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Product Mix Optimization at Minimum Supply Cost of an Online Clothing Store using Linear Programming

Marivic G. Molina*[1]

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Abstract: Starting a small business with little capital can be very challenging to new business owners. Oftentimes, they resort to using trial and error in managing their finances especially when it comes to purchasing products from their suppliers. This study considered an online clothing store as a case study. The data provided by the online clothing store owners were used to estimate the parameters of the linear programming model. The LP model was solved using QM for Windows software to determine the most economical product mix to be purchased by the online clothing store owners from their suppliers and therefore provide an optimum solution. It was recommended that the owners should continue using linear programming in determining the number of each product to be purchased from the suppliers while minimizing the overall supply cost. Likewise, as their online clothing store grows, they must also explore the possibility of using linear programming to determine the optimal product mix for maximum profit.

Keywords: *Linear Programming, Online Clothing Store, Optimization, Product Mix, Simplex Method, Supply Cost,*

1. Introduction

Starting a small business need not involve a big amount of money. Instead, the business owners should have the ability to use and manage as little capital as possible to put up the business. Moreover, with good money management abilities, any venture could develop into a success story.

However, not all business owners are good at handling finances. Oftentimes, since most businesses consist of several product lines – groups of items featuring similar characteristics – challenges in handling finances usually happen in product mix determination.

Product mix is the combination of the total product lines that a company offers [1]. Woubante [2] enumerated four important reasons that make product mix determination essential to the success of a business. First, it provides the best opportunity of meeting customers' needs. Second, it shapes the company's image and its brand. Third, it keeps the company to stay focus on its core business. Lastly, it limits the company in the number of products it is able to offer.

To be able to determine what mix of product lines produces output at lowest cost while maintaining the desired level of quality, a cost minimization technique must be utilized. A technique that involves either minimization or maximization of a quantity is called linear programming (LP). In fact, one of the most common linear programming applications is the product mix problem [3]. According to Shaheen and Ahmad [4], in determining an optimal solution among alternatives to meet a specified objective function limited by various constraints, the best method to be used is linear programming.

Minimization of costs can also be attained if the business is done online. Creating a website or a page can easily be done due to a variety of free or affordable programs and ready-made templates in the internet. Furthermore, with the advancement of technology, promoting the products becomes easier and cheaper since thousands of people can easily be reached through social networking sites.

In this connection, this study focused on product mix determination by considering an online clothing store as a case study with the aim of applying linear programming in determining the most economical product mix.

2. Problem Statement

A budding online clothing store that has been operating for two months as of the writing of this study is currently selling two product lines: dresses and blouses. Each product was obtained from four suppliers: two dress suppliers (A and B) and two blouse suppliers (C and D). Each supplier offers a fixed price on their products for a corresponding minimum number of pieces to be purchased. However, the price depends on the size of the blouse or dress. Furthermore, the four suppliers offer policy in charging shipping fees. For the soft opening of the online clothing business, the clothes they sold were obtained from the four suppliers through trial and error. With this, the problem addressed here was to determine how many of each product should be obtained from the four suppliers while minimizing the overall supply cost.

3. Objective of the Study

The objective of this study was to apply linear programming in determining the most economical product mix.

4. Literature Review

Linear programming has numerous real-life applications [5]. Some of the enumerated, with corresponding examples provided, basic applications of linear programming techniques are: (a) Financial

[1] *College of Science, Pamantasan ng Lungsod ng Maynila, Gen. Luna cor. Muralla St.,Intramuros, Manila, Philippines 1002*
* *Corresponding Author: Email: molinamg30@gmail.com*

Applications which were discussed under three sections – Portfolio Selection problem, Financial Mix, and Investment Strategies; (b) Marketing Application which was discussed under two sections – Media Selection and Marketing Strategy; (c) Management Applications which considered the Production Scheduling and Manpower Planning Application; (d) Transportation Model; (e) Assignment Model; (f) Urban Planning; (g) Diet Problem; (h) Currency Arbitrage; (i) Blending Model; and (j) Environmental Protection. However, they argued that despite the aforementioned real-life applications, the general public does not seem to give the desired level of recognition and acceptance to linear programming techniques. Hence, a reconciliation between the seemingly apathy to linear programming techniques and the benefits derived therein was deemed necessary. Furthermore, they recommended that the main thrust of the study become a national policy, that is, to make the teaching and learning of operations research and its applications a national priority.

Consistently, Miller [6] regarded linear programming as a generalization of linear algebra which is used to successfully model an overwhelming number of real life problems ranging from scheduling airline routes to shipping oil from refineries to cities for meeting the minimum daily requirements through finding inexpensive diets. Similar with Kanu et. al. [5], they described several types of problem that can be handled by linear programming and solved them using the simplex method.

Akpan and Iwok [7] applied the concept of simplex algorithm for maximizing profit by allocating raw materials to competing variables (big loaf, giant loaf and small loaf) in bakery. They found out that small loaf, followed by big loaf contribute objectively to the profit and further recommended that in order to maximize profit, more of small loafs and big loafs must be produced.

Similarly, with the aim of profit optimization of an Ethiopian chemical company, Maurya et. al. [8] utilized a linear programming model. Using MS-Excel solver, the model equations with adequate restraints considering manufacturing limitations were solved.

Olayinka et. al. [9] examined the impact of linear programming to profit maximization with the available resources in entrepreneur decision making process. They considered a fast food firm, Kingston Joe Nigeria Limited, and analyzed its problem in the production of meat pie, chicken pie and donut due to an increment in the price of raw materials. They obtained an optimal solution using simplex method and therefore recommended the discontinuity of production of chicken pie or donut or both to concentrate with the production of meat pie.

The use of linear programming to determine the optimal product mix for profit maximization was likewise demonstrated by Sengupta [10]. He found the optimal product mix using the generic approach.

Yahya [11] demonstrated the applicability of the use of linear programming in the manufacturing industry. They determined the maximum profit that would accumulate to the KASMO Industry Limited, Osogbo, Nigeria based on the costs of raw materials. The results showed that if the company concentrates mainly on the unit sales of their medicated soap product and ignores other forms of sales packages, optimal monthly profit level would be attained.

To increase the production of toys and the profit, Shaheen & Ahmad [4] dealt with the idea of optimum utilization of resources. They used linear programming to adjust the resources in order to achieve the maximum profit in the production of toys under given constraints.

Woubante [2] used linear programming as a quantitative decision making tool for the optimization problem of product mix. He considered an apparel industrial unit in Ethiopia and recorded resource utilization as the major constraint in the apparel manufacturing industry. He concluded that to determine the apparel company's optimal product mix, the company should use quantitative research methods of linear programming.

Alagoz et. al. [12] developed a multi-product linear programming model which is based on hypothetical data under the constraint of resources to obtain output through certain mix proportions of multiple raw material input and to determine the optimal product mix that maximizes profitability in the flour industry in which products are obtained using the mixtures of these outputs.

Nabasirye et. al. [13] utilized linear programming in formulating a least-cost diet. They have identified cost of feed as a major factor in the overall cost of production and thus applied linear programming to minimize this cost. Moreover, they discussed the computer output and particularly emphasized the importance of proper interpretation of the sensitivity report based on Microsoft Excel® Solver output format.

Savsar [14] considered a chain of gas station and studied its maintenance problem. He established the optimum schedules for preventive maintenance operations using linear programming and maintenance model. Additionally, to determine feasibility of the proposed preventive maintenance schedule, he carried out a detailed cost analysis.

According to Kumar et. al. [15], linear programming has been effectively used in the hospitals to solve the nurses' scheduling problem. They illustrated this by presenting an example of nurse scheduling for 8-hour shift and finding the optimum solution by Excel solver. They emphasized that though the nurse scheduling problem seeks to determine the minimum number of nurses to be employed so that a sufficient number of nurses are available to handle the hospital needs, the primary aim of the study was the maximization of the fairness of the schedule.

Workie et. al. [16] applied linear programming to minimize the costs of resources that can yield more gross income in determining the type and quantity of textile dyed fabrics. In conclusion, they highly recommend the use of linear programming and its techniques to managers in making decisions regarding their employees and resources utilization rather than using trial and error.

5. Methodology

This study used a data collection procedure that was quantitative in nature. The data were obtained from the personal interview with the online clothing business owners and their corresponding suppliers' existing records. The relevant information on the price (in Philippine Peso, ₱) per piece offered by the suppliers according to the size of the product to be purchased was summarized in Table 1.

Table 1. Price (in Philippine Peso, ₱) per Piece offered by the Suppliers according to the Size of the Product

Supplier	Size				
	S	M	L	XL	XXL
A	₱ 220	₱ 240	₱ 260	₱ 280	-
B	₱ 200	₱ 220	₱ 240	₱ 260	-
C	₱ 90	₱ 100	₱ 110	₱ 120	₱ 130
D	₱ 110	₱ 120	₱ 130	₱ 140	₱ 150

Table 2 shows the information on the minimum number of pieces per purchase offered by the four suppliers.

Table 2. Minimum Number of Pieces per Purchase offered by the Four Suppliers

Supplier	A	B	C	D
Minimum number of pieces per purchase	10	6	30	25

Based on the turnout of sales of the online clothing store's soft opening, the demand for each product according to size is shown in table 3.

Table 3. Demand of each Product according to Size

Product	Size				
	S	M	L	XL	XXL
Dress	40	20	30	10	0
Blouse	40	50	60	30	20

The shipping fees (in Philippine Peso, ₱) charged by the four suppliers based on the specified number of pieces per product were depicted in table 4.

Table 4. Shipping Fees (in Philippine Peso, ₱) Charged for a Specified Number of Pieces per Product

Dresses Suppliers				Blouses Suppliers			
A		B		C		D	
Quantity (Pieces)	Shipping Fee (₱)	Quantity (Pieces)	Shipping Fee (₱)	Quantity (Pieces)	Shipping Fee (₱)	Quantity (Pieces)	Shipping Fee (₱)
		1 – 6	165	1 – 10	170	1 – 10	165
		7 – 12	247	11 – 20	255	11 – 20	247
		13 – 18	329	21 – 30	340	21 – 30	329
		19 – 24	411	31 – 40	425	31 – 40	411
		25 – 30	493	41 – 50	510		
		31 – 36	575	51 – 60	595		
		37 – 42	657	61 – 70	680		
10 or more	Free Shipping	43 – 48	739	71 – 80	765		
		49 – 54	821	81 – 90	850		
		55 – 60	903	91 – 100	935		
		61 – 66	985	101 – 110	1, 020	41 or more	Free shipping
		67 – 72	1, 067	111 – 120	1, 105		
		73 – 78	1, 149	121 – 130	1, 190		
		79 – 84	1, 231	131 – 140	1, 275		
		85 – 90	1, 313	141 – 150	1, 360		
		91 – 96	1, 395	151 – 160	1, 445		

In order to save more capital, the online clothing store owners would like to avail of the free shipping offered by suppliers A and D. Moreover, they restricted the shipping fee to be paid for suppliers B and C to ₱ 1, 000 each.

5.1. Linear Programming Model Formulation

Linear Programming is a method of solving problems that involve a quantity to be optimized (maximized or minimized) when that quantity is subject to certain restrictions [17]. It is considered as the most prominent operations research (OR) technique that is designed for models with objective and constraints that are all linear functions [18]. An LP model consists of three basic components, namely: decision variables, objective function, constraints. Decision variables are the variables to be determined; objective function is the goal to be optimized (maximize or minimize); and the constraints are the restrictions or conditions to be satisfied [18].

5.2. Assumptions of the LP Model

Before formulating the LP Model, the following assumptions were taken into consideration:

1. Proportionality: The contribution of each decision variable in the objective function and in the constraints is directly proportional to the value of the variables [19].
2. Additivity: The total contribution of all the variables in both the objective function and the constraints is the sum of the individual contributions of each variable [19].
3. Certainty: All the objectives and constraints coefficients are deterministic and do not change during the period being studied [19].
4. Divisibility: The solutions need not be in whole numbers and may take any fractional value [20]. However, this assumption may not be valid in the product mix problem since the product under consideration are dresses and blouses.

5.3. Steps in Formulating LP Model

The steps in LP Model formulation are discussed as follows [21]:
Step 1. Clearly define the decision variables of the problem and express them as $x_1, x_2, x_3, \ldots, x_n$.
Step 2. List the constraints and translate them into linear inequalities in terms of the pre-defined decision variables.
Step 3. Clearly identify the objective function which is required to be maximized or minimized and express it in terms of the pre-defined decision variables, $z = f(x)$.

5.4. Standard Form of LP Model

The standard form of LP Model with m constraints and n decision variables is as follows [20]:

Maximize (or Minimize): $z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$

Subject to:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n &= (\text{or} \le \text{or} \ge) b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n &= (\text{or} \le \text{or} \ge) b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n &= (\text{or} \le \text{or} \ge) b_m \\ x_1, x_1, \ldots, x_n &\ge 0 \end{aligned}$$

Observe that the constraints may be expressed as equations (=) or inequalities (≥ or ≤). However, strict inequalities such as ">" or "<" are not allowed for it may lead to vague problems.

5.5. Formulation of the LP Model of the Product Mix Optimization at Minimum Supply Cost of the Online Clothing Store

The information collected from the online clothing store owners was analysed to provide estimates for the LP model. To set up the model the steps in LP model formulation are used as follows:

Step 1: The problem seeks to determine the number of dresses and clothes to be purchased from each of the four suppliers, thus leading to the following definition of decision variables:

Let
x_1 be the number of small size dresses purchased from supplier A
x_2 be the number of small size dresses purchased from supplier B
x_3 be the number of medium size dresses purchased from supplier A
x_4 be the number of medium size dresses purchased from supplier B
x_5 be the number of large size dresses purchased from supplier A
x_6 be the number of large size dresses purchased from supplier B
x_7 be the number of extra-large size dresses purchased from supplier A
x_8 be the number of extra-large size dresses purchased from supplier B
x_9 be the number of small size blouses purchased from supplier C
x_{10} be the number of small size blouses purchased from supplier D
x_{11} be the number of medium size blouses purchased from supplier C
x_{12} be the number of medium size blouses purchased from supplier D
x_{13} be the number of large size blouses purchased from supplier C
x_{14} be the number of large size blouses purchased from supplier D
x_{15} be the number of extra-large size blouses purchased from supplier C
x_{16} be the number of extra-large size blouses purchased from supplier D
x_{17} be the number of double extra-large size blouses purchased from supplier C
x_{18} be the number of double extra-large size blouses purchased from supplier D

Step 2: The problem has sixteen constraints and they are identified as follows:

Constraints based on the minimum number of pieces to be purchased

$$x_1 + x_3 + x_5 + x_7 \geq 10$$
$$x_2 + x_4 + x_6 + x_8 \geq 6$$
$$x_9 + x_{11} + x_{13} + x_{15} + x_{17} \geq 30$$
$$x_{10} + x_{12} + x_{14} + x_{16} + x_{18} \geq 25$$

Constraints based on the maximum number of pieces to avail of at most Php 1, 000 shipping fee or free shipping

$$x_2 + x_4 + x_6 + x_8 \leq 66$$
$$x_9 + x_{11} + x_{13} + x_{15} + x_{17} \leq 100$$
$$x_{10} + x_{12} + x_{14} + x_{16} + x_{18} \geq 41$$

Demand Constraints

$$x_1 + x_2 \geq 40$$
$$x_3 + x_4 \geq 20$$
$$x_5 + x_6 \geq 30$$
$$x_7 + x_8 \geq 10$$
$$x_9 + x_{10} \geq 40$$
$$x_{11} + x_{12} \geq 50$$
$$x_{13} + x_{14} \geq 60$$
$$x_{15} + x_{16} \geq 30$$
$$x_{17} + x_{18} \geq 20$$

Non-negativity constraints

$$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0, x_6 \geq 0,$$
$$x_7 \geq 0, x_8 \geq 0, x_9 \geq 0, x_{10} \geq 0, x_{11} \geq 0, x_{12} \geq 0,$$
$$x_{13} \geq 0, x_{14} \geq 0, x_{15} \geq 0, x_{16} \geq 0, x_{17} \geq 0, x_{18} \geq 0,$$

Step 3: Objective Function

The objective function seeks to minimize the total supply cost which includes the shipping cost. However, since the amount of shipping fee depends on the number of pieces purchased, the shipping cost can be computed and likewise added after determining the number of pieces to be purchased per product and it need not be reflected in the objective function. Hence, the objective function is

$$z = 220x_1 + 200x_2 + 240x_3 + 220x_4 + 260x_5 + 240x_6 + 280x_7 + 260x_8 + 90x_9 + 110x_{10} + 100x_{11} + 120x_{12} + 110x_{13} + 130x_{14} + 120x_{15} + 140x_{16} + 130x_{17} + 150x_{18}$$

Therefore, the LP model, minimizing the supply cost is

Minimize:

$$z = 220x_1 + 200x_2 + 240x_3 + 220x_4 + 260x_5 + 240x_6 + 280x_7 + 260x_8 + 90x_9 + 110x_{10} + 100x_{11} + 120x_{12} + 110x_{13} + 130x_{14} + 120x_{15} + 140x_{16} + 130x_{17} + 150x_{18}$$

Subject to:

$$x_1 + x_3 + x_5 + x_7 \geq 10$$
$$x_2 + x_4 + x_6 + x_8 \geq 6$$
$$x_9 + x_{11} + x_{13} + x_{15} + x_{17} \geq 30$$
$$x_{10} + x_{12} + x_{14} + x_{16} + x_{18} \geq 25$$
$$x_2 + x_4 + x_6 + x_8 \leq 66$$
$$x_9 + x_{11} + x_{13} + x_{15} + x_{17} \leq 100$$
$$x_{10} + x_{12} + x_{14} + x_{16} + x_{18} \geq 41$$
$$x_1 + x_2 \geq 40$$
$$x_3 + x_4 \geq 20$$
$$x_5 + x_6 \geq 30$$
$$x_7 + x_8 \geq 10$$
$$x_9 + x_{10} \geq 40$$
$$x_{11} + x_{12} \geq 50$$
$$x_{13} + x_{14} \geq 60$$
$$x_{15} + x_{16} \geq 30$$
$$x_{17} + x_{18} \geq 20$$
$$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0, x_6 \geq 0,$$
$$x_7 \geq 0, x_8 \geq 0, x_9 \geq 0, x_{10} \geq 0, x_{11} \geq 0, x_{12} \geq 0,$$
$$x_{13} \geq 0, x_{14} \geq 0, x_{15} \geq 0, x_{16} \geq 0, x_{17} \geq 0, x_{18} \geq 0$$

6. Results and Discussion

The aforementioned LP model was solved using the simplex method. To hold the simplex procedure, the QM for Windows software was used. The optimal solution report for this model is as follows:

Table 5. QM for Windows' Optimal Solution Report for the LP Model

Variable	Status	Value
x_1	NONBasic	0
x_2	Basic	40
x_3	NONBasic	0
x_4	Basic	20
x_5	Basic	24
x_6	Basic	6
x_7	Basic	10
x_8	NONBasic	0
x_9	NONBasic	0
x_{10}	Basic	40
x_{11}	NONBasic	0
x_{12}	Basic	50
x_{13}	Basic	50
x_{14}	Basic	10
x_{15}	Basic	30
x_{16}	NONBasic	0
x_{17}	Basic	20
x_{18}	NONBasic	0
surplus 1	Basic	24
surplus 2	Basic	60
surplus 3	Basic	70
surplus 4	Basic	59
slack 5	NONBasic	0
slack 6	NONBasic	0
surplus 7	NONBasic	0
surplus 8	NONBasic	0
surplus 9	NONBasic	0
surplus 10	NONBasic	0
surplus 11	NONBasic	0
surplus 12	NONBasic	0
surplus 13	NONBasic	0
surplus 14	NONBasic	0
surplus 15	NONBasic	0
Optimal Value (z)		46280

Hence, the optimal solution is

$$x_2 = 40,\ x_4 = 20,\ x_5 = 24,\ x_6 = 6,\ x_7 = 10,\ x_{10} = 40,\ x_{12} = 50,\ x_{13} = 50,\ x_{14} = 10,\ x_{15} = 30,\ x_{17} = 20$$

$$x_1 = x_3 = x_8 = x_9 = x_{11} = x_{16} = x_{18} = 0$$

$$z = ₱\ 46,280$$

Based on the optimal solution, the online clothing store owners must purchase 24 large size dresses and 10 extra-large size dresses from supplier A; 40 small size dresses, 20 medium size dresses, and 6 large size dresses from supplier B; 50 large size blouses, 30 extra-large size blouses, and 20 double extra-large blouses from supplier C; and 40 small size blouses, 50 medium size blouses and 10 large size blouse from supplier D for a minimum supply cost of ₱ 46, 280.

Now, considering the shipping fee charged by the suppliers, we have

For supplier A, it offers free shipping provided that the minimum number of dresses (at least 10) was satisfied. Based on the optimal solution obtained, the total number of dresses to be purchased is 34, hence free shipping fee may be availed.

For supplier B, since based on the optimal solution obtained, the total number of dresses to be purchased is 66, hence the shipping fee to be charged is ₱ 985.

For supplier C, since based on the optimal solution obtained, the total number of blouses to be purchased is 100, hence the shipping fee to be charged is ₱ 935.

For supplier D, since based on the optimal solution obtained, the total number of blouses to be purchased is 100, hence free shipping may be availed.

Therefore, adding the shipping fees (₱ 985 + ₱ 935 = ₱ 1, 920) charged to the optimal supply cost (₱ 46, 280), the most economical total supply cost is ₱ 48, 200.

The most economical product mix (in Philippine Peso, ₱) is summarized in table 6.

Table 6. Most Economical Product Mix (in Philippine Peso, ₱)

Supplier	Size					Shipping Fee	Total Amount
	S	M	L	XL	XXL		
A	0	0	₱ 260 x 24 = ₱ 6, 240	₱ 280 x 10 = ₱ 2, 800	-	Free shipping	₱ 9, 040
B	₱ 200 x 40 = ₱ 8, 000	₱ 220 x 20 = ₱ 4, 400	₱ 240 x 6 = ₱ 1, 440	0	-	₱ 985	₱ 14, 825
C	0	0	₱ 110 x 50 = ₱ 5, 500	₱ 120 x 30 = ₱ 3, 600	₱ 130 x 20 = ₱ 2, 600	₱ 935	₱ 12, 635
D	₱ 110 x 40 = ₱ 4, 400	₱ 120 x 50 = ₱ 6, 000	₱ 130 x 10 = ₱ 1, 300	0	0	Free Shipping	₱ 11, 700
			Total Amount				₱ 48, 200

7. Conclusion

This study focused on product mix determination by considering an online clothing store as a case study with the aim of applying linear programming in determining the most economical product mix. Upon applying the simplex method through the use of QM for Windows software, it was found that the most economical product mix to be purchased is 24 large size dresses and 10 extra-large size dresses from supplier A; 40 small size dresses, 20 medium size dresses, and 6 large size dresses from supplier B; 50 large size blouses, 30 extra-large size blouses, and 20 double extra-large blouses from supplier C; and 40 small size blouses, 50 medium size blouses and 10 large size blouse from supplier D. Hence, adding the shipping fees (₱ 1, 920) charged to the optimal supply cost (₱ 46, 280), the most economical total supply cost is ₱ 48, 200.

8. Recommendation

The researcher therefore recommends that the online clothing store owners should continue using linear programming in determining the number of each product to be purchased from the four suppliers while minimizing the overall supply cost. Likewise, as their online clothing store grows, they must explore the possibility of using linear programming to determine the optimal product mix for maximum profit.

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