Assessing the Initiatives in Climate Responsive and Energy Efficient Architecture: Bridging the Gap between Architectural Research and Practice

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Abstract- *Climate Change is an environmental concern. It is caused by the emission of Green House Gases (GHG) into the atmosphere. Much of the literature on architectural studies highlight that Environment and Energy are important components of a built environment; as such environmental quality and energy conservation are acknowledged as the important parameters to study the relationship between environment and architectural design. This paper puts an effort to reduce the use of conventional energy by utilizing passive heating and cooling techniques, day lighting, ventilation, and using appropriate thermal design of buildings for space conditioning. Thereby emphasize the integration of several environmental factors in architectural design. Thereby highlight the importance of architecture in relation to the environment.*

Keywords- Climate change, energy efficient, architecture, building byelaws.

I. URBANIZATION IN INDIA

Urban areas as huge emitters of carbon- di-oxide (CO_2) not only contribute to climate change, but also experience the resulting impacts of climate change (Bell &Batterson, 1978). Climate Change is caused by the emission of Green House Gases (GHG) into the atmosphere. Carbon dioxide in the atmosphere is due to an increased amount of fossil fuel use and land use change, while those of nitrous oxide and methane are primarily due to agriculture. An example of climate change is Global Warming and refers to an observed increase in the average temperature near Earth's surface and oceans during the recent decades. According to the United Nations, almost 80% of the world population lives in urban areas. Urban activities consume huge amounts of energy to improve the quality of life and as a result emit about 78% of CO_2 gas into the atmosphere.

According to Environmental Planning Agency (EPA), the major sources of CO_2 emissions are electricity accounting for 38%, transportation emitting 31%, industrial activities accounting for 14% of CO_2 emissions followed by residential and commercial activities emitting 10% and non-fossil fuel combustion accounting to 6%. Studies have shown that buildings and construction activities use 40% energy, 30% mineral resources and 20% water of the world's resources. It also accounts for 40% CO2 emissions, 30% solid wastes and 20% water pollution in the world Hence, built environment significantly increase CO_2 level in the atmosphere thereby, contribute to climate change.

Impacts of climate change such as loss of ecosystem, heat related illness, increased mortality rates and high economic losses are expected to have an effect on almost all aspects of human life (Post & Altman, 1994). Recently, scientific evidence reveals that all over the world, almost 160 million people residing in 20 coastal cities are expected to be affected by the rising sea levels (Nicholls, 1995). Hence, the impacts of climate change are very alarming and it is necessary to address climate change.

According to the United Nation Environmental Programme's (UNEP) report, India is one of the fastest developing construction sectors in the world. During the past five years, expenditure in the construction industry has increased in India by as much as 10% as a result the built-up floor area has nearly doubled. This rapid increase in construction activity in India is mainly driven by urbanization.

India is a rapidly developing country with high population and economic growth rates. India contributes to 18% of the world population next to China which accounts for 19.4 % of world population. Since the 1990s urbanization in India has been fast, unplanned and brings with it a unique set of advantages and disadvantages. Though urbanization is driving the economies of most of the cities in India, a serious concern regarding the negative impacts of urbanization on the environment, transportation and public health is warranted.

Environmental impacts include loss of high ecological-significance habitats (Aguilar 2008; Bohnet and Pert 2010), decrease of water quality, increase of demand for water supply (Conway and Lathrop 2005), increase of river-flood frequency (White and Greer 2006), reduction of drainage density (Zhou et al. 2011), increase of maintenance costs for the city administration (Balta et al. 2012; Klug and Hayashi 2012), and loss of arable land (Rawashdeh and Saleh 2006; Bayramoglu and Gundogmus 2008; Han et al. 2009).

A close review at the pattern of urban growth across various cities in India highlights that urbanization is very prominent among million-plus cities. Share of the total urban population within the million plus cities has risen drastically from 32 to 38 per cent during 1991–2001 and recently to 54 percent in 2011. It is estimated that by 2030, the population within the million-plus cities will increase up to 68 percent. Overall, these statistics affirm that India is catching up fast in the process of urbanization (Sudhira, 2012).

Since the last 10 decades India has been progressively changing from a rural to an urban society. While only 10.86 per cent of the total population constituted city dwellers in 1901, this statistic stood at around 31.16 percent in 2011 and by 2030 it is expected that nearly 43% of the country's population will live in urban areas. This means that rural population in 1901 was 89.14% and has decreased in the last 11 decades to the current 68.84%. On the other hand urban population has increased almost threefold from 10.86% in 1901 to 31.16% in 2011. As such, it is projected that India's urban population would increase drastically from 288 million in 2011 to about 475 million in 2031 and 820 million by 2051.

II. SUSTAINABILITY CHALLENGES FOR THE INDIAN BUILDING SECTOR

Besides, demand for commercial building has also driven highly due to the boom in the services sector which has added 53% to the value of GDP in 2008. Accordingly, the amount of built office space is projected to increase from approximately 200 million square meters in 2009 to 890 million square meters by 2030, thereby leading to an increase of more than 70%.

It has been observed that, contemporary style office buildings use increased amount of typical glass-curtain wall design thereby leading to an increase demand for mechanical cooling in a predominantly warm climate like India. Recent studies on energy performance of commercial buildings in India highlight that energy efficiency does not meet the international standards, as such showcasing and. Thereby leading urbanized Indian cities toward in-efficient in terms of increased greenhouse gas emissions as such potentially uncompetitive energy efficiency in building stock.

According to IIR (2010), in the year 1970, the total national commercial energy consumption has risen from 14% in the year 1970's to nearly 33% by the year 2005. Thereby, showcasing an increase of nearly 8% per year in energy consumption of buildings. Further, it was identified that nearly 54% of electricity in India is generated from coal-fired power plants; as such highlighting that energy performance of buildings is a highly significant factor in greenhouse gas emissions.

The main aim of the Energy Conservation Building Code (ECBC) 2007 is to deliver significant energy efficiency gains from India's commercial building sector. For instance, full implementation of the Energy Conservation Building Code could reduce energy consumption in new commercial buildings by 25-40%. Further 25% of potential energy savings can be achieved by using cost-effective retrofitting for existing commercial buildings. Most of the Indian cities are vulnerable to the impacts of climate change due to increased urbanization in India; as such by the year 2050 it is projected that about 50-60% of Indian's will be living in cities.

As such, it is necessary to sustain prosperity and well-being of individuals. In this regard, buildings play a major role in providing climate change adaptation options. A key climate change stress on the built-environment is the decreased availability of water in the urban areas. Most of the Indian cities rely profoundly on ground-water for daily use. However, ground-water levels in India are projected to be diminishing.

III. CLIMATE RESPONSIVE AND ENERGY EFFICIENT CONSIDERATIONS IN BUILDINGS

Thermal comfort is considered as the temperature level at which a human tend to feel comfortable. Generally, thermal comfort of building mainly deals with the heat radiations and lighting flux that is entering into the building through the building fenestration and through building materials that are specified on the exposed surfaces.

The building fenestration design plays an important role in improving the climate responsive architecture features and energy efficiency of the buildings through various multi-dimensional concerns such as improving day lighting, ventilation, and indoor air quality and comfort levels in the building. Architectural studies highlight that there are mainly seven design parametersthat tend to have an impact on the energy consumption of buildings. They are as follows: Day Lighting, Air Quality, Ventilation, Passive Heating, Building Specifications and Embodied Energy through building materials, Landscape, Water bodies, Open space and built form and Street width and orientation.

A. Solar Space Conditioning in Buildings

Solar space conditioning is an art of utilizing solar energy to create thermal comfort in a built environment. Solar space conditioning is challenging due to its multi-dimensional approach in creating and achieving human comfort in buildings. According to Baylon et al (2010) extensive studies and research were conducted on space conditioning options. As such, researchers felt that there was a need to integrate solar space conditioning in architectural design.

Literature studies on solar space conditioning identified that there are two systems of solar space conditioning of buildings. They are active system and passive systems (Sodha et al, (1986), Bansal and Cook, (2001)). The conventional approach of space conditioning of buildings tends to incorporate a separate collector and a separate thermal storage for heating a building. As such in a regulated manner, the thermal energy is transferred from the thermal storage to the thermal control system with the help of a heat transport liquid which may be either air or liquid. This type of space conditioning of buildings is known as active solar heating system.

On the other hand, thermal space conditioning of a building can be achieved without the help of a separate collector and a separate thermal storage. Such a system is termed as passive heating system. In passive heating system the structure of the building itself acts asa natural solar collector. In the passive ***solar design*** an in built solar collector is the main component and it tends to have a profound impact on the architectural design of the building as well as on the lifestyle of the occupants.

This inbuilt solar collector acts as an inbuilt character of the building and it includes all the building elements that have an ability to admit, absorb, stores and release solar energy. Thereby, reducing the need of auxiliary energy for comfort heating and cooling of a building.

Accordingly, the building envelope is considered as one of the important element that can be considered for understanding and exploring the potentials and opportunities to either increase or reduce the thermal load of a building. In this regard, it is necessary to study and analyze the building components and their thermal behavior so as to achieve thermal comfort within the building.

Passive design in a building can be broadly classified into direct gain, indirect gain, passive gain convective loops and thermal storage components of roof/walls. The simplest passive system for heating a building is the direct gain passive space heating system. The concept behind this type of heating system is that of sunlight penetrating into a room through south facing windows, thereby heating the building with help of solar radiations.

However, it is essential to avoid over heating during the day and night. This can be achieved by constructing the building components especially the wall and floors with materials that have an ability to not only heat the building during the day but also store the heat gained during the dayfor heating the building in the night. Accordingly, the most commonly used materials for this purpose are masonry and water.

For instance, more than one material is used in a building. As such, a RCC roof or masonry wall has plaster on both the sides of the surface. Particularly, the exposed surfaces of the walls and roof must be treated differently to take care of insulation and waterproofing.

Thermal mass is considered as any building component which has an ability to absorb and store solar radiation during the day. In passive solar heating systems, the glazing and thermal mass have a very close relationship as such they influence the interior temperatures of the buildings. Thereby have an ability to develop thermal comfort in the building. Likewise, heating of a building during winter can be achieved by absorbing and storing the desired quantity of solar radiation.

Accordingly building components such as walls, roofs and floors can be designed such that they have the desired insulation capacity so as to avoid excess heat from penetrating into the building. As such there is no replacement for heating and cooling of a building through energy conserving architectural design, which has an ability to optimize solar gains in the building.

Moreover, temperature of a building is mainly determined by thermal diffusivity and thickness of the building. As such, building elements such as roof with terracing and brick walls tend to absorb more amount of solar radiation in a given time. In such a manner, it may increase there is a tendency for an increase in the temperature levels during the non-sunshine hours.

Thereby leading to thermal comfort conditions particularly during the day time especially during the winter seasons when the temperature outside the building is cold as such reducing the heating load of a building. Hence, it is of vital importance to study various combinations of building materials for walls, roof and terracing to escalate the thermal conditions of the building envelope thereby achieve the required thermal comfort levels with minimal dependence on HVAC systems.

In this regard, there is a need for regulations to promote climate responsive and energy efficient building design and specifications. Besides, it is of vital importance as they have an ability to minimize the solar heat gains in the summer. As such developing proper designs and specifications of the building components during the initial stages of the building architectural design process tends to effectively help in attaining the desired level of thermal comfort with low energy requirements and relatively minimum reliance on HVAC system.

Much of the literature studies highlight that the amount of solar energy stored depends upon the size and distribution of the thermal mass. According to Bansal and Singh (1985)significant heating requirement can be met by using properly sized thermal storage in the floor. Sodha *et al;*(1992) analyzed how the thermal performance can be coupled to evaporative cooled storage tank which is placed below the floor. As such undertaking energy analysis of buildings requires an in depth knowledge on the flow of heat in buildings.

Studying the heating and cooling load of a building is the most important requirement during the development of a thermal design of building. Recent studies highlight that heat flows I a building in three ways. They are through conduction, convection and radiation. This flow of heat also known as solar energy can be characterized in mathematical form with the help of heat transfer processes [Chandra and Puri (2000)].

In this manner, investigations of thermal behavior for a non-air-conditioned buildings with its material and component specifications such as windows, roof and wall, exposed to the periodic solar radiations was undertaken. The developed model is mainly based on periodic heat transfer analysis. The main intention of this model is to evaluate the overall heat flux that is entering into the room. There by, identify the hourly indoor temperature difference. Hence, provide the required additional cooling or heating load; thereby meet the desirable thermal comfort conditions. Besides, this model can be used to control the additional cooling load or heating load.

This chapter deals with the systematic review and comparative study of various materials wall/roofing design configurations of building The effect of thermal parameters such as ho, hi, window area, building volume absorptivity of surfaces and number of (ACH) air changes per hour on indoor air temperature for cooling and heating period.

It is identified that locally available building materials have a considerable effect on the hourly room air temperature during the heating and cooling period. Materials such asreinforced brick, conventional brickwork and lime concrete highlight average temperature difference of 2.75degree centigrade where as timber structure and concrete highlight the average temperature difference 4.84 degree centigrade and 3.0 degree centigrade respectively during cooling period.

Similarly the absorptivity of the surface tends to have a considerable effect on the room air temperature during cooling period. An absorptivity value of 0.2 has an ability to reduce the hourly room air temperature by 3 to 4 0C when compared to a maximum value of 0.9. Using of white paint and aluminum sheet when placed on exposed surfaces tend to reduce room the indoor temperature by 3.5 degree centigrade when compared to the conventional plastered brickwork. Likewise, in modern buildings the usage of aluminum sheet on ACP for structural façade may also has an ability to enhance the indoor thermal conditions.

B. Lighting and Ventilation

Proper utilization of daylight in the buildings tends to result in a significant saving in electricity consumption. The concept of introducing dynamic building envelope technologies tends to introduce a potential for a higher quality work environment as well as an increased energy-efficient solutions. Introduction of innovative day lighting systems have an ability to increase daylight levels and also improve daylight uniformity within the space, by controlling sunlight with the help of window sizing and reducing glare by window placement [Lorenz (2000)].

Accordingly, advanced predictive control algorithms, can help determine the operation of building envelope systems and HVAC system components. Thereby, achieve the annual minimization of energy consumption required for maintaining good human comfort [Mc Hugh (1995)].

In this regard, locally available material for an indoor multipurpose auditorium, cavity type rat trap and air chimneys can be used. The measured result highlight that nearly 4 degrees centigrade was reduced. Hence, with reference to the available measured result, there is a need to examine the temperature difference due to the thermal buoyancy thereby integrate it in the thermal model of a building.

Thereby, analyze the thermal conditions of a building. Similarly, sizing of the building fenestrations is also one of the most important design parameters for the proper day lighting and ventilation. The openings of windows are designed to create a visual link between the interiors and the surroundings there by contribute adequate day light illumination for different functional spaces of the building.

C. Day lighting

It is of vital importance to analyze the available daylight and utilize it efficiently in buildings for various functional spaces. Before, beginning an architectural design it is very important to analyze factors of the interior environment, exterior environment, and fenestration. Each opening that is placed on the exterior wall irrespective of its facing must be evaluated for the total impact of the opening on the human occupants and on the interior environment.

The placement of a fenestration in a building design must not be based on superficial reasoning and arbitrary. The size of the windows varies from one room to another room, depending on the size of the room, the function of the room, the number of occupants and its orientation. Once the requirement is identified with regard to the thermal impact of the opening and daylight potential, the size of the opening and the placement of the opening can be undertaken in the design.

The size of the opening and the placement of the opening must be based on the amount of the daylight that is entering the space. The exterior environment that is producing the daylight also has an ability to influence the daylight calculations as the exterior daylight is the main source of light for the interior environment. Sky luminance is a function of the cloud cover, which is mainly termed as over cast sky or clear sky luminance. The light that enters in tot the interior environment after it is reflected from the ground mainly depends on the ground cover reflectance property. In this manner developing different daylight models which helps in calculating and analyzing the availability of daylight is very necessary.

As such, calculation of illumination levels inside a building is carried out with respect to the internal reflected components, external reflected component, day light factors, and maintenance considerations of the window glazing. In this regard, user-friendly tables were developed by BIS (1989) with an intention to calculate the indoor illumination levels with respect to the opening sizes irrespective of the interior surface. Different measurements of openings and the placement of the openings in different locations tend to create different illumination levels on the interior of a building. Thereby present desirable solutions for different functional requirement of the indoor space. The relevant parameters such as window areas (inlet) and slit areas (outlet) are used in developing the model. It is identified that natural ventilation by thermal buoyancy tend to reduce the indoor air temperature from 3 to 5 degrees centigrade during the summer season and in the winter season.

It was analyzed that the drawing room with regard to the Daylight Factor requires 152 lux, which is considered as a desirable illumination level. As per the BIS calculation it was identified that opening sizes of 2.5mX1.35m, 2.0mX1.8m, 1.75mX1.80mand 2.25mX1.35m to some extent have an ability to moderately to satisfy the desirable illumination levels for a working plane. Accordingly, ventilation through thermal buoyancy tends to indicate that window areas which are of approxiamately10 to 15 % of a room's carpet area can reduce nearly 3.5 degree centigrade of the interior temperature when compared to the exterior temperature which is in line with the daylight requirement.

D. Embodied Energy in Building Materials

According to Walker *et. al*, (2000), in designing a building, building materials is one of the vital parameter for functional and structural aspects of the building. A good amount of energy is generally in the manufacture of various building materials. Conserving energy by developing climate responsive and energy efficient buildings by promoting the use of building materials is very important in the context of reducing green house gas emissions into the atmosphere and also in reducing the cost of materials. Hence, it is important to focus on utilizing those building materials that have an ability to conserve energy in buildings particularly within Indian context.

In this regard, a sustainable building with locally available low cost and energy efficient materials was constructed. Accordingly, a mud house with a thatched pitch roof was constructed and later the indoor temperatures were measured. It was identified that here was a difference of 7 to 8 degrees centigrade the indoor air temperatures when compared to the outdoor air temperature. This is due to a time lag of 8 hours because of mud masonry. Laterite stone was used as a load bearing material; for stone masonry mud mortar was used and pitched roof was used. Palm trunk was used as a supporting system. The roof was of a thatched roof which is of 8 inch thick.

Recently, there is an increased awareness for sustainable environment was developed in the construction sector. In this regard a lot of research is being focused on reducing the energy consumption thereby reducing green hose gas emissions at source level itself. At the source level is referred to as the manufacturing level. In this regard, an extensive research was conducted in the field of energy efficient materials for construction industry. It was identified that during the manufacture of building material a lot of greenhouse gas is emitted into the atmosphere thereby causing adverse environmental impacts.

Besides, selection of building materials and appropriate technologies for building construction is necessary because it must satisfy the needs of the end- user and also be aesthetically appealing without causing any adverse impact on environment Mullick(1993). Minimizing the consumption of conventionally used materials by replacing those materials with alternative materials, techniques and methods has an ability to save energy and results in energy savings. I this regard, it is very essential to identify energy efficient materials and thereby replace the conventional materials with energy efficient materials.

With an intention to reduce and minimize the consumption of commercial energy and to increase the usage of suitable energy efficient materials there by conserve the usage of commercial energy in the building Industry research was undertaken. As such, a residential building was designed by treating the southern wall with rattrap bound brick masonry and filler slab for the floors. Solar PV panels were installed and the openings for the residential building were calculated as per the daylight factor. Accordingly 250 – 300 lux was found to be sufficient for the building and the opening sizes were adhered to the lux requirement.

E. Energy Efficient Landscape

Landscape and energy are the most critical elements required for the physical development of a built environment. Accordingly, landscape quality and energy conservation are widely acknowledged as the most important parameters for the design of any built-up space in urban areas. While designing a building, landscape is considered as one of the important parameter for not only aesthetical and functional considerations but also for promoting environmental awareness and considerations within the built areas.

In this regard, it is vital to study and analyze the contribution that can be made for promoting energy and environment awareness so as to enable the designer as well as the occupants of the built environment to effectively utilize and develop an integrated environmental design approach. In the same line it also facilitates in promoting an environmental sensitive thought process with a due consideration to promote climate change responsive built environment.

Accordingly promoting climate change responsive and energy efficient architecture also has the potential to reduce greenhouse effect there by lessen the impacts of climate change. For this reason, a southern wall of a residence which is located in a hot and humid region in India was designed by shading the southern wall with dense vegetation like deciduous trees. It was identified this type of treatment not only reduced the thermal transmittance but also acted like a wind break for the residence.

The thermal transmittance was achieved as the vegetation obstructed the harsh solar radiation by allowing it into the building and only allowed the diffused radiation to enter into the southern room. As such it was identified that the temperature in the southern room was less by about 5 to 7 degrees centigrade prior to when the room did not have any vegetation on the southern side.

As such, this type of research highlights that vegetation helps in creating thermal comfort in the built environment. Thereby, promotes the integration of energy efficient landscape features in the built environment to conserve energy. As such, it was identified that plant materials have an ability to contribute to environmental friendly designs by reducing light and heat penetration by providing shading and absorbing dust and reducing wind pressure. As such reduce the heat island effect.

F. Indoor Air quality

Indoor air quality refers to the natural air that webrea the and which promotes healthy and human comfort conditions. Indoor air quality is mainly measured in terms of humidity, odors, temperature, etc. As such, it is very difficult to define the acceptable air quality. According to ‘ASHRAE’, indoor air quality is referred to as acceptable when 80 percent of the people who are exposed to the air feel comfortable.

However, industrialization and urbanization have led to increased population densities in urban areas and which have increased car density in the urban areas (Raparthi, 2014). As such increased usage of cars have led to increased carbon dioxide emissions and eventually increased greenhouse gas emissions. In this regard, it is identified that greenhouse gas emissions can be reduced by promoting environmental friendly architectural design and also developing building codes to be implemented in the Development Control Rules (DCRs)by detailing the building bye laws.

This can be of immense help to the architects who on the mainly rely DCRs at the designing architectural drawing. Besides, it is identified that urban planning policies can also be promoted at the macro level. Besides, urban and town planners also benefit from this while allocating the built up areas in the urban settlement. As such promoting building byelaws and urban planning policies will help to reduce greenhouse gas emissions both at the micro and also at the macro level. Green House gases mainly comprise of carbon dioxide, nitrous oxide and methane.

IV. RECOMMENDATIONS

Analysis of solar thermal model considering the feasibility and the availability of local materials for a few of the building components such as wall, roof and terracing for achieving thermal comforts within the built environment was carried out.

Different configurations of roof / walls /specifications such as rat trap bond masonry, cavity in wall masonry, conventional brick masonry, hollow cement block and stone cladding brick masonry were combined with roof terracing options like lime concrete terracing, mud phuska (1(clay): 1(cow dung)) terracing, earthen pot cum mud phuska terracing, normal terracing on conventional RCC slab and ceiling insulation were integrated and coupled with the solar thermal model of a non-air conditioned building so as to appreciate the indoor thermal conditions.

Besides, analysis of feasibility of an underground storage system for various design configurations was conducted to comprehend and analyze the extent of its contribution in achieving thermal comforts within the built environment.

Theoretical analysis of window sizing, with day lighting and thermal buoyancy in the building is coupled to the thermal model of a building with an intention to determine the indoor temperature. Several day lighting models were analyzed to identify a model for formatting and developing the design. The indoor day light illumination levels are prepared for the openings that are placed in different locations with respect to the NBC and BIS.

In this manner, an appreciation of embodied energy profile in buildings with reference to available/local materials was achieved. Three building cases with three possible options of material specifications were studied in this research to determine energy intensive options so as to conserve energy. The major building components like roofing, walls, flooring, terracing plastering, and mortar mixes were analyzed with different options of less energy intensive materials.

V. CONCLUSION

Climate responsive and energy efficiency is major and an integrated task in the field of bio-climatic architecture. A lot of advancements are carried out in the field of Technology that help architects to understand and analyze both the qualitative and quantitative configurations of environment and energy.

The paper explores the impact of various passive solar heating methods and very briefly describes a few of the important components by highlighting the methods that were undertaken. Later, this paper explicates the emerging trends in the field of architectural design thereby help architects in designing and achieving climate responsive and energy efficient buildings.

This paper highlights that environmental quality and energy conservation are acknowledged as the important parameters to study the relationship between environment and architectural design. This paper puts an effort to reduce the use of conventional energy by utilizing passive heating and cooling techniques, day lighting, ventilation, and using appropriate thermal design of buildings for space conditioning. Thereby emphasize the integration of several environmental factors in architectural design. Thereby highlight the importance of architecture in relation to the environment.

REFERENCES

[1] ASHRAE (2004), ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy, ASHRAE Inc., Atlanta.

[2] BSI (2006), BS EN ISO 7730:2005, Ergonomics of the Thermal Environment – Analytical and Interpretation of Thermal Comfort Using Calculations of the PMV and PPD Indices and Local Thermal Comfort Criteria, BSI, London.

[3] C.G. Webb (1952), Journal of the Institution of Heating and Ventilating Engineers 20, 189.

[4] C.G. Webb (1959), British Journal of Industrial Medicine 16, 297.

[5] F.A. Chrenko (Ed.) (1974), Bedford's Basic Principles of Ventilation and Heating, third ed., HK Lewis & Co. Ltd., London.

[6] Hunt, J. (2004). How can cities mitigate and adapt to climate change? Building Research & Information, 32(1), 55-57.

[7] G.S. Brager and R.J. de Dear (1998), Energy and Buildings 27.

[8] Kaiser, E. J., David R. Godschalk, and F. Stuart Chapin, Jr. 1995. Urban Land Use Planning, 4th ed.

[9] K.R. Rao and J.C. Ho (1978), Building and Environment 13 (3), 161.

[10] M.R. Sharma and S. Ali (1979), A thermal stress index for warm, humid conditions in India, Educational Building Report 14, UNESCO Regional Office for Education in Asia and Oceania, Bangkok.

[11] M.R. Sharma and S. Ali (1986), Building and Environment 21 (1), 11.

[12] Nicholls, R. J. (1995). Coastal megacities and climate change. Geojournal, 37(3), 369- 379.

[13] P.O. Fanger (1972), Thermal Comfort: Analysis and Applications in Environmental Engineering, McGraw-Hill Book Co., New York

[14] Protneyo, K. (2003). Taking Sustainable Cities Seriously: Economic Development, the Environment, and Quality f Life in American Cities. Cambridge, MA.

[15] Post, J., & Altman, B. (1994).Managing the environmental change process: Barriers and opportunities.Management, 7(4), 64-81

[16] Raprthi, K. (2014), Impact of urban planning policies on carbon-dioxide emissions, an Indian perspective.Doctoral thesis (Published), University of Texas at Arlington.

[17] Raparthi, K. (2014). Assessing Smart Growth Strategies in Indian Cities: A Grounded Theory Approach to Planning Practice". Journal of Urban planning and development. 10.1061/(ASCE)UP.1943-5444.0000267 , 05014031. ISSN (print): 0733-9488. American Society of Civil Engineers.

[18] Raparthi, K. (2015). Analyzing the Relationship between Environmental Planning Policies and Climate Change: Multinomial Logit Regression Model Evaluation of Tarrant County, Texas. Current Urban Studies, 3, 1-10.

[19] Raparthi, K. (2015). Assessing climate change planning in Indian cities: Bridging the gap between climate change research and practice. Social science and Humanities Journal. DOI: 10.1234.67/sshj.1013 SSHJ 2016, 3, 160-174

[20] Wilbanks, T. J. (2003). Integrating climate change and sustainable development in a place-based context.Climate Policy, (Supplement 1), S147-S154.