November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

Developing Sustainability Performance Indicators (SPI) for the Textile Industry

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Abstract:
Sustainable development and manufacturing are a key area of emphasis across the globe in the present day. Accordingly, there is considerable attention to sustainability reporting. The textile industry has been recognized as a consumer of natural and chemical materials, and also as a significant source of various pollutants. However, there is a lack of indicators to measure sustainability performance in this industry. This paper proposes a set of Sustainable Performance Indicators (SPIs) for evaluating the sustainable environmental practices of textile firms. The Analytical Hierarchy Process (AHP) method is applied to prioritize the SPIs. It is anticipated that the proposed SPIs will enables the textile industry to achieve greater performance in sustainable manufacturing and waste management.

Keywords: *sustainability; performance indicators; textile industry; SPIs; India.*

I. INTRODUCTION

The role of sustainable development and social responsibility in accomplishing state reforms, executing strategic projects associated with the state, enhancing the climate for investment, and stimulating enduring economic growth in developing countries is acknowledged (Orazalin, Mahmood, &Narbaev, 2019; World Bank, 2006). Sustainable development has been described as "*development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs*" ("Our Common Future," WCED, 1987, p. 8). In other words, the term Sustainable development, from a macroeconomic viewpoint, pertains to the judicial usage of resources to achieve present targets with the far-reaching objective of enabling subsequent generations to profit from and fulfill their needs using the resources preserved and augmented in this manner. The objective of sustainable development thus appears to be to achieve a state of affairs where the activities of humans display a deliberate attempt to maintain natural resources so as to ensure that these resources are available to future generations in a matter comparable to, if not better than, the present. On the other hand, sustainable development from a microeconomic viewpoint, implies that three principal components are contained in organizational sustainability namely, society, economic performance, and the environment. This viewpoint is comparable with Elkington's (1998, 2004) notion of the triple bottom line (TBL) which proposes that there must be equilibrium between all three elements

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

(economic, societal, and environmental performance). Moreover, organizations are required to simultaneously consider them in their activities related to social responsibility (Hallikas, Lintukangas, &Grudinschi, 2019).

Increasingly, different groups of stakeholders are requesting enhanced transparency and methodical reporting of non-financial indicators of business performance due to a growing number of corporate scandals, and global economic and environmental crises (Hąbek, 2014). Consequently, business firms in the present day exhibit their loyalty to sustainability development and performance in response to growing consciousness and sensitivity of the general public concerning financial, societal, and environmental issues (Ehnert, Parsa, Roper, Wagner, & Muller-Camen, 2016). Company stakeholders are informed about the company's financial, societal, and environmental performance by the company to satisfy society's requirements and expectations of the company and also to validate their business operations and activities (de Villiers, Low, &Samkin, 2014; Dissanayake, Tilt, &Xydias-Lobo, 2016). From this perspective, initiatives and reporting related to sustainability help business organizations meet the interests of all stakeholders who desire to improve their investment choices and make balanced decisions. Sustainability disclosures with greater levels of application are provided by businesses to improve transparency, enhance their brand name and value, decrease irregularity of information, inspire employees and managers, and finally gain an edge over their competition (Kiliç, Kuzey, &Uyar, 2015). Further, a substantial contribution is provided by sustainability reporting on financial, environmental, and societal performance to stability, ongoing growth, and advancement of a firm (Lozano &Huising, 2011).

Accordingly, there has been a considerable increase in the number of organizations that publish disclosures of their sustainability performance (Diouf&Boiral, 2017). In the United States, it has been reported by the Governance and Accountability (G&A) Institute that the number of organizations reporting sustainability has grown from 20% in 2011 to 85% in 2017 in the S&P 500 Index® (G&A Institute, 2018). Globally, indicators provided by the Global Reporting Initiative (GRI) are utilized by 63% of N100 (i.e., top 100 companies by revenue) and 75% of G250 (i.e., 250 largest companies according to the Fortune 500, again by revenue) organizations (KPMG, 2017). It appears thus, that sustainability reporting has become a common practice with increased standardization due to the usage of standard indicators (Chen &Bouvain, 2014; KPMG, 2017).

The textile industry has end-to-end responsibility to transform natural and chemical fibers to goods suitable for users such as, garments and household goods. As one of the oldest industries in existence and moreover to deal with different environmental challenges, the textile industry has a considerable responsibility with regard to maintaining sustainability. This is particularly so because of its impact to the environment due to the manufacturing process that entails various operations such as, pre-treatment, dyeing, printing, and finishing. Further, the process of fabrication involves the utilization of a significant quantity of water and power and also generates a considerable amount of waste. Moreover, the industry utilizes chemicals and dyes which results in the generation and disposal of huge amounts of effluents unusable by any other operations. This aspect also has the capacity to bring about environmental problems is not efficiently treated (Madhav, Ahamad, Singh & Mishra, 2018). The call of the United Nations Environment Programme (UNEP) for cleaner production is therefore especially applicable to the textile industry. Cleaner production implies "*the continuous application of an integrated preventive environmental strategy to processes, products,* *and services, to increase overall efficiency, and reduce risks to humans and the environment*" (UNEP, 2006, p. 3).

However, an examination of the sustainability reporting of textile industries revealed that there are no sustainability performance indicators specific to the industry and consequently, the present study is an attempt to determine appropriate indicators for the textile industry.

The researcher performed a scrutiny of sustainability reports of leading textile manufacturers across the globe in an attempt to determine indicators commonly used by them. This paper thus proposes a set of Sustainability Performance Indicators (SPIs) which can be utilized to evaluate the extent of sustainable practices in a textile manufacturer. The SPIs are then used to develop an evaluation model of sustainable practices. The Analytical Hierarchy Process (AHP) methodology is utilized for weighting the SPIs. It is believed that the proposed SPIs and the resulting assessment model would enable and assist the textile industry to fine-tune and maintain their sustainable practices.

It must be noted that the scope of the study is limited to environmental parameters. Further, this present study is part of an on-going research project in Environmental Engineering that was undertaken with the objective of developing SPIs for the textile industry.

II. METHODOLOGY

The methodology for the study contains three principal stages comprised of six steps. The first stage involves the identification of factors that affect waste management from a thorough scrutiny of sustainability reports of the world's leading textile manufacturers. This was followed by the second stage wherein the Analytical Hierarchy Process (AHP) was utilized to create a mathematical model to develop the SPIs for the textile industry. Thirdly, SPIs were developed with respect to waste management in the textile industry. The details are presented in the following sections.

Table 1 summarizes the steps undertaken as part of the methodology.

Table 1: Methodology of the Study

Step #	Activity	Stage
1	Selection of textile firms for the study of sustainability parameters	1
2	Tabulation and Subject Matter Study of the reported parameters	
3	The mathematical tool for developing the model using Analytical Hierarchy Process (AHP)	2
4	Application of the AHP process and development of the model	
5	Consistency check and global priorities	3
6	Finalization of the Sustainability Performance Indicators	

III. DEVELOPMENT OF SPIS FOR THE TEXTILE INDUSTRY& RESULTS

Step 1: Selection of textile firms for the study of sustainability parameters

Similar to other industries across the globe, firms in the textile industry have been including environmental sustainability reporting in their annual sustainability or company reports. A predominant trend in the textile industry is for firms in developed nations to move the manufacturing activities to developing nations primarily in the East (Eryuruk, 2012). Nevertheless, to ensure that the developed SPIs are applicable to both large- and small-scale textile/apparel manufacturers and retailers, firms were selected from across the globe.

The list of textile companies for this study was collated from the 2016 list of world's top textile companies by Value.Today, the Forbes 2016 list of world's largest textile and apparel companies, and the Top clothing companies in the world by Ranker. These 3 sources were picked randomly with the objective of identifying prospective textile firms for the present study. A list of 300 textile companies was finally chosen for the study. Subsequently, the websites of the identified textile firms were scrutinized to identify firms that had sustainability reports, advanced policies for environment sustainability, green initiatives (e.g., generation and usage of renewable energy), measures for water conservation and reduction in waste to landfill, to name a few (Caniato, Caridi, Crippa, &Moretto, 2012). Global companies that report environmental sustainability outcomes elaborately in great detail were selected for the study so that the goal of developing SPIs for the textile industry is accurate, feasible, realistic, and also robust and inclusive (Burman, 2015). It could be seen that the difference between sustainability efforts and sustainability outcomes was unclear and the reports often had comprehensive narratives while reporting of metrics was limited (D'Aquila, 2018). Moreover, only a small percentage of the firms reported sustainability metrics with precise outcomes. In fact, SASB reported this to be only 24% for the year 2017 (Sustainability Accounting Standards Board (SASB), 2017).

Consequently, at this stage, only firms that were reporting on environmental metrics were considered in the compilation of data (Eryuruk, 2012). Moreover, firms that had no annual or sustainability reports (or business responsibility reports) were excluded. Firms that reported regularly every year were included and annual sustainability reports for three years (2015-2017) were collected and scrutinized. At the end of the process, 80 firms were shortlisted from the original list of 300. Microsoft Excel was the tool utilized to manage the lists.

Step 2: Tabulation and Subject Matter Study of the reported parameters

The objective of this step was to record the set of parameters and their corresponding values / results as reported by the firms shortlisted from Step 1 and understand them. It could be seen that the sustainability reports of the different firm were unique and differed from each other and also differed across years with regard to the narratives and areas of focus. Moreover, the reports had both qualitative and quantitative data. Another discrepancy observed was in the number of parameters reported with some firms reporting as many as 90 parameters whereas others reported only 15-20. At the end of the process, 99 unique parameters with specific metrics could be identified (Table 2).

Table 2: Sustainability parameters for the textile industry

Category	Indicators
Consumer Cycle	Circular Design - Packaging
	End Of Life
	Water Efficiency Improvement In The Consumer Cycle
	Maintenance Services Of The Product
	Circular Design - Product
	Energy Efficiency Improvement In The Consumer Cycle
	Enhance Usage Of The Product
	Micro Fiber Emission
Energy	Clean Energy Development

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

Category	Indicators
	Renewable Energy Utilization
	Generation Of Solar Energy
	Technology Upgrade For Energy Efficiency
	Total Energy Utilization
	Decrease In Energy Utilized
	Improvement In Clean Energy Development
	Specific Energy Utilization
	Improvement In Solar Energy Generation
	Decrease In Specific Energy Utilization
	Improvement In Renewable Energy Utilization
Green House Gases	Total Emissions CO2e
	Direct Emissions
	Indirect Emissions
	Upstream Emissions
	Downstream Emissions
	NOx
	SOx
	Particulate Matter
	Air Emissions
	Ozone Depleting Substances
	Decrease In Total Emissions
	Decrease In Direct Emissions
	Decrease In Indirect Emissions
	Decrease In Scope 3 Emissions
	Specific Emission
	Decrease in NOx
	Decrease in SOx
	Decrease In Specific Emissions
	Decrease In Particulate Matter
	Decrease In Ozone Depleting Substances
	Carbon Neutrality
Institutional	Awareness Creation
	Sustainability Development Goals
	Sustainability Communications
	Integrated Certifications & Memberships
	Interactions With Stakeholders
	Tie Up With Research Institutes
Raw Materials	Eco Friendly Packaging Materials
	Reuse Of Packaging Materials
	Packaging Materials
	Efficiency Of Raw Materials
	Recycled Raw Materials
	Recycled Packaging Materials

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

Category	Indicators
	Sustainable Raw Materials
	Increase In Efficiency Of Raw Materials Utilization
	Increase In Eco-Friendly Packaging Utilization
	Increase In Recycled Packaging Materials Utilization
	Increase In Reuse Of Packaging Materials
	Increase In Sustainable Raw Materials Utilization
	Increase In Recycled Raw Materials Utilization
	Decrease In Packaging Materials Utilization
	Traceability Of Materials
Sustainability Abled Processes	Local Partners Development
	Voluntary Environmental Activities
	Green Methods Adaption Across The Business
	Prohibition Of Unhealthy Practitioners / Products
	Uplift Green Businesses
	Support Responsible Partners
	Track Environmental Sustainability Expenses
	Materiality Matrix
	Life Cycle Analysis
Waste	Recycled
	Total Generated
	Paper Utilized
	Non-Hazardous Type
	Hazardous Type
	Landfill
	Decrease In Waste Generated Over Baseline/ Last Year
	Decrease In Hazardous Waste Generated Over Baseline / Last Year
	Waste Recycle Efficiency
	Decrease In Non-Hazardous Waste Generated Over Baseline / Last Year
	Decrease In Specific Waste
	Specific Waste Generated
	Circular Business
	Zero Waste Center
Water	Recycled
	Total Utilization
	Source Management
	Vendor Compliance
	Outlet Quality
	Hazardous Chemicals
	Volume Treated
	Improvement In Water Utilization
	Improvement In Outlet Quality
	Specific Water Utilization
	Specific Outlet Quality

Category	Indicators
	Improvement In Specific Water Utilization
	Improvement In Specific Outlet Quality
	Zero Liquid Discharge
	Water Neutrality

Step 3: Developing a mathematical model using Analytical Hierarchy Process (AHP)

The objective of this step was to develop a mathematical model using the statistical tool, AHP. AHP is a technique to offer solutions concerning the development and use of a multi-criteria evaluation system (Cabala, 2010). AHP can be outlined as a method of ordering a collection so as to extensively evaluate it followed by prioritization of alternatives. This process is essentially a model of assessment using quantitative and/or qualitative data (Saaty, 2008). The process of prioritization of alternatives is achieved in two stages using AHP. In the first stage, the formulation of the hierarchy construction and organization takes place. In other words, the grouping of the components of the system takes place and these are then grouped into a hierarchy.

In the second stage, all the components are weighed and gauged individually and the reliability of the weightages is scrutinized. After the hierarchy explained in the first stage is finalized, the assessment at the second stage is performed by comparing and matching all groups of parameters at a certain level from the perspective of each component with a higher priority in the formulated hierarchy structure. The outcome from this activity is a cluster of matrices, one for each comparison group. These matrices are established as the basis for the final priority and global priority ratings after normalization and consistency checking (Cheng & Li, 2001).

Step 4: Application of AHP and development of the model

AHP was utilized in the following manner by the present study:

1. Formulate the decision hierarchy structure
2. List of Alternatives
3. Determination of Ratings for the Criteria and Sub Criteria
4. Pairwise comparisons
5. Determination of Priorities
6. Calculation of the Eigen vector

1. Formulate the decision hierarchy structure

The first step in AHP is the preparation of a decision hierarchy which contains the objective, criteria, and sub-criteria (level 1 to level 3). The topmost level of the hierarchy describes the activity's overall objective. That is, "To determine the SPI for the textile industry." Level 2 contains the decision criteria to be taken into account.

All the short-listed 99 parameters were grouped into heads based on the wider aspect addressed by them. All parameters reported were associated with water (e.g., volume of water utilized, volume of water recycled, chemical oxygen demand in water, water neutrality %) were classified under the criteria 'water.' In a similar manner, all parameters associated with waste (e.g., total volume of waste generated, volume of hazardous waste generated, specific waste generated, reduction in waste) were classified under 'waste.' Similarly, it was observed that the 99 parameters dealt with a certain factor and these fashioned the factors affecting waste management in the textile industry. The resulting eight factors were Water, Waste, Energy, Green House Gases, Raw materials, Consumer Cycle, Sustainability Abled processes, and Institutional. These factors are termed as "Criteria" and constituted the middle level of the hierarchy (Figure 1).

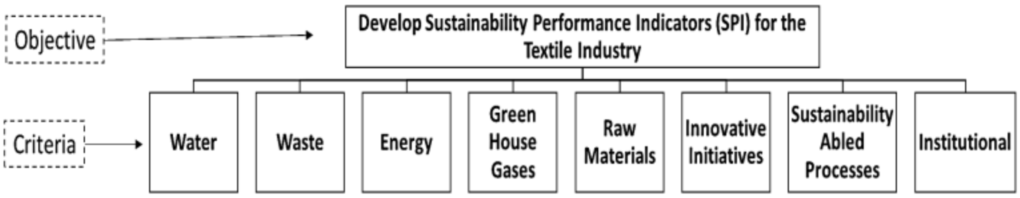

Figure 1: Defined Objective and Criteria

The lowest level in the hierarchy contains the sub-criteria for each of the criteria individually. From the data collected, it was observed that the measured parameters could be categories into two principal categories namely, base parameters and derived parameters.

Sub-criteria – Base Parameters

Some of the tabulated parameters pertained to basic information, that is, the data collected in connection with a certain criterion. Such parameters, numbering 57, were categorized as Base sub-criteria. These parameters are the fundamental building blocks of an organization's sustainability management. Figure 2 depicts the decision hierarchy structure for the base indicators.

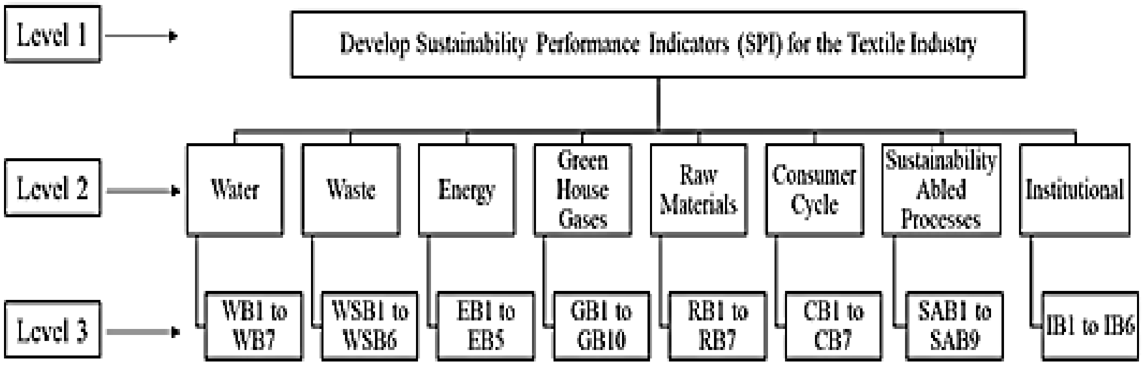

Figure 2: Decision Hierarchy Structure for Base Indicators

Sub-criteria – Derived Parameters

The second sub-criteria are derived or calculated parameters which are arrived at by utilizing the base parameters (one or more) and/or in comparison against base parameters. Nevertheless, it was observed that the derived parameters were not a characteristic of all the criteria. In other words, the criteria with derived parameters required separate grouping as they have greater significance (address various areas) over the others. 35 of the short-listed parameters fell into this category of sub-criteria.

Figure 3 depicts the decision hierarchy structure for the derived indicators.

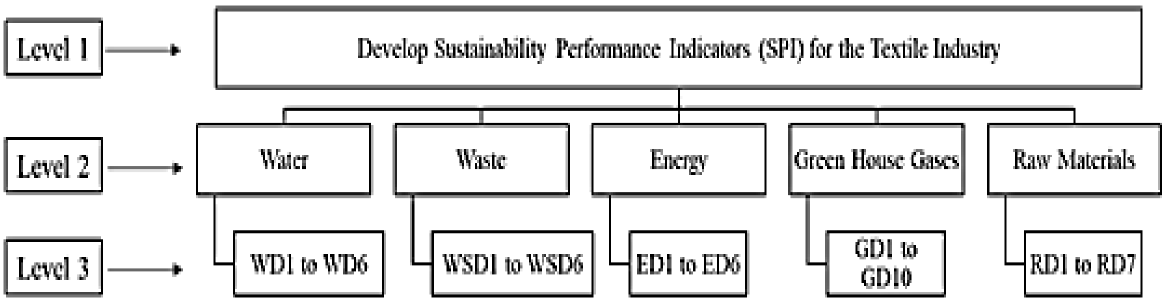

Figure 3: Decision Hierarchy Structure for Derived Indicators

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

2. List of Alternatives

The list of alternatives is the collective list of measures of all the parameters. These are in measurable form and facilitate comparisons, evaluation of the performance of the criteria or sub-criteria. Further, each criterion-sub-criterion is connected to at least one alternative. Alternatives are picked based on the final ranking of the criteria and sub-criteria. These alternatives form the final SPIs. Table 3 depicts the list of alternatives for water and waste.

Table 3: Sample Alternatives (water and waste)

Alternatives for Water
Volume of water utilized for all the processes - end to end
Volume of waste water treated
Volume of water recycled across all the processes
% Conformance to Zero discharge of Hazardous chemicals
Volume of fresh water managed by rain water harvesting
Chemical Oxygen Demand let out from all the processes
% of vendor partners meeting waste water quality standards as per PCB/ WHO standards
% Decrease in water utilization over baseline / last year
Specific water utilization per unit production OR per employee
% Decrease in specific water utilization over baseline (per unit production OR per employee) / last year
% Decrease in COD let out over baseline / last year
Specific COD let out per unit production OR per employee
% Decrease in specific COD over baseline/ last year
Alternatives for Waste
Volume of total waste generated by all the processes
Volume of hazardous waste generated by all the processes
Volume of non-hazardous waste generated by all the processes
% decrease in paper utilized over last year
Volume of waste recycled across all the processes
% decrease in waste to landfill
% decrease in waste generated over baseline / last year
% decrease in hazardous waste generated over baseline / last year
% decrease in non-hazardous waste generated over baseline / last year
Specific waste generated per unit production OR per employee
% decrease in specific waste generated over baseline / last year (per unit production OR per employee)
% Waste recycled

3. Determination of Ratings for the Criteria and Sub-Criteria

a. Sub-Criteria ratings

The calculation of ratings for each sub-criterion was performed in two steps. In the first step, a questionnaire was sent to 10 industry experts requesting them to rate each criterion and sub-criterion. A rating of 100% was given if each criterion/sub-criterion was agreed to by all the 10. On the other hand, a rating of 80% was given if only 8 of theexperts agreed with a certain criterion/sub-criterion. A binary preference rating (0/1) was used over the traditional manner of rating priorities (i.e., 1, 2, 3, 4 …) so as to facilitate equal ratings in certain cases given that there was a large data set. Finally, a percentage value was derived for each criterion/sub-criterion based on the collective response from the 10 experts. In the second step, using the data tabulated from the study of 80 textile firms, the proportion of firms reporting each of the sub-

TEST Engineering & Management
November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

criteria was evaluated. This resulted in a percentage score for each sub-criterion. The final score for a specific sub-criterion was calculated using the average score from both steps. Table 4 presents the sub-criteria related to water.

Table 4: Sub-criteria for Water

Parameter Code	Parameter Type	Parameters/Sub-criteria	Units	Industry status Ratings		Industry Experts Ratings		Average Ratings	
				1	0	1	0	1	0
WB1	Base	Utilization	cubic meters	85%	15%	90%	10%	88%	13%
WB2	Base	Volume Treated	cubic meters	35%	65%	50%	50%	43%	58%
WB3	Base	Recycling	cubic meters	88%	13%	100 %	0%	94%	6%
WB4	Base	Hazardous chemicals	%	41%	59%	50%	50%	46%	54%
WB5	Base	Source management	cubic meters	66%	34%	70%	30%	68%	32%
WB6	Base	Outlet Quality	Tons	38%	63%	70%	30%	54%	46%
WB7	Base	Vendor compliance	%	63%	38%	60%	40%	61%	39%
WD1	Derived	Improvement In Water Utilization	%	83%	18%	70%	30%	76%	24%
WD2	Derived	Specific Water Utilization	cubic meters / unit product OR cubic meters per employee	39%	61%	100 %	0%	69%	31%
WD3	Derived	Improvement In Specific Water Utilization	%	39%	61%	70%	30%	54%	46%
WD4	Derived	Improvement In Outlet Quality	%	40%	60%	100 %	0%	70%	30%
WD5	Derived	Specific outlet quality	Tons per unit product OR tons per employee	21%	79%	100 %	0%	61%	39%
WD6	Derived	Improvement in specific Outlet Quality	%	36%	64%	70%	30%	53%	47%

a. *Criteria Ratings*

Unlike the sub-criterion ratings, the calculation of ratings for the criteria were entirely based on the ratings of the industry experts since there were only respectively eight and five base and derived factors. For each of the criteria, the industry experts were required to provide a ranking in terms of priority. In this case, the order of priority (1, 2, 3, 4 …) was utilized since the preferential rating (0/1) was not valid for the primary data set. For instance, while the industry experts would not be able to choose between Water/Waste/Energy, they would be able to rank them by priority. Table 5 presents the priorities for the different criteria.

Table 5: Priorities for the Criteria

Parameter Code	Parameter Type	Criteria	Industry Experts Ranking
B1	Base	Water	21%
B2	Base	Waste	19%

B3	Base	Energy	14%
B4	Base	Green House Gases	17%
B5	Base	Raw Materials	11%
B6	Base	Consumer cycle	5%
B7	Base	Sustainability Abled processes	9%
B8	Base	Institutional	4%
D1	Derived	Water	31%
D2	Derived	Waste	26%
D3	Derived	Energy	15%
D4	Derived	Green House Gases	21%
D5	Derived	Raw Materials	7%

4. Pairwise comparisons

This stage of the AHP process entailed assessment of each criterion against all the other criteria. The reference point for the comparisons was a criterion which was higher ranked in the hierarchy based on the ratings.

The below equations were utilized for the pairwise comparisons:

$[a_{ij}]$, where i, j = 1,2,3...n (eq.1)

a_{ij}= 1 for I = j, (eq.2)

$a_{ij}=\frac{1}{a_{ij}}$ for i ≠ j (eq.3)

The result of a pairwise comparison of all the criteria is a decision matrix, with the above properties. Similarly, the pairwise comparisons of the base and derived sub-criteria of each criterion among themselves results in the decision matrices, again with the above properties.

Property as given in eq.1 indicates that the matrix is of the dimensions 'n x n', where n is the number of elements compared. Property as per eq.2 indicates that two identical elements, which have similar priorities, are being compared. No difference in priority is expressed by the numeric 1. Hence, all the values along the diagonal matrix are equal to 1. While doing the pairwise comparisons, the elements on row ' i ' are compared with an element in column ' j ' and 'a_{ij}' indicates, how much more (or less) important the 'i^{th}' element is in comparison to the 'j^{th}' element. Also, the assumption of AHP is that the priorities are reciprocal, which is expressed by property as per eq.3.In the pairwise comparisons of 'n' elements, it is sufficient to compare the values above the diagonal in matrix A. The values are reciprocals of the ones above the diagonal. The diagonal values are equal to 1.

The pairwise comparison uses a scale that ranges from equally important (1) to extremely important (9) (Table 6).

Table 6: Scale for pairwise comparison (Cabała, 2010)

Intensity of Importance	Definition
1	Equal Importance
2	Weak
3	Moderate Importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus

7	Very strong or demonstrated importance
8	Very, Very Strong
9	Extreme Importance

5. Determination of Priorities

The ratings from the previous step are converted to the intensity of importance using the pairwise comparison scale. This is calculated as per the below formula:

a12 =Rating% of C1 – Rating % of C2,

where C1 and C2 are a pair of sub-criteria or criteria being compared.

If the value of is equal to 0, it means that both C1 and C2 are of equal importance and hence a rating of 1 is assigned to this pairwise comparison. If the value of A12 is positive, it means that C1 is preferred over C2 and if it is negative, it means that C2 is preferred over C1. This preference is recorded in the matrix as the reciprocal of the rating. Table 7 was formulated to equate the a12 value to the intensity of importance scale.

Table 7: Equating a12 value range to the Intensity of Importance Scale

	Equal Importance								Extreme Importance
Intensity of Importance	1	2	3	4	5	6	7	8	9
a12 value	0	1-10	11-20	21-30	31-40	41-50	51-60	61-70	>71

The reciprocal matrix $[a_{ij}]$ is created for all the pairwise comparisons based on the scale, where a_{ij} is the preference of the i-th element in relation to the j-th element. The result from the pairwise comparison is the following matrix (Figure 4):

$$A = \begin{vmatrix} 1 & a_{12} & \dots & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & \dots & 1 \end{vmatrix}$$

Figure 4: Reciprocal Matrix

Table 8 presents the reciprocal matrix for the base parameters of water.

Table 8: Indicative reciprocal matrix (Base parameters of water)

	WB1	WB2	WB3	WB4	WB5	WB6	WB7
WB1	1	6	1/2	6	3	5	4
WB2	1/6	1	1/7	1/2	1/4	1/3	1/3
WB3	2	7	1	6	4	5	5
WB4	1/6	2	1/6	1	1/4	1/2	1/3
WB5	1/3	4	1/4	4	1	3	2
WB6	1/5	3	1/5	2	1/3	1	1/2
WB7	1/4	3	1/5	3	1/2	2	1

6. Calculation of the Eigen vector

The prepared pairwise comparison matrix is normalized using Saaty's Method of normalized arithmetic averages. This normalized matrix is

Matrix B = $[b_{ij}]$

The values of Matrix B are calculated as per the below formula:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

(eq.4)

To calculate the priorities between the elements under investigation, the Eigen vector (priority vector) W = $[w_i]$ is calculated according to the below formula:

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

$$w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n}$$
(eq.5)

Step 5: Consistency check and Global priorities

The Principal Eigen Value (also known as the Maximum Eigen Value) is calculated as per the below equation:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(Aw)_i}{w_i}$$
(eq.6)

Evaluation of the consistency in the pairwise comparisons helps to ascertain the consistency of the ratings.

Consistency index (CI) is the index of the consistency of judgments across all pairwise comparisons

$$CI = \frac{\lambda_{max} - n}{n-1}$$
(eq.7)

Consistency ratio (CR) for every set of comparison is calculated as follows:

$$CR = \frac{\lambda_{max} - n}{r(n-1)} 100\%$$
(eq.8)

Where,

r = random consistency index table

If CR is less than or equal to 10%, means the pairwise comparisons are consistent

If CR is greater than 10%, means the pairwise comparisons are inconsistent and the pairwise comparisons weightages need to be reworked.

Table 9 summarizes the Principal Eigen Value, CI, and CR for the base parameters of water. As can be seen from the table, the value of CR is <10% indicating that the pairwise comparisons were consistent.

Table 9: Principal Eigen Value, CI, and CR for base parameters of water

WB	λmax	7.44
	CI	0.0736
	CR	5.45%

Step 6: Ranking and Finalization of the Sustainability Performance Indicators

The final step was carried out in 3 steps as follows:

1. The Eigen vector and rankings
2. Calculation of the global priority vector
3. Selection of the final SPI

1. The Eigen vector and rankings

The Eigen Vector w_i calculated depicts the order of that particular criterion or sub criterion. The higher the value of the Eigen vector w_i, the greater the priority. For each of the sub criterion and criterion, the pairwise comparisons were done as per the above procedure to arrive at the rankings. Table 10 presents an indicative normalized comparison matrix for base parameters of water.

Table 10: Normalized comparison matrix for base parameters of water

	WB1	WB2	WB3	WB4	WB5	WB6	WB7	EIGEN VECTOR wi
WB1	0.2429	0.2308	0.2033	0.2667	0.3214	0.2970	0.3038	0.2666
WB2	0.0405	0.0385	0.0581	0.0222	0.0268	0.0198	0.0253	0.0330
WB3	0.4858	0.2692	0.4066	0.2667	0.4286	0.2970	0.3797	0.3620
WB4	0.0405	0.0769	0.0678	0.0444	0.0268	0.0297	0.0253	0.0445
WB5	0.0810	0.1538	0.1016	0.1778	0.1071	0.1782	0.1519	0.1359
WB6	0.0486	0.1154	0.0813	0.0889	0.0357	0.0594	0.0380	0.0668
WB7	0.0607	0.1154	0.0813	0.1333	0.0536	0.1188	0.0759	0.0913

2. Calculation of the global priority vector (GPV)

The global priority vector is calculated as the product of the criterion Eigen vector and of the respective sub-criterion Eigen vector. Table 11

TEST Engineering & Management

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

presents an indicative priority vector for base parameters of water.

Table 11: Priority vector for base parameters of water

	WB1	WB2	WB3	WB4	WB5	WB6	WB7
WB	1.0973	0.8586	0.8902	1.0010	1.2687	1.1237	1.2021

3. Selection of the final SPI

In the last step of the process, the SPIs were ranked by priority based on consultation from Industry experts, the SPIs for the textile industry were determined by dividing the global priority vectors into 3 stages: I, II, and III. Stages I and II have 3 levels each: A, B, and C, respectively; while Stage III has no level bifurcations. The alternatives were mapped against their respective sub criteria and these formed the Sustainability Performance Indicators. Table 12 presents the SPIs obtained from the base criteria and sub-criteria

Table 12: Final list of SPIs (Base indicators)

L1 code	Level 1	Priority (L1)	L2 code	Level 2 - Base Indicators	Priority (L2)	Global Priority	Ranking
B1	Water	24.31	WB3	Recycle	36.20	8.80%	1
B2	Waste	19.32	WSB5	Recycle	39.46	7.62%	2
B1	Water	24.31	WB1	Utilization	26.66	6.48%	3
B2	Waste	19.32	WSB1	Total generated	26.73	5.17%	4
B4	Green House Gases	15.55	GB1	Total Emissions CO2e	26.05	4.05%	5
B3	Energy	12.50	EB3	Clean energy development	32.00	4.00%	6
B5	Raw Materials	9.51	RB5	Eco friendly packaging materials	37.42	3.56%	7
B1	Water	24.31	WB5	Source management	13.59	3.30%	8
B3	Energy	12.50	EB2	Renewable energy Utilization	24.22	3.03%	9
B4	Green House Gases	15.55	GB2	Direct emissions	18.13	2.82%	10
B4	Green House Gases	15.55	GB3	Indirect emissions	18.13	2.82%	11
B2	Waste	19.32	WSB4	Paper utilized	14.46	2.79%	12
B3	Energy	12.50	EB5	Generation of Solar energy	18.67	2.33%	13
B1	Water	24.31	WB7	Vendor compliance	9.13	2.22%	14
B6	Consumer cycle	6.20	CB5	Circular design - packaging	30.56	1.89%	15
B5	Raw Materials	9.51	RB7	Reuse of packaging Materials	19.14	1.82%	16
B3	Energy	12.50	EB4	Technology upgrade for energy efficiency	14.33	1.79%	17
B7	Sustainability Abled processes	7.69	SAB1	Local partners development	23.25	1.79%	18
B8	Institutional	4.92	IB1	Awareness creation	33.38	1.64%	19
B1	Water	24.31	WB6	Outlet Quality	6.68	1.62%	20
B2	Waste	19.32	WSB3	Non-hazardous type	8.18	1.58%	21
B7	Sustainability Abled processes	7.69	SAB7	Voluntary environmental activities	18.62	1.43%	22
B6	Consumer cycle	6.20	CB1	End of life	21.80	1.35%	23
B4	Green House Gases	15.55	GB4	Upstream emissions	8.68	1.35%	24

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

L1 code	Level 1	Priority (L1)	L2 code	Level 2 - Base Indicators	Priority (L2)	Global Priority	Ranking
B4	Green House Gases	15.55	GB5	Downstream emissions	8.68	1.35%	25
B3	Energy	12.50	EB1	Utilization	10.78	1.35%	26
B5	Raw Materials	9.51	RB4	Packaging materials	14.00	1.33%	27
B2	Waste	19.32	WSB2	Hazardous type	6.51	1.26%	28
B8	Institutional	4.92	IB4	Sustainability Development Goals	25.49	1.26%	29
B7	Sustainability Abled processes	7.69	SAB8	Green methods adaption across the business	15.70	1.21%	30
B1	Water	24.31	WB4	hazardous chemicals	4.45	1.08%	31
B5	Raw Materials	9.51	RB3	Efficiency of raw materials	10.92	1.04%	32
B7	Sustainability Abled processes	7.69	SAB3	Prohibition of unhealthy practitioners / products	13.31	1.02%	33
B6	Consumer cycle	6.20	CB2	Water efficiency improvement in the consumer cycle	14.95	0.93%	34
B4	Green House Gases	15.55	GB8	NOx	5.94	0.92%	35
B4	Green House Gases	15.55	GB9	SOx	5.94	0.92%	36
B2	Waste	19.32	WSB6	Landfill	4.65	0.90%	37
B8	Institutional	4.92	IB2	Sustainability communications	18.23	0.90%	38
B7	Sustainability Abled processes	7.69	SAB4	uplift green businesses	11.56	0.89%	39
B1	Water	24.31	WB2	Volume Treated	3.30	0.80%	40
B6	Consumer cycle	6.20	CB6	Maintenance services of the product	12.46	0.77%	41
B5	Raw Materials	9.51	RB2	Recycled raw materials	8.02	0.76%	42
B7	Sustainability Abled processes	7.69	SAB2	support responsible partners	9.37	0.72%	43
B4	Green House Gases	15.55	GB7	Particulate matter	4.19	0.65%	44
B6	Consumer cycle	6.20	CB4	Circular design - product	9.97	0.62%	45
B8	Institutional	4.92	IB5	Integrated certifications & Memberships	12.49	0.62%	46
B5	Raw Materials	9.51	RB6	Recycled Packaging materials	6.04	0.57%	47
B5	Raw Materials	9.51	RB1	Sustainable raw materials	4.46	0.42%	48
B4	Green House Gases	15.55	GB6	Air emissions	2.58	0.40%	49
B6	Consumer cycle	6.20	CB3	Energy efficiency improvement in the consumer cycle	5.68	0.35%	50
B8	Institutional	4.92	IB3	Interactions with stakeholders	6.01	0.30%	51
B6	Consumer cycle	6.20	CB7	Enhance usage of the product	4.58	0.28%	52
B4	Green House Gases	15.55	GB10	Ozone depleting substances	1.69	0.26%	53
B7	Sustainability Abled processes	7.69	SAB9	Track environmental sustainability expenses	3.27	0.25%	54
B8	Institutional	4.92	IB6	Tie up with Research Institutes	4.40	0.22%	55
B7	Sustainability Abled processes	7.69	SAB6	Materiality Matrix	2.75	0.21%	56
B7	Sustainability Abled processes	7.69	SAB5	Life cycle analysis	2.18	0.17%	57

November-December 2019
ISSN: 0193-4120 Page No. 6048 - 6064

IV. CONCLUSION

The textile industry is a considerable producer of waste. Hence, waste management practices require scrutiny and reporting. This paper has described the process of developing a set of Sustainable Performance Indicators (SPIs) for the textile industry. An initial list of parameters was identified and derived from the sustainability reports of leading textile firms across the globe. These were then validated by industry experts. A mathematical model was developed using Analytic Hierarchy Process (AHP) to determine priorities and ranking for the identified SPIs. A hierarchy structure was established based on the proposed SPIs for the textile industry. Subsequently, the importance weights of the SPIs were assigned by pairwise comparison and computed using the AHP methodology. Future work will include evaluation of the proposed SPIs in case studies in the textile industry.

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