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RESIDENTIAL GREEN BUILDINGS: A PARAMETRIC EVALUATION OF LEADING NATIONAL CONSULTANTS

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ABSTRACT

'Green Building' has now become a flagship of sustainable development in this century that takes the responsibility for balancing long-term economic, environmental and social health. These buildings not only reduce negative environmental impact but also improve human comfort and safety. Green buildings need to be assessed by 'Assessment tool' for checking its overall contribution towards achievement of 'sustainability'. In this paper an attempt is made to know Indian Architects 'perceptions' and 'preferences' regarding the framework of "Green Building Assessment Tool (GBAT)" for India. Feedbacks were collected from the Architects of major metro cities of India. Total 97 responses were analyzed with SPSS 16 statistical analysis software. Indian Architects' gave an opinion that 'GBAT' for India should be prepared firstly for residential buildings. It should target 'Architects' first and must be applied at the building level. 'GBAT' should be a comprehensive one with flexible and easy to calculate scoring system. 'GBAT' must cover non-controllable factors along with negative scoring sys- tem. Results can be utilized in the coming years to prepare a comprehensive 'GBAT' for developing country like India.

Keywords: Green Residential Buildings, Building assessment tool, Architects and developers, SPSS16.

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1. INTRODUCTION

Building construction is believed to consume around half of all the resources taken from nature, Buildings account for 16% of the water used annually worldwide, Buildings contribute for global warming by releasing greenhouse gases into the atmosphere through energy usage and during manufacturing of materials. It is estimated that built environment accounts for about 40% of world's greenhouse gas emissions, Building sector constitutes approximately 44% of the society's total material use, Thus, to say that buildings are the single largest source of terrestrial and atmospheric pollution is not an overstatement. Throughout the world, the construction industry is responsible for high levels of pollution, resulting from the energy consumed and during the extraction, processing and transportation of raw materials. This has led to the emergence of a sustainable design agenda. So countries will have to adopt 'Sustainable Construction' to respond to achieve Sustainable development. 'Green building' is a recent design philosophy that requires the consideration of energy, resources depletion and waste emissions during its whole life cycle in addition to minimizing and creating a healthy environment for people. It has been noted that initial building assessment tools focused only on environmental performance but there is a discussion required on the need to bring sustainability concerns into the tools. This includes economic and social concerns as well as environmental aspects of sustainability. Economical, social and cultural issues are not considered as major issues by many of the countries till date while performing building assessments. The main emphasis is on ecological impacts to the environment. So, there is a need of a paradigm shift in the approach as: earlier construction industry was emphasizing on three factors: cost, quality and time. Then new approach emerged which added: resources, emissions and biodiversity to protect environment. Now, global need for SD calls for addition of new factors as: social equity and cultural issues, economic constraints, service quality and safety aspects.

1.1. Study Objectives

The objective of this research is to develop an easy-to-use and comprehensive residential Building Assessment Model in Indian context. Following are the research objectives:

1. To establish parameters for different stages which contributes for sustainable residential green building in form of numeric weights by multi criteria decision making theory.
2. To develop a flexible scoring system of criteria evaluation by fuzzy logic approach suitable to Indian condition.
3. To develop pre-occupancy and post-occupancy green building assessment model for residential building in Indian context.

2. GREEN BUILDING ASSESMENT PARAMETERS

As the study is divided into two parts: Pre occupancy and Post occupancy assessment the parameters for the both parts are different. The existing building assessment models were studied to frame the study parameters. Fig 1.0 shows the parameters for the preoccupancy stage. The pre-occupancy stage is divided into two parameters: Architectural aspects and Construction. The sub parameters are sustainable site, project planning, Innovation in design, Material resource and reuse, economic and social aspects and environmental loadings. Fig. 2.0 shows the parameters for the sub model – 2 for post occupancy. The sub model – 2 is mainly divided into two parameters: Occupancy stage and Building Maintenance. The sub parameters are Indoor environmental, Health and wealth being, waste management, security and safety, operation and management, flexibility and adaptability.

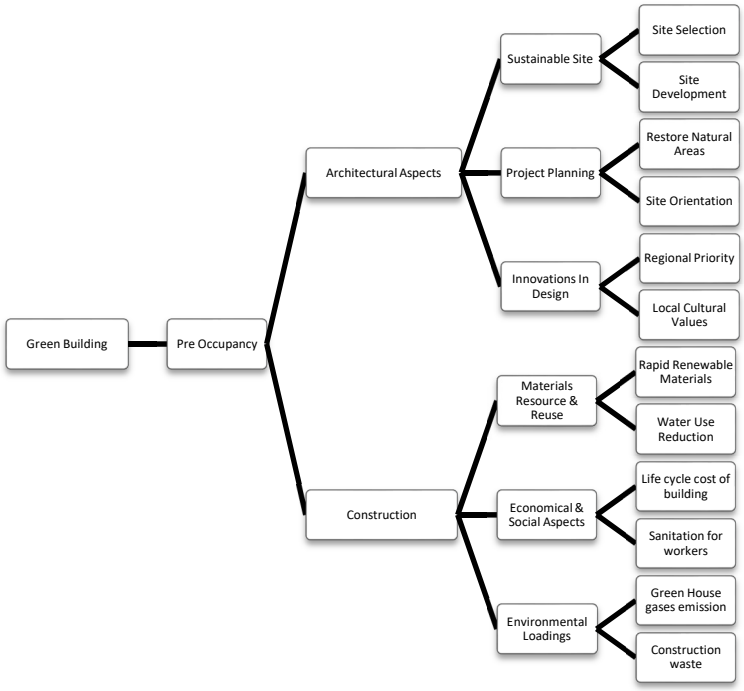

Figure 1 Sub-model 1 for Preoccupancy stage

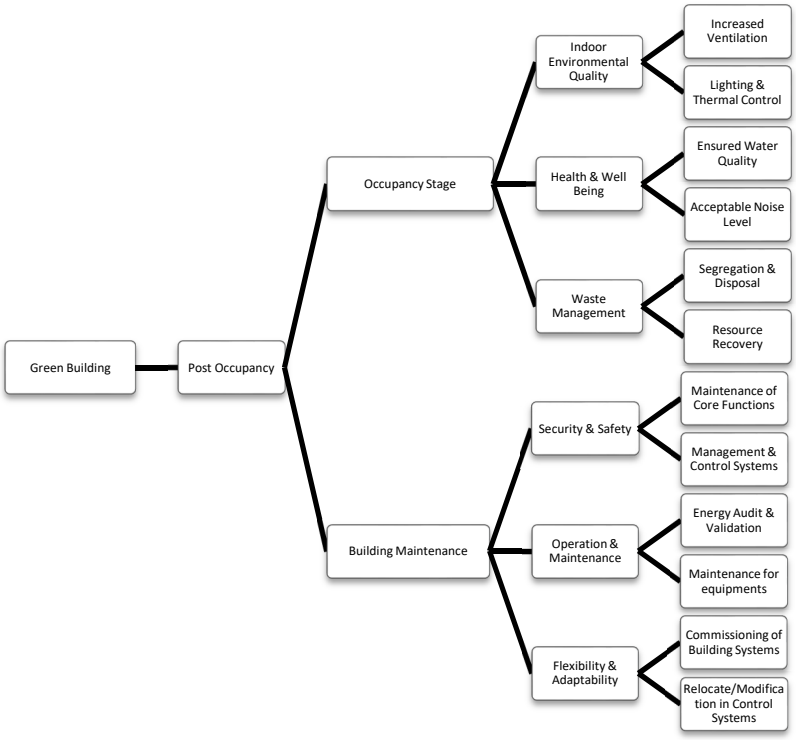

Figure 2 Sub-Model 2 for Post occupancy

3. STUDY METHODOLOGY

India is in developing stage in the direction of having comprehensive assessment tools for 'GBs'. The objective of this paper was to find out the current status of 'GB' concept and to get direction for the correct framework of ''GBAT'' in Indian conditions. This can be done by knowing Architects' perceptions about GB status and development in India. Architects are

key stakeholders whose views are important for developing GB assessment tool in Indian conditions. Architects are the first among all stakeholders who are actually designing the concept of 'GB' and getting it approved by the client or the developer. Local architects directly communicate with a large variety of owners, developers, researchers and material manufacturers. So, they are in good position to provide an information regarding expectation of users for future GB assessment tools. A survey methodology is adopted in this research. Indian leading Architects' preferences are found by conducting a survey in selected metro cities of India. A survey questionnaire was prepared with open-ended, close-ended and partially close-ended questions. Leading architects from the major metro cities were selected as the respondents who are engaged in 'green' designs of buildings. Mumbai, Ahmedabad and Surat were selected for the survey. Questionnaires were sent to the respondents by post or E-mail. Total 197 copies of questionnaire were sent, out of which this research could receive 97 responses. The response rate of this survey was 49.24 %.

City	No. of Respondents
Mumbai	12
Surat	08
Ahmadabad	08
Vadodara	03
Pune	03
Navi Mumbai	03
New Delhi	06
Noida	04
Gurgaon	06
Chandigarh	03
Chennai	09
Hyderabad	17
Bangalore	10
Lucknow	05
Total	97

Table 1 Frequency distribution of Indian Architects – City wise

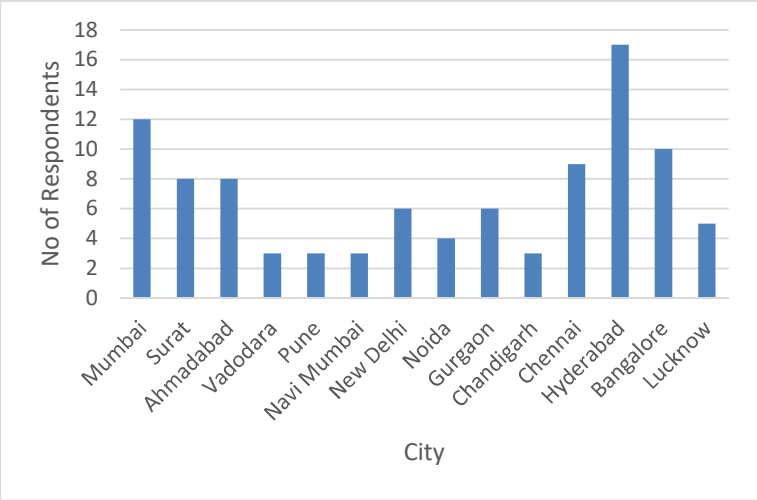

Figure 3 City wise distribution of respondent

The responses were analyzed with the Statistical Package for Social Sciences (SPSS) 16 software. Data was classified according to the coding approach and analyzed for the output through the software. Frequency analysis was carried out for each question. Pearson Chi square test and analysis of variances (ANOVA) test were also performed for finding statistical significance of the results. The results of the survey are discussed in the following sections.

4. DATA COLLECTION AND ANALYSIS

Table 2 Descriptive statistics of present conditions regarding Site selection parameters for GB development and assessment in Indian cities

Site Selection Parameters	Minimum	Maximum	Mean	Std. Deviation	Variance
Sensitivity	0	3	1.68	0.848	0.720
Agricultural	1	3	1.87	0.824	0.680
Vulnerability	0	3	1.80	0.862	0.742
Transport	1	3	1.47	0.805	0.648
Residential	0	3	1.80	0.837	0.701
Commercial	1	3	1.67	0.774	0.598
Recreational	1	3	1.61	0.873	0.762

Descriptive statistics of the survey results are shown in Table 2.0. It shows that the mean values of most conditions regarding site selection parameters for GB development and assessment are between 1.47 and 1.87 (minimum and maximum value of mean from Table 4). This indicates that these parameters are “Most Preferable” or “Moderate Preferable”. Most Less Preferable site selection parameter is “Transportation nearby site” (minimum Mean value = 1.47)

Table 3 Frequency distribution of Indian Architects’ preference site development parameters

Site Development Parameter		Highest Priority	Next Highest Priority	Total Nos.	Overall Priority Value
Site Leveling	No.	58	39	97 (100 %)	160
	%	59.80	40.20		
Site Cleaning	No.	52	54		136
	%	53.60	46.40		
Safety Measures	No.	56	41		156
	%	57.70	42.30		
Sanitation for Workers	No.	38	59		138
	%	39.20	60.80		
Installation of Equipments	No.	51	46		143
	%	52.60	47.40		
Others	No.	0	0		0
	%	0	0		

(Note: No. = number of respondents, % = percentage of respondents, Total Nos. = total number of respondents)

In Table 3.0, the number of respondents for each parameter divided by the total respondent number for that building type is recorded as the percentage of respondents. The “overall priority value” of each building type is calculated by adding up the numbers in the “Highest priority” column times 2 (weight) and the numbers in the “Second highest priority” column time 1 (weight) (Liu, 2005). For example, the overall priority value of Site leveling is:

[(58*2) + (39*1)] = 160. The overall priority value of each building type is displayed in the last column.

Regarding site selection parameters, the majority of respondents gave the highest priority to site leveling (59.80 %) and safety measures (57.70 %). The overall priority value of 'Site leveling' (160) and "Safety measures" (156) is much higher than any other parameters. This indicates that Indian architects are concerned about site cleaning and safety measures in site development. Second overall priority is given to "Installation of Equipments (143)" and "Sanitation for workers (138)" by the architects.

Table 4 Descriptive statistics of present conditions regarding project planning parameters for GB assessment

Project planning parameters	Minimum	Maximum	Mean	Std. Deviation	Variance
Evaluation of environmental impact	0	3	1.61	0.715	0.512
Conserve existing natural areas	1	3	1.64	0.695	0.483
Surface water management systems	1	3	1.74	0.807	0.652
Potable water management systems	0	3	1.72	0.760	0.578
Site orientation	0	3	1.77	0.797	0.636
Optimum use of site	0	3	1.48	0.805	0.648

(Note: Minimum 1 = Most Preferable, Maximum 3 = Less preferable)

Descriptive statistics of the survey results are shown in Table 4.0. It shows that the mean values of most conditions regarding project planning parameters for green building development and assessment in India are between 1.48 and 1.77 (minimum and maximum value of mean from Table 4.0). This indicates that these all parameters are "Most Preferable" in India. Most Less Preferable site selection parameter is "Optimum use of site during construction" (minimum Mean value = 1.48)

Table 5 Frequency distribution of knowledge of Indian architects of Sustainable residential building design of regional priority

	Frequency	% Frequency
No	37	38.14
Yes	60	61.86
Total	97	100

Results in table5.0 shows that the 61.86% Indian architects are in the opinion that the sustainable residential building design should be done on the basis of regional priority.

Table 6 Cross-tabulation of experience of respondents and regional priority for GB assessment tool

Group of Respondents			Yes	No	Total
Experience	Less than 15 Years	No.	32	19	51
		% within experience	62.75 %	37.25 %	100 %
		% of total	32.99 %	19.59 %	52.58%
	More than 15 Years	No.	28	18	46
		% within experience	60.87 %	39.13 %	100 %
		% of total	28.87 %	18.56 %	47.42 %

Cross-tabulation in Table 6.0 shows that less experienced respondents (62.75%) are in higher numbers who are in favour of that the green building design should be on the basis of regional priority compared to more experienced respondents (60.87%).

Table 7 Frequency distribution of knowledge of Indian architects of residential green building design of local cultural values

	Frequency	**% Frequency**
No	15	15.46
Yes	82	84.54
Total	97	100

Result in Table 7.0 shows that there is an absolute majority of Indian architects who are in favour of residential green building design should compatible with local cultural values.

Table 8 Cross-tabulation of experience of respondents and design compatible with local cultural values for GB assessment tool

Group of Respondents			**Yes**	**No**	**Total**
Experience	Less than 15 Years	No.	46	6	52
		% within experience	88.46%	11.54 %	100 %
		% of total	47.42 %	6.19 %	53.61 %
	More than 15 Years	No.	36	9	45
		% within experience	80.00 %	20.00%	100 %
		% of total	37.11%	9.28 %	46.39 %

Cross-tabulation in Table 8.0 shows that less experienced respondents (88.46 %) are in higher numbers who are in favour of that the green building design should be compatible with local cultural values compared to more experienced respondents (80.00%).

Table 9 Frequency distribution of Indian Architects' preference for reuse and resources of materials

Marks	**Frequency**	**% Frequency**
0	0	0
1	5	5.15
2	13	13.40
3	33	34.02
4	38	39.18
5	8	8.25
Total	97	100

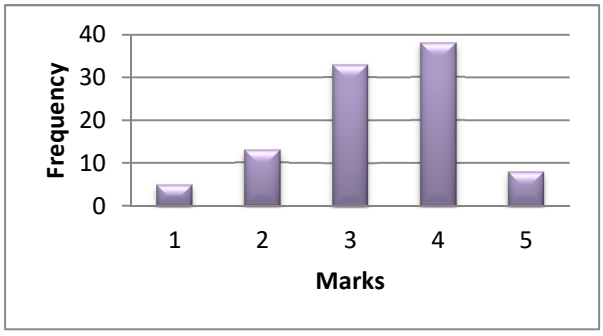

Figure 4 Frequency Distribution of Marks given by respondents

Result in Table 9.0 shows that there is an absolute majority of Indian architects who are in favor of reuse of materials for residential green building construction.

Table 10 Frequency distribution of Indian Architects' preference for rapid Renewable Materials

Rapid Renewable Materials		Highest Priority	Next Highest Priority	Total Nos.	Overall Priority Value
Fly ash	No.	63	34	97	160
	%	64.95	35.05		
Bamboos	No.	60	37		157
	%	61.86	38.14		
Cork	No.	52	45		149
	%	53.61	46.39		
Wheat Board	No.	59	38		156
	%	60.82	39.18		
Strawboards	No.	45	52		142
	%	49.39	53.61		
Cotton/ Soya – based foam	No.	54	43		151
	%	55.67	44.33		
Other	No.	0	0		0
	%	0	0		

Regarding the use of rapid renewable materials, the majority of respondents (65%) gave the highest priority to Fly ash. The overall priority value of 'Fly ash' (160) is much higher than any other Materials. This indicates that Indian architects are much aware to use Fly ash in green building construction. Second overall priority is given to "Bamboos" and "Wheat boards" (overall priority value = 157 & 156 respectively) by the architects.

Table 11 Frequency distribution of Indian Architects' opinion about reduction in water usage during construction

Parameters	Frequency	% Frequency
Rain water harvesting systems	20	20.62
Use of admixtures	24	24.74
Using precast materials	15	15.46
Using recycled water	17	17.53
Providing green technologies	21	21.65
Total	97	100.0

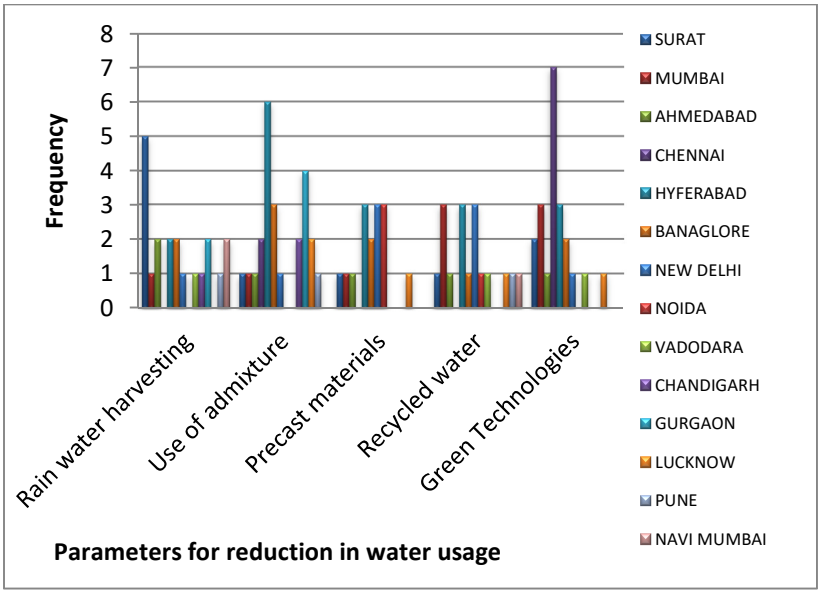

Figure 5 Frequency distribution of city wise response for result indicating parameters for reduction in water usage

Regarding the water reduction during construction, the majority of respondents (25%) gave the highest priority to Use of admixtures.

Table 12 Frequency distribution of Indian Architects' preference for reduction in environmental loadings

Parameters		Highest Priority	Next Highest Priority	Total Nos.	Overall Priority Value
Reduced Co_2 emission	No.	55	42	97 (100%)	152
	%	56.70	43.30		
Minimizing Construction solid waste	No.	45	52		142
	%	46.40	53.60		
Locally available materials	No.	47	50		144
	%	48.50	51.50		
Nonpolluting construction equipments	No.	57	40		154
	%	58.80	41.20		
Preserving green spaces	No.	51	46		148
	%	52.60	47.40		

Regarding reduction of environmental pollution, the majority of respondents (59%) gave the highest priority to use Nonpolluting construction equipments. The overall priority value of 'Nonpolluting construction equipments' (154) is much higher than any other parameters. This indicates that Indian developers are concerned about the Nonpolluting construction equipments to reduce environmental loadings. Second overall priority is given to "Reduced Co_2 emission" and "Preserving green spaces" (overall priority value = 152 & 148 respectively) by the architects.

Table 13 Frequency distribution of Indian Architects' opinion about construction cost

Parameters	Frequency	% Frequency
using more nonrenewable materials	26	26.80
minimizing building material wastage	34	35.05
using locally available materials	22	22.68
providing energy efficient equipments	15	15.46
Total	97	100.0

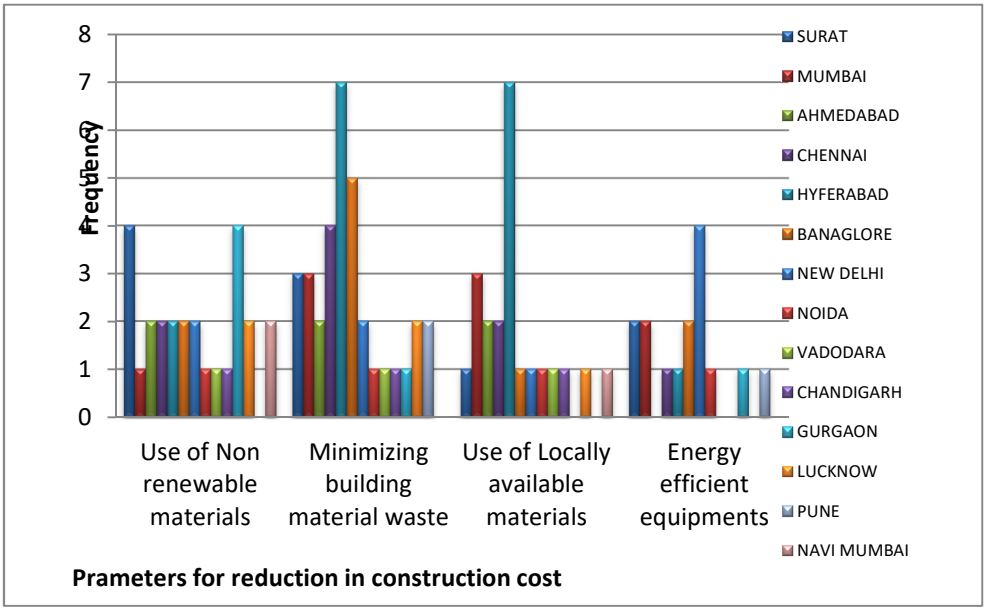

Figure 6 Frequency distribution of city wise response for result indicating parameters for reduction in construction cost

The results in table 13.0 shows the majority of developers are in the opinion that by minimizing the building material wastage (35 %) the cost of construction can be reduced.

Table 15 Frequency distribution of Indian Architects' opinion to maintain social aspects during construction

Parameters	Frequency	% Frequency
Minimization of construction accidents	40	41.24
Access for physically handicapped persons	28	28.87
Providing minimum level of sanitation facilities for construction workers	29	29.90
Total	97	100.0

The results in table 15.0 show that the majority of Indian developers are in the favor of minimization of accidents during construction.

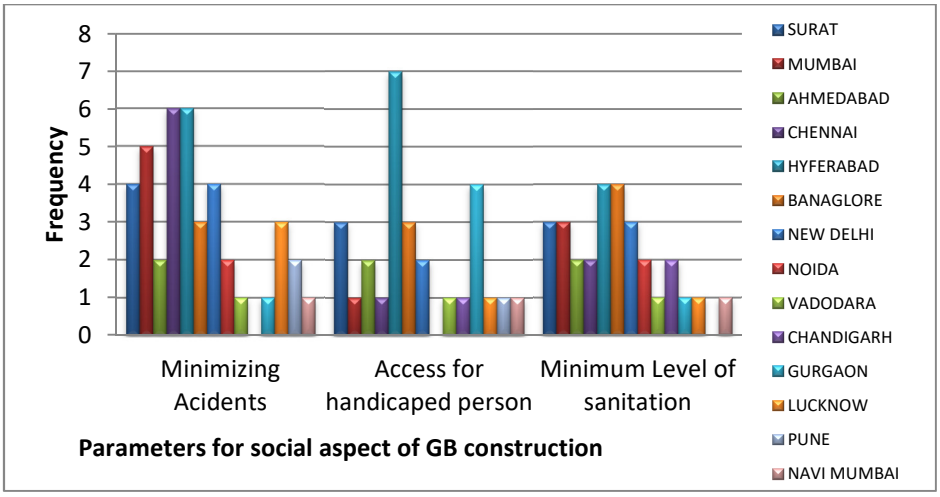

Figure 7 Frequency distribution of city wise response for result indicating social aspect of GB construction

5. CONCLUSION

India is facing major turnaround of construction activities in all urban sectors. Survey research finds that Indian construction industry is facing shortage of availability of GB technology, materials and expertise. This research has taken the feedback of Architects who are key stakeholders in implementation of GB aspects. A survey has finalized perceptions and preferences of Indian Architects' through statistical analysis of SPSS software. For a comprehensive assessment of GBs, one must consider criteria from all aspects: Environmental, Social, Economical and Functional. With a view to reduce negative environmental impact of the upcoming buildings, it is highly required to adopt the concept of 'GB' in the design stage by the architects and developers. The future GB assessment tool should be targeted for residential buildings. The architects felt that the main function of the GB assessment tool should be 'to measure actual results of GB performance'. It must cover all types of criteria to apply it at the design stage with inclusion of non-controllable factors. The negative scoring system should be added for considering the adverse impact of criteria.

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