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EVALUATING SUSTAINABILITY FACTORS FOR INDIAN MARBLE INDUSTRIES USING ANALYTIC HIERARCHY PROCESS

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Abstract- This paper highlights the concept of sustainability and provides a view of the relative importance of critical factors of sustainability as which one is more impactful. This work focuses on the environmental, economic, and social impact of stone and marble industry in the north western region of India and presents a case study of three marble processing plants by evaluating the extent of sustainability of these plants. The goal of this paper is to rate and compare marble processing plants of north western India on the basis of various factors of sustainability such as reuse and recycling of waste marble dust, waste water treatment, worker health and safety, government policies and low processing cost. This paper presents an empirical study for evaluating the critical factors of sustainability in Indian marble processing industries using analytic hierarchy process (AHP). AHP provides a structural solution for complex decision problems. In this study, a survey methodology has been adopted which uses both academia and industry. The relative importance of the factors for sustainability implementation is determined through brainstorming sessions and the factors' rating in three case industries has been found out on the basis of survey. Finally the rank analysis of the case industries has been done.

Keywords— Environment safety, Sustainability, Marble sector, Multi-criteria decision making (MCDM), Analytic Hierarchy Process (AHP).

I. Introduction

Sustainability is an increasingly important requirement for human activities, making sustainability a key objective in human development. At its core, sustainability is the view that social, economic and environmental concerns should be addressed simultaneously and holistically in the development process. Sustainability has been applied to many fields, including engineering, manufacturing, processing and design. Manufacturers are becoming increasingly concerned about the issue of sustainability. For instance, recognition of the relationship between manufacturing operations and the natural environment has become an important factor in the decision making among industrial societies.

Hence in this paper, a case of marble processing industries is presented in which key factors of sustainability are to be evaluated through AHP technique. The objectives of this paper are:

a. Preparation of an overall performance matrix to determine relative importance of critical sustainability factors,

b. To evaluate factor's rating in three marble processing industries,

c. To conduct rank analysis for these industries using AHP.

The structure of the paper is as follows: Literature review is discussed in Section II; Section III describes the key factors of sustainability while Section IV presents AHP approach and its application is described in Section V. The results are discussed in Section VI followed by conclusion in Section VII.

II. Literature review

The literature has been reviewed from two perspectives; applications of AHP technique in various fields and applications of sustainability in marble industries.

A significant amount of work has been done in AHP applications. Gupta et al. [1] suggested a mathematical model for measuring the effectiveness of technical education/service after enlisting the critical factors that affect the technical education. Odhar and Ray [2] formulated a model using AHP for supplier performance evaluation and ranking. Lee et al. [3] suggested a methodology leading to effective supplier management process utilizing information obtained from the supplier selection processes. A model to evaluate the relative performance of various suppliers along with the environmental traits is been proposed by Handfield et al. [4] using AHP. A lot of research has done in the field of sustainability but a very few literature is available about sustainability in marble sector specifically.

A Review presented by Haapala et al. [5] says that sustainability concept emerged between 1970s & 1980s due to environmental incidents, excessive emissions, ozone layer depletion loss of safety values of people so it was a result of constant meetings held between this duration by industry experts. Theoretically this concept came from the meeting held and is reported in the 1987 Brundtland Report, Our Common Future. The Brundtland

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report [6] titled "Our Common Future" that was released in 1987 by United Nations World Commission on Environment and Development (WCED) defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."Challenges in Sustainability implementation in various fields of manufacturing and processing have been demonstrated by Nambiar et al. [7]. Gunasekaran et al. [8] have highlighted the Sustainable business development (SBD) in manufacturing and services (M&S). They have shown concerns about the way of doing manufacturing for the sake of environmental, economic and social health. Zang et al. [9] described the importance of environmental conscious design & manufacturing (ECD&M), role of sustainability in discrete & continuous manufacturing. Gupta et al. [10] have shown a number of factors to implement sustainability in electrical panel industry. In a recent study presented by shukla et al. [26] the sustainability factors related to Indian automobile industries were evaluated using AHP technique.

III. Key Factors Of Sustainability

From the literature available on sustainability and marble processing related problems the most significant factors responsible for sustainability implementation in the field of marble processing industries, are identified from the literature and shortlisted based on the expert opinion. Brief review of sustainability key factors is given in Table I. These factors are organized as follows:

1) Reuse and Recycling of waste marble dust (RR)
2) Waste water treatment (WWT)
3) Worker health and safety (WHS)
4) Government policies and regulation (GP)
5) Lowering processing cost (LPC)

Table 1:Brief review of sustainability key factors

Authors	Factors considered	Description
Topcu et al. [11]; Kishore & Chowdary [12]	Reuse and Recycling of waste marble dust	Reuse of scrap marble pieces in Self Compacting Concrete and use of waste marble dust as filler material
Hameed & sekar [13], Topcu et al. [11]	Waste water treatment	Techniques of waste water treatment are identified and measures of Separation of solid wastes and dust particulate mixed in water.
Aukour et al. [14]; Georgiadis & amp; Besiou [15]	Worker health and safety	Provision of safety devices and proper medical attention for workers
Kulatunga et al. [16]; Amrina and Yusof [18]; NMCC [17]	Government policies and regulation	Law Enforcement and Judicial Regulations, Private-Public Participation and Social accountability. pollution control, landfill taxes, emissions trading, eco-label etc.
Azapagic [19]	Lowering processing cost	Efficient Process Management With Minimum Waste outputs.

1) Reuse and Recycling of waste marble dust

In marble processing plants and manufacturing centres by reusing the scrap and discarded pieces of marble the negative impact of these scrap pieces can be minimized. Recycling of stone pieces can be carried out by re-crushing them into aggregate to be used in self compacting concrete (SCC) as in a study presented by Hanieh et al. [21] in stone and marble sector of Palestine. In a recent study presented by Aliabdo et al. [22] in Egypt about the possibility of reusing the marble dust generated during cutting and polishing process in marble factories has been useful in cement and concrete production.

2) Waste water treatment

During the marble cutting process by gang saws, water is used as a coolant and the powder flows along with it as waste marble slurry. This waste marble slurry can be treated as mentioned in the study presented by Topcu et al. [11] that waste slurry of dust is useful in increasing density of SSC and the waste water can be treated for further use.

3) Worker health and safety

As we know that a healthy worker can improve the productivity manifold if he is fit and the atmosphere in which he works is fit to work. In a research presented by Beriha et al. [20] in high risk industries of India highlights the importance of proper working condition in three sectors such as construction, refractory and steel industries. This study emphasises on occupational health and safety (OHS) norms for processing industries.

4) Government policies and regulation

According to Garg et al. [24] the government promotions and policies are a strong motivation for many manufacturing firms as by abiding the government policies organizations can publicize their products to be standard and safe that will enhance the image of organization and improve its market share. It is very good and safe for consumers as well as for safeguarding of environment. As described by Bhanot et al. [23] that the conformance to law enforcement and judicial regulations is essential to maintain proactive environmental strategies to enhance environmental performance.

5) **Lowering processing cost**

Based upon the report presented by The National Manufacturing Competitiveness Council (NMCC) [17] said that low cost of manufacturing is always a motivating factor for any organisation as it would increase their customer segments. To maintain both low cost of product and quality is difficult according to Bhanot et al. [23].

IV. Analytical Heirarchy Process (AHP)

The concept of AHP was developed by Thomas L. Saaty in 1970s and has been extensively studied and refined since then. The AHP is a structured technique for organizing and analysing multiple criterion decisions. According to Saaty [25] the steps to be followed while implementing AHP technique are described below:

Step1: Develop a decision hierarchy by decomposing the entire problem in to hierarchy of parameters or criteria.

Step2: Establish priorities among the factors or criteria of the hierarchy by making a series of judgments based on pair wise comparisons. In this step preferences among parameters are rated on the scale 1-9.

Step3: Synthesize these judgments to yield a set of overall priorities for the hierarchy. In this step weighted criteria scores are calculated which yields relative ranking of factors or criteria.

Step4: Compare the qualitative and quantitative information using informed judgments to derive weights & priorities for checking the consistency of the judgments. The consistency ratio must be less than 10% (or 0.1) for validation of the relative comparisons.

Step5: Selection of best alternative on the basis of available sample data and calculating the final score of each alternative.

The formula used during solving the matrices in AHP steps is given in Table II and the flow chart of AHP steps is shown in figure1.

$A\omega = \lambda_{max}\omega$, where A is preference matrix, ω is Eigen Vector of order n, λ_{max} is Maximum Eigen value.

Consistency Index, $C.I. = \frac{\lambda max - n}{n-1}$, where n is the number of Parameters.

Consistency Ratio, $C.R. = \frac{C.I.}{R.I.}$, where R.I. is Random Index

For selection of best option:

Option performance matrix × Eigen value vector = Final score vector

Table –II Criterion for Satty's Rating [25]

Degree of importance	Description
1	Two factors are having equal importance
3	One factor is less important than the other
5	Much important over the other factor
7	Very much importance of one factor over the other
9	Highest possible importance of one factor
2,4,6,8	Intermediate values of importance

V. Application Of AHP Technique

The present work focuses on sustainability implementation and in this regard three marble processing industries are considered which are of same segment and are competitor to each other. This study utilizes the survey data to do a comparative analysis for industries under sustainability. The data for pair-wise comparison had been obtained from the results of the survey which was conducted to find out relative importance of factors affecting sustainability concept. A questionnaire based on 5-point Likert scale, was sent to industry experts and academia. They have a good working experience in marble production and processing. AHP is implemented in the following steps:

Step1: Developing a Decision Hierarchy

AHP decision hierarchy (Figure. 2) shows goal, factors and alternatives arranged linearly and the network connections denotes the set of pair-wise comparisons between them.

Step 2: Establishing priorities

After the problem is decomposed into the parameters, the next step is to generate the overall preference matrix as in Table III. This overall preference matrix is formulated by decision makers (include industry experts and academia) through brainstorming sessions.

The next stage, there is a need to calculate pair wise comparisons for marble processing industries MI-1, MI-2, MI-3 in terms of five parameters LPC(Table IV), WWT (TableV), WHS (TableVI), GP (TableVII), RR (TableVIII).

Fig.1. Decision Hierarchy for AHP application

Table-III Overall preference matrix

	LPC	WWT	WHS	GP	RR
LPC	1	1/2	3	2	1/3
WWT	2	1	4	3	1/3
WHS	1/3	1/4	1	2	1/5
GP	1/2	1/3	1/2	1	1/4
RR	3	3	5	4	1

TABLE-IV Preference matrix of the parameter (LPC)

LPC	MI1	MI2	MI3
MI1	1	0.78	0.936
MI2	1.28	1	1
MI3	1.06	1	1

Table-V:Preference matrix of the parameter (WWT)

WWT	MI1	MI2	MI3
MI1	1	0.799	0.826
MI2	1.251	1	1.033
MI3	1.21	0.967	1

Table –VI Preference matrix of the parameter (WHS)

WHS	MI1	MI2	MI3
MI1	1	1.23	0.536
MI2	0.813	1	0.985
MI3	1.865	1.015	1

Table VII. Preference matrix of the parameter (GP)

GP	MI1	MI2	MI3
MI1	1	0.921	1.413
MI2	1.08	1	1.533
MI3	0.707	0.652	1

Table VIII.Preference matrix of the parameter (RR)

RR	MI1	MI2	MI3
MI1	1	1.061	1.097
MI2	0.942	1	1.033
MI3	0.911	0.967	1

Step 3: Synthesis

After preparing the pair wise comparison matrix, calculate the normalized weights (Eigen values) for each factor. Here the number of factors is 5; therefore the random index value for this problem is 1.12 which is taken from Satty's random index table [25]. The 0.447 means the 'Reuse and Recycling of waste marble dust' is the most important factor which affects the sustainability; whereas factor 'government policy' has been given the least importance (0.073).

Table IX. Eigen value vector (λ_{max}, C.I., C.R.) for overall preference matrix

Eigen Value Vector (EVV)	λ_{max}
LPC = 0.156	
WWT = 0.239	CI= 0.0579
WHS= 0.082	
GP= 0.073	CR= 0.0516
RR = 0.447	

In the next stage, calculate the Eigen value vector, λ_{max}, C.I. & C.R. of five parameters LPC(Table X), WWT (TableXI), WHS (TableXII), GP (TableXIII) and RR (TableXIV).

Table X:Eigen value vector (λ_{max}, C.I., C.R.) for preference matrix of LPC

Eigen Value Vector	
	λ_{max} = 3
0.299	C.I. = 0
0.361	C.R. = 0
0.339	

Table XI.Eigen value vector (λ_{max}, C.I., C.R.) for preference matrix of WWT

Eigen Value Vector	
	λ_{max} = 3
0.288	C.I. = 0
0.361	C.R. = 0
0.349	

Table XII. Eigen value vector (λ_{max}, C.I., C.R.) for preference matrix of WHS

Eigen Value Vector	
	λ_{max} = 3.07
0.286	C.I. = 0
0.305	C.R. = 0
0.407	

Table XIII. Eigen value vector (λ_{max}, C.I., C.R.) for preference matrix of GP

Eigen Value Vector	
	λ_{max} = 3
0.357	C.I. = 0
0.388	C.R. = 0
0.253	

TableXIV. Eigen value vector (λ_{max}, C.I., C.R.) for preference matrix of RR

Eigen Value Vector	
0.350	$\lambda_{max} = 3$
0.330	C.I. = 0
0.319	C.R. = 0

Step 4: Check the consistency of the judgments

To ensure whether the pair wise comparisons are logical or not, consistency ratio of comparison matrices are calculated. Here overall preference matrix has C.R. value of 0.0516 and all preference matrices have C.R. values of zero (or equivalent to zero) which are less than 0.1. Therefore in this case all the comparison matrices are consistent.

Step 5: Selection of the best Industry

For selection of the best Industry, final score matrix (Table XVII) is generated from multiplying the option performance matrix (Table XV) with Eigen value vector for overall performance matrix (Table XVI).

Table XV.Option performance matrix

	LPC	WWT	WHS	GP	RR
MI1	0.299	0.288	0.286	0.357	0.350
MI2	0.361	0.361	0.305	0.388	0.330
MI3	0.339	0.349	0.407	0.253	0.319

Table XVI.Eigen value vector for overall performance matrix

Eigen Value Vector (EVV)
LPC = 0.156
WWT = 0.239
WHS= 0.082
GP= 0.073
RR = 0.447

Table XVII.Final score vector

	Final score vector	Rank
MI1	0.321	3
MI2	0.343	1
MI3	0.330	2

VI. Results And Discussion

Today's time is very competitive and in the era of globalization, an organization must be truly focused upon the highly important factors in order to maintain its position in the market. The concept of sustainability has become very crucial in present time for most of the manufacturing and processing firms as due to ever increasing industrialization, the exploitation level of natural resources have come to a very serious situation along with this risk, the risk of health and safety for workers also the economic health of a customer is at stake. It can be summarized that the solution of problems related to environment is adoption of sustainability concept. First level pair-wise comparison, i.e. comparison of attributes with respect to goal, gives the Eigen values which can be used as a score to differentiate between the high importance factors and the low importance factors. In our study we found; reuse and recycling of waste marble dust (EVV 0.447) and waste water treatment (EVV 0.239) are the high importance factors whereas government policy (EVV 0.073) is the least important factor. Reuse and recycling of waste marble dust for marble processing industry (MI1) is better than its competitors whereas, MI1 fares low against its competitor MI3 in the waste water treatment. For all other attributes MI2 fares better. Final results of the AHP bring out MI2 (Final score value 0.343) as the most preferred choice, whereas MI1 (Final score value 0.321) is the least preferred choice for sustainability implementation.

VII. Conclusion

Key factors of sustainability implementation in marble processing industries have been evaluated in the present work using AHP. The decision hierarchy was formed based on key factors of sustainability related to marble processing industries. Then relative importance of factors i.e. factor weights were calculated through pair wise comparison matrix. At the end, the industries' rank was found out based on final score vectors. The present research scores second marble industry as the best in implementation of sustainability as the final score was highest which shows that industry two implements the sustainability in best way and promotes its implementation.

It is suggested that with the use of AHP, marble processing industries can conduct similar studies on a large scale and do the analysis to find out inputs for the future strategic and operational level decisions.

References

[1] Gupta R, Garg TK, Gupta S, and Goel A. "Decision analysis approach for quality in technical education". Global Journal of Human-Social Science Research. 2010 Jan 1; 10(1).

[2] Ohdar, Rajkumar, and Pradip Kumar Ray. "Suppliers' Performance Evaluation and Ranking in a Supply Chain: An Analytical Hierarchy Process-Based Approach." IUP Journal of Supply Chain Management 9, no. 2 (2012): 73.

[3] Lee, E.K., Ha, S. and Kim, S.K., "Supplier selection and management system considering relationships in supply chain management", IEEE transactions on Engineering Management, 48(3), 2001, pp.307-318.

[4] Handfield, R., Walton, S.V., Sroufe, R. and Melnyk, S.A., "Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process". European Journal of Operational Research, 141(1), 2002, pp.70-87.

[5] Haapala, K. R., Zhao, F., Camelio, J., Sutherland, J. W., Skerlos, S. J., Dornfeld, D. A., and Rickli, J. L., "A review of engineering research in sustainable manufacturing", Journal of Manufacturing Science and Engineering, 2013, 135(4), 041013.

[6] Brundtland,G.H.(1985).World commission on environmentand development. Environmentalpolicyandlaw, 14(1),26-30.

[7] Nambiar, Arun N. "Challenges in sustainable manufacturing."Proceedings of the International Conference on Industrial Engineering and Operations Management", Jan. 2010.

[8] Gunasekaran A, and Spalanzani A., "Sustainability of manufacturing and services: Investigations for research and applications, International Journal of Production Economics. 2012 Nov 30, 140(1):35-47.

[9] Zhang HC, Kuo TC, Lu H, and Huang SH. "Environmentally conscious design and manufacturing: a state-of-the-art survey", Journal of manufacturing systems, 1997 Sep 1;16(5):352.

[10] 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.

[11] Topcu,I.B.,Bilir,T.,&Uygunoğlu,T.(2009).Effecto fwastemarbledustcontentasfilleronpropertiesofself -compactingconcrete. Construction and Building Materials, 23(5),1947-1953.

[12] Kishore, I. S., & Chowdary, C. M. (2015). A Study on Waste Utilization of Marble Dust in High Strength Concrete Mix. International Journal of Civil Engineering and Technology, 6, 12.

[13] Hameed, M. S., & Sekar, A. S. S. (2009). Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate. ARPN J. Eng. Appl. Sci, 4(4), 83-89.

[14] Aukour, F. J. (2009). Incorporation of marble sludge in industrial building eco-blocks or cement bricks formulation. Jordan Journal of Civil Engineering, 3(1), 58-65.

[15] Georgiadis, P., & Besiou, M. (2010). Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: a system dynamics analysis. The International Journal of Advanced Manufacturing Technology, 47(5-8), 475-493.

[16] Kulatunga, A. K., Jayatilaka, P. R., & Jayawickrama, M. (2013). Drivers and barriers to implement sustainable manufacturing concepts in Sri Lankan manufacturing sector. 10.14279/depositonce-3753.

[17] NMCC, 2006. The National Strategy for Manufacturing. Technical Report. URL: http://nmcc.nic.in/pdf/strategy_paper_0306.pdf.\

[18] Amrina, E., & Yusof, S. M. (2012). Drivers and barriers to sustainable manufacturing initiatives in Malaysian automotive companies. In Proceedings of the Asia Pacific Industrial Engineering & Management Systems Conference (pp. 629-634).

[19] Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry. Journal of cleaner production, 12(6), 639-662.

[20] Beriha, G. S., Patnaik, B., & Mahapatra, S. S. (2011). Safety performance evaluation of Indian organizations using data envelopment analysis. Benchmarking: An International Journal, 18(2), 197-220.

[21] Hanieh, A. A., AbdElall, S., & Hasan, A. (2014). Sustainable development of stone and marble sector in Palestine. Journal of cleaner production, 84, 581-588.

[22] Aliabdo, A. A., Elmoaty, A. E. M. A., & Auda, E. M. (2014). Re-use of waste marble dust in the production of cement and concrete. Construction and building materials, 50, 28-41.

[23] 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.

[24] Garg, D., Luthra, S., & Haleem, A. (2014). An Evaluation of Drivers in Implementing Sustainable Manufacturing in India: Using DEMATEL Approach. World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic,

Business and Industrial Engineering, 8(12), 3843-3848.

[25] Saaty, T. L. The Analytic Hierarchy Process, McGraw-Hill, New York, 1980.

[26] Shukla, O. J., Jangid, V., Siddh, M. M., Kumar, R., & Soni, G. (2017, February). Evaluating key factors of sustainable manufacturing in Indian automobile industries using Analytic Hierarchy Process (AHP). In Advances in Mechanical, Industrial, Automation and Management Systems (AMIAMS), 2017 International Conference on (pp. 42-47). IEEE.