Mathematical Programming Modeling and Analysis of Covenant University Supermarkets System for Profit Optimization

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Abstract

Supermarkets in Covenant University are with little or no competition. However, the level of profit making is below the optimal. This study attempted to identify the factors responsible for the low level of profit making and apply linear programming algorithm to maximize the profit by identifying the factors with highest contributions in order to improve profit making of these supermarkets. The resulting model was solved with the aid of computer software - LINGO. The results obtained showed that staff turnover and late restocking are two of the factors that significantly contribute to the low-level profit making of the supermarkets.

Keywords
Profit Optimization, Covenant University, Supermarkets, Mathematical Programming, Modeling

1. Introduction
Efficient management of information is needed in large and complex business systems such as supermarkets. With respect to the fast growing industrialized age, profit making is the key word that thrives performance. Profit making for supermarkets can be very crucial because of the non-negotiable factor of high rated competition among themselves. Optimization, linear or nonlinear, helps to attain the highest profit. Often optimization problems involve making the most efficient use of available resources-including money, time, machinery, staff, inventory, and more. In order to optimize the profit of an outfit such as the supermarkets in Covenant University, Lingo software has proven to be a very good tool.

Covenant university is one of the fastest growing Universities in Africa and this makes it a very large community hosting quite a large population including, the faculty, staff and student as well as visitors (Agarana and Ehigbochie, 2015). The serenity of the environment gives the luxury of shopping within the environment to limit the stress of travelling far distances to satisfy wants and enjoy the luxury of comfort. This institution has three main strategic supermarkets located within the premises; they are called the SBS mall, CU guest house mini mart and the CU shopping mall, which run concurrently under the same authority and same line of distribution. In general, these supermarkets are monopolistic in nature with absolutely zero competition compared to many supermarkets outside the campus. The limitations of being monopolistic in nature as an organization is that profits are not carefully detailed because of negligence caused by overfamiliarity. It is quite undisputable that self-satisfying profit is made at every point in time, but the reality is that this profit never reaches its optimality which can be considered as an indirect loss, and this is a major problem yet to be understood (Agarana and Olokunde, 2015)

Covenant University is a potential world class Universities (Agarana and Ayeni, 2015). The University has many supermarkets inside the campus. The system of supermarkets are run by a special unit called the strategic business unit of the University. The University is presently one of the best five Universities in Africa. This has made it a University of choice. Consequently, the population is relatively high. Members of the University community usually do their shopping within the campus in order to limit the stress of travelling far distances to shop in the big malls in the town. It is quite undisputable that good profit is made in all the supermarkets, but the profit making can be optimized (Abbas 2019). Efficient management of resources and information are needed in supermarket systems of Covenant University in order to achieve the optimal profit. In addition to driving performance, profit making generally, because of the non-negotiable factor of high rated competition among supermarkets. Though Supermarkets in Covenant University are with little or no competition, but the customers should not be allowed to take a decision of going to the supermarkets outside the campus for their shopping. This can be achieved by providing some incentives for the customers among other things.
Literature reveals that profit with respect to supermarkets are enhanced with regards to competition, as carefully analysed by some researchers, (Agarana et al, 2019) on the profitability performance of supermarkets of which profits were analysed based on performance and not optimized. Overtime, optimizing profit and analysing strategies based on high performance using Dutch supermarkets as a case study was done by André de Waal et.al (2016), using the high-performance organization framework (HPO). This technique with its time-consuming characteristic ended up analysing profit and not optimizing profit due to the competitive nature of the supermarkets.

Linear programming is an operation research technique that is summarized as a technique that optimizes a linear function to get the best outcome. Mathematically, it deals with the optimization (maximization or minimization) of a function of variables known as objective function, subject to set of linear equations and/or inequalities called constraints (Agarana et al, 2014). Prior to history, George Dantzig, (2011) and his associates found out a technique for solving military planning problems while they were working on a project for U.S. Air Force. This technique consisted of representing the various activities of an organization as a linear programming model. Afterwards, Dantzig suggested his approach for solving business and industrial problems. He also developed the most powerful mathematical tool known as “simplex method” to solve linear programming problems (Dantzig, 1947) and (Gupta&Hira, 2014). It is perhaps the most widely applied mathematical technique that helps managers in decision-making and planning for optimal allocation of limited resources (Parlesak et al, 2016). Relatively, it has been applied to some areas in terms of optimizing profit and to baking industry (Agarana et al, 2003, 2016), (Ferguson, 2004).

Although, there are other numerous areas and works to be counted, including that of Kawaguchi and Nagel (2008), Eiselt and Sandblom (2007), and Agarana et al (2019), where the concept of linear and integer programming were applied to real life situations.

1.1 Assumptions

The following assumptions were made in this study:

(i) The three supermarkets are patronized equally
(ii) There is an efficient management of information in the three supermarkets

2. Problem Formulation

Focusing on the three malls as stated above, analysis was drawn on the specific products of which most, in generic terms, are the ones that generate profit based on customer demand. In order of priority, the products that generate major profit for both the SBS and the CU shopping mall are:

A: Drinks
B: Breads
C: Chocolate
D: Snacks
E: Household toiletries
F: Provisions
G: cosmetics

The major difference between the products stated above and that defined for the guest house minimart is that the snacks are replaced with Jewelries. Although the three stations have the same line of distribution and supervision, their targets each month are in terms of profit making. There is slightly minimal price difference amongst the three supermarkets, yet it is believed that profit is not at its optimal most times due to the unavailability of certain products at costumer demand which is a major constraint observed. In this study, an attempt was made to optimize profit making of these supermarkets despite the zero-competition strength that exists. The profit generation is mainly based on the seven major products which are in accordance with customer's high demand for them. It is labelled A to G. In this research, the profit generation period is taken to be one month. Data is measured and weighed in terms of percentage mainly because of some of the generic terms such as provisions, cosmetics etc. the Data was further transformed to a linear programming problem and solved using the simplex method, with the aid of a programming software – LINGO. In order to formulate the linear programming, the decision variables are defined as follows:

$x_1 = \text{the quantity of product A}$
$x_2 = \text{the quantity of product B}$
$x_3 = \text{the quantity of product C}$
$x_4 = \text{the quantity of product D}$
$x_5 = \text{the quantity of product E}$
$x_6 = \text{the quantity of product F}$
$x_7 = \text{the quantity of product G}$

The interest here is to maximize profit denoted, hence the objective function is defined as follows:

$$\text{Maximize } P = C_1x_1 + C_2x_2 + C_3x_3 + C_4x_4 + C_5x_5 + C_6x_6 + C_7x_7 .$$

Where:

P = the total profit

$C_1 = \text{Contribution of 1 unit of } x_1$
$C_2 = \text{Contribution of 1 unit of } x_2$
$C_3 = \text{Contribution of 1 unit of } x_3$
$C_4 = \text{Contribution of 1 unit of } x_4$
$C_5 = \text{Contribution of 1 unit of } x_5$
$C_6 = \text{Contribution of 1 unit of } x_6$
$C_7 = \text{Contribution of 1 unit of } x_7$

Hence, the general linear programming model for the proposed problem is:

Maximize: $P=\sum_{j=1}^{7} C_j x_j$

subject to: $\sum_{j=1}^{7} a_{ij} x_j \left(\leq,=,\geq\right) b_i, i = 1,2,...,m$

and $x_j \geq 0, j = 1,2,...,7.$

where $a_{11},...,a_{n7}$ are the amount of resources needed to acquire one unit of the decision varibles respectively, $b_1,...,b_n$ = limited number of available resources.

The major inhibition of profit maximization of these supermarkets has been attributed to operations expenses. Data was collected and analyzed from all three supermarkets.

2.1 Data Collection

Table 1: Data collected from the Covenant University Guest House Minimart

		A	B	C	D	E	F	G	
		DRINKS	BREAD	CHOCOLATE	JEWELRIES	TOILETRIES	PROVISIONS	COSMETICS	
CONTRIBUTION TO MONTHLY PROFIT (%)		12.5	12	12	12	12	5	22.5	AVAILABLE RESOURSES (‘000)
‘ OPERATIONS(‘ 000)	STORAGE	5	10	5	5	5	5	5	50
	STAFFING	5	10	5	5	5	5	5	1
	STANDARD	2.5	2	4	4	4	1	4.5	50
	ECONOMY	1	1	1	1	1	1	1	50
	SUPPLY	5	10	5	5	5	5	5	100
	RESTOCKING	1	1	1	1	1	1	1	50
	DEMAND	5	10	4	1	5	1	3	20

Table 2: Data Collected from the Covenant University Shopping Mall

		A	B	C	D	E	F	G	
		DRINKS	BREAD	CHOCOLATE	SNACKS	TOILETRIES	PROVISIONS	COSMETICS	
CONTRIBUTION TO MONTHLY PROFIT (%)		12	10	10	12	15	20	15	AVAILABLE RESOURSES (‘000)
OPERATIONS (‘ 000)	STORAGE	10	20	10	5	10	10	10	100
	STAFFING	10	20	10	5	10	10	10	4
	STANDARD	2	5	10	4	4	2	5	50
	ECONOMY	1	1	1	1	1	1	1	50
	SUPPLY	10	20	10	10	10	10	10	150
	RESTOCKING	1	1	1	1	1	1	1	50
	DEMAND	15	30	10	10	15	20	15	200

Table 3: Data Collection from the SBS Supermarket

		A	B	C	D	E	F	G	
		DRINKS	BREAD	CHOCOLATE	SNACKS	TOILETRIES	PROVISIONS	COSMETICS	
CONTRIBUTION TO MONTHLY PROFIT (%)		15	20	10	20	5	15	10	AVAILABLE RESOURSES (‘000)
‘ OPERATIONS (‘ 000)	STORAGE	15	30	10	5	10	10	10	200
	STAFFING	15	30	10	5	10	10	10	6
	STANDARD	2	7	10	4	5	1.5	1.75	50
	ECONOMY	1	1	1	1	1	1	1	50
	SUPPLY	15	30	10	5	10	10	10	250
	RESTOCKING	1	1	1	1	1	1	1	50
	DEMAND	30	40	15	10	20	20	20	300

2.2 Linear Programming Modelling of the Problem

Using the data in table1, the linear programming model for Covenant University Guest House Minimart is as follows:

$$\text{Maximize } P_1 = 12.5x_{11} + 12x_{12} + 12x_{13} + 12x_{14} + 12x_{15} + 5x_{16} + 22.5x_{17}$$

subject to:

$$5x_{11} + 10x_{12} + 5x_{13} + 5x_{14} + 5x_{15} + 5x_{16} + 5x_{17} \le 50$$
$$5x_{11} + 10x_{12} + 5x_{13} + 5x_{14} + 5x_{15} + 5x_{16} + 5x_{17} = 1$$
$$2.5x_{11} + 2x_{12} + 4x_{13} + 4x_{14} + 4x_{15} + x_{16} + 4.5x_{17} \ge 50$$
$$2x_{11} + 2x_{12} + 2x_{13} + 2x_{14} + 2x_{15} + 2x_{16} + 2x_{17} \le 100$$
$$5x_{11} + 10x_{12} + 5x_{13} + 5x_{14} + 5x_{15} + 5x_{16} + 5x_{17} \le 100$$
$$5x_{11} + 10x_{12} + 4x_{13} + x_{14} + 5x_{15} + x_{16} + 3x_{17} \le 20$$
$$x_{11} \ge 0, x_{12} \ge 0, x_{13} \ge 0, x_{14} \ge 0, x_{15} \ge 0, x_{16} \ge 0, x_{17} \ge 0$$

Using the data in table 2, the linear programming model for Covenant University Shopping Mall is as follows

$$\text{Maximize: } P_2 = 12x_{21} + 10x_{22} + 10x_{23} + 12x_{24} + 15x_{25} + 20x_{26} + 15x_{27}$$

subject to:

$$10x_{21} + 20x_{22} + 10x_{23} + 5x_{24} + 10x_{25} + 10x_{26} + 10x_{27} \le 100$$
$$10x_{21} + 20x_{22} + 10x_{23} + 5x_{24} + 10x_{25} + 10x_{26} + 10x_{27} \le 4$$
$$2x_{21} + 5x_{22} + 10x_{23} + 4x_{24} + 4x_{25} + 2x_{26} + 5x_{27} \ge 50$$
$$2x_{21} + 2x_{22} + 2x_{23} + 2x_{24} + 2x_{25} + 2x_{26} + 2x_{27} \le 100$$
$$10x_{21} + 20x_{22} + 10x_{23} + 10x_{24} + 10x_{25} + 10x_{26} + 10x_{27} \le 150$$
$$15x_{21} + 30x_{22} + 10x_{23} + 10x_{24} + 15x_{25} + 20x_{26} + 15x_{27} \le 200$$
$$x_{21} \ge 0, x_{22} \ge 0, x_{23} \ge 0, x_{24} \ge 0, x_{25} \ge 0, x_{26} \ge 0, x_{27} \ge 0$$

Using the data in table 3, the linear programming model for SBS Supermarket is as follows

$$\text{Maximize: } P_3 = 15x_{31} + 20x_{32} + 10x_{33} + 20x_{34} + 5x_{35} + 15x_{36} + 10x_{37}$$

subject to:

$$15x_{31} + 30x_{32} + 10x_{33} + 5x_{34} + 10x_{35} + 10x_{36} + 10x_{37} \le 200$$
$$15x_{31} + 30x_{32} + 10x_{33} + 5x_{34} + 10x_{35} + 10x_{36} + 10x_{37} \le 6$$
$$2x_{31} + 7x_{32} + 10x_{33} + 4x_{34} + 5x_{35} + 1.5x_{36} + 1.75x_{37} \ge 50$$
$$2x_{31} + 2x_{32} + 2x_{33} + 2x_{34} + 2x_{35} + 2x_{36} + 2x_{37} \le 100$$
$$15x_{31} + 30x_{32} + 10x_{33} + 5x_{34} + 10x_{35} + 10x_{36} + 10x_{37} \le 250$$
$$15x_{31} + 30x_{32} + 10x_{33} + 10x_{34} + 15x_{35} + 20x_{36} + 15x_{37} \le 3800$$
$$x_{31} \ge 0, x_{32} \ge 0, x_{33} \ge 0, x_{34} \ge 0, x_{35} \ge 0, x_{36} \ge 0, x_{37} \ge 0$$

3. Model Solution and Analysis

LINGO 8.0 was used to solve the formulated model. The software was also used to analyze the solution.
Objective function value for maximum $P_1 = 55.7056$, while the values of quantity needed to achieve the maximum P_1 are as follows:

Drinks = 0.000
Breads = 0.000
Chocolate = 0.466
Snacks = 0.809
Toiletries = 0.371
Provisions = 1.235

Cosmetics = 2.282

Objective function value for maximum P_2 = 89.384, while the values of quantity needed to achieve the maximum P_2 are as follows:

Drinks = 0.000
Breads = 0.000
Chocolate = 1.643
Snacks = 0.000
Toiletries = 0.000
Provisions = 1.235
Cosmetics = 0.000

Objective function value for maximum P_3 = 77.3116, while the values of quantity needed to achieve the maximum P_3 are as follows:

Drinks = 0.000
Breads = 0.000
Chocolate = 1.643
Snacks = 0.000
Toiletries = 0.000
Provisions = 1.235
Cosmetics = 0.000

4. Result Discussion

It can easily be observed from the results above that the maximum profit for Covenant University Shopping Mall is the highest, P_2 = 89,384, when compared with the other two supermarkets. This can be attributed to the fact that most students patronize this particular supermarket because of its proximity from their hostels and lecture halls. The major items contributing to the profit are chocolate and provisions, which are student's delights.

However, for the SBS supermarket, the maximum profit is the next highest (P_3 =77.31). Most Faculty and staff patronize this supermarket. Few students patronize the supermarket because of the distance from student's center of daily activities. The same items coincidentally, contribute to the maximum profit.

The third supermarket with the lowest maximum profit, P_1 = 55.71, is the Covenant University Guest House Minimart. The reason for this is not far-fetched; few people patronize the minimart. The main reason for its location was to take care of guests' immediate needs, such as toiletries, cosmetics and so on. This explains why such items contribute significantly to the maximum profit.

In all, items like chocolate and provisions are very significant in maximizing the profits of all the three supermarkets.

5. Conclusion

In order to optimize the level of profit making in all the three supermarkets considered in this study, the factors responsible should be taken seriously. These items mostly in demand. The operations expenses notwithstanding, if the products or items such as chocolates, provisions and cosmetics are concentrated upon, the optimal profit would be achieved at the three supermarkets. The application of linear programming algorithm and LINGO software have really aided the results obtained.

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