Application of linear programming model for machinery mix purchasing decision during the startup plan of garment companies

BY

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ABSTRACT

The new business starter in the garment industry is facing great challenge with respect to improper resource utilization mainly budget and space. This is mostly due to traditional planning method of machinery allocation technique. Inconvenient production and productivity achievement also the result of improper investment plan during the startup phase. The aim of this is study is to propose an integer programming approach that considers the fluctuations of the resource demands for optimal and dependable allocation of production machines. At the heart of the approach there are techniques for optimally partitioning the time-horizon into intervals of re-structuring phase variable lengths and for reliably estimating the resource demands in each interval. Results shows that the proposed approach allocates garment production machines successfully in a linear programing mathematical modeling where the dependability requirement has been strictly considered.

Keywords: Linear programing; Startup plan; Resource allocation

INTRODUCTION

The success of any apparel manufacturing firms mainly depends on the proper allocation and usage of available resources including time, material and labour resources (Woubante, 2017). Manufacturers are outstanding for better resource allocation not only to maximize profits, but also to enhance its quick responsiveness for better competitive advantage. (Lee, 2013). In order to meet the companies planned objective, the available resources such as machineries should be allocated or selected based on the desired operations will be performed and the amount of output to be expected from each individual machines (Ashraf et. al, 2016). Different methods were designed to achieve the most effective use of limited resources to reach at decisions on best utilization of scarce resources and also to implement the decisions effectively (Osagie, and Icheme, 2018). The application of linear programing is the most popular and suitable tool among the common methods of resource allocation techniques used in the manufacturing industry (Darlington and Osaremwinda, 2018).

However Allocating of machinery resources for the entire production plan is limited to different restrictions. The most critical concern during the startup phase of establishing an apparel business is to make an optimum decision about machinery investment with reasonable mixes. This startup task in the apparel business is restricted to different constraints such as capacity, working capital space requirement and technical reasons (Shaheen and Ahmad, 2015). Decision making regarding the quantity of machineries to be purchased was based on trial and error method which yielded sub-optimal results (Subramaniam et. al, 2008). Poor utilization of equipment or machine investment and improper space usage is the result of random machinery investment plan. Conducting an optimum allocation approach during the startup phase of any business establishment is considered to satisfy many requirements and parameters including the available space, allocated capital and the planed output of the company (Oladejo et. al, 2019).

The country Ethiopia has placed significant policy emphasis on the textiles and garment sector, the country has located this sector as prioritized segment on its second growth and transformation plan (GTP II), this sector is expected to play a vital role to boost the country’s economy in line with decreasing unemployment as this sector is labour intensive and maximize the export capacity for hard currency (Tesfaye et al., 2016). Because of this national strategic concern, there is a remarkable initiation of launching new garment industries by both local and foreign investors (ETIDI, 2014). From the researcher's investigation, most of Ethiopian garment manufacturing startup plan depended on trial and error method of decision making which results improper utilization of machineries and space. This gap inspires the researcher to apply linear programing model application during garment manufacturing startup plan in order to make realistic decisions for machinery verities before purchasing activity is done. While investors purchase their machines without detail justification and analysis, they may be missed the most efficient machines (i.e. buy in small number) and instead they might behave an excess number of machine types which may have minimum contribution (Tesfaye et al., 2016). The second potential challenge is related to space utilization in which machines or equipment’s having least production contribution may be cover the maximum area of the production space, as a result, space limitation will happen for the most important machines /equipment’s (Osagie, and Icheme, 2018). And thirdly the time value of money is a vital issue for any business organization, however because of improper machinery sourcing plan, company’s budget will be invested on unrequired machines /equipment’s.

Ethiopian Institute of Textile and Fashion Technology Institute has been purchased new garment factory named NARGA Garment Production and Teaching Center from Ethiopian development bank. The university wants to use this factory for income generating and students practical teaching center. Because of the factory is very old, EiTEX wants to modify and restructure the factory as a new manner to suite it for both production and teaching purpose. According to this, the institute plans different restructuring methods. Among those methods, purchasing new machineries and replacing equipment’s are the first prioritized activity. According to the institute strategic plan for 2022, 1,000,000.00 ETB capitals are allocated for the first restructuring phase. Therefore, during machine layout and equipment purchasing phase, we must consider the space requirements that includes student’s demonstration space for teaching area in each production section without interrupt the normal production task. The aim of this paper was to study the optimum machinery mixes to be purchased for this company by the help of linear programing model. The Linear programming model is a mathematical instrument used for solving managerial decision difficulties (Osagie, and Icheme, 2018).

1. Research methods

Case company: Narga Garment Production and Teaching Center, Ethiopian Institute of Textile and Fashion Technology (EiTEX), Bahir Dar University, Bahir Dar, Ethiopia.

Data collection

The secondary data sources have been drawn from the institute stakeholder's manly office of apparel production research and innovation center (**APRIC**) under Ethiopian institute of textile and fashion technology. The objective of performing this secondary data is to know the total capital which allocates for machine purchasing purpose in the first phase, the type of machines (Table 2) that the institute wants to purchase and the planned daily production volume.

a. Secondary data

Table 1, Allocated capital and planned production capacity

Total allocated capital	ETB 1,000,000
Type of machine must be purchase	Sewing machine, spreading machine, fusing
Planned production target per day with basic shirt equivalent	480 shirts per day

Source: EiTEX strategic plan document for 2022

Table 2, Machine types to be purchased and their corresponding estimated price

S/N	Type of machines planned to be purchased	Estimated unit price [ETB]	Reference for machine pricing
1	Sewing machine	12000	Amazona, 2020
2	Fusing machine	40,000	Amazonb, 2019
3	Band knife cutting machine	35,000	Amazonc, 2019
4	Spreading machine	300,000	Alibaba, 2019

a. Primary data

The primary data have been conducted with the physical presence of the researcher on the case company. During the field study, actual measurements have been taken for the space requirements of each single machine (including sewing machine, spreading machine, fusing machine and band knife cutting machine). The total available space for each section has been measured from the existing company as indicated in table 3.

Table 3, Machine type with space requirement (Direct measurement result taken from the existing case factory).

S/N	Machine type	Space requirement per machine [m^2]	Total available space for each section [m^2]
1	Sewing machine	1.4	126
2	Fusing machine	5	120
3	Band knife	9	
4	Spreading machine	36	
5	Learning area per one group	6	

2. Result and discussion

The available space allocated for single needle and over lock sewing machine is 126 m^2 and the total available space allocated for spreading machine, fusing machine and band knife is 120 m^2**.** As we explain in the introduction section, the institute needs to use this factory for student's practical demonstration class and income generation purpose, so that the space requirement of student's demonstration must be taken to in account during machine allocation of each department. Then, we expect at least one group of students (6 students per group) must be inter to the production area at a time period for practical class.

Based on this, the company has the following planned production amounts per day from each type of machines. 16 full sleeve shirts from one sewing machine, 500 fused garment parts from each fusing machine, 800 cut garment components per band knife machine and 3 spreading lays with 60 fabric plies per spreading table will be expected as a planned production. In addition to this, a minimum of one group and maximum of two groups of students will inter to the machine area at a time period for practical class (6 students per group).

Note The estimation of production volume is calculated with men's shirt equivalent (**Table 4**). Based on the Ethiopian standard time of one shirt which has 30 minutes per shirt and it gives 16 shirts per individual machines within 8 hours working time. And the company plans to produce at least 480 shirts per day as a production center, so a minimum of 30 sewing machines are needed to get the desired daily output. At least one machine should be purchase for each type to accomplish the anticipated output.

Formulating mathematical model

According to the planned capacity of sewing room, one band knife cutting machine is enough for this project passé and one up to two machines should be purchased for fusing and spreading work. The number restriction of fusing machine, spreading machines and band knife cutting machine is based on the capacity of sewing rooms that can be absorb the all works that produce in spreading / cutting section, fusing machine and ban knife cutting machine. So that the allocated 1,000,000.00 Birr capital should be distributed properly throughout each machine types and the machine mix to meet the planned production goal and students practical learning center based on the primary and secondary data input summarized in table 4, .To solve this optimization problem the following linear programming producers have been employed by the researcher

Step 1: defining key - decision variables

Step 2: setting objective functions to maximize the total production and space utilization

Step 3: writing mathematical expressions for the capital, and space constraints.

Step 4: restricting the key-decision variables not to be negative values

Step 5: Solving the mathematical model developed through step 1 to step 4

Table 4, summarized list of constraints and the planned production

Type of Machineries Needed	Planned production output/day/machine	Cost/machine [ETB]	Space requirement
Single needle sewing machine	16 shirts	12000	1.4
Fusing machine	500 fused components	40,000	5
Band knife	800 cut components	**35**,000	9
Spreading machine	3 spread lays	300,000	36
Total allocated budget		1,000000.00	

Step 1: set the decision variables

X_1 = the number of swing machines to be purchased

X_2 = the number of fusing machines to be purchased

X_3 = the number of band knife machines to be purchased

X_4 = the number of spreading machine to be purchased

X_5 = the number of student groups will visit at time period

Step 2: Define the Objective Function

$$Maximize\ Z = 16x1 + 500x2 + 800x3 + 3x4 + x5 \qquad (1)$$

Step 3: list of constraints

For the objective function, the estimated output from each machine type has been taken for the coefficient of decision variables. But in case of constraints, both budget and space constraints are affecting the objective function. The budget constraints has been formulated by taking the machine prices as a coefficient of decision variables written at the left hand side (LHS) with respect to the total allocated budget written at the right hand side (RHS). For the space constraint, the space requirement for each machine is considered as the coefficient of decision variables to be written at the left hand side (LHS) with respect to the total available space to be written at the right hand side (RHS). The sign restriction is based on the maximum and minimum amount of machines to be purchased according to the planned production volume and the maximum available space can accommodate the planned machineries.

$$12000x1 + 40000x2 + 35000x3 + 300000x4 < 1{,}000{,}000 \,\}\, budget\ constraint \qquad (2)$$

$$\left.\begin{matrix} 5x2 + 9x3 + 36x4 + 6x5 \leq 120 \\ and\ \ 1.4x1 + 6x5 \leq 126 \end{matrix}\right\} space\ constraint \qquad (3)$$

Step 4: The non-negativity restriction

At a minimum value, at least 1 machine should be purchased form each type of machine verities and a minimum of one group of students must be attained for practical teaching during the production time. Based on this logic, the following equation is developed for the purpose of sign restriction.

Sign restrictions

$$\mathrm{x1} > 30, \mathrm{x5} \leq 2, \mathrm{x2} + \mathrm{x3} + \mathrm{x4} \leq 5\} \qquad (4)$$

Optimum solution model for purchasing plan

To solve this linear programing problem, the researcher used MS Excel problem solving method (Table 5) with respect to the integer programing method, because these result must be set in the form of whole number or integer as it defined in the above sign restriction equations.

Table 5. Problem Solution by Using MS Excel Technique

Objective Function	$Z\ maximize$ $16x1 + 500x2 + 800x3 + 3x4$						Sign restrictions based on X1 ≥ 30, 0≤ X 5 ≤2 (X5 is about the number of student groups will inter to the production room)
Constraints	subject to:						
	$12000x1 + 40000x2 + 35000x3 + 300000x4 \leq$						
	$5x2 + 9x3 + 36x4 + 6x5 \leq 120 \leq 120$						
	$1.4x1 + 6x5 \leq 126$						
	x1	x2	x3	x4	x5	TC	
	16	500	800	3	1	2573	
	48	2	1	1	2		
						LHS	RHS
C1	12,000	40,000	35,000	300,000		991,000	1,000,000
C2	0	5	9	36	6	67	120
C3	1.4	0	0	0	6	79.2	126

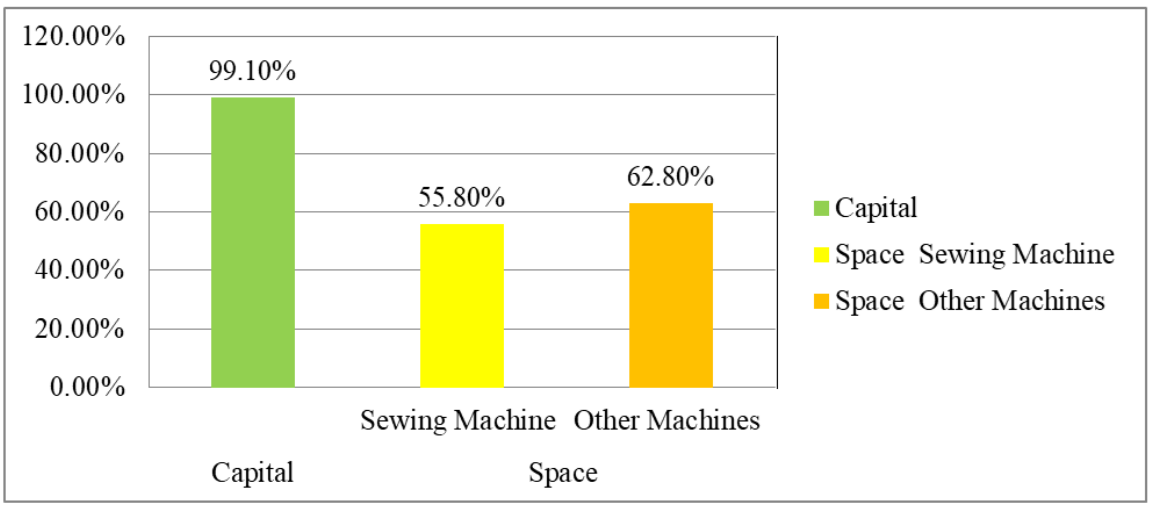
From this result, we can understand that the total amount of allocated budget is limited for the number of machines to be purchased rather than the available space constraint. There is remaining areas of space for each production room. But as we have seen the budget constraint, only ETB 9000 remains from the total ETB 1,000,000. As it is briefly shown on the estimated machine prices (Table 4), we can't buy any type of machine with 9000 ETB. Based on the decision variables formulation section shown above, the type of machine mixes to be purchased have been represented by the variables $x1, x2, x3, x4\ and\ x5$ for number of sewing machines, fusing machines, band knife cutting machines, spreading machines and number of student groups respectively. According to the above optimum solution shown in (Table 5), the allocated capital is optimally distributed through 48 sewing machines, 2 fusing machines, 1 band knife cutting machine and 1 fabric spreading machine for purchasing decision. Based on the objective function, the above result can be interpreted as follows:

$$16x1 + 500x2 + 800x3 + 3x4 + x5 = 16 \times 48 + 500 \times 2 + 800 \times 1 + 3 \times 1 + 2 \times 1 = 2573$$

Means that:

Expected Production from single needle sewing machine $= 48 \times 16 = 760$ shirt sewn garment product per day Production from fusing machine $= 500 \times 2 = 1000$ fused garment components. Amount of production by band knife cutting machine $= 1 \times 800 = 800$ shirts can be cut per day. Amount of production from spreading machine $=$ 1×3 lays of spread fabric having with 60 plices per lay can be spread. Number of student groups will inter to the production section for practical teaching $= 1 \times 2 = 2$ group of students having. This result gives a clear guide line to the management for next expansion of the company. In order to increase the production capacity, the management can be decided to invest more capital for additional machinery purchasing to be installed on the remaining space. (Figure 1), explains the available resource utilization status of Narga garment factory after optimization.

Figure 1, Resource utilization status after optimization



This result gives a clear guide line to the management for next expansion of the company. In order to increase the production capacity, the management can be decided to invest more capital for additional machinery purchasing to be installed on the remaining space. According to the established resource utilization status after optimization, the researcher examines that the remaining or unutilized space can absorb additional 38 sewing machines and 1 fabric spreading machine. This management decision can maximize the company production capacity from 768 shirts per day to 1376 shirts per day. The company space utilization efficiency can be increased from 55% to 100% but the allocated capital is limited for buying additional machines in this case so that if the institute needs to maximize the volume of the company, the researcher confirmed that additional capital is required.

5. Conclusion

The study has shown that linear programming model can be appropriate tool for new start-up companies in order to make suitable purchasing decision of machinery mixes. The researcher, through observation, noted that decision making concerning the quantity and variety of machineries to be purchased during business launching time was based on trial and error method which produced poor utilization of resources. This paper has been conducted to fill this gap, has established practical means of developing a working linear programming model to find solution to the problem of machinery mixes for purchasing decision. Also, the related literature reviews in this work have supplementary acknowledged that linear programming model is effective for such kind of problems in the manufacturing industries.

Data Availably

The data used to support the findings of this study are cited in the article.

Conflicts of Interest

The author would like to assure and declares that there are no conflicts of interest for this research funding and other related issues.

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