following procedures are necessary when formulating Linear Programming (LP) problems: write down decisions variables of the problem; formulate the objective function in terms of decision variables; formulate the other conditions/constraints of the problem to which the optimization process is subjected to, such as resources limitation, market constraints as linear equations in terms of the variables; add non-negativity conditions/ constraints- the considerations that negative values of physical variable in most cases do not have any valid physical interpretation. Summarily, the objective function, the set of constraints and the non-negativity together form the linear programming model of the problem.

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Model Formulation: When there are n choice variables and m constraints, the productivity improvement model takes the general form with a linear objective function, a set of linear inequality constraints and a set of non-negativity restrictions as its major ingredients. The generalized n variable linear programme can be stated as below:

Maximize $\pi = c_1x_1 + c_2x_2 + \ldots\ldots\ldots\ldots + c_nx_n$ (objective function)

Subject to $a_{11}x_1 + a_{12}x_2 + \ldots\ldots\ldots\ldots + a_{1n}x_n \leq r_1$

$a_{21}x_1 + a_{22}x_2 + \ldots\ldots\ldots\ldots + a_{2n}x_n \leq r_2$

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$a_{m1}x_1 + a_{m2}x_2 + \ldots\ldots\ldots\ldots + a_{mn}x_n \leq r_m$

$x_j \geq 0$ ($j = 1,2,\ldots\ldots\ldots\ldots n$) (non-negativity restrictions)

where c_i, a_{ij} and r_i are given constants. The variables $x_1, x_2, \ldots\ldots, x_n$ are called decision or structural variables. The problem is to find the values of the decision variables ($x_1, x_2, \ldots, x_n$) which maximize the objective function π subject to the m constraints and the non-negativity restriction on the x_j variable. The resulting set of decision variables which maximize the objective function is called the optimal solution. This procedure is called "Simplex Algorithm).

The model for use in the present study is:

MAXIMIZE $Z = P_1X_1 + P_2X_2 + P_3X_3 + P_4X_4$

$P_5X_5 + P_6X_6 + P_7X_7 + P_8X_8$

SUBJECT TO: $C_{11}X_1 + C_{12}X_2 + C_{13}X_3 + C_{14}X_4$

$C_{15}X_5 + C_{16}X_6 + C_{17}X_7 + C_{18}X_8 \leq B_1$

$C_{21}X_1 + C_{22}X_2 + C_{23}X_3 + C_{24}X_4$

$C_{25}X_5 + C_{26}X_6 + C_{27}X_7 + C_{28}X_8 \leq B_2$

$C_{31}X_1 + C_{32}X2 + C_{33}X_3 + C_{34}X_4$

$C_{35}X_5 + C_{36}X_6 + C_{37}X_7 + C_{38}X_8 \leq B_3$

$C_{41}X_1 + C_{42}X_2 + C_{43}X_3 + C_{44}X_4$

$C_{45}X_5 + C_{46}X_6 + C_{47}X_7 + C_{48}X_8 \leq B_4$

$C_{51}X_1 + C_{52}X_2 + C_{53}X_3 + C_{54}X_4$

$C_{55}X_5 + C_{56}X_6 + C_{57}X_7 + C_{58}X_8 \leq B_5$

$C_{61}X_1 + C_{62}X_2 + C_{63}X_3 + C_{54}X_4$

$C_{65}X_5 + C_{66}X_6 + C_{67}X_7 + C_{68}X_8 \leq B_6$

$C_{71}X_1 + C_{72}X_2 + C_{73}X_3 + C_{74}X_4$

$C_{75}X_5 + C_{76}X_6 + C_{77}X_7 + C_{78}X_8 \leq B_7$

$t_1x_1 + t_2x_2 + t_3x_3 + t_4x_4$

$t_5x_5 + t_6x_6 + t_7x_7 + t_8x_8 \leq T$

$X_i \geq 0$ (where I = 1,2,….,8)

where:

Z = total profit contribution of the various products of GPIL for the month of May, 2012.

$P_{1....8}$ = profit contribution coefficients i.e. the numerical values that express per unit contribution to the profit equation.

$X_{1...8}$ = the set of unknown we are seeking to determine i.e. the various products produce by firm.

$C_{1....8}$ = technological coefficients i.e. the numerical values that express the per unit usage of the right hand side.

$B_{1....8}$ = the resource values that we seek to fully utilize.

T = the maximum labour time available for production within the production

period (in hours or mins).

$t_{1....8}$ = the labour time required to produce one unit of the various products of

Industry.

Estimates of the variables will be presented in tables. The optimum values of the different brands produced by the firm will show the combination (product mix) obtained through the application of linear programming model. The tables will also show those resources that are abundant and those that are in short-fall.

Data Collection and its Products: Golden Plastic Industry Limited (GPIL), Emene is engaged in the production of different sizes, shapes, and lengths of plastic pipes known as PVC pipes. These products are differentiated by their sizes, thickness and length. The pressure pipes used for circulating tap water is usually thicker than the waste pipes used in water system toilets and bathrooms. The products of GPIL include the following:

110mm by 5.4m thick pressure pipes

75mm by 5.4m light pressure pipes

63mm by 5.4m thick pressure pipes

50mm by 5.4m waste pipes

40mm by 5.4m thick pressure pipes

32mm by 5.4m thick pressure pipes

25mm by 5.4m conduit pipes

20mm by 5.4m thick pressure pipes.

In order to produce these pipes, the firm requires different materials in different combinations. It requires machines of different types and sizes, skilled and unskilled labour and raw materials. But for the purpose of this research work, we shall concentrate on raw materials and two factors: man and machine hours needed for production from the 1st day to the 31st day of May, 2012. Other factors are held constant. The major raw materials used by the firm in the production of the above products include:

- Resin (the major raw material)
- Calcium carbonate
- Titanium oxide (Tio_2)
- Stabilizer
- Cast

- Carbon black
- Blend

The raw materials are mixed in different proportions and as such take different percentages of the production costs.

Table 1: Raw material to the quantity of each pipe specification

RAW MATERIAL	X1	X2	X3	X4	X5	X6	X7	X8
Resin	516	344	322.50	40	279.50	137.60	14.40	86
Calcium carbonate	180	120	112.50	21	97.50	48	6	30
Titanium dioxide	60	40	37.50	7	32.50	16	2	10
Stabilizer	108	56	67.50	5	58.50	28.80	3.20	18
Cast	48	72	30	4	26	12.80	1.20	8
Carbon black	84	16	52.50	6	45.50	22.40	2.80	14
Blend	204	152	127.50	17	110.50	54.40	10.40	34
Labour time in hours	0.0213	0.0179	0.0180	0.0143	0.0086	0.0069	0.0054	0.0043

Table 2: Cost of various raw materials provided by GPIL

RAW MATERIAL	TOTAL COST OF EACH RAW MATERIAL
Resin	3500000
Calcium carbonate	1500000
Titanium dioxide	300000
Stabilizer	500000
Cast	350000
Carbon black	700000
Blend	2600000
Labour time(hrs)	648

Data Analysis: Unit Profit Contribution by the various Products (see below). Based on all the information provided, Golden Plastic can be translated into the model above, thus:

MAXIMIZE $Z = 30X_1 + 40X_2 + 25X_3 + 15X_4 + 30X_5 + 25X_6 + 15X_7 + 35X_8$

SUBJECT TO: $516X_1 + 344X_2 + 322.50X_3 + 40X_4 + 279.50X_5 + 137.60X_6 + 14.40X_7 + 86X_6 \leq 3{,}500{,}000$

$180X_1 + 120X_2 + 112.50X_3 + 21X_4 + 97.50X_5 + 48X_6 + 6X_7 + 30X_8 \leq 1{,}500{,}000$

$60X_1 + 40X_2 + 37.50X_3 + 7X_4 + 32.50X_5 + 16X_6 + 2X_7 + 10X_8 \leq 300{,}000$

$108X_1 + 56X_2 + 67.50X_3 + 5X_4 + 58.50X_5 + 28.80X_6 + 3.20X_7$

$+ 18X_8 \leq 500{,}000$

$48X_1 + 72X_2 + 30X_3 + 4X_4 + 26X_5 + 12.80X_6 + 1.20X_7 + 8X_8$

$\leq 350{,}000$

$84X_1 + 16X_2 + 52.50X_3 + 6X_4 + 45.50X_5 + 22.40X_6 + 2.80X_7$

$+ 14X_8 \leq 700{,}000$

$204X_1 + 152X_2 + 127.50X_3 + 17X_4 + 110.50X_5 + 54.40X_6 +$

$10.40X_7 + 34X_8 \leq 2{,}600{,}000$

$0.0213X_1 + 0.0179X_2 + 0.0180X_3 + 0.0143X_4 + 0.0086X_5 +$

$0.0069X_6 + 0.0054X_7 + 0.0043X_4 \leq 648$

Matlab program will be employed to solve the mathematical problem the result will then be shown below;

Table 3: Unit profit contribution by various products

S/N	PRODUCT	PRODUCTION COST PER UNIT (NAIRA)	UNIT SELLING PRICE (NAIRA)	UNIT PROFIT (NAIRA)
1	110mm by 5.4m thick pressure pipe.	1200	1230	30
2	75mm by 5.4m light pressure pipe.	800	840	40
3	63mm by 5.4m thick pressure pipe.	750	775	25
4	50mm by 5.4m waste pipe.	100	115	15
5	40mm by 5.4m thick pressure pipe.	650	680	30
6	32mm by 5.4m thick pressure pipe.	320	345	25
7	25mm by 5.4m conduit pipe.	40	55	15
8	20mm by 5.4m thick pressure pipe.	200	235	35

Results Obtained

Table 4: The primal optimal values of decision variables

S/N	DECISION VARIABLES	OPTIMUM VALUES
1	110mm by 5.4m thick pressure pipes x_1	0
2	75mm by 5.4m light pressure pipes x_2	0
3	63mm by 5.4 thick pressure pipes x_3	0
4	50mm by 5.4m waste pipes x_4	0
5	40mm by 5.4m thick pressure pipes x_5	0
6	32mm by 5.4m thick pressure pipes x_6	0
7	25mm by 5.4m conduit pipes x_7	114,317.2
8	20mm by 5.4m thick pressure pipes x_8	7,136.564

Table 5: The dual resources value (shadow prices)

RESOURCES	VALUES (SHADOW PRICES)

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Resin	Y_1	0
Calcium carbonate	Y_2	0
Tio 2	Y_3	2,742,29 1
Stabilizer	Y_4	0
Cast	Y_5	0
Carbon Black	Y_6	0
Blend	Y_7	0
Labour time (hours)	Y_8	1762.12
Optimum Value	**W**	1964.537

Table 6: Post optimality A(unit profit increases)

Decision variable	**Optimal values**
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0
X_7	114.317.2
X_8	1736.564
Optimum Profit	2946806

Table 7: Post optimality B (unit profit decreased)

DECISION VARIABLES	**OPTIMAL VALUE**
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0
X_7	114.317.2
X_8	7136.564
Optimum	982,268.8

Profit	

Table 8: Post optimum c(resource budget and work time increased)

Decisionvariable	**Optimal values**
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0
X_7	171476
X_8	10704.9
Optimum Value	1473403

Table 9: Post optimality D resource budget and working capital

Decision variable	**Optimal values**
X_1	0
X_2	0
X_3	0
X_4	0
X_5	0
X_6	0

X_7	57,138
X_8	3368259.9
Optimal Profit	982259.87

Decision Variables;

X_1 = the quantity of 110mm by 5.4m thick pressure pipes to be produced.

X_2 = the Quantity of 75mm by 5.4m light pressure pipes to be produced.

X_3 = the quantity of 63mm by 5.4m thick pressure pipes to be produced.

X_4 = the quantity of 50mm by 5.4m waste pipes to be produced.

X_5 = the quantity of 40mm by 5.4m thick pressure pipes to be produced.

X_6 = the quantity of 32mm by 5.4m thick pressure pipes to be produced.

X_7 = the quantity of 25mm by 5.4m conduit pipes to be produced.

X_8 = the quantity of 20mm by 5.4m thick pressure pipes to be produced.

Profit Contribution Coefficients (Given Constants)

Profit contribution coefficients represent the numerical values that express the per unit contribution to the profit equation (Z).

P_1 = the average net contribution by one unit of 110mm by 5.4m thick pressure pipe.

P_2 = the average net contribution by one unit of 75mm by 5.4m light pressure pipe.

P_3 = the average net contribution by one unit of 63mm by 5.4m thick pressure pipe.

P_4 = the average net contribution by one unit of 50mm by 5.4m waste pipe.

P_5 = the average net contribution by one unit of 40mm by 5.4m thick pressure pipe.

P_6 = the average net contribution by one unit of 32mm by 5.4m thick pressure pipe.

P_7 = the average net contribution by one unit of 25mm by 5.4m conduit pipe.

P_8 = the average net contribution by one unit of 20mm by 5.4m thick pressure pipe.

Technology Coefficients (given constants)

In the model, technological coefficients represent the numerical values that express the per unit usage of the various raw materials in the production of the various products. For instance;

C_{11} = Cost of Resin in producing one unit of 110mm by 5.4m thick pressure pipe.

C_{21} = Cost of Calcium Carbonate used in producing one unit of 110mm by 5.4m thick pressure pipe.

C_{71} = Cost of Blend used in producing one unit of 110mm by 5.4m thick pressure pipe.

C_{12} = Cost of Resin used in producing one unit of 75mm by 5.4m light pressure pipe etc.

Labour Time

Labour time here represents the labour time required to produce one unit of the various products of GFIL. For instance;

t_1 = the labour time (in hours) required to produce one unit of 110mm by 5.4m thick pressure pipe.

t_2 = the labour time (in hours) required to produce one unit of 75mm by 5.4m light pressure pipe.

T = the maximum labour time available for production within the production period etc.

Right-hand Side values (given constants)

These represent the resource values that we seek to fully utilize. For instance;

B_1 = the amount of money available within the production period for the purchase of Resin.

B_2 = the amount of money available within the production period for the purchase of Calcium carbonate

Discussion: The various estimated values of the optimization model for Golden Plastic Industry Limited are presented in 6 different tables (tables 4 to 9). Tables 4 and 5 present the primal and dual values of the estimates respectively while tables 6 to 9 present the computer print-out of the post optimality values of the optimization model.

From table, the optimal solution of the problem is zero production for 6 out of the 8 products of GPIL. The production level of 25mm by 5.4m conduit pipes and 20mm by 5.4m thick pressure pipes yielded 114,317.2 and 7,136.564 respectively while the objective function yielded N1,964,532. But Golden Plastic could only make a total profit of N982,656 from 1st to 31st May, 2012. This obvious reduction in profit is partly attributed to random selection of product mix and resource allocation. Application of linear programming would have indicated to management that the company should produce only 114,317.2 of 25mm by 5.4m conduit pipes and 7136.564 of 20mm by 5.4m thick pressure pipes in order to make the maximum profit of N1,964,537 and thereof improve productivity of (GPIL). The other products should not be produced since their production adds more to cost than to profit. The dual solution in table 6 re-affirms the authenticity of the optimal value of the objective function in the primal result. It also shows that while tio 2 (Y3) and labour time (Y8) are abundant due to their positive values, resin (Y1), calcium carbonate (Y2), stabilizer (Y4), cast (Y5), carbon black (Y6) and blend (Y7) are scarce due to their zero values. This means that they were consumed completely by the activities of the model. Therefore for the optimal solution to be improved, the scarce resources should be increased since any increase of the abundant resources will only make them more abundant without affecting the optimum solution.

The optimal values of the products; 25mm by 5.4m conduit pipes and 20mm by 5.4m thick pressure pipes increased and decreased with the post optimality C – when the resource budget and working time are increased and decreased respectively. However, it is important to note that the increase in the resources budget and working time in post optimality C yields a smaller optimal profit compared to the maximum profit of 1,964,537 naira in table 5 which suggests that there is a limit to which resources can be increased in other to achieve the objective function.

Conclusion: The study was successfully determined the product mix of Golden Plastic Industry Limited, Emene. In the process, the optimal quantities of the various PVC pipes to be produced within the study period in order to improve productivity were established. Also the status of the resources and the unit worth of each resource to the objective function were known. This is the advantage of going beyond mere knowledge of existing decision making tools to actual practical proof of its workability.

Another issue becomes how the managerial cadre of the productive firms at Emene Industrial Layout could be exposed to the rigorous steps involved in arriving at the optimal values of the linear programming model. From the researchers' personal observations in the course of this study, Golden Plastic Industry Limited, Emene was relatively few persons skilled in the Operations Research techniques who also possess a broad understanding of business environment and knowledge of the managerial roles and functions. As such, the firm should rely on outside consultants to bring this and other techniques to bear on management's decision problems. This can go a long way to assisting the management.

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