

# GREEN MANUFACTURING PRACTICES IN BRICK INDUSTRIES: A CASE STUDY USING AHP

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**Abstract:** This paper presents an exploratory study in an environmentally important but less researched Brick industries situated at Ranchi, Jharkhand, India and its outskirts areas having manufacturers within 20 km radius. This study has been done due to ever increasing requirement for organizations to be more environmentally responsive with respect to their product and process planning, design and striving positively towards their competitive outcomes in Real Estate Business. Factors taken into consideration are: Quality/Technology, Recycle/Reuse (water, solid waste), Reduce Energy Use, Reduce Emissions, Reduce Solid Waste, Train employees in sustainability, Encouraging suppliers to use sustainable process. The industries management supported and advised for the weight age of different criteria. All criteria with the simultaneous evaluation of industries were evaluated using Analytical Hierarchical Process (AHP) developed by SATTY in 1970's. which is a powerful and flexible decision making tool for complex, multi criteria problems. Consistency ratio was calculated. Based on Composite Rank Score decisions and recommendations were made. These findings /recommendations can be helpful to different organizations as they respond to environmentally demands.

**Keywords:** Green Manufacturing, Consistency ratio, AHP, Brick Industries.

## I. INTRODUCTION

Commitment to natural environment has become an important variable within the current competitive scenarios. Over decades, there has been a renewed focus and increasingly motivation towards green manufacturing. The opportunities for companies to use green practices to enhance their reputation and strengthen their position in the marketplace constitute the business case for green production. Financial institutions increasingly price companies according to their social & environmental liabilities, thus leading investors to take into consideration corporate green reputation during their acquisition decisions. (Dobers & Wolff, 2000), (Fairchild, 2008) [1],[2],[3]. There is a growing body of environmental regulations (e.g. in Europe, ELV 2000, WEEE 2003, RoHS 2003, PPW 2004, EUP 2005, REACH 2007) and also ISO9001, ISO14000, and OHSAS18000 that are forcing companies to reduce their resources consumption, to minimise their waste, and to take responsibility for the take-back of products at the end of the use phase (Kleindorfer et al., 2005; van Hillegerberg et al., 2001) [4]. Porter and Van der Linde (1995) [5] provide several examples of how environment focused can help companies use a range of inputs more productively. Such innovations include process enhancements, more complete material utilisation, design simplification, recycling of scraps, etc. The commercial brick industries has had a long history of environmental challenges, including heavy use of resources, disposal of manufacturing waste, & disposal of manufacturing waste, & disposal of used products. (Cathy, 2007) [6].

There are several green manufacturing practices (criteria's) which could be considered in case of brick industries for competitive outcomes. The Quality/Technology (Q/T) plays an important role in brick manufacturing as quality and technology are inter dependent, if we use the highly improved technologies such as VSBK (vertical shaft brick kiln)

due to which there is efficient heat transfer between bricks and air circulation is possible. Kiln is well insulated on all sides resulting in better output. (VSBK Technology, Sameer Maithel, 2007) [7]. In initial phase of brick making process plenty of water is used from blending to separation which can be recycled along with solids remain which can be reused thus justifying Recycling Water/Solid Waste (RC W/S). (Green Brick Making Manual, vsbk, cesef, Nepal) [8]. As the ever increasing requirement, we need to reduce the demand of energy in the whole process as by making of hollow bricks which reduces the mass to be fired thereby reducing the energy consumption thus justifying Reduce Energy Use (REU) (Green Brick Making Manual, vsbk, cesef, Nepal) [8]. In any brick firing the source of environmental pollution is the use of external fuel with high sulphur & high ash content as well as incomplete combustion of same releases higher amount of suspended particulate matter in the atmosphere and by using internal fuel emissions can be reduced to certain level thus justifying Reduce Emissions (RE). (Green Brick Making Manual, vsbk, cesef, Nepal). Solid wastes can be controlled by modifications in moulding so that collected remain should be again blended or should be used for other constructive work thus justifying Reduce solid waste (RSW). Training of employees in sustainability (TES) of any firm is the need of the time so that green manufacturing initiatives can cope up the ever increasing demand as they involve the positive attitude of the employees towards environment. Encouraging Suppliers to use sustainable measures (ESUSM) is important because it will directly or indirectly save our environment and the valuable resources as they are the first consumers and the prime motive of the green manufacturing is to reduce the resources utilisation, reduce emissions, and beating the competitive race with sustainable & healthy environment for a greener future. In the process of our evaluation using AHP [10], [11], which has been used extensively for studying case studies, outranking method, promethee method [12], [13], [14], [15], around seven industries (AA, BB, CC, DD, EE, FF, GG) are requested to evaluate the impact of the above mentioned factors on the prospects of advantageous green manufacturing and after the evaluation recommendations will be made. We will say about industries ranking which will determine up to what extent they are opting for green manufacturing process factors or criteria's in their business routine. While we can't fully say or conclude that answers may reflect the effects of product as well as process innovations, but it can be expected that people/employees tend to have process innovations in mind when answering this question which would reflect the effects of process innovations. More recent empirical studies that find a generally positive relationship between environmental manufacturing process and competitive outcomes [16], [17].

## II. METHODOLOGY

AHP is a systematic procedure for representing the elements of any problem hierarchically. The pair wise comparison matrix is of size  $n \times n$ , where  $n$  is number of elements to be compared pair wise. The matrix will be filled up accordingly using the following procedure.

(a) Each element compared with itself will get a value 1. i.e.  $a(1,1)=a(2,2)=a(3,3)=\dots a(n,n)=1$ .

(b) When the  $i$ th element is compared with  $j$ th element, it has got the value  $A(i,j)$ ,  $j$ th element being compared with has got a value  $a(j,i)=1/a(i,j)$ . i.e.  $a(1,2)=1/a(2,1)\dots\dots a(n,1)=1/a(1,n)$ .

(c) Relative Weight (RW)

$$= \sqrt[n]{a(1,1) \times a(2,1) \times a(3,1) \times a(4,1) \times a(5,1) \times a(6,1) \times a(7,1)}$$

(d) Normalized weight (NW) =  $RW / \sum RW$ .

(e) Maximum Eigen Value ( $\lambda_{Max}$ ) =  $\sum \text{column A} \times \text{NW value row A} + \sum \text{column B} \times \text{NW value row B} + \dots + \sum \text{Column n} \times \text{NW value row n}$ .

(f) Consistency Index (CI) =  $(\lambda_{Max} - n) / (n - 1)$

(g) Random Index (RI) =  $1.98 \times (n - 2) / n$ .

(h) Consistency Ratio (CR) =  $CI / RI$ , should be within 10 percent

(i) Composite rank (COR) = NW Parameter 1 weightage × NW of that Parameter + NW Parameter 2 weightage × NW of that Parameter + ..... + NW Parameter n weightage × NW of that Parameter.

III. CASE STUDY

This study was conducted on brick industries located near Ranchi, Jharkhand state, India. which deals with the green manufacturing issues, the commercial sector of real estate business is selected because the commercial sector is more advanced with respect to sustainable manufacturing practices; more importantly the methods of recovery and disposal in resident market and also ever increasing demand for the population needs. Some researchers have found that environmental practices may have a negative impact on company’s performance, however other research indicates that being environmentally proactive can produce competitive gains. Criteria for evaluation are Quality/Technology(Q/T) , Recycle/Reuse (water, solid waste) (RC W/S),Reduce Energy Use(REU), Reduce Emissions(RE), Reduce Solid Waste (RSW), Train employees in sustainability(TES), Encouraging suppliers to use sustainable process (ESUSM).

Relative Weight (RW), Normalised Weight (NW)

RW of Q/T is =2.661103

NW of Q/T is 2.661103/8.618956= 0.30875

Similarly RW and NW for other criteria are calculated.

$\lambda_{Max} = 7.449093$

$$CI = (\lambda_{Max} - n) / (n-1) = (7.449093-7) / (7-1) = 0.074848833$$

$$RI = 1.98 \times (7-2) / 7 = 1.414285714$$

$$CR = CI / RI \times 100 = 0.052923417\% \text{ (10\% < is acceptable)}$$

Similarly all other values corresponding to (RC W/S), (REU), (RE), (RSW), (TES), (ESUSM) are calculated

Table 1 represents the matrix for weightage to all seven criterias corresponding to green manufacturing. In Table 2- Table 8 relationship matrix for all seven brick companies are calculated corresponding to one criterion at a time. Table 9 represents the relative worth of alternatives.

Criteria	(Q/T)	(RC W/S)	(REU)	(RE)	(RSW)	(TES)	(ESUSM)	RW	NW
(Q/T)	1	3	2	2.5	3.5	4	4.5	2.661103	0.30875
(RC W/S)	0.333333	1	1.5	2	3	3.5	4	1.705661	0.197896
(REU)	0.5	0.666667	1	5	2	3	3.5	1.661809	0.192809
(RE)	0.4	0.5	0.2	1	2.5	2	3.75	0.959736	0.111352
(RSW)	0.285714	0.333333	0.5	0.4	1	2.5	2	0.714687	0.08292
(TES)	0.25	0.285714	0.333333	0.5	0.4	1	5	0.586283	0.068022
(ESUSM)	0.222222	0.25	0.285714	0.266667	0.5	0.2	1	0.329678	0.03825
TOTAL	2.99127	6.035714	5.819047	11.66667	12.9	13.7	23.75	8.618956	1

Table 1: Matrix for weightage to criteria:

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	3	5	2	2.5	3.5	5.5	2.827197	0.298435
BB	0.333333	1	2	3	4	4.5	5	2.099819	0.221654
CC	0.2	0.5	1	2.5	3.5	4	3	1.399214	0.147699
DD	7.449093	0.333333	0.4	1	3	2.5	4	1.624033	0.171431
EE	0.4	0.25	0.285714	0.333333	1	3	4.5	0.745993	0.078746
FF	0.285714	0.222222	0.25	0.4	0.333333	1	2	0.458086	0.048355
GG	0.181818	0.2	0.333333	0.25	0.222222	0.5	1	0.319074	0.033681
TOTAL	9.849959	5.505556	9.269048	9.483333	14.55556	19	25	9.473416	1

Table 2: Relationship Matrix for Q/T

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	2	5	2.5	3	3.5	5	2.788963	0.32174
BB	0.5	1	2	4.5	3	3.5	2	1.915158	0.220936
CC	0.2	0.5	1	1.5	2	4	4	1.251181	0.144339
DD	0.4	0.222222	0.666667	1	4	3	3.5	1.139127	0.131412
EE	0.333333	0.333333	0.5	0.25	1	1.75	3	0.687934	0.079361
FF	0.285714	0.285714	0.25	0.333333	0.571429	1	2.5	0.515837	0.059508
GG	0.2	0.5	0.25	0.285714	0.333333	0.4	1	0.37017	0.042704
TOTAL	2.919048	4.84127	9.666667	10.36905	13.90476	17.15	21	8.66837	1

Table 3: Relationship Matrix for RCW/S

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	2	2.5	3	3.5	4	4.5	2.661103	0.304589
BB	0.5	1	4	3	2	3.5	2.5	1.944202	0.222532
CC	0.4	0.25	1	2	3	4	5	1.426162	0.163238
DD	0.333333	0.333333	0.5	1	4	4.5	3.75	1.207826	0.138247
EE	0.285714	0.5	0.333333	0.25	1	2.75	2	0.677437	0.077539
FF	0.25	0.285714	0.25	0.222222	0.363636	1	3	0.459559	0.052601
GG	0.222222	0.4	0.2	0.266667	0.5	0.333333	1	0.360424	0.041254
TOTAL	2.99127	4.769048	8.783333	9.738889	14.36364	20.08333	21.75	8.736713	1

Table 4: Relationship Matrix for REU

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	3.5	3	3.75	2	4	4.5	2.819795	0.33504
BB	0.285714	1	1.5	2.5	2.75	1.75	1.25	1.304987	0.155055
CC	0.333333	0.666667	1	3	1.5	2	2.5	1.258499	0.149531
DD	0.266667	0.4	0.333333	1	3	5.5	6	1.196954	0.142219
EE	0.5	0.363636	0.666667	0.333333	1	3.5	5	0.951688	0.113077
FF	0.25	0.571429	0.5	0.181818	0.285714	1	2.75	0.519444	0.061719
GG	0.222222	0.8	0.4	0.166667	0.2	0.363636	1	0.364932	0.04336
TOTAL	2.857937	7.301732	7.4	10.93182	10.73571	18.11364	23	8.4163	1

Table 5: Relationship Matrix for RE

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	1.75	2.5	4	3.5	5.5	5	2.890146	0.332241
BB	0.571429	1	1.5	4.5	4.25	1.5	3	1.84858	0.212506
CC	0.4	0.666667	1	1.75	3.75	2.5	4	1.50514	0.173025
DD	0.25	0.222222	0.571429	1	2	1.75	2	0.806648	0.092729
EE	0.285714	0.235294	0.266667	0.5	1	2	3	0.658661	0.075717
FF	0.181818	0.666667	0.4	0.571429	0.5	1	2	0.599114	0.068872
GG	0.2	0.333333	0.25	0.5	0.333333	0.5	1	0.39067	0.04491
TOTAL	2.888961	4.874183	6.488095	12.82143	15.33333	14.75	20	8.698958	1

Table 6: Relationship Matrix for RSW

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	3	2.75	5	3.5	4.25	4	3.049842	0.350283
BB	0.333333	1	2.5	2	2.25	4.75	2.5	1.719981	0.197545
CC	0.363636	0.4	1	1.5	3.75	3.5	2.25	1.304926	0.149874
DD	0.2	0.5	0.666667	1	4	2	3	1.069449	0.122829
EE	0.285714	0.444444	0.266667	0.25	1	1.25	1.75	0.565608	0.064962
FF	0.235294	0.210526	0.285714	0.5	0.8	1	4	0.582097	0.066855
GG	0.25	0.4	0.444444	0.333333	0.571429	0.25	1	0.414899	0.047652
TOTAL	2.667978	5.954971	7.913492	10.58333	15.87143	17	18.5	8.706801	1

Table 7: Relationship Matrix for TES

Brick Industries	AA	BB	CC	DD	EE	FF	GG	RW	NW
AA	1	2	3	4	5	3.25	4.25	2.883513	0.311634
BB	0.5	1	2.5	3	4.5	5.5	4.5	2.368115	0.255933
CC	0.333333	0.4	1	3	3.25	3.5	5.5	1.584046	0.171195
DD	0.25	0.333333	0.333333	1	2.5	4.5	1.75	0.917393	0.099147
EE	0.2	0.222222	0.307692	0.4	1	2	3.75	0.633673	0.068484
FF	0.307692	0.181818	0.285714	0.4	0.5	1	5	0.553839	0.059856
GG	0.235294	0.222222	0.181818	0.571429	0.266667	0.2	1	0.312299	0.033752
TOTAL	2.82632	4.359596	7.608558	12.37143	17.01667	19.95	25.75	9.252878	1

Table 8: Relationship Matrix for ESUSM

Criteria	(Q/T)	(RC W/S)	(REU)	(RE)	(RSW)	(TES)	(ESUSM)	Composite Rank Score
Criteria Weightage	0.30875	0.197896	0.192809	0.111352	0.08292	0.068022	0.03825	
Brick Industries								
AA	0.298435	0.32174	0.304589	0.33504	0.311634	0.332241	0.350283	0.313686453
BB	0.221654	0.220936	0.222532	0.155055	0.255933	0.212506	0.197545	0.215563024
CC	0.147699	0.144339	0.163238	0.149531	0.171195	0.173025	0.149874	0.153988185
DD	0.171431	0.131412	0.138247	0.142219	0.099147	0.092729	0.122829	0.140653957
EE	0.078746	0.079361	0.077539	0.113077	0.068484	0.075717	0.064962	0.080873531
FF	0.048355	0.059508	0.052601	0.061719	0.059856	0.068872	0.066855	0.055925756
GG	0.033681	0.042704	0.041254	0.04336	0.033752	0.04491	0.047652	0.039308598
Total								0.999999503*

Table 9: Relative worth of alternatives

\*Taking (0.999999503= 1.00 Approximately)

Composite rank (COR) of AA Brick Industry is calculated as:

$$(0.30875 * 0.298435) + (0.197896 * 0.32174) + (0.192809 * 0.304589) + (0.111352 * 0.33504) + (0.08292 * 0.311634) + (0.068022 * 0.332241) + (0.03825 * 0.350283) = 0.313686453$$

Similarly COR was calculated for the Brick Manufacturing Industries (BB ,CC,DD,EE,FF,GG). Maximum COR means most preferred for green manufacturing practices.

Brick Industries	Composite Rank Score	Rank
AA	0.313686453	1
BB	0.215563024	2
CC	0.153988185	3
DD	0.140653957	4
EE	0.080873531	5
FF	0.055925756	6
GG	0.039308598	7

Table 10: Rank table

## IV. RESULTS &amp; CONCLUSION

As per the composite rank score obtained using the tool AHP (TABLE 10) we can say that A,BB,CC,DD,EE,FF,GG is in the order of most preferred selection for green manufacturing practices and hence by using this we can recommend for the greener manufacturing practicing among investigated Brick industries in our survey. The manufacturing practices in Bricks industries can be incorporated to achieve greenness. The proposed method using AHP among large number of existing manufacturing processes to assess suitability in this case study. AHP not only helps to arrive at best decision but also provides a clear rationale for the choice. This is true for any industry. The proposed method offers more objective, simple and consistent greenness approach. This is very scientific approach and it gives correct results in less time.

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