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APPROACHING A LINEAR PROGRAMMING MODEL FOR PRODUCTION PLANNING OF A READY-MADE GARMENTS INDUSTRY

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ABSTRACT. The ready-made garments (RMG) have been making a crucial contribution about of 81 % of total export and 12.36 % of total GDP of the country which is now the single biggest export earner for Bangladesh. The cheap production cost is the key important factor to explore this RMG sector. But these RMG sector is running on the basis of intuition based decisions. Though they are making profit it is not optimal. In this study, a deterministic model is developed to help the RMG to minimize the production cost and to maximize their profit along with optimal utilization of available resources. 10 different types of products are taken from one of the garments factories of Gazipur, Dhaka to prepare this research work. This model suggests the manufacturer on which products along with how much should be produced to meet the future demand by maintaining the lowest production cost that ultimately maximize the profit of the organization, and also helps Bangladesh to compete in the international market with 'Made in Bangladesh'. LINDO programming is used here to solve this LP model.

AMS Mathematics Subject Classification : 65H05, 65F10.
Key words and phrases : Deterministic linear programming (DLP), ready-made garments industry (RMG), optimization.

1. Introduction

Bangladesh is a developing country. Bangladesh has faced significant swings in her economy in trade, industrial, fiscal, agricultural and financial policies over the last two decades. Many segments take part in the growth of our economy in the struggling period. RMG sector is one and the most important of these segments. It is now playing a very vital role in Bangladesh's economy. That's why we have to take proper care of this segment. Bangladesh's ready-made garment

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exports started their journey in the late 1970s mostly as a result of native initiatives. When jute and jute making products were losing their export market, the RMG sector came to lead. It takes the jute's position and then overtakes it. While traditional export sectors were failing one after another then this sector gradually inserted their dynamism in the economy of Bangladesh. The primary stage of this sector was not lively enough, nowadays it is getting healthier. Ready-made garments segment is now exporting 35 different items to 31 different countries. About 30 million people of our country are engaged with this sector directly or indirectly. Hossain, M. S. [5] Employment generation, poverty reduction and rural women empowerment are occurring by this sector. Bangladesh is the second largest garments exporter next to china all over the world and ready-made garments is Bangladesh's largest exporting sector also, which has experienced exponential growth during the last 25 years. Since 2004, Bangladesh has an average of 6.5 percent GDP growth by the exports of ready-made clothing, remittances, and domestic farming. Knit or woven shirts, blouses, trousers, skirts, shorts, sweaters, sportswear's & many more casual & fashion items are the main source of 76 % earnings out of 85 % of total foreign earnings (which comes from clothing and textiles) Hasan, K. F. et. Al. [4]. Therefore we have to give deep concentration to this segment as it is directly related to our economic growth. And the research topic is to maximize its profit by improving productivity and minimizing its production cost. In the time of taking any decision we want to take the best alternatives with available resources. It is called optimization. Optimization problems arise in all branches of economics, finance, chemistry, materials science, astronomy, physics, structural and molecular biology, engineering, computer science and medicine. Linear programming (LP) Eiselt, H. A. et al.[3] is a technique of optimization for optimizing linear objective function, subject to linear equality and linear inequality constraints where all the variables must be nonnegative. The objective function may be profit, loss, cost, production capacity or any other measure of effectiveness which is to be maximized or minimized. A Linear Programming (LP) model has been developed in this paper for optimizing the profit of RMG sector. And the DLP (Deterministic Linear Programming) model is solved by LINDO (is an add-in to Excel that allows you to build large scale optimization models in a free form layout within a spreadsheet) package. The rest of the paper is organized as follows. In Section 2, some existing relevant papers are analyzed. In Section 3, the methodology and data collection procedure are discussed. In Section 4, the discussion of the problem, formulation of LP model, analysis and findings are presented and in Section 5, a conclusion will be made after solving LP model.

2. Literature Review

In this section some existing relevant papers are analyzed. Thoughts of some papers on optimization, on RMG sectors etc. are studied in this part. Jain., A. K. et al. [8] optimized the net return of interest from loans like Personal loan, Car loan, Home loan, Agricultural loan, Commercial loan, Education loan and also maximize the net return of the investor of Central Bank of India by using Linear Programming model. Scott [12] used the linear programming model in a feed firm to show the realism of the tool in management any found that the profit of that feed firm would be maximized . In their paper Yahya, Garba [14] demonstrated the linear programming model in a soap manufacturing company and found that the monthly profit will be maximized if they would concentrate on unit production. They used R statistical package using the library "lpSolve". Belhorim and sibler [2] applied linear programming model in financial sector, National City Bank. In their paper Nasir, S. B. et al. [10] presented the profit maximization of a company through employees' satisfaction by CSR (corporate social responsibilities) practices. Since employees are the main patron of a concern so they showed a correlation between CSR and profitability. Woubante, G. W. [13] optimized Profit of golden plastic industry, Nigeria with a recommendation of producing certain two products by the linear programming model. Alam, S., et al. [1] proposed a smooth supply chain management for a productive RMG sector. For this they first forecasted the future demand by using some forecasting methods like exponential smoothing, weighted average. Hussain, H. I, et al. [6] presented quantile on quantile regression is a unique methodology that has the ability to create a relationship between non-linear variables across several quantile distributions. Furthermore, the proposed method aids in explaining the asymmetric response in the quantiles of economic growth of the nations analyzed caused by the textile and garment industry quantiles. Jadhav, S. S., et al. [7] described by reviewing time study of manufacturing process. They found that timely supply of pieces and order sheets can play a major role in improving its productivity and also elaborated the scope for reducing the time taken and improvement in the production. In this paper, an LP model will be formed to optimize the profit of the organization and a feasible production schedule will be offered with sensitivity analysis as well. The methodology of this paper is stated in next part.

3. Methodology

In this section the methodology of this paper is discussed. Linear programming is the name of a branch of applied mathematics that deals with solving optimization problems of a particular form. Linear programming problems consist of a linear cost function (consisting of a certain number of variables) which is to be minimized or maximized subject to a certain number of constraints. The constraints are linear inequalities of the variables used in the cost function. Khan, Anam [9], Reza, Suraiya [11]

A linear programming problem is written as:

$$\text{minimize} \quad \sum_{j=1}^{m} c_j x_j$$

Subject to

$$\sum_{j=1}^{m} a_{ij}x_j \le b_i, \quad i = 1, 2, 3, \ldots .n$$

$$x_j \ge 0$$

The problem has m variables and n constraints.

The data were collected from a RMG industry and 10 products are under consideration. These are the secondary data and on monthly basis. They were kind enough to provide 3 years figures monthly that means 36 months of time series analysis which will be used for further research. The LP model that is used for this research is to optimize the profit of a RMG sector is

$$maximize \quad z = \sum_{j=1}^{10} c_j x_j$$

Subject to

$$\sum_{j=1}^{10} f_j x_j \le b_1 \text{ total fabrics} \qquad \sum_{j=1}^{10} t_j x_j \le b_2 \text{ total thread}$$

$$\sum_{j=1}^{10} i_j x_j \le b_3 \text{ total labels} \qquad \sum_{j=1}^{10} z_j x_j \le b_4 \text{ total zipper}$$

$$\sum_{j=1}^{10} b_j x_j \le b_5 \text{ total button} \qquad \sum_{j=1}^{10} p_j x_j \le b_6 \text{ total polybag}$$

$$\sum_{j=1}^{10} cr_j x_j \le b_7 \text{ total carton} \qquad \sum_{j=1}^{10} ht_j x_j \le b_8 \text{ total handtags}$$

$$\sum_{j=1}^{10} rl_j x_j \le b_9 \text{ total river lace} \qquad \sum_{j=1}^{10} h_j x_j \le b_{10} \text{ total hanger}$$

$$\sum_{j=1}^{10} t_j x_j \le b_{11} \text{ total tapes/velcro} \qquad \sum_{j=1}^{10} e_j x_j \le b_{12} \text{ total elastic}$$

$$\sum_{j=1}^{10} lh_j x_j \le b_{13} \text{ total labour hour} \qquad \sum_{j=1}^{10} mh_j x_j \le b_{14} \text{ total machine hour}$$

$$\sum_{j=1}^{10} lc_j x_j \le b_{15} \text{ total lobour cost} \qquad \sum_{j=1}^{10} oc_j x_j \le b_{16} \text{ total operating cost}$$

$$\sum_{j=1}^{10} ic_j x_j \le b_{17} \text{ total inventory cost}$$

where

decision variables:

x_j = monthly production of the jth product produced (j = 1, 2,. . . ,10)
x_1 = amount of T - shirt should be produced
x_2 = amount of vest should be produced
x_3 = amount of sweat - shirt should be produced
x_4 = amount of legging should be produced
x_5 = amount of shirt should be produced
x_6 = amount of hoddy - jacket should be produced
x_7 = amount of jogger should be produced
x_8 = amount of polo - shirt should be produced
x_9 = amount of casual - shirt should be produced
x_{10} = amount of girls' top should be produced

parameters:

f_j = required fabrics to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
t_j = required threads to produce one unit of jth product $(j = 1, 2, \ldots, 10)$
l_j = required labels to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
z_j = required zipper to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
b_j = required button to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
p_j = required polybag to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
cr_j = required carton to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
ht_j = required hand tags to produceoneunitof$j$th product $(j = 1, 2, \ldots, 10)$
r_j = required rivets lace to produceoneunit of$j$th product $(j = 1, 2, \ldots, 10)$
h_j = required hangers to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
t_j = required tapes to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
e_j = required elastics to produce one unit of$j$th product $(j = 1, 2, \ldots, 10)$
lh_j = required labor hour to produceoneunit of$j$th product $(j = 1, 2, \ldots, 10)$
mh_j =required machinehour toproduce oneunitof$j$th product $(j = 1, 2, \ldots, 10)$
lc_j = required laborcost to produceoneunit of$j$th product $(j = 1, 2, \ldots, 10)$
oc_j =required operatingcst to produceoneunit of$j$th product $(j = 1, 2, \ldots, 10)$
ic_j =required inventorycst to produceoneunit of$j$th product $(j = 1, 2, \ldots, 10)$
$c_i's$ are the unit profits for all variables respectively

4. Problem Formulation and Analysis

In this segment a real life problem is formed according to the RMG industry's regular production schedule and their available resources. Their monthly production and used raw materials information were collected and after preparing five different tables it was possible to find out the unit production cost which is used to calculate the unit profit. Then an LP model is formed and solved by Lindo programming language and finally there is the discussion regarding findings.

4.1. ***Problem Formulation:*** An established RMG factory in Gazipur, produced different types of woven and knit products such as T-Shirts, vests, sweat-shirts (a loose collarless pullover or jacket usually of heavy cotton jersey), leggings, formal-shirts, hoodie jackets, jogger, polo-shirts, casual- shirts, girl's tops etc. To produce these types of products they use various raw materials and trims (trims are all materials other than fabric used in a garment) like fabrics, thread, zipper, button, hand tags, elastics, rivets lace, tapes/Velcro, hangers, polybags, cartons etc. Their monthly average production of T-shirt is $28,45,902$ pcs and the required raw materials were $4,93,793$ kgs of fabrics $71,448$ cones of thread, 3834461 pc of labels,63628 pcs of button, 750185 pcs polybags, 26961 pcs cartons,514310 pcs of hand tags,516257 pcs of hanger, 12550 yds of tapes/Velcro, and 52000yds of elastics. Besides to produce one unit of T-shirt, labor works 1.5 minutes and machine works6 minutes. Labor cost is 0.28976, operating cost including machinery overhead is 0.153 for producing per piece of T-shirt. Similarly the rest of the 9 products needed the raw materials in a certain quantity which is given in the Table-1. Other than these there is a lower limit of leggings (x_4), shirt (x_5) and girls' top (x_{10}) with 5000, 8500 and 9000 respectively according to the customer demand.

TABLE 1. Monthly requirement or raw materials of 10 products:

Output / Input	Unit	Product-1(T-Shirt)	Product-2(Vest)	Product-3(Sweat-Shirt)	Product-4 (Leggings)	Product-5(Shirt)	Product-6(Hoodie Jacket)	Product-7(Jogger)	Product-8(Polo-Shirt)	Product-9(Casual-Shirt)	Product-10(Girls' Top)
Monthly Production	Pcs	2845902	684752	538560	388708	2950900	280200	450049	950854	2548725	845265
Fabrics	Kg	493791	57071	101433	87407	801200	920323	180020	223564	714253	213578
Thread	Cone	71448	13493	34332	16770	100200	32262	36004	23675	84520	75846
Labels	Pcs	3834461	1238152	1259324	1002062	2434461	575103	472551	1057000	2124523	548216
Zipper	Pcs			4404			294565				
Button	Pcs	63628	1326	324480		75888			50365	69254	49875
Polybag	Pcs	750186	237435	125021	220371	70853	94000	42551	29547	65824	254731
Carton	Pcs	26961	5427	9167	13284	28411	58913	59069	8452	2354	6584
Hand tags	Pcs	514310	30015	162052	135949	617000	24000	471000	17563	502485	14523
Rivets lace	Yds		98395				53385	94103			
Hanger	Pcs	516257	207300	391517	131009	626245			158568	514658	14520
Tapes/Velco	Yds	12550	4000	32400					4587		4200
Elastics	Yds	52000	153000	137950	392606			22522	17520		16542
Laborcost (incl.OT)	$	70,758,075	17,025,088	13,390,296	9,664,503	70821600	6724800	10801176	22820496	61169400	2028000
Opreration cost(incl. Mach.OH)	$	35,029,143	8,428,356	6,628,934	4,784,461	35410800	17866148	5513100.25	11885675	31859062.5	1056250
Inventory Cost	$	3394550.21	7631278.429	860823.545	9721600.811	63565547	2977691	2467485	2675210	3065547	2368470
Total demand monthly	Pcs	30,00,000	750,000	650,000	400,000	31,25,000	3,00,000	4,60,000	9,00,000	25,00,000	10,00,000
Total supply yearly	As per Monthly Production										
Selling Price	$	5294974	1112414	1495089	1080608.24	10151096	1134810	2019369.86	2576789.95	7773611.25	2121615.15

4.2. ***Monthly requirement of raw materials of* 10 *products:*** In the Table 1, the monthly production of each 10 products (T-shirt, vest, sweat shirt, leggings, shirt, jacket, jogger, polo-shirt, casual shirt, girl's top) and the required monthly raw materials (fabrics and trim) for respective product/s (collected from a garments factory of Gazipur) are given.

4.3. ***Requirement of raw materials for one unit:*** Now the monthly required materials are divided for manufacturing one unit of each product and shown in the Table: 2 from where it can be shown that to produce 1 piece of T-shirt it requires 0.173509kg fabrics, 0.0251 cone threads, 1.373 pcs label, 0.022 pcs button and so on. Similarly, for other products like shirt, sweat shirt, casual shirt, leggings, jogger etc.

TABLE 2. Requirement of raw materials for one unit:

Output / Input	Unit	Product-1(T-Shirt)	Product-2(Vest)	Product-3(Sweat-Shirt)	Product-4(Leggings)	Product-5(Shirt)	Product-6(Hoodie Jacket)	Product-7(Jogger)	Product-8(Polo-Shirt)	Product-9(Casual-Shirt)	Product-10(Girls' Top)
Monthly Production	Pcs	2845902	684752	538560	388708	2950900	280200	450049	950854	2548725	845265
Fabrics	Kg	0.173509	.0833	0.188341	0.22486	0.2715	.329	.40	.23511	.280	.2526
Thread	Cone	.0251 cone/pc	.01970	.06374	.04314	.03	.1151	.080	.02	.0331	.08
Labels	Pcs	1.3473	1.80817	2.338	2.577	.8249	2.05	1.0499	1.11	.8335	.648
Zipper	Pcs			.008177			1.051				
Button	Pcs	.02235	.001936	.6024		.0257			.0522	.02717	.059
Polybag	Pcs	.2636	.3467	.23213	.56693	.02	.3354	.094	.031	.0258	.301
Carton	Pcs	0.0094736	0.00792	0.01702	0.034174	.00962	.2102	.1312	.0088	.009236	.007789
Hand tags	Pcs	0.180719	0.04383	0.30189	0.34974	.02	.0856	.1044	.084	.19715	.01713
Rivets lace	Yds		0.14369				.1905	.2090			
Hanger	Pcs	0.181403	0.3027	0.72697	0.337037	.0212			.166	.201	.01717
Tapes /Velco	Yds	.004409	.005841	.06016					0.0048		.0046
Elastics	Yds	0.018271	0.22343	0.25614	1.010028	1.05		.05001	.0184		.0195
Labor cost (incl.OT)	$	0.28976	0.28976	0.28976	0.28976	0.28976	0.28976	0.28976	0.28976	0.28976	0.28976
Opreration cost(incl Mac.OH)	$	0.153857	0.153857	0.153857	0.153857/	0.153857 /pc	0.153857	0.153857	0.153857	0.153857	0.153 857
Inventory Cost	$	0.014	0.0108 4	0.0188	0.02184	10.06		.035	.015		
Total demand monthly	Pcs	30,00,000	750,000	650,000	400,000	31,25,000	3,00,000	4,60,000	9,00,000	25,00,000	10,00,000
Total supply yearly	As per Monthly Production										
Selling Price	$	52.11386	1.628	2.7560	2.75108	3.44	4.05	4.48	2.71	2.918	2.55

4.4. ***Cost per kg or per piece of resources/ raw materials:*** In the following table there is the per unit cost of each raw material (fabrics and trim) which are needed for mentioned 10 products to manufacture. Suppose the cost of 1 kg fabric or 1-piece zipper and so on are given for each of the raw materials in the Table 3 below.

Table 3. Cost per kg/per piece of resources/raw materials

Output / Input	Unit	Product-1(T-Shirt)	Product-2(Vest)	Product-3(Sweat-Shirt)	Product-4(Leggings)	Product-5(Shirt)	Product-6(Hoodie Jacket)	Product-7(Jogger)	Product-8(Polo-Shirt)	Product-9(Casual-Shirt)	Product-10(Girls' Top)
Fabrics	Cost $/kg	6.09	7.58	7.08	6.68	7.01	7.50	7.20	6.09	7.00	6.05
Thread	Cost $/pcs	0.56	0.50	0.52	1.34	0.56	1.50	1.50	.56	.56	.565
Labels	Cost $/pcs	0.01	0.02	0.01	0.01	.01	0.02	0.02	.01	.01	.01
Zipper	Cost $/pcs			0.21			0.70				
Button	Cost $/pcs	0.02	0.003	0.02		.021			.02	.021	.02
Polybag	Cost $/pcs	0.02	0.04	0.04	0.02	.02	0.05	0.05	.02	.02	.02
Carton	Cost $/pcs	1.15	0.80	1.06	0.65	1.05	1.20	1.02	1.05	1.10	1.15
Hand tags	Cost $/pcs	0.01	0.03	0.01	0.01	.01	0.03	0.04	.01	.01	.01
Rivets lace	Cost $/yds		.99				0.60	0.60			.80
Hanger	Cost $/pcs	0.08	0.13	0.07		.07	0.15		.075	.067	.08
Tapes/ Velcro	Cost $/yds	0.03	0.03	0.03					0.03		.032
Elastics	Cost $/yds	0.05	0.05	0.09	0.08		0.05	0.08	.048		.045
Labor hour	min$/pcs	1.5	2	3	1.5	2.00	3.00	2.50	1.5	2.00	1.5
Machine hour	min/pcs	6	8	12	8	6.5	12.00	9.00	6.0	6.25	6

4.5. ***Cost for producing one-unit product:*** Suppose 0.17 kg fabrics, 0.02 cones thread (from Table 2) etc. are needed for producing one piece of T-shirt. Then the cost of each raw material that is needed for each of the product is shown in the Table 4, i.e. the unit production costs are given for each the 10 products.

Table 4. Raw materials' cost for per unit product

Output / Input	Unit Cost	Product-1(T-Shirt)	Product-2(Vest)	Product-3(Sweat-Shirt)	Product-4 (Leggings)	Product-5(Shirt)	Product-6(Hoodie Jacket)	Product-7(Jogger)	Product-8(Polo-Shirt)	Product-9(Casual-Shirt)	Product-10(Girls' Top)
Fabrics	$/pcs	1.05667	0.6317	1.334	1.5021	1.903	2.465	2.88	1.4317	1.86	1.5282
Thread	$/pcs	0.01405	0.00985	0.0331	0.05781	.0168	.172	6 .12	.448	.01853	.0452
Labels	$/pcs	0.01347	0.03616	0.02338	0.02577	.00829	.041	.02098	.0111	.00833	.00648
Zipper	$/pcs			0.01717			.0735				
Button	$/pcs	0.000447	0.00000580	0.01204		.0053			.002099	.000569	.00118
Polybag	$/pcs	0.00527	0.01386	0.00928	0.011338	.0004	.016777	.0047	.00662	.00516	.00602
Carton	$/pcs	0.01089	.0063	0.01804	0.02221	.0101	.25224	.133824	.00924	.01015	.00907
Hand tags	$/pcs	0.001807	0.00135	0.003008	0.003497	.0002	.002568	.004176	.00084	.00197	.00017
Rivets lace	$/pcs		.142257				0.1143	0.1254			.11
Hanger	$/pcs	0.01451	0.0393	0.05088	0.05055	.00148			.01245	.013467	.00137
Tapes/ Velcro	$/pcs	.0001322	.0017503	.0018048					0.000144		.0001472
Elastics	$/pcs	0.0009135	0.0117	0.02305	0.080802		.070	.05	.00071		.008771
Total cost /unit	$	1.113489	0.892659	1.5102998	1.754095	1.9408	3.064	3.2767	1.922	1.913	1.6066
Selling price/unit	$	2.11386	1.628	2.7560	2.75108	3.44	4.05	4.48	2.71	2.918	2.55
Profit/ unit	$	1	0.8	1.246902	1.001	1.5	0.99	1.21	0.79	1.005	0.95

4.6. *Monthly cost of raw materials for* 10 *products:* The monthly total cost for manufacturing each of the 10 products is shown in the Table 5.

TABLE 5. Monthly cost of raw materials for 10 products

Output / Input	Unit	Product-1(T-Shirt)	Product-2(Vest)	Product-3(Sweat-Shirt)	Product-4 (Leggings)	Product-5(Shirt)	Product-6(Hoodie Jacket)	Product-7(Jogger)	Product-8(Polo-Shirt)	Product-9(Casual-Shirt)	Product-10(Girls' Top)	Total
Fabrics	Cost in $	3000000	400000	718000	583878	5518700	690200	1296000	1361337	4740628	1291564	19555476.97
Thread		4000	6744	178269	22471	48720	48420	54000	13311.95	47151.41	38205	629812.5
Labels		38135	24760	12591	10017	24462	11488	9442	10554	21230	5477	168156
Zipper				9532			19637					29169
Button		1337	9039	6484		2060.15			1995	14502 997	36414	
Polybag		1499 7	9490	4997	4407	11803	4698	18001	6294.65	13151	5088	88926.65
Carton		30991	4331	9715	8633	29801	70677	60216	8785.89	25869.55	7666.55	256685.9
Hand tags		5142.54	924.41	1619.98	1359.31	5901.8	719.55	1876.70	798.71	5020.98	143.69	23507.67
Rivets lace			97410.76				32026.86	56436.14			92979.15	278852.15
Hanger		41294	26910.75	27401.93	19649.18	161709			11838.13	34323.07	1158.013	32428407
Tapes/ Velcro		376.22	1198.22	917.91					136.92		124.42	2753.69
Elastics		2599.73	8011.59	12413.83	31408.38		19614	22502	675.106		7413.819	104638.455
Labor hour	in minute	4268853	1369504	1615680	583062	5901800	840600	11251.22	1426281	5097450	1267897.5	22382387.12
Machine hour	in minutes	17075412	5478016	6462720	3109664	19180850	3362400	4050441	5705124	15929531.25	5071590	108761317.3

The selling price and the unit costing of each the 10 types of products are clearly found from Table 4 and thus the unit profit is established. And in the next section an LP model is formed for optimizing the profit of the stated organization and also there is a discussion regarding output which is found by LINDO.

4.7. *Linear Programming Formulation.* In this section the linear program is formulated from the tables stated above for optimizing profit.

$$Max x_1 + 0.8x_2 + 1.2469x_3 + 1.001x_4 + 1.5x_5 + 0.99x_6 + 1.21x_7 + 0.79x_8 + 1.005x_9 + 0.95x_{10}$$

ST

$$1.05667x_1 + 0.6317x_2 + 1.334x_3 + 1.5021x_4 + 1.903x_5 + 2.465x_6 + 2.88x_7 + 1.4317x_8 + 1.96x_9 + 1.528x_{10} \leq 20000000$$

$$0.01405x_1 + .00985x_2 + .0331x_3 + .05781x_4 + 0.0168x_5 + .1726x_6 + .12x_7 + .448x_8 + 0.01853x_9 + 0.0452x_{10} \leq 300000$$

$$0.013470x_1 + .03616x_2 + 0.02338x_3 + .02577x_4 + 0.00829x_5 + 0.041x_6 + .02098x_7 + 0.0111x_8 + 0.00833x_9 + 0.00648x_{10} \leq 220000$$

$$.001717x_3 + .00182x_6 \leq 29000$$

$$.00044x_1 + .00000580x_2 + .01204x_3 + 0.0053x_5 + 0.00209x_8 + .00569x_9 + .00118x_{10} \leq 35000$$

$$.00527x_1 + .01386x_2 + .00928x_3 + .011338x_4 + 0.0004x_5$$

$$+ .01677x_6 + .0047x_7 + .00662x_8 + .00516x_9 + .006x_{10} \leq 100000$$

$$.01089x_1 + .0063x_2 + .01804x_3 + .02221x_4 + 0.0101x_5$$
$$+ .25224x_6 + .133824x_7 + 0.00924x_8 + .01015x_9 + .009077x_{10} \leq 90000$$

$$.001807x_1 + .00135x_2 + .003008x_3 + .003497x_4 + 0.0002x_5$$
$$+ .002568x_6 + .004176x_7 + .00084x_8 + .00197x_9 + .000117x_{10} \leq 23000$$

$$.142257x_2 + .1143x_6 + 0.1254x_7 \leq 50000$$

$$.0145x_1 + .0393x_2 + .05088x_3 + .05055x_4 + 0.00148x_5$$
$$+ .01245x_8 + .013467x_9 + .00137x_{10} \leq 237000$$

$$.0001322x_1 + .000175x_2 + .0018048x_3 + .000144x_8 + .0001472x_{10} \leq 35000$$

$$.0009135x_1 + .01117x_2 + .02305x_3 + .080802x_4 + 0.0007x_5$$
$$+ .07x_6 + 0.05x_7 + .0007x_8 + .008771x_{10} \leq 100000$$

$$1.5x_1 + 2x_2 + 3x_3 + 1.5x_4 + 3.5x_5 + 3x_6 + 3x_7 + 1.5x_8 + 2.5x_9 + 1.6x_{10} \leq 25000000$$

$$6x_1 + 8x_2 + 12x_3 + 8x_4 + 10x_5 + 12x_6 + 9x_7 + 6x_8$$
$$+ 6x_9 + 5.5x_{10} \leq 60000500$$

$$.1538x_1 + .1538x_2 + .1538x_3 + .1538x_4 + .1538x_5$$
$$+ .1538x_6 + .1538x_7 + .1538x_8 + .1538x_9 + .1538x_{10} \leq 950000$$

$$.28976x_1 + .28976x_2 + .28976x_3 + .28976x_4 + 0.5x_5$$
$$+ 0.3x_6 + 0.2x_7 + 0.3x_8 + 0.27x_9 + .28x_{10} \leq 1700000$$
$$.014x_1 + 0.0108x_2 + .0188x_3 + .0218x_4 + 0.2x_5$$
$$+ .1x_6 + .02x_7 + .03x_8 + .015x_9 + .011x_{10} \leq 5500000$$

$$x_4 \geq 5000; x_5 \geq 8500; x_{10} \geq 9000$$

where

$$A = \begin{pmatrix} 1.056 & 0.63 & 1.334 & 1.50 & 1.90 & 2.46 & 2.88 & 1.43 & 1.96 & 1.52 \\ 0.014 & .009 & .033 & .057 & .016 & .172 & .12 & .49 & .018 & .045 \\ .013 & .036 & .023 & .025 & .0082 & .04 & .02 & .011 & .008 & .006 \\ 0 & 0 & .0017 & 0 & 0 & .00182 & 0 & 0 & 0 & 0 \\ .0004 & .000005 & .012 & 0 & .005 & 0 & 0 & .002 & .0056 & .001 \\ .005 & .013 & .009 & .011 & .0004 & .0167 & .004 & .0008 & .0019 & .0001 \\ .01 & .006 & .018 & .022 & .01 & .25 & .133 & .009 & .01 & .009 \\ .001 & .0013 & .003 & .003 & .0002 & .0025 & .0041 & .0008 & .0019 & .00017 \\ 0 & .14 & 0 & 0 & 0 & .11 & .125 & 0 & 0 & 0 \\ .0145 & .039 & .05 & .05 & .001 & 0 & 0 & .012 & .013 & .0013 \\ .0001 & .0001 & .0018 & 0 & 0 & 0 & 0 & .0001 & 0 & .008 \\ .0009 & .011 & .02 & .08 & .0007 & .07 & .05 & .0007 & 0 & .008 \\ 1.5 & 2 & 3 & 1.5 & 3.5 & 3 & 3 & 1.5 & 2.5 & 1.6 \\ 6 & 8 & 12 & 8 & 10 & 12 & 9 & 6 & 6 & 5.5 \\ .153 & .153 & .153 & .153 & .153 & .153 & .153 & .153 & .153 & .153 \\ .289 & .289 & .289 & .289 & .289 & .289 & .289 & .289 & .289 & .289 \\ .014 & .01 & .01 & .018 & .02 & .2 & .1 & .02 & .03 & .015 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}, \quad b = \begin{pmatrix} 20000000 \\ 300000 \\ 220000 \\ 29000 \\ 35000 \\ 100000 \\ 90000 \\ 23000 \\ 50000 \\ 237000 \\ 35000 \\ 100000 \\ 25000000 \\ 60000500 \\ 950000 \\ 1700000 \\ 5500000 \\ 5000 \\ 8500 \\ 9000 \end{pmatrix}$$

4.8. ***Output:*** The outputs are

Table 6. Output

OBJECTIVE FUNCTION VALUE	Variables	Suggested (pcs)
6579290	x_1 (T-shirt)	3014303
	x_2 (Vest)	000
	x_3 (Sweat shirt)	2790443
	x_4 (Leggings)	5000
	x_5 (Shirt)	8500
	x_6 (Jacket)	000
	x_7 (Jogger)	48990
	x_8 (Polo shirt)	000
	x_9 (Casual shirt)	000
	x_{10} (Girl's top)	9000

4.9. ***Sensitivity Analysis.*** Sensitivity analysis is a financial model that, based on changes in other variables known as input variables, decides how target variables are affected and this sensitivity analysis is incorporated here in the Tables 7 and 8.

Table 7. Sensitivity for all variables (10)

Variables	Co-efficient	Allowable Increase	Allowable Decrease
x_1	1	0.226320	0.026640
x_2	0.8	0.172637	Infinity
x_3	1.24	1.044587	.056351
x_4	1.001	0.037729	Infinity
x_5	1.5	0.274229	Infinity
x_6	0.99	1.039303	Infinity
x_7	1.27	0.996277	0.411582
x_8	0.79	0.267521	Infinity
x_9	1.005	0.025595	Infinity
x_{10}	0.95	0.024311	Infinity

It is found from findings that if 3014303pcs of T-shirts(x_1) are produced it would be more feasible and from the Table 7 we can see that the amount of T-shirt's(x_1) production can vary from .026640 to 0.226320 similarly the range for leggings(x_4) is from infinity to 0.037729 that means the production can be decreased upto infinity and increase to 0.154 from the recommended amount and for this range, the objective function will not be changed. For all of the 10 products it is shown in the Table 7. And in Table 8 the sensitivity analysis for 20 constraints are shown. For example, for 1st constraint the RHS could be decreased to 12913896 from 20000000 and could be increased up to infinity for not changing the objective function.

TABLE 8. Sensitivity for all of the constraint and RHS

Constraints	Slack or Surplus	Dual Prices	Current RHS	Allowable ↑	Allowable ↓
1.	12913896	0.000000	20000000	Infinity	12913896
2.	158567.90625	0.000000	300000	Infinity	158567.90625
3.	112871.3281	0.000000	220000	Infinity	112871.3281
4.	24208.808	0.000000	29000	Infinity	24208.808
5.	0.000000	18.7311	35000	10048.037	32398.3457
6.	57874.96	0.000000	100000	Infinity	57874.96
7.	0.000000	4.160901	90000	44240	6197.1411
8.	8934.680	0.000000	23000	Infinity	8934.680
9.	43856.636	0.000000	50000	Infinity	43856.636
10.	51037.20	0.000000	237000.00	Infinity	51037.20
11.	29563.99	0.00000	35000	Infinity	29563.99
12.	29988.31	0.000000	100000	Infinity	29988.31
13.	11908596.0	0.000000	25000000	Infinity	11908596.0
14.	7813953.50	0.000000	60000500.00	Infinity	7813953.50
15.	46234.90	0.00000	5500000	Infinity	5402451.5
16.	0.000000	3.265858	1700000	89431.375	794956.500
17.	5402451.50	0.00000	5500000	Infinity	5402451.50
18.	0.000000	-0.037729	5000	393741.281	5000.00
19.	0.000000	-0.27422	8500	2153061	8500.00
20.	0.000000	-0.0243	9000	3302983.00	9000.00

4.10. *Findings.* After solving the LP model by Lindo, it is found that if the garment factory produces 6 types of products instead of 10 it would be more optimal for them. After the data collection it is found that they had a monthly production schedule of T- shirt 2845902pcs, vest 684752 pcs, sweat shirt 538560pcs, leggings 388708pcs, shirt 2950900 pcs, hoodie jacket 280200pcs, jogger 450049pcs, polo shirt950854pcs, casual shirt 2548725 and girls' tops 845265pcs. But analyzing their available resources it is found that if the factory produces 3014303 pcs T-shirt, 2790443 pcs sweat shirts, 5000pcs leggings, 8500pcs shirts, 48990pcs jogger, and 9000 pcs girls' tops it would be more optimal in terms of their profit. In this optimal solution there is no production of vest, jacket, polo shirt and casual shirt but in a garment factory all types of products must be produced in least amount and that will be shown in our further research.

Therefore, this optimal solution and this LP model is suggested for this RMG and the sensitivity analysis is also discussed as well.

5. Conclusion and recommendations of future work:

In this research a deterministic linear programming model is designed with the goal of producing optimal number of different products to minimize the total production cost which ultimately maximizes the profit. The garments factory definitely has a planning and production schedule but by means of this paper, it is tried to give an optimal solution for them. Some recommendations for future work are to develop a stochastic model using fluctuating demand and to consider additional constraints.

Conflicts of interest : There is no conflicts of interest.

Data availability : https://drive.google.com/drive/folders/1TR37WCxRq6E-1N7qw3DusOBv7f6iQ8a4?usp=share_link

References

1. S. Alam, M. Alam, I. Uzzaman, & M. Rahman, *A Research on Supply Chain Network of RMG Sector. Irfan and Rahman, Mohammad*, A Research on Supply Chain Network of RMG Sector October 10, 2016.
2. M. Ben-Horim & W.L. Silber, *Financial innovation: a linear programming approach*, Journal of Banking and Finance **1** (1977), 277-296.
3. H.A. Eiselt & C.L. Sandblom, *Linear programming and its applications*, Springer Science & Business Media, New York, 2007.
4. K.F. Hasan, M.S. Mia, M.M. Rahman, A.A. Ullah, & M.S. Ullah, *Role of textile and clothing industries in the growth and development of trade & business*, International Journal of Textile Science **5(3)** (2016), 39-48.
5. M.S. Hossain, & C.L. Sandblom, *Growth and Contribution of Bangladeshi RMG Sector: Quantitative and Qualitative Research Perspectives*, Fibres & Textiles in Eastern Europe. **5** (2020), 27-36.
6. H.I. Hussain, M. Haseeb, S. Kot, K. Jermsittiparsert, & C.L. Sandblom, *Non-linear impact of textile and clothing manufacturing on economic growth: The case of top-Asian economies*, Fibres & Textiles in Eastern Europe. **5(143)** (2020), 27-36.

7. S.S. Jadhav, G.S. Sharma, A.M. Daberao, & S.S. Gulhane, *Improving Productivity of Garment Industry with Time Study*, International Journal on Textile Engineering and Processes **3** (2017), 1-6.
8. A.K. Jain, R. Bhardwaj, H. Saxena, A. Choubey, *Application of Linear Programming for Profit Maximization of the Bank and the Investor*, International Journal of Engineering and Advanced Technology, **8** (2019), 4166-4168.
9. M.M. Khan, A.R. Anam, & A.K. Chakrabarty, *Developing Linear Programming Model to Reduce Bottleneck Operation: An Approach to Minimize Labor Cost of Ready Made Garments Sector in Bangladesh*, Jahangirnagar University, 2014.
10. S.B. Nasir, M.M. Sarker, & S.F. Kabir, *CSR as a way of employee satisfaction and profit maximization*, Bangladesh Text. Today **7** (2014), 1-7.
11. A.S. Reza, S. Suraiya, & M.B. Hasan, *A Procedure for Scheduling Inventory of an Industry by Merging Forecasting and Linear Programming*, The Dhaka University Journal of Science **68** (2020), 65-70.
12. J.T. Scott, *Application of linear programming for profit maximization in the feed firm*, Iowa State University, 1957.
13. G.W. Woubante, *The Optimization problem of product mix and linear programming applications: Case study in the apparel industry*, Open Science Journal **2** (2017), 1-11.
14. W.B. Yahya, M.K. Garba, S.O. Ige, & A.E. Adeyosoye, *Profit maximization in a product mix company using linear programming*, European Journal of Business and management **4** (2012), 126-131.

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