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Analysis of the barriers to implement sustainable manufacturing practices in footwear sector of Bangladesh using graph theory and matrix approach

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A B S T R A C T

The footwear industry is booming with the increasing demand for leather-based products and manufacturers from the Asia region are leading the market. In the meantime, the negative impact on the environment of footwear goods and manufacturing processes of footwear-based products concerns the buyers and consumers as the global environmental situation is worsening day by day. For this reason, footwear industries are bound to use environmentally friendly production techniques to cope with the conditions as well as demands of the buyers otherwise the manufacturer can face the drop of order which can be affected financially. The Bangladeshi footwear industry is most unlikely to adopt sustainable manufacturing and thus lagging in the competitive market containing manufacturers from other Asian countries. The reason behind not implementing sustainable manufacturing practices should be explored to ensure this practice. In the study, Graph Theory and Matrix Approach (GTMA) was utilized along with the best and worst matrix using the weighted values as the diagonal and off-diagonal elements which was found from the two surveys after consultation with experts from the Bangladeshi footwear industry to gather responsible barriers for both large-scale and small-medium sized enterprises. Ranking based on impact was developed for two scales and an index value was found from the calculations of the matrix formed by permanent functional value found for each of the barriers and their best-worst values also which was another determinant of this study for expressing the fitness level for this certain adaptation. Similarity coefficient was another factor to be determined for the decision making required for the first objective of this research.

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Nomenclature

SMP:	Sustainable Manufacturing Practices
GTMA:	Graph Theory and Matrix Approach

1. Introduction

The footwear industry is one of the leading industries expanding day by day. The global market for footwear, which was anticipated to be worth US$349 billion in 2020, is expected to grow to US$427.4 billion by 2027 (Yahoo, 2022). Asia is at the forefront of production in the world market because of the availability of high-quality leather and cheap labor cost. China, Vietnam, Pakistan, Turkey, Indonesia, and Bangladesh create most of the leather shoes sold worldwide which was represented in research (Muller, 2017). Bangladesh's second-highest generator of foreign currency is now the footwear sector. By 2021, the Bangladeshi government wants the leather sector to generate 5 billion USD in income. Bangladesh is a desirable location for outsourcing to industrialized nations due to its affordable labor and access to raw materials enables it to create leather goods at a lower cost than its competitors (Chowdhury et al., 2019). The production of various types of footwear for the internal market and export is now being done in Bangladesh by around 4500 small, non-mechanized units and about 42 mechanized plants (Msrblog., 2022) . In the financial year 2017-2018, the industry generated export revenue

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of USD 483 million, so that Bangladesh is now the world's sixth-largest supplier of shoes and leather items (DATABD.CO., 2022). In fiscal years 2020–21, Bangladesh exported shoes valued at $669.91 million (July-March). Twenty to twenty-five percent of Bangladesh's total footwear production is assigned for satisfying local demand and the remainder is supplied to all over the world. United States, Germany, Netherlands, Hong Kong and Italy are the most common destinations for the finished leather footwear and Spain, India, France etc. serve as the export destination for non-leather footwear (Polese et al., 2019). According to the Business Inspection BD, top brands in terms of market share are Apex Footwear, Bay Emporium, Fortune Shoes, Legacy Footwear, and BATA Shoes. Francesco Polese et al. described that the term "shoes" covers a wide range of goods made of diverse materials and subject to various dangers, including poisons and toxic chemicals used in the production of leather products (Siddiqui et al., 2019). Sumita Dixit et al. showed their concern as bovine leather is made from the processing of animal hides, and product items are linked to harmful and unsafe properties, for example the use of toxic components such chromium in tannery, vulcanized ductile elements and chemical-based glues, have a significant negative impact on the surroundings when released into open air (Yoshihisa Nagatomo, 2018). Mitchell Jones et al. warned as the growing environmental risks associated with these kinds of products in recent years have gradually sparked serious concerns about the sustainability of the leather industries mainly in the footwear sector (UKEssays.com., 2018). For these reasons, buyers and consumers are leaning towards the SMP. Francesco Polese et al. also stated that due to the adoption and enforcement of regulations on the use of toxic materials on production process and to be more successful in the market, the market is evolving and buyers as well as footwear brands are more conscious of the necessity for ethical business practices, where products are manufactured with decent working environment and low ecological damage (Polese et al., 2019). A study conducted about footwear business and found out that the footwear business has a very cheap switching cost for consumers, and consumers have strong negotiating leverage. It implies that if the business doesn't meet the requirements and criteria, the customer could be lost (Program at a Glance, 2022).

2. Literature Review

Sustainability in the manufacturing process improves worker, public, and product safety. Nordin et al. described SCP as the process which attempts to increase a company's performance while reducing the environmental effects of its manufacturing processes as the Products are being evaluated more on the basis of the company' sustainable business practices than their pricing and the efforts to lessen the negative environmental effects of manufacturing activities have been seen as a barrier to profitability and productivity (Nordin et al., 2014). Despeisse et al. (2011) explained sustainable manufacturing as the rapidly developing field in practice. Berndtsson explored the connection between circular economy and sustainable practice and the impact of the circular economy in the system within some boundaries. He concludes his studies with the decision of circular economy being an important part of long-lasting progress which is one of the major concerns for the industries with some additional perspectives (M & Sinha, 2021). Bhanot et al. (2015) said that in the current competitive context, where many firms still rely on environmental assets while simultaneously producing pollution and causing degradation, SMP has become increasingly important. Appolloni et al. (2022) described sustainability as an enabler of competitive advantage in manufacturing and competitive advantage requires recognition of a green-circular premium. Many researchers discussed the impact and necessity of SMP in various sectors. Sumit Gupta and Amit Kumar Singh suggested adopting SMP in the electrical panel industry to achieve competitiveness in the market after evaluating the phenomena with analytical hierarchy process (AHP) model (Gupta et al., 2015). Purnell and Velenturf (2022) discussed ten principles for the development, application, and assessment of a circular fashion economy. Sarkis et al. (2011) expressed that circular economy provides through promoting consciousness about converting goods in a way that establishes an effective interaction between natural preservation and industrial progress, the limit of ecological sustainability can be expanded. Menon and Ravi (2021) discussed finding out the barriers of applying a resilient supply chain in electronics industries in Indian context and determining through a structural model the interrelationship among challenges and identifying their driving and driven strength. Dwivedi et al. (2022) talked about Sustainable Footwear Production (SFP) and Sustainable Development Goals. The footwear industry of Bangladesh is the second-highest export earner of Bangladesh and acts like the important source of growth in Bangladesh's rapidly growing economy. In the World Footwear Yearbook 2021, it is displayed that the position of Bangladesh moved from 18th to 16th in 2020 on global footwear export (Businesspostbd.com., 2022). Francesco Polese et al. (2019) described that the term "shoes" covers a wide range of goods made of diverse materials and subject to various dangers, including poisons and toxic chemicals used in the production of leather products. Dixit et al. (2015) showed their concern as bovine leather is made from the processing of animal hides, and product items are linked to harmful and unsafe properties, for example the use of toxic components such chromium in tannery, vulcanized ductile elements and chemical-based glues, have a significant negative impact on the surroundings when released into open air. Jones et al. (2020) warned as the growing environmental risks associated with these kinds of products in recent years have gradually sparked serious concerns about the sustainability of the leather industries mainly in the footwear sector. Rathinamoorthy (2018) presented the global awareness of the topic of sustainability that has caused the footwear market to gradually shift in favour of environmentally friendly goods. This concept has brought about a new trend in the leather industry by gradually altering shoppers' perceptions of environmentally sustainable products. Nam and Lee (2018) expressed in their research that the comparative to a traditional system, the transition to using natural elements produced from the surroundings to build footwear parts and associated items, shape the system more ecologically and sustainable and lessens its negative effects on the surroundings. Large quantities of toxic waste, including colors, sodium sulphate, sodium chloride, sodium hydroxide, and traces of other salts, are produced during the textile dyeing for leather. Additionally, these are producing "after dyeing" and "after washing" of clothing or fabrics (Aktar, 2014). Others identified that the footwear business has emphasized green operations more and more. Nike and other footwear manufacturers have prioritized green production (Schifrin et al., 2018). A study conducted about footwear business and found out that the footwear business has a very cheap switching cost for consumers, and consumers have strong negotiating leverage. It implies that if the business doesn't meet the requirements and criteria, the customer could be lost (Program at a Glance., 2022). Heale expressed the methods for sustainability across the whole life cycle of the footwear item. This approach makes it possible to limit harmful effects on the environment by protecting resources, conserving water and energy, ensuring a safe workplace, and reducing and reusing waste (Heale, 2013). So, sustainable development is becoming a major concern for the footwear industry of Bangladesh. Alzubi and Akkerman (2022) addressed the fact that manufacturing process organizations were occasionally considered to adopt sustainable practices without strong motivation.

2. Research Methodology

2.1 Framework

The following (Fig.1) is an illustration of our research framework:

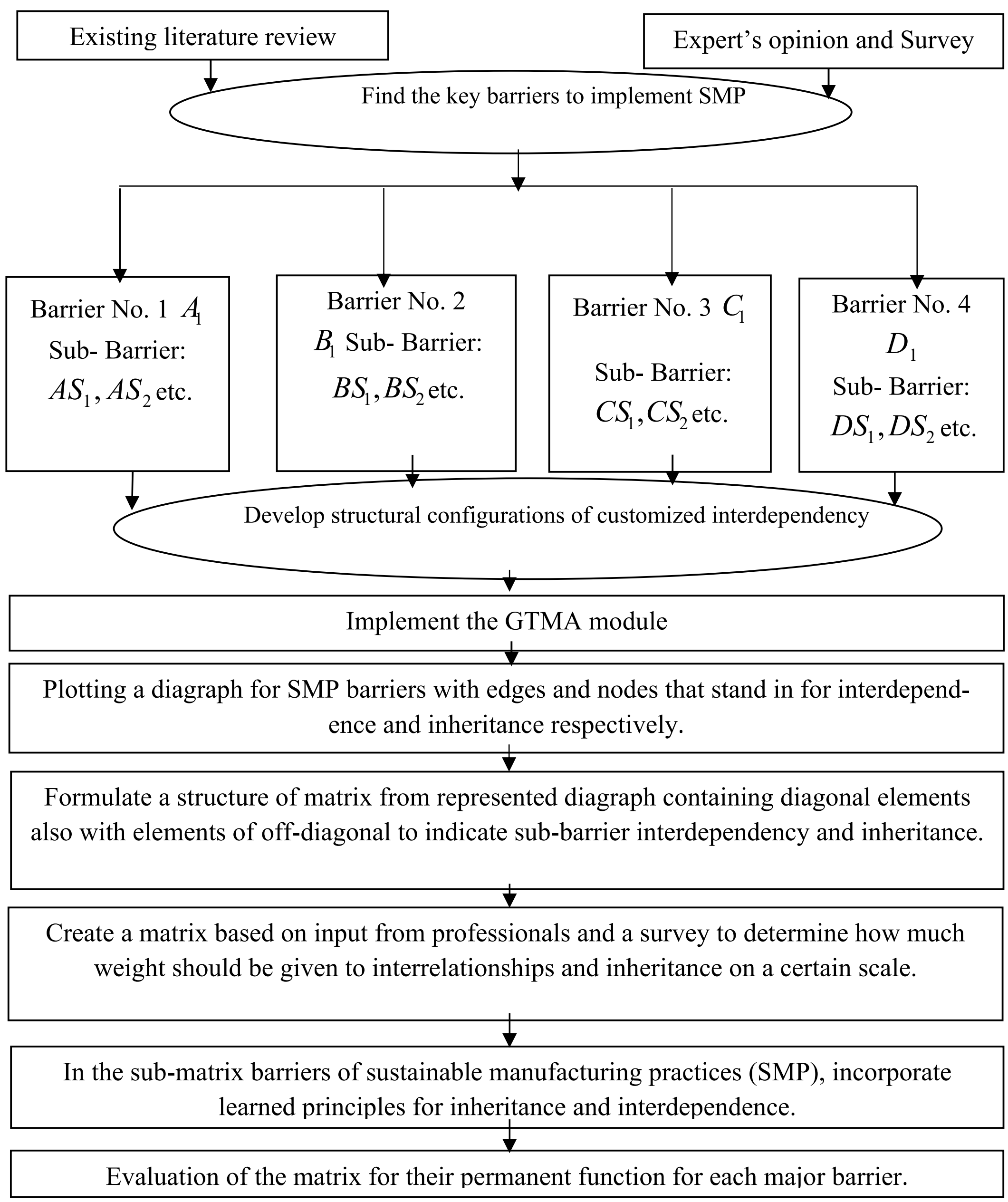

Fig. 1. Framework for the methodology.

2.2 Behavioral Diagraph Representations

The principal barrier is shown by F_i (see Fig.2), while the level of interdependence between the '*j*'-th and '*i*'-th barrier is shown by b_{ij}. An edge directed from node '*i*' towards node '*j*' will be shown as b_{ij} in a different diagram. The key barriers are represented in a diagram by the nodes $F_1, F_2, F_3, F_4, ..., F_m$ while interdependencies between the major barriers will be shown by b_{ij}. In a different figure, the sub-barrier of a barrier F_1 will be shown as $F_1^1, F_1^2, F_1^3, F_1^4, ..., F_1^n$ and so on. The interactions between these sub-barriers are indicated by r_{ij} (see Table 1).

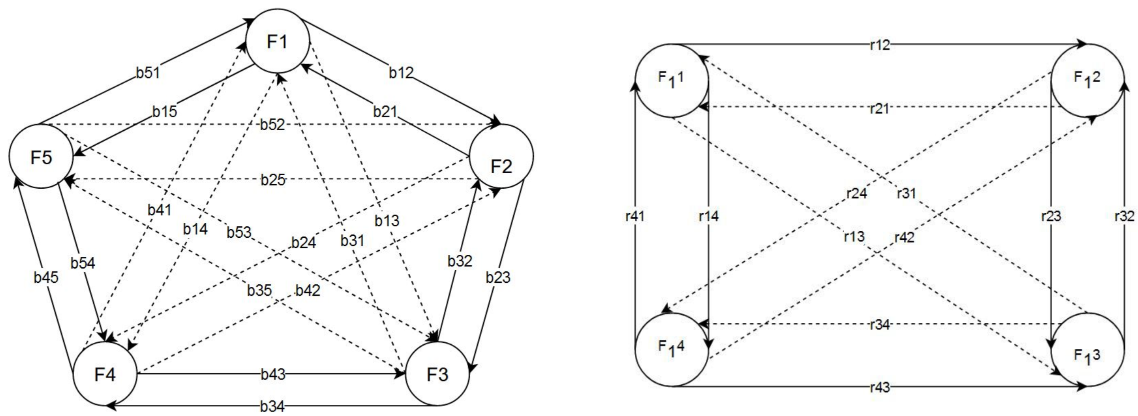

Fig. 2. Behavioral Diagraph for barriers and sub-barriers associated with main barrier.

Table 1
Weightings assigned for the attributes (r_{ij})

Description of Class	Relative importance of the attributes	
	r_{ij}	$r_{ji} = 10 - r_{ij}$
Case 1	0	10
Case 2	1	9
Case 3	2	8
Case 4	3	7
Case 5	4	6
Case 6	5	5
Case 7	6	4
Case 8	7	3
Case 9	8	2
Case 10	9	1
Case 11	10	0

2.3 Matrix Representations and Evaluations

A graph *B={M(X), T(X)}* is made up of *v*, a collection of non-empty nodes *T* which is also called as point is a collection of the edges or lines. The mapping is made from set edges set *T* to the set of the sorted or the pair of unordered elements in the set *M* (Awasthi et al., 2020). The following is a description of the steps involved with these goals:

Step 1: The first stage is to determine the traits or factors that have an impact on the system or process.

Step 2: Recognizing the values of interdependencies between the sub-systems of the potential options interacts.

Step 3: The represented digraph consists of a set of directed edges $T = \{P_{ij}\}$ and nodes set $P = \{n_i\}$ with the value of *i=1,...,n* where i-th alternative nodal representation, n_i. The possibilities number taken into consideration is equal to the number of nodes, *m*. An edge which is directed is made from node *'i'* toward the node *'j'* if node *'i'* has interdependency over the 9ve importance over node *'i'* (P_{ji}).

Step 4: This $M \times M$ matrix of selection criteria takes into account each criterion represented by A_i and their relative weights a_{ij}. In this contrast, A_i represents the value of criterion *i*-th represented by node A_i and a_{ij} is the representation of the edge p_{ij} express the *i*-th criterion's relative relevance to the *j*-th criterion. The values of A_i are normalized on the same scale and should ideally be derived from the experimental data. The matrix representations of the attributes, *B* is shown in the following:

$$B = \begin{bmatrix} B_1 & b_{12} & b_{13} & b_{14} & \cdots & \cdots & b_{1m} \\ b_{21} & B_2 & b_{23} & b_{24} & \cdots & \cdots & b_{2m} \\ b_{31} & b_{32} & B_3 & b_{34} & \cdots & \cdots & b_{3m} \\ b_{41} & b_{42} & b_{43} & B_4 & \cdots & \cdots & b_{4m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & b_{n3} & b_{n4} & \cdots & \cdots & B_M \end{bmatrix}$$

where, the terms in the constant expression are grouped into ($n+1$) groups. As a result, there are seven categories of physical significance that are expressed when $n = 6$. For this instance, in the first grouping where only contains one phrase that depicts the interplay between the four main forces behind sustainable manufacturing processes namely B_1, B_2, B_3, B_4, B_M . The third grouping consists of two terms where each of which denotes $b_{ij}b_{ji}$. Each term in the fourth grouping indicates a certain number of barrier interdependences ($b_{ij}b_{jk}b_{ki}$ or its pair $b_{ik}b_{ki}b_{ji}$) and a measure of the remaining barriers. A collection of two-barrier interdependences ($b_{ij}b_{ji}$ and $b_{kl}b_{lk}$) and measurement of other barriers make up the first subgrouping. The second sub-grouping consists of a measure of the remaining barriers, a set of four barrier interdependences ($b_{ij}b_{jk}b_{kl}b_{li}$ and $b_{il}b_{lk}b_{kj}b_{ji}$) and so on.

Step 5:

The permanent function value for the matrix of previous step can be represented as-

$$Per(B) = \prod_{i=1}^{M} B_i + \{\sum_i \sum_j \sum_k \cdots \sum_m (b_{ij}b_{ji}) B_k B_l \ldots B_M\} + \{\sum_i \sum_j \sum_k \sum_l \sum_m \cdots \sum_p (b_{ij}b_{ji}b_{jk}b_{kl}b_{lm} +$$
$$b_{ik}b_{kj}b_{ji}b_{jp}b_{mp}) B_l B_m \ldots B_p\} + \{\sum_i \sum_j \sum_k \sum_l \cdots \sum_p (b_{ij}b_{ji})(b_{kl}b_{lk})(b_{lm}b_{ml})(b_{mp}b_{pm}) B_k B_l \cdots B_m\} +$$
$$\{\sum_i \sum_k \sum_m \sum_n \cdots \sum_p (b_{ij}b_{ji})(b_{kl}b_{1m}b_{mk} + b_{km}b_{ml}b_{lk}) B_n B_m \ldots B_p + \sum_i \sum_j \sum_k \sum_l \cdots \sum_p (b_{ij}b_{jk}b_{kl}b_{lm}$$
$$b_{mn}b_{np} + b_{im}b_{ml}b_{lk}b_{kj}b_{ji}b_{pn}) B_m B_n \ldots B_p + \ldots\ldots\ldots\}$$

The following is a representation of the matrix for each main barrier's permanent function:

$$Per(Main - Barrier) = \begin{bmatrix} B_i^l & b_{ij}^l & b_{ij}^l & b_{ij}^l & b_{ij}^l \\ b_{ji}^l & B_i^l & b_{ij}^l & b_{ij}^l & b_{ij}^l \\ b_{ji}^l & b_{ji}^l & B_i^l & b_{ij}^l & b_{ij}^l \\ b_{ji}^l & b_{ji}^l & b_{ji}^l & B_i^l & b_{ij}^l \\ b_{ji}^l & b_{ji}^l & b_{ji}^l & b_{ji}^l & B_i^l \end{bmatrix}$$

Where,

B_i^l = The rating of the sub barrier *'i'* and barrier number expressed by *'l'*.

b_{ij}^l = The relative importance for sub barrier *'i'* with respect to sub barrier *'j'* and barrier number *'l'*.

$b_{ji}^l = 10 - b_{ij}^l$

$i = 1, 2, \ldots, m$ (for the rows)

$j = 1, 2, \ldots, n$ (for the columns)

m = Total number of the sub barrier (number of rows) associated with the barrier number 'l'.

n = Total number of the sub barrier (number of columns) associated with the barrier number 'l'.

l = The serial number of the barrier.

Step 6: Best-worst matrix have an impact on the impact evaluations of the barriers on this certain case. For the best values,

$$Per(B_{Barrier}) = \begin{bmatrix} 1 & b_{ij} & b_{ij} & b_{ij} & b_{ij} \\ b_{ji} & 1 & b_{ij} & b_{ij} & b_{ij} \\ b_{ji} & b_{ji} & 1 & b_{ij} & b_{ij} \\ b_{ji} & b_{ji} & b_{ji} & 1 & b_{ij} \\ b_{ji} & b_{ji} & b_{ji} & b_{ji} & 1 \end{bmatrix}$$

Alternatively, using the similar procedure for the worst values,

$$Per(W_{Barrier}) = \begin{bmatrix} 5 & w_{ij} & w_{ij} & w_{ij} & w_{ij} \\ w_{ji} & 5 & w_{ij} & w_{ij} & w_{ij} \\ w_{ji} & w_{ji} & 5 & w_{ij} & w_{ij} \\ w_{ji} & w_{ji} & w_{ji} & 5 & w_{ij} \\ w_{ji} & w_{ji} & w_{ji} & w_{ji} & 5 \end{bmatrix}$$

Here, $b_{ij} = b_{ji} = w_{ij} = w_{ji} = 5$

Step 7: The matrix for this calculation of the SMP index value can be represented as following-

For the SMP index of the barriers,

$$Per(SMP) = \begin{bmatrix} Per(B_1) & r_{ij} & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & Per(B_2) & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & Per(B_3) & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & Per(B_4) & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & r_{ji} & Per(B_5) \end{bmatrix}$$

For the SMP index of the best values,

$$Per(B) = \begin{bmatrix} Per(B_{B_1}) & r_{ij} & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & Per(B_{B_2}) & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & Per(B_{B_3}) & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & Per(B_{B_4}) & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & r_{ji} & Per(B_{B_5}) \end{bmatrix}$$

For the SMP index of the worst values,

$$Per(W) = \begin{bmatrix} Per(W_{B_1}) & r_{ij} & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & Per(W_{B_2}) & r_{ij} & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & Per(W_{B_3}) & r_{ij} & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & Per(W_{B_4}) & r_{ij} \\ r_{ji} & r_{ji} & r_{ji} & r_{ji} & Per(W_{B_5}) \end{bmatrix}$$

Here,

Per(SMP) = SMP index value for the permanent function values for the barriers.

Per(B) = SMP index value for the permanent function values of the best values of the barriers.

Per(W) = SMP index value for the permanent function values of the best values of the barriers.

$Per(B_i)$ = Permanent function values of the barrier no. *'i'*.

$Per(B_{B_i})$ = Values of Permanent function for the best value of the barrier no. *'i'*.

$Per(W_{B_i})$ = Values of Permanent function for the worst value of the barrier no. *'i'*.

r_{ij} = Relative importance value for the barrier *'i'* with respect to barrier *'j'*.

$r_{ji} = 10 - r_{ij}$

$i = 1,\ldots,u$ (u = Total number of rows)

$j = 1,\ldots,v$ (v = Total number of columns)

2.4 Calculations of Co-efficient of Similarity

The formula required for the computations of the coefficient of similarity is as follows:

$$C_{yi} = \frac{W_{ij} - P_{ij}}{W_{ij} - B_{ij}}$$

where, C_{yi} = Co-efficient of similarity for the identical barriers.

W_{ij} = Worst value associated with the barriers.

B_{ij} = Best Value associated with that barrier.

P_{ij} = Permanent function value associated with that barrier.

For the calculation for dissimilarity, If C_{di} and C'_{di} are the coefficient of dissimilarity with respectively for the best and worst values. Then,

$C_{di} = 1 - C_{yi}$

and $C'_{di} = 1 - C'_{yi}$

2.5 Data Collection

Initially we have studied a few previously conducted research for gathering barriers which are most likely challenge the implement of sustainable practices in footwear sector. After that we have discussed those barriers with two experts in footwear industry of Bangladesh and fixed 31 barriers which are compatible in the Bangladeshi scenario (see Table 2). We have constructed a questionnaire and reach 22 experts on footwear industry of Bangladesh for their opinion about the most impactful barriers among the 31 barriers as well as their impact on large size and small-medium sized enterprise. For the better accuracy of the data, we have only reached out to the officer level managerial or production persons who had the experience of working in a footwear manufacturing company like Bata, Apex footwear Ltd and Edison footwear. From the survey (see Fig 4, 5, 6) we have obtained 5 major barriers for large size enterprise and 6 major barriers for small-medium sized enterprise. For those barriers we have identified sub-barriers by reviewing literature (Appendix). Then we have conducted another survey among those experts to gather their opinion about the relative importance between the barriers and sub-barriers. After analyzing those data, we have calculated the outcome of our study.

Table 2
Initial barriers obtained from literature review and discussion with experts

Barriers
Cost of sustainability & economic condition
Capacity constraints
Lack of funds for sustainable supply chain practices
Green power shortage
Lack of government support & guideline to adopt sustainable supply chain practices
Less of business-friendly policy
Lack of technical expertise
Resistance to change and adopt innovation
Lack of eco-literacy amongst shareholders
Lack of awareness of local customers in green product
Lack of commitment from top management
Lack of training and education about sustainability
Information gap
Lack of interest in investing money for sustainability, and economic conditions not as good as developed countries
Pressure from community, NGOs and environmental authorities is low
Lack of support and guidelines from regulatory authority/poor legislation
Unwilling to adopt pollution control & prevention technology
Supply chain partner have insufficient knowledge of sustainable manufacturing practices
Absence of reverse logistics facility
Inadequate supply chain strategic planning
Lack of market demand
Pressure for lower prices
Inadequate application of e-ordering, companywide enterprise resource planning (ERP) and intelligent network system
Less control over minimizing environmental impact during the design, production or sale of products over their entire life cycle
Industries are not interested in sharing risks and rewards for adopting environmentally-friendly concepts
Lack of quality worker and management personnel to implement sustainable manufacturing practice
Uncertain benefits insignificant economic advantage, slow return on investment
Higher prices of imported processing chemicals for hides/skins
Outdated machineries present in tannery industry
Absence of green disposal system
Lack foreign direct investment FDI
Cost of sustainability & economic condition
Capacity constraints
Lack of funds for sustainable supply chain practices
Green power shortage
Lack of government support & guideline to adopt sustainable supply chain practices
Less of business-friendly policy
Lack of technical expertise
Resistance to change and adopt innovation
Lack of eco-literacy amongst shareholders
Lack of awareness of local customers in green product
Lack of commitment from top management
Lack of training and education about sustainability
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Lack of market demand
Pressure for lower prices
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Less control over minimizing environmental impact during the design, production or sale of products over their entire life cycle
Industries are not interested in sharing risks and rewards for adopting environmentally-friendly concepts
Lack of quality worker and management personnel to implement sustainable manufacturing practice
Uncertain benefits insignificant economic advantage, slow return on investment
Higher prices of imported processing chemicals for hides/skins
Outdated machineries present in tannery industry
Absence of green disposal system
Lack foreign direct investment FDI

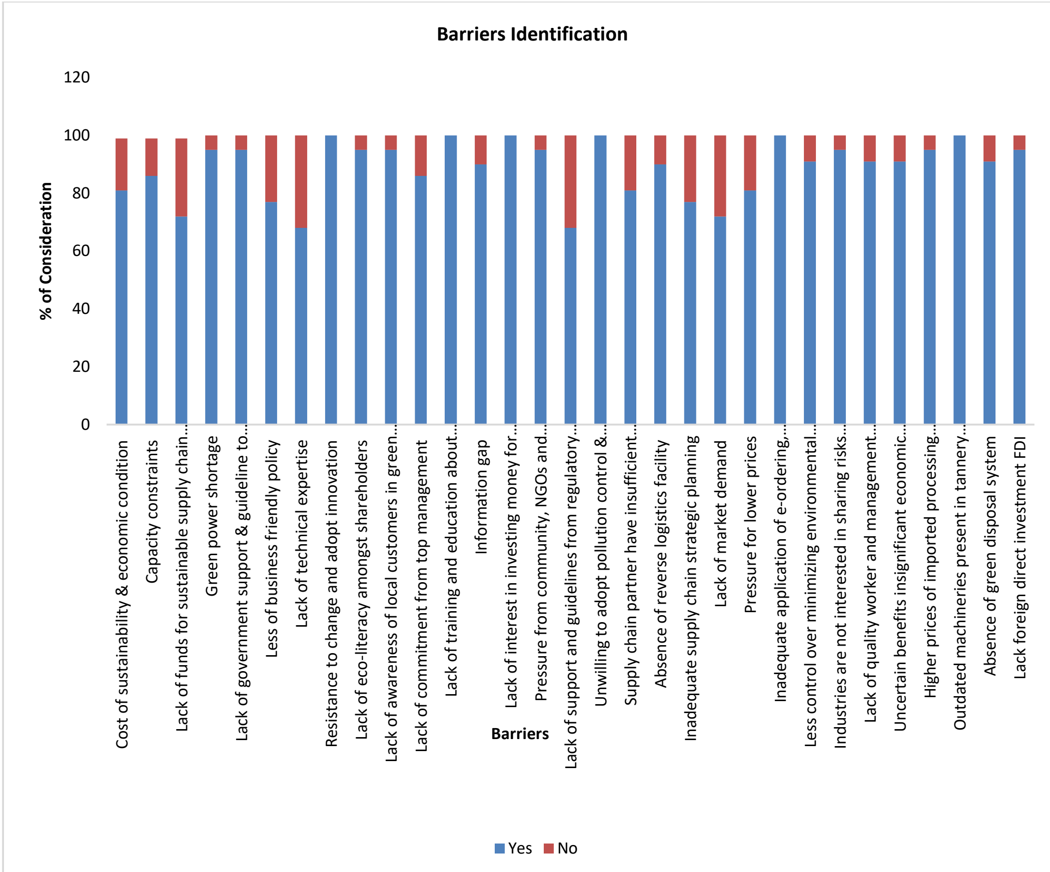

Fig. 4. Barrier identification

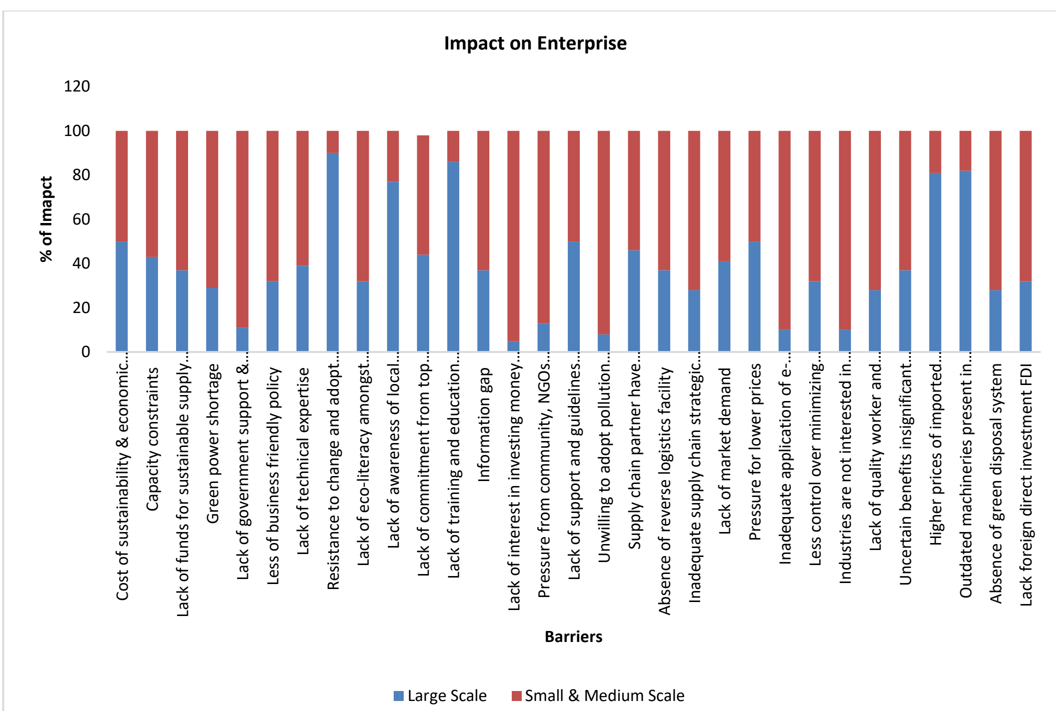

Fig. 5. Impact on enterprise.

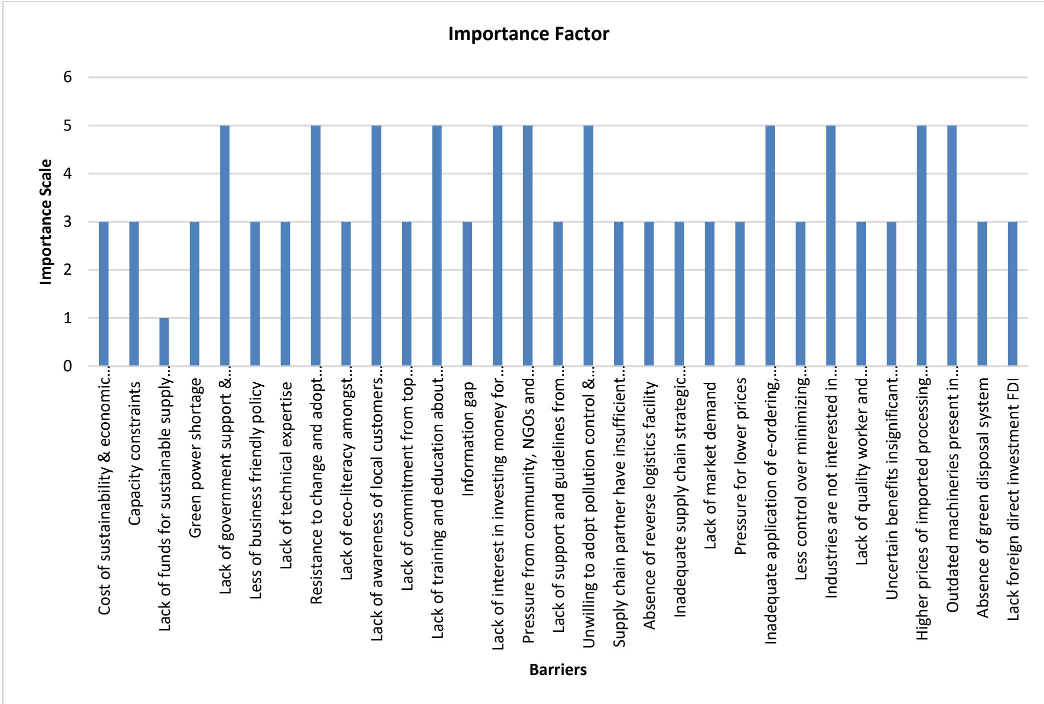

Fig. 6. Importance factor for the barriers.

Relative importance was gathered for both large scale and small-medium size enterprise. The table (see Table 3,4,5 and 6) represents those importance as well as the relative importance for their sub-barriers.

Table 3
Data for main barriers of large scale

i	*j*	r_{ij}	$r_{ji} = 10 - r_{ij}$	Rating of Barriers
1	2	5	5	7
	3	2	8	
	4	1	9	
	5	4	6	
2	3	7	3	2
	4	4	6	
	5	1	9	
3	4	3	7	9
	5	6	4	
4	5	3	7	6
5	-	-	-	3

Table 4
Data for main barriers of small and medium scale.

i	*j*	r_{ij}	$r_{ji} = 10 - r_{ij}$	Rating of Barriers
1	2	2	8	5
	3	4	6	
	4	3	7	
	5	2	8	
	6	1	9	
2	3	6	4	3
	4	1	9	
	5	4	6	
	6	3	7	
3	4	7	3	9
	5	2	8	
	6	3	7	
4	5	5	5	2
	6	4	6	
5	6	1	9	7
6	-	-	-	6

In the Table 3 and Table 4,

i ,j = Serial no. of the main barrier.

r_{ij} = Relative importance of main barrier 'i' with respect to 'j'.

r_{ji} = Relative importance of main barrier 'j' with respect to 'i'.

Table 5
Data for sub barriers associated with main barriers.

i	j	l	x_{ij}^l	$x_{ji}^l = 10 - x_{ij}^l$	X_i^l
1	2	1	4	6	2
	3		7	3	
	4		8	2	
2	3		3	7	6
	4		4	6	
3	4		1	9	9
4	-		-	-	10
1	2	2	1	9	7
	3		3	7	
	4		6	4	
2	3		2	8	6
	4		3	7	
3	4		3	7	4
4	-		-	-	1
1	2	3	8	2	2
	3		5	5	
	4		3	7	
	5		2	8	
2	3		3	7	10
	4		5	5	
	5		6	4	
3	4		2	8	7
	5		3	7	
4	5		1	9	5
5	-		-	-	4
1	2	4	3	7	3
	3		7	3	
	4		5	5	
2	3		4	6	6
	4		2	8	
3	4		2	8	10
4	-		-	-	8
1	2	5	4	6	6
	3		1	9	
	4		4	6	
2	3		5	5	2
	4		8	2	
3	4		3	7	7
4	-		-	-	10

Table 6
Data of sub-barriers associated with small and medium scale

i	*j*	*k*	y_{ij}^{k}	$y_{ji}^{k} = 10 - y_{ij}^{k}$	Y_{i}^{k}
1	2	1	3	7	2
	3		8	2	
	4		1	9	
2	3		4	6	5
	4		2	8	
3	4		6	4	9
4	-		-	-	3
1	2	2	2	8	1
	3		5	5	
	4		7	3	
	5		6	4	
2	3		3	7	3
	4		5	5	
	5		4	6	
3	4		2	8	6
	5		1	9	
4	5		1	9	8
5	-		-	-	7
1	2	3	3	7	2
	3		6	4	
	4		4	6	
2	3		3	7	5
	4		1	9	
3	4		2	8	8
4	-		-	-	6
1	2	4	1	9	6
	3		4	6	
	4		3	7	
2	3		3	7	7
	4		4	6	
3	4		7	3	10
4	-		-	-	3
1	2	5	3	7	8
	3		1	9	
	4		2	8	
2	3		2	8	5
	4		5	5	
3	4		3	7	7
4	-		-	-	10
1	2	6	3	7	8
	3		2	8	
	4		4	6	
	5		6	4	
2	3		1	9	5
	4		1	9	
	5		3	7	
3	4		2	8	6
	5		4	6	
4	5		2	8	4
5	-		-	-	2

In the Table 5 and Table 6,

i,j = Serial no. of the sub- barrier.

l,k = Serial no. of the main barriers connected to sub-barriers.

x_{ij}^{l} = Relative importance of sub-barrier '*i*' with respect to '*j*' under main barrier no. '*l*'.

x_{ji}^{l} = Relative importance of sub-barrier '*j*' with respect to '*i*' under main barrier no. '*l*'.

X_{i}^{l} = Rating of the sub-barrier '*i*' under main barrier '*l*'.

y_{ij}^{k} = Relative importance of sub-barrier '*i*' with respect to '*j*' under main barrier no. '*k*'.

y_{ji}^{k} = Relative importance of sub-barrier '*j*' with respect to '*i*' under main barrier no. '*k*'.

Y_{i}^{k} = Rating of the sub-barrier '*i*' under main barrier '*k*'.

3. Calculations

3.1 Calculations for the large scale

Step 1: Determination of the Permanent Function Values for the matrix-

For main function of the sustainable manufacturing practice (SMP), the matrix can be represented as,

$$\text{SMP} = \begin{bmatrix} X_i & x_{ij} & x_{ij} & x_{ij} & x_{ij} & x_{ij} \\ x_{ji} & X_i & x_{ij} & x_{ij} & x_{ij} & x_{ij} \\ x_{ji} & x_{ji} & X_i & x_{ij} & x_{ij} & x_{ij} \\ x_{ji} & x_{ji} & x_{ji} & X_i & x_{ij} & x_{ij} \\ x_{ji} & x_{ji} & x_{ji} & x_{ji} & X_i & x_{ij} \\ x_{ji} & x_{ji} & x_{ji} & x_{ji} & x_{ji} & X_i \end{bmatrix} = \begin{bmatrix} X_1 & x_{12} & x_{13} & x_{14} & x_{15} & x_{16} \\ x_{21} & X_2 & x_{23} & x_{24} & x_{25} & x_{26} \\ x_{31} & x_{32} & X_3 & x_{34} & x_{35} & x_{36} \\ x_{41} & x_{42} & x_{43} & X_4 & x_{45} & x_{46} \\ x_{51} & x_{52} & x_{53} & x_{54} & X_5 & x_{56} \\ x_{61} & x_{62} & x_{63} & x_{64} & x_{65} & X_6 \end{bmatrix}$$

Here,

X_i = The rating for the barriers number '*i'*.

x_{ij} = The relative importance for the sub barriers *'j'* associated with the main barriers *'i'*.

$$x_{ji} = 10 - x_{ij}$$

i = 1,2,….,m

j= 1,2,….,n

m= Total number of rows in the matrix.

n= Total number of columns in the matrix.

The permanent function for this matrix of sustainable manufacturing practice can be written as,

Per (SMP) =

$$\prod_{i=1}^{6} X_i + \sum_i\sum_j\sum_k\sum_l\sum_m\sum_n x_{ij}x_{ji}x_{ik}x_{ki}x_{jk}x_{kj}X_kX_lX_mX_n + \sum_i\sum_j\sum_k\sum_l\sum_m\sum_n (x_{ij}x_{jk}x_{ki}x_{ij}x_{li} +$$
$$x_{ik}x_{kj}x_{ji}x_{kl})X_l + \sum_i\sum_j\sum_k\sum_l\sum_m\sum_n (x_{ij}x_{ji}x_{kj}x_{kl}) \times (x_{ki}x_{lk}x_{km}x_{mi}) + \sum_i\sum_j\sum_k\sum_l\sum_m\sum_n (x_{ij}x_{ji}x_{ik}x_{ki}x_{jk}x_{kj}$$
$$+ x_{il}x_{lk}x_{ik}x_{il}x_{im}x_{mn})$$

For the 1st barrier:

The permanent function for the barrier "Resistance to change and adopt innovation (RCAI)" of large scale,

$$Per^{LS}(RCAI)=\begin{bmatrix} X_i^l & x_{ij}^l & x_{ij}^l & x_{ij}^l \\ x_{ji}^l & X_i^l & x_{ij}^l & x_{ij}^l \\ x_{ji}^l & x_{ji}^l & X_i^l & x_{ij}^l \\ x_{ji}^l & x_{ji}^l & x_{ji}^l & X_i^l \end{bmatrix} = \begin{bmatrix} X_1^1 & x_{12}^1 & x_{13}^1 & x_{14}^1 \\ x_{21}^1 & X_2^1 & x_{23}^1 & x_{24}^1 \\ x_{31}^1 & x_{32}^1 & X_3^1 & x_{34}^1 \\ x_{41}^1 & x_{42}^1 & x_{43}^1 & X_4^1 \end{bmatrix} = \begin{bmatrix} 2 & 4 & 7 & 8 \\ 6 & 6 & 3 & 4 \\ 3 & 7 & 9 & 1 \\ 2 & 6 & 9 & 10 \end{bmatrix}$$

where,

X_i^l = The rating of the sub barrier *'i'* and barrier number expressed by *'l'*.

x_{ij}^l = The relative importance of the sub barrier *'i'* with respect to sub barrier *'j'* and barrier number *'l'*.

$x_{ji}^l = 10 - x_{ij}^l$

i = 1, 2,....,m (for the rows).

j = 1, 2,....,n (for the columns).

m = Total number of the sub barrier (number of rows) associated with the barrier number '*l*' = 4.

n = Total number of the sub barrier (number of columns) associated with the barrier number '*l*' = 4.

l = The serial number of the barrier = 1 (for the 1st barrier).

Permanent value representation for the matrix of the first barrier by the following ways-

$$X_1^1X_2^1X_3^1X_4^1+(x_{12}^1x_{21}^1X_3^1X_4^1+x_{13}^1x_{31}^1X_2^1X_4^1+x_{14}^1x_{41}^1X_2^1X_3^1+x_{23}^1x_{32}^1X_1^1X_4^1+x_{24}^1x_{42}^1X_1^1X_3^1+x_{34}^1x_{43}X_1^1X_2^1)+(x_{23}^1x_{34}^1x_{42}^1X_1^1+x_{24}^1x_{43}^1x_{32}^1X_1^1$$
$$+x_{13}^1x_{34}^1x_{41}^1X_2^1+x_{14}^1x_{43}^1x_{31}^1X_2^1+x_{12}^1x_{24}^1x_{41}^1X_3^1+x_{14}^1x_{42}^1x_{21}^1X_3^1+x_{12}^1x_{23}^1x_{31}^1X_4^1+x_{13}^1x_{32}^1x_{21}^1X_4^1)+(x_{12}^1x_{21}^1x_{34}^1x_{43}^1+x_{13}^1x_{31}^1x_{24}^1x_{42}^1+x_{14}^1x_{41}^1x_{23}^1x_{32}^1$$
$$+x_{12}^1x_{23}^1x_{34}^1x_{41}^1+x_{14}^1x_{43}^1x_{32}^1x_{21}^1+x_{13}^1x_{34}^1x_{42}^1x_{21}^1+x_{12}^1x_{24}^1x_{43}^1x_{31}^1+x_{14}^1x_{42}^1x_{23}^1x_{31}^1+x_{13}^1x_{32}^1x_{24}^1x_{41}^1)$$

= 12432

Similarly,

$$Per^{LS}(LALC)=\begin{bmatrix} 7 & 1 & 3 & 6 \\ 9 & 6 & 2 & 3 \\ 7 & 8 & 4 & 3 \\ 4 & 7 & 7 & 1 \end{bmatrix} = 13128$$

$$Per^{LS}(LTES)=\begin{bmatrix} 2 & 8 & 5 & 3 & 2 \\ 2 & 10 & 3 & 5 & 6 \\ 5 & 7 & 7 & 2 & 3 \\ 7 & 5 & 8 & 5 & 1 \\ 8 & 4 & 7 & 9 & 4 \end{bmatrix} = 285634$$

$$Per^{LS}(OMPT)=\begin{bmatrix} 3 & 3 & 7 & 5 \\ 7 & 6 & 4 & 2 \\ 3 & 6 & 10 & 2 \\ 5 & 8 & 8 & 8 \end{bmatrix} = 11934$$

$$Per^{LS}(HPIC)=\begin{bmatrix} 6 & 4 & 1 & 4 \\ 6 & 2 & 5 & 8 \\ 9 & 5 & 7 & 3 \\ 6 & 2 & 7 & 10 \end{bmatrix} = 14380$$

Step 2:

$$Per(SMP^{LS})=\begin{bmatrix} 12432 & 5 & 2 & 1 & 4 \\ 5 & 13128 & 7 & 4 & 1 \\ 8 & 3 & 285634 & 3 & 6 \\ 9 & 6 & 7 & 11934 & 3 \\ 6 & 9 & 4 & 7 & 14380 \end{bmatrix}$$

$$= 55.68\times 10^{21}$$

Step 3:

$$Per(B_{RCAI/LALC/OMPT/HPIC}{}^{LS}) = \begin{bmatrix} 1 & b_{12} & b_{13} & b_{14} \\ b_{21} & 1 & b_{23} & b_{24} \\ b_{31} & b_{32} & 1 & b_{35} \\ b_{41} & b_{42} & b_{43} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 5 & 5 & 5 \\ 5 & 1 & 5 & 5 \\ 5 & 5 & 1 & 5 \\ 5 & 5 & 5 & 1 \end{bmatrix} = 6776$$

$$Per(B_{LTES}{}^{LS}) = \begin{bmatrix} 1 & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & 1 & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & 1 & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & 1 & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 5 & 5 & 5 & 5 \\ 5 & 1 & 5 & 5 & 5 \\ 5 & 5 & 1 & 5 & 5 \\ 5 & 5 & 5 & 1 & 5 \\ 5 & 5 & 5 & 5 & 1 \end{bmatrix} = 168376$$

Here, $b_{ji} = b_{ji} = 5$

Alternatively,

$$Per(W_{RCAI/LALC/OMPT/HPIC}{}^{LS}) = \begin{bmatrix} 5 & w_{12} & w_{13} & w_{14} \\ w_{21} & 5 & w_{23} & w_{24} \\ w_{31} & w_{32} & 5 & w_{34} \\ w_{41} & w_{42} & w_{43} & 5 \end{bmatrix} = \begin{bmatrix} 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \end{bmatrix} = 15000$$

$$Per(W_{LTES}{}^{LS}) = \begin{bmatrix} 5 & w_{12} & w_{13} & w_{14} & w_{15} \\ w_{21} & 5 & w_{23} & w_{24} & w_{25} \\ w_{31} & w_{32} & 5 & w_{34} & w_{35} \\ w_{41} & w_{42} & w_{43} & 5 & w_{45} \\ w_{51} & w_{52} & w_{53} & w_{54} & 5 \end{bmatrix} = \begin{bmatrix} 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \end{bmatrix} = 375000$$

Here, $w_{ij} = w_{ji} = 5$

Step 4: Computations of the SMP index for the worst and best value

$$So,\ Per^{LS}(B) = \begin{bmatrix} 6766 & 5 & 2 & 1 & 4 \\ 5 & 6766 & 7 & 4 & 1 \\ 8 & 3 & 168376 & 3 & 6 \\ 9 & 6 & 7 & 6766 & 3 \\ 5 & 9 & 4 & 7 & 6766 \end{bmatrix} = 38.28 \times 10^{21}$$

$$Per^{LS}(W) = \begin{bmatrix} 15000 & 5 & 2 & 1 & 4 \\ 5 & 15000 & 7 & 4 & 1 \\ 8 & 3 & 375000 & 3 & 6 \\ 9 & 6 & 7 & 15000 & 3 \\ 6 & 9 & 4 & 7 & 15000 \end{bmatrix} = 19.62 \times 10^{22}$$

3.2 Calculations for the small and medium scale

Step 1:

For the 1st barrier:

$$Per^{SS}(LIEC) = \begin{bmatrix} 2 & 3 & 8 & 1 \\ 7 & 5 & 4 & 2 \\ 2 & 6 & 9 & 6 \\ 9 & 8 & 4 & 3 \end{bmatrix}$$

Permanent value representation for the matrix of the first barrier by the following ways-

$$\begin{aligned} & Y_1^1Y_2^1Y_3^1Y_4^1 + (y_{12}^1y_{21}^1Y_3^1Y_4^1 + y_{13}^1y_{31}^1Y_2^1Y_4^1 + y_{14}^1y_{41}^1Y_2^1Y_3^1 + y_{23}^1y_{32}^1Y_1^1Y_4^1 + y_{24}^1y_{42}^1Y_1^1Y_3^1 + y_{34}^1y_{43}^1Y_1^1Y_2^1) + (y_{23}^1y_{34}^1y_{42}^1Y_1^1 + y_{24}^1y_{43}^1y_{32}^1Y_1^1 \\ & + y_{13}^1y_{34}^1y_{41}^1Y_2^1 + y_{14}^1y_{43}^1y_{31}^1Y_2^1 + y_{12}^1y_{24}^1y_{41}^1Y_3^1 + y_{14}^1y_{42}^1y_{21}^1Y_3^1 + y_{12}^1y_{23}^1y_{31}^1Y_4^1 + y_{13}^1y_{32}^1y_{21}^1Y_4^1) + (y_{12}^1y_{21}^1y_{34}^1y_{43}^1 + y_{13}^1y_{31}^1y_{24}^1y_{42}^1 \\ & + y_{14}^1y_{41}^1y_{23}^1y_{32}^1 + y_{12}^1y_{23}^1y_{34}^1y_{41}^1 + y_{14}^1y_{43}^1y_{32}^1y_{21}^1 + y_{13}^1y_{34}^1y_{42}^1y_{21}^1 + y_{12}^1y_{24}^1y_{43}^1y_{31}^1 + y_{14}^1y_{42}^1y_{23}^1y_{31}^1 + y_{13}^1y_{32}^1y_{24}^1y_{41}^1) \end{aligned}$$

= 7267

Similarly,

$$Per^{SS}(IAEC) = \begin{bmatrix} 1 & 2 & 5 & 7 & 6 \\ 8 & 3 & 3 & 5 & 4 \\ 5 & 7 & 6 & 2 & 1 \\ 3 & 5 & 8 & 8 & 1 \\ 4 & 6 & 9 & 9 & 7 \end{bmatrix}$$

= 223558

$$Per^{SS}(UAPP) = \begin{bmatrix} 2 & 3 & 6 & 4 \\ 7 & 5 & 3 & 1 \\ 4 & 7 & 8 & 2 \\ 6 & 9 & 8 & 6 \end{bmatrix}$$

=11668

$$Per^{SS}(PCNE) = \begin{bmatrix} 6 & 1 & 4 & 3 \\ 9 & 7 & 3 & 4 \\ 6 & 7 & 10 & 7 \\ 7 & 6 & 3 & 3 \end{bmatrix}$$

=10759

$$Per^{SS}(LGSG) = \begin{bmatrix} 8 & 3 & 1 & 2 \\ 7 & 5 & 2 & 5 \\ 9 & 8 & 7 & 3 \\ 8 & 5 & 7 & 10 \end{bmatrix} =$$

11642

$$Per^{SS}(ISRR) = \begin{bmatrix} 8 & 3 & 2 & 4 & 6 \\ 7 & 5 & 1 & 1 & 3 \\ 8 & 9 & 6 & 2 & 4 \\ 6 & 9 & 8 & 4 & 2 \\ 4 & 7 & 6 & 8 & 2 \end{bmatrix} =$$

230946

Step 2: Determination of the SMP index value using permanent function value**.**

$$\text{So, } Per(SMP^{SS}) = \begin{bmatrix} 9210 & 2 & 4 & 3 & 2 & 1 \\ 8 & 221848 & 6 & 1 & 4 & 3 \\ 6 & 4 & 11668 & 7 & 2 & 3 \\ 7 & 9 & 3 & 10759 & 5 & 4 \\ 8 & 6 & 8 & 5 & 11642 & 1 \\ 9 & 7 & 7 & 6 & 7 & 220848 \end{bmatrix} = 76.14 \times 10^{20}$$

Step 3:

$$Per(B_{LIEC/UAPP/PCNE/LGSG}{}^{SS}) = \begin{bmatrix} 1 & b_{12}^{'} & b_{13}^{'} & b_{14}^{'} \\ b_{21}^{'} & 1 & b_{23}^{'} & b_{24}^{'} \\ b_{31}^{'} & b_{32}^{'} & 1 & b_{34}^{'} \\ b_{41}^{'} & b_{42}^{'} & b_{43}^{'} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 5 & 5 & 5 \\ 5 & 1 & 5 & 5 \\ 5 & 5 & 1 & 5 \\ 5 & 5 & 5 & 1 \end{bmatrix} = 6776$$

$$Per(B_{IAEC/ISSR}{}^{SS})=\begin{bmatrix} 1 & b'_{12} & b'_{13} & b'_{14} & b'_{15} \\ b'_{21} & 1 & b'_{23} & b'_{24} & b'_{25} \\ b'_{31} & b'_{32} & 1 & b'_{34} & b'_{35} \\ b'_{41} & b'_{42} & b'_{43} & 1 & b'_{45} \\ b'_{51} & b'_{52} & b'_{53} & b'_{54} & 1 \end{bmatrix} = \begin{bmatrix} 1 & 5 & 5 & 5 & 5 \\ 5 & 1 & 5 & 5 & 5 \\ 5 & 5 & 1 & 5 & 5 \\ 5 & 5 & 5 & 1 & 5 \\ 5 & 5 & 5 & 5 & 1 \end{bmatrix} = 168376$$

Here, $b'_{ij} = b'_{ji} = 5$

$$Per(W_{LIEC/UAPP/PCNE/LGSG}{}^{SS}) = \begin{bmatrix} 5 & w'_{12} & w'_{13} & w'_{14} \\ w'_{21} & 5 & w'_{23} & w'_{24} \\ w'_{31} & w'_{32} & 5 & w'_{34} \\ w'_{41} & w'_{42} & w'_{43} & 5 \end{bmatrix} = \begin{bmatrix} 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 \end{bmatrix} =15000$$

$$Per(W_{IAEC/ISRR}{}^{SS})=\begin{bmatrix} 5 & w'_{12} & w'_{13} & w'_{14} & w'_{15} \\ w'_{21} & 5 & w'_{23} & w'_{24} & w'_{25} \\ w'_{31} & w'_{32} & 5 & w'_{34} & w'_{35} \\ w'_{41} & w'_{42} & w'_{43} & 5 & w'_{45} \\ w'_{51} & w'_{52} & w'_{53} & w'_{54} & 5 \end{bmatrix} = \begin{bmatrix} 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \\ 5 & 5 & 5 & 5 & 5 \end{bmatrix} = 375000$$

Here, $w'_{ij} = w'_{ji} = 5$

Step 4: Computations of the SMP index for the worst and best value for the small and medium scale.

$$Per^{SS}(B)=\begin{bmatrix} 6766 & 2 & 4 & 3 & 2 & 1 \\ 8 & 168376 & 6 & 1 & 4 & 3 \\ 6 & 4 & 6766 & 7 & 2 & 3 \\ 7 & 9 & 3 & 6766 & 5 & 4 \\ 8 & 6 & 8 & 5 & 6766 & 1 \\ 9 & 7 & 7 & 6 & 9 & 168376 \end{bmatrix} = 62.73\times10^{20}$$

$$Per^{SS}(W)=\begin{bmatrix} 15000 & 2 & 4 & 3 & 2 & 1 \\ 8 & 375000 & 6 & 1 & 4 & 3 \\ 6 & 4 & 15000 & 7 & 2 & 3 \\ 7 & 9 & 3 & 15000 & 5 & 4 \\ 8 & 6 & 8 & 5 & 15000 & 1 \\ 9 & 7 & 7 & 6 & 9 & 375000 \end{bmatrix} = 31.24\times10^{21}$$

Step 5:

$$C'_{LGSG} = \frac{375000-220484}{375000-168376} = 0.746$$

$$C'_{UAPP} = \frac{15000-11642}{15000-6766} = 0.407$$

4. Result Analysis

From the calculation of permanent function values of the barriers of large-scale enterprises (see Table 7),

Table 7

Permanent Function Values for Barriers of Large Scale

Barrier of Large Scale	Permanent Function Value
$Per^{LS}(RCAI)$	12432
$Per^{LS}(LALC)$	13128
$Per^{LS}(LTES)$	285634
$Per^{LS}(OMPT)$	11934
$Per^{LS}(HPIC)$	14380

Table 8

Barriers for the large scale

	Barriers					
Category	**Resistance to change and adopt innovation (RCAI)**	**Lack of awareness of local customers in green products (LALC)**	**Lack of training and education about sustainability (LTES)**	**Outdated machinery present in tannery (OMPT)**	**Higher prices of imported processing chemicals for hides or skins (HPIC)**	**SMP Index Value $(\times 10^{22})$**
Permanent Function Value	12432	13128	285634	11934	14380	5.57
Theoretical Best Value	6766	6766	168376	6766	6766	3.83
Theoretical Worst Value	15000	15000	375000	15000	15000	19.62
Difference between permanent function value and best value	5666	6362	117258	5168	7614	-
Difference between permanent function value and worst value	2568	1872	89366	3066	620	-
Rank	3	2	5	4	1	-

From the calculation of permanent function values of the barriers of small and medium scale enterprises (see Table 9),

Table 9

Permanent Function Value for the Barriers of Small and Medium Scale

Barrier of Small and Medium Scale	Permanent Function Value
$Per^{SS}(IAEC)$	223558
$Per^{SS}(UAPP)$	11668
$Per^{SS}(PCNE)$	10759
$Per^{SS}(LGSG)$	11642
$Per^{SS}(ISRR)$	230946

The permanent function values found for the five barriers of the large scale are 12432, 13128, 285634, 11934 and 14380 (see Table 8). Similarly, for the six barriers of small and medium scale permanent function values were found 9210, 223558, 11668, 10759, 11642, and 230946 (see Table 10). The SMP index value is 76.14×10^{20} for the small and medium scales and 55.68×10^{21} as well as for the large scale. A 5×5 matrix is formed for this calculation purpose. For all the permanent function values of best values, a permanent best value and worst value found is 38.28×10^{21} and 19.62×10^{22} respectively which indicates the SMP index for the best and worst values of the barriers of the large-scale enterprises. Alternatively, a 6x6 matrix is formed because of having 6 barriers in the analysis of the small and medium scale. From this analysis, $62.73\times10^{20}$was the SMP index for the best and 31.24×10^{21} for the worst values. The largest index value for the large scale is "lack of training and education about sustainability" which is 285634. If the difference between the permanent function value and best value is lower than the difference between permanent function value and worst value, the lower impact is indicated that means closeness of the barrier to the best value is expressed by this. The higher difference indicates the lower impact. "Less interest in sharing the costs and benefits of adopting environmentally friendly concepts (ISRR)" has the highest index value of 230946 which is closer to the best value. This same difference is found from the other three barriers such- "Lack of interest in investing money for sustainability and economic condition (LIEC)", "Inadequate application of e-ordering and company wise ERP with Intelligent Network System (IAEC), Pressure from community, NGOs and low environment Authority (PCNE)". These barriers have a lower impact because of having the closeness of the permanent function values with the best values rather than the worst values. Alternatively, for the two barriers, "Lack of government support and guidelines to adopt sustainable supply chain methods (LGSG)" and "Unwilling to adopt pollution control and prevention technology (UAPP)" have the lower difference of permanent function values with the worst values with respect to the difference between the permanent function values and best values. This indicates the closeness of these two barriers to the worst values. Since it is difficult to find out the actual impact level for those barriers which have the same or almost same permanent function values. These barriers are treated as identical barriers. For the large scale, no two permanent function values for the barriers are the same. But for the small and medium scale, there are two barriers which have almost the same permanent values of 11642 and 11668. So, for finding the intensity or strength of one over another, it is necessary to calculate the value of similarity coefficient. The value of coefficient of similarity of "Unwilling to adopt pollution control and prevention technology (UAPP)" found was 0.407 and for "Lack of government support & guideline to adopt sustainable supply chain practices (LGSG)" it was 0.746. From the table, one barrier has the highest impact, and another has the lowest impact with the highest rank for the small and medium scale of footwear industries.

Table 10
For small and medium scale

Category	Barriers						
	Lack of interest in investing money for sustainability and economic condition (LIEC)	Inadequate application of e-ordering and company wise ERP with Intelligent Network System (IAEC)	Unwilling to adopt pollution control and prevention technology (UAPP)	Pressure from community, NGOs and low environment Authority (PCNE)	Lack of government support and guideline to adopt sustainable supply chain practices (LGSG)	Less interest in sharing risks and rewards for adopting environment friendly concept (ISRR)	SMP Index Value $(\times 10^{21})$
Permanent Function Value	9210	223558	11668	10759	11642	230946	7.61
Theoretical Best Value	6766	168376	6766	6766	6766	168376	6.27
Theoretical Worst Value	15000	375000	15000	15000	15000	375000	31.24
Difference between permanent function value and best value	2444	55182	4902	3993	4876	62570	-
Difference between permanent function value and worst value	5790	151442	3332	4241	3358	144054	-
Coefficient of similarity	-	-	0.407	-	0.746	-	-
Rank	6	4	2	5	1	3	

6. Conclusion

The major goal of this study was to conduct the analysis in a way that helps to identify the most significant obstacles to the implementation of sustainable manufacturing practices in the large and small and medium-sized footwear industries. The most influential barrier was then identified using GTMA method, coupled with a rating based on their influence. This research also identifies the primary factors that contribute to the hurdles. The top hurdle to the growth of the large-scale footwear business, according to research, is "Higher prices of imported processing chemicals for hides or skins". On the other side, the most significant impediment for the small and medium-sized footwear industry is "Lack of government support and guidelines to adopt sustainable supply chain practices". The secondary obstacles that are linked to this barrier act as the primary factors that impede the achievement of our goals. However, the small and medium-sized footwear sector should give this barrier their top priority. In both situations, the SMP index value falls between the best and worst values on the index, with the best value being closer than the worst. Thus, it was determined that both forms of industry have a significantly higher fitness for this adaptation process pointing to the advantages of removing barriers. The methodology undertaken in this study can be used in other industries such as chemicals, plastics and pharmaceuticals to identify the influence of barriers on the accomplishment of a certain set of objectives. The number of attributes considered could be increased to find the result with relatively more accuracy achieved from complex calculations.

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References

Aktar, Mst. A. (2014). Green Insights of Textile Industry in Bangladesh: A Case Study on Mozart Knitting Ltd. *Global Disclosure of Economics and Business, 3*(1), 93–108. https://doi.org/10.18034/gdeb.v3i1.176

Alzubi, E., & Akkerman, R. (2022). Sustainable supply chain management practices in developing countries: An empirical study of Jordanian manufacturing companies. *Cleaner Production Letters, 2*, 100005. https://doi.org/10.1016/j.clpl.2022.100005

Appolloni, A., Chiappetta Jabbour, C. J., D'Adamo, I., Gastaldi, M., & Settembre-Blundo, D. (2022). Green recovery in the mature manufacturing industry: The role of the green-circular premium and sustainability certification in innovative efforts. *Ecological Economics, 193,* 107311. https://doi.org/10.1016/j.ecolecon.2021.107311

Awasthi, A., Saxena, K., & Arun, V. (2020). Sustainability and survivability in manufacturing sector [Review of Sustainability and survivability in manufacturing sector].

Bangladesh Tannery & Footwear Industry Review. (2022). DATABD.CO. https://databd.co/resources/bangladesh-tannery-footwear-industry-review/

Bhanot, N., Rao, P. V., & Deshmukh, S. G. (2015). Enablers and Barriers of Sustainable Manufacturing: Results from a Survey of Researchers and Industry Professionals. *Procedia CIRP, 29*, 562–567. https://doi.org/10.1016/j.procir.2015.01.036

Chowdhury, N. A., Ali, S. M., Mahtab, Z., Rahman, T., Kabir, G., & Paul, S. K. (2019). A structural model for investigating the driving and dependence power of supply chain risks in the readymade garment industry. [Review of A structural model for investigating the driving and dependence power of supply chain risks in the readymade garment industry.]. *Journal of Retailing and Consumer Services, 51*, 102–113. https://doi.org/10.1016/j.jretconser.2019.05.024

Competition in the footwear industry. (2018). UKEssays.com. https://www.ukessays.com/essays/marketing/competition-in-the-footwear-industry-marketing-essay.php

Despeisse, M., Mbaye, F., Ball, P. D., & Levers, A. (2011). The emergence of sustainable manufacturing practices [Review of The emergence of sustainable manufacturing practices]. *Production Planning & Control, 6*(4).

Dixit, S., Yadav, A., Dwivedi, P. D., & Das, M. (2015). Toxic hazards of leather industry and technologies to combat threat: a review. *Journal of Cleaner Production, 87*, 39–49. https://doi.org/10.1016/j.jclepro.2014.10.017

Dwivedi, A., Moktadir, Md. A., Chiappetta Jabbour, C. J., & de Carvalho, D. E. (2022). Integrating the circular economy and industry 4.0 for sustainable development: Implications fo responsible footwear production in a big data-driven world [Review of Integrating the circular economy and industry 4.0 for sustainable development: Implications fo responsible footwear production in a big data-driven world]. Technological Forecasting and Social Change.

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N. (2015). Analytic Hierarchy Process (AHP) Model for Evaluating Sustainable Manufacturing Practices in Indian Electrical Panel Industries. *Procedia - Social and Behavioral Sciences, 189*, 208–216. https://doi.org/10.1016/j.sbspro.2015.03.216

Heale, M. (2013). Corporate social responsibility in the fashion industry [Review of Corporate social responsibility in the fashion industry].

Jones, M., Gandia, A., John, S., & Bismarck, A. (2020). Leather-like material biofabrication using fungi [Review of Leather-like material biofabrication using fungi]. *Nature Sustainability, 29*(5).

M, Berndtsson, Sinha, E. (2021). Circular economy—A way forward to Sustainable Development: Identifying Conceptual Overlaps and Contingency Factors at the Microlevel. Sustainable Development. https://doi.org/10.1002/sd.2263

Menon, R. R., & Ravi, V. (2021). Analysis of barriers of sustainable supply chain management in electronics industry: An interpretive structural modelling approach. *Cleaner and Responsible Consumption, 3*, 100026. sciencedirect. https://doi.org/10.1016/j.clrc.2021.100026

Muller, D. (2017). How to do better: an exploration of better practices within the footwear industry [Review of How to do better: an exploration of better practices within the footwear industry].

Nam, C., & Lee, Y.-A. (2018). Multilayered Cellulosic Material as a Leather Alternative in the Footwear Industry. *Clothing and Textiles Research Journal, 37*(1), 20–34. https://doi.org/10.1177/0887302x18784214

Nordin, N., Ashari, H., & Rajemi, M. F. (2014). A Case Study of Sustainable Manufacturing Practices [Review of A Case Study of Sustainable Manufacturing Practices]. *Journal of Advanced Management Science, 4*(2).

Polese, F., Ciasullo, M. V., Troisi, O., & Maione, G. (2019). Sustainability in footwear industry: a big data analysis. *Sinergie Italian Journal of Management, 37*(1), 149–170. https://doi.org/10.7433/s108.2019.09

Problems and Prospects of Footwear Industry in Bangladesh - Msrblog. (2022). http://msrblog.com/assign/business/finance/problems-prospects-footwear-industry-bangladesh.html

Program at a Glance. (2022). https://doi.org/10.1109/pecon54459.2022.9988858

Rathinamoorthy, R. (2018). *Consumer's Awareness on Sustainable Fashion, in: Textile Science and Clothing Technology [Review of Consumer's Awareness on Sustainable Fashion, in: Textile Science and Clothing Technology].* Springer Singapore, 1–36.

Sarkis, J., Zhu, Q., & Lai, K. (2011). An organizational theoretic review of green supply chain management literature. *International Journal of Production Economics, 130*(1), 1–15. https://doi.org/10.1016/j.ijpe.2010.11.010

Schifrin, D., Carroll, G., & Brady, D. (2018). Nike: Sustainability and Labor Practices 1998–2013 [Review of Nike: Sustainability and Labor Practices 1998–2013]. Stanford Graduate School of Business.

Siddiqui, E., & Pandey, J. (2019). Assessment of heavy metal pollution in water and surface sediment and evaluation of ecological risks associated with sediment contamination in the Ganga River: a basin-scale study. *Environmental Science and Pollution Research, 26*(11), 10926–10940. https://doi.org/10.1007/s11356-019-04495-6

The Business Post. (2022). Businesspostbd.com. https://businesspostbd.com/trade/bangladesh-steps-into-global-footwear

Velenturf , A. P. M., & Purnell, P. (2021). Principles for a Sustainable Circular Economy [Review of Principles for a Sustainable Circular Economy]. Sustainable Production and Consumption.

Yahoo | Mail, Weather, Search, Politics, News, Finance, Sports & Videos. (2022). Www.yahoo.com. Retrieved March 15, 2024, from https://www.yahoo.com/?err=404&err_url=https%3a%2f%2ffinance.yahoo.com%2fnews%2fglobal-footwear-market-reach-427-115000297.html.

Yoshihisa Nagatomo, Usui, S., Ito, T., Kato, A., Makoto Shimosaka, & Taguchi, G. (2014). Purification, molecular cloning and functional characterization of flavonoidC-glucosyltransferases fromFagopyrum esculentumM. (buckwheat) cotyledon. *Plant Journal, 80*(3), 437–448. https://doi.org/10.1111/tpj.12645

Appendix

Table A.1

Sub-Barriers of the Major Barriers

Barriers	Sub-barriers
Resistance to change and adopt innovation	Resistance in personality
	Selective perception
	Illusion of impotence
	Insecurity and regression
Lack of awareness of local customers in green product	Lack of public interest
	Lack of public acceptance
	Lack of promotion
	Perception that sustainable products are of low quality
Lack of training and education about sustainability	Lack of skilled human resources
	Lack of technical expertise
	Lack of funding
	Non-Learning Culture
	Work-Learning Dichotomy
Outdated machinery present in tannery	Popularity of traditional technologies
	High transaction costs
	High initial investment in latest technology
	Uncertainty about return on investment
Higher prices of imported processing chemicals for hides/skins	Supply disruptions caused by sanctions
	Export restrictions
	Devaluation of Taka against the USD
	High fuel costs

Lack of interest in investing money for sustainability, and economic conditions not as good as developed countries	Organizational norms and culture
	Inbuilt organizational resistance
	Internal bureaucracy
	Lack of common vision and policy framework
Inadequate application of e-ordering, company-wide enterprise resource planning (ERP) and intelligent network system	Lack of technical expertise
	Limited access to market information
	Risk of information loss
	Lack of trust among cross-sector collaborators
	lack of funding
Unwilling to adopt pollution control & prevention technology	Lack of market demand
	Lack of understanding of customers
	Fear of extra workload and loss of flexibility
	Lack of entrepreneurial skills and out of box thinking
Pressure from community, NGOs and environmental authorities is low	Lack of consumer paying capacity
	People are not aware of green products
	Pressure for lower price
	Lack of information about small sized enterprise
Lack of government support & guideline to adopt sustainable supply chain practices	Political instability
	Lack of RE policy
	Corruption, nepotism, & favoritism
	Lack of power asymmetry
Industries are not interested in sharing risks and rewards for adopting environmentally-friendly concepts	Internal bureaucracy
	Negative attitudes towards sustainability concepts
	Lack of functional integration and cooperation
	Lack of top management commitment
	Lack of communication

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