

HUMAN COMFORT INDICATORS PERTAINING TO INDOOR ENVIRONMENTAL QUALITY PARAMETERS OF RESIDENTIAL BUILDINGS IN BHOPAL

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ABSTRACT: Human is innovating its residential conditions continuously for better health comforts. The productivity of human depends upon his/her comfort index, if person is in a comfort zone he/she feels better and lives healthy life. This research based paper intends to assess the human comfort parameters, based on the opinion and perception of different class of people and clusters of housing in Bhopal. To attain the research specified result, 350 questionnaire were distributed and collected from the study area. The research study outcomes, revealed that the thermal comfort factor is dominating factor which is on top priority as compared to other four factors namely air quality, lighting, acoustic, and visual comfort. The paper also provide the ranking of comfort parameters based on perception of Bhopal residents, so based on the findings of research these comfort parameters can be improvised by different ways which are mentioned in this paper.

This research findings are useful for engineers and architects to take care about residents expectations on comfort issues of life. The research outcomes having vital importance in developing country's prospect where judicious use of renewable energy sources will help in reducing cost and energy consumption and in long term achieving better human comfort and reduced health issues along with providing them a quality built infrastructure for life.

KEYWORDS: Bhopal, Residential Buildings, Indoor Environmental Quality (IEQ), Thermal Comfort, Indoor Air Quality (IAQ), Indoor Human Comfort.

1. INTRODUCTION

All technological developments on this earth is towards the betterment of life, health and working conditions of human being. The construction of house is the first invention of human towards making its life comfortable. The invention of building engineering has added many features towards the comfort of human life. But during last century this comfort parameters are under assessment and buildings and their indoor environment has been

improved a lot. Due to this improvisation human comfort indicators are being assessed. These human comfort indicators vary from place to place, season to season according to the climatic changes on the earth. If comfort conditions are good and supportive it gives better life and productivity of human workforce. On the other side if indoor environment of building is not conducive and comfortable it's negative impacts are visible on human health, life and productivity. In India most of the houses are constructed with a very limited knowledge of architecture and civil engineering and houses are not properly plan, keeping in mind the human comfort requirements. The housing conditions and living environment conditions are impacting a lot. In the developing parts of the globe people are liable to spend more of their time in their homes. Indoor conditions are very important for their health, general working patterns and for economic growth along with energy efficient living. There are number of physical, chemical and psychological factors that have been identified that affects the indoor comfort conditions. There are standards that are developed for indoor environmental quality which define acceptable ranges for the parameters.

Although there are various parameters and standards but for different people there are different effects due to their different perception of comfort and conditions. Different people cannot be satisfied with the same Indoor Environment Quality (IEQ) standard and so their responses are different for the similar parameters and their standards. Due to high variance in physical and economic conditions it becomes very difficult to satisfy every individual with a similar standard of a parameter.

In view of critical assessment of human comfort indicators and indoor environmental quality for different residents/occupants, a research study has been decided to take-up for residential buildings of Bhopal.

1.1 Description of Study Area

The city of lakes Bhopal is the capital of Indian state Madhya Pradesh, and the administrative headquarters of Bhopal divisions. The entire city of Bhopal is spread across the area of 285.88 Sq.km. and the elevation of 527 meters above mean sea level. Bhopal hosts a total population of 1,798,218 according to the census of 2011. Bhopal is placed at 131st rank in the world when the discussion is made about the largest cities. Bhopal is having a humid subtropical climate with a hot summer, cool, dry winters, and a humid monsoon season. Bhopal experiences an avg. high temperature of 31.7 degree Celsius and the temperature here dips down to up to 18.6 degree Celsius on an average. May is the hottest month of the year during which the temperature rises to as high as 46.4 degree Celsius followed by June and April which witnesses the temperature of as high as 45.6 degree Celsius and 44.4 degree Celsius respectively. Under PM Modi’s vision of smart cities in India Bhopal has been selected among the first twenty Indian cities for its development as a smart city.

1.2 Response Rate

Following table shows the response rate of the questionnaire survey.

TABLE-1: Response Rate

METHOD USED	DISTRIBUTED QUESTIONNAIRE	RESPONSE RECEIVED	RESPONSE RATE
Manual	300	246	82.00%
Online	50	22	44.00%
TOTAL	350	268	76.57%

1.3 Identification & Deciding Indoor Human Comfort Parameters for this Study

Indoor Environmental Quality has been adopted in building grading systems like BREEAM (Building research establishment environmental assessment method), BEPAC (Building Environment Performance Assessment Criteria), and HK BEAM (Hong Kong Building environment assessment technique). The feeling of comfort is a mixed state of occupant’s psychological responds to the physical senses according to environmental parameter together with air temperature, air speed, humidity, noise level, illumination and lighting, visual comfort, thermal comfort etc. Good IEQ is essential for healthy efficient lifestyle. IEQ

is the composition of various parameters which affects the indoor human comfort.

Five major human comfort parameters are decided for this research study, which influence the indoor human comfort the most. The five parameters are namely thermal comfort, visual comfort, air quality, acoustic, and lighting. So all these five parameters are chosen for this research study.



Fig-1: Human Comfort Parameters

TABLE-2: Comfort Parameters and Components

COMFORT PARAMETER	COMPONENTS
Lighting	Amount & Type Of Light, Glare & Illuminance
Thermal Comfort	Activity Level, Humidity, Clothing, Space
Air Quality	Indoor Air Pollutants, Humidity, Inadequate Ventilation, Outdoor Air Pollutants, Microbiological
Visual Comfort	Indoor Space, Surrounding Views, Access from Indoor to Outdoor, Colour & Texture
Acoustic	Sound, Echo, Audibility

2. METHODOLOGY

To assess the comfort level and the parameters that act as the major factors for attaining a comfortable living standards in Bhopal a field survey will have to be conducted and its further analysis will be prepared, so that the perception of public towards a particular parameter that majorly influences the comfort level can be obtained. For this the ranking of parameters (thermal, visual, air

quality, acoustic, lighting) will have to be done after that the detailed analysis of the survey result will be prepared. The steps of methodology adopted is been mentioned below;

- Identification & Deciding Human Comfort Parameters
- Preparation of Questionnaire
- Validation of Questionnaire
- Administration of Questionnaires
- Data Collection
- Data Analysis
- Data Interpretation
- Data Interpretation
- Conclusion and Suggestions

After the thorough review of literature and works done in this field some important parameters were found out that effect the perception of comfort level among people. For this research Age group, Gender, Duration of living, Education, Income group, Time spent at home daily, Occupancy type, Comfort parameter ranking, Occupancy information, and Preference order for emerging system are the components of Questionnaire.

According to the pin codes in which Bhopal is completely divided (to be precise the entire city of Bhopal is divided in 50 different pin code section that range from 462001 – 462050). This was prepared with the aim to cover the maximum amount of people taking into account their educational background, their financial standards and their standard of living so that the result obtained from this study can be maximize on a greater bunch of population.

3. RESULTS

Following data table shows the analysis outcome done after the survey.

TABLE-3: Outcomes of Data Analysis

Component	Divisions of Component	Response Weightage	Response Percentage
Distribution of Age-Group	Less than 25 yrs.	118	44%
	25 to 60 yrs.	139	52%
	Greater than 60 yrs.	11	04%
Distribution	Male	189	71%
	Female	79	29%

of Gender	Other	0	-
Distribution of Living Duration (In Years)	Less than 5 yrs.	89	33%
	5 to 15 yrs.	111	42%
	More than 15 yrs.	68	25%
Distribution of Education Level	Undergraduate	49	18%
	Graduate	159	59%
	Post Graduate & Above	60	23%
Distribution Based on Income Group	Lower Middle	35	13%
	Middle	190	71%
	Upper	35	13%
	Higher	08	03%
Distribution of Time Spent Indoors Daily (In Hours)	1 – 10 hr.	135	50%
	10 – 18 hr.	104	39%
	18 – 24 hr.	29	11%
Distribution of Type of Occupancy	Owned	142	53%
	Rental	126	47%
Distribution of Data for Comfortable Month Group	Nov – Feb	171	64%
	Mar – Jun	37	14%
	July - Oct	60	22%
Distribution Based on IE Control Preference	Manually	51	19%
	Mechanically	57	21%
	Both Manual-Mechanical	160	60%
Distribution of Self Perceived Indoor Comfort	Comfortable	220	82%
	Not Comfortable	36	13%
	Don't Know	12	05%
Distribution According to Electricity Used	Low	34	13%
	Moderate	184	68%
	High	50	19%
Distribution of Lighting Type Used	Natural	133	50%
	Artificial	135	50%

Five parameters that were ranked according to the self-perception of the people was converted in the form of a marking system that considered a five star rating scale.

The score which was obtained for each individual's perception was jotted down for the further calculation of its mean which came out to be 3.00. Also the individual marking of each parameter was done and its mean was calculated and a combined percentage was derived. The data for this has been graphically shown along with the table below. The cells that have been marked with green color in the table shows the parameter that are above the mean value of 3.00, further the table can also be interpreted as, the parameters that have been marked by green colors are the most important factors than the rest.

TABLE-4: Mean, Percentage & Ranking of Parameters

PARAMETERS	MEAN	PERCENTAGE	RANKING
THERMAL COMFORT	3.7201	24.80	1
ACOUSTIC	2.4813	16.54	4
VISUAL COMFORT	2.4366	16.24	5
AIR QUALITY	3.5672	23.78	2
LIGHTING	2.7948	18.63	3

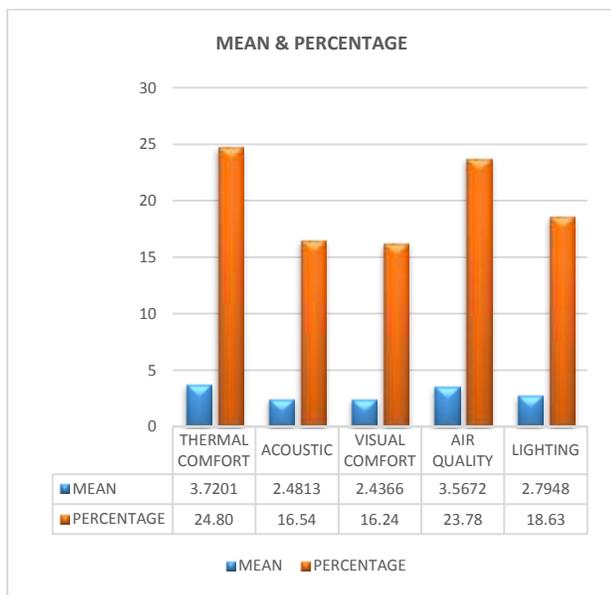


Fig-2: Mean & Percentage of Parameters

TABLE-5: Ranking of Parameters

RANK	PARAMETER
1	THERMAL COMFORT
2	AIR QUALITY
3	LIGHTING
4	ACOUSTIC
5	VISUAL COMFORT



Fig-3: Ranking of Parameters According to Mean Value

The ranking done for the different parameters under Emerging comfort system was converted in the form of a marking system that considered a four star rating scale. The score which was obtained for each individual's perception was jotted down for the further calculation of its mean which came out to be 2.5. Also the individual marking of each parameter was done and its mean was calculated and a combined percentage was derived. The data for this has been graphically shown along with the table below. The cell that have been marked with green color in the table shows the parameter that is above the mean value of 2.5, further the table can also be interpreted as, the parameter that have been marked by green color is the most important factor than the rest.

TABLE-6: Mean, Percentage & Ranking for Emerging System

PARAMETERS FOREMERGING SYSTEM	MEAN	PERCENTAGE	RANKING
EFFICIENCY	2.4142	24.14	3
COMFORT	3.1007	31.01	1
PRICE	2.4627	24.63	2
RELIABILITY	2.0224	20.22	4



Fig-5: Ranking of Emerging System Parameters according to Mean Value

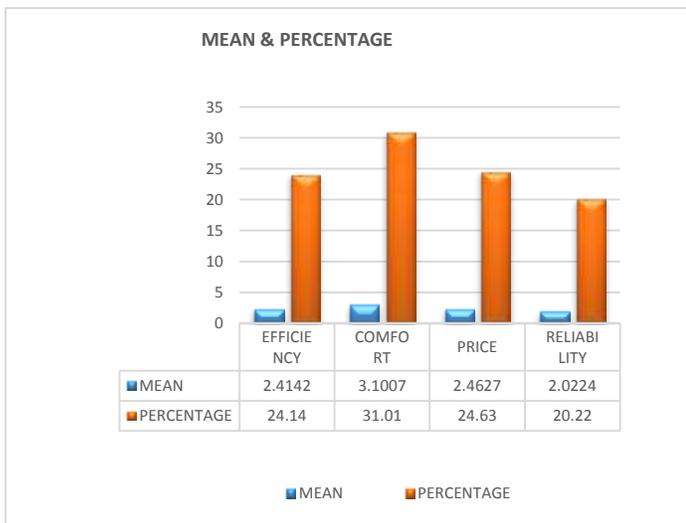


Fig-4: Mean & Percentage for Emerging Systems

TABLE-7: Ranking of Emerging System Parameters

RANK	EMERGING PARAMETER SYSTEM
1	COMFORT
2	PRICE
3	EFFICIENCY
4	RELIABILITY

4. CONCLUSION

In this research the five most important indoor human comfort parameter namely thermal comfort, indoor air quality, lighting, acoustic, and visual comfort are ranked by the 268 residents of Bhopal (**response rate 76.57%**) according to their perception. From the analysis of the data obtained from this research study it is concluded that among all five parameters,

The **Thermal comfort** is on the top priority for the residents of Bhopal with having the mean value of **3.7021** & overall percentage of **24.80%**, the second important factor i.e. **Indoor Air Quality (IAQ)** which is having the mean value of **3.5672** & overall percentage of **23.78%**, third factor is **Lighting**, with having the mean value of **2.7948** slightly less than the overall mean of **3.00** & having overall percentage of **18.63%**, the **Acoustic** comes on the fourth position with having the mean value of **2.4813** less than the overall mean of **3.00** & overall percentage of acoustic is **16.54%**, and the last indoor comfort factor which comes on fifth position is **Visual comfort** with the mean values of **2.4366** less than the overall mean of **3.00** & having overall percentage of **16.24%**.

Similarly, analyzing the data for emerging comfort system it is concluded that among all the four parameters. **Comfort** is the top most priority for the residents of Bhopal with having the mean value of **3.1007** & overall percentage of **31%**, followed by the **Cost price** which have the mean value of **2.4627** which is slightly less than the mean value of **2.5**, & overall percentage of **24.63%**, **Efficiency** remains at third position with having the mean value of **2.4142**, less than the mean value of **2.5** & the overall percentage for efficiency is **24.14%**, the last

parameter for emerging system is **Reliability**, which got fourth position with having the mean value of **2.0224**, less than the mean value of **2.5** & overall percentage of **20.23%**.

4.1 Suggestions for Increasing Thermal Comfort Level

With regards to thermal comfort in the residential buildings in Bhopal passive ways are used for achieving a better thermal comfort as it is the most suitable option considering the fact of erratic and high cost of power and costly air conditioning system. These solutions are derived after the detailed analysis which shows the level of comfort is the major criteria followed by price for the respondents of Bhopal when install a new comfort system. Some of these ways are:

- Proper Orientation of Building
- Using Shading Devices
- Proper Ventilation of Building
- Creation of Microclimate
- Proper Lighting
- Use of Light Color Paint
- Preventing Infiltration
- Training of Building Professionals
- Proper Use of Electric Equipments

4.2 Suggestions for Increasing Indoor Air Quality

For increasing the indoor air quality with low price and for maximum comfort some solutions are provided here, these solutions are best for reducing pollution and health issues related to respiratory system.

- Restrictions
- Increase in Green Spaces
- Distant From Highways/ Flyovers
- Use of Renewable or Green Energy Sources
- Source Control
- Increasing Ventilation
- Air Filters

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BIOGRAPHIES



Nishant Raj Kapoor has received his Bachelor of Technology degree from RTU, Kota in the year of 2014. Later he worked as an Assistant Professor in Vedant College of Engg. And Technology, Bundi. At present he is pursuing M.Tech with the specialization of Construction Technology and Management in National Institute of Technical Teachers' Training and Research, Bhopal. His area of interest is in the study of real time comfort problems; i.e. Indoor Human Comfort, Indoor Environmental Quality, Comfort Perceptions.



Dr. J.P. Tegar is presently working as professor of Department of Civil and Environmental Engineering at National Institute of Technical Teachers Training and Research, Bhopal, (M.P.). He has received his Bachelor of Engineering degree in Civil Engineering from Jiwaji University, Gwalior and M.Tech from MANIT, Bhopal. He has also completed his PhD from Barakatullah University, Bhopal. He has published so many research papers in national and international journals. Dr. J.P. Tegar has visited several foreign universities of Europe, America and Australia.