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KEY PERFORMANCE INDICATORS IDENTIFICATION AND PRIORITIZATION FOR ENVIRONMENTAL SUSTAINABILITY IN THE CEMENT MANUFACTURING INDUSTRY IN PAKISTAN USING ANALYTICAL HIERARCHY PROCESS

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Abstract

This paper examines the role of Key performance Indicators (KPIs) that is believed to influence the environmental sustainability of cement production of Pakistan. Environmental sustainability decision requires a scientific approach of identifying and prioritization of KPIs. The cement industries are confronted with challenges to implement sustainable manufacturing processes. The data gathered through questionnaire distributed among 213 respondents representing 24 cement plants were analyzed using Analytical Hierarchy Process (AHP). The proposed KPIs are supposed to assist the decision makers in achieving environmental sustainability. Among the 11 KPIs identified, the KPI "Total amount of Emissions in Metric tons of CO2 equivalent per year" was identified as having the highest impact on environmental sustainability.

KEYWORDS: *Analytical hierarchy process, environmental sustainability, key performance indicators, carbon foot print, cement.*

INTRODUCTION:

Manufacturers around the world in the past have been using global resources with the sole purpose of economic gains and competition. It has led to the indiscriminate use of the natural resources with minimal regard for the wastages and environmental pollution they created. Sustainable manufacturing gained importance, with companies started focusing on not only fulfilling the current market demands but also keeping in view the future demands(Seuring, Sarkis *et al.,*, 2008, Schoenherr 2012). The fast depletion of non - renewable energy resources and raw materials along with stricter government environmental regulations, and increasing consumer preference for environmental-friendly products, was also forcing these organizations to strive for the sustainable manufacturing (Jayal, Badurdeen *et al.,*, 2010, Amrina and Vilsi 2015) . Man - made activities is one of the major reason for global warming, Greenhouse gas emissions (GHG), bio diversity, deforestation and climate change to name a few. Concrete is one of the most consumed material after water and cement being the primary ingredient in concrete and buildings construction, accounts for 5% of the Global man made carbon dioxide (CO2) emissions (Zhong and Wu 2015).. With increasing urbanization, the demand for building infrastructure is growing, this demand comprises both to repair old infrastructure and a need to build new infrastructure (M.W. Doyle 2009). This growing demand, increased the usage of mineral resources exponentially which is also a source of major environmental concern (Tost, Hitch *et al.,* 2018) The definition of Sustainability focuses on the usage of resources to meet today's requirement without compromising the future generations capability to meet their own requirements (Jonathan D. Linton 2007). The growing commitment to environmental sustainability is visible from the adaptation of environmental initiatives such as ISO 14000 (Montabon, Melnyk *et al.,* 2000, CORBETT and KIRSCH 2001), pollution prevention (King and Lenox 2002, Hoque and Clarke 2013, Bhupendra and Sangle 2016), recycling (Contrafatto 2017, Bourtsalas, Zhang *et al.,* 2018), use of alternative fuels (Rahman, Rasul *et al.,* 2015, Georgiopoulou and Lyberatos 2017, Tsakiridis 2017) and reduction in wastages (Kamalapurkar 2006).

In this study the environmental sustainability KPIs for cement industries are studied and prioritized based on Eigen values achieved by each KPI. Analytical Hierarchy Process (AHP) introduced by Thomas Saaty in 1980 is a tool that can aid in making decisions. It considers a set of criteria and a set of alternatives to make a decision.

Pakistan with 24 cement industries is currently

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producing approximately 49 million tons of cement per annum. Additional plants are in planning and installation phase while some of the existing plants are planning to increase their capacities owing to the increasing demand of local market, due to large scale infrastructure and housing projects. This is a matter of concern for the environment.

METHODOLOGY

The objective of this study was to identify and prioritize the environmental KPIs for sustainability of the cement industry in Pakistan. AHP has been commonly used in multi criteria decision making problems. The questionnaire designed from a literature review was sent to 15 experts and the final questionnaire were prepared after analyzing the KPIs identified with the pilot study through principal component analysis (PCA). The final questionnaire based on Likert scale were then distributed among 213 executives and engineers working in the 24 cement industries within the country; 80 valid questionnaires received, showing a response rate of 37.5% was analyzed through AHP. The results were to identify and prioritize the KPIs based on the Eigen values achieved by each KPI in AHP.

QUESTIONNAIRE DESIGN

The questions concerning environmental sustainability were selected from literature. Several key performance indicator sets have been developed for measuring sustainability but for measuring sustainable manufacturing there are at least eleven major indicator sets that analyze and score sustainability of manufacturing processes (Joung, Carrell *et al.,* 2013), however, there is a lack of agreement between manufacturers as to which indicator set to be used in which industry. There is no agreement on a representative taxonomy of sustainability metrics (Sikdar 2003). Global Reporting Initiative (GRI) has identified a list of 70 indicators covering the all the three areas of sustainability: economic, environment and society. Dow jones sustainability indexes (DJSI) measures the economic aspect with 12 indicators but also covers some environmental and social aspects as well. Amrina and Vilsi identified 19 KPIs for sustainable manufacturing in cement industry (Amrina and Vilsi 2015). The initial list of 19 KPIs identified with literature for measuring environmental sustainability; shown in column 2 of table 1, were distributed among 15 experts as pilot study. The results received from those experts were then evaluated through PCA. PCA is used to extract the significant information from a multivariate data and express that information as a set of new variables called principal components. The PCA was conducted on the 19 environmental KPIs used in the pilot study. Initially the PCA assigned all the KPIs an Eigen value of 1.0 meanings that all the KPIs represent unique information but further analysis identified and removed the communalities among the KPIs and a new set of 6 variables "principal components" were developed, having variance

Table 1. Initial list of key performance indicators

KPI	Environmental Key performance Indicator
En1	Total amount of energy used in Gj/T of Cement production
En2	Total Electricity consumption per ton of cement production.
En3	Total electricity consumed from Renewable sources (Kwh)
En4	Total electricity consumed from Non-Renewable sources (Kwh)
En5	Total amount of coal fuel used per ton of cement production
En6	Total amount of natural gas used per ton of cement production
En7	Total amount of waste fuel used per ton of cement production
En8	Amount of heat captured by ton of cement production
En9	Total amount of Emissions in metric tons of CO2 equivalent per year
En10	Amount of CO2 that is emitted into the Environment.
En11	Amount of significant Air Emissions of SOX
En12	Amount of significant Air Emissions of NOX
En13	Amount of significant Air Emissions of Hazardous Air Pollutants (HAP)
En14	Amount of Air Emissions of Particulate Matter (PM).
En15	Gas and coal fuel are not used for energy generation in the cement production
En16	Total number of grievances filed about environmental impacts.
En17	Total number of the grievances addressed about environmental impacts.
En18	Total number of the grievances resolved about environmental impacts.

greater than 1.0 were selected as shown in column 2 of Table 2.

The cumulative variance represented by these 6 principal components was 71.209% as shown in column 7 of Table 2. Factor loading on these 8 components showed that only 11 KPI's from Table 3 have a correlation value equal to or more than 0.60. Final questionnaire consisting these 11 KPIs was developed and distributed.

Table 2. List of principal component analysis along with variance

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	Percentage of Variance	Cumulative Percentage	Total	Percentage of Variance	Cumulative Percentage
1	5.513	30.625	30.625	5.513	30.625	30.625
2	2.213	12.295	42.921	2.213	12.295	42.921
3	1.543	8.575	51.495	1.543	8.575	51.495
4	1.311	7.281	58.777	1.311	7.281	58.777
5	1.209	6.716	65.493	1.209	6.716	65.493
6	1.029	5.716	71.209	1.029	5.716	71.209
7	.842	4.679	75.887			
8	.742	4.120	80.007			
9	.604	3.354	83.362			
10	.556	3.091	86.453			
11	.531	2.950	89.403			
12	.481	2.673	92.075			
13	.338	1.876	93.951			
14	.309	1.717	95.668			
15	.266	1.478	97.146			
16	.229	1.273	98.419			
17	.167	.928	99.346			
18	.118	.654	100.000			

The Likert scales questionnaire consisting 11 Environmental KPIs was then distributed among 213 executives and engineers in 24 cement plants in Pakistan.

Table 3. Factor Loading of KPIs on Components

	Component					
	1	2	3	4	5	6
En 11	.811					
En 12	.772		-.332			
En 14	.765					
En 4	.755					
En 09	.651	-.341				
En 10	.601		-.317		-.463	
En 07	.595				-.319	
En 05	.577			-.455		
En13	.571			.535		-.363
En 16	.413	.708			.346	
En 17	.399	.686				
En 02		.616	-.503			

En 03	.371	.431	.386			
En 08	.448		.706			
En 01	.422		.503			
En 18	.437			-.662		-.301
En 15			-.348		.706	
En 06	.400	-.488				.533

Likert scale is usually used to determine the respondents' opinion, therefore 5 point Likert scale was used for 1 being strongly disagree and 5 being strongly agree.

RESEARCH METHODOLOGY

Analytical Hierarchy Process (AHP) introduced by Thomas Saaty in 1980 is known as the structured multi-attribute decision method and is a widely used tool that helps the decision makers with complex decisions making by helping the decision maker to set criteria to make a decision. Here the AHP is adopted to assign weights and prioritize the KPIs. AHP is used to assign weights and rate the KPIs, this method can identify the important KPIs from other KPIs by assigning numerical weights representing the relative importance of each KPI. This five step process is shown in Fig. 1. The AHP methodology is based on the three principles: (1) Decomposition (Stage 1 and 2), which develops the hierarchy to identify the goal, criteria and KPIs; (2) Comparative judgement (Stage 3); pairwise comparisons of criteria to establish priorities; and (3) synthesis of priorities into overall rating (Stage 4 and 5)(Ali and Al Nsairat 2009). In stage 1 the research problem and objectives were defined. The research problem was to develop a weighting system for assessment of KPIs that affect environmental sustainability of cement manufacturing in Pakistan, and the objective was to prioritize and assign weights to each of the identified KPI. The problem was broken down into an environmental hierarchical structure in stage 2 as shown in Fig. 2; the top level of the hierarchical model is defined as the goal, the second level is the criteria and the third level is the KPIs In stage 3, the pairwise comparisons were conducted for each KPI over the other KPI. A matrix (A) was formed, in which each entry aij in the matrix was built by comparing the row element Ai with the column element Aj (Ramanathan 2001)

A = (aij) (i,j , 1, 2,….,the number of criteria)

The pairwise comparisons were determined between

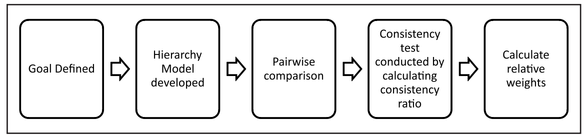

Figure 2: Five stages of Analytical Hierarchy Process

KPIs. A Saaty' scale of 1 to 9 (1= equally, 3= moderate, 5= strong, 7= very strong, 9= extreme) was used to reflect these preferences.

Once the judgmental matrix was formed, the local priorities were then calculated, and the consistency of the outcome was determined. In order to avoid inconsistency, the consistency ratio (CR) was calculated at stage 4, to measure the degree of contradictions in the opinions of the survey respondents. The CR was calculated at each level using the following formula.

$$Consistency\ Ratio = \frac{Consistency\ index\left(CI\right)}{Random\ Index\left(RI\right)}$$

Where

$$CI = \frac{\lambda_{max} - n}{n-1}$$

$$\lambda_{max} = approximation\ of\ the\ maximum\ eigen\ value$$

$$n = number\ of\ elements$$

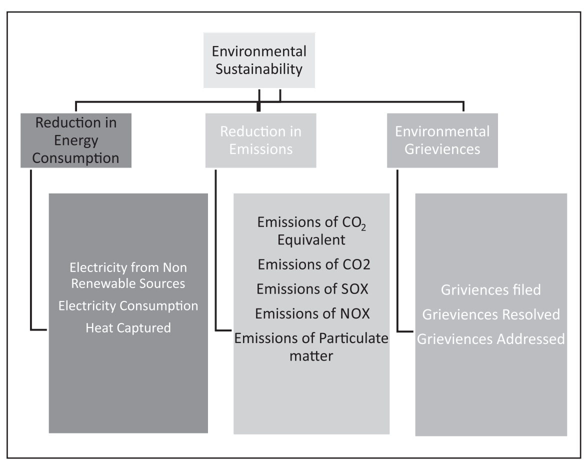

Figure 2: Hierarchy process of AHP

If the CR is lower than 0.1, then it is determined that the weights assigned in stage 5 are valid. Otherwise the results are inconsistent and the comparison has to be repeated again. The consistency test revealed that the consistency ratio for all the comparisons is 0.0, which shows that all the pairwise comparisons are consistent. This indicates that the respondents have selected their preferences consistently in identifying the importance weightages to the KPIs.

Table 4. Weightage and Ranking of Environmental KPIs

Criteria	Weight	Key Performance Indicator (KPI)	Weight	Ranking
Reduction in energy consumption	0.27797	Total Electricity Consumption	0.09613	2
		Electricity from Non Renewable Sources	0.09285	4
		Heat Captured	0.08898	8
Reduction in Emissions	0.46815	Emissions of CO2 Equivalent	0.09821	1
		Emissions of CO2	0.09464	3
		Emissions of SOX	0.09285	5
		Emissions of NOX	0.09136	6
		Emissions of PM	0.09107	7
Environmental Grievances	0.25386	Grievances Filed	0.08541	9
		Grievances Resolved	0.08482	10
		Grievances Addressed	0.08363	11

Table 4 shows the summary of the results of the importance weights assigned to all the environmental KPIs of the sustainable cement manufacturing. The importance weights shows the importance value of one KPI over the other KPI. The ranking was assigned to each KPI depending according to the weightage. In terms of criteria the reduction in emissions achieved the highest importance weight (0.46815) followed by reduction in energy consumption (0.27797) and environmental grievances (0.25386), whereas in key performance indicators "emissions of CO2 equivalent" was considered to be the most important KPI among all the KPIs (0.09821) while total energy consumption (0.9613) is considered to be the most important KPI among the Reduction in energy consumption Criteria.

CONCLUSIONS

The cement industry consumes a large quantities of raw materials and energy. It emits enormous amount of CO2, SOX, NOX and PM into the environment, it is therefore essential to measure the environmental sustainability of cement manufacturing. This paper has identified environmental sustainability KPIs from literature to evaluate sustainability in cement industries. The initial KPIs identified with literature were validated through pilot survey. A hierarchy model was then developed using AHP methodology. The importance weights were assigned through pairwise comparisons and ranking of the KPIs were developed accordingly. The 11 environmental KPIs in column 3 of table 4 belonged to 3 criteria shown in column of table 4. The criteria "reductions in emissions" was the most important criteria having importance weightage of 0.46815, while the KPI "emission of CO2 equivalent" was the most important KPI having the highest importance weightage of 0.09821 This paper has identified and prioritized the KPIs for environmental sustainability in cement manufacturing. This research will help the organizations to focus on continuous improvement in the areas (KPIs) to achieve the environmental sustainability.

Future Recommendations

Similar studies are suggested to be performed to identify and prioritize the economic and social aspects of the cement manufacturing sustainability to achieve and assess the total sustainability, furthermore it is suggested to study the impact of each aspect of sustainability; environment, economic, and social on each other.

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