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Inspection cost minimization by optimizing the number of inspectors in apparel manufacturing

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Apparel manufacturing organizations aim to minimize costs, including inspection costs, but there is a research gap in optimizing the number of inspectors without compromising quality. This study focuses on reducing inspection costs by determining the minimum number of inspectors required. A mathematical model has been developed to calculate inspection costs based on the standard minute value and cost per minute. Additionally, a linear programming (LP) model is introduced to optimize the number of inspectors based on cost and inspection volume while considering their capacity and skill levels. Data from large, medium, and small-scale factories reveal that 30%–35% of inspectors exceed the standard requirement due to a lack of awareness among quality managers regarding inspection capacity, skills, and targets. Large-scale companies employ 25% more inspectors for operational flexibility, while medium and small-scale factories exceed standard requirements by 30% and 35%, respectively, to meet inspection demands. This study proposes an inspection cost reduction tool using LP to determine the optimal number of low-, medium-, and high-skilled inspectors per line for a given production target. Findings suggest that implementing this model can reduce the number of inspectors by 30%, leading to significant inspection cost savings without compromising quality.

1. Introduction

Reducing costs in the apparel manufacturing industry is a crucial factor in surviving in the competitive market. On November 1, 2018, the RMG sector in Bangladesh increased wages for low-level workers by more than 50% [1]. The garment owner urged the buyer to increase manufacturing costs, but unfortunately, they denied it. There was an alternative way to reduce costs by minimizing the workforce and improving productivity at that time to sustain the business. However, they still have the option to reduce inspection costs. The reason behind this is that the customer is trying to reduce costs by providing training for the factory's nominated quality control (QC) to reduce inspection costs. At the same time, they are pushing factory owners to reduce prices by reducing quality inspection costs. Henceforth, there is no alternative option to minimize inspection costs in the garment manufacturing industry in Bangladesh.

At present, cost reduction is a hot topic in the apparel manufacturing industry. Since labor costs have increased dramatically, the need for cost reduction has become a crying need for the RMG sector to survive in the competitive market. As a result, quality cost is the most important factor in total cost. The quality department's organogram constitutes Fig. 1. A minimum of two to three QI is inspected for finished garments at the end table for lingerie items, and three to four QI for woven and knit items. Every two-line possesses one roaming QC. A Quality Controller follows up on 5 lines, and 10 to 11 lines are controlled by a quality executive. Henceforward, it is clear from Fig. 1 that the structure of the quality department is to maintain the quality standard of the customer. It is so expensive and the number of quality-responsible people should be reduced to ensure inspection costs are going down to endure the competition.

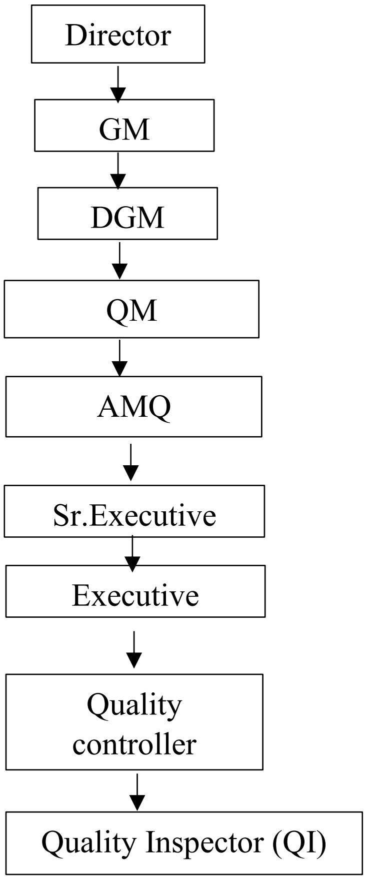

Fig 1. Schematic view of quality department's structure

The factory was not aware in the past of the cost of quality. However, as labor costs have increased, the main focus now goes on cost-cutting. To do so, the owner wants to know the cost of poor quality, the cost of good quality, and overall, the cost of quality.

Cost minimization is a crucial task for the apparel manufacturing industry to sustain in this competitive and cost-effective market. The research [2][3] shows that reducing non-productive activities in the cutting section leads to time and cost savings. So, the cutting operation is one of the core value-adding processes in a garment manufacturing unit. However, there are different options in the apparel industry to save costs, which involve wastage reduction, avoiding faulty work, and so on [4][5].

Many garment manufacturing companies adopted the lean philosophy to reduce waste and save money. The reduction of work in progress (WIP) by ensuring on-time material delivery is one area of focus under the lean concept [6][7]. Moreover, a study [8] was conducted on the reduction of the total procurement cost, focusing on the optimization model for vendor selection. The drawbacks of the research were that they could not develop multiple-item mathematical programming for the vendor selection model with inventory management. The supplier selection model proposed by [9][10] demonstrates how costs can be reduced while selecting the best supplier while also providing

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other benefits. Some researchers[11][12] demonstrated the use of cost-cutting techniques in the purchase of materials using TCO (total cost of ownership). Financial paybacks can be derived from revenue extension cost minimization, or both concurrently. According to the author [13], the company can be financially developed by focusing on increasing revenue and decreasing costs. An analytical study is directed at the reduction of the cost by increasing the sales value of the company. The concentration of the research [14] was on building relationships amid employee loyalty, service quality and cost reduction, and company performance, to examine the effect of employee loyalty on employee performance. Using diverse statistical models (the Kolmogorov-Smirnovljev statistic, Path analysis, A.M.O.S. statistic software, and Lavaan software) leads to the deduction that employee loyalty is vastly related and has a positive impact on company performance, which supports the cost reduction as a whole for the designated company.

Reference [15] investigated the effects of the company-customer relationship on company performance, as well as the related influence on service quality and the variables that influence performance, concluding that employees and return on investment, which includes cost reduction, have an impact on performance. Another study [16] demonstrated the relationship between cost reduction and improved performance, assuming that organizations that are successful in lowering costs will perform better. The research [17] examined cost-cutting strategies to boost company value and performance. The investigation [18] employed cost reduction analysis and continuous improvement programs to gain a competitive edge. The study [19] explored reducing labor costs to increase firm performance. The analysis [20] demonstrated the way of minimizing the cost of quality (COQ) in the textile and garment manufacturing industry. They employed prevention, failure, appraisal, and opportunity cost models. It focused mainly on the implementation of lean and sustainable initiatives to reduce the COQ of manufacturing units from 6.8% to 4.5%. Several studies looked at how much material is used and how to decrease costs in the garment-cutting process. The study [21] developed a genetic optimization decision-making model through adaptive evolutionary robust strategies to manage cut order planning. Their study showed at least 50% of the manufacturing costs. To control cut order planning, we created a genetic optimization decision-making model using adaptive evolutionary resilient techniques. At least half of the manufacturing costs can be minimized, according to their research. The research (Jeffrey M and Evans N) investigated the costs connected with the fashion sector and discovered that they ranged from 45 to 60 percent. This study [22] evaluated the lay plan's optimal results and their impacts; their analysis found 50 percent to 80 percent of the associated costs. The examination [23] offered additional information on cut order planning, T&G waste, and material utilization in the Macedonian garment industry, where raw material expenses account for 75% of total production costs. The ITJ (2008) examined fabric utilization and multiple fabric losses in the cutting section; the corresponding garment material costs ranged from 40 to 60 percent. Because material prices can account for up to 75% of the cost of making clothes, analyzing and optimizing raw material costs can boost revenues.

This study implements the six-sigma methodology to improve the quality of the garments manufacturing organization where they were able to increase by 5.48 % sigma and decrease defects by 44.09 %. It has been successful in raising the level of Sigma, automatically lowering the percentage of defects, and increasing the productivity of formal men's jackets in the garment sector by integrating the Six Sigma method with the DMAIC methodology [24]. This study analyzes defects reduction in selected sewing lines of a garments factory with the DMAIC methodology of Six Sigma which entails increasing the Sigma percentage and reducing the rate of defects [25].

The study investigates how applying the Total Quality Management (TQM) approach in Bangladesh's garment manufacturing sector may enhance the quality, productivity, and cost elements of a sewing line. The goal of this study is to decrease the four main kinds of errors that occur in DMC Apparels Ltd.'s sewing department: up-down, broken stitch, joint stitch, and uncut thread. The operators and assistants gave accurate information on several stitching faults, and that information is used to evaluate the study in the following stage. Part of the investigation involves using histograms and the Pareto analysis to pinpoint the main issues. Ultimately, the investigation was finished by determining the total equipment effectiveness and examining the basic pitch time graph [26].

A study [27] proposed a configuration that helps with the minimization of the total cost of the reverse supply chain by concentrating on inspection costs. A mathematical model is generated for the creation of returns in a reverse supply chain considering quality assurance (QA). They implemented an exponentially weighted moving average (EWMA) to monitor the mean and variance of a process. The joint control method is designed using an EWMA cost reduction model based on performance requirements. Some authors [28] described a path for lowering inspection costs by reducing rework, which leads to increased productivity in the apparel manufacturing industry. They focused on optimizing process loss, increasing process performance of the critical operation, utilizing maximum resources, and maintaining a consistent quality level of the process to decrease inspection costs. Some researchers [29] suggested reducing the defects, which would minimize the rework rate and, ultimately, reduce inspection costs by optimizing quality inspectors in a leading apparel manufacturing organization. To do the analysis, it applied 5S and PDCA tools to minimize the defect rate. [30] analyzed the current circumstances of the Indian apparel manufacturing industry. He found that the cost of quality was augmented due to the intensified rate of defects and low productivity. On average, factories lose 25%–30% of their costs because of poor quality, which leads to an upsurge in inspection costs. They calculated COQ and identified major operations where defects occurred repeatedly, and then factory concerns took the initiative to improve quality to reduce overall inspection costs.

In his article "Cost of Quality in the Apparel Industry," [30] explains the cost of poor quality and how it affects the profitability of the organization and the industry as a whole. According to this study, quality is one of the most undervalued and misunderstood aspects of the apparel industry. Due to poor quality, companies are losing more than 25% of their manufacturing expenditure.

An analysis of [31] stated that to improve operational smoothness, it is mandatory to ensure the "right first time", which will help to reduce overall costs along with inspection costs and to survive in this competitive market. They presented how to minimize defects by introducing the DMAIC (Define, Measure, Analyze, Improve, and Control.) of Six Sigma into a sewing section of a designated garment manufacturing unit. At the same time, they used Pareto chart analysis to classify the top defects occurring in the process and take remedial action to control them.

After the implementation of the proposed methodology, the defect rate was reduced from 11.229 to 7.604 percent, and overall, the Sigma level was enhanced from 2.714 to 2.93. Quality encompasses productivity.

Hence, the factory can increase productivity and profitability with improved quality creation by diminishing the need for reworks. It also reduces costs and recovers internal resources over time. Moreover, a study [32] showed that minimizing inspection costs by shaping the minimal number of inspectors in the apparel manufacturing industry was feasible. They formulated a model for inspection error, inspection capacity, and inspection cost for the garment industry, focusing on the goal programming-preemptive method. The findings of the study were to optimize values of objective functions that include inspection cost per day, inspection quantity, and inspection error rate. They implemented QM optimization software to get such an output. The study's limitations are that it considers time-varying factors such as inspector skill level, inspection target, and quality inspector learning behavior.

Reference [33] proposed a configuration that supports minimizing the total cost of the reverse supply chain by focusing on inspection costs. A mathematical model is generated for product return in a reverse supply chain considering quality assurance (QA). Reference [27] outlined a way of lowering inspection costs by reducing rework, which leads to increased productivity in the garment manufacturing business. Reference [28] stated that by optimizing quality inspectors in a prominent garment manufacturing organization, they may be able to reduce defects, which would lower the rework rate and, in turn, lower inspection costs.

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In his essay "Cost of Quality in the Apparel Industry," some studies [30] showed the cost of poor quality and how it affects the profitability of the organization and the industry as a whole. According to this study, quality is one of the most underappreciated and misunderstood components of the apparel industry. Companies are losing more than 25% of their production expenses due to poor quality. According to a study [31], it is critical to ensure the "right first time" to increase operational smoothness, which will help to minimize total costs, as well as inspection costs, and to survive in this competitive market. Because productivity and quality are intertwined, as a result, by reducing the requirement for reworks, the plant can boost production and profitability while also improving quality. It also saves money over time by lowering costs and recovering internal resources.

Furthermore, a study [32] showed that in the textile manufacturing industry, reducing inspection costs by utilizing an optimal number of inspectors can save money. They developed a model for inspection error, capacity, and cost, based on the goal programming-preemptive method. The study's findings were used to improve the values of objective functions such as inspection cost per day, inspection quantity, and inspection error rate. To achieve this, they used QM optimization software. The study's limitations include time-varying factors such as the inspectors' skill level, inspection target, and quality inspectors' learning behavior. In this study, its focuses is on overcoming the limitations of the study to find out the skill level of the inspector, as if it can decide how many optimal inspectors will be required to inspect targeted garments. It will also emphasize the importance of setting up an inspection target for the quality inspector to make sure inspectors are being utilized in a scientific way [33].

On the other hand, some studies [34][35][36][37] pointed out that productivity and efficiency improvements, lack of higher productivity and efficiency, and deficiency of the ergonomically designed workstation could severely affect garment quality. The reason behind this is that the workers get highly paid and get bonuses or incentives once the factory makes money by improving productivity and efficiency and then the owner could eagerly provide extra payment to the garment workers. That excessive payment got joyful, and they become motivated and after that they work by taking ownership which ensures good product quality. Since the worker gives product quality so any owner can get the route to minimize the quality inspection cost by optimal usage of the number of inspectors in the premises.

Undoubtedly, there are other alternative ways to optimize everywhere to minimize cost. Thus, the supply chain optimization in the apparel industry includes the optimization of every echelon like cutting, printing, sewing, finishing, packing, and shipping. Every echelon must apply quality inspectors to make sure the garments or products are being manufactured while maintaining the standards of the buyer. The optimization focuses on cost and manpower including quality which the authors emphasized in their study [38-46].

The research contributions are twofold: (1) We develop a mathematical model for determining the optimal number of inspectors required, considering skill levels and inspection targets, and (2) we present a cost-minimization strategy that reduces the number of inspectors by up to 30% without compromising on garment quality.

2. Methodology

2.1 Objectives of the Study

- To minimize quality inspection costs by determining the optimal number of inspectors required.
- To develop a proposed model that assists in determining inspection costs and optimizing the number of inspectors to achieve maximum inspection efficiency.
- To formulate a mathematical model for assessing the skill levels of inspectors.
- To establish a mathematical model for setting inspection targets for quality inspectors, thereby maximizing the quantity of garments inspected.

2.2 Methodology of the Study

Fig. 2 represents **a** methodology flowchart outlining the steps involved in minimizing inspection costs, developing a mathematical model, determining inspection targets, and assessing inspector skill levels.

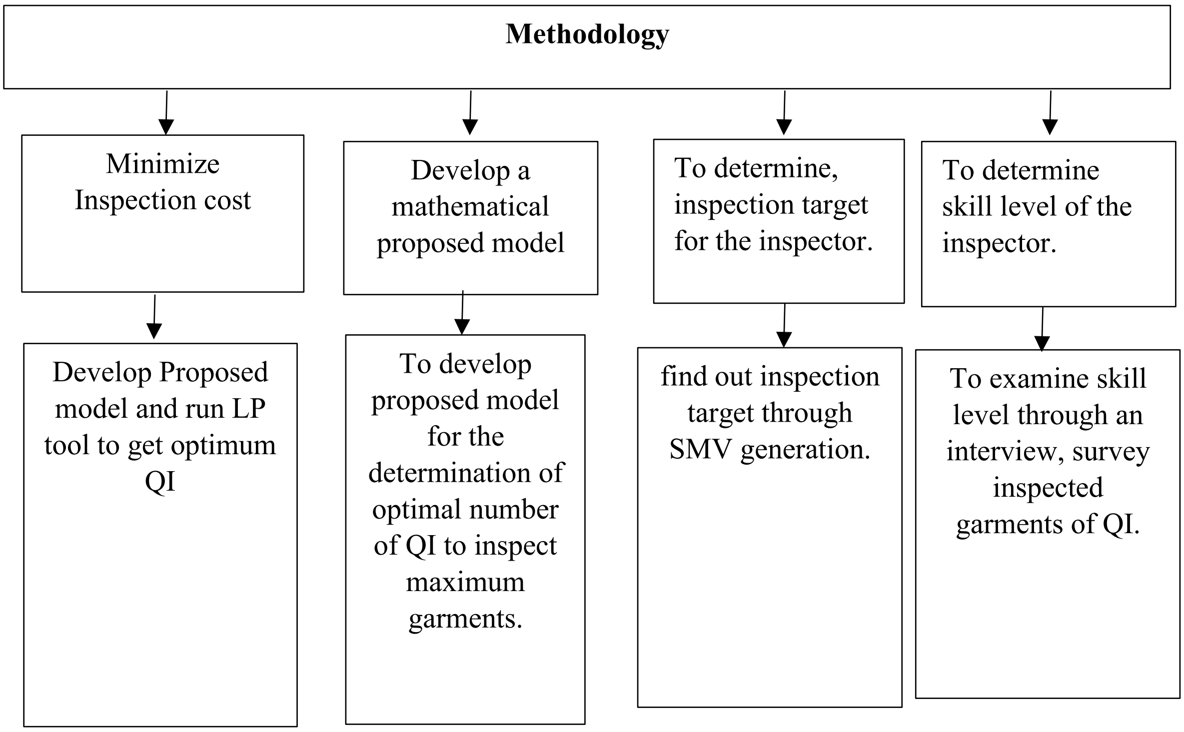

Fig 2. Methodology of the study

(a) Minimize inspection cost:

To develop a linear programming model (PLM) for determining the required optimum number of quality inspectors. To collect data from the factory about the current QI exists per line and the total number of QI required for the whole process. Determine cost per minute (CPM) and standard minute value (SMV) to relate and formulate linear equation based on hourly line target to inspect.

(b) Develop a proposed mathematical model

The development of a mathematical model aims to formulate the SMV for low, medium, and high-skilled quality inspectors. This model helps determine both the total inspection cost and the individual cost, enabling decision-making on the required number of inspectors at each skill level to meet the hourly line inspection target. Additionally, the mathematical formula will assess the inspectors' capacity and skill level by focusing on technical aspects.

(c) To determine the inspection target for the inspector

The SMV is generated to establish the expected inspection capacity per hour. This process involves conducting a time study to analyze the time taken by inspectors for each inspection task. By scientifically setting targets based on SMV calculations, the company can ensure optimal efficiency and maximize throughput. This approach enables inspectors to perform at their best while maintaining quality standards, ultimately improving overall productivity.

(d) To determine the skill level of the inspector

To assess the skill level of inspectors, a capacity study is conducted to evaluate their performance. The skill level is then examined through interviews and surveys of inspected garments by quality inspectors (QI). Additionally, a written test is administered to assess the inspectors'

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theoretical knowledge, which serves as a certification of their skill level. Based on these evaluations, the final determination of skill level is made..

3. Model Development

3.1. Current Model

Inspect cost: Total inspection cost (TIC) is the summation of the fixed cost and variable cost, in which, variable cost (VC) is linked to the quantity inspected per day. The inspection cost of all inspectors of one skill level can be calculated using Eq. (1).

$$VC1 = \frac{1}{12[\{L(IQ1)\}]}\ x\ Ir \tag{1}$$

where IQ1 is the inspected quantity by low-skilled inspectors, VC_l is the value of variable cost for low-skilled inspectors, and I_r , the inspection rate. The total inspection cost of all quality inspectors (VCo) working in inspection station is calculated using Eq. (2).

$$VCo = \frac{1}{12}[\{L(IQl) + M(IQm) + (IQh)\}x\ Ir \tag{2}$$

where IQl, IQm, and IQh is the inspected quantities by low-skilled, medium, and high-skilled inspectors. Objective function's goal programming (GP) is a widely used method for multi-objective decision-making. Each objective has a target value that must be achieved. GP has three commonly used methods, namely preemptive method, non-pre-emptive method, and fuzzy method. Their selection is related to the available information of the objective functions [32]. In this study, preemptive GP is used. The four basic objectives of this study are to minimize the total inspection cost per day by finding the optimal number of quality inspectors of each skill level (refer to Eq. (3)).

$$TICt = \frac{1}{12}[\{L(IQl) + M(IQm) + H(IQh)\}]x\ Ir + dl(-) - dl(+) \tag{3}$$

where Ir=Inspection rate; dl(-) = Inspected quantity under target ; dl(+)= Inspected quantity expected target.

3.2. Proposed Model

The existing model presents several limitations that require further clarification and refinement. Firstly, it states that the skill level of inspectors should be assessed through a capacity. Secondly, it suggests that the inspection target for quality inspectors should be determined by generating the Standard Minute Value (SMV). Lastly, in the total inspection cost formula, the model defines the total inspection cost ($TICt$) as the product of inspection quantity and inspection rate (Ir). However, it fails to clarify whether Ir represents the cost per inspection or an acceptable quality level, leading to potential ambiguity in cost calculations and quality control assessments. These gaps highlight the need for a more precise and well-defined framework to enhance the model's effectiveness. The calculation of total inspection cost ($TICt$) can be presented in Eq. (4), and SMV calculation is shown in Eq. (5).

$$TICt = \{L(SMV) + M(SMV) + H(SMV)\} \times CPM \tag{4}$$

$$SMV = \frac{(Time\ taken\ by\ inspector) + (Time\ taken\ by\ inspector \times Allowance\ rate)] \times Rating\ percentage}{60} \tag{5}$$

where the inspection time for each piece varies based on the skill level of the inspector. $L(SMV)$ represents the time taken by a low-skilled inspector to complete the inspection of a single piece, which is typically longer due to lower efficiency and experience. $M(SMV)$ denotes the time required by a medium-skilled inspector, reflecting a more balanced level of efficiency and accuracy.

Meanwhile, $H(SMV)$ indicates the inspection time for a highly skilled inspector, which is generally the shortest due to greater expertise and proficiency. These variations in SMV highlight the impact of skill levels on inspection performance, emphasizing the need for appropriate workforce planning and efficiency optimization. Then, the calculation of the cost per minute (CPM) is presented in Eq. 6. Then, the formula of IC_L, IC_M, and IC_H are shown in Eq. (7-9), respectively. In addition, Eq. (10) presents the linear programming model used to determine the optimal number of operators required to meet the daily line target while minimizing costs.

$$CPM = \frac{\text{Total cost per day}}{(\text{Number of total manpower x Produced minutes per day x Efficiency })} \tag{6}$$

$$IC_L = L(SMV) \times CPM \tag{7}$$

$$IC_M = M(SMV) \times CPM \tag{8}$$

$$IC_H = H(SMV) \times CPM \tag{9}$$

$$C = Cl \times x + Cm \times y + Ch \times z \tag{10}$$

In this model, several key variables are defined to support optimal workforce allocation. Specifically, $Cl, Cm,$ and Ch represent the costs associated with employing low-skilled, medium-skilled, and high-skilled inspectors, respectively. The decision variables $x, y,$ and z denote the number of inspectors required for each corresponding skill level. Additionally, the capacity is calculated using the formula $600/SMV$, where SMV reflects the time efficiency of the inspection process. This capacity calculation determines the number of units that can be inspected in a given period, thereby ensuring that the daily production target is met while the overall inspection cost is minimized.

3.3. Proposed Model Comparison of the proposed model over the current model

The proposed model addresses a key drawback of the current system by developing a formula that determines the hourly inspection target for each inspector. This innovation not only enables the calculation of actual inspection costs for low-skilled, medium-skilled, and high-skilled inspectors but also provides a method to compute the standard time required for inspecting garments. By linking this standard inspection time with the cost per minute, the model derives both the total inspection cost and the individual costs based on inspector skill levels. Furthermore, it measures an inspector's efficiency by assessing the number of inspections completed per hour, which serves as an indicator of their skill level. Finally, by integrating with a linear programming model, it optimizes the workforce by determining the optimal mix of low, medium, and high-skilled inspectors needed to meet the daily garment inspection targets while minimizing costs.

4. Results and Discussion

4.1. Data Analysis

Table 1 outlines the cost of quality for the factory by breaking it down into two main components: the cost of good quality (CoGQ) and the cost of poor quality (CoPQ). Expressed as a percentage of sales, this means that 5.5% of the factory's revenue is dedicated to quality-related expenses. This percentage can be minimized by reducing the number of inspectors in the operation. It requires analysis of the cost of low-skilled, medium-skilled, and high-skilled inspectors. It should be focused on low cost, and then it might be possible to decrease.

Table 1. Cost of quality for the factory

Revenue	\$15,00,000
Good quality	
Quality checks and inspection	\$20,000
Raw material appraisal cost	\$30,000
Cost of good quality product (CoGQ)	\$50,000
Poor quality	

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Rework on finished goods	\$15000
Rework on sewing items	\$18000
Cost of poor quality product (CoPQ)	\$33000
Cost of Quality = CoGQ+CoPQ	\$83000
Calculation of cost of quality as the percentage of sales	5.5%

Data analysis was conducted on three large-scale production units. Initially, Production Unit-1 employed 90 inspectors to perform inspection tasks at the factory. Although the product is relatively large in size, its production volume is low compared to knit items, which resulted in high inspection costs. A linear programming program was then executed to determine the minimum number of inspectors required across low, medium, and high skill levels. The results indicated that only 60 inspectors are needed to meet the factory's inspection requirements, resulting in a 33% reduction in inspectors (see on Table 2).

Large scale, EWIPL:

$$2x + y \geq= 180; x + 2y \geq= 160; 2y + z \geq= 200;$$

$$x \geq= 0; \; y \geq= 0; \; z \geq= 0;$$

Table 2. Results of LP: QI-PU-1

x	y	z	Current QI	Proposed QI
40	100	0	110	60

Currently, Production Unit-2 employs 320 inspectors to carry out inspection tasks at the factory. Although the product is small in size, its high production volume compared to woven items results in significant costs due to the large number of inspectors. After running the linear programming program to determine the minimum number of inspectors required across low, medium, and high skill levels, the results showed that only 200 inspectors are necessary (refer to Table 3). This means that 38% of the current inspectors are more than the required number.

MIL:

$$x + 2y \geq 250; 2x + y \geq 200; y + z \geq 300$$

x>=0;y>=0;z>=0;

Table 3. Results of LP: QI-PU-2

X	Y	z	Current QI	Proposed QI
0	200	100	320	200

Previously, Unit-3 employed 100 inspectors to handle inspection tasks at the factory. Although the product size is large, its production volume is low compared to knit items, which resulted in disproportionately high costs due to the excessive number of inspectors. After running the linear programming program to determine the minimum number of inspectors needed at low, medium, and high skill levels, the results confirmed that only 60 inspectors are necessary to meet the factory's inspection requirements (refer to Table 4). This indicates that 40% of the current inspectors are more than the required number. Fig (3) – Fig (5) illustrates the skill-wise percentage distribution of Quality Inspectors (QI) across different production units: PU-MIL, PU-EFL, and PU-EWIPL. These figures provide insights into the proportion of low-skilled, medium-skilled, and high-skilled inspectors within each unit. Fig 6 presents the factory-wise trend in QI minimization, showcasing how the optimization process has reduced the number of required inspectors across various factories. Finally, Fig 7 highlights the percentage reduction in QI for each factory, emphasizing the overall efficiency improvements achieved through the proposed model.

EPL:

$$2x + y \geq= 180; 2x + y \geq 160; 1y + 2z \geq= 200$$

x>=0; y>=0; z>=0

Table 4. Results of LP: QI-PU-3

x	y	z	Current QI	Proposed QI
0	190	5	100	60

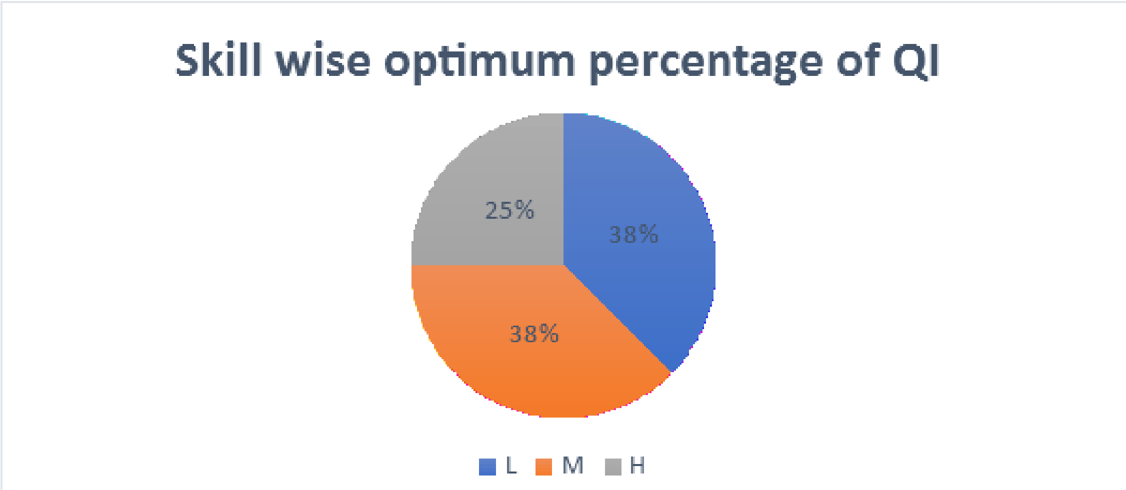

Fig 3. Skill wise percentage of QI-PU-MIL

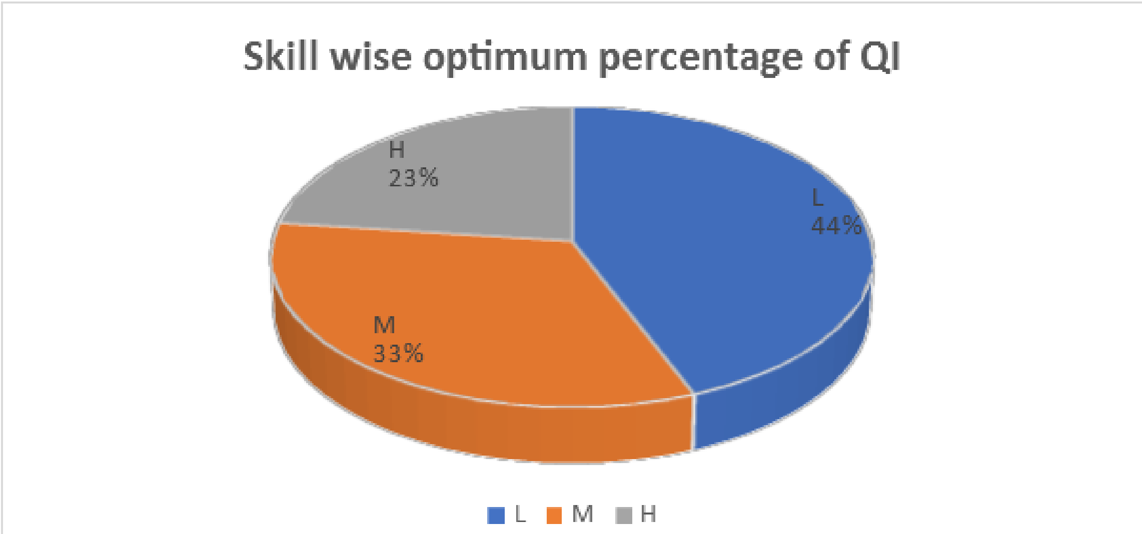

Fig 4. Skill wise percentage of QI-PU-EFL

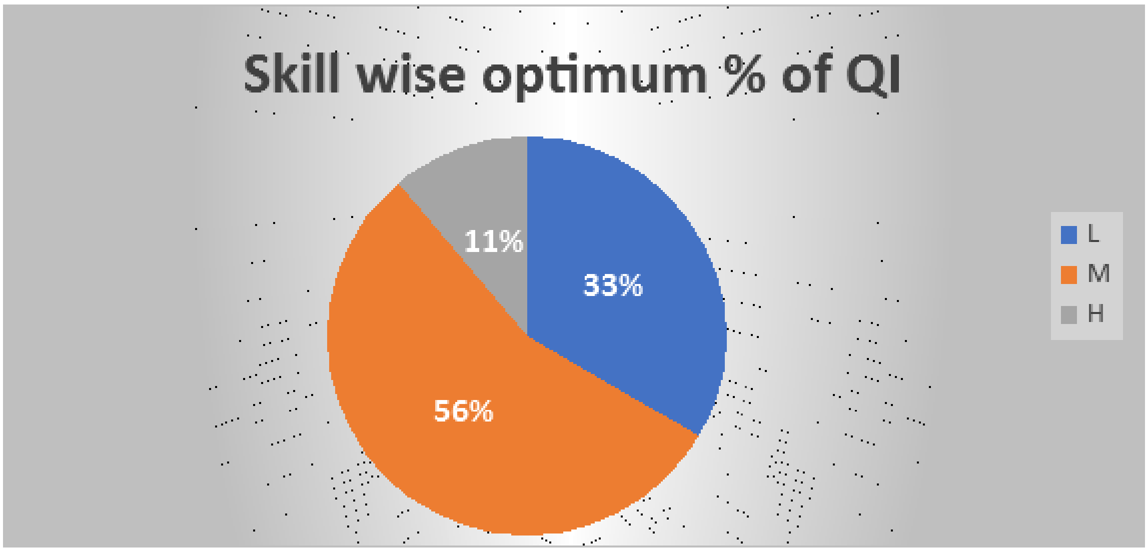

Fig 5. Skill wise percentage of QI-PU-EWIPL

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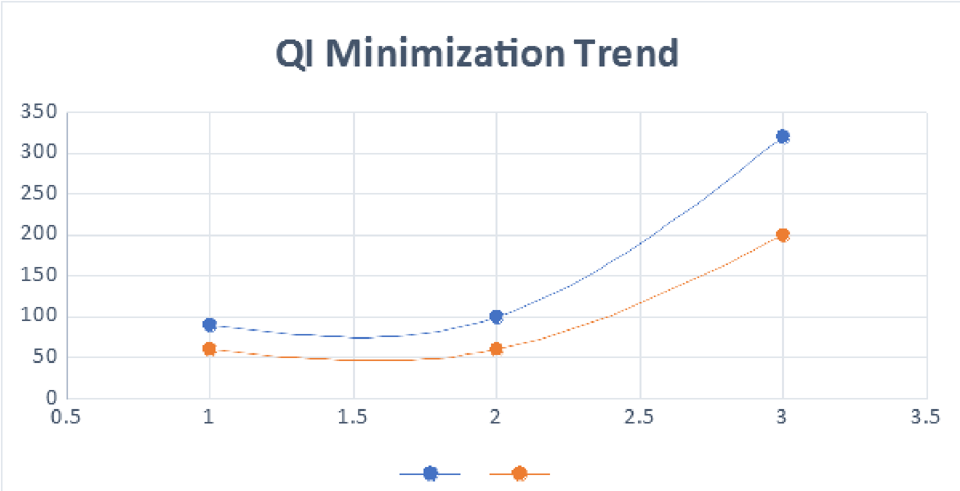

Fig 6. Factory wise QI minimization trend

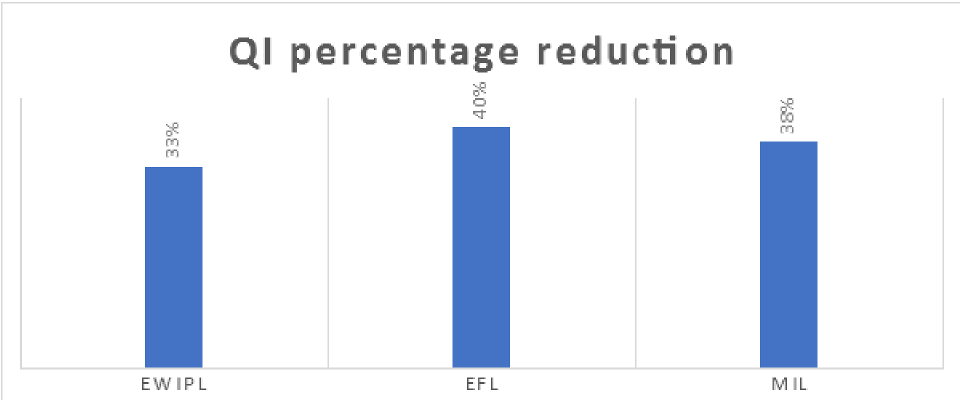

Fig 7. Factory wise QI percentage reduction

4.2. Discussion

The apparel manufacturing industry cannot survive without cutting costs at various echelons. The ideology has been reverted to the garment manufacturing industry since 2009. Once the labor cost was very low, the unit price of the garments was higher, the material cost was cheaper, and the owner kept more workforce to get the job done. However, it is the toughest task to withstand in the competitive market by allowing a higher man-machine ratio. In this research, we have developed a mathematical model to detect the total cost of the inspection. At the same time, it is possible to determine an individual inspection cost for the inspector. So, it can help to decide to keep a certain number of inspectors skilled-wise. The mathematical model also aids in regulating the capacity of the inspector. A SMV has been developed which gives the inspection target of the individual inspector as per their skill level. From this, it can help to find out the inspection cost of the inspector by using CPM. The LPP software will run to get the optimum number of inspectors required to perform the inspection. From Table 1, Table 2, and Table 3, it is shown that the optimal number of inspectors for PU 1, 2, and 3 is 4. This result is provided by LPP software.

The structure of the quality department is portrayed as a lot of employees are shown, which is undoubtedly costly and cumbersome for a manufacturing unit. The skill-wise percentage of QI has been exposed where it is shown in Fig. 2 that 37.6%, 38%, and 25% of inspectors are required for low, medium, and high skill levels, respectively. The model verified that low and medium-skilled inspectors are needed more than highly skilled inspectors. Because the cost of highly skilled inspectors is approaching its peak. That's why the software outcome showed low and medium-level inspectors' percentage is higher to optimize cost. Similarly, high-skilled inspectors' requirements are less than low and medium for PU 2 and 3 to optimize TIC, which is shown in Fig. 3 and Fig. 4 separately. Fig. 5 shows the number of QI minimized from 90 to 60, 100 to 60, and 320 to 200 for PU 1, 2, and 3 respectively, which is the best outcome from the analysis. The number of QI has been lessened to 33%, 40%, and 38% for PU 1,2, and 3 correspondingly as well. Compared to previous methods such as[47], which focused primarily on defect reduction to lower inspection costs, our model goes further by optimizing the number of inspectors based on skill level and inspection targets. While GOKHALE's approach reduced costs by minimizing defects, our method achieves a more substantial reduction of up to 30% in inspection costs by efficiently utilizing inspectors across skill levels. Similarly, [48] emphasized minimizing inspection costs through defect management, whereas our model addresses cost reduction through inspector optimization, providing a more comprehensive and scalable solution.

5. Conclusion

Reducing manufacturing costs in the apparel industry is essential, especially as other expenses have significantly increased. Garment factories consist of multiple departments where a large workforce is employed. However, it is feasible to operate with 5%–10% fewer workers without major disruptions. This requires a mindset of ownership and efficiency. This research focuses on minimizing the number of inspectors in the sewing, cutting, and finishing sections. The findings indicate that approximately 30% of inspectors can be reduced while maintaining the same production output. In production unit-1, a total of 5,500 employees are currently working, including 200 executives and 500 officers. The average monthly revenue of this unit is $4.5 million. However, despite these earnings, the factory struggles with on-time payments due to excessive costs. To remain competitive, manufacturing costs must be reduced by optimizing the workforce, processes, and other operational factors, particularly as labor costs in Bangladesh have risen significantly over the past decade. In this unit, the number of quality inspectors (QI) was reduced from 90 to 60, leading to substantial cost savings. Production unit-2 employs 7,000 workers, including 500 executives and 800 officers, with an average monthly revenue of $6.5 million. Cost minimization, particularly in inspections, is crucial for financial stability. In this unit, the number of QI was reduced from 320 to 200, representing a significant cost-saving measure. Similarly, production unit-3 has 4,000 employees, including 150 executives and 300 officers, generating an average monthly revenue of $3.5 million. Here, the number of QI was reduced from 100 to 60, contributing to substantial savings for the factory. Across all three units, the percentage of inspectors was optimized based on cost and hourly inspection targets. The findings suggest that 73% of inspectors should be low- or medium-skilled, while 11%–25% need to be highly skilled. High-skilled inspectors were selected using the Linear Programming (LP) model, as they are more costly compared to medium- and low-skilled inspectors.

In this research, the mathematical model defines the capacity of the inspector and the inspection target of the inspector. The linear programming model gave the optimal number of inspectors required for an apparel manufacturing organization. It gives optimum solution for the unnecessary inspector reduction from the quality department. LP models do not provide the solution to how many minimum highly skilled inspectors can necessitate inspection jobs to justify the company's target, it could help to minimize workstation reduction as well as less hassle. The more inspectors, the more management personnel are required to monitor them. It is the drawback of this research.

This research identifies the need for an optimal balance between inspector skill levels and the number of inspectors to reduce costs. By applying our proposed model, we demonstrate significant cost savings, with a potential inspector reduction of up to 30%. Future research should explore minimizing manufacturing costs by optimizing total workforce and wastage reduction, including inspection costs, to minimize factory total costs, which will positively impact COQ percentage.

 10.12928/ijio.v6i1.9279

References

[1] I. S. Swazan and D. Das, “Bangladesh’s emergence as a ready-made garment export leader: An examination of the competitive advantages of the garment industry,” *International Journal of Global Business and Competitiveness*, vol. 17, no. 2, pp. 162–174, Feb. 2022. doi: 10.1007/s42943-022-00049-9.

[2] A.-U.-Z. Ashik and M. A. M. Khan, "Minimum Wage Impact on RMG Sector of Bangladesh: Prospects, Opportunities and Challenges of New Payout Structure," *International Journal of Business and Economics Research*, vol. 10, no. 1, pp. 8-20, 2021, doi: 10.11648/j.ijber.20211001.12.

[3] C. Jacobs-Blecha, "System Modeling for Apparel Manufacturing: Focus on the Cutting Room," Georgia Institute of Technology, G93Nl, pp. 161-164, 1993.

[4] M. McClellan et al., "Lean Manufacturing: Tools, Techniques, and How to Use Them," He St. Lucie Press/APICS Series on Resource Management, pp. 1-245, 2000. Available: https://www.taylorfrancis.com/.

[5] A. T. M. Mohibullah, " A Sewing layout which is enlarged with a part of finishing can be more effective to cost reduction of Apparel Industry," *International Journal of Scientific & Engineering Research*, vol. 7, no. 4, pp. 1131-1137, 2016. Available: https://www.researchgate.net/.

[6] B. S. Kuma, "Garment Manufacturing Through Lean Initiative," *International Journal on Lean Thinking*, vol. 3, no. 2, pp. 1-12, 2017. Available: https://admin.umt.edu.pk/

[7] N. Paneru, "Implementation of Lean Manufacturing Tools In Garment Manufacturing Process," 2011. [Online]. Available: https://www.theseus.fi/.

[8] F.-B. Pan, "The Optimization Model of the Vendor Selection for the Joint Procurement from a Total Cost of Ownership Perspective," Journal of Industrial Engineering and Management, vol. 8, no. 4, pp. 1251-1269, 2015, doi: 10.3926/jiem.1551.

[9] H. Lee, "A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks," Expert Systems with Applications, vol. 36, pp. 2879-2893, 2009, doi: 10.1016/j.eswa.2008.01.045.

[10] E. Lee, S. Ha, and S. Kim, "Supplier selection and management system considering relationships in supply chain management," IEEE Transactions on Engineering Management, vol. 48, no. 3, pp. 307-318, 2001, doi: 10.1109/17.946529.

[11] L. Carr and C. Ittner, "Measuring the cost of ownership," *Journal of Cost Management*, vol. 6, no. 3, pp. 7-13, 1992.

[12] J. Cavinato, "A total cost/value model for supply chain competitiveness," *Journal of Business Logistics*, vol. 13, no. 2, pp. 285-301, 1992.

[13] R. T. Rust, C. Moorman, and P. R. Dickson, "Getting return on quality: revenue expansion, cost reduction, or both?," Journal of Marketing, vol. 66, no. 4, pp. 7-24, 2002, doi: 10.1509/jmkg.66.4.7.18515.

[14] I. Tomic, Z. Tesic, B. Kuzmanovic, and M. Tomic, "An empirical study of employee loyalty, service quality, cost reduction and company performance," Economic Research-Ekonomska Istraživanja, vol. 31, no. 1, pp. 827-846, 2018, doi: 10.1080/1331677X.2018.1456346.

[15] S. L. Berman, A. C. Wicks, S. Kotha, and T. M. Jones, "Does stakeholder orientation matter? The relationship between stakeholder management models and firm financial performance," Academy of Management Journal, vol. 42, no. 5, pp. 488-506, 1999, doi: 10.2307/256972.

[16] J. H. Dyer and W. Chu, "The role of trustworthiness in reducing transaction costs and improving

performance: Empirical evidence from the United States, Japan, and Korea," Organization Science, vol. 14, no. 1, pp. 57-68, 2003, doi: 10.1287/orsc.14.1.57.12806.

[17] C. Schuh, J. L. Raudabaugh, R. Kromoser, M. F. Strohmer, and A. Triplat, “The purchasing chessboard,” *The Purchasing Chessboard: 64 Methods to Reduce Costs and Increase Value with Suppliers*, 31-48, 2008, doi: 10.1007/978-3-540-88725-6.

[18] R. Reider, "Cost reduction analysis: A bench-marking guide for treasury managers," The Journal of Corporate Accounting & Finance, Wiley Periodicals, Inc., 2004, doi: 10.1002/jcaf.20069.

[19] A. Rai, R. Patnayakuni, and N. Patnayakuni, "Technology investment and business performance," *Communications of the ACM*, vol. 40, no. 7, pp. 89-97, 1997, doi: 10.1145/256175.256191.

[20] R. Muhammad, Z. A. Ali, "A case study in the textile industry for the reduction of cost of quality," *Journal of Advances in Technology and Engineering Research (JATER)*, vol. 5, no. 6, pp. 219-230, 2009.

[21] W. K. Wong and S. Y. Leung, "Genetic optimization of fabric utilization in apparel manufacturing," *International Journal of Production Economics*, vol. 114, no. 1, pp. 376–387, 2008, doi: 10.1016/j.ijpe.2008.02.012.

[22] E. Dumishllari and G. Guxho, "Influence of lay plan solution in fabric efficiency and consume in cutting section," *Autex Research Journal*, vol. 16, no. 4, pp. 222–227, 2016, doi: 10.1515/aut-2015-0055.

[23] S. Krsteva and G. Demboski, "Determination of generated textile waste in clothing companies of different technological level," in *3rd Scientific-Professional Conference Textile Science and Economy*, 10-11 Nov. 2011, Zrenjanin, Serbia, pp. 203-208, 2011.

[24] D. Sjarifudin, H. Kurnia, H. H. Purba, and C. Jaqin, "Implementation of six sigma approach for increasing quality formal men’s jackets in the garment industry," *Jurnal Sistem dan Manajemen Industri*, vol. 6, no. 1, pp. 33–44, 2022, doi: 10.30656/jsmi.v6i1.4359.

[25] S. N. Hlaing and A. M. Lwin, "Defect reduction in selected sewing lines of a garment factory with DMAIC methodology of six sigma," *International Journal for Innovative Research in Multidisciplinary Field*, vol. 9, no. 4, pp. 111–117, 2023.

[26] R. A. Joy et al., "Improving quality, productivity, and cost aspects of a sewing line of apparel industry using TQM approach," *Mathematical Problems in Engineering*, vol. 2024, no. 1, p. 6697213, 2024, doi: 10.1155/2024/6697213.

[27] M. M. Islam, A. M. Khan, and M. M. R. Khan, "Minimization of reworks in quality and productivity improvement in the apparel industry," *International Journal of Engineering*, vol. 1, no. 4, pp. 2305-8269, 2013, Available: https://www.academia.edu/.

[28] M. Tahiduzzaman, M. Rahman, S. K. Dey, and T. K. Kapuria, "Minimization of sewing defects of an apparel industry in Bangladesh with 5S & PDCA," *American Journal of Industrial Engineering*, vol. 5, no. 1, pp. 17-24, 2018, doi: https://www.academia.edu/.

[29] A. Gokhale, Cost Analysis of Poor Quality in Apparel Manufacturing – A Case Study (Doctoral dissertation), 2015. [Online]. Available: http://dspace.dtu.ac.in:8080/.

[30] R. Bheda, "Do you know 'the cost of poor quality' in your organization," *Indian Textile Journal*, vol. 1, no. 2, pp. 57-68, 2005.

[31] S. Bala, "Factors Influencing Costing of Woven Fabrics," *The Indian Textile Journal*, vol. 1, no. 2, pp. 57-68, 2003.

[32] M. B. Ramzan and C. W. Kang, "Minimization of inspection cost by determining the optimal number of quality inspectors in the garment industry," *Indian Journal of Fibre & Textile*

Research, vol. 41, pp. 346-350, Sept. 2016, Available: https://nopr.niscpr.res.in/.

[33] H. Fazlollahtabar, "Operations and inspection cost minimization for a reverse supply chain," *Operational Research in Engineering Sciences: Theory and Applications*, vol. 1, no. 1, pp. 91-107, 2018, doi: 10.31181/oresta19012010191f.

[34] S. Ahmad, A. A. B. Khalil, and C. A. A. Rashed, "Impact of efficiency in apparel supply chain," *Asian Journal of Natural and Applied Sciences*, vol. 1, no. 4, pp. 36-45, 2012, Available: https://www.academia.edu/.

[35] S. Ahmad and M. Kamruzzaman, "Analysis of Availability of Fire Fighting Equipment in Selected Knitting Garment Factories in Bangladesh," in *Proceedings of the 2015 International Conference on Operations Excellence and Service Engineering*, Orlando, Florida, USA, Sept. 2015, Available: https://ieomsociety.org/.

[36] S. Ahmad et al., "Productivity improvement focusing on investigation of injuries, accidents and hazards occurred in a garments manufacturing organization," *Bangladesh Research Publication Journal*, 8(4): 256-264, 2016, Retrieved from https://www.academia.edu/.

[37] S. Ahmad and M. Iqbal, "Impacts of E-commerce in apparel supply chain," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2019, pp. 1400-1405, Available: https://ieomsociety.org/.

[38] S. Ahmad et al., "Apparel supply chain optimization by developing e-commerce: An impact analysis," *4th North American International Conference on Industrial Engineering and Operations Management*, Toronto, Canada, October 25-27, 2019.

[39] S. Ahmad, M. Kamruzzaman, and M. Iqbal, "Impacts of optimization in apparel supply chain focusing on ANN and Genetic Algorithm," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2020, Available: http://www.ieomsociety.org/.

[40] S. Ahmad and M. Kamruzzaman, "Apparel Supply Chain Optimization Focusing On Right Supplier Selection," *Journal of Management and Economic Studies*, vol. 4, no. 1, pp. 1-14, 2022, doi: 10.26677/TR1010.2022.955.

[41] S. Ahmad and M. Kamruzzaman, "Supplier Selection and Evaluation in Apparel Industry," *Economic Research*, vol. 6, no. 2, pp. 24-40, 2022, doi: 10.29226/TR1001.2022.296.

[42] S. Ahmad and M. Kamruzzaman, "Mathematical analysis of supply chain optimization focusing on artificial neural network: a case study in apparel manufacturing organization," 2022, doi: 10.21203/rs.3.rs-1173130/v1.

[43] S. Ahmad and M. Kamruzzaman, "Optimization in Apparel Supply Chain Using Artificial Neural Network," *European Journal of Logistics, Purchasing and Supply Chain Management*, vol. 10, no. 1, pp. 1-14, 2022, doi: 10.37745/ejlpscm.2013/vol10no1pp.1-14.

[44] S. Ahmad, "A Review on Inspection Cost Minimization by Optimal Number Inspectors in Apparel Manufacturing," in *8th North America Conference on Industrial Engineering and Operations Management*, June 2023, doi: 10.46254/NA8.20230318.

[45] S. Ahmad, M. M. Rashid, M. Iqbal, and M. R. Sarkar, "Ergonomics for Tabloid Chair Manufacturing," *International Journal of Business, Social and Scientific Research*, vol. 2309, no. 7892, 2021.

[46] S. Ahmad, S. K. Badra, and M. Iqbal, "Impacts of low productivity in apparel value chain," *3rd North American International Conference on Industrial Engineering and Operations Management*, MI, USA, September 27-29, 2018.

[47] Gokhale, Collaborative Learning Enhances Critical Thinking, *Journal of Technology Education*, vol.7, issue 1, page 22-30, 1995, doi: 10.21061/jte.v7i1.a.2.

[48] R. Bheda, A.S. Narag, and M.L. Singla, "Apparel manufacturing: a strategy for productivity improvement", *Journal of Fashion Marketing and Management*, Vol. 7 No. 1, pp. 12-22. 2023, doi: 10.1108/13612020310464331.