Idama A. and Nyor, N. (2005). Resource Allocation in a Retail Shop: a linear programming approach. *The Nigerian academic Forum*, vol 9, No 5, pp 91-98

NIGERIAN ACADEMIC FORUM

ISSN 1596-3306

A MULTI DISCIPLINARY JOURNAL

* JOURNAL *

Volume 9 No. 5 November, 2005

Published by
National Association of the Academics
(NAA)

RESOURCE ALLOCATION IN A RETAIL SHOP: A LINEAR PROGRAMMING APPROACH

Adamu Idama and Ngutor Nyor

Abstract

Discussed in this paper is the application of the Operations Research (OR) method of Linear Programming in the allocation of scarce resources in a retail shop. This unique study demonstrated the application of Operations Research in a rear situation; because of the expensive nature of Operations Research services, small businesses cannot afford it. Through this study we have shown that small business enterprises can benefit from Operations Research studies; in fact we argued that for Operations Research to come into wide usage in developing countries especially, the small business enterprise should be the focus of Operations Research activities. Amongst pandemic poverty stricken people small improvements do make significant differences and this can be achieved through Operations Research, "The Science of Better".

Introduction

The application of Operational Research (OR) models in aid of small businesses is not common. There are diverse reasons for this. One common argument is that OR is an expensive undertaking well beyond the reach of small businesses. However, if OR is to make some impact in the developing countries like Nigeria, in particular, where there is no history of OR application, and where big businesses are not willing to experiment with OR, OR may have to advertise itself by undertaking studies for small businesses. The small business manager can easily appreciate small improvements, and is therefore a good client for OR scientists. Discussed in this paper is a study on how linear programming (LP) was used to assist a small trader in the allocation of scarce and limited resources in the purchase of retail goods.

Business Questions

Three broad questions help businesses managers decide whether certain environmental opportunities represent viable organizational growth or start-up opportunities (Hitt, Ireland, and Hoskisson, 1996, Peterson and Kerin 1998, Hisrich and Peters 2002). These questions are:

1. What might we do? This question introduces unmet or changing consumer needs, unsatisfied buyer groups, and new means, or technology for delivering value to prospective buyers as opportunities for his business. This is the environmental context of decision-making and it is vital for organizational survival.
2. What do we do best? This introduces the question of organizational capacity or distinctive competences, such as skills or technology, or distinctive resources. The organizational strength must be imperfectly imitable by competitors (or the cost of doing so must be prohibitively high). These resources must make significant contributions to the benefit perceived by the customers.
3. What must we do? This question deals with critical success factors, which are basic tasks that business must perform in order to compete effectively and successfully. They are subtle in nature and thus are often overlooked. For example, firms competing in the personal computer Industry recognize that the requirements for success include low cost production capabilities, access to distribution channels, and continuous innovations in software development.

As argued by Magono (1991), every business can be improved, hence Operational Research (OR) described as "The Science of Better", takes particular interest in looking at ways by which a business might improve or become better. Profitability can be improved by doing a number of things. These include:

1. Increasing sales volume. That is selling more of your products and services
2. Increasing sales prices. Care must be taken however to ensure that this does not produce the effect of damping the demand for your products or services.

3. Cutting your costs. Cost cutting is often very difficult to achieve for a firm that has been operating effectively, though it can be argued that there is always room for improvement.
4. Changing the product mix or diversification of services rendered. For a retail shop, this means selling more of the higher profit lines, (faster moving lines) and less of those showing slimmer profit margins (or slow moving products). Here internal capabilities are matched against external demands.

This particular study focused on the fourth approach to profitability improvement. The Operational Research technique of linear programming was applied to the business of Mr. Emeka Nnamanyi Grains Shop to identify the higher profit items in which the manager should engage in order to maximize his profit. Linear programming (LP) is a procedure by which choices can be made of the best set of activities in which to engage, particularly when the possible activities from which to choose are numerous, the available resources to allocate to them are scarce and there is linear relationship among the variables (Dantzing 1947, Hillier and Lieberman 2001).

Emeka Nnamanyi Grains Shop

Emeka Nnamanyi Grains Shop was established in April 1995 as a sole proprietorship business venture. The shop is located at Zone C No. 427, Jimeta Market, Yola, Adamawa State, Nigeria. The Shop retails such grains as: guinea corn, brown beans, white beans, garri, rice, bambaranut, and groundnuts. He generally purchases these items in bulk or large quantities from Yola Market (which holds every Friday) some 2 km away. He disposes of them generally by retailing – selling in small quantities usually called "measures", using locally accepted basins generally referred to as "mudu".

The Problem Situation

Mr. Nnamanyi usually purchases grains in full bags (approximately 50kg or 100kg). The profit contributions from the grains vary. Their sales are however independent of one another. Mr. Nnamanyi has limited capital resources to invest in the purchase of these products every time he goes to the market. In other words these products compete against each other for the limited financial resource available to Mr. Nnamanyi. Retailers, especially small retailers, like Mr. Nnamanyi, have difficulties in allocating resources among the diverse items which they stock. While some items are fast-movers, others are slow-movers. The profit contributions from the items vary widely. Most retailers in the traditional market are illiterate. They do not know about optimal allocations models or how to make use of them. Their decisions are often based on intuition, family practice, apprenticeship experience or even folklores. Thus the problems solved in the study were:

1. Identification of the optimum combination of items, which will yield maximum profit to the business
2. Alleviation of the stress (emotional, mental, and psychological) suffered by Mr. Nnamanyi every time he goes to the market in deciding how to allocate his scarce resources in order to maximize profit.
3. Introduction to proven scientific methods of resource allocation with the view to replace intuitive models of resource allocation.
4. Introduction of modern methods of running a business to Mr. Nnamanyi.
5. Doing Operational Research for a small business enterprise who otherwise would not have profited from the OR approach because of prohibitive consulting costs.

The Model

Broadly, there are three basic steps involved in a linear programming model formulation:

1. Identify the decision variables. These are the variables whose value the decision maker wishes to determine. The variables are generally defined as $x_1, x_2, \ldots, x_n$.
2. Identify the objective function. This is the goal desired by the decision masker. The objective criterion could be to maximize profit, or minimize costs. Its formulation goes along with the decision variables.
3. Identify the constrains. These are the conditions or restrictions which must be satisfied. They are formulated as mathematical expressions involving the decision variables.

Assumptions of Linear Programming.

Linear programming is an optimization model; it is most useful in dealing with problems, which satisfy certain conditions. The basic assumptions are:

1. An objective criterion. There must be a quantitatively determined objective criterion to optimize. It may be in terms of optimizing profit, cost, market share, productivity, investment in capital market, distance traveled, project duration etc..
2. Limited resources. Generally, the resources at the disposal of the decision maker must be limited and the decision maker must desire to allocate them in a way that yields maximum benefit. The resources could be money, production capacity, human resources, machine/labour hours, time, technology, etc.
3. Proportionality. The contribution of each resource to the value of the objective function is proportional to the level of resource. Thus, if production materials, for example, are increased by 5%, we expect to see a direct proportional increase in production output.
4. Additivity. Every function is the sum of the individual contributions of all the resources. The total profit must be the sum of the profit from each product. Similarly, the amount of resources used for production must equal exactly the sum of the resources required for making the product.
5. Divisibility. Decision variables can have any values either integer, or no integer (or fractional) values.
6. Certainty of (or deterministic) parameters. The value assigned to each parameter or model coefficient is assumed to be a known constant (or known with certainty).
7. Nonnegativitay. Negative productions of activity – goods, investment, food served etc. is not permissible. Zero output, that is, no production is however allowed.

According to Hillier and Lieberman (2001), a general standard form of a linear programming model can be stated as:

Maximize $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$

Subject: to:

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \leq b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \leq b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2x2} + \ldots + a_{mn}x_n \leq b_m$$
and $x_1 \geq 0,\ x_2 \geq 0, \ldots, x_n \geq 0$

where:

Z = value of overall measure of performance

x_j = level of activity j (for j = 1,2,...,n).

c_j = increase in Z that would result from each unit increase in level of activity j

b_i = amount of resource i that is available for allocation to activities (for i = 1,2,...,m)

a_{ij} = amount of resource i consumed by each unit of activity j

In a tabular form, this standard form would be represented as shown in Table 1.

Table 1. A Standard Form of a Linear Programming Model Involving the Allocation of Resources to Activities.

Resources	Resource Use Per Unit of Activity 1	2	...	n	Amount of Resources Available
1	a_{11}	a_{12}	...	a_{1n}	b_1
2	a_{21}	a_{22}	...	a_{2n}	b_2
...	...	....	...	...	...
m	a_{m1}	a_{m2}	...	a_{mn}	b_m
Contribution to Z per unit of activity	c_1	c_2	...	c_n	

Linear Programming Formulation of Mr. Nnamany's Problem

Data Collected

Data were collected on the food items sold by the client. These were:

1. Guinea corn
2. Maize
3. Brown beans
4. White beans
5. Garri
6. Sieved rice that has been processed and bagged, generally called "Foreign Rice"
7. None para-boiled processed rice generally called" Nigerian White Rice"
8. Para-boiled rice which is locally produced and usually contains some sand particles, generally called "Local Rice"
9. Bambara nut
10. A variety of groundnut produced by the Tiv people in Benue State generally called "Tiv Groundnut". Scientifically it is Known as 59 – 127 (SAMNUT 10)
11. A white stroked variety of groundnut generally known as "Campalla Groundnut" scientifically called RMPP 12 (SAMNUT10).
12. A variety of groundnut produced upper North of Nigeria, popularly known as "Gargagia Groundnut" meaning "traditional groundnut". It is scientifically known as M554-76 (SAM NUT – 16).

Table 1 shows a summary of the data collected. Table 2 shows a summary of profit per bag and profit per trip.

Table 1. Data Collected for the Study.

Product or food item	No. of bags purchased per trip	Cost price per bag (₦)	Sales duration per bag	Cost of transportation per bag (₦)	No. of mudus per bag	Weight per mudu (Kg)	Weight per bag (Kg))	Selling price per mudu (₦)
Guinea corn	7	3,000	1 week	200	70	1.8	126	50
Maize	13	3,100	1 week	200	68	1.2	81.6	50
B Brown beans	3	6,500	2 weeks	200	72	1.5	108	100
White beans	5	5,500	2 weeks	200	72	1.5	108	80
Garri	5	1,200	2 days	50	24	1.1	26.4	60

Foreign rice	10	4,300	1 day	10	29	1.7	49.3	160
Nigerian white rice	2	5,200	2 weeks	200	72	1.7	122.4	120
Bambara nut	1	5,000	2 weeks	100	55	2.0	110	100
Tiv groundnut	5	8,400	3 weeks	100	70	1.5	105	140
Campalla groundnut	2	7,800	2 weeks	100	70	1.5	105	130
Gargagia groundnut	2	7,800	2 weeks	100	70	1.5	105	130
Local rice	2	7,200	2 weeks	200	72	1.7	1,22.4	130

Problem Formulation

Decision Variables

Let x_1 represent the quantity of Guinea Corn

x_2	,,	Maize
x_3	,,	Brown beans
x_4	,,	White beans
x_5	,,	Garri
x_6	,,	Foreign rice
x_7	,,	Nigerian white rice
x_8	,,	Bambara nut
x_9	,,	Tiv groundnut
x_{10}	,,	Campalla groundnut
x_{11}	,,	Gargagia groundnut
x_{12}	,,	Local rice

Table 2 Profit per Bag and Profit per Trip

Product or food item	No. of bags per trip	No. of mudus per bag	Cost price per bag (₦)	Cost price per trip (₦)	Selling price per mudu (₦)	Selling price per bag (₦)	Selling price per trip (₦)	Profit per bag (₦)	Profit per trip (₦)
Guinea corn	7	70	3,000	21,000	50	3,500	24,500	500	3,500
Maize	13	68	3,100	40,300	50	3,400	44,200	300	3,900
Brown beans	3	72	6,500	19,500	100	7,200	21,600	700	2,100
White beans	5	72	5,500	27,500	80	5,760	28,800	260	1,300
Garri	5	24	1,20	6,000	60	1,440	7,200	240	1,200
Foreign rice	10	29	4,300	43,000	160	4,640	46,400	340	3,400
Nigerian white rice	2	72	5,200	10,400	120	8,640	17,280	114	2,280
Bambara nut	1	5	5,000	5,000	100	5,500	5,500	500	500
Tiv groundnut	5	70	8,400	42,000	140	9,800	49,000	1400	7,000
Campalla	2	70	8,400	15,000	130	9,100	18,200	1300	2,600

groundnut									
Gargagia groundnut	2	70	7,800	15,600	130	9,100	18,200	1300	2,600
Local rice	2	72	7,200	14,400	130	9,360	18,720	2,160	4,320
Total	57			260,300			299,600		39,300

Note:

1. Cost price per trip = cost per bag x No. of bags per trip
2. Selling price per bag = Selling price per measure(mudu) x No. of measures per bag
3. Selling price per trip = Selling price per bag x No. of bags per trip
4. Profit per bag = Selling price per bag – cost price per bag
5. Profit per trip = Profit per bag x No. of bags per trip (or Selling price per trip) – Cost price per trip.

Objective Function

Our objective is to maximize the profit contributions per bag subject to the various constraints

Basic Assumption

It is assumed that all purchases are made or done at a trip.

Constraints

Since we want to allocate what is available to the various products in a business transaction; we consider each variable to be a constraint during each trip.

1. Constraint 1 (Guinea corn): The total number of bags of Guinea corn should not exceed 8
2. Constraint 2 (Maize): The total number of bags of Maize should not exceed 9
3. Constraint 3 (Brown Beans): The total number of bags of Brown beans should not exceed 8
4. Constraint 4 (White Beans): The total number of bags of White beans should not exceed 4
5. Constraint 5 (Garri): The total number of bags of Garri should not exceed 5
6. Constraint 6 (Foreign Rice): The total number of bags of Foreign rice should not exceed 6
7. Constraint 7 (Nigerian White Rice): The total number of bags of Nigerian white rice should not exceed 8
8. Constraint 8 (Bambara nut): The total number of bags of Bambara nut should not exceed 2
9. Constraint 9 (Tiv Groundnut): The total number of bags of Tiv Groundnut should not exceed 6
10. Constraint 10 (Campalla G/N): The total number of bags of Campalla G/N should not exceed 3
11. Constraint 11 (Gargagia G/N): The total number of bags of Gargagia G/N should not exceed 3
12. Constraint 12 (Local Rice): The total number of bags of Local rice should not exceed 3
13. Constraint 13 (Shortages): The total number of bags of the products listed in Table 3 showing higher demand should be at least three times those listed as showing lower demand.
14. Constraint 14 (Trip limit): For the business to hold, the maximum quantity of bags of items to purchase per trip should not exceed 57 bags.

Table 3. Demand Profile of Commodities.

Commodities with higher demand	Commodities with lower demand
Maize x_2	Guinea corn x_1
White beans x_3	Garri x_5
Brown beans x_4	Bambara nut x_8.
Foreign rice x_6	
Nigerian white rice x_7	
Local rice x_{12}	

Linear Programming Formulation

Maximize $Z = 5x_1+3x_2+7x_3+6x_4+4x_5+4x_6+4x_7+5x_8+14x_9+13x_{10}+13x_{11}+6x_{12}$.

$$x_1 \leq 8$$
$$x_2 \leq 9$$
$$x_3 \leq 4$$
$$x_4 \leq 5$$
$$x_5 \leq 6$$
$$x_6 \leq 8$$
$$x_7 \leq 3$$
$$x_8 \leq 2$$
$$x_9 \leq 6$$
$$x_{10} \leq 3$$
$$x_{11} \leq 3$$
$$x_{12} \leq 3$$
$$x_2+x_3+x_4+x_6+x_7+x_{12} \leq 48$$
$$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12} \leq 57$$
$$x_i = 0 \cdot (i = 1,2,3,...,12).$$

Solution

The problem was solved on computer software: OM-EXPERT: Decision Tools for Operations Management, designed by Noori (1995). The optimal Tableau was arrived at the 13th iteration. Table 4 shows the optimal solution of the linear programming. This is the optimal combination of the number of bags to purchase per trip in order to maximize profit.

Table 4. Optimal Solution of Linear Programming.

Variable	Solution
x_1	8
x_2	9
x_3	4
x_4	5
x_5	3
x_6	8
x_7	3
x_8	2
x_9	6
x_{10}	3
x_{11}	3
x_{12}	3

Objective Function Value: ₦41,340

Linear Programming Solution versus Intuitive Model Solution

Table 5 shows the linear programming solution compared with the intuitive model solution. With the linear programming solution Mr. Nnamanyi would earn per trip profit of ₦41,340 as against ₦39,300 by current practice which is based on intuition. In the long run the additional profit of ₦2,040 would become significant. The larger profit however lies in the easy with which resources can now be allocated and the assurance that the allocation is optimal

Table 5. Linear Programming Solution Compared With Intuitive Model Solution.

	Bags Per Trip	
	LP Solution	Current Purchase
Guinea Corn (x_1)	8	7
Maize (x_2)	9	13
Brown beans (x_3)	4	3
White Beans (x_4)	5	5
Garri (x_5)	3	5
Foreign rice (x_6)	8	10
Nigerian White Rice (x_7)	3	2
Bambare nut (x_8)	2	1
Tiv Ground nut (x_9)	6	5
Campalla Groundnut (x_{10})	3	2
Gargagia Groundnut (x_{11})	3	2
Local rice (x_{12})	3	2
Profit Per Trip	**₦41,300**	**₦39,300**

Conclusion

In this paper we have discussed the applicability of Operational Research to solving the problems of resource allocation for a small business enterprise. In developing countries such as Nigeria, where the use Operational Research is not yet widespread, largely due to ignorance and the prohibitive nature of consulting fees, one way to popularize Operational research would be to undertake Operational Research for small business enterprises. For this category of organizations any improvement, however small, is significant. Amongst pandemic poverty stricken people small improvements do make significant differences and this can be achieved through Operational Research, "The Science of Better".

References

Dantzig G. B. 1963. *Linear Programming and Extensions*, Princeton University Press, Princeton, N. J.

Hisrich, R. D. and Peters M. P. 2002 *Entrepreneurship,* Fifth Edition McGraw – Hill Irwin, Boston.

Hitt M. A., Ireland, R. D. and Hoskisson, R. E. 1996 *Strategic Management: Competitiveness and Globalization,* 2nd Edition, West Publishing Company, Minneapolis/St Paul.

Hellier F.S and Lieberman G.J (2001), *Introduction to Operations Research,* 7th Edition, McGraw- Hill, New York.

Mogono M (1991), *How to Make Bigger Profits*, Graham and Trotman ltd, London.

Noori, Hmid and Russell Radford (1995) *Production and Operations Management. Total Quality and Responsiveness*, McGraw-Hill, Inc., New York

Nyor, Ngutor (2004), "Application of Linear Programming Method to Resource Allocation in Retail Shops: A Case Study of Mr. Emeka Nnamanyi Grains Shop Jimeta Market, Adamawa State, Unpublished B. Tech (Hons) Project, Department of Statistics and Operations Research, Federal University of Technology, Yola, Nigeria.

Peterson P. and Kerin K. (1998). *Strategic Marketing Problem* Prentice - Hall, Toronto.