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Cities and the Environment (CATE)

Volume 10
Issue 1 *Biodiversity, Ecosystem Services, and Urban Design*

Article 10

2017

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Recommended Citation

Abraham, Pleasa Serin and Gundimeda, Haripriya (2018) "'Greening' the Buildings - An Analysis of Barriers to Adoption in India," *Cities and the Environment (CATE)*: Vol. 10: Iss. 1, Article 10.
Available at: https://digitalcommons.lmu.edu/cate/vol10/iss1/10

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'Greening' the Buildings - An Analysis of Barriers to Adoption in India

The building sector is one of the main contributors to climate change with its high energy footprint. However, the potential of this sector in reducing greenhouse gases at low cost to get fair returns offers a win-win scenario for planners and environmentalists. In addition, they do offer substantial advantages to customers like property appreciation, reduction in electricity and water consumption, reduction in waste generation, use of green and less energy-intensive materials in construction and preservation of greenery. Despite the environmental and economic advantages offered by the green buildings, the shift has been difficult due to multi-faceted barriers. The objective of this paper is to quantitatively identify, rank and prioritize the barriers to the adoption of green building using the Analytic Hierarchy Process (AHP). The study identifies 20 specific barriers which are classified in four categories- (1) Policy and Market Barriers; (PMB) (2) Financial and Economic Barriers (FEB); (3) Information, Promotion and Education Barriers (IPE) and (4) Managerial and Organizational Barriers (MOB). Seven groups of stakeholders - builders, potential occupants, architects, engineers, project managers, contractors, and government representatives took part in the ranking and prioritization of barriers. Calculation of local and global weight reveals that IPE barriers are ranked high and PMB comes second whereas FEB and MOB lag much behind with lower global weights. Among the top seven specific barriers, lack of expertise in life-cycle cost, lack of information on benefits on green buildings, lack of labeling and lack of infrastructure and training are the barriers which belong to IPE barrier category. Weak enforcement of building codes, the absence of incentives and high capital costs also find space among top seven specific barriers with high weights.

Keywords

Green building, stakeholder perception, Analytical Hierarchy Process, building sector, credence good

Acknowledgements

The authors wish to thank the guidance and help on 'Green Building Rating' received from The Energy Research Institute (TERI), India.

1. INTRODUCTION

The construction sector's high energy footprint is responsible for 33% of all energy-related emissions and is expected to emit between 11– 15.6 billion metric tonnes by 2030 in a high growth scenario according to the Intergovernmental Panel for Climate Change (IPCC, 2007). Construction is the second largest economic activity in India after agriculture, employing 33 million employees directly and contributing 52.4% of gross fixed capital formation (NSDC, 2009). The sector has a large resource footprint, accounting for 30% of electricity consumption, 23.6% of greenhouse gas (GHG) emissions and 10% of total electricity consumption (Parikh et al. 2009). The construction sector has two sub-segments - real estate (residential, commercial, industrial and Special Economic Zones) and infrastructure (transportation, urban development, utilities); real estate contributes 24% of value addition to the construction industry (NSDC, 2009).

The importance of the construction industry as a mitigation option is especially important in light of the Indian Government's pledge to voluntarily reduce domestic emission intensity levels by 20-25% by 2020 and the current focus on low carbon inclusive growth in the twelfth five-year plan. India has developed an ambitious Intended Nationally Determined Contribution that envisions reducing the country's emissions intensity of its GDP by 33–35% by 2030 from the 2005 level, which is 75% higher than the target set earlier (MoEF, 2015). Government initiatives, such as one hundred 'Smart Cities' in India, aim to build climate resilient cities with the principles of recycling and reuse of waste, use of renewable energy and protection of the natural environment, and are based on lines of sustainable urban development.

The building sector is part of the larger construction sector, which in India is growing at 10% annually. Green buildings[1] offer potential opportunities to curtail further buildup of GHGs and adapt to climate change at least-cost (IPCC, 2007) through substitution of raw materials, use of energy efficient technologies, energy conservation, waste treatment, low emissions and the reduced usage of hazardous substances. Green buildings in the residential and commercial sector can play a major role in the ongoing efforts to mitigate and adapt to climate change. Most of the commercial buildings in India, for instance, have an Energy Performance Index[2] (EPI) of 200-400 kWh/m2/year and the improved design practices can reduce the EPI to 100-150 kWh/m2/year (Vedala, et al., 2012). The sector consumes 40% of the energy, 30% of raw materials, 20% of water and 20% of land in cities, 30% of solid waste generation, and 20% of water effluents discharged in the Indian cities (Satya et al. 2016).

Since the inception of sustainable development movements, various building rating systems have been adopted in different parts of the world including: the Building Research Establishment Environmental Assessment Method (BREEAM), the European Union's Energy Performance of Buildings Directive (EPBD), Canada's Building Environmental Performance Assessment Criteria (BEPAC), Green Building Tool (GBTool), LEED (Leadership in Energy and

[1] "Green building" is a term encompassing strategies, techniques, and construction products that are less resource-intensive or pollution-producing than regular construction. The scope is wide that it can mean a building merely doing without extra space, finishes, or appliances or a building that substitutes a less polluting product for more polluting ones (Hoffman & Henn, 2008). In literature, it is sometimes called low impact building, high-performance building, and sustainable building.

[2] EPI (Energy Performance Index): Indicates the specific energy usage of a building. It is the ratio of total energy used to the total built-up area. Total built-up area excludes basement and parking areas.

Environmental Design), etc. In India, two major green building rating systems currently publicize the adoption of energy efficient sustainable buildings - LEED, developed by the Indian Green Building Council (IGBC), and GRIHA (Green Rating for Integrated Habitat Assessment), developed by TERI (The Energy Research Institute). LEED India ratings are provisioned for new construction as well as Core and Shell, Green Factory Building, Green SEZ (Special Economic Zone) and Green Cities. GRIHA is an indigenous rating system for new construction based on nationally accepted energy and environmental practices. GRIHA rating guidelines keep in view the Indian agro-climatic conditions and in particular the preponderance of non-air-conditioned buildings.

Despite the fact that green buildings have the potential to offer win-win scenarios and that green buildings are currently constructed in different countries, we believe that the adoption of green buildings does have some barriers. The barriers arise due to the inherent complexities and the high degree of conflicting priorities involving multiple stakeholders in the fragmented building sector. The adoption of green buildings is dependent on the perceptions of the stakeholder on possibility and risk of adoption in green practices. For successful adoption, an integrated approach across all stakeholders is required and the building sector should take into consideration the expectations and endeavors to meet their needs (Bal et al. 2013). A green building project can only happen when constant communication and idea exchange is assured between the stakeholders. While the relative literature on barriers to energy efficiency is pretty rich, there is a dearth of India-specific studies on barriers to green building. There are business case studies and market research studies on green buildings which provided useful insights. However, barriers to the adoption of green buildings must be identified and studied systematically, as not much has been done in the Indian context.

Under this backdrop, the study aims to understand the barriers to the adoption of green buildings in India and tries to quantitatively identify, rank and prioritize the barriers. The paper is organized as follows: Section 2 explains the methodology and data collection along with the profiling of different stakeholders who were part of the questionnaire survey. Section 3 lists the barriers to adoption and section 4 applies the Analytic Hierarchy Process (AHP) methodology to analyze the barriers and section 5 discusses the results of the study and section 6 concludes the study with policy suggestions.

2. METHODOLOGY AND DATA

As prioritizing the barriers involves multiple criteria rather than a single criterion and involves both tangible and intangible qualitative value judgments, we used Analytic Hierarchy Process (AHP) to rank and identify the most significant barriers. Application of AHP involves three fundamental concepts: 1) structuring the complex decision problem as a hierarchy of goal, criteria, and alternatives; 2) a pair-wise comparison of elements at each level of the hierarchy with respect to each element on the preceding level; and 3) vertically synthesizing the judgments over different levels of the hierarchy (Saaty, 1980).

Before seeking the views of selected stakeholders, the following steps were taken: 1) identified the potential barriers from the literature and focus group discussions with experts working in Green Building Rating Systems; 2) used a questionnaire survey to elicit the qualitative and quantitative responses of various stakeholders and 3) determined a normalized weight for each barrier category and each specific barrier. The approach was to conduct both structured and unstructured interviews within focus groups to identify the main barrier categories and the indicators to be incorporated into the questionnaire for further analysis. Opinions and judgments were sought from the experts who are knowledgeable about the working of the construction sector. The professionals working in green building rating mechanisms like LEED and GRIHA participated in focus group discussions to give significant insights into the linkages among different stakeholders and the functioning of the building sector. Based on the focus group discussions, twenty specific barriers and four barrier categories hindering the widespread adoption of green buildings were identified and seven groups of stakeholders were identified to be part of the survey.

The questionnaire survey was carried out in the Indian cities of Delhi, Mumbai, and Bangalore. Approximately 250 questionnaires were distributed and sent to stakeholders and 105 were completed and passed the consistency test. Purposive random sampling was used to elicit the rankings and preferences to get respondents from a range of disciplines and with different levels of expertise.

Stakeholder involvement is considered a key element in generating value; in the context of construction industry, value signifies parameters like cost, function, and quality. Value is generated through a process of negotiation between customer ends and means (Salvatierra-Garrido et al. 2010). Emmitt *et al*. (2004) divided value into two; external value and internal value. External value is the client/customer value, the value that the project should end up with and the delivery teams focuses on achieving. Internal value is the value by and between the participants of the delivery team. Bjornfot and Sarden (2006) stress considering stakeholders and argue that internal value should be delivered considering the owner, user and society, and that external value should be delivered by keeping in mind the concerns of the contractor, sub-contractor and designer. The coordination activities among construction sector stakeholders can significantly influence the success of a project. Being a highly fragmented industry, the lack of coordination between the efforts of owners, consultants and clients can create serious issues like non-compliance to the schedule, cost and non- adherence to quality and failure to reduce disputes (Jha & Mishra, 2007). Ballard (2000) shows that most acute flow problems of construction are caused either by traditional design, production and organization concepts, or the peculiarities of construction and these significantly influence the three main processes - *design, construction and project management.* Lovins (1992) points to the fact that although all the stakeholders are in pursuit of a common goal, their priorities, performance objectives, and incentive structure are different. Stakeholders' are financed, designed, coordinated and operated within this institutional framework of the sector. The fragmented nature of the sector, false price signals, outdated 'rules of thumb,' conflicting objectives between multiple actors, along with perverse incentives like the fee/remuneration structure of engineers and project managers, increases complexity in taking energy efficiency investments. The tight schedules to complete assignments and the tendency to oversize HVAC systems because of safety margins are some disadvantages. The difficulty in carrying out interdisciplinary work between coordinators and specialists is an important issue with the work culture in the building sector. The integrated design approach is essential to meet sustainability goals in the building sector. Mechanical designers are usually among the last to do design work for a given building: they are presented with building form and envelope, lighting and plug loads as given, not as variables to be co-optimized with their own options. Designers are also concerned about getting penalized if their design is underspecified but there is no penalty for oversizing. The fee structure for engineers and designers also favors over-specification as the fees are calculated as a percentage cost of equipment. These kinds of perverse and misplaced incentives in the building sector lead to oversized HVAC systems. Unless stakeholders are rewarded for the energy savings from the system, they will continue to design energy systems with high capital cost, without considering operational cost. The failure to adopt sustainability goals in the building sector is to a large extent associated with conflict between stakeholders, be it in the name of performance measures, challenges or incentives (Lovins, 1992). The green goals of the building sector can only be addressed through cooperation and the practice of interdisciplinary discussions between stakeholders. The Integrated Design Approach could only find limited success in building sector due to this confrontational culture and conflicting objectives between stakeholders instead of cooperation.

Seven groups of stakeholders who have a significant role and potential in influencing the adoption of green building measures were identified for the study based on the literature review and focus group discussions with experts in the building sector. The seven stakeholder groups chosen are: 1) developers, investors and builders, 2) occupants, 3) architects and designers, 4) engineers, 5) contractors and sub-contractors, 6) project managers, and 7) government authorities. This categorization is based on the performance objectives, shared challenges and disincentives they face in the adoption of green practices stakeholders in the status-quo situation. Table 1 highlights how the indicators of performance/measurement, the challenges and incentive structure vary across the stakeholders.

Table 1: Stakeholders: Objectives, Challenges and Disincentives

Stakeholders	Performance Measures	Challenges in the adoption of green practices	Disincentive faced for promotion of green building
Developers, Investors & Builders	Rupees / sq.ft, risk-reward ratio, return on investment, resale value	Energy costs is just one of the costs, absence of life cycle costing	High investment made in the building does not fetch high resale value or higher rents.
Occupants	Increased employ satisfaction and productivity, long-term comfort, low operation & maintenance costs	Lack of knowledge about new innovations & technology	No indicator for high performance or green building, invisibility of green elements.
Architects, Landscape Architects, Interior designers	Aesthetics, visual & space planning	Safety motives, data shortage discourages optimal sizing, design is changed as per convenience	Fee structure disincentivizes green innovation in design, concerns about potential liability is met by over-sizing at the expense of clients.
Engineers (Civil, Water, Structure, mechanical, electrical)	Watt/sq m, kW/ton	Joins at a later stage and not part of conceptualization, working on multiple projects at a time, lack of interaction between different departments	Engineering fees have been customarily based on a percentage of the capital cost of the project, process like installation of equipment rewards over-sizing.
Contractors & Subcontractors	Budget & schedule, profit margin	No long-term contract on efficient functioning, liability is there for under sizing not for creative initiatives, familiarity and punctuality of suppliers is important	Absence of relational contracting, presence of short-term partnering
Project Managers	Critical path and drawing adherence	Between owner and designer, time, price and familiarity works. Not responsible for operating budgets. Needs to change the design as per convenience and availability of materials, adoption of green measures incur more work.	More work in limited time, more coordination required. Always there is a tendency to follow 'rules of thumb'
Government Authorities	Implementation of building codes and compliance with other laws and regulations	Data shortage, lengthy process for commissioning	Difficulty in educating stakeholders, non-mandatory nature of several sections in building codes due to mounting pressure from multiple group of people

The questionnaire consisted of three parts: problem definition, the specification of barrier categories for assessment, and ranking the specific barriers. The participants were asked to rank these barriers based on their perceptions and the questionnaire has been semi-structured with more space for listing additional perspectives. The representative profiles and percentage distribution of the stakeholders who have participated in the questionnaire are given in Table 2.

Table 2: Representative profiles of the stakeholders

Stakeholder	Number of Responses	Percent of Valid Questionnaires	Nature of Respondents
Architects	28	26.67	Industry experience of the respondents who have participated varied from 1-25 years. People who work practice in other firms and those who practice independently have participated.
Engineers	15	14.29	Industry Experience of respondents varied from 1-35 years. Projects have been carried out in public and private sector. Few of them have worked in green building projects.
Realtors/ Builders	7	6.67	Mid-level builders operating in Delhi and Mumbai. No one had experience in green construction. Most of them were in residential and commercial construction.
Government Authorities	17	16.19	Authorities are in charge of commissioning, verification and sanctioning of the building. All were based in Delhi and Mumbai.
Contractors/ Sub-Contractors	11	10.48	Mainly in the supply of raw materials, equipment, precast systems. All of them are in the construction business for more than 15 years.
Occupants	13	12.38	Administrative level officials of firms who already have an office space which the firm owns or are at lease.
Project Managers	14	13.33	Professionals with industry experience that varies from 6-23 years. Already been part of public, private and PPP projects in commercial, residential and infrastructure construction.
Aggregate	105	100	

3. WHAT ARE THE 'BARRIERS TO ADOPTION OF GREEN BUILDINGS'?

The barrier literature on energy efficiency and green investment is very rich. Different researchers adopt varying terminologies to describe them. According to Hirst and Brown (1990), there are several structural and behavioral barriers that do not allow green technologies to be adopted. The former includes distorted market signals, limited financial capital, regulatory policies, codes and standards, and the latter includes stakeholders' attitude towards energy efficiency, perceived risk of energy efficiency investments, information gaps and misplaced incentives. Bates (1993) blames market imperfections, distorted price signals, and the deficient decision-making process for underinvestment in energy services market. Lovins (1992) points out the perverse incentives to stakeholders, fragmentation in the construction sector, lack of coordination, and obsolete rules of thumb as the main barriers that resist investment in energy efficiency. Golove and Eto (1996) identify six barriers: misplaced incentives, lack of access to financing, flaws in market structure, mispricing imposed by regulation, decision-making influenced by custom, lack of information or misinformation and inseparable features of gadgets which cannot be compromised while going for energy efficiency. According to Weber (1997) there are institutional barriers, organizational barriers and behavioral barriers. Brown (2007) classifies barriers to development and deployment of environment-superior technologies as cost-effectiveness barriers, fiscal barriers, regulatory and statutory barriers, intellectual property barriers and information barriers. Reddy (2007) identifies that the barriers faced by the industry are multifaceted: the technology specific (micro), organizational (meso), external structures (like government, market), and civil society (macro). Neiji and Moukametshina (2009) point out issues like high initial cost, design style, aesthetics, unavailability, lack of awareness, incompatibility, performance problems, compatibility dissatisfaction, product size and discontinuous features of some products to be the main causes behind preventing the adoption of energy efficient devices. Gillingham et al. (2009) lists energy market failures, capital market failures, innovation market failures, information problems and potential market failures as the possible barriers.

Hoffman (2008) found that more than technological and economic factors, social and psychological fears dominate while investing in green buildings. He stresses that behavioral barriers arise from ‘taken for granted’ social and institutional structures and from the psychological perceptions which favor the standardized models and prefer a ‘hands-off’ policy towards off the shelf technologies. Behavioral barriers can arise at the individual, organizational and institutional levels.

Some cross-country observations are noteworthy. The UK construction industry underwent major changes after the Egan[3] and Latham[4] (Egan 1998; Latham 1994) reports were published. Now they have also set up initiatives to include climate goals in the construction sector. Some of the recommendations include making developers more accountable for the performance of buildings in use, widespread adoption of whole life costing, encouragement of integrated design, adoption of post-occupancy evaluation, long-term and relational partnership with the client, client education and benchmarking building performances. The United States initiated the ‘2030 challenge,’ calling for all new buildings and renovations to be designed so as to reduce their fossil-fuel, GHG emitting (CO_2) energy consumption. The ‘Building America’ program produces new homes on a community scale that use an average of 40% to 100% less source energy. The ‘ENERGY STAR’ Building Program is the most widely used building energy label for existing buildings in the U.S., which ensures their energy performance (Gupta & Chandiwala, 2011).

Based on the review of the literature and focus group discussions, four main groups of relevant barrier categories were selected for our study – policy and market barriers, financial and economic barriers, information promotion and education barriers and managerial and organizational barriers. The removal of these barriers can bring positive change in the green building industry. Some of the specific barriers are those of the ‘win-win’ type which are relatively

[3]Lord Ethan submitted a report of the Construction Task Force on the scope for improving the quality and efficiency of U.K construction sector in 1998.
[4] Michael Latham submitted a government review on procurement and contractual agreement in the U.K construction industry in 1994

easy to implement as they will only bring gains. At the same time, there are barriers with trade-offs that can lead to revenue loss. Table 3 lists the sub-barriers within these four groups.

1. Policy and Market Barriers (PMB): An external barrier resulting from the inadequacy of regulation due to a lack of adequate incentives for the promotion of green building, weak implementation and execution of building and energy codes, poor standard of commissioning building, etc. that adversely affects the interest of a stakeholder. Due to the small size of markets for green buildings, green rating mechanisms are not popular and as a result, the premium and resale value are not attractive to incentivize the investors.

2. Financial and Economic Barriers (FEB): The high initial investment, limited financial resources and budget act as barriers to the adoption of green buildings. The sector, in addition, faces other barriers including: a lack of soft loans, long payback period, and difficulty in the quantification of benefits. High capital costs and payback period are perceived as potential barriers for green buildings. The threat of riskiness perceived by the banks and financial investments on loan repayment by the client due to an uncertain rate of return on green investment poses a potential barrier. Split incentives exist in this sector, as the actors who spend the money and the investors reaping the benefit of investment are different. Green building is about saving energy, water, and space and optimizing their use. Oftentimes, quantification of the worthiness of green building investments becomes a barrier.

3. Information, Promotion and Education Barriers (IPE): The IPE barriers arise internally due to information asymmetry, lack of knowledge and expertise in life cycle costing of building, etc. The sector has a lot of asymmetric information on technical and management aspects and it impacts various firms and stakeholders in their decision to invest. The asymmetric information pertains to issues like energy efficiency, energy labels, building Acts, wastage, etc.

4. Managerial and Organizational Barriers (MOB): The MOB barriers also arise internally due to the management and organizational structure that disincentivizes the stakeholders, leading to suboptimal investments in green buildings. These barriers, for example, arise from the capital budgeting, daily scheduling of routine tasks, conflicting schedules, fear of outrunning schedule and budget, and from the fragmentation and multiplicity in the industry usually resulting in inertia and exerting pressure on stakeholders, leading to compromises on green motives.

Table 3: Typology of Barriers in the study and their description

Typology of barrier		Description of barriers
A1 Policy and Market Barriers (PMB)		
A1.1	*Absence of economic incentives (ABEC)*	Lack of economic incentives in the form of tax exemption or grants for investments in green buildings by the government in the case of investment in green buildings.
A1.2	*Weak enforcement of building codes (WEBC)*	Non-implementation of the building codes in the country (National Building Code and Energy Conservation and Building Code), which helps evasion from construction regulations.
A1.3	*Lack of popularity of green rating mechanisms (LPGRM)*	Difficulty in understanding the rating mechanisms by the investors, making them skeptical of the ratings.
A1.4	*Lack of significant demand and supply of green buildings in the market (LDS)*	Lack of demand and supply side push leading to slow take-off of green buildings
A1.5	*Poor quality and time lag in commissioning (PQTC)*	Time taken in commissioning a project and non-transparency of the system.
A2 Financial and Economic Barriers (FEB)		
A2.1	*High capital costs (HCC)*	High initial investment costs of new green and sustainable techniques acts as a hindrance in investing in high performance building.
A2.2	*Difficulty in accessing financial capital for green investments (DFCGI)*	Non-relaxation in interest rates from financial institutions for new ventures with high initial investment costs.
A2.3	*High pay-back period and low returns on green building (HPBLR)*	The payback period of such investments is high and returns are low. They cannot fetch attractive premiums or higher rents despite the advantages they have.
A2.4	*Investors and occupants belonging to two different categories (IOP)*	Lack of investments in green buildings due to heterogeneity between those who spend money on improving building features and those who reap benefit out of them.
A2.5	*Difficulty in quantifying the worthiness of investment (DWI)*	Lack of interest in green buildings arising due to the lack of measurement and difficulty in quantifying potential savings in energy, water and waste from the adoption of a particular approach

Table 3, continued

A3 Information, Promotion and Education Barriers(IPE)		
A3.1	*Lack of expertise in the application of life cycle costing of materials and energy efficient techniques in building sector (LELC)*	Priority is given to the initial cost of construction and initial expenditure leaving out the calculations on expenditure over the life time of building. There is a lack of expertise in implementing techniques/features related to green building.
A3.2	*High information costs due to lack of labelling of green products and materials (LLABEL)*	Time and resource costs to research the features and products which are more energy efficient, water-saving and waste minimizing is quite high.
A3.3	*Lack of information related to benefits in green investment (LIGI)*	Lack of proper knowledge on the economic, environmental, health and technological benefits arising out of green buildings.
A3.4	*Additional requirements of training and infrastructure for green construction (AITC)*	High requirement of new equipment, infrastructure, and skilled professionals to get into green construction.
A3.5	*Lack of clarity in green rating systems (LCGR)*	Confusing rating systems and their points and questionable priorities and pragmatism in implementation.
A4 Managerial and Organizational Barriers (MOB)		
A4.1	*Strict norms about the capital budget and fear of overrunning it (SNCB)*	Experimenting with a new design may imply budget over runs and the key motive to operate under the allocated budget acts as a barrier for new green features.
A4.2	*Schedule conflicts and time delays in case of introduction of new styles (SCTD)*	A new style or pattern of construction can adversely affect the committed delivery time and can result in schedule conflicts
A4.3	*Sticking on to 'day to day' routine and resistance to change (DRRC)*	Rigidity to adopt new practices due to resistance towards change, negligence and tendency to stick on to 'status quo.'
A4.4	*Conflicts arising from fragmentation in the industry and disintegration among stakeholders (FICD)*	Conflicts from priority clashes arising from short-term contracts and multiplicity of stakeholders.
A4.5	*Lack of incentives for stakeholders in terms of profits or fees to ensure optimal solutions (NIPO)*	No incentives in the form of profits or fees for the stakeholder to enable the shift to the green features.

4. PROBLEM FORMULATION: ANALYZING THE BARRIERS USING AHP FRAMEWORK

The hierarchy structure of the barriers is given in figure 1. The AHP tree is segmented into four levels: level one introduces the overall barriers inhibiting the promotion of green buildings; the second level contains the four barrier categories; the third level includes five specific barriers under each barrier category, so there are 20 in total; and in the fourth level, barriers are prioritized on the basis of their importance. Any insignificant barriers are given negligible weight.

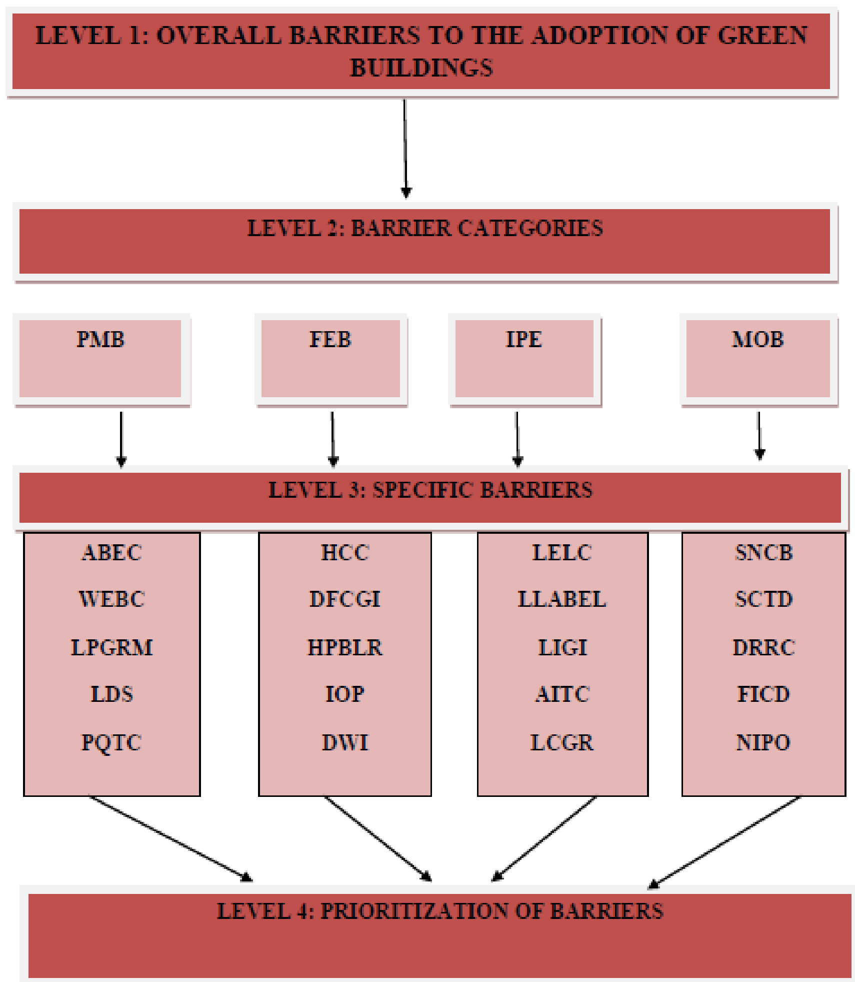

Figure 1: AHP tree hierarchy for prioritization of barriers

Questionnaires were designed to capture the views of seven different stakeholders. The stake-holders were asked to assign ranks to barriers within each major category and the ranks are con-verted to a point scale 1 to 9, where the most intense barrier ranked 1 gets 9 points and the least intense barrier, ranked 5 gets a score of 1. Mean value of ratings of all respondent groups is taken. Each 5 X 5 matrix is constructed using the difference of mean values of the specific barriers and converted using the algorithm given in Table 4. The scale was determined based on the spread of mean difference values.

In the next step, AHP methodology requires pair-wise comparison of the criteria, which requires the criteria to be compared against one another. Pair-wise comparisons allow only two criteria at a time, thereby, translating the problem into a series of pair-wise assessments. The participants are given a scale based on which criteria they weigh more heavily . The number of comparisons that need to be made by each participant is n (n-1)/2, where n represents the number of criteria evaluated. Once all comparisons are completed for the participant, the values give to each criterion are normalized and converted to percentage criteria weight. Five sets of local weights were calculated from five matrixes using equation 1.

$$W_{Bi} = \frac{(\prod_{j=1}^{n} b_{ij})^{1/n}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} b_{ij})^{1/n}} \qquad (1)$$

The sum of one given set of the calculated local weight always equals to 1. The value of a local weight indicates the perceived relative importance of a barrier or barrier category within its comparison matrix, i.e. the relative importance of the specific barrier among the barrier category it belongs to or the relative importance of the barrier category (Shi, Peng, Liu, & Zhong, 2008).After determining the local weights, the global weights of each specific barrier and barrier category are calculated using equation 2.

$$B_i = \frac{\sum_i \prod_j b_{ij}}{\sum \sum_i \prod_j b_{ij}} \qquad (2)$$

Table 4: Pair wise Comparison Scale

Scale	Explanation of Scales	Equivalent Algorithm
>1.75	X is extremely more important than Y	9
1.25-1.75	X is drastically more important than Y	7
0.75-1.25	X is strongly more important than Y	5
0.25-0.75	X is moderately more important than Y	3
-0.25-0.25	X is equally important to Y	1
(-0.25)- (-0.75)	X is moderately less important than Y	1/3
(-0.75)- (-1.25)	X is strongly less important than Y	1/5
(-1.25)-(-1.75)	X is drastically less important than Y	1/7
< (-1.75)	X is extremely less important than Y	1/9

Such an approach gives a better understanding about each criteria barrier and more importantly each barrier category. Thus, this helps in obtaining reliable results of the relative importance of each barrier category and criteria. The upper bound is included in each class.

Normalized Matrix

$$B = \begin{bmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{n1} & \cdots & b_{nn} \end{bmatrix} = \begin{bmatrix} 1 & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ 1/b_{1n} & \cdots & 1 \end{bmatrix} \qquad (3)$$

The sum of one given set of the calculated local weight always equals to 1.

Different from local weights, the global weight indicates the relative importance of each criteria or each barrier category among all the studied barriers and barrier categories. Therefore, the global weights of the four barrier categories on the second level of the tree-hierarchy model are the same as their local weights. On the third level, the global weights of specific barriers are the product of the local weights and the global weights of associated barrier categories on the second level.

5. Results and Analysis

Table 5 depicts the ranking of barrier categories as classified by each stakeholder group according to their global weights. The first column shows the aggregate weight across all the stakeholders for every barrier category. Engineers, realtors, government authorities, occupants and project managers rate the IPE barrier group as the most intense barrier category, while architects and contractors gave this barrier category second and third places respectively. Architects and contractors rate PMB as the most important barrier group. A3, IPE (Information, Promotion and Education barriers), fetches the highest global weight of 0.441. The A1, PMB (Policy and Market Barriers) follows behind with a global weight of 0.268. The A2 and A4, FEB (Financial and Economic Barriers) and MOB (Management and Organizational Barriers), respectively, lag much behind the two by having a global weight of 0.172 and 0.117 respectively.

Table 5: Ranking of barrier categories

Rank	Aggregate Results		Architects		Engineers		Realtors/ Builders		Government Authorities		Contractors		Occupants		Project Managers	
	Barrier	GW	Barrier	GW	Barrier	GW	Barrier	GW	Barrier	GW	Barrier	GW	Barrier	GW	Barrier	GW
1	IPE	0.441	PMB	0.487	IPE	0.640	IPE	0.512	IPE	0.476	PMB	0.461	IPE	0.442	IPE	0.483
2	PMB	0.268	IPE	0.293	FEB	0.278	PMB	0.311	MOB	0.220	FEB	0.254	FEB	0.271	PMB	0.282
3	FEB	0.172	MOB	0.201	MOB	0.071	FEB	0.145	FEB	0.156	IPE	0.240	PMB	0.173	MOB	0.151
4	MOB	0.117	FEB	0.018	PMB	0.012	MOB	0.032	PMB	0.148	MOB	0.031	MOB	0.113	FEB	0.084

Table 6: Ranking of specific barriers

Rank	Aggregate Results		Architects		Engineers		Realtors/ Builders		Government Authorities		Contractors		Occupants		Project Managers	
	Barriers	GW	Barriers	GW	Barriers	GW	Barriers	GW	Barriers	GW	Barriers	GW	Barriers	GW	Barriers	GW
1	LELC	0.220	WEBC	0.238	LELC	0.389	LELC	0.298	LELC	0.241	WEBC	0.258	LIGI	0.222	LELC	0.296
2	WEBC	0.130	ABEC	0.143	HCC	0.158	WEBC	0.160	LIGI	0.121	HCC	0.141	IOP	0.123	WEBC	0.147
3	ABEC	0.081	LELC	0.135	LLABEL	0.136	LLABEL	0.110	SNCB	0.104	LELC	0.132	AITC	0.109	ABEC	0.084
4	LIGI	0.079	NIPO	0.091	AITC	0.069	ABEC	0.103	DFCGI	0.074	ABEC	0.109	ABEC	0.063	SCTD	0.079
5	LLABEL	0.066	AITC	0.081	DFCGI	0.062	LIGI	0.066	ABEC	0.059	LPGRM	0.061	WEBC	0.063	LLABEL	0.069
6	HCC	0.064	LDS	0.044	SNCB	0.035	IOP	0.060	LLABEL	0.048	DFCGI	0.043	HCC	0.059	AITC	0.069
7	AITC	0.061	DRRC	0.044	HPBLR	0.032	DWI	0.060	AITC	0.048	IOP	0.043	DWI	0.059	HCC	0.043
8	IOP	0.038	LIGI	0.043	LIGI	0.028	AITC	0.028	DRRC	0.046	LIGI	0.043	FICD	0.050	SNCB	0.037
9	SNCB	0.034	SNCB	0.038	DRRC	0.021	LPGRM	0.021	WEBC	0.043	LLABEL	0.034	LELC	0.046	LIGI	0.032
10	DFCGI	0.032	LPGRM	0.033	LCGR	0.017	PQTC	0.021	NIPO	0.037	AITC	0.026	LLABEL	0.046	PQTC	0.028
11	LPGRM	0.027	PQTC	0.029	DWI	0.017	HCC	0.016	HCC	0.031	PQTC	0.023	LPGRM	0.028	NIPO	0.020
12	NIPO	0.027	LLABEL	0.018	IOP	0.009	DRRC	0.014	LPGRM	0.031	HPBLR	0.020	LCGR	0.020	DFCGI	0.019
13	DWI	0.025	LCGR	0.017	SCTD	0.007	LCGR	0.010	DWI	0.025	NIPO	0.012	SNCB	0.019	LCGR	0.016
14	DRRC	0.022	SCTD	0.014	NIPO	0.005	SCTD	0.009	SCTD	0.024	LDS	0.010	DRRC	0.019	LPGRM	0.015
15	SCTD	0.020	FICD	0.014	ABEC	0.004	LDS	0.007	LCGR	0.018	FICD	0.009	NIPO	0.019	DRRC	0.011
16	PQTC	0.016	DFCGI	0.005	LPGRM	0.004	DFCGI	0.006	IOP	0.015	DWI	0.007	HPBLR	0.018	HPBLR	0.009
17	LCGR	0.015	IOP	0.005	FICD	0.003	NIPO	0.005	HPBLR	0.012	SNCB	0.007	LDS	0.013	IOP	0.009
18	HPBLR	0.014	DWI	0.004	LDS	0.002	HPBLR	0.004	LDS	0.010	LCGR	0.005	DFCGI	0.011	LDS	0.008
19	LDS	0.013	HCC	0.002	WEBC	0.002	SNCB	0.002	FICD	0.009	SCTD	0.002	SCTD	0.007	FICD	0.005
20	FICD	0.013	HPBLR	0.002	PQTC	0.001	FICD	0.002	PQTC	0.005	DRRC	0.001	PQTC	0.007	DWI	0.004

Table 6 shows the ranking of specific barriers according to the global weights. Among specific barriers, LELC (lack of expertise in application of life cycle costing and other energy efficient techniques in construction sector) emerged as the most important barrier. Engineers, realtors, government authorities and project managers also rated LELC as most intense barrier they face while considering investments in green building. The second and third barriers in aggregate, WEBC (weak enforcement of building code) and ABEC (absence or misplacement of economic incentives) weigh 0.13 and 0.08, respectively, belong to the PMB category. Architects and Contractors rated WEBC as their top priority barrier, while Architects rated ABEC as their second important barrier. LIGI (lack of information relating to benefits in green investment) and LLABEL (lack of labelling of green products and materials make information costs very high) were ranked less important in aggregate with weights of 0.079 and 0.066. HCC (high capital costs) became the sixth most important barrier with a weight of 0.064. These are the top six barriers which need urgent attention when any kind of action is sought in favor of green building.

It must be noted that five of the top ten barriers are internal in nature, that four of them belong to the IPE barrier category and one belongs to the MOB barrier category. LELC, LIGI, LLABEL, AITC which belong to the IPE barrier group have weights of 0.22, 0.079, 0.066, 0.061 and rank one, four, five and seven respectively. SNCB from the MOB category bags a weight of 0.035 and ranks nine.

The five external barriers in the top ten belong to the PMB and FEB groups. They are WEBC, ABEC, HCC, IOP and DFCGI with weights of 0.13, 0.08, 0.064, 0.038, 0.032 and ranks of two, three, six, eight and ten respectively. The first two (WEBC and ABEC) belong to the PMB category and other three (HCC, IOP and DFCGI) to the FEB category.

IPE barriers dominate in a clear way by being the first (LELC), fourth (LIGI), fifth (LLABEL) and seventh (AITC) in the top ten. The PMB group shows its importance by being second (WEBC) and third (ABEC) in the top ten barrier list. From the FEB group, HCC (sixth), IOP (eighth), DFCGI (tenth) marks its presence and the MOB group’s only representation in the top ten barrier list is by SNCB (ninth).

6. CONCLUSIONS AND RECOMMENDATIONS

The building sector has a very important role to play in reducing energy consumption and carbon emissions. However, several barriers hinder the effective adoption and diffusion of buildings with superior environmental performance. This study identified the significant barriers that should be prioritized in the Indian context.

LELC is the lack of expertise in life cycle costing of building and other energy-efficient techniques. The LCC analysis method is used to assess the cost-effectiveness of a building/ building material. More importance is given to the initial cost of building and initial expenditure, while the expenditure over the lifetime of the building is not calculated. A buildings average life would be 50 to 60 years and over its life cycle operating costs like repair and maintenance is going to cost much higher than incremental cost. Building a group of energy experts and training the existing crew can significantly improve the use of this method. The LCC method can be included in the curriculum of disciplines like architecture and engineering. This will give training to future professionals who are supposed to carry forward green projects.

Weak enforcement of building codes and regulations (WEBC) is the second most important barrier. The main building codes in the country are the National Building Code (NBC) and the Energy Conservation and Building Code (ECBC). Codes lay down the minimum requirements for the energy-efficient design and construction of buildings and analysis done during the development of ECBC indicated that energy savings ranging from 27% to 40% could be achieved in an ECBC compliant building. The NBC also gives specification to optimize spaces and promotion of integration among stakeholders. ECBC is a voluntary standard developed based on ANSI[5] /ASHRAE[6] /IESNA[7] mainly for commercial buildings having a load of 500kW or to buildings having conditioned space of more than 1000 m^2. Codes should be mandatory with proper evaluation and enforcement mechanisms and, refusals for non-compliance should be penalized. It is the weak enforcement of the codes and non-mandatory nature of ECBC in most of the states that prevents the adoption of green building practices. However, the highly urbanized states with major real estate activities are taking an interest in implementing the code.

Absence or lack of economic incentives (ABEC) stems from the government in terms of promotion grants, reduction in stamp duty and reduction in property taxes. The incentives on the part of government are only to buildings with high ratings. Reductions in stamp duty or a reduction in property taxes can actually contain the high initial cost in the construction of a building. There is lack of information on the economic, environmental, health and technological benefits green buildings could bring (LIGI). Economic benefits are the reduced operating costs, enhanced asset value and profits, improved employee productivity and satisfaction and optimized lifecycle economic performance. Environmental benefits are protected ecosystems, improved air, and water quality, reduced solid waste and to conserve natural resources. Health benefits are improved air, thermal, and acoustic environments; enhanced occupant comfort and health; and minimized strain on local infrastructure.

Lack of labelling of green products and materials (LLABEL) is a barrier which gets priority. Labelling as a market mechanism decreases search costs, experience costs and reduces credence costs without resorting to a command and control mechanism. It neither imposes the producer to produce his/her goods in a particular way nor the customer to buy a particular product. Rather, it provides information on the production of good and leaves it to the market forces of demand and supply. Labelling, in this case, provides market information about production attributes and can be used as a mechanism revealing consumer valuation of environmental attributes which brings long-term economic advantages through market instruments. This can solve the problem of 'missing market' in the case of green buildings.

High capital cost (HCC) is an intense barrier, as the initial investment costs are perceived to be very high in green buildings compared to conventional buildings. The high cost pulls back the investor from making an investment in green buildings. The pay-back period of the investment also matters to the investor. In addition, with soft loans for building, energy improvement mortgages can also help tackle this barrier to a large extent because it is specific and values the potential savings a builder can reap from implementing energy efficiency measures. The idea of

[5] American National Standards Institute
[6] American Society of Heating, Refrigerating, and Air-Conditioning Engineers
[7] Illumination Engineering Society of North America

'Green Leases' for green rated buildings can fetch higher rent and can also increase the resale value of the property.

Additional infrastructure and training (AITC) are required to create an expertise in green buildings. A lack of information provisions and unavailability of professionals who have experience in this area becomes an issue. IGBC is conducting workshops, training programs and exams to professionals in building sector to expose them to green building practices. This examination offered by IGBC is a credential for professionals to participate in green building projects and it is not based on any specific green rating.

The IPE barrier category has clearly emerged as the category needing the most attention due to its high weight. Among the top seven, LELC, LIGI, LLABEL and AITC belong to the IPE barrier category. The credence characteristics[8] of green building causes underinvestment in the good. It shows the informational asymmetry between sellers and buyers, as sellers have more knowledge on the peculiar attributes of their goods, whereas buyers even after purchase and use, lack information on the good. This is because the buyer may lack technical expertise in the good or the cost of acquiring sufficient and accurate information costs more than its expected value. The tangible link between the expected attributes and consumption of the product can be missing which makes the measurement of utility very difficult (Dulleck & Rudolf, 2006).

The social constructivist approach tells that technology and change have to be seen from a dual perspective. There is a social shaping of technology and the technical shaping of society. The increasing power of persuasion through media and images has an important role in popularizing the technology and translating it into ideas that fit into the society. Besides the technical prescription, there needs to be increased awareness to capture the societal imagination of 'why going green' is important. This can be tackled through demonstration programs, training of professionals, labelling, or popularization of green building certification. Compulsory energy audits in buildings will create a clear notion of the importance of energy efficiency. The benchmarking and identification of best practices will serve positively in increasing the visibility of the green building movement in India and can also help the building sector to become resource-conscious.

This study clearly shows that the barriers are many and so a single policy may not be effective in facilitating the shift to green buildings in India. There is a clear need for government regulation including setting this as part of the national agenda and the implementation of command and control, as well as market-based instruments to enable the shift. A judicious mix of various instruments like regulation, taxes, green subsidies for consumers, preferential housing loans to buy green buildings, information disclosures, etc. are required. Financial incentives in the form of Additional Floor Area Ratio (FAR), reduced stamp duty, and soft loans are suggested as part of the low carbon strategy by Indian Planning Commission. Some of the most significant policies require reducing information provision to ensure the market penetration of green buildings. The results of the study also show that there is the need for eco-labelling of green buildings so that the users and potential adopters know what they get for their investment. The idea of 'Green Leases' for green rated buildings can fetch higher rent and can also increase the resale value of the property.

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[8] Credence characteristics are characteristics of goods and services where an expert knows more about the quality than a customer need himself/herself are called credence goods. (Dulleck& Rudolf, 2006)

A unified view of both the builders, as well as users, is that green buildings do incur substantial costs and thus there is an urgent need to adopt lifecycle perspective to compute the cost savings that the green buildings provide.

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