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Empirical Analysis of Barriers to Energy Efficiency in Small Scale Industrial Cluster

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Abstract

Objectives: This research work is conducted in small scale industries to highlight energy efficiency gap that has often been neglected from the analysis in manufacturing cluster. The study is done to evaluate - Intensity of Barrier (IOB), Easiness of Barrier Removal (EOB) and Impact of Barrier Removal (IBREE) on Energy Efficiency for the top four barrier-groups by using mathematical model based on Analytic Hierarchy Process (AHP). **Methods/Statistical Analysis:** The data for AHP matrix is collected through an online questionnaire sent to 180 respondents from the list of 330 industries selected randomly. The four barrier groups are selected based on various studies conducted on Barriers to energy efficiency in India and abroad. The total cluster population consists of 330 Small Scale Manufacturing units in Mohali district of Punjab. Considering the reliability of respondents, the confidence interval 0.20 and confidence level 95% is chosen respectively. The calculated sample size using these parameters is 22. **Findings:** The Results highlighted many important findings that inhibit the energy efficiency benefits is these cluster and affect degree of implementation. Policy and Regulatory Barrier followed by Personal & Informational Barrier having score value 0.36 and 0.24 respectively are found to be high-intensity Barriers that act as impediments to energy efficiency policies in manufacturing cluster. The Personal & Informational Barrier is easiest to remove whereas Policy and Regulatory Barrier is most difficult to remove barrier group according to AHP results. **Application/Improvements:** The analysis pointed out that if Policy and Regulatory Barrier is removed would result in significant chances of achieving energy efficiency in these clusters. An initiative from state government bodies in collaboration with field specific experts is necessary to formulate effective policies to address this barrier group. The Personal & Informational Barrier can be addressed through regular interactions with experts, training programs and behavior modification techniques.

Keywords: AHP, Barriers, Criteria-Alternatives, Energy-Efficiency, Manufacturing Cluster

1. Introduction

India accounts for 4.5 percent of industrial energy use worldwide. Energy supply and consumption in India was 819 and 493 million tonnes of oil equivalents (MTOE) respectively in 2011. The energy demand is expected to increase further with rapid industrialisation and economic expansion. It is essential to optimise our methods of energy use due to limited resources and ever-growing demand.[1,2] SSI have a significant role in the Indian economy, contributing 40% in domestic and 35% in exports business which accounts for 7% of India's GDP, producing more than 7500 diversified products.[3] SI is clustered almost all across the county forming roughly above 2400 groups.[4] The definition of small scale industry in India is termed as "Any enterprise having an investment in plant and machinery more than twenty-five lakh rupees but does not exceed five Core rupees".[5] The SSI Enterprises employed more than 30 million people and generated 4200 billion US dollars in the year 2014-15 as per report of finance ministry of India.[6] The SSI clusters consume significant energy that cannot be ignored. According to IEA estimates, SSI accounts to more than 11 % of total global energy demands which is equivalent to 74 exajoules.[7] The rough estimation of cost-effective measures on energy efficiency could bring down

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their energy consumption up to 30% as per IEA report published in 2014 These clusters are usually engaged in producing similar types of products, having similar work culture, skill and awareness level. Small scale industries lack resources to explore energy efficient systems due to little knowledge about their energy usage pattern and lack of funds whereas large scale industries have largely overcome these obstacles. It is, therefore, necessary to analyze and identify most recurring barriers prevalent in SSI to address them scientifically. The research on impediment to energy efficiency started almost two decades ago classified barriers into six categories and developed a theoretical framework.[8] A part of literature comprised of empirical studies who extended the work of Sorrell to a step further.[9-13] Apart from this, many case studies conducted in energy intensive industries provides a better understanding and vivid pictures of barriers dimensions, inter-relationship and their intensity present empirical investigation of 71 Italian manufacturing SMEs through multiple case studies approach, he identified various drivers to energy efficiency like high energy prices, strict energy policies, brand name and long term benefits that promote energy efficiency in industries.[14] Barriers to energy efficiency in developing countries are more significant, due to fewer research studies and weak energy policies as compared to developed countries reported a lack of reliable indicator of energy intensity for energy intensive sectors of India like Iron and steel, cement, paper and pulp on energy efficiency ground. [15] He reported many interesting factors due to which energy efficiency technologies are compromised. He also suggested few reforms cut down CO2 emissions devised a Demand Side Management (DSM) model for electric utilities to increase energy efficiency and reducing barriers to natural adoption of energy efficiency studied small-scale foundry clusters in north Karnataka to identify relevant barriers in foundry units.[16,17] He priorities these barriers into five major categories using has done a deep analysis of two energy intensive clusters of SSI to reverse their closure following court orders.[18] TERI and DCSSI-Development Commission initiated These projects in small-scale industries. This study reviewed various attempts done at grassroots to increase energy efficiency. The failure of many industrial energy efficiency programs in the United States is accounted for inappropriate government policies, regional differences and lack of R&D activities within industrial clusters published his research findings giving many valuable suggestions on R&D partnership, voluntary information exchange programs, regulatory policies and financial schemes for successful implementation of energy efficient technologies.[19]

2. Methodology

2.1 Introduction to AHP

N.L. Satty developed the Analytic Hierarchy Process (AHP) technique in the 1970s. AHP helps decision-makers choose the best solution from several options and selection criteria.[20] It has been used widely in many complex decision-making problems such as Operation research, energy policy, and performance measurement and advanced manufacturing technologies.[21] It is well tested and accepted problem-solving model used across the world by scientists, managers and research scholars. AHP uses the judgments of decision makers to form a decomposition of problems into hierarchies. Problem complexity is represented by the number of levels in the hierarchy which combine with the decision-making model of the problem to be solved.[22] The ranking of decision items using comparisons between each pair of items expressed as a matrix. Paired comparisons produce weighting scores that measure the importance of criteria after considering every alternate pair using matrix algebra to sort out factors and arriving at a mathematically optimal solution.

2.2 Problem Formulation using AHP Framework

- Define the main objective of the problem
- Identify criteria and their alternatives as in section C and D.
- Structure the problem as a hierarchy of Goal, Criteria and Alternatives (Figure 1).
- Assign the weights by working through the matrix comparing each of the criteria, deciding the most important by assigning the appropriate score from Table 1.
- Construct a pair wise matrix by dividing each element by its respective columns sum, and ensure consistency of pairwise comparison.
- Similarly developing ratings for each decision alternatives on each criterion by developing pairwise comparison and check a Consistency Ratio (CR).

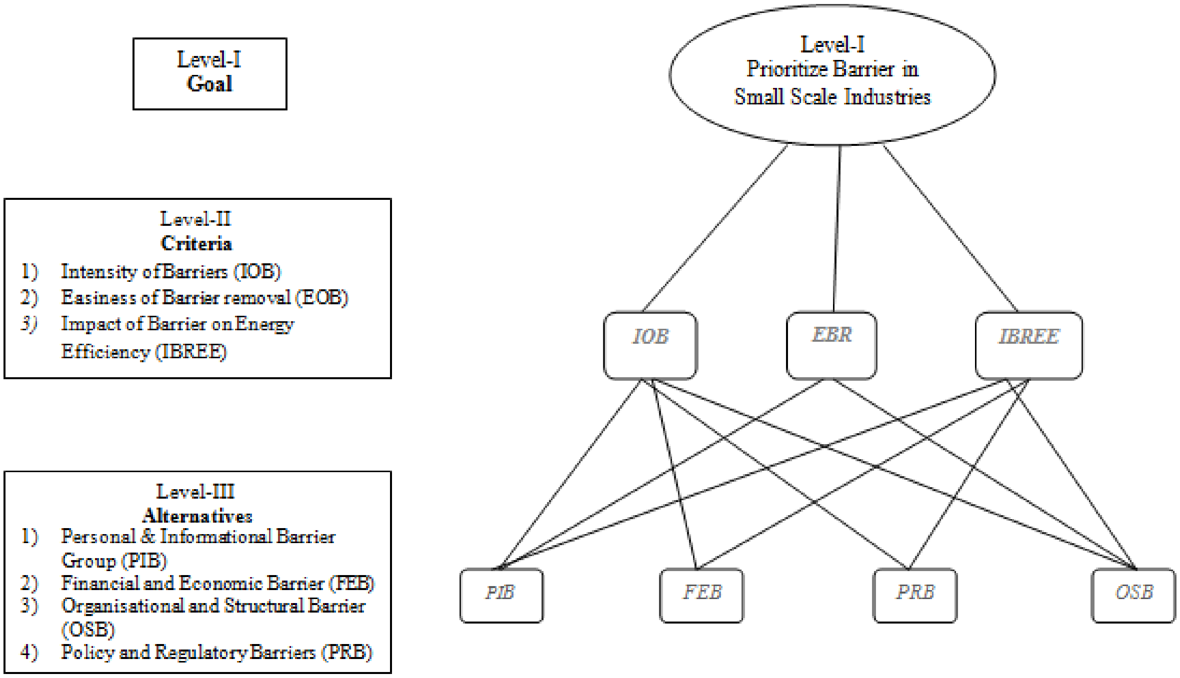

Figure 1. Analytic Hierarchy Process Model-Tree.

Finally, calculate the weighted-average ratings for each decision alternative and order them according to their score values.

Table 1. Criteria for pair-wise comparison for assigning weight

Numerical Rating	i = Criteria along Row j = Criteria along Column
3	i is strongly important than j
2	i is slightly more important than j
1	i is equally important to j
1/2	j is strongly important than i
1/3	j is slightly more important than i

2.3 Procedure

The barrier group is chosen after feedback from the industrial owners and concerned staff through a questionnaire based on various barrier groups that are of relative importance. The scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision maker, which is followed by discussions with experts and energy managers of the region. The dimensions of selected barrier group is discussed in section-D

2.4 AHP Level-I Selection of Criteria

2.4.1 Intensity of Barriers (IOB)

It is taken as an indicator of the occurrence of a barrier group which is considered to be the most prevalent within the industrial cluster. This barrier group would require greater efforts and resources to remove it.

2.4.2 Easiness of Barrier Removal (EOB)

The second criterion is taken as ease of barrier removal, which is an indicator of efforts required to eliminate a particular barrier group. The level of efforts is assumed to be different in each class of barrier group. The efforts may be in the form of awareness programs, policy changes, capital investments, time and human resources. For example, the Informational and Awareness barrier is easier to remove compared to policy and regulatory barrier.

2.4.3 Impact of Barrier on Energy Efficiency (IBREE)

The perceived impact of barrier removal on energy efficiency is to be considered in this criterion while assigning priorities to a barrier groups under this criteria. The impact of barrier removal is measured by considering all the direct and indirect benefits.

2.5 AHP Level-II Selecting Barrier Groups

2.5.1 Personal and Informational (PIB)

This Barrier group is found to directly affect the implementation of energy efficiency programs in SSI since most of them are governed by the owner of the industry. The technological decisions solely depend on his awareness and education level. The main hurdles come under this barrier group are other priorities, lack of interest, lack of awareness, remote location, lack of access to technical experts and poor communications with R&D institutions.

2.5.2 Financial and Economic Barrier (FEB)

This is one of the major impediments faced by many SSI concerning resistance to energy efficient investments, lack of funds, financial constraints, rigid government financing schemes and high investment cost of newer technology may be the factors. These barriers can be removed by appropriate policy interventions, incentives on energy savings, providing sufficient information on energy efficient technologies available in the market and floating flexible public partnership financing plans.

2.5.3 Organisational and Structural Barrier (OSB)

The small scale industries often face the resistance of staff and workers to technological changes. The corporation of the employee is a fundamental element in the success of energy efficiency programs. The joint initiative by government and industries is necessary to motivate the workers in adopting energy efficient technologies.

2.5.4 Policy and Regulatory Barriers (PRB)

In many instances, SSI lags behind LSI because of lack of cluster specific policies which must be formulated to sustain economic and technological growth. This inefficiency may result in usage of obsolete and inefficient technologies. Moreover, standards and labelling are not made mandatory in most of the cases due to which suppliers do not provide sufficient information about equipment energy efficiency and other performance parameters.

3. Data Collection

The data is collected from non-energy intensive SSI industrial cluster located in Mohali (Punjab) which is a satellite town of Chandigarh. It is one of the prominent Manufacturing industrial clusters of this region. There are around 4000 MSME units in the Mohali, divided into nine different industrial zones out of which there are 330 registered manufacturing SSI units' producing tractor and automobile parts, sheet metal components, forging and railway components, bathroom fittings and fasteners.[23] The general characteristic of the industrial cluster under study is given in Table 2. The sample size is calculated using the Slovin's formula for a finite population with following parameters:

Table 2. Characteristics of SSI in Mohali cluster, source

Cluster size	About 330 firms
Main products	Forging, Railway, auto and tractor parts
Sample size	Randomly selected 22 SSI firms
Annual energy consumption	1600 toe/ year
Energy breakup	Electrical 84%, diesel 14%, Furnace oil 2%

At 95% confidence level, the z-score would be 1.96

Taking maximum value of Standard Deviation for unknown population, σ = 0.5

Confidence Interval, e = 20%

Population size, N = 330

$$\text{Sample size, n} = \frac{\dfrac{z^z * p(p-1}{e^2}}{1+(z^z * p(p- \over e^2 N}$$

The calculated value of n is 22. Data is collected through a questionnaire specifically designed to get precise feedback on four relevant barrier groups in present case study. Link to this questionnaire has been sent to 180 manufacturing units selected randomly from a proposed list through email. The response of only 9 percent is received initially from 16 respondents. Through regular follow-up, the response is increased to 12 percent recording total of 23 replies. A guided interview is also conducted for prioritisation of barrier groups within each criterion. This feedback is sufficient in developing AHP hierarchy model. Four points Likert scale is used to assess the barrier intensity.

4. Results and Discussions

4.1 Barrier Ranking based on Alternatives

A pair-wise comparison matrix as shown in Table 3(a) is developed by using three criterion IOB, EBR, and IBREE by computing weights according to average AHP scale, Table 1. The choice of weight is based on feedback from respondents as depicted in Tables 3-6. The resulting normalized Matrix and relative scores are shown in Tables 3B-6B. Similarly, three pair-wise comparison matrices are developed for each of the four alternatives for each criterion, the pair-wise comparison for each group against every other barrier group in a matrix related to given criteria. The PRB group has shown prominence with a score of 0.42 Table 4A, which indicates that Policy and Regulatory Barrier is perceived to as a major hurdle by SSI. This can be attributed to the fact that most of the government policies are formulated without giving personal attention to such industrial clusters. On the contrary, these industrial clusters need to be studied at a regional level. The PIB got the second rank, which indicates that low awareness level, lack of initiatives and lack of interest are found to be made an impact on energy efficiency implementation programs. The results for the matrix: Easiness of Barrier removal Table 5A, 5B is showing OSB with a score of 0.38 got the first rank followed by PIB with a score of 0.24. The Organizational and Structural Barrier is assumed to be removed easier as compared to PRB and FEB, but there is a good scope for Personal and informational Barrier. It is imperative to assume that PIB and OSB are interlinked to some extent as owners are solely responsible for organization culture; therefore these two barriers are considered to be easily removed as compared to other two. The last criteria IBREE Table 6A, the PRB with a score value of 0.40 followed by PIB with a score of 0.23 Table 6B are assumed to make a high impact on Energy Efficiency if removed effectively. This result seems to validate the previous results that high-intensity barriers if removed effectively would help to attain the energy efficiency. The overall ranking of barrier group at third level is done by pair-wise comparison of each element at each level of the hierarchy and then for criteria on proceeding level Table 7. A normalised matrix is formed by dividing each matrix element by sum of the respective columns element and calculating the arithmetic mean of each row to calculate the priority vector. The results of Table 7 indicate Policy and Regulatory Barriers (PRB) on the top of the list followed by Personal & Informational Barrier (PIB) with scores 0.36 and .24 respectively. It indicates that PRB is considered to be the primary barrier group, comparing the result with previous studies in countries like Sweden and Italy. In [9] for Swedish non-energy-intensive manufacturing Industries for Italian manufacturing SMEs on foundry industrial cluster have not highlighted this as a major issue. It is obvious that Indian policies for SSI lack many ground level issues which need to be reviewed with mutual efforts of Ministry of small scale industrial experts, manufacturers and owners. The second barrier group PRB has been reported by many researchers like Rohdin and Hollander in their research on Barriers to and driving forces for energy efficiency in the non-energy-intensive manufacturing industry also reported this barrier as a major hurdle in the case of SSI.

Table 3a. Pairwise comparisons among Criterion

Criterion	IOB	EBR	IBREE
IOB	1	2	1/3
EBR	1/2	1	1/3
IBREE	3	3	1
Column Total	**4.50**	**6.00**	**1.67**

Table 3b. Normalized matrix, CR=0.6

IOB	EBR	IBREE	Scores
0.22	0.33	0.20	0.25
0.11	0.17	0.20	0.15
0.67	0.50	0.60	0.58
1.00	1.00	1.00	0.99

Table 4a. Pairwise comparisons among alternatives for IOB

IOB	PIB	FEB	PRB	OSB
PIB	1	2	1/2	2
FEB	1/2	1	1/3	1
PRB	2	3	1	2
OSB	1/2	1	1/2	1
Column Total	**4.00**	**7.00**	**2.33**	**6.00**

Table 4b. Normalized matrix, CR=0.2

PIB	FEB	PRB	OSB	Scores
0.25	0.29	0.21	0.33	0.27
0.13	0.14	0.14	0.17	0.14
0.50	0.43	0.43	0.33	0.42
0.13	0.14	0.21	0.17	0.16
1.00	1.00	1.00	1.00	0.99

Table 5a. Pairwise comparisons of alternatives for EBR

EBR	PIB	FEB	PRB	OSB
PIB	1	2	2	1/2
FEB	2	1	2	1/3
PRB	1/2	1/2	1	1/2
OSB	2	3	2	1
Column Total	**5.50**	**6.50**	**7.00**	**2.33**

Table 5b. Normalized matrix, CR=0.6

PIB	FEB	PRB	OSB	Scores
0.18	0.31	0.29	0.21	0.24
0.36	0.15	0.29	0.14	0.22
0.09	0.08	0.14	0.21	0.12
0.36	0.46	0.29	0.43	0.38
1.00	1.00	1.00	1.00	0.96

Table 6a. Pairwise comparisons of alternatives for IBREE

IBREE	PIB	FEB	PRB	OSB
PIB	1	2	1/3	2
FEB	1/2	1	1/2	2
PRB	3	2	1	2
OSB	1/2	1/2	1/2	1
Column Total	**5.00**	**5.50**	**2.33**	**7.00**

Table 6b. Normalized matrix, CR=0.9

PIB	FEB	PRB	OSB	Scores
0.20	0.36	0.14	0.29	0.23
0.10	0.18	0.21	0.29	0.18
0.60	0.36	0.43	0.29	0.40
0.10	0.09	0.21	0.14	0.13
				0.95

Table 7. Final Matrix of Overall Scores

	IOB	EOBR	IBREE	Overall Scores
PIB	0.07	0.04	0.14	0.24
FEB	0.04	0.03	0.11	0.18
PRB	0.10	0.02	0.24	0.36
OSB	0.04	0.06	0.08	0.17
Column Total	**0.24**	**0.15**	**0.56**	**0.95**

5. Conclusion

Looking at the current trend of imposing strict pollution related policies and hiking retail energy prices by central and state governments to promoting energy efficient technologies in Small Scale Industries seems to fail in achieving targets. This may be the reason that most of the SSI owners perceive Policy and Regulatory Barrier (PRB) as the main hurdle. The energy efficiency can be achieved by promoting flexible and technology specific policies which can address cluster problems. Initiating awareness programs about the adoption of energy efficient technologies and lending expert help while purchasing new equipment. It is observed that there is broad diversification in technology being used in similar types of industries; some are very efficient, while others are inefficient, but the users are not aware of it. The government has to play a significant role by providing experts of relevant technology and giving free access to consultancy services. Most of the SMEs don't have any scientific approach while purchasing new technology and pieces of equipment, and hence they end up in buying cheap but most inefficient technology which results in inefficiency and higher production costs in the long run. The regular training programs and interaction with experts could help to reduce PIB barrier within the organisation.

The survey is still in progress, and we are awaiting responses from many industries from other regions like Baddi and Panchkula. While conducting survey interviews, we came across many suggestions from managers and industrial owners. Most of them admit that very few people are sensitive towards the environment and make personal efforts to save energy; otherwise, most of the staff never bothers about this aspect neither they have any awareness of energy efficiency.

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