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Interpretive Structural Modeling Based Approach for Sustainable Supplier Evaluation and Selection in Textile Supply Chains

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Abstract- Today, developing countries are realizing the need for sustainability because of environmental degradation, natural resources depletion and climate issues. In addition, Social organizations are raising their voices against social and environmental issues. Therefore, manufacturing organizations are facing more pressure from the government bodies and customers to carry out production that meets the sustainability. This study purposes a structured and integrated decision model for the evaluation and selection of sustainable suppliers in the context of the textile industry by using Interpretive Structural Modeling (ISM). ISM is used to identify the importance of the factors which are selected through literature review and verified by the team of experts in textile sector of Pakistan and to identify the driving and dependence power of each selection criteria.

Keywords- *Sustainable Supply Chain, Supplier Evaluation, Supplier Selection, Interpretive Structural Modeling*

I. Introduction

Sustainability can be defined as the development that fulfils current needs by caring for the needs of future generations and many other views found regarding three dimensions of sustainability that are economic, environmental and social. In this regard, supply chain management is the activity of material and information streams with the assistance of the organization to achieve the sustainability dimensions [1]. The definition of SSCM (sustainable chain management) can be written as an integration of all three dimensions economic, environmental and social measure in the global chain that provides you green product, accurate information and top services [2]. The supplier selection process is one of the key tasks in sustainable supply chain management [3]. According to Sardar, et al. [4], companies can only make success in the global market when they make supplier decision appropriately, on which there is a high emphasis for a long time. As most of the companies are only assembling the parts to deliver the finished product that means they are totally dependent upon their suppliers, hence the purchase decision has become more important, direct and indirect decision for supplier selection is more serious [5].

Keeping in view the need and importance of sustainability in manufacturing operations, this research work is concerned with the sustainable supplier evaluation and selection within the textile supply chain. The supply chain practices of the Pakistani companies are observed and identified key sustainable practices for the evaluation of sustainable suppliers. The aim of this research is to find out the sustainable supply chain practices within the textile sector of Pakistan for the supplier evaluation and selection processes. The textile sector of Pakistan is the backbone of the country economy and to improve sustainable performance it is necessary to evaluate suppliers based on sustainability pillars [6]. For this purpose, the ISM based technique is proposed to identify important supplier selection factors and evaluate the driving and dependence power of each factor.

II. Literature Review

A. Sustainable Supplier Evaluation and Selection

Today with the increased awareness of sustainability, the sustainable supplier selection is an integral part of the strategic decision. Supplier evaluation is a process of making an assessment of the company suppliers based on certain features like quality of products, product price, reliability, and others. For a company, it can be used to evaluate new suppliers for new orders and purchases or it can also be implemented to the existing suppliers and there measure their effectiveness and performance. The evaluation can take the form of conducting interviews and surveys [7]. The selection of an appropriate supplier based on sustainability criteria (ecological, economic, and social) is the only way to move towards sustainable supply chain development [8].

B. Factors Affecting Sustainable Supplier Selection and Evaluation

There are several factors which can be considered in the supplier evaluation and selection process like the price of the product, quality, lead time and transportation cost etc. In the concept of sustainable supply chain management, the factors affecting supplier evaluation and selection process change accordingly.

In this research, thirty factors related to environmental, economic, and social perspective are considered and then analyzed depending upon their respective impacts on the sustainable supplier evaluation and selection process and resulting into few major factors that can help the companies in the evaluation phase and then in the selection process of their suppliers based on core concept of sustainability. The summary of environmental, economic, and social factors considered in this study are explained in Table 1.

TABLE I. FACTORS AFFECTING SUSTAINABLE SUPPLIER SELECTION AND EVALUATION

S#	Sustainability factors	Factors affecting Sustainable supplier Evaluation and selection
1	ENVIRONMENTAL (ENV)	Environment management systems (EM)
2		Green design and purchasing (GDP)
3		Green manufacturing (GM)
4		Green management (GRM)
5		Green packing and labelling (GL)
6		Waste management (WM)
7		Pollution prevention
8		Environmental competencies (ENC)
9		Green R & D and Innovation (GRD)
10		Reuse and recycle
11	ECONOMIC (ECO)	Price of the product (PP)
12		Profit on product (PR)
13		Quality of product (QP)
14		Flexibility (FL)
15		Technological & financial capability (TC)
16		Delivery and Service of product (DP)
17		Lead time required (LR)
18		Transportation cost (TRC)
19		Rejection ratio (RR)
20		Reverse logistics (RL)
21	SOCIAL (SOC)	Occupational health & safety systems (OS)
22		The interests & rights of employees (IE)
23		The rights of stakeholders (RS)
24		Information Disclosure (IS)
25		Quality education & training
26		Annual number of accidents
27		Donations for sustainable projects
28		Safety practices
29		Ethics, Gender discrimination
30		Child labour

III. INTERPRETIVE STRUCTURAL MODELLING (ISM)

The following steps are used to analyze the factors affecting sustainable supplier section decision in the textile supply chain of Pakistan.

Step 1: Structural Self-Interaction Matrix (SSIM): ISM methodology suggests the use of the skilful ideas based on various management techniques such as brainstorming, nominal group technique, etc. in developing the contextual relationship among the variable [9]. For this purpose, experts from the industry and academic circles should be consulted in finding the nature of the contextual relationship among the factors. These experts from the industry and academic circles should be familiar with the problem under consideration. For examining the factors, a contextual relationship of 'leads to' or 'effects' type must be chosen. This means that one factor affects another factor. Based on this, the contextual relationship between the identified factors is developed. Keeping in mind the contextual relationship for each factor and the existence of a connection between any two factors (i and j), the associated direction of the relationship is quizzed. The following four symbols are used to denote the direction of the relationship between two factors (i and j):

- V for the relation from factor i to factor j (i.e., factor i will affected by factor j)
- A for the relation from factor j to factor i (i.e., factor i will be affected by factor j)
- X for both direction relations (i.e., factors i and j will influence each other)
- For no relation between the factors (i.e., barriers i and j are dissimilar).

Based on the relative relationships, the SSIM is developed. To obtain consent, the SSIM should be further discussed by a group of specialists. Based on their responses, SSIM must be finalized.

Step 2: Reachability Matrix: The next step in ISM approach is to develop an initial reachability matrix from SSIM. For this, SSIM is converted into the initial reachability matrix by substituting the four symbols (i.e., V, A, X or O) of SSIM by 1s or 0s in the initial reachability matrix. The rules for this substitution are as follows:

- If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the matrix becomes 1 and the (j, i) entry also becomes 1.
- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, the initial reachability matrix is prepared. 1* entries are included to include transitivity to fill the gap, if any, in the opinion collected during development of structural self-instructional matrix. After including the transitivity concept as described above, the final reachability matrix is obtained.

Step 3: Level Partitions: From the final reachability matrix, for each factor, reachability set, and antecedent sets are derived. The reachability set consists of the factor itself and the other factor that it may affect, whereas the antecedent set consists of the factor itself and the other factor that may affect it. Thereafter, the intersection of these sets is derived for all the factors and levels of a different factor are determined. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level factors are those factors that will not lead the other factors above their own level in the hierarchy. Once the top-level factor is known, it is removed from attention. Then, the same process is repeated to find out the factors at the next level. This process is continued until the level of each factor is found. These levels help in creating the digraph and the ISM model.

Step 4: Classification of Barrier: Conical matrix is developed by gathering factors in the same level across the rows and columns of the final reachability matrix. The drive power of a factor is derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in the columns [10]. Next, drive power and dependence power ranks are calculated by giving the highest ranks to the factors that have the maximum number of ones in the rows and columns, respectively.

Step 5: Digraph: From the conical form of the reachability matrix, the preliminary digraph including transitive links is obtained. It is generated by nodes and lines of edges [10]. After removing the indirect links, a final digraph is developed. A digraph is used to represent the elements and their interdependencies in terms of nodes and edges or in other words digraph is the visual depiction of the elements and their interdependence [11]. In this development, the top-level factor is positioned at the top of the digraph and second level factor is placed at the second position and so on until the bottom level is placed at the lowest position in the digraph.

Step 6: ISM Model: Digraph is transformed into an ISM model by substituting nodes of the factors with statements.

IV. Result Analysis and Discussion

The interpretive structural modelling is the corporative learning process. In this method, a set of directly and indirectly related elements are arranged into compressive modelling. On the behalf of these relations factors ranking is estimated to identify driving and dependence power of the factors. In order to do so following steps are conducted.

A. Development Of Self Interaction Matrix

The most effective factors influencing sustainable supplier evaluation and selection are identified by reviewing the literature available. Thirty factors are identified from the literature survey. All these factors further analyzed by conducting the survey from experts of the textile sector in Pakistan. Experts opinion suggested fourteen factors which have a direct relationship with the selection of suppliers. The self-interaction matrix is developed as shown in Table II.

B. Development of Reachability Matrix

The second step in the ISM approach is to develop an initial reachability matrix from Self Interaction Matrix which is developed by the team of experts. The initial reachability matrix is shown in Table III.

C. Final Reachability Matrix

The final reachability matrix shows the driving and dependence power of each factor (see Table IV). The driving power of each factor is the total number of factors (including it) which it affects i.e. the sum of the interaction in the row. The dependence power of each factor is the total number of factors (including it) which is affected i.e. the sum of the interaction in the column.

TABLE II. Self Interaction Matrix

Elements	Factors	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	Quality of Product	O	A	O	A	V	A	A	A	A	A	V	O	V	
2	Price of product	A	A	A	A	V	A	O	A	A	O	V	O		
3	Flexibility	A	A	A	A	V	A	O	A	A	A	V			
4	Lead time	O	O	A	O	V	A	A	A	A	A				
5	Transportation Cost	A	A	A	A	V	A	O	O	O					
6	Green Management	A	A	A	O	V	O	O	O						
7	Green Manufacturing	V	V	V	V	V	V	O							
8	Green Research, Development & Innovation	O	A	A	A	V	O								
9	Green Packaging	V	O	V	A	V									
10	Pollution Prevention	A	O	O	O										
11	Occupational Health & Safety	V	V	V											
12	The Interest & Rights of Employees	O	V												
13	Quality Education & Training	A													
14	Child Labour														

TABLE III. INITIAL REACHABILITY MATRIX

	Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Quality of Product	1	1	0	1	0	0	0	0	0	1	0	0	0	0
2	Price of product	0	1	0	1	0	0	0	0	0	1	0	0	0	0
3	Flexibility	0	0	1	1	0	0	0	0	0	1	0	0	0	0
4	Lead time	0	0	0	1	0	0	0	0	0	1	0	0	0	0
5	Transportation Cost	1	0	1	1	1	0	0	0	0	1	0	0	0	0
6	Green Management	1	1	1	1	0	1	0	0	0	1	0	0	0	0
7	Green Manufacturing	1	1	1	1	0	0	1	0	1	1	1	1	1	1
8	Green Research, Development & Innovation	1	0	0	1	0	0	0	1	0	1	0	0	0	0
9	Green Packaging	1	1	1	1	1	0	0	0	1	1	0	1	0	1
10	Pollution Prevention	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11	Occupational Health & Safety	1	1	1	0	1	0	0	1	1	0	1	1	1	1
12	The Interest & Rights of Employees	0	1	1	1	1	1	0	1	0	0	0	1	1	0
13	Quality Education & Training	1	1	1	0	1	1	0	1	0	0	0	0	1	0
14	Child Labor	0	1	1	0	1	1	0	0	0	1	0	0	1	1

TABLE IV. FINAL REACHABILITY MATRIX

Factors		1	2	3	4	5	6	7	8	9	10	11	12	13	14	**Driving Power**
1	Quality of Product	1	1	0	1	0	0	0	0	0	1	0	0	0	0	**4**
2	Price of product	0	1	0	1	0	0	0	0	0	1	0	0	0	0	**3**
3	Flexibility	0	0	1	1	0	0	0	0	0	1	0	0	0	0	**3**
4	Lead time	0	0	0	1	0	0	0	0	0	1	0	0	0	0	**2**
5	Transportation Cost	1	0	1	1	1	0	0	0	0	1	0	0	0	0	**5**
6	Green Management	1	1	1	1	0	1	0	0	0	1	0	0	0	0	**6**
7	Green Manufacturing	1	1	1	1	0	0	1	0	1	1	1	1	1	1	**11**
8	Green Research, Development & Innovation	1	0	0	1	0	0	0	1	0	1	0	0	0	0	**4**
9	Green Packaging	1	1	1	1	1	0	0	0	1	1	0	1	0	1	**9**
10	Pollution Prevention	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
11	Occupational Health & Safety	1	1	1	0	1	0	0	1	1	0	1	1	1	1	**10**
12	The Interest & Rights of Employees	0	1	1	1	1	1	0	1	0	0	0	1	1	0	**8**
13	Quality Education & Training	1	1	1	0	1	1	0	1	0	0	0	0	1	0	**7**
14	Child Labor	0	1	1	0	1	1	0	0	0	1	0	0	1	1	**7**
	Dependence Power	**8**	**9**	**9**	**10**	**6**	**4**	**1**	**4**	**3**	**11**	**2**	**4**	**5**	**4**	

D. Level Partitioning

The final reachability matrix provides the antecedent and reachability set and those factors which have the same reachability and intersection sets are assigned levels and the iteration is completed and in such a way the process will go on until each factor are assigned a level. The details of iterations involved in level partitioning are shown Table V to Table XIV.

TABLE V. IDENTIFICATION OF FACTOR LEVEL (ITERATION 1)

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
Quality of Product	1,2,4,10	1,5,6,7,8,9,11,13		
Price of Product	2,4,10	2,6,7,9,11,12, 14		
Flexibility	3,4,10	3,6,7,9,11,12, 13,14		
Lead time	4,10	1,2,3,4,5,6,7,8,9,12		
Transportation Cost	1,3,4,5,10	5,9,11,12,13, 14		
Green Management	1,2,3,4,6,10	6,12,13,14		
Green Manufacturing	1,2,3,4,7,9,10,11,12,13,14	7		
Green Research & Development & Innovation	1,4,8,10	8,11,12,13		
Green Packaging	1,2,3,4,5,9,10,12,14	7,9,11		
Pollution Prevention	10	1,2,3,4,5,6,7,8,9,10,14	**10**	**I**
Occupational Health & Safety	1,2,3,5,8,9,11,12,13,14	7,11		
The Interest & Rights of Employees	2,3,4,5,6,8,12,13	7,9,11,12		
Quality Education & Training	1,2,3,5,6,8,13	7,11,12,13,14		
Child Labor	2,3,5,6,10,13,14	7,9,11,14		

TABLE VI. IDENTIFICATION OF FACTOR LEVEL (ITERATION 2)

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
Quality of Product	1,2,4	1,5,6,7,8,9,11,13		
Price of Product	2,4	2,6,7,9,11,12, 14		
Flexibility	3,4	3,6,7,9,11,12,13,14		
Lead time	4	1,2,3,4,5,6,7,8,9,12	**4**	**II**
Transportation Cost	1,3,4,5	5,9,11,12,13, 14		
Green Management	1,2,3,4,6	6,12,13,14		
Green Manufacturing	1,2,3,4,7,9,11,12,13,14	7		
Green Research, Development & Innovation	1,4,8	8,11,12,13		
Green Packaging	1,2,3,4,5,9,12,14	7,9,11		
Occupational Health & Safety	1,2,3,5,8,9,11,12,13,14	7,11		
The Interest & Rights of Employees	2,3,4,5,6,8,12,13	7,9,11,12		
Quality Education & Training	1,2,3,5,6,8,13	7,11,12,13,14		
Child Labor	2,3,5,6,13,14	7,9,11,14		

TABLE VII. IDENTIFICATION OF FACTOR LEVEL (ITERATION 3)

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
Quality of Product	1,2	1,5,6,7,8,9,11,13		
Price of Product	2	2,6,7,9,11,12,14	**2**	**III**
Flexibility	3	3,6,7,9,11,12, 13,14	**3**	**III**
Transportation Cost	1,3,5	5,9,11,12,13, 14		
Green Management	1,2,3,6	6,12,13,14		
Green Manufacturing	1,2,3,7,9,11,12,13,14	7		
Green Research, Development & Innovation	1,8	8,11,12,13		
Green Packaging	1,2,3,5,9,12,14	7,9,11		
Occupational Health & Safety	1,2,3,5,8,9,11,12,13,14	7,11		
The Interest & Rights of Employees	2,3,5,6,8,12,13	7,9,11,12		
Quality Education & Training	1,2,3,5,6,8,13	7,11,12,13,14		
Child Labor	2,3,5,6,13,14	7,9,11,14		

TABLE VIII. IDENTIFICATION OF FACTOR LEVEL (ITERATION 4)

Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
Quality of Product	1	1,5,6,7,8,9,11,13	**1**	**IV**
Transportation Cost	1,3,5	5,9,11,12,13, 14		
Green Management	1,6	6,12,13,14		
Green Manufacturing	1,7,911,12,13,14	7		
Green Research, Development & Innovation	1,8	8,11,12,13		
Green Packaging	1,5,9,12,14	7,9,11		
Occupational Health & Safety	1,5,8,9,11,12,13,14	7,11		
The Interest & Rights of Employees	5,6,8,12,13	7,9,11,12		
Quality Education & Training	1,5,6,8,13	7,11,12,13,14		
Child Labor	5,6,10,13,14	7,9,11,14		

TABLE IX. IDENTIFICATION OF FACTOR LEVEL (ITERATION 5)

	Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
5	Transportation Cost	5	5,9,11,12,13, 14	**5**	**V**
6	Green Management	6	6,12,13,14	**6**	**V**
7	Green Manufacturing	7,911,12,13,14	7		
8	Green Research, Development & Innovation	8	8,11,12,13	**8**	**V**
9	Green Packaging	5,9,12,14	7,9,11		
11	Occupational Health & Safety	5,8,9,11,12,13,14	7,11		
12	The Interest & Rights of Employees	5,6,8,12,13	7,9,11,12		
13	Quality Education & Training	5,6,8,13	7,11,12,13,14		
14	Child Labor	5,6,10,13,14	7,9,11,14		

TABLE X. IDENTIFICATION OF FACTOR LEVEL (ITERATION 6)

	Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
7	Green Manufacturing	7,9,11,12,13,14	7		
9	Green Packaging	9,12,14	7,9,11		
11	Occupational Health & Safety	9,11,12,13,14	7,11		
12	The Interest & Rights of Employees	12,13	7,9,11,12		
13	Quality Education & Training	13	7,11,12,13,14	**13**	**VI**
14	Child Labor	13,14	7,9,11,14		

TABLE XI. IDENTIFICATION OF FACTOR LEVEL (ITERATION 7)

Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
Green Manufacturing	7,9,11	7		
Green Packaging	9	7,9,11		
Occupational Health & Safety	9,11	7,11		
The Interest & Rights of Employees	12	7,9,11,12	**12**	**VII**
Child Labor	14	7,9,11,14	**14**	**VII**

TABLE XII. IDENTIFICATION OF FACTOR LEVEL (ITERATION 8)

Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
Green Manufacturing	7,9,11	7		
Green Packaging	9	7,9,11	**9**	**VIII**
Occupational Health & Safety	9,11	7,11		

TABLE XIII. IDENTIFICATION OF FACTOR LEVEL (ITERATION 9)

Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
Green Manufacturing	7,11	7		
Occupational Health & Safety	11	7,11	**11**	**IX**

TABLE XIV. IDENTIFICATION OF FACTOR LEVEL (ITERATION 10)

Factors	Reachability Set	Antecedent Set	Intersection Set	Levels
Green Manufacturing	7	7	**7**	**X**

E. ISM model sustainable supplier evaluation criteria

After level partitioning analysis, the ISM model is developed which shows the level of all factors considered for evaluating sustainable suppliers. The digraph is shown in Figure 1.

From above analysis and ISM model, it is clear that green manufacturing is a key factor in sustainable supplier evaluation and selection decision. Green manufacturing drives all the other factors considered in this study. It is not possible for any organization to provide a safe and secure atmosphere to the society without doing green manufacturing, because by having green knowledge the textile industries are able to produce the products those who has less waste and can be recycled. After green manufacturing, the second most important driving factor is green packaging and labelling. It is found from research that, poor labelling and packaging leads to wastage/spoilage of products. Hence green packaging which sometimes includes green distribution is also an important factor to be considered in sustainable supplier selection decision.

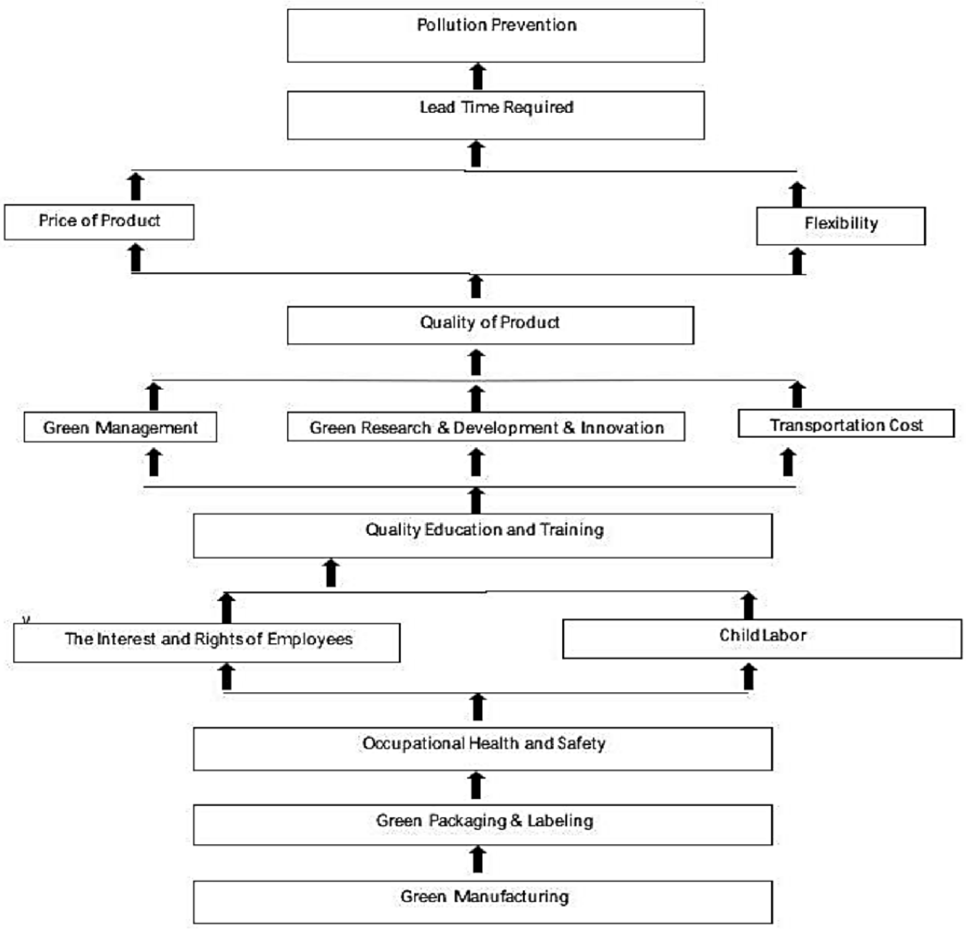

Figure 1. ISM Model

The ISM model shows that child labour and employee rights are at the same level of importance and both factors are related to the social perspective of sustainable supply chain management. Similarly, the other important factors, such as education and training, green management, green R&D, transportation, product quality, product price, lead time, and finally, pollution prevention techniques are the important criteria for sustainable supplier selection decision. The ISM model shows that the ultimate aim of sustainable supplier selection is not only to minimize total embodied carbon footprints but social perspective should also be considered.

V. Conclusion and Future Suggestions

Sustainable Supplier Evaluation & Selection is a strategic decision that significantly influences an organization's competitive advantage. Recognizing the essence of such critical decisions, the research is conducted in order to identify those factors which are most important to the companies in the supplier evaluation and selection process based on the core concept of sustainability, as knowing the level of environmental, social and economic impact and viability of your supplier is becoming increasingly common as all the industries move towards a more sustainable future. In this research, a decision model is developed by using Interpretive Structure Modeling (ISM) to assist the supply chain managers or purchasing managers of the textile industries in the sustainable supplier evaluation and selection process. The thirty most important factors are extracted from the literature available on the sustainable supply chain management which is then verified by the group of experts in the textile sector of Pakistan. The Interpretive Structure Modeling (ISM) is used to identify the ranking of each factor in the textile sector of Pakistan and to identify the driving dependence power of each factor. The ISM shows the relationship of each factor and clearly define which factor is driving others. Considering these derived factors the textile industries may select suitable suppliers by prioritizing their needs and sustainable development goals.

In this research only fourteen factors related to textile industries are analyzed, therefore in future, this study can be a guide to implement in another type of industries by little modification factors. Also, in this research, the relationship model among the identified barriers has not been statistically validated. Structural equation modelling (SEM) has the capability of testing the validity of such hypothetical models. Hence, it has been recommended that future research may be targeted to develop the initial model through ISM and then testing it using SEM.

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