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Strategic Prioritization of Environmental Sustainability Practices in

Leather Industries : An Integrated Delphi-AHP-TOPSIS Analysis

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Abstract

Despite the fact that the Indian leather sector employs about 4.42 million people and brings in around USD 5 billion in export revenue, with plans to reach USD 30 billion by 2030, stakeholders are still becoming more concerned about the environmental sustainability practices (ESPs) and performance of this sector. Though a lot of work is being done in literature, still recognizing, executing, and assessing suitable ESPs continues to be difficult, especially in pollution-heavy industries like leather processing, where sustainability governance is frequently regarded as inadequate, particularly in developing nations. This study examines four primary questions: which ESPs are frequently implemented across various industrial sectors; whether these practices are relevant to the Indian leather processing industry; how they can be systematically categorized to support efficient analysis, monitoring, and assessment; and how ESPs can be prioritized to allow firms to concentrate on a select few high-impact practices during the initial stages of adoption.

The above objective was first achieved through a thorough literature review that revealed 30 ESPs, which were then evaluated by domain experts for their

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pertinence to leather processing activities. The Delphi method was employed to achieve expert consensus and refine the list of applicable practices. The Delphi validated 10 ESPs were then prioritised using an integrated multi-criteria decision-making framework combining the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Due to the financial and operational limitations encountered by numerous leather processing companies, prioritization was crucial for facilitating a feasible and incremental adoption. The results provide valuable information for policymakers and industry professionals by pinpointing few key prioritised ESPs that can be implemented initially to enhance environmental performance and bolster sustainability management within the leather sector.

Keywords: Environmental Sustainability Practices (ESPs), Delphi, Analytic Hierarchy Process (AHP), Leather Industries, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

1. Introduction: The raw skin, a byproduct of the meat industry used for leather manufacture, is a very perishable material that necessitates preservation measures to reduce its degradation rate. These preservation measures has

evolved significantly from traditional production to cuttingedge technology with advancements in materials science and technical innovation. From the perspective of leather manufacturers, they function as a scavenging industry that processes waste from the meat industry, thereby enhancing its value. Without this value addition, such waste would necessitate disposal in secure landfills, presenting a significant challenge. From the another perspective of various stakeholders, only a specific weight percentage (approximately 20%) of raw skin is transformed into leather[1], while the remainder is produced as solid waste, accompanied by a substantial

volume of effluent containing diverse chemicals. The management of this solid waste and effluent presents a significant challenge and contributes to severe environmental degradation. Utilizing various technologies, the raw skin may be transformed into products beyond leather, including glue and adhesive manufacturing, gelatin and collagen production, as well as fertilizers and conditioners. However, considering economies of scale and scope, leather processing from raw hides remains the market's favored option. This directed the efforts of technicians and engineers towards reducing environmental deterioration caused by leather processing.

Environmental sustainability practices (ESPs) are essential for enhancing the environmental performance of micro, small, and medium enterprises (MSMEs), particularly in developing economies where industrial activities are likely to significantly contribute to environmental deterioration. The leather business is recognized as one of the most environmentally taxing sectors, chiefly due to its reliance on chemical-intensive processing, substantial water use, and enormous generation of both solid and liquid waste. ESPs include all the steps that businesses take to lessen their impact on the environment[2]. Governments and businesses around the world, in many different sectors, are actively working to slow down the rapid decline of the environment by making policies for sustainability, setting environmental standards, and supporting projects that focus on the environment[3]. Though, a lot of work is being done in literature, but it is still hard for some sectors to find, use, and evaluate the right ESPs because of the unique nature of their raw materials, handling variety of hazardous

chemicals and the problems they face in processing. Finding the correct collection of ESPs is also a big difficulty for improving the performance of leather processing businesses. This study sought to address present gap by investigating several key questions: which Environmental Sustainability Practices (ESPs) are commonly employed across diverse industrial sectors; the relevance of these practices to the Indian leather processing industry; the systematic categorization of ESPs to facilitate efficient analysis, monitoring, and evaluation; and the prioritization of ESPs to enable leather industries to focus on a limited number of high-impact practices during the initial phases of adoption for anticipated performance improvement. The first objective was accomplished through a comprehensive literature research that identified 30 ESPs, subsequently assessed by domain experts for their relevance to leather processing processes. We then used an integrated multi-criteria decision-making framework that included the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the validated ESPs.

2 Review of the Literature:

The identification of ESPs was achieved by initially selecting the articles for data collection and subsequently analyzing them. Following the recommendations of researchers[4]–[6], we choose to utilize the Scopus database for data collection in this literature study. The relevant search terms were used to query the database, and the resulting publications were inspected for mentions of a certain ESP. Table 1 shows several ESPs that came from this search along with the prevailing sectors and concerned researchers.

In accordance with the literature[54], the Delphi technique was employed to ascertain the critically important and significantly important Environmental Sustainability Practices (ESPs) related to the leather processing sectors, based on the ESPs derived in Table 1. The selected ESPs for the leather sector were subsequently prioritized through multi-criteria decision making utilizing AHP and TOPSIS methodologies.

Table 1: Various ESPs identified across distinct sectors by previous researchers

S.No.	Details of an ESP	Sector	Researcher
1	Classify all Process Chemical constituents	Fashion Industry; Leather Industry	[7];[8]
2	Utilization of certified or eco-friendly raw materials	SMEs in Spain; Leather	[9]; [10]
3	Reduced consumption of harmful/toxic chemicals	Leather; Chemical	[11];[12]
4	Recyclable/ Extended product life	Clothing/footwear; Textile	[13]; [14]
5	Reduced energy use	Chemical; Construction	[15];[16]
6	Using renewable/reducing non-renewable energy	Automotive; Cement	[17]; [18]
7	Energy-efficient systems	Manufacturing; SMEs in Europe	[19];[20]
8	Reduced water use	Chemical; Textile	[15];[21]
9	Used water reuse/recycling	Chemical/Oil/Meat; UK manufacturing	[22];[23]
10	water-efficient systems	Chemical; Fashion;	[15];[7]
11	Treatment of wastewater	Industrial waste water treatment; Paper	[24];[25]
12	Collecting selective waste	Industrial waste; PPP projects in China	[26];[27]

13 Reduce/reuse/recycle solid waste Fashion; Industrial sector [7]; [28]

14 Reduce/control emissions Manufacturing; Paper [29];[25]

15 Environment protection and restoration initiative Oil refinery sector; PPP projects in China [30];[27]

16 Noise reduction Rubber manufacturing; Public transport [31];[32]

17 Setting environmental sustainability targets Freight Transportation; Energy sector [33];[34]

18 Implementing ISO 14001 and other standards SMEs in Spain; Food [9]; [35]

19 Environmental regulation tools (subcommittee etc.) Dairy product; Mexican manufacturing [36];[37]

20 Environmental audits/compliance Oil refining; Freight Transportation [38];[33]

21 Report environmental sustainability annually Mining/telecommunication; Energy [39];[40]

22 Fixing environmental damage liability Dairy product; Energy Sector [36];[41]

23 Production standardization Manufacturing; Chemical [42]; [15]

24 Investment in green processes SMEs in US; Cement and plastic [43];[44]

25 Lifecycle analysis Manufacturing sector; Fashion Industry [45];[46]

26 Recovery of waste heat Cement industry; Industrial Sector [18];[47]

27 Environmentally conscious behavior Hospitality; Mining/telecommunication [3];[39]

28 Environmentalism/Education/Training Textiles/clothing/leather; Steel [48];[49]

29 Lower environmental accidents Petrochemical Industry; Manufacturing [50];[51]

30 Converting waste to value Agricultural sector; Food Processing [52];[53]

3 Research Methodology:

3.1 Delphi Method: Through data collection, problemsolving ideation, issue prioritization, prediction, and choicemaking, this research approach offers a systematic and participatory method for gathering and analyzing expert opinions[55]. A commission comprising nine to eighteen experts is recommended in this approach to ensure relevant outcomes and prevent disagreements among experts[56]. To save time and money, leather experts in academia, science, and business were emailed a questionnaire. Survey Coefficient of variation (CV) and content validity ratio (CVR) were investigated. Researcher[57] define CV as the ratio of standard deviation to mean, and CVR as , where P is the number of participant/experts who participated in the expert survey and n is the number who indicated a particular environmental sustainability practice as “extremely important” or “very important”. A second criteria assessment is unnecessary if CV<0.5 (Solangi et al., 2019). A positive CVR demonstrates expert consensus on a criterion’s importance. Assessing CVRs > 0.29 is sufficient (Solangi et al., 2019). The screened selected ESPs were prioritised using TOPSIS, this prioritization was made based on 4 criteria namely Reduction of Environmental Impact (REF), Cost of Implementation (CIF), Implementation Ease (IEF), and Long-Term Benefits (LBF), these criteria were taken from the literature[58].

3.2 Analytic Hierarchy Process (AHP): AHP compares options using pairwise comparisons and provide numerical criteria to choose the best. Following the researcher[58]–[60], AHP was used to rank the abovementioned four criteria according to their importance to LPI environmental performance. The detailed AHP methodology (including the creation of the AHP model and problem definition, expert data contributions for AHP, establishment of normalized priority weights for each criterion, prioritization and creation of aggregate comparison matrices, and verification of results through

consistency checks) for ranking the aforementioned four

criteria can be referenced from our previous work[58].

3.3 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution): The TOPSIS is a popular multi-criteria decision making (MCDM) method due to its simplicity and the idea that the best solution is closest to the positive ideal solution and farthest from the negative ideal solution[61]. Discrete criteria weights must be specified before TOPSIS computations. The AHP approach allowed us to calculate TOPSIS’ weight, which represents the decision maker’s criteria preference. The sequential stages of the TOPSIS methodology for ranking the evaluated ESPs include Problem Formulation, Normalization of the decision performance matrix, Integration of Criteria weights with Normalized performance ratings, Identification of ideal solutions (both positive and negative), Calculation of the separation distance from the ideal positive and negative solutions, and Computation of total preference scores, as detailed in our previous work[58].

4 Results & Discussion:

4.1 Delphi Analysis: The computed CV values for all practices, derived from data gathered from nine domain experts, were <0.5, indicating that all 30 ESPs are suitable for implementation in the leather sector. However, based on the CVR calculation, one ESP, specifically Noise Reduction, was excluded due to a CVR value of 0.11 (<0.29). As 29 ESPs are still a huge number to be implemented by an immature leather industry due to its limited resources, we have picked only those ESPs with CVR value 1 (meaning 100% unanimity among experts for an ESP to be extremely significant in leather industries). The CVR value 1 was resulted for Only 10 ESPs namely: Classify all Process Chemical constituents (CPC); Reduced consumption of harmful/toxic chemicals (RCC); Recyclable/ Extended product life (RPL); Using renewable/reducing non-renewable energy (URE); Energy-efficient systems (EES); Reduced water use (RWU); Used water reuse/recycling (UWR); Waterefficient systems (WES); Treatment of wastewater (TWW); and Investment in green processes (IGP). The abovementioned 10 ESPs were prioritised using AHP and TOPSIS.

4.2 AHP Analysis: This work prioritised (through TOPSIS) the above screened 10 ESPs based on four criteria: Reduction of Environmental Impact (REF), Cost of Implementation (CIF), Implementation Ease (IEF), and Long-Term Benefits (LBF), using AHP approach. The selected 4 criteria and their estimated weights resulting from AHP were based on our prior work[58]. The AHP determined the criteria for leather industries in descending order as REF, CIF, IEF, and LBF, with corresponding weight values of 0.54, 0.26, 0.13, and 0.07, respectively[58].

4.3 TOPSIS Analysis: The Hierarchical Model for prioritization of 10 ESPs using TOPSIS is presented in

Table 2: TOPSIS Choice Matrix

Criteria Weights as

Average of the score assigned by experts on each criteria for 10 ESPs

Criteria

determined by

AHP[58]

CPC RCC RPL URE EES RWU UWR WES TWW IGP

REF 0.54 6.44 8.89 4.11 7.11 6.89 8.44 8.78 7.11 8.89 7.44

CIF 0.26 3.89 8.67 7.11 7.89 8.44 6.33 8.11 8.44 8.89 8.89

IEF 0.13 8.89 7.78 5.56 7.22 4.89 7.33 5.67 5.44 4.89 8.11

LBF 0.07 7.67 8.89 5.78 7.11 6.78 8.89 8.56 8.44 8.44 8.56

The normalization of the aggregate rating choice matrix constitutes the second stage in the TOPSIS methodology, computed by dividing the score of an ESP for a specific criterion by the square root of the sum of the squares of

Table 3: TOPSIS Normalised Choice Matrix

Criteria Weights as determined by

Criteria

Normalised Score for 10 screened ESPs

AHP

CPC RCC RPL URE EES RWU UWR WES TWW IGP

REF 0.54 0.27 0.37 0.17 0.3 0.29 0.35 0.37 0.3 0.37 0.31

CIF 0.26 0.16 0.35 0.29 0.32 0.34 0.26 0.33 0.34 0.36 0.36

IEF 0.13 0.42 0.37 0.26 0.34 0.23 0.35 0.27 0.26 0.23 0.38

LBF 0.07 0.3 0.35 0.23 0.28 0.27 0.35 0.34 0.33 0.33 0.34

Fig. 1. Following the researcher[62], the first stage in ranking each ESP is to assign it a score on a scale of 1 to 9 on the four selected criteria. Except for CIF (cost of implementation), a greater score is preferable as a benefit criteria, whereas a lower score is better FOR CIF. Our chosen nine experts were asked to rate all ten environmental sustainability practices based on four factors. The choice matrix is created by averaging the scores provided by each of the nine experts (Table 2), with the assumption of equivalent dependability among experts because the selected experts have 20 years or more of experience in the leather sector.

the values of all 10 ESPs inside that criterion in the choice matrix. The computed normalized choice matrix is presented in Table 3.

Goal Criteria ESPs

Reduction of Environmental

Impact (REF)

Prioritising 10 ESPs resulted from Delphi

Cost of Implementation

(CIF)

(CVR value 1)

Implementation Ease (IEF)

Long-Term Benefits (LBF)

Fig. 1: Hierarchical Model for Prioritization of ESPs

Additional weighted normalized choice matrices are produced by multiplying the weight of the criteria that were

Table 4: TOPSIS Weighted Normalized Choice Matrix

Weighted Normalized Score for 10 screened ESPs

Criteria

CPC RCC RPL URE EES RWU UWR WES TWW IGP

REF 0.146 0.201 0.093 0.161 0.156 0.191 0.199 0.161 0.201 0.169

CIF 0.041 0.091 0.075 0.083 0.089 0.067 0.085 0.089 0.094 0.094

IEF 0.054 0.048 0.034 0.044 0.03 0.045 0.035 0.033 0.03 0.05

LBF 0.021 0.025 0.016 0.02 0.019 0.025 0.024 0.023 0.023 0.024

Additionally, the Ideal solutions, encompassing both positive and negative aspects, are computed from the weighted normalized choice matrix. The Ideal positive is the maximum value obtained among all evaluated ESPs for the

CPC

RCC

RPL

URE

EES

RWU

UWR

WES

TWW

IGP

determined by AHP with the values of the normalized choice matrix, which are calculated in Table 4.

specified criteria (REF, IEF, LBF) and the minimum value obtained for the cost criterion (CIF). Conversely, the Ideal negative is the smallest value obtained among all evaluated ESPs for the specified criteria (REF, IEF, LBF) and

the greatest value achieved for the cost criterion (CIF). The Ideal positive and negative values are reported in Table 5.

Table 5: Ideal Positive and Ideal Negative Solutions

Criteria Ideal Positive Score Ideal Negative Score

REF 0.201 0.093

CIF 0.041 0.091

IEF 0.054 0.03

LBF 0.025 0.016

Additionally, in accordance with the researchers[61], [62], the Euclidean distance of each ESP from the ideal positive and negative solutions is calculated. Positive Euclidean distance ( ) for each ESP is calculated by calculating the square root of the sum of the squares of the differences between the weighted normalized choice score of that ESP and the ideal positive score of that ESP across all four criteria. In a similar manner, negative Euclidean distance ( ) is calculated for each ESP by computing the square root of the sum of the squares of the differences between the weighted normalized choice score of that ESP and the ideal negative score of that ESP across all four criteria. The further preference score for each ESP is determined by dividing the value of negative Euclidean distance (+) by the sum of the negative and positive Euclidean distances. A superior preference score was employed to finally rank the ESP for the leather sector in India, as detailed in Table 6.

Table 6: Final preference score and environmen-

tal sustainability practice ranking

ESP □□+ □□− Preference Score Rank

CPC 0.055 0.077 0.582 5 RCC 0.051 0.110 0.684 3 RPL 0.116 0.017 0.128 10 URE 0.059 0.070 0.541 7 EES 0.071 0.063 0.472 9 RWU 0.029 0.103 0.778 1 UWR 0.049 0.106 0.686 2 WES 0.066 0.068 0.509 8 TWW 0.058 0.108 0.651 4 IGP 0.062 0.078 0.558 6

In our analysis, Reduced water use (RWU) is a top ranked environmental sustainability practice followed by Used water reuse/recycling (UWR) and Reduced consumption of harmful/toxic chemicals (RCC) for leather industries in India.

5. Conclusion and Implications: Despite extensive literature, organizations may struggle to identify the right ESPs for environmental performance. To fill this gap, the present study initially searched Scopus database for ESPs mentioned in different sectors by previous researchers. This study identified 30 ESPs that domain experts vetted for leather industry applicability. Delphi was used to minimize this number and highlight a few techniques. Only 10 practices (based on determined CVR value 1) were prioritized utilizing an integrated MCDM technique of AHP and TOPSIS. Four criteria—REF, CIF, IEF, and LBF— determined this order, where AHP was utilized to set priority among these 4. The 10 selected ESPs were prioritised using TOPSIS based on the aforementioned 4 criteria and resulted in descending order: RWU>UWR>RCC>TWW>CPC>IGP>URE>WES>EES >RPL. This TOPSIS research found that Reduced water use (RWU) is the top environmental sustainability practice, followed by Used water reuse/recycling (UWR). Our findings appear to be substantiated by the comparative environmental performance of various leather clusters, where the leather industry in southern India demonstrate superior performance by diligently adopting water based practices which were also identified as top-ranked ESPs in this present work. Further the energy related ESPs like Using renewable/reducing non-renewable energy (URE) are not among the top 5 practices for this sector which is in contrary to many other sectors like cement, this may be due to the fact that based on economic aspects energy cost in leather processing is only 3 % of the total cost[63].

There are two types of implications from this work: those for the LPIs and those for the policy makers. An industry can concentrate on or adopt some of our highest priority ESPs in the hopes of increasing their environmental sustainability because they lack the resources to implement all of the ESPs at a time. Furthermore,

authorities should focus more on water-related ESPs by offering incentives with strict rules (like ZLD, which the state of Tamil Nadu has embraced) if improved environmental performance is expected from LPIs in India. The fact that this work hasn’t quantitatively evaluated the connection between implementing an ESP and enhancing environmental performance may be one of its weaknesses, and future researchers may choose to use it.

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