© International Academic Forum
Sakae 1-16-26 – 201, Naka Ward
Nagoya, Aichi, Japan 460-0008

Satish B. K., Brennan J. (2015), *Significance of boundary conditions towards sustainable housing [...]*, IAFOR Journal of Sustainability, Energy and the Environment **2(1)**:21-40.

SIGNIFICANCE OF BOUNDARY CONDITIONS TOWARDS SUSTAINABLE HOUSING STRATEGIES: A CASE STUDY OF MYSORE, INDIA

B. K. Satish[1], John Brennan[2]

Abstract. *Background*: For developing nations the development of sustainable communities has to go hand in hand with the achievement of wider goals, where emphasis has to be given to the importance of lifestyle and social change. This interdisciplinary research draws understanding from the social, cultural and economic studies to define the values and aspirations of the middle class and the associated implications for sustainable housing. Middle class mores are aspirational and aim to achieve Western living standards, moving away from a traditional communitarian social model. *Methods and Results*: This research presents the results of extensive field work in the Southern-Indian city of Mysore that defines the values held by the emergent middle class in respect to the built environment. Common areas and shared spaces have traditionally been very actively used and have played a crucial role in both passive cooling strategies and the maintenance of socially sustainable communities. Fieldwork shows that attitudes to the built environment are polarised between well-maintained and protected housing interiors and poorly organised and maintained external spaces and examines how these transition spaces are used to reflect these values and concerns. Possible options for the external boundary conditions are tested by generating 3D models and applying an environmental design method, Integrated Environmental Solutions (IES). *Conclusion*: The paper reflects on whether earlier traditions in sustainable building design in South Asia (Mysore) have relevance in a contemporary context and the importance of understanding the changing preferences and values of the newly affluent demographic..

Keywords: Sustainable Housing, Indian middle class, Developing countries, 3D Model simulation.

1. Background of the Study

Those nations in the developing South inevitably differ in their approaches to sustainable development (Skea and Nishioka 2008). The imperative to reduce poverty and increase economic activity means that resource use will grow to meet the legitimate aspirations of both government and society and this has to be reconciled with transnational concerns to promote sustainable strategies for the future. Economic expansion is required before the recognised process of contraction and convergence takes place in concert with the developed world. (Mayer 2004). The research engages with sustainable development in its widest sense as formulated through the Bruntland (Brundtland 1987) definition of interdependence between social, economic and environmental realms.

[1] Programme Leader, BA Architectural Technology and the Environment & Lecturer, School of Architecture, Design and the Environment, Plymouth University, Plymouth, PL4 8AA, UK, e-mail: satish.bk@plymouth.ac.uk
[2] John Brennan, Head of Edinburgh School of Architecture and Landscape Architecture, Edinburgh College of Art, The University of Edinburgh, 20 Chambers Street, Edinburgh, EH1 1JZ, UK, e-mail: john.brennan@ed.ac.uk

The research is based on whether such assumptions still hold true for the design of housing that might appeal to the burgeoning Indian middle class. This has been achieved through two intensive periods of fieldwork to uncover the key drivers of housing development in the middle income demographic, using mapping activity, structured interviews and questionnaires with key stakeholders. These include architects, builders, developers, planners, householders and potential purchasers. The work was undertaken in Mysore, India (Figure 1). The first published stage of the research clearly reflects a shift away from climate responsive, socially inclusive, community oriented housing to a more individual, exclusive and independent housing typology (Satish et al. 2011). This paper is concerned with the second stage of the fieldwork that market tests with key stakeholders, potential sustainable design strategies that explicitly aim to meet the expectations of the middle income consumer. The methodology for construction of a series of scenario models for market testing is described as well as using simulation techniques to benchmark the models to a series of quantitative indicators.

The fast growing Indian economy has empowered an emergent middle class whose new-found economic status and affluence have a critical impact in the process of sustainable development (Fernandes 2000a, Fernandes 2000b, Singh 2009, Wessel 2004). A former class identity based on simplicity has been transformed by economic empowerment to one of affordable indulgence (Varma 1999). Consumerism has become the primary Indian value, fuelled by the influence of the West and a more pervasive media (Fernandes 2006).

In an Indian context, changes in housing procurement and design are as much a social and cultural phenomenon as a technical one. A recognition of this fact can allow insights into the effective formulation of localised, resilient and relevant sustainable housing strategies that address quantitative issues such as carbon reduction (Skea and Nishioka 2008). India's economic growth has also increased the spending power of the middle class (Fernandes 2006). Changing lifestyles and consumption patterns have clear impacts on housing (Imtiaz and Helmut 2001, Swarup 2007). Although increased affluence and consumption benefit the middle class, it also increases carbon emissions (Saavala 2003). 60% of the emissions originating from construction activities are attributed to the housing sector (Tiwari 2003).

This increase in energy consumption is not limited to ownership of more consumer goods but can also be attributed to changes in housing typologies resulting from changing expectations of homeowners. (Satish and Brennan 2010). Traditional middle income housing as studied by the authors was communally configured with a looser relationship between external and internal realms. Contemporary dwelling templates now reflect a culture of individuality that feature highly defined boundaries forcing dwelling activities into air conditioned interiors with resource and carbon implications (Satish et al. 2011).

In the case of Mysore (Figure 1), a South Indian city, traditional residential layouts were either linear with a shared party wall, or with houses distributed around an open space (Figure 2). Entry to the house was through a semi open raised platform (Jagali) (Issar 1991). These Jagalis were shaded for most of the day and used extensively for socializing and actively used as interaction areas (Ikegame 2007). Jagalis worked as an effective climate mediating transition space and there were no other boundaries to define individual territories. Materials used for construction, thick mud walls (later brick) and terracotta tile roofs were locally sourced and with small openings towards shaded areas, they were climate responsive and exhibited sustainable features in their material choice and construction details.

Figure 1. India map: Mysore location.

Shared facilities and the efficient use of semi-open outdoor spaces for much of the day also resulted in a compact building footprint. Such climatically responsive layouts and construction using locally available material are a good example of efficient sustainable development (Vandana 2008). These houses were thermally comfortable due to planning techniques which reduced solar gain and due to the use of local materials and construction details which were climate responsive and had low ecological footprints (Satish et al. 2011).

Housing design and residential layout both changed drastically after independence in 1947. It could be argued that a move from communal provision predates contemporary economic expansion and its attendant societal changes, a sense of the communal being replaced by a priority to preserve privacy. Contemporary housing designs feature large openings, a defined and fenced plot boundary (Figure 3) making each building self-contained and introspective (MUDA 2005). Roads, independent of houses, have pedestrian ways and are clearly segregated from the property of private individuals by fencing into compounds. This is supported by local planning legislation (MUDA 1996). It is an embedded expectation that buildings no longer enclose and define the open spaces and encourage outdoor activities (CITB 1987, Satish et al. 2011).

Figure 2. A typical Agrahara, Jagali typology.

Figure 3. New houses.

Altered social and cultural values have played a crucial critical role in the adoption of new housing typologies. Changed social conditions mean that people have started to associate the strengths of community living with weaknesses. For instance, shared facilities are interpreted as leading to a lack of privacy (Satish et al. 2011).

A new housing typology has been inadvertently implemented that does not reflect local climatic conditions and this has led to increased consumption of operational energy (Figure 3). As an executive engineer responsible for urban housing development recollects, until 1970 people were careful to stay close to the city centre (Fort and Palace) (respondent no.12, interviewed on 23 July 2009). To encourage residents to move away from city centre, the City Improvement Trust Board (CITB) built houses in plots and allotted some sites free of cost for those who bought houses away from the city centre (CITB 1987). This has had a direct impact on the land footprint (Figure 4). Whereas in the earlier Jagali typology, nearly thirteen square meters of land was used per person this increased to 27 square meters per person (CITB 1987). Now, middle class people prefer the plot typology and the land footprint has increased up to 43 square meters per person (MUDA 1996, MUDA 2005). Emphasis on privacy has resulted in the use of further resources to protect property. Improved financial resources coupled with changing aspirations have contributed to building bigger houses and the choice of imported materials to reflect their owners' aspirations. These have clearly increased the embodied energy of houses (Figure 4). Changing social and cultural needs have resulted in climate responsive spaces like Jagalis becoming redundant. Social activities have moved indoors coupled with large windows, increasing conductive heat gain and increased comfort expectations have resulted in use of more lighting and spot cooling, all of which has increased operational energy requirements (Figure 4).

Unsustainable development can be identified at every level. The first published stage of the research clearly reflected and summed up the unsustainable features of community living, siting, entrances, house planning, finishes and facades. Reflecting on the earlier work, the second stage of the research focuses on particular sections of the house to investigate the specific rationale for the changes, people's preferences and the implications for sustainable housing.

Housing is thereby identified as a social and cultural phenomena and this research looks at built environment sustainability from a more bottom-up perspective. The earlier research clearly indicated changes at all levels but more so at the entrance point, the transition from street to main door. This area clearly demonstrates people's preferences, aspirations and changed attitudes and the impact of this on housing form. It is also impacted on by reconfigured layouts, preferences and requirements of homeowners.

The research focuses on this boundary condition and the second stage of the fieldwork engages with key stakeholders in examining sustainable design strategies that could also meet the expectations of the middle income consumer.

2. Boundary condition and its implication on sustainable housing

It has been argued that the pre-industrial architecture of India served the physical and spiritual needs of the populace well. At a physical level, it demonstrated an understanding of the local climate, available materials and construction techniques. Indian architect B.V. Doshi has argued that "at the spiritual level, the built-form conveyed total harmony with the regional lifestyle in all its daily as well as seasonal rituals, unifying the socio-cultural and religious aspirations of the individual and the community" (Ameen 1997).

Closer inspection reveals that the key change has been the way the house boundary is defined and the values and changes taking place at this interface. As practising architect-planner Charles Correa (1991) has argued, the climatic conditions of most Indian cities allows for the use of open and semi open spaces for interaction, gatherings and other social activities (Correa 1991). Correa identified specific Indian conditions, which aid sustainability. The use of natural light for most of the day and very minimal construction, which reduces embodied energy. He has identified (Correa 1991) four major elements as:

1. Internal private spaces
2. Area of inmate contact (the front door step)
3. Neighbourhood meeting places
4. Principal urban area

In a traditional Indian context, these spaces will always have very high usability coefficients due to the nature and way in which these spaces are used (Correa 1983). Though the notion of threshold is a theoretical construct used in sociology, anthropology, and architecture, primarily in a Western context, it is none the less relevant in interrogating modern urban conditions in India.

The research is thus focussed on these boundary conditions as they may reflect fundamental changes since Correa's writing about threshold. Although relevant in 1990, such has been the change in society that a virtuous link between building form, bioclimatic response and social structures in the household may be broken. We therefore examine whether contemporary expectations regarding security and privacy have anything to offer sustainable design strategies and if any of the more traditional approaches to threshold and form can be incorporated in the design of new housing.

3. Models and simulation analysis

The research aimed to use the observations and conclusions of the earlier research and fieldwork to identify the needs and wants of middle class homeowners. Structured interviews and surveys clearly indicated concerns regarding security and the notion of protecting one's boundary, coupled with the need for privacy, and the use of form and façade to provide visual cues in expressing wealth and aspiration (Glendinning 2011, Satish et al. 2011).

The results of the fieldwork were then triangulated with literature studies and the outcomes related to boundary conditions were used to produce different computer models, representing alternatives for major elements, a sustainability agenda and middle class aspirations. Feedback from architect, builder, and homeowner was used to define these models, which are then related to sustainable values.

The fieldwork was combined with intensive literature reviews of both contemporary Indian building typologies (Annapurna 1999, MUDA 2008, Shirley 2008, Tiwari 2001) and research on boundary, threshold and border that help explain contemporary preoccupations with security and defensible space (Blaisse 2009, Georges 2005, Georges 2008, Rashid 1998, Suzanne and Lennard 1977). From this a series of four test models were generated for study in respect to both predictive quantitative performance and as a basis for revisiting the fieldwork. The models were organised to test housing market stakeholders' responses to a range of sustainable criteria. One model was based on a traditional bioclimatic solution that reflects past models of communal living and at the other end of the spectrum, a model representative of current private sector middle class housing was constructed. Two further models pitched somewhere between these two extremes were also designed primarily to get a finer understanding of the exact levels of privacy and social interaction that might be embraced by potential stakeholders (Figure 4).

The model prepared to reflect the prevailing typology (model 3): has an approximately 4 feet high compound between neighbouring plots. The front and rear of the plot has a minimum set back of 1 meter as required by the BDA regulations. The aspiring model (4): has a very high compound that insulates it from the external world and has extensive use of imported material and ostentatious finishes in addition to very wide openings. The earlier Agrahara typologies are represented in model 1: a raised platform in the front with small openings and use of locally available material, overlooking the street. Finally based on the feedback from the first fieldwork, a combination of climate responsive and aspirational typology (model 2) was developed (Figure 5).

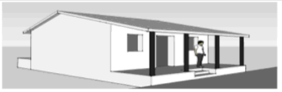
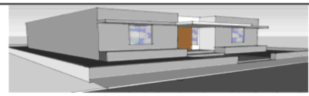
	Typologies	Model 1 Jagali Typology	Model 2 Jagali + Plot	Model 3 Plot + Gate	Model 4 Plot + High Gate
					
Description	Boundary condition	A traditional bioclimatic solution that reflects past models of communal living	A representative model of a combination of traditional and current middle class housing. Demarcation of boundary with very low wall. Combination of Jagali and plot system.	A representative model of current private sector middle class housing	a representative model of aspirations and high end / upper middle class housing
	Physical	Sharing party wall either in a row or arranged around the open space	The plot is defined more as a very low hedge to retain the permeability of the Jagali typology	About four feet high compound. Clear definition of one's territory	Very high compound. Min 6 feet high. Totally cut off from the external world.
	Spatial:	Use of semi-open space for most of the time	Opportunity to use open space for informal activity	Clear demarcation of territory. Presently, the space is not used for much of the activities.	Well defined barrier segregating the inside and outside. Open space and landscape areas for personal consumption.
	Visual	House and central open space are visually connected. Kids can play and people can use the Jagali for informal gatherings/activities	Developed more to suit the prevailing plot typology. Scope for interaction among neighbours.	There is a visual connection if not physical. Owners have the option to interact with the neighbours.	Insulated and visually cut off from the street and neighbours.
Qualitative	Communal / Social	Community oriented. Common open space and other than the rear utility area, there is no individual house open space	Scope to use open space for most of the day	Scope for informal interaction with the neighbours and street. Not much importance for the exterior open spaces and community activities	Totally cut off from the neighbours. Introverted, independent and more importance for privacy. Independent of neighbours and not involved in community activities.
	Economics / reflection	More emphasis on culture than economics (Rangoli). More functional	More functional	Combination of function and appears. Skin and compound used for demonstration of one's aspiration.	Skin and compound used for demonstration of one's aspirations
	Security	Social security, compact community and known neighbours	More importance attributed to social security	Compound used as a psychological barrier, main door with steel shutter	Compound itself acts as first level of defence. Totally grill and very high individual security.
Quantitative	land foot print	13 Smt / person	27 Smt / Person	27 Smt / Person	43 Smt / Person
	Embodied energy	Use of least embodied energy and lifecycle energy	Less embodied energy		Use of very high embodied energy and lifecycle energy
	Embodied energy	0.47 MWh / SQM	0.57 MWh / SQM	0.63 MWh / SQM	0.78 MWh / SQM
	carbon emission	0.24 t CO2 / SQM	0.29 t CO2 / SQM	0.33 t CO2 / SQM	0.40 t CO2 / SQM
	Openings	Very small, just enough light inside.	Narrow openings, enough light for the interiors	Wide openings, no relation to direction and requirements	Very wide openings. Spanning most of the wall
	Climate responsive features	Climate responsive, roof, wall, construction and materials were reflective of local climate	Jagali area is shaded and could be used for most of the day	Design is independent of climate	Highly insensitive to the climatic condition.
	source of material	Use of locally sourced materials	Emphasis on use of locally sourced materials	Combination of local and imported materials.	Use of imported materials
	Security	No/least number of materials used for security other than the regular wooden door	Steel door as additional security to the main and rear doors	Steel grill for the portico area	Entire or most of the plot is covered by a grill
Summary		Most sustainable typology	Some of the features are sustainable	Some of the features are unsustainable	Least sustainable typology

Figure 4. Analysis of different model typologies.

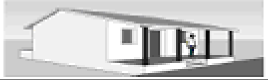
		Model 1	Model 2	Model 3	Model 4
	Typologies	Jagali Typology	Jagali + Plot	Plot + Gate	Plot + High Gate
	General description				
Volume	Different activities and their features are highlighted. Each typologies represent most desired to most prevailing and also vernacular typology.	There is no demarcation of private spaces and public areas. Sharing party wall either in a row or arranged around the open space.	The plot is defined more as a very low hedge to retain the permeability of the Jagali typology. A representative model of combination of traditional and current middle class housing.	This most prevailing model has physical barrier between street and inside plot. The height of the wall is about four feet, where the homeowners can still retain some connection with street and neighbours. Portico defines the main entrance and also acts as informal reception area of guests.	this most aspiring model has clear definition of internal and external part of individuals space. High wall, gate an elaborate portico emphasis the status of the person.
Entrance	Main relation of street and Entrance door, different activities between the two are explored.	There is a smooth transition from street to main door through semi open raised area (Jagali). Jagali is used for most part of the day.	Similar to Jagali typology entrance with additional space in the front with hedge to define ones plot area.	Direction of the opening is influenced by many factors and owners tend to locate the main door close to street and additional open space near the main door used for parking two wheel and four wheel vehicles.	Main door is recessed inside the individual property and not visible fron the street. There is no relation betwee street and main door.
Opening	Larger openings will increase conduction gain and increase cooling load. Different alternatives are worked out based on the window size and two more models are developed to examine peoples preference of overlooking shared spaces.	Very small, just enough light inside.	Narrow openings, Enough light for the interiors.	Wide openings, no relation to direction and requirements.	Very wide openings. Spanning most pa of the wall.
Security	Concern of safety and both perceived and real threat are reflected the way the boundary and openings are protected. Different level of security are represented in each model.	Social Security; compact community and new members are identified by people. Least materials used for security other than the regular wooden door.	Emphasis on social security. Steel door as additional security to the main and rear door.	Compound used as a psychological barrier and main door with steel shutter. Most of the cases steel grill for the portico area.	Compound itself acts as first level of defence. Very high individual security. entire plot or most part is covered by steel grill.
Interaction	Interaction among neighbours and home owners is the crucial part of the boundary condition. Different typologies represent degree of interaction among community.	Community oriented. Common open space. Visually connected with each other. Kids can play around and people can use the Jagali for various activity.	Scope to use open space for most part of the day. Developed more to suit the prevailing plot typology. Scope for interaction among neighbours.	Scope for interaction with the neighbours and street. There is a clear physical barrier and visual connection. Owners have the option to interact with the neighbours.	Both physically and visually cut off fron the neighbours. Importance for privacy No interaction with neighbours and no involved in community activities.
Skin	Skin used for elevation, is either construction material used as masonry or cladding for the entrance and front side of the building. The choice of material is independent of building typology. However, peoples preference of each typology is listed.	Use of locally sourced materials. Use of Mud blocks	Emphasis on use of locally sourced materials. Use of Brick and mud blocks	Combination of local and imported materials. Mostly Plastered with entrance area and street side clad with stone or Tiles	Use of imported materials. Emphasis o aesthetics and cost of the material. Extreme of use of polished granite and imported materials and also cement tiles.

Figure 5. Description of elements of different model typologies.

The models were generated with similar configuration in terms of built up area, number of rooms, size of the plot and provision for minimum light and ventilation. To focus the research more on the boundary conditions, all other components such as constructional systems and spatial planning were kept as constants. Each option was then modelled first in Google Sketch Up then exported into an environmental simulation package, Integrated Environmental Systems (IES), to predict energy consumption and carbon emissions. Longitude and latitude were specified for Mysore using hourly climate data from Bangalore, the nearest city to the study area.

Before testing stakeholders' responses to the models, the models were validated for their predictive quantitative performance by simulating them using environmental design software. IES supports a range of analytical tools for lighting, thermal comfort and resultant energy consumption and carbon emission (IES 2010). The results of the simulation for each of the four models are shown in Figures 6, 7 and 8 in respect of conductive heat gain, cooling load, peak energy demand and carbon emissions for a representative day; May 19, one of the hottest days chosen to analyse the heat gain and energy consumption due to cooling. The focus of this research is to access the implication of varied boundary condition in terms of change in energy consumption and resultant carbon emission. For the simulation purpose, only these boundary conditions of different typologies are altered while providing input in IES. For instance, the internal parameters like number of rooms, number of occupants, comfort conditions expected inside the house, minimum light, and ventilation desired are kept constant across all the models. Details like size of the openings and their location are altered among the models. Similarly, the construction materials and internal partitions are kept constant, whereas the external finish either the cladding or plastering or use of construction material as external fabric, are altered as defined in each typology. Finally, the boundary condition as either shared party wall, independent plot system, four feet compound or very high compound with high gate details are constructed and fed to IES.

IES is a dynamic simulation software which allows one to model a building by inputting form, location, meteorology, materials and building services. The simulation engine then uses real weather data to simulate models over a year in 15 minute intervals to give a relatively accurate indication of comfort and energy use (IES 2010). Since the emphasis is on social sustainability and buildings are typical middle class homes, this research does not intend to measure or compare against a benchmark or absolute standards, rather it will investigate the performance of each model on a comparison basis. In this context, IES has been a very useful tool in analysing the building performance by defining the required parameters.

IES allows the input of each typology to be altered while retaining some of the features as constant across all typologies. Further, it allows comparison of specific parameter across typologies during output. For instance the models can be run to simulate only the conductive heat gain, where the internal temperature rise is due only to heat gain by conduction. Similarly, the energy consumption due to cooling load, resultant of bringing down the internal temperature to set comfort condition is assessed (Figure 6, 7 and 8).

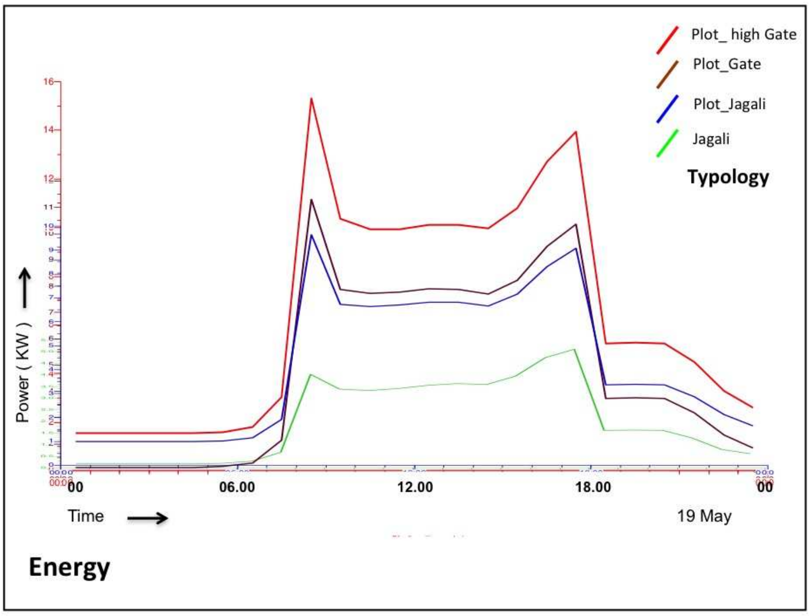


Figure 6. Energy consumption.

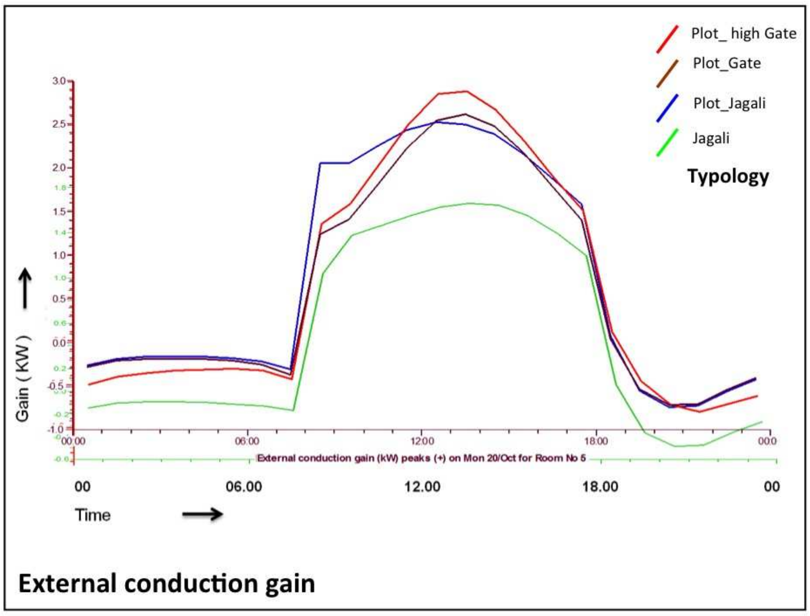


Figure 7. Conduction heat gain.

The outcome clearly indicates higher conduction gain, cooling load, energy consumption and resultant carbon emission in plot and high gate typologies and consistently lowest energy consumption and carbon emission in the Jagali typology.

A key finding is one of increased energy consumption in model 4 which represents the aspirational model. It uses nearly 65% more energy than model 1 (the Jagali typology). Similarly, there are differences in the performance of other models; for instance, in the case of energy consumption, the high compound typology (model 4) requires nearly 300% more cooling load compared to a Jagali house typology (model 1).

This will also increase the conduction gain by nearly 90%. All the results are tabulated and compared in Figure 9.

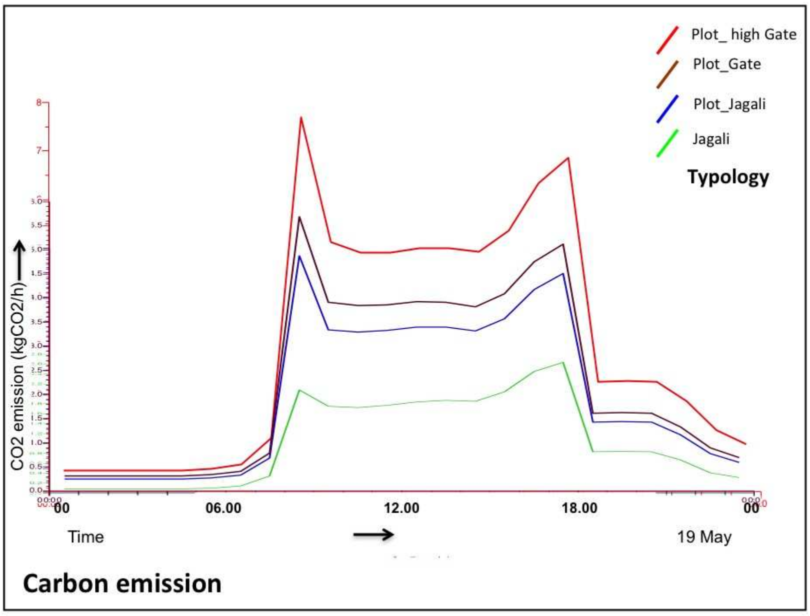


Figure 8. Carbon emission.

The simulation output demonstrates that changed boundary conditions have implications for energy consumption and resultant carbon emission. They also validate the hypothesis while developing models that explore different boundary conditions (Figure 4 and 5). It also clearly points to a direct relation between peoples' changed preferences and aspirations and the implications for energy consumption and carbon emission.

5. Field work

The main objective of achieving sustainable strategies within the existing middle class paradigm is achieved by contextualising the broad term of sustainability to Mysore condition on one hand whilst reflecting the middle class homeowners' preferences and acceptability on the other. The models and simulations reflect the local sustainability agenda and present different levels of sustainability with specific reference to boundary condition. Further fieldwork looked at the aspirations of the middle class people and their willingness to align towards more sustainable features.

With the series of scenario models complete, a second series of field work was carried out during Feb – April 2011. Here the research is more focused on testing the acceptability and preferences of homeowners by drawing on their feedback to these predefined models. The models were tested with homeowners by semi-structured interview and with key stakeholders in the design and procurement process. To analyse the issues reflected in transition spaces, elements representing middle class aspirations and the sustainability agenda were identified, namely: Volume, Entrance, Opening, Security, Interaction and Skin.

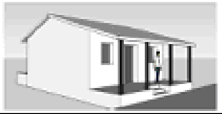
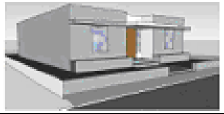
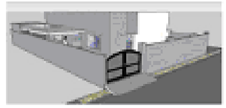
IES Simulation Result	Typologies ->	Model 1 Jagali Typology	Model 2 Jagali + Plot	Model 3 Plot + Gate	Model 4 Plot + High Gate
Parameters	General description				
Energy Consumption / SMT	Energy consumed by electrical appliance are considered. To bring in uniformity, it is converted to SMT and all the models are compared to the base results of Jagali typology as 0	Bench mark	20 % of Jagali Typology	35 % of Jagali Typology	65 % of Jagali Typology
Cooling load	This simulation result accounts for the energy consumed to cool the internal spaces to comfort temperature of 23 degree.	Bench mark	100 % of Jagali Typology	200 % of Jagali Typology	300 % of Jagali Typology
conduction gain	Window size is altered in each typology and with other construction materials being constant, the simulation result reflect the conduction heat gain due to size of the opening.	Bench mark	58 % of Jagali Typology	65 % of Jagali Typology	90 % of Jagali Typology
Embodied Energy	Source of the material, energy consumed for the processing and transportation are considered to qualify the other simulation results.	Locally resourced material and construction system. Least materials imported from beyond 10 miles.	Most of the materials Locally resourced and few materials imported from beyond 10 miles.	Some of the materials Locally resourced and few materials imported from beyond 100 miles.	least of the materials Locally resourced and most of the materials imported from far distance.
Total energy consumption	it includes energy consumed due to electrical appliance, maintenance and cooling load.	Bench mark	138% of Jagali Typology	175% of Jagali Typology	275 % of Jagali Typology
Carbon emission / SMT	Total carbon emission due to energy consumed due to maintenance and cooling energy. To bring in uniformity, it is converted to SMT and all the models are compared to the base results of Jagali typology as 0	Bench mark	20 % of Jagali Typology	35 % of Jagali Typology	65 % of Jagali Typology
Summary		Most sustainable typology	Some of the features are sustainable	Some of the features are unsustainable	Least sustainable typology

Figure 9. IES simulation output.

To elicit preferences and log the choices of homeowners, architects and builders, a 'multi sorting task' methodology was followed. As Groat (1982) has argued, participants can either sort representations of buildings they have experienced directly or use pictures that function as simulations of the real environments. This research used models that were deconstructed to highlight the exact element under investigation; for instance, while asking people about their priorities regarding openings / window size and location, views showing different window conditions were derived from the original models and prepared so that the participants could reflect purely on the concerned issue and not be distracted by other elements in the images.

This technique is very helpful in this type of study as respondents are asked to place the cards in priority order from the most acceptable to least acceptable. Once noted, they are given a briefing about sustainable issues in housing and how each model and typology reflects different energy and carbon footprints. Stakeholders are asked to place the cards again in the light of their understanding of the sustainable implications of their choices. Their preferences are noted and the implications of any change in the respondents' choices are ascertained.

This multi sorting process was validated through a semi-structured interview. Apart from noting their preferences, the process was recorded and interviewees were informally questioned about their decisions.

5. Field work analysis and discussion

The outcome of this second stage of fieldwork addresses issues including social and cultural values and perception of key stakeholders towards middle-income sustainable housing. The study can be broadly addressed at two levels; firstly, it deconstructs how various stakeholders perceive boundary and threshold in housing. The interview and survey assesses the choices and preferences of a particular topology based on issues like, security, material, interaction etc. and their choice of most preferred and least preferred are further triangulated with a discussion regarding the rationale behind their choices and why they think their choice is appropriate. Triangulation of the research is thus achieved through the complementary use of literature review, semi structured interview (MST) and quantitative environmental simulation.

At second level, the study analyses how the peoples' perception changes with awareness. The homeowners were asked first to prioritise their preferences. Later after being given information on issues relating to climate change and sustainable housing, they were asked to again place their preferences. Feedback from stakeholders; architects, builders, contractors and homeowners were analysed for each element identified namely; Volume, Entrance, Opening, Security, Interaction and Materials. Though there is a clear departure from the sustainable boundary condition, the outcome clearly reflects varied preferences among different elements identified. To summarise the field work results; two representative outcomes, Volume and Opening, are discussed below.

5.1. Volume

In the case of different Volume options, stakeholders strongly feel that the prevailing plot typology is the most desirable aspect followed by the high gate typology preferred by more than 65% of homeowners. The most sustainable, Jagali typology is the least preferred option (Figure 10). According to an architect interviewed, “Privacy, dust, vibrations due to vehicle movement, forces people to build house away from road” (respondent no.111, interviewed on 11 March 2011). One builder felt that privacy is a major concern and people would not prefer to build “their house on the street without privacy” (respondent no.109, interviewed on 10 March 2011). When their attention was drawn to the well-established Jagali typology, respondents felt that there was clear deficit of trust among neighbours which is crucial for social / community living (respondent no.98, interviewed on 19 March 2011). The strong preferences of respondents are evident however while analysing these preferences it became clear that they altered significantly after they had been provided with the information regarding sustainable concerns. Homeowners’ revised preferences clearly reflect a marginal decrease in the high gate typology, which is reflective of many unsustainable features and a less than 10% increase in the preferences for Jagali typology (Figure 10). Similar trends can be observed among other elements like, Entrance, and Security.

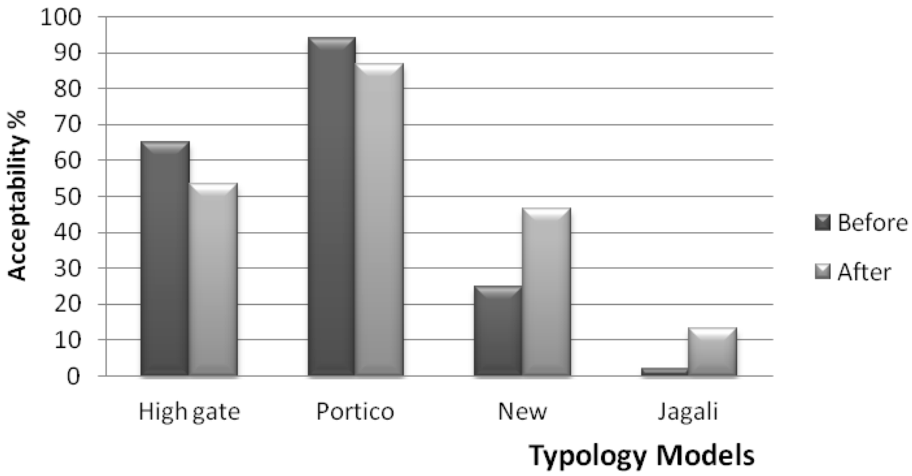


Figure 10. Volume.

5.2. Opening

In the case of different opening options, stakeholders are divided among preferences for wide, small or inward openings. Less than 10% of homeowners prefer opening towards shared areas (Figure 11). According to one architect, changed social network and priorities makes this the least feasible typology (respondent no.76, interviewed on 09 March 2011). One builder posed a more practical concern regarding flexible design and spatial organization, stating that two or four owners may have their own plans that do not correspond, and won’t be successful unless they are all designed, financed and built together as a group (respondent no.115, interviewed on 13 March 2011). The concern of homeowners regarding sustainability and their willingness to adapt their choices accordingly is evident in the results. For example, after being presented with information on issues relating to climate change and sustainable housing, preferences for wide openings reduced to less than 5%, and preferences for small openings increased by 20% (Figure 11). Similar trends can be found in the case of Material choices as well.

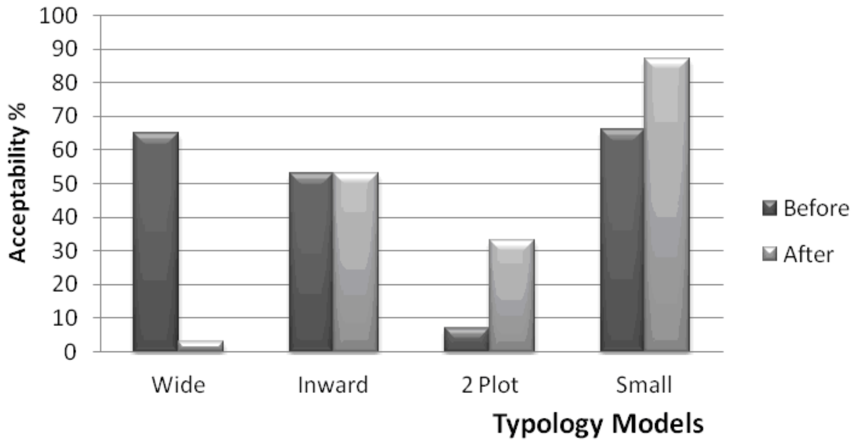


Figure 11. Opening.

Analysis of these representative elements reflects the concerns and aspirations of the middle class homeowners and also demonstrates variation in their preferences among different elements. The understanding of homeowners' perceptions and expectations enables the production of sustainable strategies, which work within an existing middle class paradigm. The outcome of the fieldwork could be summarised based on the level of acceptance of sustainable models and probability of aligning towards Sustainable Housing (Table 1).

Table 1. Summary of field work outcome.

Field Work Reflections		
	Level of acceptance of sustainable models	**Probability of aligning towards Sustainable Housing**
Volume	Least	Negative
Entrance	Least	Negative
Openings	Most	Positive
Interaction	Moderate	Perhaps
Security	Least	Negative
Skin	Most	Positive

Choices and preferences clearly represent the area in which we can expect people to support and adapt to sustainable features. The feedback can be classified in to three types. First, the elements where people are ready to change their preferences for the cause of sustainability, in this we can easily find the materials, skin and openings as two aspects which people are ready to align towards a sustainable agenda. There are certain elements for which they do not have very strong preferences and to some extent are ready to align themselves. In this case people might consider some adjustment but are not ready to forthrightly support a sustainability agenda.

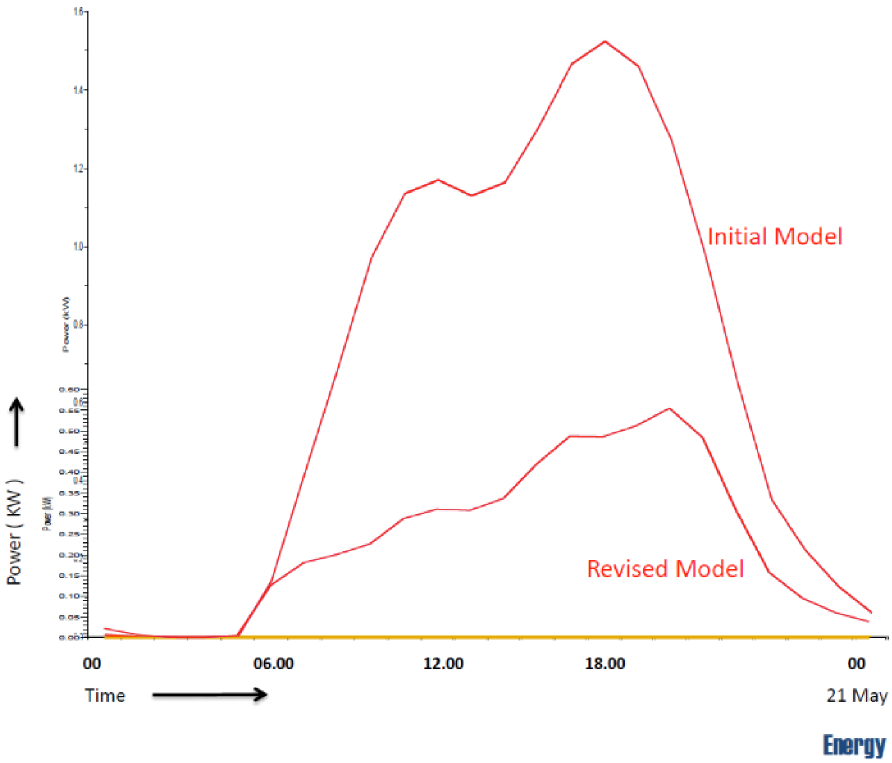


Figure 12. Post-field work: Energy consumption.

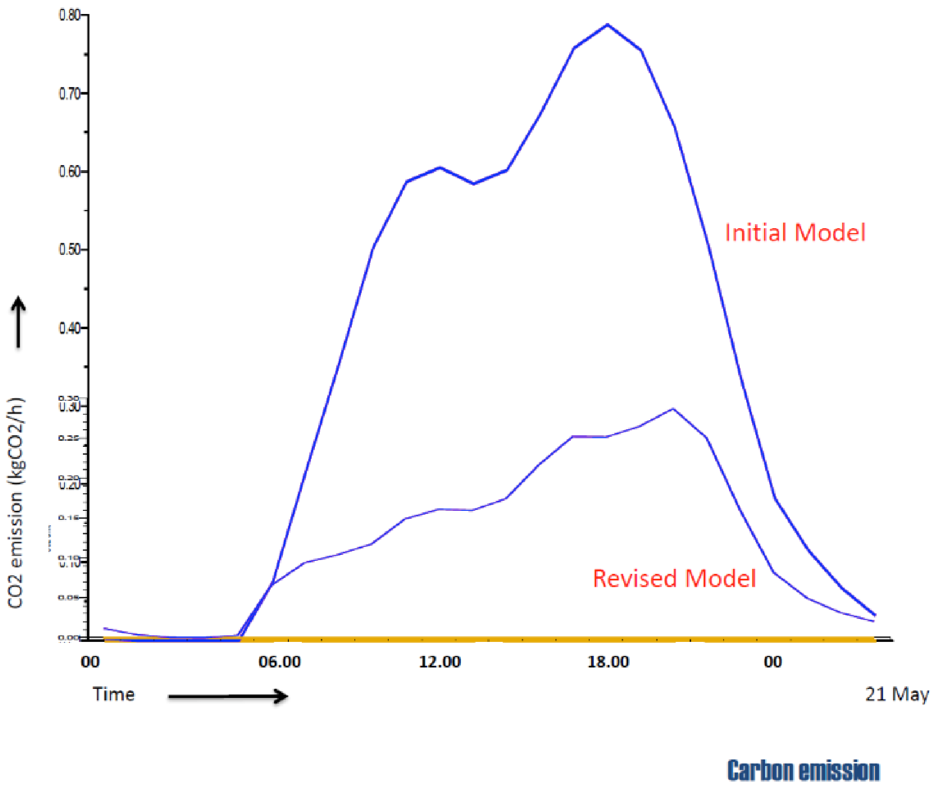


Figure 13. Post-field work: Carbon.

However when it comes to issues like security; people are not ready to compromise and would not be interested in sustainability issues and would not compromise on their perception of what is safe and secure for them. This study has been very useful in disentangling one area, the boundary condition and looking at each element within this area separately so as to identify people's choices and preferences regarding housing typology and hence the resultant sustainable concerns rather than broadly summing up the boundary conditions as unsustainable in present context.

The new IES simulation chart clearly shows a drop in the energy consumption of 40% and thus a reduction in carbon emission. The changed window parameter has also reduced the conductive heat gain by 20%. The results clearly show that, by changing the elements which people are ready to alter, we can reduce carbon emission by a fifth. This is significant because it is useful to know where we can really target and reduce emissions.

This study is also helpful in identifying the areas and elements where it is easier to achieve higher sustainable goals compared to areas where there will be higher resistance to change. Revising the model to suit both peoples' choices and the sustainable agenda further tests this. Peoples' choices and preferences, collected by social methods, were fed into the IES simulation model to analyse the difference in the process of sustainable housing. To test this one model is altered to have optimum size windows which people would be ready to align with to achieve more sustainable housing.

6. Conclusion

This study using survey field work and model simulations has highlighted the relatively recent shift in attitudes and cultural values relating to housing in Mysore India; from an inherently sustainable approach which valued shared spaces, local materials and communal activities, to one which reflects a move towards a twentieth century Western approach; of individualism, nuclear families and consumer driven values. The study also clearly demonstrates that there are elements of sustainable design like materials and openings, which people are willing to align themselves with and that there are other elements such as security, on which they would not compromise. Their immediate concerns regarding security for example would be of greater importance than the global issues of carbon emission and sustainable housing.

The results from this research highlight these particular points:

This study has explored the people's attitudes and their implication for housing in India, particularly the people of Mysore. There are however specific factors, which are unique to Mysore. For instance, although the aspiration to own a house is an Indian phenomena, middle class homeowners in Mysore are particularly desirous of owning a plot and identifying their own territory.

Though there is a clear move away from sustainable living, the values of people can be recognised as being more than 40% ready to change their life style to align themselves towards more sustainable housing.

In the process of achieving more sustainable housing there are factors like security where the perception of the owners plays a crucial role. Though homeowners are sympathetic to sustainable concerns, their fear and psychological concerns with regard to security and other issues like unorganised exterior spaces, stray animals and perceived lack of moral values in society has prompted the middle class homeowners to define and identify their territory, and protect and insulate their boundaries.

Finally the revised IES simulations demonstrates that nearly 40% energy savings and carbon reduction could be achieved without altering peoples' preferences. Further reduction requires intervention at higher level; for instance to change the entrance and setbacks which are now prevalent. To achieve this regulations and legislation will have to be reworked. On the other hand concerns about security can only be addressed at regional and policy levels.

We have to acknowledge the need for people to express and accommodate their desire for upward mobility against a backdrop of complex class and caste structure on one hand and consumerist driven influences of the media and the West.

India has identified housing as one of the eight national missions to reduce carbon emission as part of its commitment to reduce the vulnerability of the people to the impacts of climate change (NAPCC 2008), this bottom-up approach to identify the sustainable strategies acknowledging people's needs and aspirations should be a useful contribution to achieving carbon reduction and sustainable housing.

Acknowledgement

This paper is a revised version of the paper presented at 'The Asian conference on Sustainability, Energy and the Environment (ACSEE)' May 12 2012 in Osaka, Japan.

References

Ameen, F. (1997) *Contemporary architecture and city form : the South Asian paradigm,* Mumbai: Marg Publications.

Annapurna, S. (1999) 'The Planning and Development of New Bombay'. *Modern Asian Studies, 33*(4). 951-988.

Blaisse, P. (2009) 'The Instinctive Sense of Space and Boundary'. *Inside Outside*. 84 - 87.

Brundtland, G. H. (1987) *Our common future / World Commission on Environment and Development,* Oxford : Oxford University Press, 1987.

CITB (1987) *'Asha mandir' housing scheme*, 1:100. Mysore: City improvement trust board.

Correa, C. (1983) 'Urban housing in the third world: Role of the Architect'. in *Architecture and Community*, Renata Holod, D. R., (ed.)New York: Aperture. pp. 43-45.

Correa, C. (1991) 'Space as a Resource'. *Building and Environment, 26*(3). 249-252.

Fernandes, L. (2000a) 'Nationalizing 'the global' media images, cultural politics and the middle class India'. *Media, Culture & Society, 22*. 611-628.

Fernandes, L. (2000b) 'Restructuring the new middle class in Liberalizing India'. *Comparative studies of South Asia, Africa and Middle east, 20*(1 & 2). 88-104.

Fernandes, L. (2006) *India's new middle class : democratic politics in an era of economic reform,* Minneapolis, Minn.: University of Minnesota Press.

Georges, T. (2005) 'A topology of thresholds'. *Home Cultures, 2*(1). 89–116.

Georges, T. (2008) 'Mapping the threshold: a theory of design and interface'. *AA Files, 57*. 3-12.

Glendinning, S. (2011) 'Editorial'. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability, 164*(4). 249–260.

Groat, L. (1982) 'Meaning in post-modern architecture: An examination using the multiple sorting task '. *Journal of Environmental Psychology 2*. 3-22.

IES (2010) *Integrated Environmental Solutions Limited,* http://www.iesve.com/, Available: [Accessed 02 Feb 2010].

Ikegame, A. (2007) Royalty in Colonial and Post-Colonial India : A Historical Anthropology of Mysore from 1799 to the present. in *Ph.D. thesis* The University of Edinburgh.

Imtiaz, A., Helmut, R. (2001) *Middle class values in India & Western Europe,* New Delhi: Social Science Press.

Issar, T. P. (1991) *Mysore- the royal city,* Bangalore: My tec process Pvt. Ltd.

Mayer, A. (2004) 'Briefing: contraction and convergence'. *Engineering Sustainability, 157*(4). 189-192.

MUDA (1996) Comprehensive development plan for Mysore. in: The Mysore urban development authority, Mysore.

MUDA (2005) Sarawatipuram Layout. http://www.mudamysore.org (accessed 22/10/2008): The Mysore urban development authority, Mysore.

MUDA (2008) *Mysore Development Authority,* Mysore.

NAPCC (2008) National Action Plan on Climate Change. in Prime Ministers council on climate change, (ed.),New Delhi: Government of India.

Rashid, M. (1998) 'Reconstituting Traditional Urban Values:The Role of the Boundary in the Contemporary City'. *T D S R, 9*(11).

Saavala, M. (2003) 'Auspicious Hindu houses. The new middle classes in Hyderabad, India'. *European Association of Social Anthropologists, 11*(2). 231- 247.

Satish, B., Brennan, J., Pedreschi, R. (2011) 'Influence of affluence on sustainable housing in Mysore, India'. *Proceedings of the Institution of Civil Engineers, Engineering Sustainability, 164*(4). 249–260.

Satish, B. K., Brennan, J. (2010) Harmonising middle-class aspirations for low-carbon housing: contextual study of Mysore, India. in *International conference: Sustainable Architecture & Urban Design 2010*, Penang, Malaysia: Universiti Sains. pp. 880-887.

Shirley, B. (2008) The Town Planning Mechanism in Gujarat, India. in,Washington, D.C. 20433: The International Bank for Reconstruction and Development /The World Bank.

Singh, Y. (2009) *Social change in India: Crisis and Resilience,* New Delhi: Har-Anand Publications Pvt Ltd.

Skea, J., Nishioka, S. (2008) 'Policies and practices for a low-carbon society'. *Climate Policy, 8*. 5-16.

Suzanne, C. L., Lennard, H. (1977) *Architecture: Effect of Territory, Boundary, and Orientation on Family Functioning*. New York: Center for Policy Research.

Swarup, P. R. (2007) *Indian construction industry*. New Delhi: Construction Industry Development Council.

Tiwari, P. (2001) 'Housing and development objectives in India'. *Habitat International, 25*( ). 229-253.

Tiwari, P. (2003) 'Sustainable Practices to Meet Shelter Needs in India'. *Journal of Urban planning and Development,* ( ). 65 – 83.

Vandana, B. (2008) *A Pre-history of Green Architecture: Otto Koenigsberger and Tropical Architecture, from Princely Mysore to Post-colonial London*. Unpublished Ph.D, The University of Michigan.

Varma, P. K. (1999) *The great Indian middle class,* New Delhi ; London: Viking.

Wessel, M. v. (2004) 'Talking about consumption: How an Indian Middle Class Dissociates from Middle-Class Life'. *Cultural Dynamics, 16*(1). 93-116.

Received: 7 June 2012 • **Revised**: 26 July 2014 • **Accepted**: 21 September 2014