A PRODUCTION OPTIMIZATION IN ASSEMBLY LINE AT KAWASAKI MOTORS PHILIPPINES CORPORATION USING LINEAR PROGRAMMING TECHNIQUE

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ABSTRACT

Kawasaki Motors Philippines is one of the most leading motorcycle brands in the Philippines. It has different units of motorcycle made not only in local, but also in the international market. The researchers were tasked to use Linear Programming of the Operations Research in the Assembly Line of Supply Chain Division as an optimizing tool. It has been found out that they need to come up with a new production plan to fully utilize their system and production. Linear programming is known for minimizing costs and maximizing profits of a certain production. The researchers came up with an idea of identifying the needed constraints in developing a Linear Programming Model to utilize the resources in the KMPC. The study focused on the Assembly Line which almost had the by parts up to the finished goods of Product H. The researchers found a way to minimize the production cost by using Linear Programming model. The researchers gathered the needed data from the company to solve the linear programming model. From their existing total production cost of Php 1,251,358,293.56, it has been minimized to Php 1,248,367,000.00 by using the Linear Programming in LINGO software. It has a difference of Php 2,989,253 of production cost that helps the company to gain more profit. The results obtained from the LP model gave a minimized production costs outcome which means that the formulated model successfully optimized the production.

Keywords: *Linear Programming, Assembly Line, Constraints, Minimized Production Cost*

INTRODUCTION

Manufacturing companies often face problems related to the productivity optimization and efficiency of the production line. A production optimization is essentially "production control" where you minimize, maximize, or target the production of the product in order to satisfy the customers' demand in relation to the available workers and raw materials and resources.[1]

In this manner, linear programming model was used in order to optimize the production of the company. There are computer application solvers or software that are available in showing the optimal solution of a mathematical model. Linear programming model is appropriate in optimizing the production of the company whether to minimize the production costs or maximizes the profit. In using linear programming model, all constraints and factors should be identified.

Linear programming is concerned with describing the interrelations of the components of a system. It is concerned with creating and arriving at the best design, given the technology, the required specifications, and stated objective.[2] It is a method of allocating resources in an optimal way. It is one of the most widely used operations research tools[3] to determine optimal resource utilization.[4]

Linear Programming is used to successfully model numerous real worlds' situations. From scheduling of airline routes to shipping different products from refineries to cities to finding an optimal solution for minimizing cost and maximizing profit of a manufacturing industry.[5]

Another research shows that linear programming has been widely applied in Breweries, as most managerial problems involve resource allocation. For example, management decision problems such as production planning, capital budgeting, personnel allocation, advertising and promotion planning are concerned with the achievement of a given objective (profit maximization or cost minimization) subject to limited resources (money, material, labor, time, etc.).[6]

The researchers want to contribute in the increase of both productivity and profitability and, at the same time, reducing the cost of the whole organization by constructing an optimized linear programming model. Developing of a flexible linear programming model procedure contributes to the goals of the research. In constructing the model, the researchers should consider the factors that may affect introduction optimization. This work aimed to be able to find an optimal solution in the industry, specifically in Kawasaki Motors Philippines Corporation (KMPC).

Conceptual Framework

A research paradigm was used by the researchers to show the data, process, and the output of the Linear Programming model.

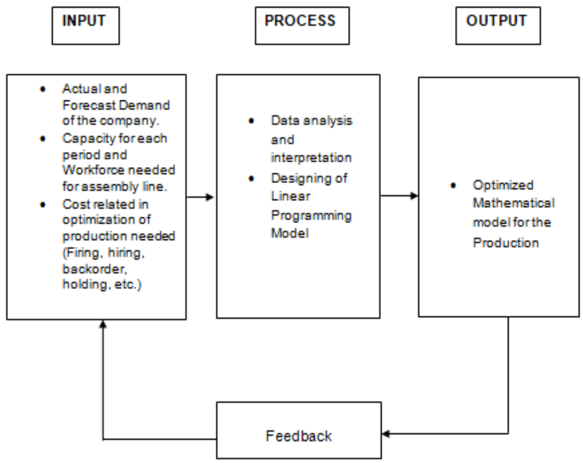

Figure 1. Research Paradigm

Objectives of the Study

The main objective of this research aimed to develop a Linear Programming model to optimize the production of Kawasaki Motors Philippines Corporation (KMPC). Specifically, this study aimed to:

1. identify the decision variables and constraints of the problem;
2. develop the linear programming model;

3. analyze the result of the Linear Programming model;

4. compare the result of linear programming model with KMPC's current production cost; and

5. propose the optimized production using Linear Programming model.

METHODOLOGY

The researchers used the applied research approach that solves specific problems and take action on certain issues. This involved investigating of causes and seeks answers to the problem face by the industrial organization. It required checklist and structured interview in collecting data. The gathering of information about determining the constraints needed was done by collecting the data from different departments of the company. In line with this, the approach for this project was in the area of Linear Programming (LP) techniques to solve business problems in manufacturing.

Data Analysis

In this study, the researchers primarily used the Linear Programming technique under Operations Research. A general linear programming procedure (setting of objective function, constraints and non-negativity restriction) has been applied to set the data gathered from KMPC into its mathematical model. In order to solve the mathematical expression, the LINGO software for a linear programming technique was used. The optimal solution generated by the LINGO software was compared against the existing company's performance of production optimization. After that, conclusions were made regarding the findings of the study.

Design of Constraints

ECONOMIC:

- Production costs, excluding labor, do not change over the planning horizon and thus are ignored.

- A unit produced, but not sold in a month, is counted as inventory for that entire month (end-of-month inventory).

- The mathematical model only focused on the production costs such as, price per parts, minimum wage of the assembly line workers, inventory costs, and standard working hours per day.

- Total production cost that has been compared to the model's result was also limited with the same constraints and excluded other unsaid costs.

ENVIRONMENTAL:

- The proposed mathematical equation needed for the production is subject for approval especially if there are weather occurrences such as typhoon, flood etc.

SOCIAL:

- The mathematical equation is accepted if the forecasted output could achieve within the operating days, without having a need for overtime.

POLITICAL:

- By using the model, it is important to check if there are no violated regulations set by the Job, Safety and Quality Departments of the Philippines.

HEALTH AND SAFETY:

- The model should undergo a mock production to see if the workers could do it in their normal workload and to avoid any health concerns that may arise in case the work would be in full load.

MANUFACTURABILITY:

- The demand for motorcycles should be taken into consideration by checking the demand could be achieved set by the model.

SUSTAINABILITY:

- There is chance for modification in the mathematical model depending on the needs of the customer, quality, and safety or production output.

- All other constraints (labor, other costs, etc.) should be included for further optimization of the model.

RESULTS AND DISCUSSION

Identification of decision variables and constraints.

Parameters

Identification of decision variables and constraints.

Parameters

T = planning-horizon length, in periods

t = index of periods, t = 1,2,…, T

D_t= forecasted number of units demanded in period t

N_t= number of units that can be made by one worker in

period t

C_t^P = cost to produce one unit in period t

C_t^W = cost of one worker in period t

C_t^H = cost to hire one worker in period t

C_t^L = cost to lay off one worker in period t

C_t^I = cost to hold one unit in inventory for period t

Definition of decision variables

The required optimal numbers of the following variable are denoted as follows:

P_t= the number of units produced in period *t*

W_t= the number of workers needed in period *t*

H_t= the number of workers hired in period *t*

L_t= the number of workers laid off in period *t*

I_t= the number of units held in inventory at the end of period *t*

The objective function for optimizing the production is formulated as shown below:

$$\sum_{t=1}^{T}(C_t^P P_t + C_t^W W_t + C_t^H H_t + C_t^L L_t + C_t^I I_t)$$

Min C = The list of constraints can be formulated as follows:

The Production-Capacity Constraints:

$$P_t \leq n_t W_t$$

The Work-force Constraints

$$W_t = W_{t-1} + H_t - L_t$$

The Inventory-balance Constraint

$$I_t = I_{t-1} + P_t - D_t$$

$$P_t, W_t, H_t, L_t, I_t \geq 0$$

5.2 Linear Programming Model for Kawasaki Motors

Philippines Corporation Assembly Line

Min C = $36752.779P_1 + 36752.779P_2 + 36752.779P_3 +$
$36752.779P_4 + 36752.779P_5 + 36752.779P_6 +$
$10,014.224W_1 + 12,370.512W_2 + 11,781.44W_3 + 12,959.584W_4$
$+ 10,014.224W_5 + 12,959.584W_6 +$
$0*H_1 + 0*H_2 + 0*H_3 + 0*H_4 + 0*H_5 + 0*H_6 +$
$0*L_1 + 0*L_2 + 0*L_3 + 0*L_4 + 0*L_5 + 0*L6 +$
$1.79I_1 + 1.79I_2 + 1.79I_3 + 1.79I_4 + 1.79I_5 + 1.79I_6$

Subject to:

$P_1 \leq 119.185W_1$
$P_2 \leq 147.229W_2$
$P_3 \leq 140.218W_3$
$P_4 \leq 154.239W_4$
$P_5 \leq 119.185W_5$
$P_6 \leq 154.239W_6$

$W_1 = 27 + H_1 - L_1$ → Number of workers from the previous period.

$W_2 = W_1 + H_2 - L_2$
$W_3 = W_2 + H_3 - L_3$
$W_4 = W_3 + H_4 - L_4$
$W_5 = W_4 + H_5 - L_5$
$W_6 = W_5 + H_6 - L_6$

$I_1 = P_1 - 4490$
$I_2 = I_1 + P_2 - 6300$
$I_3 = I_2 + P_3 - 5580$
$I_4 = I_3 + P_4 - 6599$
$I_5 = I_4 + P_5 - 5050$
$I_6 = I_5 + P_6 - 5870$

→ Forecast Demand from the month of December to May

$$P_t, W_t, H_t, L_t, I_t \geq 0$$

5.3 Analysis of the result of Linear Programming Model

Constraints	Existing Situation	Optimal Solution
Unit Produced	**Value**	**Value**
P_1	4460	4490
P_2	6216	6300
P_3	5600	5580
P_4	6512	6599
P_5	5032	5050
Workers Needed	**Value**	**Value**
W_1	35	37.73109 ≈ 38
W_2	37	42.85714 ≈ 43
W_3	35	39.85714 ≈ 40
W_4	37	42.85065 ≈ 43
W_5	37	42.43697 ≈ 42
W_6	33	38.1168 ≈ 38
Units held in Inventory	**Value**	**Value**
I_1	-30	0
I_2	-84	0
I_3	-20	0
I_4	-87	0
I_5	-18	0
I_6	-62	0
Workers Hired	**Value**	**Value**
H_1	8	10.73109 ≈ 11
H_2	2	5.12605 ≈ 5
H_3	0	0
H_4	2	2.993506 ≈ 3
H_5	0	0
H_6	0	0
Workers Laid-off	**Value**	**Value**
L_1	0	0
L_2	0	0
L_3	2	3
L_4	0	0
L_5	0	0.4136746 ≈ 1
L_6	4	4.320092 ≈ 4
Total Production Cost =	**₱ 1,251,358,293.56**	**₱ 1,248,367,000**

The number of produced units from the existing situation and from the optimal solution was different. The numbers of units required by the customer was achieved when it comes to the optimal solution of linear programming model. For workers needed in the optimal solution, the company needed to hire workers more than the existing numbers of workers available. The row of units held in inventory, the existing solution had a large number of inventories that had a large impact to the total production cost of the company. While in the optimal solution, it did not have an inventory that lessened the cost of production. For the workers hired, the company should add more workers to achieve the customer demand. The result from the LINGO software was P1, 248,367,000, while the company's current cost was P1, 251,358,293.56.

CONCLUSION

In making important business process decisions, strategies for solving a Linear Programming models can be made efficient to impart reliable results. Identifying the decision variables and constraints, parameters should be considered first to avoid miscalculations in developing the model. Three important constraints were identified that have a big impact for the total production cost. First set of constraint was Production-Capacity, to settle the number of workers available for the starting period and how many workers to be hired and laid off. Work-force size constraint limits the number of units that can be produced. Inventory-balance constraint dealt with the number of units that should be inside the warehouse if there were excess units produced.

In this study, a linear programming equation was developed to optimize the total production costs for the month of December-January. The linear programming model equated the sum of units produced costs, hiring and lay-off costs, and inventory holding costs over all periods.

For the analysis of the model, LINGO software was used to get the results. The forecast demands of the company and the proposed number of units to be produced were attained. The production needed additional workers to meet the necessary demand per month. Those workers should be hired for the month of December, January, and April, while workers to laid-off should be in the months of March and May. No inventories of product H were recorded in the warehouse because of the equal units of forecasted demand and actual outputs.

Compared to Kawasaki's existing production, the LP model result had lesser production cost. There was a difference of Php 2,989,253 in favor of the LP model. There were instances that the optimized solution had bigger cost on a certain month but it did not affect the total cost because of the lower costs on the following months. This study has helped the company to achieve an optimized cost compared to their existing process.

The researchers have proposed the results attained from the LP model that made their production costs more optimized. The data used in this research were average values obtained from the previous year transactions (December 2016-May 2017). According to its existing process, operational environment was relatively stable. Though there are times that demands are not necessarily met, the inventory fills up the insufficient units for the month. With Linear programming, demands were met and inventories were reduced. Adding of workers for the Assembly Line made an impact to meet the necessary production demand. Also having no costs for the hiring and firing of workers made those additional workers an advantage for the company to also reduce the total production costs.

RECOMMENDATIONS

Linear programming has a wide range of practical methodology in solving processing problems. The concept behind the formulation of production problem into linear programming models is quite simple and provides an analytical methodology as basis for factual decision-making in the industry. The application requires business data to be interpreted in a meaningful way and to be quantified as linear relationships existing between objective function and its constraints. Although this requirement in the application of linear programming may seem restrictive, many real-world business problems can be formulated in this manner. Results of such models interpreted in a very accurate business data can really have an edge to come up with important decisions on optimization of production output.

The main problem that can be encountered in making this study is usually associated with getting sufficient data and having these accurately. Having an insufficient data may lead uncertainties and wrong results which basically informs about product optimization. Accurate and adequate data provide linear programming models that are reliable for the probable outcomes due to operational changes.

For the improvement of this study, and to achieve better results, the researchers highly recommend to consider all needed factors to fully attain the whole production costs of the company. Since linear programming is a good tool in performing managerial decision making problems related to the production, Products available under changing operational constraints, identification of fast selling products and benchmark to serve as reference performance indicators have been well-discussed in relations to the outcome of the original problem.

LINGO software has been used in simulating the model of this study, it is also recommended to use other programming software, which is comfortable to the users. Ms Excel, POM-QM, and LINDO software are just examples that can also be used as simulators.

The linear programming model in this study can also be modified based on what the company needs or what the problem dictates to attain accurate results of the model. Also, remember to consider the right parameters, variables, and constraints in formulating a linear programming model. If there are problems that can be encountered that deals with minimizing the costs, using a Linear programming strategy in solving the problem is highly recommended given the fact that all constraints were accurately considered.

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