Supplier Selection and Evaluation: A Case Study in an Apparel Manufacturing Organization

Shibbir Ahmad* and Mohammad Kamruzzaman

Department of Mechanical Engineering, Dhaka University of Engineering & Technology (DUET), Bangladesh.

*Corresponding Author
Shibbir Ahmad, Department of Mechanical Engineering, Dhaka University of Engineering & Technology (DUET), Bangladesh.

Abstract
The supply chain is incomplete without a supplier. A manufacturer is completely reliant on its suppliers, and it is critical for an apparel manufacturing company to choose the proper ones in order to maintain uninterrupted operations. The impacts of traditional supplier selection have been demonstrated in this research. In addition, the best provider was chosen using a proposed supplier selection and evaluation approach. However, four supplier selection and assessment procedures have been used to determine the study's outcome. In addition, the dimensional analysis approach, the cost ratio analysis method, and the weighted point method were used to choose the trim supplier. Benefits increased by 16 percent after making orders with the proper supplier, according to this report. The main finding of this study is that 94 percent of materials are received on time from the best selected source, compared to 50 percent in the past when using the traditional method.

1. Introduction

A supplier has become an important part of the apparel manufacturing industry to keep customers' commitment. Buyers' demand has reverted in the last decade. In the past, the main focus was on quality and, secondly, on delivery. However, the customer pushes the manufacturer to achieve a timely shipment along with good quality nowadays. The ideology has reversed. Like, if a manufacturer produces high quality garments but if it is unable to meet the selling period, then it will be gone for the discount option. It is happening due to competitiveness in the market. In this context, the supplier should be reliable and professional to provide delivery of the materials within the lead time while maintaining standard quality. Hence, the garment manufacturing industry is more conscious when selecting suppliers. It is the core job of the supply chain manager (SCM) to evaluate the supplier and select the long-term business partner. The reason behind it is that nobody likes to change suppliers. According to their findings, the most significant aspect of suppliers to supervisors is quality, followed by delivery and pricing. Around the turn of the century, research on the impact of measures in the production network began with the perceived dependability of conveyance as a rule of choice while others noted the need to include development as an equivalent rule in their review [1,2]. According to various academics in 2001, you must first develop a strategy that considers the customer-supplier relationship before establishing the most important criteria by which providers must be rated [3]. Procurement

managers must first negotiate terms with suppliers and establish particular agreements. According to the same author, the criteria for selecting suppliers can be classified into five categories: cost, logistics, quality, development, and management; nevertheless, they used four aspects to evaluate suppliers in their study: price, quality, technology, and service [4]. It was later shown that it could process equivalent criteria in a study [5]. One of the key hurdles to a solid supply chain is the acquisition of resources from outside Bangladesh for the clothing manufacturing business. Analytical hierarchy process (AHP) has been implemented to develop weights that are used to select the right supplier by scoring analysis. A model for supplier relationship development has been built and implemented to assist in selecting the right supplier. They used Web-HIPRE software to analyze data and make decisions for the best supplier selection [6].

Some research works have been conducted on supplier selection and evaluation using an analytical hierarchical process (AHP) with a case study in an apparel manufacturing organization. It shows that the right supplier was selected by analytical study and placed an order with this supplier. It has some limitations as AHP is a difficult mathematical analysis. It is tough to implement by the merchandising department as some of them do not understand mathematical analysis. Later, a software based on this technique was developed [7]. Some researchers focused on green issues and environmental factors while selecting suppliers using the fuzzy AHP method. The results of this research were

that green thinking had an influence on supplier selection. However, it is undeniable to consider conventional criteria like cost, quality, and delivery, which are the limitations of the study [8]. In today's modern supply chain, selecting the right suppliers is a strategic problem for the company. A corporation's entire business is a crucial strategic aspect. The relevance of this is that competent supplier selection was recognized at the start of the previous century's last decade [9]. The context and relevance of individual measure changes, on the other hand, complement the creators' work, which includes over 110 papers on the topic of provider choice [10] .Without having realistic knowledge about quality, delivery, and other essential criteria, the textile manufacturing industry's merchandising staff places raw material orders with suppliers by dialing a phone number, sending an email, or contacting any known individual. Scientific analysis of supplier selection methods can be utilized in the garment manufacturing business to discover the best suppliers in real time. In supply chain management, the importance of the connection between procurement, external suppliers, and quality has a significant impact on product and service quality [11].

Supplier selection and evaluation have been performed, focusing on social, environmental, and ethical criteria. It's an unusual and different criterion. AHP has been implemented to make supplier selection and evaluation decisions. The outcome of the research is that managers can use skeletons which have developed to select suppliers [12]. The apparel manufacturing industry has tried to modernize, for example, by introducing the green supply chain concept [13]. Geographically, lead time and production costs for the textile manufacturing industry are lower in Vietnam than in the United States. Other countries that used to manufacture garments, such as Bangladesh, India, Sri Lanka, and other Asian countries, are, however, far away from Europe and the United States. Even raw materials are taken from China, which is also costly for the subcontinent. The aim of supplier selection and evaluation is to reduce product costs while improving quality and on-time delivery. They have implemented Artificial Neural Network (ANN), Fuzzy AHP and the preference ranking organization method for enrichment of evaluations (PROMETHEE II) to rank suppliers and take decisions based on that ranking. The outcome of this research is to select the right supplier using a mathematical approach, which is useful in the textile and apparel manufacturing industries [14]. It takes 60 days for materials from overseas country like China to arrive in Bangladesh, and the manufacturer has fewer than 30 days to make and ship the items to the target clients. Meanwhile, creating a seamless supply chain and achieving optimal chain performance requires selecting the appropriate supplier at the right time. As a result, for clothing factories under our jurisdiction, supply chain optimization through careful supplier selection is important. Supplier selection employs artificial perspicacity. Although a lot of study has been done on supplier selection and evaluation, just a few companies have used it in the garment business. Using artificial neural networks, several researchers examined mathematical analysis for garment supply chain optimization, focusing on correct supplier selection [15]. The study's limitations were the inability to carry out the real process of selecting the best supplier for an apparel manufacturing company. In this research, there are four supplier selection and evaluation methods applied to get the best results, and accordingly, selected suppliers who have acquired an apex score among them. The supply chain manager of that apparel manufacturing organization has been struggling to select the best suppliers. After implementing four methods for selecting suppliers, the SC manager was motivated and acknowledged that evaluating with these methods can be result oriented task in the right supplier selection.

Subsection 1.1 discusses the conventional supplier selection strategy and its effect on the apparel supply chain. Section 2 describes the methods which have been applied to the supplier selection. Section 3 explains the study's results in detail, and Section 4 elaborates discussion of the study.

1.1 Current Practices

Currently, the supply chain department selects suppliers based on items produced by the supplier as well as average quality and delivery without performing any evaluation. Consequently, raw materials are delivered past the due date, which impacts the shipment date. Table 1 depicts the impact of delayed material receipt. It has been seen that style numbers 303, 310, 313, 315, 317, 319, and 320 are shipped out by air due to delayed materials being sent from the supplier. It occurred because the merchandiser did not accomplish the selection and evaluation process before selecting and placing an order with this supplier. In addition to this, styles 306 and 308 imposed a 5% discount on the total FOB value.

Style No	no of days delay	Consequences
301	5	Sea
302	11	Sea
303	38	Air
304	25	Sea
305	21	Sea
306	21	5 % discounts
307	30	Sea
308	30	5 % discount
309	30	Sea

310	35	Air
311	7	Sea
312	2	Sea
313	68	Air with sales claim
314	0	Sea
315	42	Sea-air
316	27	Sea
317	27	Air
318	27	Sea
319	58	Air
320	58	Air

Table 1: PO vs. delay status

From table 2, It showed that the production unit (PU) had to provide an air shipment due to delayed materials. It cost the company $23,000.

Factory	Order quantity	price	Income	Production cost	Air cost	Total cost	Profit/loss
PU	300000	$ 0.22	$ 66,000.00	$75,000	$14,000	$89,000	$ (23,000.00)

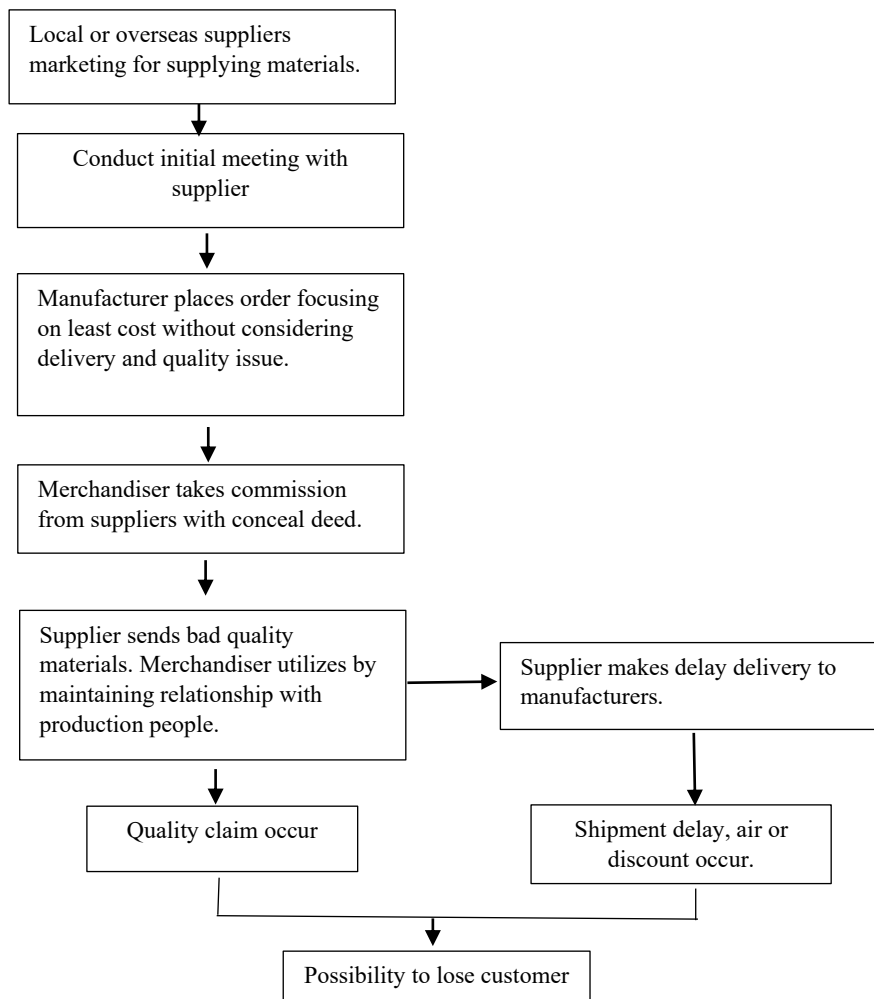**Table 2: Factory wise Income vs. profit loss**

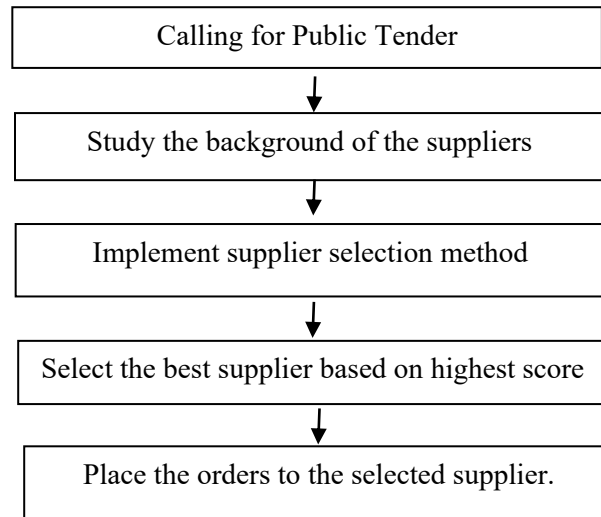**Figure 1:** effect of traditional supplier selection system

Figure 2: Proposed supplier selection method

2. Methods

There are four methods have been implemented in a leading apparel manufacturing organization to select the right supplier and associated performance evaluation. The methods are listed and discussed implementation steps as follows:

2.1.1 Dimensional Analysis Method

In this paper, the dimensional analysis method is applied to pick the right supplier in right time for the apparel manufacturing industry to optimize the supply chain.

$$\text{VPI} = \sqrt[w]{\prod_{i=1}^{n}\left(\frac{X_i}{Y_i}\right)^{w_i}} \quad (1)$$

Here,
VPI=Vendor Parameter Index

X_i= Performance Criteria Score for Supplier
Y_i=Standard Performance Criterion (i=1,2,3,……...nth)
W_i=Weight (Relative Importance) Assigned to Criterion

$$w = \sum_{i=1}^{n}|w_i|$$

In this research, the supplier selection process is analyzed using equation 1. Table 3 shows that the VPI scores for suppliers A is higher than any other supplier. Hence, this supplier should be selected as the right suppliers. The demo calculation is given below for understanding the selection methodology using the dimensional analysis method.

$$\text{VPI(A)} = \sqrt[16]{(0.90/1.00)^6.(21/27)^{-3}.(2/2)^{-5}} = 13.93$$

	Quality (%)	Delivery (days)	Cost($)	VPI
Weights	6	-3	-5	
Supplier A	90	22	2	13.93
Standard	100	27	2	
	Quality(%)	Delivery (days)	Cost($)	
Weights	5	-4	-5	
Supplier B	85	26	2	9.99
Standard	100	27	2	
	Quality(%)	Delivery (days)	Cost($)	
Weights	4	-3	-6	
Supplier C	95	30	2	10.75
Standard	100	27	2	
	Quality(%)	Delivery (days)	Cost($)	
Weights	7	-6	-2	
Supplier D	70	32	2	2.38
Standard	100	27	2	
	Quality(%)	Delivery (days)	Cost($)	

Weights	3	-5	-3	
Supplier E	60	29	2	6.71
Standard	100	27	2	

Table 3: Implementation of dimensional analysis method to select the right suppliers

2.2.2 Genetic Algorithm Method

In this method, five steps required to complete the implementation using equation 1. Initially, it requires to choose encoding technique at step 1. Secondly, its mandatory to choose the population size. it's meant that how many populations consider for this application. Thirdly, choose initial population randomly which must be integer number. In step 4, select parental chromosomes and find out value of f(x) using roulette wheel method. In this step, our main goal is to find out expected value of f (x).

$$F(x)=x^2 \qquad (1)$$

where value of x = 0-31

Step 1: choose an encoding technique

0 = 00000

31 = 11111

Step 2: choose the population size

n= 4

Step 3: Randomly choose initial population

12,18,22,27

Step 4: Select parental chromosomes

Following through Roulette wheel selection method

String no	Initial population (Binary value of x)	X Value	f(x) Value= x^2	Probability count(f(x)/$\sum$ f(x))	Expected count(f(x)/ Average (f(x))	Actual count
1	1100	12	144	0.09	0.34	0
2	10010	18	324	0.19	0.77	1
3	10110	22	484	0.29	1.15	1
4	11011	27	729	0.43	1.73	2
		Total	1681	1.00	4.00	
		Average	420			

Step 5: crossover and mutation

String no	Initial population (Binary value of x)	X Value	f(x) Value	Probability count	Expected count	Actual count
1	1100	12	144	0.09	0.34	0
2	10010	18	324	0.19	0.77	1
3	10110	22	484	0.29	1.15	1
4	11011	27	729	0.43	1.73	2

Legend: 2+3 ; 3+4

String 2	10010	Parental Combination 1
String 3	10110	

String 3	10110	Parental Combination 2
String 4	11011	

Crossover:

String 2	10010	10010
String 3	10110	10110
String 3	10110	10111
String 4	11011	11010

Step 5: Evaluation of offspring

String no	Initial population (binary value)	X Value (integer value)	f(x) Value	Supplier selection (String no count as supplier)
1	10010	18	324	
2	10110	22	484	
3	10111	23	529	
4	11010	26	676	4

In step 5, we have separated parental chromosome 1 and 2 by adding string number 2 and 3, and 3 and 4. Once it is done, and then do crossover function to find out new binary number to calculate the converted value of f(x). The highest value of f(x) will be considered as the best supplier, and string number has reflected as supplier number.

2.3.3 Cost Ratio Method
In order to select the best supplier, we had to calculate net adjusted cost (NAC) and least NAC will be estimated to be a best supplier. Quality cost, delivery cost and service cost had been calculated for the supplier which will assist to analyze the right supplier selection using cost ratio method. From table 4, it has shown that supplier J should be selected since net adjusted cost for this supplier is lesser than other supplier.

Supplier	Quality cost ratio	Delivery cost ratio	Service cost	Total Penalty	Quoted price/ unit($)	Net Adjusted cost
A	2%	1%	1%	4%	$1.05	$1.09
B	1%	1%	1%	3%	$1.20	$1.24
C	2%	2%	2%	6%	$1.05	$1.11
D	2%	2%	1%	5%	$1	$1.05
E	1%	2%	2%	5%	$1.15	$1.21
F	2%	1%	2%	5%	$1.02	$1.07
G	3%	1%	2%	6%	$1	$1.17
H	2%	2%	1%	5%	$1.07	$1.12
I	2%	2%	2%	6%	$1.05	$1.11
J	2%	3%	2%	7%	$0.95	$1.02

Table 4: Implementation of cost ration method to select the right suppliers

2.3.4 Weighted Point Method
In this method, calculated supplier's score using weighted value with supplier's performance rating criteria wise. Details calculation as follows:

Total score for supplier A: Weight value of quality * suppliers rating + Weight value of delivery * suppliers rating + Weight value of cost * suppliers rating + Weight value of compliance * suppliers rating + Weight value of capacity * suppliers rating + Weight value of service * suppliers rating
= 30 * 0.6 + 25*0.8 +10*0.6 + 15 *0.7 +10*0.7 = 69.5
Supplier A possessed highest score, so it should be selected as the best supplier.

Factor/ Supplier	Criteria						Score
	Quality	Delivery	Cost	Compliance	Capacity	Service	
weight	30	25	10	10	15	10	69.5
Supplier A	0.6	0.8	0.6	0.8	0.7	0.7	
weight	30	25	10	10	15	10	49.5
Supplier B	0.4	0.6	0.4	0.6	0.5	0.5	
weight	30	25	10	10	15	10	50.5
Supplier C	0.4	0.6	0.3	0.8	0.6	0.5	
weight	30	25	10	10	15	10	57.5
Supplier D	0.5	0.7	0.5	0.6	0.6	0.5	
weight	30	25	10	10	15	10	44.5

Supplier E	0.3	0.5	0.6	0.6	0.4	0.5	
weight	30	25	10	10	15	10	47.75
Supplier J	0.8	0.6	0.4	0.6	0.6	0.5	

Table 5: Implementation of weighted point method to select the right suppliers

3. Results

It is also evident from Figures 3 and 4 that the benefit-to-cost (BCR) ratio intensified. The BCR is shown at 1.18 on average from Figure 3 while materials are taken from traditionally selected suppliers and the significance of the delay in delivery of the materials to the production unit is unclear.
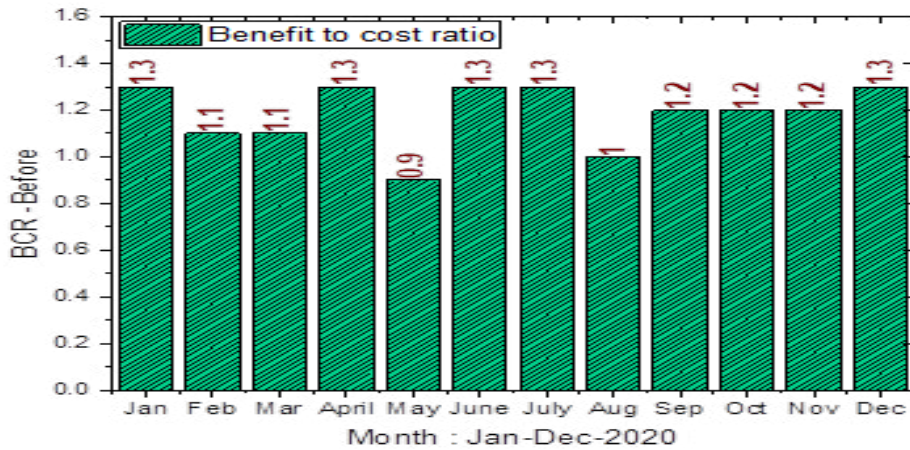
Figure 3: Benefit -to-cost ratio analysis -before

However, the BCR has increased by 50%, which is reflected in Figure 4, when the supplier is selected using the mentioned methods.
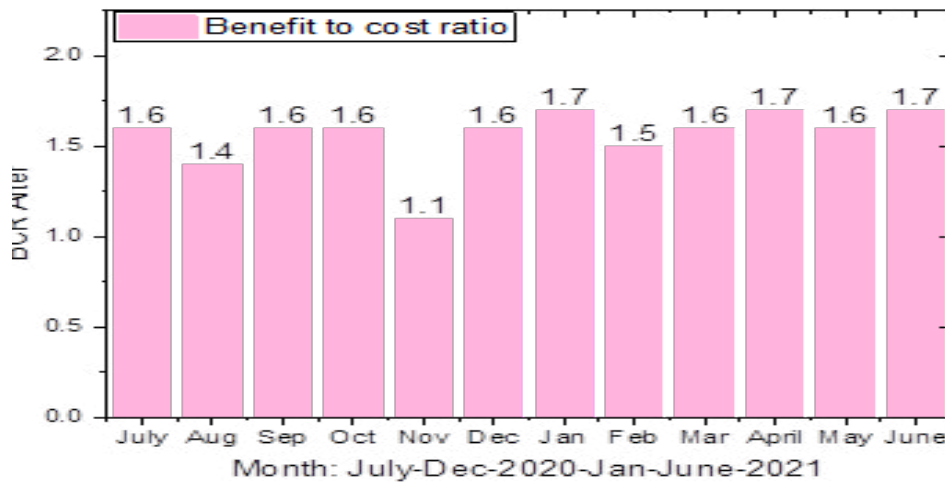

Figure 4: Benefit -to-cost ratio analysis -after

From 5 figures, it is shown that the percentage of on-time materials receiving status is high. Previously, 50-60% of materials were received on time. Hence, the progress is outstanding. It has increased to 94% in the first month after the four supplier selection methods have been applied to select the right supplier rather than the traditional approach.
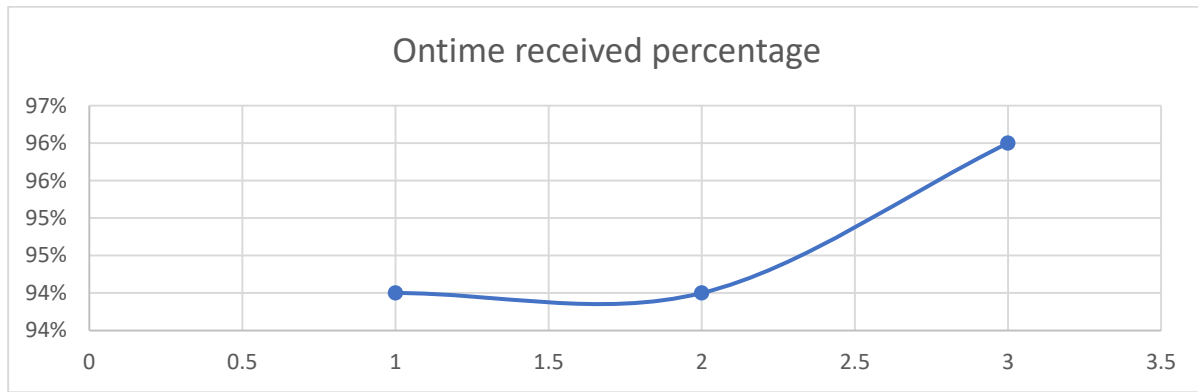
Figure 5: Ontime materials received status

4. Discussions

Supplier selection is the core activity for the apparel manufacturing industry. The garment business completely depends on the supplier. So, the supplier is a very important member of the supply chain. The supplier and the manufacturer should have strong collaboration between them to smoothly do the business. The medium and small-scale apparel manufacturing industries overlook this operation. As a result, the business falls into a risky situation. In this competitive era, the selection and evaluation of suppliers is a mandatory action.

In the apparel manufacturing business, supplier selection and evolution are unavoidable mechanisms. Some factories place orders without first evaluating the supplier's performance. As a result, they should bear the brunt of on-time delivery, quality concerns, and other issues. The consequences of tractional supplier selection are depicted in Figure 1. It costs the consumer money and delays the delivery of materials. As a result, the corporation either gives the consumer a discount or transports the products by air rather than sea. Because such problems are frequent in the garment manufacturing business, researching and proposing a supplier selection approach (figure 2) that was executed and found to have massive outcomes was a challenge. We used four different supplier selection and assessment methodologies in this article.

We used four different supplier selection and assessment methodologies in this article. Supplier A received the highest score using the dimensional analysis approach, and as a result, supplier A should be chosen. It's for a waistband elastic supplier for a men's underwear manufacturing. Simultaneously, we saw that when using the genetic algorithm method, supplier 4 received an apex score, as it did for fabric supplier. As a result, we should choose supplier 4 as the best option. Using the weighted point method and the cost ratio analysis method, we have suppliers A and J for thread or yarn suppliers who received the highest score. As a result, we should choose A and J as the best and most appropriate cloth providers. We adopted this proposed supplier selection approach at a large garment manufacturing business since the merchandising department selects suppliers. This factory reaped the benefits depicted in figures 3, 4 and 5 after selecting the correct supplier and placing orders with them.

5. Conclusions

The industrial unit, where the data used for the analysis was gathered, employs 5,000 people. 400 of them are officers, and 300 of them are executives. The monthly average income is $3.5 million. However, they are still having trouble securing on-time payment because of internal material delays. Since labor costs have risen significantly in Bangladesh over the past ten years, manufacturing costs must be reduced by optimizing the personnel, process, and other elements to survive.

The cost of materials in the textile manufacturing industry is something we are aware of materials account about 75% of the entire cost of a garment. Cutting and manufacturing accounts for only 25% of the total cost. In this case, utilizing the recommended supplier selection process, there is no other option to place orders with the best provider. Those factories who select suppliers using the old method are still in problems in some situations, resulting in an increase in air costs. A leading factory employs 2000 people, and we have applied our proposed approach to get the desired results. If the company pays more for air shipment or the buyer gives a discount because of a delay in delivery that has proven intolerable for the company.

We used four supplier selection and assessment approaches in this article, as if the correct supplier could be chosen at the right time to provide the best service in terms of delivery, quality, and pricing. The efficiency of the chosen production unit is substantially increased because the supplies are purchased from the top vendors. The rate of on-time delivery has grown considerably compared to the previous status since the proper supplier was chosen. Because many of the merchandisers came from general studies, this study's limitation is to evaluate suppliers using the dimensions analysis method, the cost ratio approach, and the genetic algorithm method. Despite the fact that it necessitates fundamental mathematical calculations, it is recommended that software based on this computation be developed because it will be more user-friendly.

Data Availability Statement

The basis data supporting the results of this research are stated in the manuscript.

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