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Cost and Profit Analyzing Mathematical Model: A Strategic Tool for Garment Manufacturers

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ABSTRACT

Utilizing data-driven analysis leads to higher-quality decisions. Analytical approaches allow the manufacturers of ready-made garment (RMG) factories to examine various factors and consider multiple scenarios. Manufacturers often determine profit margins based on their personnel's experience rather than using data-driven analysis. This approach will help manufacturers determine the appropriate profit margin for pre-costing through cost minimization, which they can then incorporate into the total product cost for final pricing. The first step identifies and describes the variables required to develop a model. We will develop a manufacturing cost optimization model in the second stage using mixed-integer linear programming (MILP) techniques. By integrating various factors, such as production capacity, demand variations, raw material sourcing, and pricing strategies, the model aims to provide a strategic tool for garment manufacturers to enhance their profitability. We use a mathematical programming language (AMPL) to solve the formulated mixed integer linear program. This model can determine the profit by changing one parameter and keeping all other parameters unchanged. Using this concept, the manufacturer can assess the impact of a change in any parameter on profit. Manufacturers put their manufacturing costs in the data file of this model and can determine whether they generate profit or loss. Garment manufacturers can use this idea to calculate the percentage of profit margin they need to add to the total production cost to achieve profitability. We have framed the issue and presented some simulations to test our model. Based on collected data, the model estimates that increasing the cost value by 10% decreased the profit margin by 4% to maintain the same selling price.

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1. Introduction

Following the pandemic, 2022 presented an opportunity to recuperate from the COVID-19-induced damage to the Ready-Made Garment (RMG) sector. During our fight, we encountered new challenges, such as the global recession, unfavorable trade policies, rising energy costs, the depreciation of the taka, and an increase in the inflation rate, all of which impacted the textile industry's growth. In 2022, the global inflation rate soared to over 9%, increasing prices across various sectors, from essential commodities to utilities. Throughout the year, we grappled with challenging circumstances, including record-high cargo rates and container shortages, which had a ripple effect on manufacturing costs in our garment industry. In line with worldwide trends, the garment sector saw substantial cost hikes, aggravated by the rise of diesel and other utility prices. Our factories are finding it increasingly difficult to maintain competitiveness in the global market due to the lingering impacts of COVID-19. In addition to these challenges, geopolitical factors have been raising production costs recently. The abovementioned reason for cost increases forces manufacturers to either increase the product's price or accept the loss. Therefore, pricing is one of the critical factors for profitability. As a garment factory manufacturer, we must regularly monitor all costs. According to a Bangladesh Bank report, value addition in ready-made garment product exports dropped to 51.39%, reaching $10,274.34 million in the first quarter (July-September) of the current financial year, mainly owing to an increase in the prices of raw materials in the global market. Due to the increasing cost of raw materials, exporters must reduce profit margins to maintain the current export price. The Vice President of the Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA) highlighted the sharp rise in raw material costs, mainly yarn, which has nearly doubled in price, as the reason for the significant decline in value added to apparel items. However, despite this surge in material costs, buyers have not adjusted their product prices accordingly.

Garment export businesses calculate their costs based on the type of order specified by Incoterms (International Commercial Terms). Most factories received FOB (free on board) or CMT (cut-make-trim) orders. The garment industry primarily uses the FOB delivery term, or FOB pricing (Kiron, 2016). When we add the profit margin to that FOB pricing, it becomes a FOB order through which we can sell the unit product to the buyer (Sarkar, 2012). A higher profit margin indicates a more profitable company (Singh and Nijhar, 2015). Due to demand uncertainty and fluctuating costs, determining the appropriate profit margin to add to total garment costs is critical for manufacturers. Usually, a 10–20% margin is considered for FOB costs (Rajib et al., 2023; Sarkar, 2012; Welford, 2023). This percentage of the amount depends on the final FOB negotiation with the buyers. The buyer has a fixed target FOB for an order. We must conduct a thorough cost analysis to secure that order and ensure a balanced profit margin. Negotiating a profitable deal with a buyer can cause the profit margin to fluctuate beyond our target margin.

1.1. Cost and Profit Margin Relationship & Pricing Strategies

Profit is the difference between revenue and total cost. When the average price remains constant, revenue increases linearly with the quantity sold. If we maintain sales volume and apply an optimization technique to minimize cost, then increased profitability occurs. By minimizing cost, a profit margin can be determined.

Set Profit $= z$, Revenue $= r$, Total cost $= z_4$, Average Price $= p_{il}$ and Total Sold $= y_{iljt}$

Therefore, $z = r - z_4$, (1)

$z = (p_{il} * y_{iljt}) - z_4$. (2)

From the relation between Eqs. (1) and (2):

$$z_{max} = (p_{il} * y_{iljt}) - min\,(z_4), \quad (3)$$

Profit Margin, $P = \frac{(p_{il}*y_{iljt})-min\,(z_4)}{(p_{il}*y_{iljt})} \times 100\%$,

$$\Longrightarrow P = \frac{r - \min(z_4)}{r} \times 100\%,$$

$$\Longrightarrow P = 1 - \frac{min\,(z_4)}{r} \times 100\%. \quad (4)$$

Because of demand uncertainty, both revenue and cost change over time. Therefore, the differential equation of the profit margin from Eq. (4),

$$\frac{dP}{dt} = -\frac{1}{r}\frac{dz_4}{dt} + \frac{z_4}{r^2}\frac{dr}{dt} \quad (5)$$

Equation (5) indicates that, if $\frac{dz_4}{dt} > 0$, then $-\frac{1}{r}\frac{dz_4}{dt} < 0$, which means P decreases reflecting that higher costs lead to lower profit margins. If $\frac{dr}{dt} > 0$, then $\frac{z_4}{r^2}\frac{dr}{dt} > 0$ indicates that if revenue increases while the cost remains constant or grow slower than revenue the P may increase. The study has satisfied these statements.

The profit margin and all associated costs of garment goods are the prominent components of a FOB order. For-profit maximization, the manufacturer must calculate this FOB cost meticulously. The manufacturing cost of garment goods includes labor, fabrics, accessories, machinery, packaging, and more. Manufacturers strive to maintain cost competitiveness to secure orders from reputable buyers and establish long-term relationships to attract larger orders. Therefore, to compete in a competitive market, understanding cost is crucial, in addition to resource availability and access to the latest technology (Singh and Nijhar, 2015). In the present-day high-tech, uncertain industrial environment, determining the expected cost per piece or batch is often needed before production (Jha, 1992). The manufacturer must complete these cost calculations before negotiating with the buyer to place an order (Sarkar, 2012). Some companies implement rigorous quoting processes to protect their financial interests, but they find that monthly profit margins fall short of expectations. A lack of data analysis in their decision-making processes often results in an overreliance on experience and assumptions instead of empirical evidence, which accounts for this discrepancy (Johnson, 2018). The manufacturer has to go through a data-based decision-making process to see whether it is a profit or loss deal.

2. Literature Review

Shakirullah et al. (2020) formulated a linear programming model to maximize profit and minimize cost for a knit garment manufacturing unit in Bangladesh. When solved with Microsoft Excel Solver and AMPL, the model reveals a 22% profit increase when there is sufficient demand and a 12.33% profit increase when meeting client requests. On the other hand, costs may decrease by 37% by using the LPP model. Islam et al. (2016) formulated a mixed-integer program for the manufacturer and retailer systems of poultry firms in Bangladesh. They showed that profit and selling price have a favorable relationship with production and raw material costs but no significant relationship with the fixed cost. Islam et al. (2015) also developed a mixed integer and linear fractional program model. This model introduces a price-sensitive nonlinear demand function instead of a price-sensitive linear or deterministic demand function. These models demonstrate that the coordination mechanism can enhance individual and coordinated profits while lowering consumers' purchasing prices. Islam et al. (2020) developed a mixed-integer linear programming (MILP) model, solving it using AMPL with the solver MINOS. They assumed that the producer's inadequate production capacity caused product shortage. They aimed to demonstrate that outsourcing the product could enhance the overall coordinated profit. The coordination will be among the distributor, the retailer, and the farmers. For the pharmaceutical industries, Papageorgiou et al. (2001) formulated an optimization-based approach, known as a MILP, to select both a product development and introduction strategy and a capacity planning and investment strategy. Ahumada and Villalobos (2009) presented an integrated planning model for production and distribution to maximize a producer's revenue based on traditional factors such as price estimation and resource availability. In their study, they employ MILP for problem implementation and result computation. They have also incorporated other factors typically overlooked in traditional planning models, such as price dynamics, product decay, transportation, and inventory costs. Rajak et al. (2022) formulated a multi-objective mixed-integer linear program model (MOMILP) for a sustainable closed-loop supply chain. The proposed CLSC model was solved using CPLEX and GAMS to determine the decision variables based on the values of a set of parameters. Recently, Kalwar et al. (2022) proposed an analytically supported decision-making method to determine the number of different article pairs to produce, aiming to minimize costs and maximize profits. The comparison between the traditional method and the LP model revealed that by calculating the selection of articles and their production quantity accordingly, we could earn 39% more profit with 22% less production. Bayá et al. (2022) introduced a MILP model that applies to production planning optimization problems with multiple products and lines, including storage and limited shelf-life constraints.

We implemented the model using the AMPL modelling program language and solved it with the IBM CPLEX solver ver. 20.1.0.0. Ghosh et al. (2020) developed a linear programming problem to simplify the composite textile industry's scheduling problem, aiming to maximize profit or minimize production costs by optimizing lead time for various processes. Riskadayanti et al. (2020) developed a mathematical model for production planning to determine the optimal number of sawn timber product combinations. They have used MILP methods to maximize the profit, considering production, raw material, and purchasing costs. Woubante (2017) introduced a linear programming model to solve the product mix optimization problem. The company collected the monthly held resources, product volume, the amount of resources used to produce each product unit, and the profit per unit for each product. He solved the model using LINGO 16.0 and discovered that satisfying customer orders can increase the company's profit by 59.84%. Nisita (2021) offered a linear programming model that considered factors such as market segmentation, worker interest, machine and resource utilization, forecasted product demand, and the production capacity of the textile industry. She developed the model by considering objective functions such as profit maximization and subjecting labor, machines, and other costs to constraints. The model is solved using AMPL, and numerical results show that fabric cost and machine cost are the most sensitive costs because profit increases by decreasing this cost parameter. Tareque et al. (2023) discussed the improvement of companies' efficiency and attempted to show that increasing efficiency and reducing the manufacturing cost of a company result in more revenue. Rajib et al. (2023) generated garment cost sheets for the apparel industry, considering the main components of costing. They have selected four main apparel items to prepare the cost sheets: FOB orders. They have taken a 10% profit margin for each cost sheet and broken down the cost percentages. Ultimately, they determined the manufacturing cost percentage for each item.

2.1. Research Gap

The literature primarily focuses on optimizing profit, minimizing costs, and improving efficiency in pharmaceuticals, poultry farming, closed-loop supply chains, and timber production. However, the garment industry has yet to embrace the potential benefits of MILP for decision-making fully. Also, the garment industry has not yet utilized MILP models for profit margin determination. Comprehensive investigations into tailoring MILP models to address the complexities of garment manufacturing, such as seasonality, fashion trends, and consumer demands, are absent from the current research. The literature also reveals a reliance on traditional decision-making approaches in the industry, where market research and competitor pricing strategies prevail. The absence of mathematical tools, particularly MILP models, in decision-making processes represents a significant gap that hinders the industry from realizing the full benefits of optimization techniques. Therefore, there is a compelling research gap for studies that specifically explore the application of MILP models in the garment industry, particularly in multi-objective scenarios that consider profitability, cost efficiency, and sustainability.

3. Research Methodology

We have conducted this research at Nalin Tex Ltd., 712 Uttar Khan Mazar, Taltola, Dhaka-1230. We collected the data from the costing executives in both the planning and costing departments. The data included selective manufacture costs, i.e., raw material, labor, machine, fabric, and packaging costs. In our proposed model, five types of garment products, two factory locations, and three customers have been considered. We also collected the machine capacity for both locations, the demand from three customers, the total quantity of the product, and the production rate. We entered all the collected data into the AMPL's dat.file. The AMPL's mod.file provides the interpretation of all the data. Simultaneously, the formulation of MILP aimed to optimize cost and profit. According to the developed model, we converted the collected data into objective functions and constraints. After integrating the data into the model, we proceeded to interpret and analyze the results produced by the AMPL model. This process involves evaluating various scenarios, considering the different products, factory locations, and customer demands.

4. Theoretical and Conceptual Framework

MILP: A mathematical optimization problem that combines linear and integer programming elements. The objective is to optimize a linear objective function by considering a combination of continuous and discrete decision variables (Floudas, 1995). The MILP is of the form given by

$$\underset{x,\, y_i}{\text{Optimize}} \quad Z = z(x,y) = a^T y + c^T x,$$

where $y_i \in 0, 1$ and x is a set of continuous variables. Note that the integer programming part in the objective function is linear (Diwekar, 2020),

$$\text{subject to} \qquad g(x,y) = -By + A^T x \leq 0.$$

Type of Algorithm: Integer linear (Linear objective and constraints and some or all integer-valued variables, by a branch-and-bound approach that applies a linear solver to successive subproblems).

AMPL: For linear and nonlinear optimization issues involving discrete or continuous variables, AMPL is a complete and potent algebraic modelling language. AMPL enables the creation of optimization models and study solutions using known concepts and standard notation while the computer handles communication with the proper solver (Fourer, 2003). AMPL is fundamentally an algebraic modelling language to treat the proposed MILP.

MINOS: MINOS is a software package for solving large-scale optimization problems (linear and nonlinear programs). It is especially effective for linear programs with a nonlinear objective function and sparse linear constraints (quadratic programs).

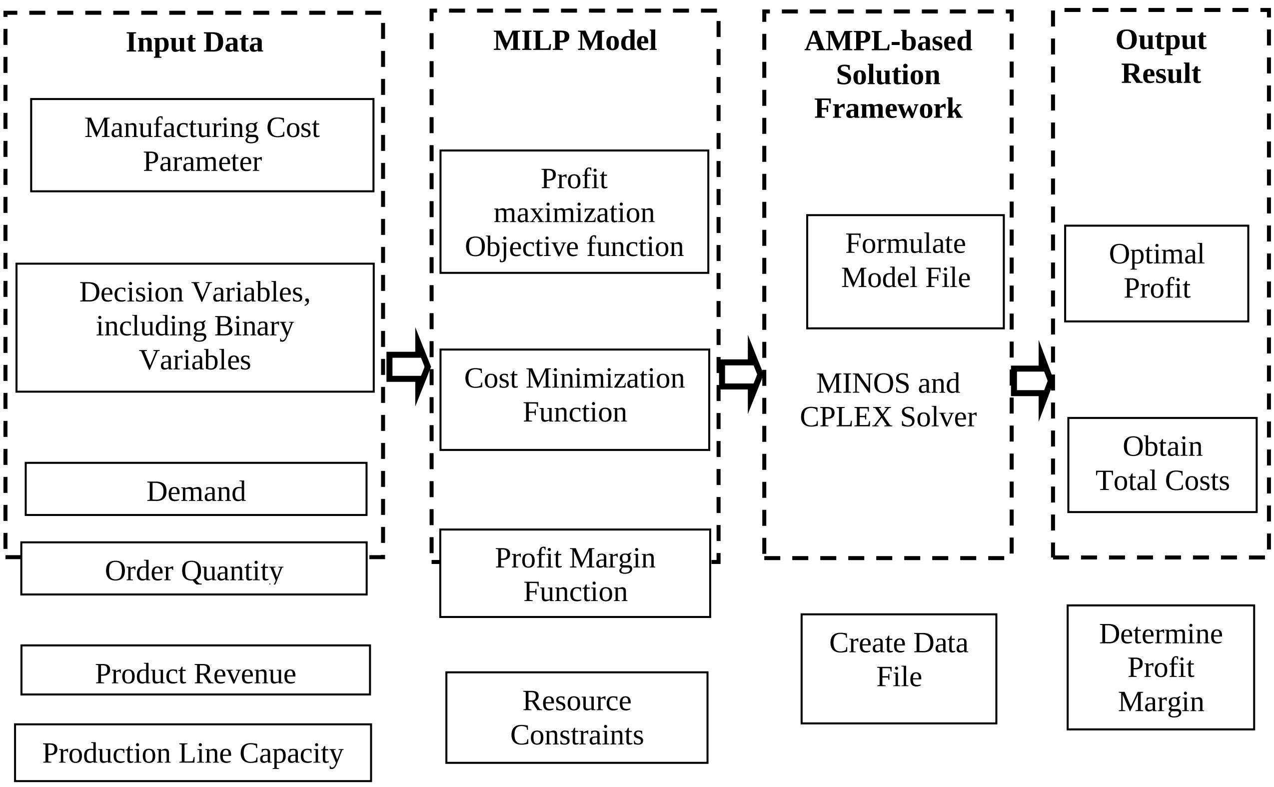

Fig. 1. Conceptual framework of the study.

5. Model Formulation

5.1. Assumptions of the Model

(i) Penalty cost is allowed.

(ii) The system considers multiple items and locations.

(iii) The production rate is constant at any time.

(iv) This analysis does not round the profit and cost values to decimal numbers because the underlying ground data maintains precision beyond the decimal point.

(v) The gross profit margin is considered among the other types of profit margins.

(vi) Each week, the number of trades is unchanged.

(vii) We use local currency for cost and profit analysis.

5.2. Indexes and Sets

$l \in L$ Location is available for the production plant; $l = \{1,2,\ldots,L\}$,

$j \in C$ Set of customers; $j = \{1,2,\ldots,C\}$,

$i \in P$ Set of products; $i = \{1,2,\ldots,P\}$.

5.3. Parameters for the model

ca_{il} Unit capacity for i^{th} product at l^{th} location,

$u1_l$ Fixed cost for l^{th} location,

q_{il}	Quantity for i^{th} product at l^{th} location,
d_{ij}	Demands of i^{th} product for j^{th} customer,
lbr_{il}	Labor cost for i^{th} product at l^{th} location,
LR_{il}	Labor requirement for i^{th} product at l^{th} location,
$rawmat_{il}$	Raw material cost for i^{th} product at l^{th} location,
$RawM_{il}$	Amount of raw material requirement for i^{th} product at l^{th} location,
$mach_{il}$	Machine cost for i^{th} product at l^{th} location,
$MacR_{il}$	Machine requirement for i^{th} product at l^{th} location,
fab_{il}	Fabric cost for i^{th} product at l^{th} location,
FR_{il}	Fabric requirement for i^{th} product at l^{th} location,
$pack_{il}$	Packaging cost for i^{th} product at l^{th} location,
PR_{il}	Amount of Package requirement for i^{th} product at l^{th} location,
$u8_{ij}$	Penalty cost of i^{th} product for j^{th} customer,
pr_{lt}	Procure for l^{th} location at t^{th} time,
$time_{il}$	Weeks to produce i^{th} product at l^{th} location,
$rate_{il}$	Produced rate per unit of time for i^{th} product at l^{th} location,
$trade_{iljt}$	Limit on i^{th} product sold at l^{th} location to j^{th} customer at t^{th} time in a week,
μ	Any large positive constant.

5.4. Decision Variables

x_{iljt}	Total amount of i^{th} product manufactured at l^{th} location for j^{th} customer at t^{th} time,
rvn_{il}	Revenue for i^{th} product at l^{th} location,
y_{iljt}	Amount of i^{th} product sold from l^{th} location to j^{th} customer at t^{th} time,
$arawmat_{il}$	Available raw materials for i^{th} product at l^{th} location,
$albr_{il}$	Available labor for i^{th} product at l^{th} location,
$amach_{il}$	Available machines for i^{th} product at l^{th} location,
$apack_{il}$	Available packet for i^{th} product at l^{th} location,
$afab_{il}$	Available fabric for i^{th} product at l^{th} location,
zz_l	$\begin{cases} 1, & if\ location\ l\ is\ used, \\ 0, & otherwise, \end{cases}$
z_3	Total return,
z_4	Total cost,
z_{max}	The maximum profit.

Objective function: maximize $z_{max} = z_3 - z_4$ (6)

$$z_{max} = \sum_{i=1}^{P}\sum_{l=1}^{L}\sum_{j=1}^{C}\sum_{t=1}^{T}(x_{iljt}\, rvn_{il})$$

$$-\sum_{i=1}^{P}\sum_{l=1}^{L}\sum_{j=1}^{C}\sum_{t=1}^{T}(mach_{il}+lbr_{il}+rawmat_{il}+fab_{il}+pack_{il}+pr_{lt}) \times x_{iljt}$$

$$-\sum_{l=1}^{L}(zz_l \times u1_l) - \sum_{i=1}^{P}\sum_{j=1}^{C}(d_{ij} \times u8_{ij})$$

subject to

$$\sum_{l=1}^{L}\sum_{t=1}^{T} x_{iljt} \le d_{ij}, \forall\, i, l \qquad (7)$$

$$\sum_{t=1}^{T} x_{iljt}\ RawM_{il} \le arawmat_{il}, \forall\, t \qquad (8)$$

$$\sum_{t=1}^{T} x_{iljt}\ LR_{il} \le albr_{il}, \forall\, t \qquad (9)$$

$$\sum_{t=1}^{T} x_{iljt}\ MacR_{il} \le amach_{il}, \forall\, t \qquad (10)$$

$$\sum_{t=1}^{T} x_{iljt}\ PR_{il} \le apack_{il}, \forall\, t \qquad (11)$$

$$\sum_{t=1}^{T} x_{iljt}\ FR_{il} \le afab_{il}, \forall\, t \qquad (12)$$

$$\sum_{j=1}^{C}\sum_{t=1}^{T} y_{iljt} \le ca_{il}, \forall\, i, l \qquad (13)$$

$$\sum_{i=1}^{P}\sum_{j=1}^{C} d_{ij} \le \mu \times zz_l, \forall\, l \qquad (14)$$

$$y_{iljt} - x_{iljt} \le 0, \forall\, j, l \qquad (15)$$

$$\sum_{i=1}^{P}\sum_{l=1}^{L}\frac{1}{Rate_{il}} * x_{iljt} \le \sum_{i=1}^{P}\sum_{l=1}^{L} time_{il}, \forall\, j, t \qquad (16)$$

$x_{iljt}, y_{iljt}, rvn_{il}, u1_l, mach_{il}, lbr_{il}, rawmat_{il}, fab_{il}, pack_{il}, pr_{lt}, d_{ij}, q_{il}, \mu \ge 0,$ (17)

zz_l is binary $\forall l$.

The objective function (6) represents the difference between net return and net cost, which maximizes the net profit. Constraint (7) expresses that the total number of manufactured products is less than or equal to the total demand for all locations. Constraints (8)-(12) ensure that the resources used by a solution do not exceed the total availability of raw materials, labor, machines, packaging, and fabric required to produce garment goods at all locations. Constraint (13) ensures that the total number of sold products is less than or equal to the total capacity for all locations. Constraint (14) mandates using a location only when a product is demanded. Constraint (15) ensures that the total product produced from all locations for all customers is either greater than or equal to the total product sold for all customers. Constraint (16) stipulates that the time available or allotted for producing all products should not exceed the week. Constraint (17) is the non-negative restriction and binary relation.

5.5. Profit Margin Estimation

After solving the model, we can determine the profit margin. A company's income statement includes gross, operating, and net profits. To calculate the profit margin, one must divide the total income by the total revenue. Gross profit is all income after accounting for the cost of goods sold, such as raw materials and labor. Gross profit reflects the percentage of each dollar of revenue retained after paying for the cost of production:

$$Prof_{mar} = \left\{ \begin{array}{c} \sum_{i=1}^{P}\sum_{l=1}^{L}\sum_{j=1}^{C}\sum_{t=1}^{T} y_{iljt}\, rvn_{il} - \sum_{i=1}^{P}\sum_{l=1}^{L}\sum_{j=1}^{C}\sum_{t=1}^{T} (mach_{il} + lbr_{il} + rawmat_{il} + fab_{il} + pack_{il}) \times x_{iljt} \\ - \sum_{l=1}^{L} (zz_l \times u1_l) - \sum_{i=1}^{P}\sum_{j=1}^{C} (d_{ij} \times u8_{ij}) + \sum_{i=1}^{P}\sum_{l=1}^{L}\sum_{j=1}^{C}\sum_{t=1}^{T} y_{iljt}\, rvn_{il} \end{array} \right\}$$

Here, all indices have the same meaning as the main model.

6. Solution Approach

Our study addresses the formulated mixed-integer linear programming (MILP) problem using the AMPL modelling language with the MINOS solver. Additionally, we validate the developed model by testing it with an alternative solver, CPLEX, using the same modelling language. AMPL takes MINOS as its default solver, but if we want to change the solver, we may put the solver option in the AMPL command (Jin, 2014).

Applying a specific dataset and running the program through AMPL yields consistent results in both solvers. This convergence of outcomes reaffirms the reliability and accuracy of our formulated MILP model across different solvers.

We use the branch and bound algorithm to solve problems. This program runs an 11th Gen Core i3 machine with a 3.00 GHz processor and 4.0 GB of RAM. The proposed model comprises two primary domains: the main module, which encompasses the actual program, and the data file, which contains the numerical data set of the various parameters. We have examined an example to evaluate the proposed model's effectiveness. We assume a vendor has established two locations and forecasts five productions for three customers. At the beginning of the result analysis, we show the variance of costs that affect the overall profit. According to our model, three customers placed their demand for five products with the supplier. The supplier then forwards the demand to the factory's manufacturer. Based on the collected data, manufacturers then make decisions concerning allocating production orders to two different plants, characterized by different manufacturing costs and other parameters.

7. Results Analysis

The manufacturer's overall fixed costs for 2 locations are 210000 and 180000 respectively. The quantity of the product is produced based on time and rate of machine for each location: {(1410, 1420, 1310, 1420, 1480), (1520, 1585, 1530, 1550, 1590)}; {(34, 36, 38, 37, 36), (33, 34, 41, 42, 35)} and {(200, 120, 130, 120, 130), (130, 110, 120, 110, 150)}. The revenue for each product of each location is {(1000, 1530, 1200, 1300, 1400), (1500, 1540, 1220, 1320, 1430)} and the penalty cost incurred for delayed delivery for each product of each customer is {(0.3, 0.1, 0.3, 0.5, 0.2), (0.2, 0.4, 0.1, 0.2, 0.1), (0.1, 0.3, 0.2, 0.1, 0. 2)}.

Table 1. Parameters for the MIP model

Parameters	**Number of Products**				
d_{ij}	i_1	i_2	i_3	i_4	i_5
j_1	4000	3200	3800	4500	3500
j_2	3000	4000	4000	5000	4500
j_3	3000	3500	4000	4000	4500
$\boldsymbol{rawmat_{il}}$					
l_1	150	115	140	180	120
l_2	160	110	170	150	165
lbr_{il}					
l_1	50	65	80	75	70
l_2	70	55	70	60	85
$\boldsymbol{mach_{il}}$					
l_1	108	107	101	107	108
l_2	105	109	100	102	105
$\boldsymbol{fab_{il}}$					
l_1	100	150	165	155	170
l_2	120	160	145	170	150
$\boldsymbol{pack_{il}}$					
l_1	30	35	32	33	31
l_2	32	34	34	32	33
$\boldsymbol{ca_{il}}$					
l_1	50000	40000	35000	45000	35000
l_2	55000	50000	50000	45000	40000

According to the abovementioned data, the formulated MILP model gives us the following results:

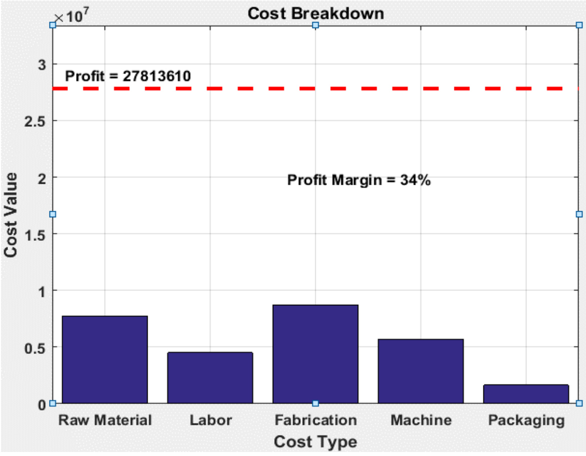

Fig. 2. Graphical representation of the results (Case 1).

One important thing to note is that in the AMPL model that was created, some parameters are labelled as stochastic to allow for changes in their values that can be caused by unknowns like market fluctuations, unpredictable customer behavior, the global recession, the falling value of the taka, the rise in inflation rates, or other random events that affect the value of the parameter. For example, cost is one such parameter. If a company decides to maintain the same selling price despite an increase in costs, its profit margin will decrease. The portion of each sale that contributes to covering fixed costs and generating profit is reduced. Higher costs may lead to reduced profit margins, and if the company is in a competitive market, it might be challenging to increase prices. In such cases, the company may need to increase sales volume to compensate for lower margins. To evaluate the accuracy of our developed model, we increase the cost by 10% while maintaining all other parameters unchanged, as demonstrated in the example mentioned above.

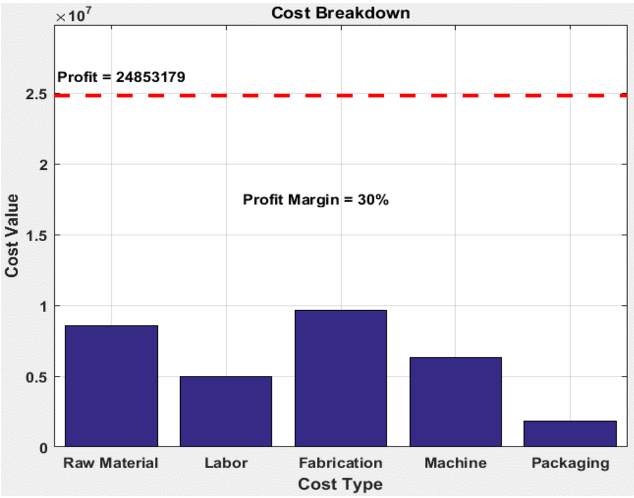

Fig. 3. Graphical representation of the results (Case 2).

Graphical representation of the result (Case 2) shows that the profit line decreases compared to Case 1. Therefore, we deduce that after increasing the cost value by 10%, the profit margin decreases by 4%

to maintain the same selling price. The coordinated demand from all locations remains constant, and the product quantity is also determined, but the dynamic market environment has led to continuous changes in both cost factors and revenue. Table 2 represents the obtained results.

Table 2. Results analysis.

Instances	Total Profit	Total Cost	Total Revenue	Profit Margin	Total Raw Material Cost	Total Labor Cost	Total Machine Cost	Total Fabric Cost	Total Packaging Cost
1	27813610	52577300	80390900	34%	7753140	4531160	5721010	8727230	1658990
2	24722831	54057500	78780300	31%	8170560	4736890	6030580	9180200	1753530
3	23169141	55611200	78780300	29%	8608790	4952850	6355440	9655630	1852750
4	28987833	57242700	86230500	33%	9068890	5179610	6696770	10154800	1956880
5	30739728	57242700	87982400	35%	9068890	5179610	6696770	10154800	1956880
6	22820585	53457300	76277900	30%	8142300	4361660	5103700	9488110	1797940
7	38011501	51033000	89044500	42%	7487070	4252890	5515210	8023910	1568200
8	21802849	53822000	75624900	29%	8104490	4703980	5981600	9108310	1737910
9	23702577	53437500	77140100	31%	7916970	4673260	5915480	9019220	1726830
10	26250801	52434700	78685500	33%	7516270	4282090	6800130	8053110	1597400

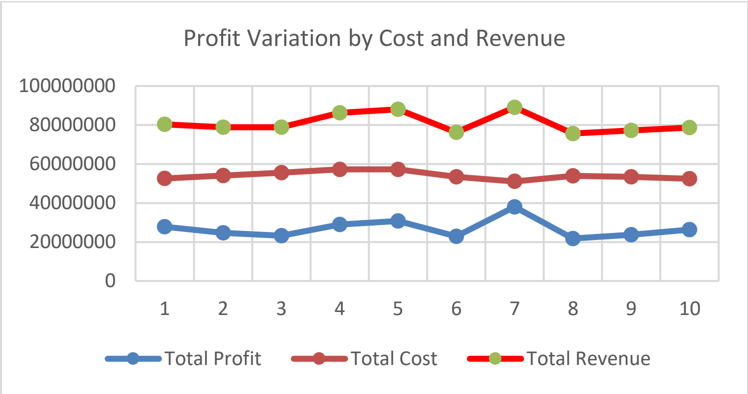

Fig. 4. Profit variation based on cost and revenue fluctuation.

From Table 3, manufacturers can insight into the following:

(i) *When Cost < Revenue*: When a business can reduce its costs without negatively affecting its revenue, it can increase profits. Cost-cutting measures can improve the profit margin if revenue remains stable or increases.

(ii) *When Cost > Revenue*: If a business experiences an increase in costs (production costs) without a corresponding increase in revenue, it could lead to a decrease in profits. This might happen if the business cannot pass the increased costs to customers through higher prices or if sales volume doesn't improve.

Sensitivity analysis can reveal the model's robustness and identify critical factors influencing profit and cost. Perform sensitivity analysis to explore how changes in various parameters impact profit. For example, in our model, changes in raw material, labor, machine, fabric, packaging, and penalty costs affect the final profit outcome. The proposed model yields the following results.

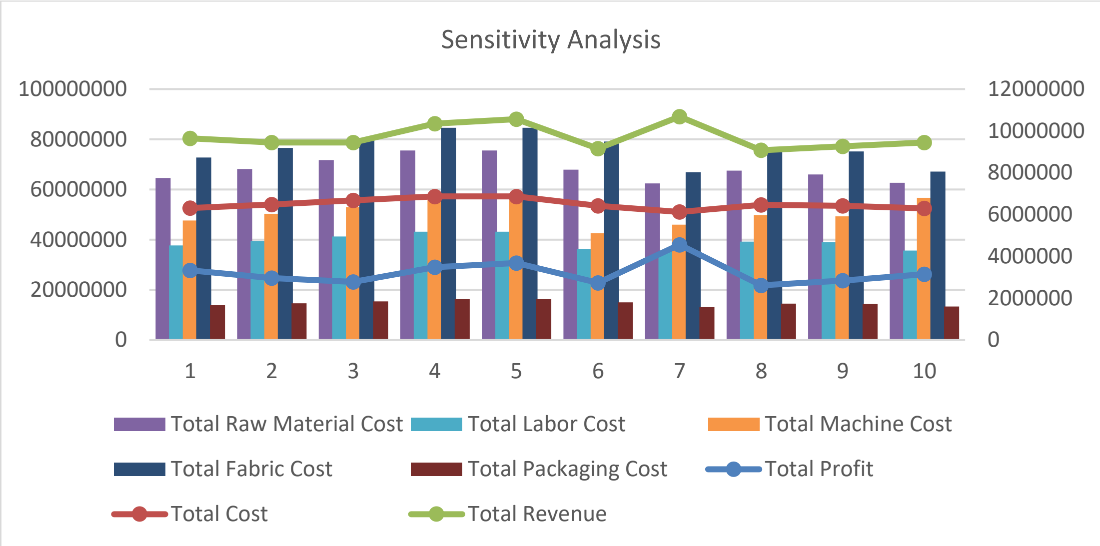

Fig. 5. Profit-cost relationship analysis.

In Figures 4 and 5, instance 7 shows that controlling and managing costs is essential for maximizing profitability. With this concept in mind, manufacturers consider effective cost-control measures such as efficient resource utilization, supply chain optimization, and waste reduction. For effective cost control, manufacturers need to know which cost components significantly impact total profit. He may find that some costs strongly influence profit while others have a lesser impact. To do such an analysis, the model must keep all parameters unchanged besides the specific impacted cost parameter (see Tables 3-9)

Table 3. Result analysis between profit and raw material cost.

Instances	Total Profit	Profit Margin	Total Raw Material Cost
1	26545624	33.5%	7753140
2	26128209	33%	8170560
3	25689977	32.4%	8608790
4	25229883	31.9%	9068890
5	24992803	31.6%	9305970
6	25254209	31.9%	9044560
7	25736288	32.5%	8562480
8	26194277	33.1%	8104490
9	26381794	33.3%	7916970
10	26811697	33.9%	7487070

Table 4. Result analysis between profit and labor cost.

Instances	Total Profit	Profit Margin	Total Labor Cost
1	26545624	33.5%	4531160
2	26339899	33.3%	4736890
3	26123941	33%	4952850
4	25897180	32.7%	5179610
5	25806422	32.6%	5270370
6	25909391	32.7%	5167400
7	26146969	33%	4929820
8	26372803	33.3%	4703980
9	26403530	33.3%	4673260
10	26545624	33.5%	4531160

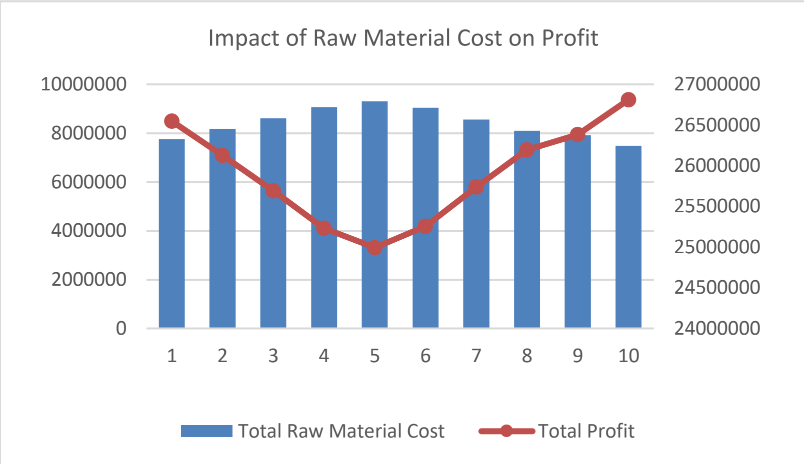

Fig. 6. Raw material cost impact analysis on profit.

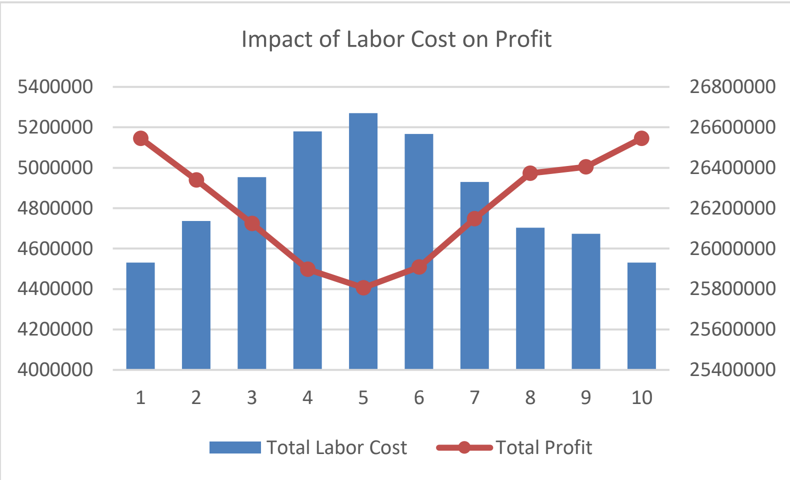

Fig. 7. Labor cost impact analysis on profit.

Table 5. Result analysis between profit and machine cost.

Instances	Total Profit	Profit Margin	Total Machine Cost
1	26545624	33.5%	5721010
2	26236061	33.1%	6030580
3	25911201	32.7%	6355440
4	25569868	32.2%	6696770
5	25495703	32.2%	6770940
6	25587984	32.3%	6678650
7	25945457	32.8%	6321180
8	26285038	33.2%	5981600
9	26351161	33.3%	5915480
10	26481342	33.4%	5785300

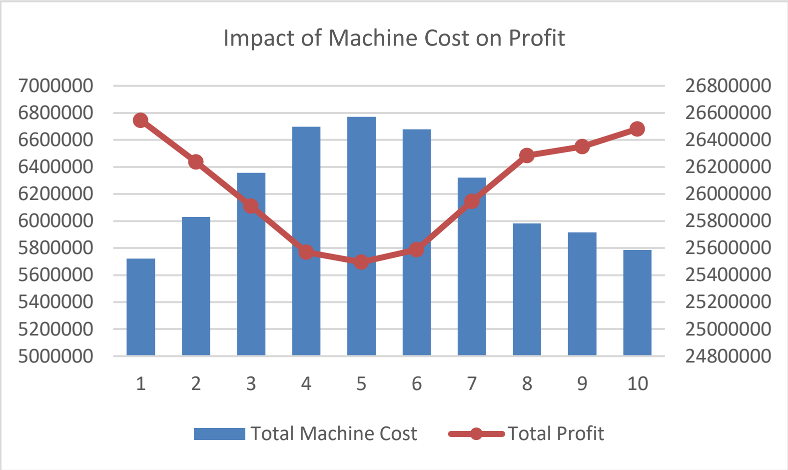

Fig. 8. Machine cost impact analysis on profit.

Table 6. Result analysis between profit and fabric cost.

Instances	Total Profit	Profit Margin	Total Fabric Cost
1	26545624	33.5%	8727230
2	26092654	32.9%	9180200
3	25617229	32.3%	9655630
4	25118021	31.7%	10154800
5	24993116	31.6%	10279700
6	25144489	31.7%	10128400
7	25667698	32.4%	9605160
8	26164545	33%	9108310
9	26253641	33.1%	9019220
10	26478122	33.4%	8794740

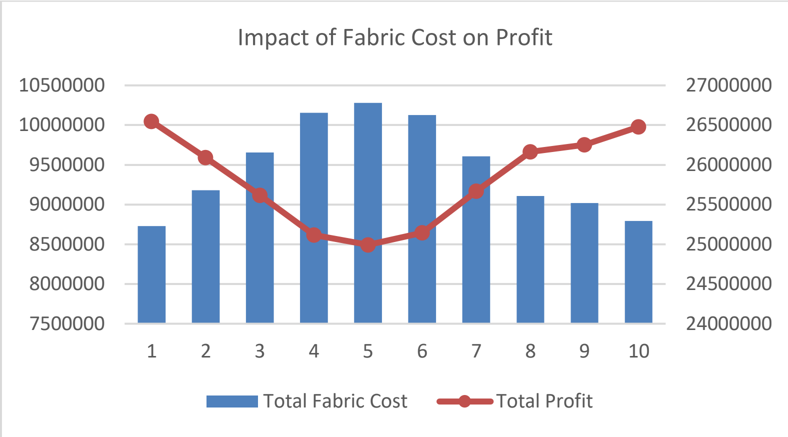

Fig. 9. Fabric cost impact analysis on profit.

Table 7. Result analysis between profit and packaging cost.

Instances	Total Profit	Profit Margin	Total Packaging Cost
1	26545624	33.5%	1658990
2	26451081	33.4%	1753530
3	26351866	33.3%	1852750
4	26247739	33.1%	1956880
5	26181744	33.1%	2022870
6	26253579	33.2%	1951040
7	26362837	33.3%	1841780
8	26466704	33.4%	1737910
9	26477785	33.4%	1726830
10	26636418	33.6%	1568200

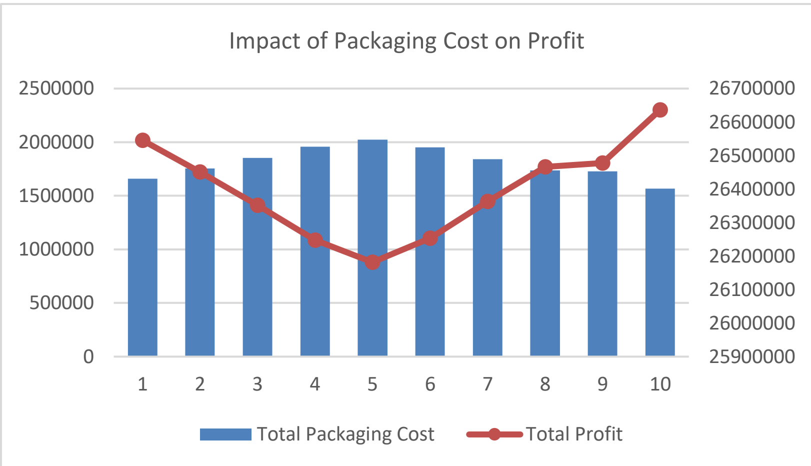

Fig. 10. Packaging cost impact analysis on profit.

We observe that a slight change in costs leads to a significant shift in profit in each instance; therefore, the profit is highly sensitive to cost fluctuations. Upon analyzing the profit and cost, the manufacturer will understand which cost parameter affects his overall profit margin. In such a case, the company's manufacturer needs to closely monitor and manage the cost factor to balance the profit margin.

Due to changing customer behaviors, the demand may vary. Variations in customer demand can directly impact the profitability of a garment factory. Increased demand can boost profits, while decreased demand leads to lower profits. To maintain profitability, factories may need to adjust their production schedules, labor allocations, and materials sourcing based on shifting customer preferences. Our proposed model allows for the projection of this evolving scenario:

Table 8. Profit analysis by demand and quantity.

Scenario	Total Demand	Total Quantity	Total Cost	Total Profit
1	49996	24671	44955200	23038909
2	52396	24815	47489400	23319358
3	50796	24870	46591300	21762799
4	61096	34920	56220300	26183428
5	53296	44970	49388000	22490222
6	62096	25020	59020800	24847438
7	83396	25070	79526900	33627705
8	81196	26245	79777100	29789416
9	87296	25170	85584800	32409373
10	96196	25220	94854700	35053232

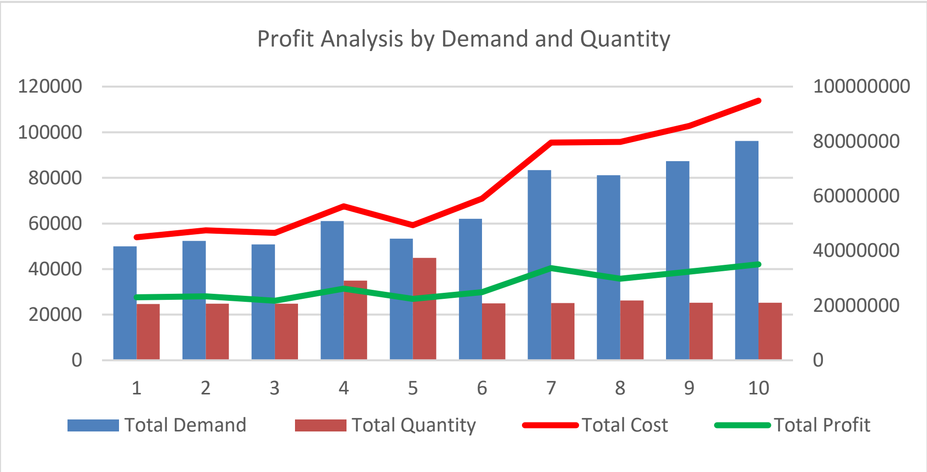

Fig. 11. Manufacturer's Profit Analysis

This analysis shows a strong relationship between demand, cost, and profit. When demand for a product goes up, the cost and profit also tend to increase. Conversely, when demand decreases, both costs and profits tend to decrease. Therefore, fluctuations in demand can substantially impact a garment factory's financial performance. From Figures 5 to 10, we observed a downward trend in the profit line due to high costs, while in Figure 11, the high demand also led to an increase in costs. The manufacturer needs to address these points. The foremost concern is to focus on cost management strategies. To improve efficiencies, a thorough review of the cost structure is necessary. The manufacturer should investigate options such as optimizing the supply chain, negotiating better deals with suppliers, or exploring alternative materials or production methods to reduce costs. Taking into account the strategies above, the manufacturer derived the following outcome from our proposed model:

Table 9. Profit analysis by cost reduction.

Scenario	Total Demand	Total Quantity	Total Cost	Total Profit
1	49996	24671	34395500	35072627
2	52396	24815	35546400	36797066
3	50796	24870	33997000	35838381
4	61096	34920	40566600	43623036
5	53296	44970	35159300	38276876
6	62096	25020	40672800	45013246
7	83396	25070	54318900	61288206
8	81196	26245	52189100	59751952
9	87296	25170	55865600	64685813
10	96196	25220	60965900	71757487

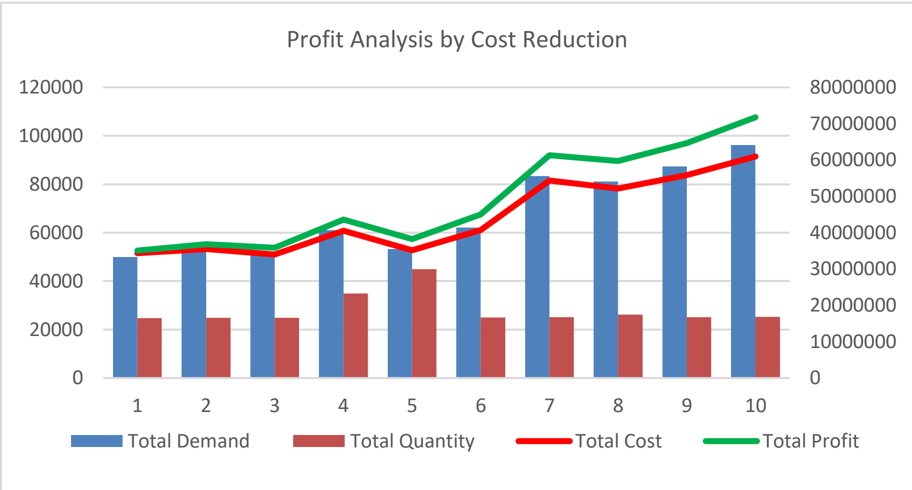

Fig. 12. Relationship between Cost Reduction and Profitability

When demand and quantity data remain constant but revenue fluctuates, Figures 11 and 12 offer valuable insights into the relationship between cost reduction and profitability. It is evident from the data that reducing costs plays a significant role in increasing profit. When examining both figures, we can observe that profit tends to increase as costs decrease. Similarly, our developed model can project the relationship between profit and any other decisive parameters. This is how the manufacturer can make data-driven decisions that optimize their operations and boost profitability. Based on this variation in production costs, manufacturers can utilize our developed model to negotiate a favorable deal with buyers. Using the insights gained from this model, they can strategically adjust their cost structure, pricing strategies, or production processes to maximize profit considering market conditions and competition.

8. Significance of the Study and Expected Results

Currently, manufacturers commonly rely on Excel sheets for cost and profit analysis. However, the sensitivity analysis tool in MS Excel has notable limitations. One major constraint is its ability to handle only two inputs simultaneously, restricting its functionality to single-variable and double-variable sensitivity. In contrast, our proposed model allows for the concurrent input of multiple variables. Moreover, the traditional approach employs basic formulas for determining profit margins, lacking the sophistication required when dealing with numerous parameters and decision variables. We adopt a more comprehensive and versatile approach in our suggested model to address these complexities.

Upon completion of this study, the manufacturer will possess the following capabilities:

1. Make a suitable decision during the negotiation with buyers.
2. Identify the effect of different parameters on profit.
3. Find the best possible deal with buyers.
4. Know the profit margin so you can grab the order.
5. Make the business profitable.

9. Conclusion

Our research has developed a robust mathematical model for cost and profit analysis in the garment manufacturing industry, offering a strategic tool that can empower manufacturers to make data-driven decisions. We have established the relationship between profit and its decisive parameters, i.e., the quantity of a product, demand, revenue, capacity, time, procurement, and different costs (labor, machine, fabric, raw material, and packaging). We used the MINOS solver to solve the mathematical model for a specific data set and tested it with the CPLEX solver. Sensitivity analysis has been carried out to validate the reliability of the developed mathematical model. For each instance of a different data set, the MILP gave the optimum profit. The model also concludes that after increasing the cost value by 10%, the profit margin decreases by 4% to maintain the same selling price. The profit analysis also reveals that an increase in product demand leads to an increase in cost and profit. Conversely, when demand decreases, both costs and profits tend to decrease. The model allows decision-makers to pinpoint the optimal pricing strategies, understand demand elasticity, and identify break-even points. This data-driven approach empowers the manufacturer to make informed decisions that lead to a more sustainable and profitable business in the long run. By implementing this model, garment manufacturers can gain deeper insights into their profit dynamics, optimize their operations, and adapt to changing market conditions. This research contributes to the industry's ability to remain competitive and financially sustainable in a dynamic market environment. A significant application of our model lies in its guidance for FOB orders. Manufacturers can leverage the insights derived from this model to inform and enhance their decision-making processes when handling FOB orders. This integration further solidifies the model's practical utility, as manufacturers can effectively align their strategies with the unique considerations of FOB transactions.

9.1. Future Work

In our existing model, we have primarily focused on manufacturing costs to calculate the profit margin. However, to determine the comprehensive cost of the total garment, it is imperative to incorporate logistics expenses, encompassing both inventory and transportation costs. Our forthcoming strategy involves formulating mathematical models for both inventory and transportation costs. Subsequently, we plan to integrate these individual models to derive the total cost of garments, allowing for a more accurate profit margin calculation.

Appendix A. Sample examples of sets in AMPL based on our developed mathematical model

.mod FILE

pd19 - Notepad

File Edit Format View Help

```
# Production model
set L; # locations
set C; # customers
set P; # products
#set D; #distribution center
#param  demand {P,C};   # number of demand perweeks
param q{P,L};

param T > 0;  # number of weeks
param prob;  # probability
param rate {P, L} > 0;
#param procure{L,1.. T} >= 0;
param trade {P, L,C,1.. T} >= 0;

#var demand {P, C} >= 0;
param demand_mean {i in P, j in C}>=0;
param demand_variance {i in P, j in C} > 0,
< demand_mean[i,j] / 2;
param  demand {i in P, j in C} =
max(Normal(demand_mean[i,j], demand_variance[i,j]), 0);
#param  ca{P,L};#capacity
param  u8{P,C}; #penaltyCost
#param  u1{L}; #fixedCost=u1
var z3>=0;
var z4>=0;
var zz{L}, binary ;
var zzz{ L,C} >= 0;
var x{P, L,C,1.. T} >= 0;
var y{i in P, l in L,j in C, t in 1..T} >= 0,
<= trade[i,l,j,t]; # unit sold
var Total_Revenue;  # Declaring Total_Revenue variable
subject to Calculate_Total_Revenue:
Total_Revenue = sum{i in P, l in L, j in C, t in 1..T}
revenue[i,l] * y[i,l,j,t];
```

.dat FILE

pd18 - Notepad

File Edit Format View Help

```
data;
#  Production model
set C := 1  2 3 ; # customers
set P := 1 2  3 4 5;
set L := 1 2  ;
param T := 4;
#param n:= 1000;
param prob:= 1;
param procure_mean:   1      2       3    4:=
                  1   450    400     320  400
                  2   400    300     400  450;
param procure_variance:   1  2   3  4:=
                      1   18  15  12 12
                      2   15  17  14 15;
param q :     1    2    :=  # e9
          1    1410 1520
          2    1420 1585
          3    1310 1530
          4    1420 1550
          5    1480 1590 ;
param time_mean :        1  2 :=
                   1     34 33
                   2     36 34
                   3     38 41
                   4     37 42
                   5     36 35 ;
param time_variance :  1   2 :=
                 1     6  7
                 2     6  5
                 3     8  7
                 4     6  8
                 5     5  6 ;
```

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