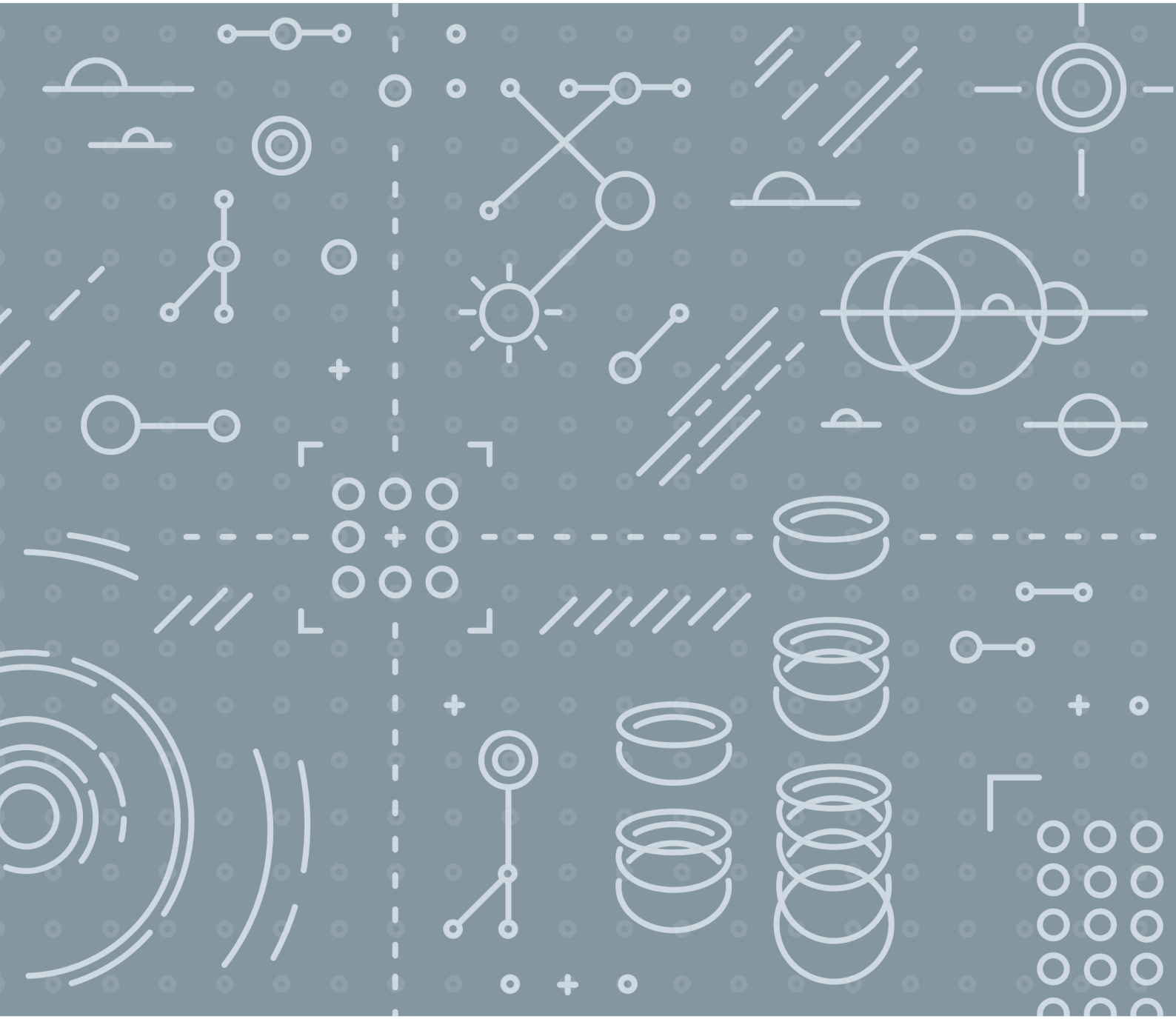
METAGREEN DIMENSIONS

2022

Proceedings

Metagreen Dimensions



C.A.T

COLLEGE OF ARCHITECTURE TRIVANDRUM

20, 21, 22
October

Proceedings

Metagreen Dimensions 2022

Third Biennial Conference on
Value by Design

Organised by

C.A.T.
College of Architecture Trivandrum

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Chairman's Message

I am glad that C.A.T is organizing the third edition of Metagreen Dimensions 2022, a three-day biennial Conference held at our college campus in Trivandrum.

It is noteworthy that the focus of the conference is on 'Value by Design', in the context of Architecture, Urban Development, and Design for the tropical regions.

It will indeed serve as a platform to deliberate on a number of topical and innovative subjects such as Sustainability, Livability and Resilience of Asian and African Cities, Performance of the Built Environment, Conservation and Documentation of Built Heritage, Design for Social Innovation, etc.

I am extremely happy to welcome eminent speakers from among experts in Indian and foreign universities to the conference and it will be a great privilege to extend all facilities and hospitality to one and all of the delegates and the presenters of technical papers.

I wish the conference all success!
Welcome to Gods own Country.
Jai Hind

Prof. J Jayakumar
Director

Foreword

Prof. Neena Thomas
Principal

Principal's Message

Warm Greetings to all !

I am immensely happy that the third edition of Metagreen Dimensions, a biennial conference organised by College of Architecture Trivandrum (CAT) , is being held from 20th to 22nd of Oct 2022 at CAT. The focus of the conference, which is Value by Design, is intended to inculcate the need for value based and performance oriented building design in the areas of Urban Development, Architecture and Design pertaining to the tropical regions.

With this focus in mind, an array of well known expert speakers and resource persons from India and abroad, are invited to deliberate and generate discussions on the various dimensions of the theme, across presentations, workshops and panel discussions. The conference also provides a platform for presentation of peer reviewed and shortlisted technical papers along with poster presentation of a few identified titles. This conference proceedings incorporating the selected technical papers will definitely serve as a valuable reference to keep the knowledge shared and updated, based on the learnings of students, faculty members and researchers from various institutes through promoting exchange and transfer of ideas in a common forum. I take this opportunity to thank all the presenters, authors and participants who contributed towards the content of the proceedings.

I also wish to appreciate the efforts of Prof. Induja, HOD of Architecture, who is also the Conference Convenor and her dedicated editorial team, for their concentrated efforts in bringing out the deliberations of the conference, as a worthwhile compilation of proceedings consisting of well researched technical papers.

I believe the success of any conference vests in providing the participants with a rich learning experience and I hope all the participants of Metagreen Dimensions 3, will be able to go back enriched and inspired to take forward the knowledge assimilated, for the benefit of the society and community at large.

Prof. K P Geetha
Dean

Dean's Message

I am extremely happy that C.A.T is organizing the biennial international conference ,METAGREEN DIMENSIONS 2022 in October . The METAGREEN DIMENSIONS focuses on urban development and architecture in tropical regions. This time the conference focuses on the climate responsive built environment.

The conference will be a platform to for Experts Academicians and Researchers to discuss on the topic and share their thoughts and experiences to bring out suggestions for better livability of tropical regions. All participants also will be benefitted with updated information.

It is really great that the organizers took remarkable efforts to materialize the event with out a break and overcome all hurdles due to the influence of unexpected pandemic disease COVID 19. The unconditional support extended by the Principal , the Director and the Management is really appreciable. All teaching and non teaching staff and students also supported the organizing team by their own way to materialize the event successfully.

I wish METAGREEN DIMENSIONS 2022 a great success and turn to a fruitful event.

HOD's Message

Prof. Anooja J
HOD, Department of Design

The fascinating Metagreen Dimensions 2022 forum will be a great place to talk about new developments in sustainability and research. We recently went through and survived a pandemic, which has helped us get closer to the idea of being sustainable in terms of how we consume and live. The conference will undoubtedly present a chance for fruitful interactions amongst academicians and researchers who are pursuing similar objectives.

I sincerely hope that Metagreen Dimensions 2022 will be just as successful as earlier iterations and spark spirited discussions on value-based design. I want to wish everyone who is taking part the best of luck and commend the team for all of their efforts.

Induja V
Associate Professor
HOD, Department of Architecture
Convenor, Metagreen Dimensions

Convenor's Message

Metagreen Dimensions 2022 is the biennial conference organized by the College of Architecture Trivandrum to discuss the urban development, architecture, and design issues of the tropical region. Metagreen Dimensions pursue this objective through Paper presentations, Keynote addresses of the experts, Student Designers Colloquium and most importantly the Hands-on Workshop sessions through which the delegates can understand issues and develop possible solutions with a peer group of researchers. We also publish a conference proceeding through which the documentation of the initiatives reaches out to promote active dialogue among stakeholders on performance, resource management, and compassion for the society and environment.

College of Architecture Trivandrum is organizing the Metagreen Dimensions conference since 2018 and this is regarded as one of the major initiatives promoting performance-oriented design in the Indian subcontinent. We are indeed proud and honored to host the third edition of the conference, especially in light of an urgent call for action by all countries - developed and developing - in a global partnership to make human settlements inclusive, resilient and sustainable and ensure responsible production and consumption as set forth by the Sustainable Development Goals of the United Nations.

We would like to thank all the authors, delegates, and stakeholders of Metagreen Dimensions for their cooperation and support since the inception of the conference. We sincerely wish that the discussions and deliberations happening across and post the sessions of the conference will have a ripple effect on the teaching-learning process in academia and a strong positive influence on the practice.

Green compatibility of the decisions, regulations and policies taken worldwide will be crucial in promoting prosperity for people and the planet, now and into the future. We regard our conference as a humble attempt to bring together the academia and the practices and provide a platform for deliberations on planning more to build less. We hope MG 2022 succeeds in adding value to the people and the process.

Co-Convenors' Message

The third edition of Metagreen Dimensions is a collective of different streams of architecture, rooted under 'Value by Design.' There is a need to explore and address the embedded values within these streams and our conference attempts to highlight and bring them to the forefront.

Subin Umar Rahman
Associate Professor
Co-Convenor, Metagreen Dimensions

Arya Narendran
Assistant Professor
Co-Convenor, Metagreen Dimensions

Reshmi Ravindran
Associate Professor
Editor, Research Proceedings, Metagreen Dimensions

From the Editor's Desk

With immense pleasure we introduce the Proceedings of Metagreen Dimensions 2022.

This year's conference on 'Value by Design' celebrates the role played by design in increasing the performance or 'value' of products, built spaces or urban realms.

As in previous years, Metagreen brings together discussions, workshops, and technical papers on five very relevant themes related to built environment design and innovation. Our esteemed Theme Chairs played a crucial role in defining the themes. They are Sustainability, Livability & Resilience of Asian & African Cities; Design for Social Innovation; Conservation & Documentation of Built Heritage; Performance of Buildings; and Green Platform: Pedagogy, Process & Policies.

As in all facets of life, the Covid pandemic left its indelible mark on architectural, urban and design research. Lockdowns and travel restrictions greatly affected the scope and scale of research work undertaken in this period. Even so, we received papers from all over India, showcasing the many different dimensions and interpretations of 'value by design' in all five themes.

After a rigorous double-blind peer review, twenty-two technical papers were selected for publication and presentation. From AI application in urban waste management and state-of-the-art digital documentation techniques for heritage documentation, to examinations of green concepts like Low-Carbon Cities and Net Zero Designs and critiques on design pedagogy and policies, the papers published here explore a wide range of concepts. The inter-disciplinarity of our themes have also emerged, highlighting the possibilities of collaborative research. We look forward to the lively discussions these presentations generate.

Despite the pandemic induced limitations in preparing for this year's conference, we were able to organize this event only due to the unwavering support and hard work of several people. The Editorial Committee extends our sincere gratitude to all our authors, speakers, workshop experts and reviewers for their enthusiastic response and effort in preparing for this conference.

We hope that this Proceedings of Metagreen Dimensions 2022 gives you an opportunity to reflect upon the current discussions on sustainable design and inspiration for further research.

CONTENTS

THEME 04: PERFORMANCE OF BUILDINGS

THEME 05: GREEN PLATFORM: PEDAGOGY, PROCESS & POLICIES

THEME 01:

Sustainability, Livability & Resilience of Asian & African Cities

In the 21st century, sustainability of cities is a major challenge as two third of the world's population resides in cities. Cities are basically the major contributors to climate change due to carbon emission despite occupying only 1% of land area. In Asian and African liveability issues in cities further complicate the scenario.

Metagreen Dimensions welcome discussions on sustainability, liveability and resilience in Asian and African cities. Areas of discussion include Outdoor environmental quality, Carbon footprint, Heat islands, Risk Mapping, Waste management, Active recreation, Urban floods etc.

Theme Chairs

Prof. Boban Varghese

Director, School of Architecture,
Nelson Mandela University, South Africa

Boban Varghese is a registered architect, industrial designer, academician, and design thinker. He is the Director of School of Architecture at Nelson Mandela University, South Africa which offers academic programmes in Architecture, Architectural Technology, and Interior Design. Collectively, he has about four decades of academic learning and teaching experience in universities in India and South Africa. He has been a design studio leader in various architectural programmes during his academic career; currently, leading the Honours studio. He is exploring the role of architectural design in developing a post-apartheid inclusive South African cityscape.

He has a Bachelor of Architecture from the University of Kerala, India and a Master of Design in Industrial Design from IDC, Indian Institute of Technology, Bombay. He worked as a designer and travelled extensively in Japan, understanding the role of design in activating economic development for the betterment of a broader society. He was associated with promoting Design for Development awards initiatives with SABS in South Africa.He serves on many validation boards for the South African Council for Architectural Profession(SACAP) and was a member of the merit award adjudication panel for the SAInstitute of Architects. He is associated with design education and innovation programmes at many design institutions in India.

Piet Louw

Piet Louw Architects
ALD (Adam, Louw and Dewar)

Piet Louw has degrees in architecture, city planning and urban design from the University of Cape Town and is principal in his own practice for some 35 years. He has also been a visiting lecturer and external examiner at a number of universities in South Africa.

He works in association with David Dewar in South Africa, Namibia and Botswana and with ALD (Adam, Louw and Dewar) in Mauritius. The association of Louw and Dewar has been in operation for over some 20 years. They offer a wide range of built environment design services (architecture,urban and regional planning, urban design and heritage) and consult widely on a wide range of issues relating to urban and regional development. The starting point for all of their work are the principles of environmentalism and humanism. One of their central strengths is that they bring a consistency of approach and a wide range of skills across scales to bear on planning and urban design challenges.

In the architectural, urban design and landscape fields, Piet has completed built works, mainly in the public and domestic arenas, and has received local (fifteen) and international (ten) awards for architectural works, urban design and planning projects, as well as for an academic paper on urban design education.

Proposing a Model to Analyse Public Acceptance when Introducing a Waste Management Facility Using Artificial Intelligence:

Case Example of Akkulam Region

Anupama VJ, Manju G Nair, Sushant SJ
Department of Architecture, College of Engineering Trivandrum, Kerala

ABSTRACT: Waste management solutions are one of the most debated and problem-creating decisions that are taken by most Urban Local Bodies and governments. The social sustainability of any waste management facility is greatly dependent on the public acceptance of that particular facility. A Questionnaire survey might not be sufficient to address Issues such as "Not In My Backyard" (NIMBY) syndrome which is prevalent in most parts of the world, especially in developing countries like India. Several factors determine how well a waste management facility will be accepted by the common public. In this paper, a Fuzzy logic inference system has been developed that considers overlaying factors like the opinion, knowledge, and willingness to participate expressed by the public. Also, the difference between organic and inorganic waste management needs has been explored through the study. Akkulam region in Trivandrum district of Kerala was taken to test the developed Fuzzy inference system. Based on results from a pilot questionnaire survey conducted amongst the public of the Akkulam region the input for the Fuzzy system was obtained using which the Level of Public acceptance was calculated and compared. It was found that composting was the most accepted organic waste management facility with 72.9 % public acceptance as compared to landfill or incineration which were at 17.8% and 23.8% public acceptance respectively. In the case of inorganic waste management Recycling facility was the most accepted with 73.2% acceptance. Waste-to-energy was also comparatively more acceptable than the incineration technique with 67.1% public acceptance indicating a lack of awareness about techniques like incineration. The developed system if effectively used can give authorities an idea if there is a lack of awareness or other issues about any particular technique which should be addressed before it is introduced.

KEYWORDS: Waste management, Fuzzy Inference, Organic waste, Inorganic waste, Public acceptance.

1. INTRODUCTION

Waste management facilities are meant to cater the society for its present as well as future needs. Public acceptance of such facilities is very important for it to sustain. It also helps authorities to take better decisions and speed up the process from initiation to completion. Nilsson-Djerf conducted a study focusing on nine European waste management programs to understand and measure the social factors of integrated waste management. The study concluded that successful waste management programs prioritised social acceptance and communication (Nilsson- Djerf, 1999). It is critical that the public has access to evaluate all background information, about the development plans, the chosen method, and any potential repercussions, both positive and negative. As a result, the public must be involved early in the decision-making process, particularly in regions where activism and protests are commonplace (Achillas et al., 2011).

2. LITERATURE REVIEW

Although Environmental management decisions are essential, they can cause distress to a certain percentage of the public and eventually lead to social rejection. The NIMBY (Not In My Backyard) effect is a term used to describe this phenomenon. Although normal to some extent, it is often associated with perceptions of danger, perceived inequality, etc. It is the assumption that a proposed function could alter their well-being thus leading to self-defence behaviour (Pol et al., 2006). While introducing new facilities, especially including newer technology, communication is the key to spreading awareness and addressing concerns. Perceptions of NIMBY are based on their individual or collective experiences and knowledge and there is no general global attitude towards any particular facility. In a study conducted to analyse the social acceptance for the development of a waste-to-energy plant in an urban area in Greece, initially, the local communities showcased reluctance towards any planned development, especially given

the intense activism in the area where as a thorough survey conducted for the metropolitan area of Thessaloniki in northern Greece revealed a rather positive public attitude toward the integration of Municipal-Solid-Waste thermal treatment in the local waste management strategy when compared to the landfill alternative (Achillas et al., 2011).

While deciding on the optimum solid waste management system, decision-makers have to typically weigh conflicting and uncertain data. Surveys are the most popular tool for evaluating waste management systems (Seo et al., 2003). However, surveys aren't always able to answer many levels of questions. Alidi incorporated the analytic hierarchy process (AHP), a decision-making approach that includes qualitative and quantitative aspects of a problem, into the model to prioritise the conflicting goals typically found when addressing the petrochemical industry's waste management problems (Alidi, 1996). Chang and Wang, for example, used a Multi-objective Mixed Integer Programming Model to examine the Solid Waste Management System and assess long-term waste management options in a metropolitan area (Chang & Wang, 1996). In all these cases, the underlying ambiguities in the situation were considered through crisp depiction, which could lead to a bad decision. In this type of decision-making environment, Fuzzy set theory, which was pioneered by Zadeh, plays an important role in coping with uncertainty (Zadeh, 1965). In the present study, a Fuzzy inference system has been developed considering different criteria to analyse the acceptance of any proposed facility. Also, organic and inorganic waste management requirements are analysed separately to understand how public acceptance can vary in both cases.

3. METHODOLOGY

The three criteria (opinion, knowledge, and willingness) were determined to analyze public acceptance and a Fuzzy logic inference system was developed. To test its efficiency a case study location was selected and a questionnaire survey was conducted on a random sample from the region. The survey results were used as input in the Fuzzy Inference system and the resulting output gave the public acceptance of different waste management facilities considered.

There are two common methods for developing a Fuzzy inference system, the Mamdani and the Sugeno method. Sugeno method is computationally efficient but requires expertise to develop while the Mamdani method is more intuitive, well-suited to human input, has a more interpretable rule base, and has widespread acceptance. (Mamdani & Assilian, 1975; Takagi & Sugeno, 1985). For the present study, a Mamdani Fuzzy inference system is developed using MATLAB software.

3.1 Fuzzy logic inference system

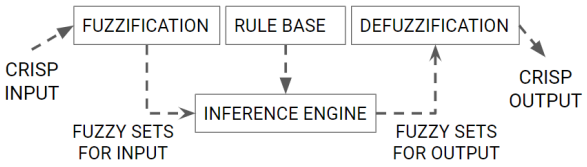

Figure 1: Steps involved in developing a Fuzzy Inference System, Source: Adapted from (Ibrahim, 2016; Mammadli, 2016)

Fuzzy logic is a multi-criteria overlaid logic that permits users to evaluate in between values rather than the conventional evaluations such as yes/no, true/false, etc. Simple and easily interpretable results make confusing and conflicting data more understandable (McAllister, 1988). Developing the inference system majorly involves four steps – defining the Membership function, fuzzification, inference, and defuzzification (Figure 1). Membership Function (MF) is a curve that assigns the degree of membership defined within the value range 0-1 for any input provided. It can take any shape varying from a simple triangular curve to a more complex bell-shaped or Gaussian curve. Fuzzification is the phase where a crisp value is simplified using 'Fuzzy sets' that determine the level of membership of the input parameter. Fuzzy sets are linguistic variables that are used in our day-to-day linguistic usage like good, average, bad, etc. Next is the inference phase where the correlation between inputs and outputs is established through a rule base created by the designer. These are also linguistic expressions defined by a set of 'if…then' rules connected using

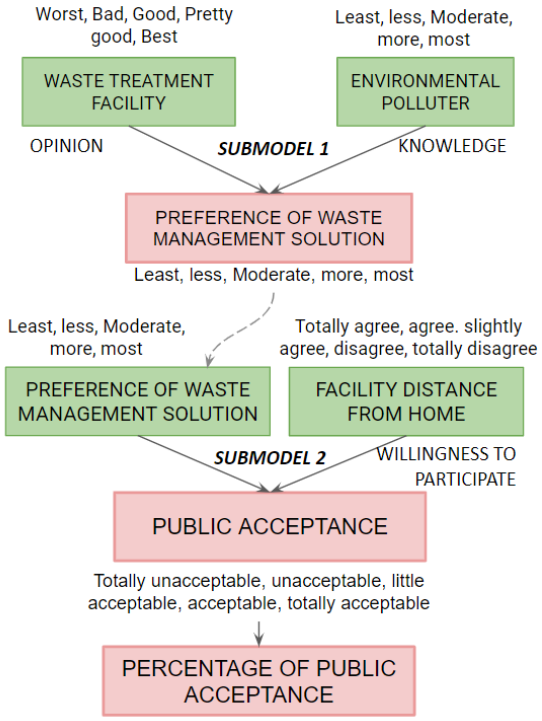

Figure 2: Sub-Models for the Fuzzy System, Source: author generated based on MATLAB input

Table 1: Rule base for Sub-model 1, Source: Author generated based on MATLAB input

Polluter	Waste Treatment facility				
	Worst	**Bad**	**Good**	**Pretty Good**	**Best**
Least	Less	Less	Moderate	More	Most
Less	Least	Less	Moderate	Moderate	More
Moderate	Least	Least	Less	Less	Moderate
More	Least	Least	Least	Least	Less
Most	Least	Least	Least	Least	Least

conjunctions 'and', 'or' etc. The defuzzification phase involves deriving the crisp output (linguistic or numerical) from the Fuzzy inference obtained (Figure 1) (Karadimas et al., 2006; Kokkinos et al., 2019; Seo et al., 2003)

The public opinion, knowledge, and willingness to participate in the planned waste management facility is considered to understand if the proposed system will sustain. The opinion of respondents is analysed through the criterion 'Preference of waste treatment facility', their knowledge of environmental issues is addressed as 'environmental polluter' and their willingness to actively participate in the waste management system is addressed as 'Distance to the facility'. The developed Fuzzy model consists of two sub-models (Figure 2).

For the sub-model 1, two input parameters are created followed by assigning linguistic variables and membership function for the same. For the input 'Waste treatment facility' (the opinion criterion) the Fuzzy set is defined by Worst, bad, good, pretty good, and best.

Linguistic variables for the second input 'Environmental pollution' which is the knowledge

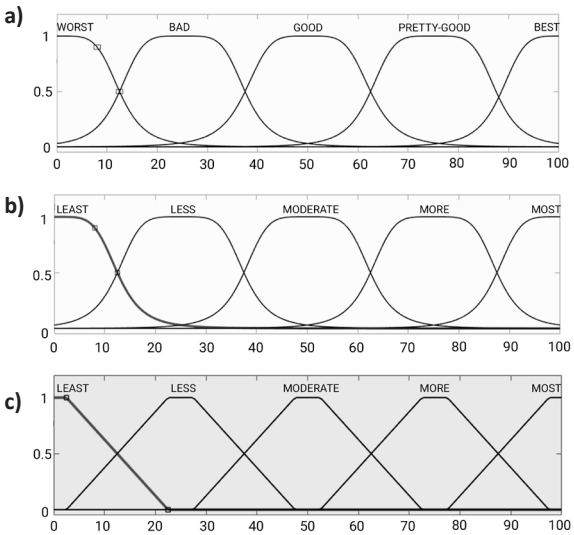

Figure 3: Membership Curves for Input variables (a) waste treatment facility, (b) Environmental Polluter, (c) Output- Preference of waste management solution, Source: Author generated based on MATLAB input

criterion are defined by the Fuzzy set least, less, moderate, more, and most. The membership curve assigned to both the inputs is a Bell-shaped curve (Figure 3(a)&(b))(Milutinović et al., 2016). linguistic variables for the output 'Preference of waste management solution' are least, less, moderate, more, and most. The membership curve assigned for this output is trapezoidal (Figure 3 (c)) (Milutinović et al., 2016). The next step involves creating the rule base for sub-model 1. It is created using 'if' and 'then' functions based on logical reasoning and previous experiences. For example, if 'waste treatment facility' is 'bad' (opinion) and 'Environmental pollution' (knowledge) is 'least' then 'Preference of waste management solution' is less. In this way, 25 rules are created for sub-model 1 (Table 1).

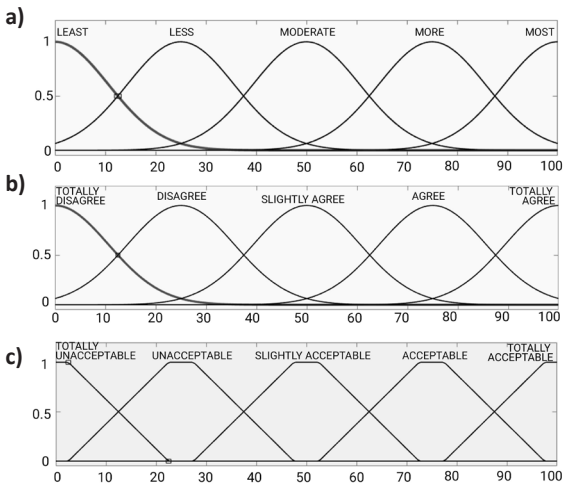

Figure 4: Membership function for Input variables (a) Preference for waste management solution (b) Distance from home and (c) output variable- Public acceptance of waste management solution. Source: Author generated based on MATLAB input

For the second sub-model the output from Sub-model 1 'Preference of waste management solution', is used as the first input, and 'Distance from home' which is the willingness criterion is used as the second input. Public acceptance is obtained as the output from this sub-model 2. The input data are fed into the Fuzzy system in percentage values obtained from the questionnaire survey giving us a crisp output also in percentages. For the input value 'Distance from home,' the Fuzzy set defined is Totally disagree, disagree, slightly disagree, agree, and Totally agree. The membership function assigned to both the input values in sub-model 2 is a Gaussian curve (Figure 4 (a) &4 (b)) (Milutinović et al., 2016). Linguistic variables that define the present output 'Public acceptance of waste management solution' in sub-model 2 are Totally unacceptable, unacceptable, slightly acceptable, acceptable, and Totally acceptable. Also, a Trapezoidal Membership curve is assigned for this second output from Submodel 2 (Figure 4 (c)) (Milutinović et al., 2016). Further another set of 25 rules is defined for the second sub-model too as for the first sub-model. (Table 2).

Table 2: Rule base for Sub-model 2, Source: Author generated based on MATLAB input

Distance	Preference of Waste Management Solution				
	Least	**Less**	**Moderate**	**More**	**Most**
Totally disagree	Totally unacceptable	Totally unacceptable	Unacceptable	Unacceptable	Unacceptable
Disagree	Unacceptable	Unacceptable	Unacceptable	Little Acceptable	Little Acceptable
Slightly agree	Unacceptable	Little Acceptable	Little Acceptable	Acceptable	Acceptable
Agree	Little Acceptable	Little Acceptable	Acceptable	Acceptable	Totally acceptable
Totally agree	Little Acceptable	Acceptable	Acceptable	Totally acceptable	Totally acceptable

3.2 Questionnaire Survey

To obtain the input for the developed Fuzzy inference system a Questionnaire survey was developed and the questions were framed to answer all three criteria of opinion, knowledge, and willingness to participate. The answers are obtained on a 5-point Likert scale starting from strongly agree to strongly disagree. For input variable 'Waste treatment facility' answers to questions 7 & 10: 'the best method to handle waste in our locality is' will be taken. For the 'environmental polluter' answer to questions 8 & 11, this is the most environmentally polluting waste management method' that will be considered. Similarly, for 'facility distance from home' answers to questions 9 & 12 'I will actively participate in managing waste even if the facility is 10 km away from my home' shall be used (Refer Appendix). Only the answers obtained in the survey with agree and strongly agree will be considered and calculated in percentage. For the different facilities considered the input values are given in percentages obtained from the survey. Both organic as well as inorganic waste management are considered separately to analyze how the same facility can be accepted differently by the public based on the classification of waste.

4. CASE STUDY

To verify the developed Fuzzy inference model a 2 km radius area around the Akkulam lake (situated between 8°31'14"N, 76°53'18"E, and 8°31'16"N, 76°53'40" E) region in the Trivandrum district of Kerala has been taken as the case study area. Akkulam is a fast-developing region experiencing gentrification in recent years. The existing waste management system in Trivandrum is a decentralized one and so there is no centralized waste treatment facility as its only solid waste Incinerator located at Vilapilsala (8°32'20"N; 77°02'19.5"E) was shut down due to local agitation in 2011(Sajinkumar et al., 2017) Although there are decentralized collection facilities for organic as well as inorganic wastes the end of life of these collected wastes especially the non-biodegradable ones is often blurred. These collection facilities are inequitably distributed and are mostly located in the core of the city and away from the study area. Akkulam lake being the conglomeration of all major streams from the city, therefore, receives all the mismanaged wastes from the entire city (Sajinkumar et al., 2017). A waste management facility is highly essential to be planned in the region considering its fast development as well as environmental degradation of the lake.

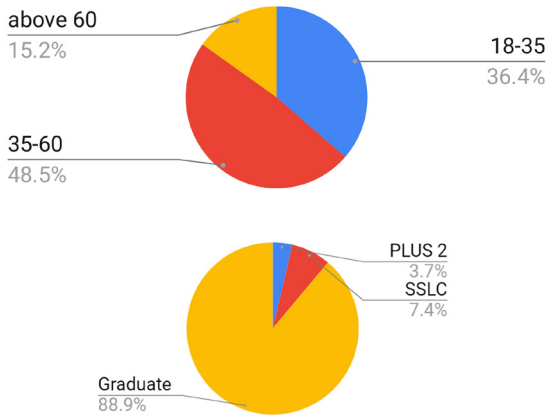

Figure 5: Survey respondents (a) Age group, (b) Education, Source: Author generated

For the present study, only a pilot survey has been conducted on a random sample of 34 participants from the Akkulam region. Almost half of the survey participants were in the age group between 35 and 60 and 90% of all the participants in the survey had at least a graduate level of education (Figure 5).

5. RESULTS AND DISCUSSION

5.1 Survey Responses

For organic waste management Composting is the most preferred waste treatment method (88.24% of survey participants). Landfill, the least preferred method is considered by 67.65% of participants for organic waste as the most polluting and by 79.41% participants for inorganic waste management. Similarly, Incineration for organic waste is considered by 47.06% of participants as the most polluting as opposed to 58.82% for inorganic waste (Table 3). For inorganic waste management Recycling facility is the most preferred (85.29% of participants) and a Landfill again is the least preferred waste management

Table 3: Survey responses for Organic and Inorganic waste management methods, Source: Author generated

Organic waste management	**Landfill**	**Composting**	**Incineration**	**Anaerobic Digestion**
Waste treatment facility	17.65	88.24	23.53	64.71
Environmental polluter	67.65	2.94	47.06	17.65
Willingness to participate	8.82	55.88	17.65	47.06
Inorganic waste management	**Landfill**	**Composting**	**Incineration**	**Anaerobic Digestion**
Waste treatment facility	0.00	85.29	14.71	76.47
Environmental polluter	79.41	0.00	58.82	11.76
Willingness to participate	5.88	73.53	20.59	67.65

solution (0% of participants). None of the participants felt that recycling was a major polluter. The variation in percentages for different criteria indicates a need for an overlaid analysis. For example, in the management of organic waste, the percentage of people who have a preference for a particular waste management facility is not the same as the percentage of people willing to participate in the same facility. Considering the most preferred organic waste management facility (i.e) Composting (88.24% preference), only 55.88 % are willing to participate. The same is the case with other organic waste management facilities indicating that even if the facility is introduced the number of people actively participating will be less than 60% of the participants.

The Fuzzy inference system developed can simplify these confusing data into crisp results. In the case of Inorganic waste although incineration and waste-to-energy plants can have similar techniques involved the results of preference of the two facilities are highly contradictory with 76.47% of participants preferring the waste-energy technique over 14.71% of participants who prefer the incineration technique. Also, only 11.76% of participants feel that waste-to-energy facilities might be polluting as opposed to incineration (58.82%) (Table 3). This indicates that although almost 90% of participants are well educated with at least a graduate level of education there is still a lack of awareness regarding the functioning and scientific feasibility of facilities like Incinerators which are often compared to open burning.

5.2 Public Acceptance Level

The public acceptance level of various waste management facilities was obtained using the developed fuzzy system which uses the survey results as input values. In the case of organic waste composting has the highest level of public acceptance with 72.9% followed by anaerobic digestion with 51.1% (Figure 6). The survey clearly shows that for organic waste around 40% of the participants do not prefer to participate in a facility that is more than 10 km away from their home indicating that more decentralized facilities closer to the source need to be provided. Anaerobic digestion can also be implemented on larger scales like institutions or residential communities.

For inorganic waste, 85.29% of participants prefer a recycling facility with 73.53% of participants ready to participate in the facility thereby giving a public acceptance of 73.2%. Also, it can be noted that the willingness to participate in a recycling facility for inorganic waste is comparatively much higher than in a composting facility for organic waste. Overall Recycling has the most acceptance. Incineration for organic as well as inorganic waste management is not considered very acceptable despite being a highly efficient method in reducing the quantity of waste (Figure6; Figure7).

Contradicting answers in the case of Incinerator facilities can be observed where 23.53% of people prefer it for organic waste but only 14.71 prefer it for inorganic waste management misinterpreting it as open burning. Spreading awareness about such methods is therefore required. In both cases, Landfills have been considered the least preferred as well as marked as the most polluting indicating the fear of open dumping and related issues. This also indicates that Not In My Backyard Syndrome is prevalent among the study participants and shows the lack of awareness about scientific landfills. Landfills can be seen as acceptable by a few participants (17.8%) for organic waste management and this may be because

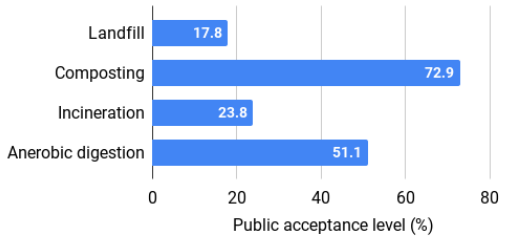

Figure 6: Organic waste management – Public acceptance, Source: Author generated

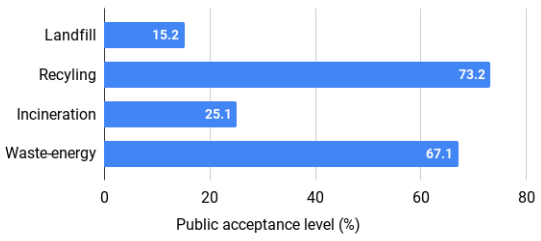

Figure 7: Inorganic waste management – Public acceptance, Source: Author generated

organic wastes are assumed to naturally decompose in the soil over time as opposed to inorganic wastes like plastic or metal that require hundreds of years to decompose in the soil.

4. CONCLUSION

The study intends to develop a Fuzzy inference system that can be used to analyze the public acceptance level of any newly introduced waste management facility. It considers multiple layers of information such as the knowledge, opinion, and willingness to participate, expressed by the survey participants. The case of organic and inorganic waste management is considered separately to analyze how public acceptance levels vary. It is evident from the study that varied responses are obtained for both. The present pilot survey intends only to test the developed Fuzzy system. A more detailed understanding of a locality or region can be obtained only through much more extensive surveys. The developed Fuzzy system is flexible and can incorporate additional criteria based on location-specific context.

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Analyzing the Vibrancy of Commercial Street
A Case of Pune

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ABSTRACT: : Due to the rapid urbanization, most of our Indian cities are expanding and are accompanied by tremendous change in land-use; both in terms of form as well structure. With the urban transformations of the city structure, especially change in land-use, the need to travel is extensively increased. In the majority of our Indian cities, motor vehicles rule the street space over people. The roadways will only serve as the conduits for motor vehicles if they are left uninterrupted in their current state. However, since the streets have primarily accomplished a historic perspective to move people not vehicle. Due to the hasty expansion of our cities, the streets lost their significance in terms of their share of land and started transforming into roads which are primarily deliberated for vehicles with a lack in holistic people-oriented approach. In order to accommodate more people and to ensure proper and proportionate use of street space, it is necessary to intervene and make the streets for people to walk. The purpose of this research is to study the physical characteristics of commercial streets and extract a referential table set that can be further used as an evaluation tool. Laxmi road in Pune, busiest Commercial Street is selected for study. Mixed method approach is used for data collection. Parameters for the study are finalized through literature review and Public Perception surveys are undertaken to rank streetscape elements. The study will synthesize the overall site context, the street connectivity, and urban dynamics changing the use of public space. This study concludes that, poor and insufficient streetscapes on commercial streets negatively impact users' experiences. On contrary, well-planned shopping streets with suitable and comfortable seats, shelters along the street, lighting fixtures everywhere, commutable and accessible sidewalks, and greenery would become livelier. Finally, the study emphasized the value of citizen involvement in fostering vibrant communities.

KEYWORDS: urbanization, commercial streets, urban public spaces, public perception, pedestrian

1. INTRODUCTION

Pune is one of India's top cities for development. It aims to create a built environment that is sustainable and upholds international standards while taking into account regional culture and traditions. Pune is heavily dependent on its bustling urban business districts, which are impacted by the nation's growing urbanization and growth. The sustainability and livability of the city depend greatly on the planning and design of existing and future commercial routes. Therefore, thorough research is necessary to examine the idea of commercial streets as urban public places. The purpose of the study is to investigate the factors that make a busy commercial street a wonderful urban gathering place. Physical and social assessment methods of study are developed to accomplish this methodically. By thinking inductively about the study issues, criteria and a scoring index are investigated. In the research, a variety of methods, including in-person interviews and on-site surveys, have been utilized to collect and analyze data from active street users. The study makes a connection between the planning and design of streets as "urban public spaces" and propose recommendations to overcome issues faced by people. The research leads to the conclusions that propose recommendations may significantly enhance selected Commercial Street.

2. BACKGROUND

Particularly in climates with tropical weather, the street serves as an important place for activities. We tend to be more active outside in the evening. Retail streets serve as gathering places for people in the urban environment and are a major draw for tourists and recreational activities, offering items, attractions, and entertainment. Similar to other cities in the global South, Indian streets have a history of balancing the need to support livelihoods with the need to manage space for other activities. However, these days, Indian streets frequently prioritize cars over other users, making it difficult to maintain this balance (Roever& Skinner, 2016). A well-known commercial street has been selected as the research location, and it will be assessed based on three main factors: the street's physical qualities, the characteristics of the public space, and pedestrian infrastructure gaps.

3. RESEARCH COMPONENTS

Aim of this research is to study the physical characteristics of commercial streets and extract a referential table set that can be further used as an evaluation tool. The entire study has been mainly focusing on defining the streets as public spaces and the implications of physical attributes of the street and the surrounding context respectively. The gathered and analyzed data will be used to provide a better and more objective understanding of specific problems of the commercial street. This study synthesizes public perception in tabular form. It can be further used to understand issues faced by people while walking for transforming the street an ideal location for socializing.

4. LITERATURE REVIEW

The urban commercial street and urban public spaces are concepts of worldwide concerns. A literature review and analysis of state-of-the-art approaches and solutions are provided as a theoretical study to define indicators, in addition to an analytical study of global examples for urban streets' solutions. As a part of literature street Design, Typology, best practices, theories on great streets, ideal street characteristics, streetscape design are studied. The parameters for the study are chosen from the literature review and used in the empirical study as a foundation for assessing the commercial street in Pune. These characteristics were chosen after a thorough visual survey and in-depth analysis of the area. The Table 1 provides a quick summary of the indicators chosen for the case study area.

5. RESEARCH METHODOLOGY

In addition to secondary sources, this study also makes use of primary sources that were gathered from the case study area. Together with the primary data that is gathered from the site and analyzed, the secondary resources integrate scholarly literature study with national and worldwide comparisons. A mixed methodology has been utilized in this study since both qualitative and quantitative methods were used to gather the data and analyze the results.

The streetscape components were chosen for this study on their regularity and frequency in the studied literature. Users were asked to rank these components based on how they affected their user experience. The walkability and accessible paving, seating, shelters, lighting, signage system, and greenery were the users' chosen components in that order. This study takes into account public engagement by examining their preferences for the streetscape element that motivates them to continue socializing. Practically more than 85 per cent of the data has been collected during the months of April, May, June and July. Hundred sample surveys of pedestrians were undertaken as a part of this study.

6. STUDY AREA DELINIATION

Table 1: Parameters finalized from literature

Area of examination	Sub-area of examination	Indicator
Street functionality and efficiency	Retail mix, safety, car-parking, transit-oriented development, street management and maintenance	Number of visitors, vacant land, shoprent, economic revenue
Street design and management	street maintenance, Land use, streetscape, street quality, walkway width, street quality, lighting, greenery, shaded areas, street wall elements	Accessibility, walkability, number of visitors
Social reaction	Culture and identity, population, community's needs, community's needs, perception, density, safety	Number of visitors, activities
Imageability and legibility, form, street unity, Morphology, context theme	street image, building architecture, Street scale, enclosure, connectivity, signage, land use	Connectivity, permeability, transparency, aesthetics

It has been discussed for several years, and is included in the CMP (Comprehensive Mobility Plan for Pune City, 2008, p. 8;24), which this thesis is partly based upon and gets its physical delimitation from. The stretch that is suggested in the CMP is approximately 2.7 km long. A shorter passage of approximately 1.3 km between Shivaji Road and the five-way crossing, Tilak Chowk, in the west end of the street was chosen as a case study area. The shorter passage is not chosen in order to say that this is the only thing that needs to be done in the core city, but due to the limitations of a short thesis project. Laxmi Road is one of Pune's most well-known streets, and is interesting to study as it is highly influenced by cultural activities and festival seasons. In connection to Laxmi Road there is an area called Tulshibaug, with small alleys. The area is full of stalls and small shops selling clothes and jewellery of various quality. Close to Laxmi Road is Mahatma Phule market or Mandai, which is mainly a fruit and vegetable market. Between Mandai and Shivaji Road there is a street passage, which is full of vendors sitting on blankets on the ground or selling fruits and things from handcarts and bicycles etc.

7. DATA COLLECTION STRATEGY

The data used in this study was gathered from Laxmi Road, one of Pune's commercial thoroughfares. Data collection is done at two levels- macro-level street typo-morphology, which encompasses things like street unity, street pattern, land use, spatial organization, enclosure, etc. and micro-level street

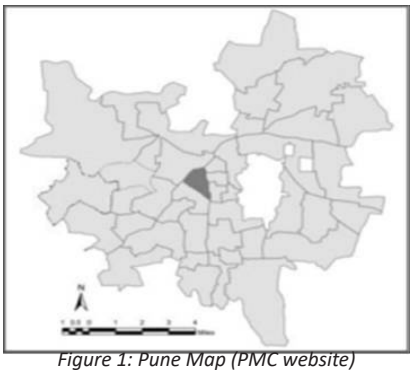

Figure 1: Pune Map (PMC website)

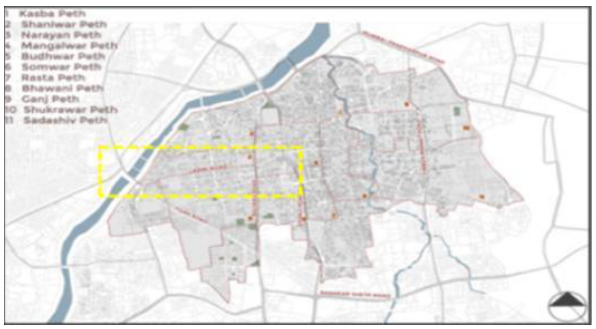

Figure 2: Pune Map highlighting study area (extracted from Pune DP)

typo-morphology which includes evaluation of the built environment with regard to private and public domain. Drive-by, walk-by, photography mapping, movies, and time-lapse photography with a GoPro camera are all methods for gathering this data. To document people's experiences on the sidewalks of the commercial streets and to keep track of the conflicts that developed over the usage of the areas, detailed field notes, sketches, and people counts has been done. Observation of movement patterns and the interactions between them in relation to the built environment, their social groups, public activities, is included, Verifying the amenities of the land use, street space, vacant properties and the variety of functions within the street, Public perception survey is undertaken on the scale of 1-10 order to get insight of people about Commercial Street. This study is analytical depiction of the commercial street. Data is gathered on the individual street blocks or street segments at the micro level. Smaller-scale Street design, as well as its physical and sociological characteristics, are also included in this and are organized and prepared following the initial site visit. In addition to cross-sections and sketches, this information is utilized to determine the parts of the streets and the elements that may influence how users perceive green spaces, street furniture, sidewalk width, and the architectural motifs of the storefronts. The fieldwork strategy used mixed approach and visual perception technique so as to explain the physical –social characteristics of the street layout, the responses of the users and the evaluation of the vitality of the streetscape.

8. CASE STUDY: LAXMI ROAD

The street is a public space, but back alleys and courtyards are frequently private or semi-private. There are sidewalks throughout the whole length of Laxmi Road. However, sidewalks are frequently broken and occupied by street vendors, and other activities. The walkways are about 1.5 m wide, and a 90-cm-high fence is installed in most areas to keep pedestrians and vehicles off the sidewalk. There are two-wheelers and vehicles parked next to the railing. Pedestrians are frequently compelled to walk outside of parked vehicles. The street is one-way and traffic flows from east to west. There aren't many parked vehicles on the street until 9:30 am. It is difficult to get a parking once the stores open at 10 am. The businesses are typically open Tuesday to Sunday, with rare exceptions during holiday seasons when they are open longer.

9 VISUAL SURVEY ANALYSIS

9.1 Building Use (Precinct)

The building use indicates strong mixed-use typology. Public Buildings like the Huzurpaga High school, Numavietc serve as an attractor on the street. Most of the core city area has a similar structure, with

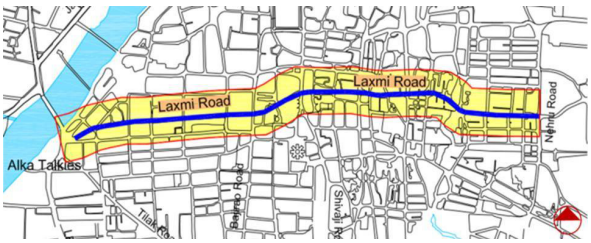

Figure 3: Map highlighting Laxmi Road (Source- Authors)

mixed land use, mainly residential and commercial and some public and semi-public buildings. Sarees, different kinds of fabrics, and clothing materials are the most popular types of store which makes Laxmi Road famous. There are also many jewellery shops, which become of prime importance around many of the festivals and popular wedding seasons. Some shops sell other types of clothes, shoes, mobile phones, kitchen utensils etc. Snack shops are also available, and along the streets there are lots of vendors and street hawkers selling both clothes and food. With varying commercial typologies on the ground floor, the streets become interesting to walk along.

9.2 Built Unbuilt (Precinct)

The street edges are completely built up with shop entrances adjacent to each other. With old planning as a backdrop the street is highly porous. The structure is

very dense, and many houses share walls. The street opens up a bit in an intersection which creates a small

Figure 4: Building use of Laxmi Road precinct (Source- Authors)

square. Some high trees are sticking up and over the wall. Apart from that and a few trees on the small square and on some courtyards, greenery is not common on Laxmi Road. Bottom floor towards the streets is of commercial use. Many houses only have connections to the street through the back alleys and courtyards. There is often something public or semi-public, like a school and/or a temple in each block. Buildings are reached either direct from the street or through arcades, back alleys and courtyards. In the deeper blocks on the north side of the street there are many houses that are only reached from narrow alleys. These houses are mainly residential.

9.3 Density

There are many of old buildings that have been converted into commercial complexes on the street. These vary from G+1 , G+2 and other high structures. Amalgamation of adjacent plans can be seen for commercial use. The building structure is not as dense

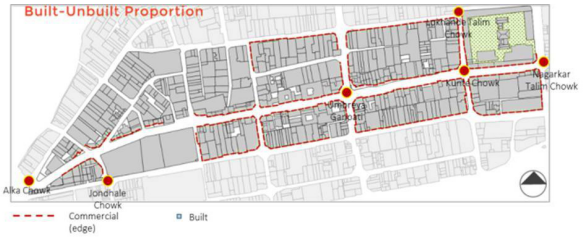

Figure 5: Built Unbuilt proportion of Laxmi Road (Source- Authors)

as most of the core city and the other blocks along Laxmi Road. Many shops are 2-3 floors, especially towards Laxmi Road, but it is also common to have commercial use in the bottom floor and residential above.

9.4 Existing Traffic Movement

Laxmi road is a one-way street leading to Alka Talkies Chowk. The road has footpaths on either side for street vending, food joints or hawking. On Laxmi Road the traffic runs from east to west, and on the parallel street, R.B. Kumthekar Road, just south of

Figure 6: Density mapping of Laxmi Road precinct (Source- Authors)

Laxmi Road, the traffic runs in the opposite direction. But the sidewalks are often damaged and/or occupied by street vendors, construction work etc. The sidewalks are approximately 1.5 m wide, and a 90 cm high railing is put up at most places to keep people on and vehicles off the sidewalk. Next to the railing there are two-wheelers and cars parked. The pedestrians are often forced side the parked vehicles. Just next to the market, however, there are two large parking houses, causing traffic jams at the entrances and exits. The street is shared by pedestrians, two-wheelers and cars heading towards the parking houses.

9.5 Typology

Activity patterns are observed throughout the day due to multiple functions that the place offers. The sense of security created by the build forms provides more opportunities for vendors. Many old buildings in

Figure 7: Existing traffic movement at Laxmi Road precinct (Source- Authors)

the core city area are built-in so-called Wada architecture, which is an old Maharashtrian style. This was the common residential style for the well-off, especially in theend of the eighteenth century (Diddie and Gupta, 2000, p. 81). Vishrambaug Wada, Kesari Wada and Shaniwar Wada are example of these. The buildings are often two storeys and have square inner courtyards surrounded by columns. The bottom floor generally has no windows towards the streets. Extensive wood carvings were made for decoration. Some of these old buildings still exist. The social structure was closely connected to the wadas which caused problems as the social structure changed over the years. Many of the older buildings are small and have a lot of details. There is always something new to be discovered, which makes the street interesting. Some of the newer buildings are lacking these qualities. To some extent the commerce in the bottom floor of these buildings makes up for the large-scale structures, providing small scale details along the street. The commercial activity makes the streets packed with people and thereby creating traffic congestions. The area is often so packed with people that no vehicles get through. Close to Laxmi Road is Mahatma Phule market or Mandai, which is mainly a fruit and vegetable market. Apart from the everyday vendors, there are many seasonal stalls being put in this area, selling specific things for the next coming holiday. Between Mandai and Shivaji Road there is a street passage, which is full of vendors sitting on blankets on the ground or selling fruits and things

from handcarts and bicycles etc.

9.6 Vegetation

The street of Laxmi Road is devoid of greenery. There aren't many trees along the route. Because the street is quite small and the buildings are medium in

Figure 8: Typology at Laxmi Road (Source- Authors)

height, it casts a shadow on the street for a short period of time. It is critical to expand plant cover along Laxmi Road and other routes in the vicinity.

9.7 Existing Road Section

Figure 9: Vegetation cover in Laxmi Road (Source- Authors

During peak hours the road is packed with vehicles and walking becomes a real task. It's difficult to find parking on this street. Vendors barge in on the footpath which creates issues for pedestrians to walk on it. Some vendors tend to walk on street for selling their goods and creates hurdles for vehicular movement and pedestrians.

Table 2 is summary of public perception survey undertaken as a part of this research. Parameters identified from literature are rated from 1 to 10 where

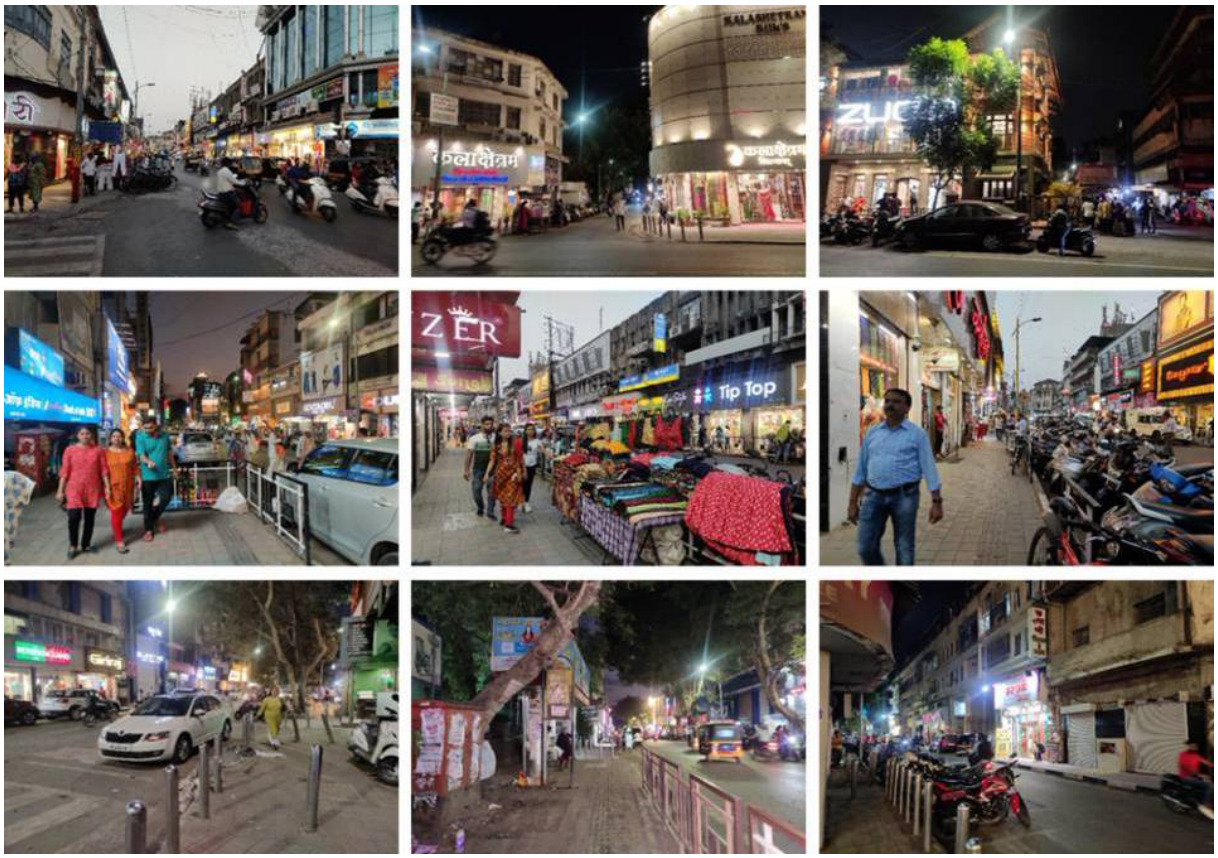

Figure 10: Photos of Laxmi Road showing road width, pedestrian facilities, parking, commercial spaces, Encroachment by Hawkers

1 being poorest and 10 being best. Average score given by pedestrians as per above table is 41 which will define street condition as below average in terms of walking and other parameters. So, there is scope for improvement.

Table 3 includes the street parameters shortlisted from literature and rated by Author from visual survey. Average score in the table 3 marked by authors is 47 which will define street condition as above average. So, there is scope for improvement. The points which have scored substantially less in Table 2 and 3 on the scale of 10 needs to be improved.

10. KEY ISSUES IDENTIFIED

Laxmi Road is very accessible because of easy connectivity due to multiple public transportation

Table 2-Rating of parameters by visitors of Laxmi Road (Source – Primary Survey)

PARAMETERS	FACTORS	RATINGS										AVG. SCORE
		1	2	3	4	5	6	7	8	9	10	
Accessibility	Connectivity											7
	Active transportation											
	Multiple transportation options											
Attractive	Accessibility											4.6
	Art											
	Unique details											
Street furniture	Seating											2
	Lighting											
	Information and Signage on Road											
Pedestrian infrastructure	Walking in the street											2.5
	Condition of Sidewalks/Footpaths											
	Width of Sidewalks/Footpaths											
	Availability of Suitable crossing points											
	Availability of suitable pedestrian routes											
	Bicycle and pedestrian paths											
Traffic calming measures	Raised Crosswalks											1.5
	Pedestrian Frindly Islands											
	Speed Tables											
	Curb Extension											
	Bollards											
	Raised Intersections											
Natural Components	Topography											5.75
	Trees and plants											
	Microclimate											
	Pollution level											
Maintenance	Cleanliness											9
Purpose of Visit	People's presence											8.6
	Food											
	Communication											
	Variety of goods											
	Shopping											
Total Score												40.95

Table 3-Rating of street parameter on the basis of Visual Survey of Laxmi Road by Authors

PARAMETERS	FACTORS	RATINGS										Avg. Score
		1	2	3	4	5	6	7	8	9	10	
Human scale	Distance and biometrics											5.66
	Edge segments											
	Proportions of building heights											
Sustainable infrastructure	Porous pavement											1
	Street water management											
	Renewable energy											
Legiblity	Legible ends											4.5
	Street length											
In between spaces	Enclosure											7.5
	Spatial hierarchy											
Edge effect	Transparency											5
	Soft edges											
Urban planning aspects	Short blocks											4
	Rest Areas/Drop Areas											
Context	Maintaining natural components											4
	Maintaining urban centers											
Diversity	Economics											7
Density	Density											8
Total Score												46.66

options ranging from auto rickshaws and buses. People prefer walking here due to the commercial nature of the street. The street can be termed attractive due to the unique details of old buildings. Sitting areas and road signage are not found in study area. Pedestrian infrastructure is average because the width of footpath is not sufficient; vendors occupying the footpaths also bring obstructions while walking. There are no traffic calming measures adopted on the street. Laxmi road is not rich in vegetation though the street is very well maintained.

11 CONCLUSION

A higher visitor control strategy with appropriate parking management is desired for smooth pedestrian flow. To turn Laxmi road into a public space, it is essential to improve pedestrian infrastructures like street furnishings including benches, signage, broader footpaths, sufficient restrooms, and drinking water centers. The next stage is to propose vegetation. Following that, regular maintenance of each streetscape component, including the lighting, benches, and pavements, is necessary. A well-organized location for provider's can reduce the difficulties faced by the pedestrians and would provide a better experience on commercial streets. The exceptional connectedness, accessibility, and visibility of Laxmi Road can be used to expand a wonderful urban public space. The public participation plays a significant role in the creation of vibrant cities. It is believed and well known that's it's difficult to have one optimum solution for streets problems in all situations. The paradigm for designing streets must change from building more road space that promotes accommodating people rather than vehicles. It is determined by better integration of pedestrian needs and safety with traffic accessibility in accordance with land use.

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Planning Strategies for Revitalization of Historic Urban Areas:

A Case of Alappuzha

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ABSTRACT: Historic urban areas showcase the origin and phases of development of the city. Many cities in India contain historic and culturally significant areas whose heritage conservation needs to be integrated with the development schemes. Urban development of historic areas, with a focus on heritage conservation has been attempted in many cities in the recent past. This research explores the strategies for revitalization of historic urban areas in the context of rapid urbanization. Alappuzha has been a port town with great potential for trade, commerce, and other economic sectors for a long time. However, it is rapidly losing its heritage resources and reputation due to neglect, outdated laws, and ineffective management. Successive development schemes of Alappuzha had included revitalization initiatives considering its built and natural heritage, but their implementation was largely unsuccessful. The research focuses on the development of a framework for the revitalization of historic areas of Alappuzha. Planning interventions of heritage cities were studied to explore the appropriate planning tools for revitalization. The conservation of historic areas of Alappuzha was examined considering its city planning and architecture. To analyze the existing situation in the historic area, a primary survey was conducted among households, commercial establishments, and tourists. Finally, a strategy that integrates conservation of historic areas with the urban agenda is proposed for Alappuzha. This framework for inclusive revitalization is aimed to restore the lost glory of historic areas and for the sustainable development of Alappuzha.

KEYWORDS: Revitalization, Conservation, Heritage

1. INTRODUCTION

Historic urban areas showcase the built and natural heritage of a city and are relics of past events. The values of traditional urban culture can be observed in cities, towns, or historic quarters. Heritage is generally understood to be confined within museums and monuments, but its current definition encompasses groups of buildings and historic quarters as well (Hobson, 2003, p. 38).Historic cities are frequently subjected to challenges caused by climate change, urbanization, commercial exploitation, or mass tourism (UNESCO, 2011, p.6). Changes in historic cities also affect the local community through the process of Gentrification or Marginalization (Orbasli, 2002, p.110).

Therefore, it is necessary to integrate heritage conservation with the overall urban planning process to avoid spatial or social segregation. To preserve the heritage, it is crucial to allow the community to express their viewpoints and actively engage in heritage management.

Alappuzha, known as the "Venice of the East", which began as a port town and evolved into an industrial center, is now on the verge of losing its heritage resources. The main reasons for this are neglect, outdated regulations, limited municipal resources, and the lack of administrative body to protect the heritage in the town. Hence, historic areas of Alappuzha need appropriate strategies for revitalization to preserve its heritage. Recently Alappuzha Heritage project was sanctioned by the Kerala State Government focusing on the conservation of built heritage in the town. Nonetheless, this effort needs to be strengthened with context specific conservation policies to restore the lost glory of the town.

This research aims to formulate planning strategies for revitalization of historic urban areas of Alappuzha. For this, three research objectives have been outlined. First objective is to comprehend the concept of revitalization in planning and the historic significance of Alappuzha. Second objective is to appraise the planning interventions for revitalization of historic urban areas by means of case studies. Third objective is to assess the existing condition of the historic areas of Alappuzha and propose strategies for revitalization. The historic core of town, mainly the canal precinct of Alappuzha was taken as the study area.

2. DATA AND METHODS

The current research examines key concepts such as revitalization, its approaches and the relationship between conservation and urban planning.

2.1 Revitalization

"Revitalization is a method combining the architectural and urban rehabilitation of historic centers, and enhancing the urban activities therein" (UNESCO, 2008, p. 94). Revitalization involves eradication of the blight and giving new existence to a declining neighborhood or district by means of placing them to contemporary use. Revitalization strategies can appeal to businesses that create extra jobs, some of which can be filled by individuals residing in the community (Zielenbach, 2000, p. 4).Historic urban areas may require both physical and economic revitalization. Physical revitalization is considered as a short time approach that focuses on an attractive, well maintained public realm. Economic revitalization is considered as long time approach because in the long run it is the effective usage of the private realm which will pay for the preservation of the public realm. (Tiesdell et al., 1996). There are three contextual attributes which call for the revitalization in historic areas: place assets, obsolescence, and intensities of development pressure. (Tiesdell et al., 1996).

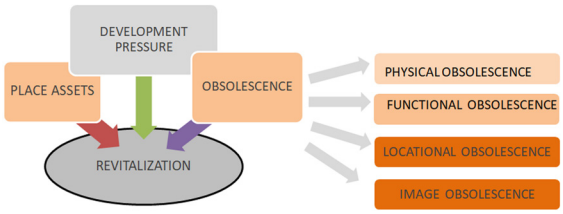

Figure 1: Need for Revitalization,three main attributes within the definition of revitalization concept.
Source: Tiesdell et al.1996)

2.2 Revitalization approaches in Historic areas

The maximum vital benefits of keeping a town's ancient heritage are economic factors wherein it is cheaper to rehabilitate a building than to construct a new one. Revitalization of historic areas can be achieved by adaptive reuse and cost recovery, fully commercialization of historic city centers, transfer of development rights (TDR) etc. (Steinberg, 2008, p. 13). Another approach is to transform historic areas as assets for tourism (Orbasli, 2000, p. 2). Integrated area development is another revitalization approach adopted in Bali Indonesia, where they incorporated cultural heritage conservation along with large scale urban infrastructure development projects (Vines, 2005 p. 49). According to the (UNESCO, 2008), successful revitalization in historic areas depends on dedicated leadership, people participation, better shared vision of the future, practical goals and action plan, effective communication, and management of implementation.

2.3 Heritage protection and revitalization in urban planning process

A lacuna is seen between the urban planning and heritage protection in many cities, where heritage is considered as a separate component. With the nomination of cities and towns as World Heritage Sites, the necessity for an area based conservation approach became apparent in the contemporary world. In the Indian context there is a shift towards integrating urban planning process with heritage conservation through various schemes like HRIDAY and JNNURM. Revitalization of historic urban areas address issues concerning urban problems caused by traffic congestion, uncontrolled development, loss of natural and cultural heritage etc. So there is a need to deal with the particular problems of historic urban areas in master plan or in development plans.

According to Feilden & Jokilehto (1993), integrating conservation practices with town planning objectives are the primary goals in planning (p. 94). Conservation as a planning tool can be incorporated in terms of delineation of conservation zones, listing and grading of buildings, formulation of special bylaws, establishment of a fund for conservation and maintenance for public buildings etc.

According to Vines (2005), revitalization measures including consultation with the community, streetscape upgradation, introduction of rigorous signage policies, and heritage impact assessment of new developments could help to retain the original character of the historic place. This research on the first objective helped the author to refine the methodology of research.

2.4 Methodology

As illustrated in the chart, the second objective of research is addressed by analyzing the planning interventions for revitalization of historic urban areas through detailed case studies. The cities of Pondicherry and Amsterdam were selected as cases after preliminary studies. They were studied to

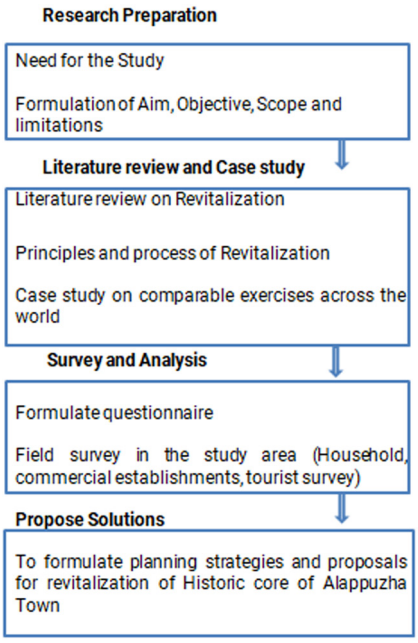

Figure 2:Methodology Chart
Source: Author

understand the potential planning interventions for the revitalization of historic urban areas. Historic areas of Alappuzha were mapped and analyzed using planning tools. Additionally, surveys were conducted among households, commercial establishments, and tourists to assess the existing situation of the town to help formulate planning strategies for revitalization of Alappuzha.

2.5 Case study

Two cities have been selected for the study Pondicherry- Boulevard Town and Amsterdam. Pondicherry has similar characteristics as Alappuzha in terms of mixed communities, heritage significant buildings and highly dense existing urban cores. Amsterdam has similar characteristics as Alappuzha in terms of small streets, short distances, and a flat landscape with canals characterize both the city.

2.6 Historic significance of Alappuzha Town

The Diwan Raja Kesavadas of Travancore founded Alappuzha in 1762. Alappuzha developed as a port town because of its strategic location along the sea coast, with canals and lakes connecting it to other regions of the state. People from various cultures, including Europeans, Cutchi Memons, Gujaratis, Tamils, and Telugus, migrated to Alappuzha as a result of the expansion of the port. Buildings were built in Baroque, Gothic, Islamic, European and Kerala architectural styles and they were reflections of the new culture that took hold in Alappuzha. With the collapse of the port, the town's prominence faded,

Table 1: Strategies adopted in Pondicherry and Amsterdam
Source: Comprehensive Development Plan for Puducherry – 2036 & City of Amsterdam, Official website

PONDICHERRY	AMSTERDAM
•Heritage Conservation Committee was set up. •"The Puducherry Building Bye-laws and Zoning Regulations 1972" are the laws for heritage conservation. • INTACH Chapter formed in 1985 •Regulatory measures include legal protection & listing, grading of Heritage buildings supported by guidelines, legal incentives, and heritage regulations. • Areas designated for high priority heritage protection & preservation. •Other initiatives included manuals, heritage walks and improvement of tourist amenities.	•Delineating canal district as conservation zone- UNESCO World Heritage Site •Regulatory tools includes Delineating Conservation areas and Listing monuments •Heritage Impact Assessment- Any construction activity in a conservation zone requires a building permit, considered in five stages: Screening, Scoping, Review, Approval. •Amsterdam City Restoration Company was formed in People-Public-Private Partnership, aiming to restore the heritages with the support of financial incentives.

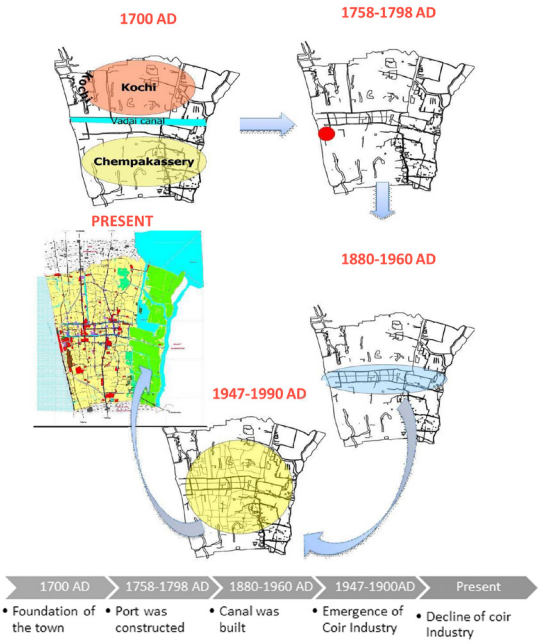

Figure 3: Evolution of Alappuzha town
Source: Alappuzha Master plan Report-2031

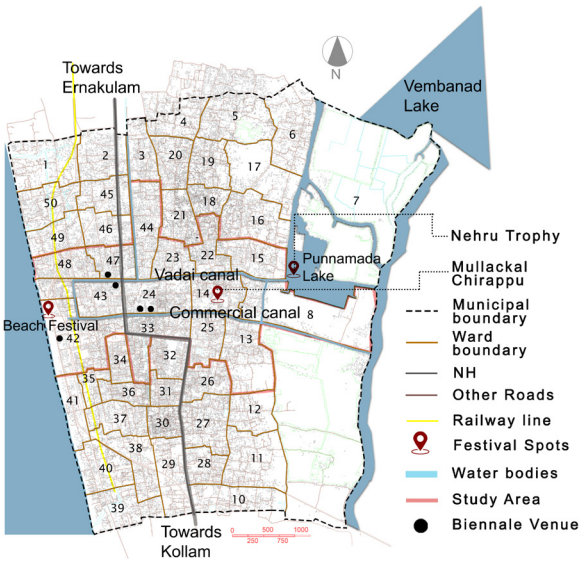

Figure 4:Map of Alappuzha municipality
Source:Author Generated with reference to Alappuzha Master plan Report-2031

and canals, sea piers, and warehouses all became obsolete. Most of the heritage buildings are now in poor condition due to lack of maintenance. At present Gujarathi, Konkani, and Tamil brahmin communities still exist and are active in commerce.

Main cultural festivals in Alappuzha include Mullakkal Chirappu, hosted in November and December, conducted on Mullackal Commercial Street. Nehru Trophy Boat Race, conducted on Punnamada Lake by August or September.Main cultural festivals in Alappuzha include Mullakkal Chirappu, hosted in November and December, conducted on Mullackal Commercial Street. Nehru Trophy Boat Race, conducted on Punnamada Lake by August or September. 'Lokame Tharavadu' Biennale

events are also being conducted in five venues in the Alappuzha. Study area is the canal precinct of the old port town, constituting 14 wards with a total area of 8.89sq.km with a population of 51,115.

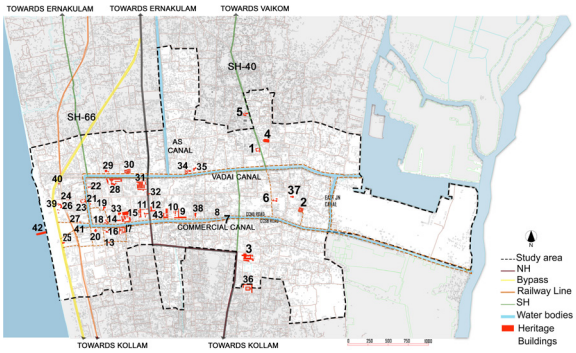

Figure 5:Map of study area showing built Heritages Source:Primary Survey

Table 2: Heritage Buildings identified in the study area Source:Primary Survey

Heritage Structures	
1.SDV School	23.Vallabhadas Khanji
2.Venkitachalapthy Temple	24.Sri Rama Temple
3.Kottaram Hospital	25.Signal Station
4.Kidangamparambu Temple	26.Bishop House
5.Uduppi Temple	27.Malathibhai Working Women's hostel
6.Mullackal Temple	28.Central Coir Marketing Society
7.Saukar Masjid	29.St.Francis Church
8.CC Varghese and Sons	30. Aleppy Co.
9.Aspinwall Company	31.William Goodacre and Sons
10.New Model Coir Society	32.St.Joseph Convent Church
11.Leo XII High School	33.Norton Bunglow
12.Mount Carmel Church	34. NC John and Sons
13.Maqam Masjid	35.St.Thomas Church
14.CSI Church	36.TD Devaswom Temple
15.Coirfed	37.Holy Cross Church
16.Cutchi Memon Masjid	38.St.George Church
17.Gujarathi Complex	39.St.Xaviers Church
18.Jain Temple	40.St.Sebastian Church
19.Gujarathi School	41.Light House
20.SP Office	42.Sea Pier
21.Post office	
22. AV Thomas and Co.	

3. RESULT AND DISCUSSION

The following surveys were conducted among the stakeholders during site study

3.1 Survey Result

Commercial Establishment Survey

Total number of responses-50

Sampling Technique: Random sampling

The majority of them (73%) are under rental ownership, while (25%) have own tenure status. Commercial buildings are either owned by private parties (for example, NC Johns), or religious commitees (for example, thirumala devaswom), or the government (Municipality).Most of them are pucca structures (84%) and are in poor or deteriorated condition. Owners must perform all maintenance without government assistance.

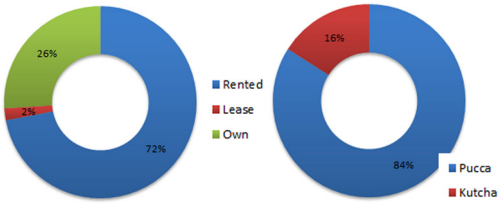

Figure 6:Tenure status/Typology of Building Source:Primary Survey

Household Survey

Total number of responses-140

Sampling Technique: Random sampling.Majority, (about 70%), stated that the government, with the assistance of the local people can maintain the historic areas in Alappuzha, only 9% felt preservation could be done by the local people alone living in the area.

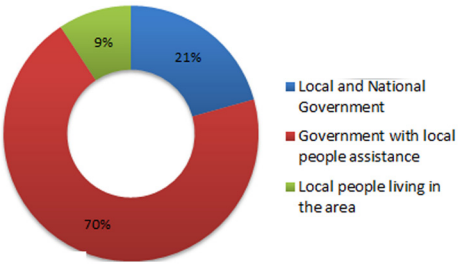

Figure 7: Response to Question 1: 'People or the government should preserve historic areas? Source:Primary Survey'

Tourist Survey

Total number of responses-140

Sampling Technique: Random sampling

The majority of visitors (51%) believe that poor waste management in heritage areas is the most serious issue in the town. Vandalism is also a threat to the built heritages of the town. The canals have been harmed by a lack of maintenance, resulting in very low levels of public use in their vicinity. Majority of the tourist were not aware of the historic significance of the place and they visit only the backwater and beach areas.

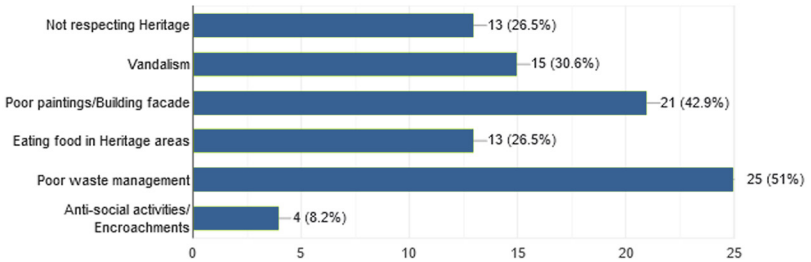

Figure 8:Factors affecting the Heritage areas Source:Primary Survey'

3.2 Detailed study of three zones

Three main zones were chosen as these areas highlight the development of diverse settlements as well as rich in social, economic, and cultural value. The importance of these sites, their architecture and religious components to people were also considered.

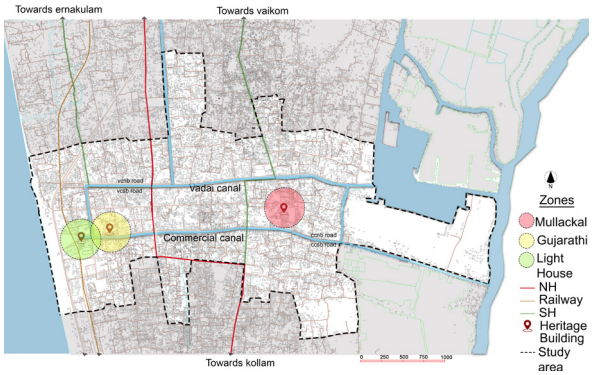

Figure 9:Location map of three main zones Source:Author

The main zones are Mullackal Street, Gujarathi Street, and Light House (Figure 9). Minimum buffer area of 250 meters around the built heritages is demarcated for conservation (Figures 10, 11, 12).

Figure 10: 250m buffer area around Mullackal Temple Source:Primary Survey

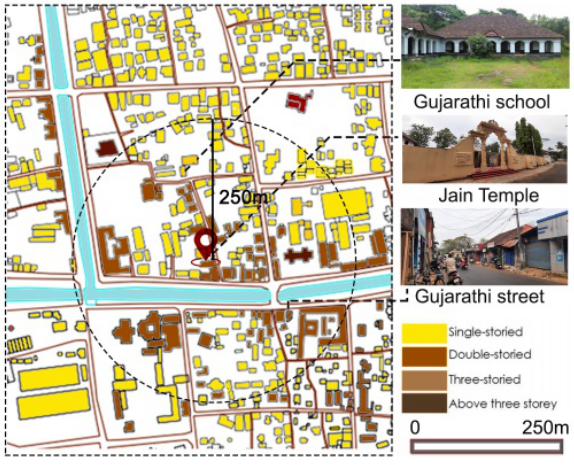

Figure 11: 250m buffer area around Gujarathi StreetSource:Primary Survey

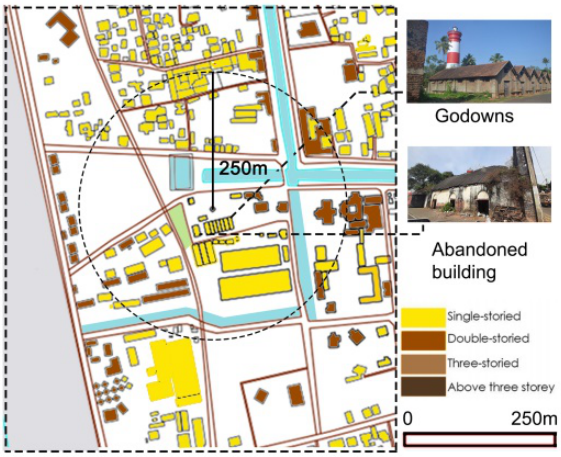

Figure 12: 250m buffer area around Light House Source:Author

Table 3: Existing condition of heritage precinct and its recommendations. Source:Primary Survey

Built Heritage	Existing condition in the heritage precinct	Recommendation
Mullackal Temple	•Preserved heritage temple complex. •Brahmin settlement can be seen near to the temple complex. •There is a tendency of high rise structures in the vicinity of Mullackal temple. Eg: BhṆma building (Causing Development pressure) •Heavy traffic, illegal parking, street vendors in the temple precinct. (Causing Image obsolescence).	•High rise buildings should not be permitted in the conserved area (Height control is advised up to three stories in the buffer area) •Mullackal street can be developed as Heritage street and pedestrianization of the street could support tourism and local economy.
Jain Temple Gujarathi Street	•Preservation is done in Jain Temple, as a part of Alappuzha Heritage Project. • Buildings near to the CSD canteen area and in CCSB road is in poor condition or left abandoned. •Most of the Buildings are under the ownership of Jain temple trustee.	•Height control is advised up to two stories in the buffer area. •Maintenance and Adaptive reuse of the old buildings in the street as new cafes, restaurants based on gujarathi culture by providing financial incentives.
Light House	•Food corporation and its godowns are present in the vicinity. •Old coir godowns are now used as food corporation godown with less maintenance. •Abandoned fort remains and acts as waste dumping site.	•Height control is advised up to two stories in the buffer area. •Adaptive reuse of the godown buildings to new cafes, restaurants, representing the industrial heritage. •Proper solid waste management and restoration of abandoned buildings nearby

3.3. Planning strategies

This study revealed the multiple planning issues of Alappuzha complicated by the apathy of stakeholders towards heritage conservation and sustainable tourism. The following strategies are proposed to be integrated with the planning process so that both built and natural heritage of Alappuzha are conserved for the future generation.

- Form a Heritage committee for Alappuzha for grading and listing of buildings, regulating the land uses, building design, heights etc. This committee may function under the Art and Heritage Commission of Kerala.
- Building use permission in the conserved area shall be granted only after a Heritage Impact Assessment to verify that there shall be no adverse effect directly or indirectly on the concerned heritage.
- Build a Heritage Fund under Municipality, with the support of local people, private sectors. Adaptive reuse and incentives options can be provided.
- Participation of the public in heritage management and its documentation. Encourage the training of locals so that they can become local guides for heritage walks and houseboat tours.
- Offer the biennale events, heritage festivals, tailored in time with the calendar of local events like Mullackal chirappu, Nehru trophy. For tourist, this could help in exploring more on local traditions, built heritages, customs, rituals, and festivals.
- Special incentives to be given to the local people for constructing temporary cottages for the tourist homestays and local cuisine, coir handicrafts, traditional fishing skills can be tourism products.

4. CONCLUSION

Maintaining the historic urban areas in the contemporary world is one of the most challenging factors of urban planning. Alappuzha as study area is chosen to identify the issues that affect its built heritages and revitalization strategies are formulated based on the primary study. Heritage tourism can be promoted by linking existing tourism spots with historical sites. There is a need of bottom-up participation of local residents in canal restoration and heritage management. It is meant to be a long term programme by involving stakeholders, encourage investment in heritage management, demarcating heritage zones, and development control regulations, aiming to promote sustainable development in historic areas. This effective inclusive revitalization measures with proper implementation and management, could bring back the lost glory of port town.

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Planning for a Safe Neighbourhood: A Case of Kollam City

Towards more Liveable, Resilient and Safer Cities

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ABSTRACT: This paper discusses the various safety aspects at the neighbourhood level in Kollam city. Safety is one of the basic needs of a man. Safety is not about crime prevention. It is the well-being of the residents inside the neighbourhood. Safety can be achieved at the individual level and at the global level. Urban safety is connected with the personal state as well as the security of a region and helps in achieving sustainability. Safety at the individual level is often associated with one's perception of safety. It can limit a person to use a place for a particular time or completely avoid a place. So, there is a need to design a place that is safe for all. Overtime number of theories and concepts have been involved such as Broken window theory by James Q Wilson and George L Kelling, Defensible Space by Oscar Newman, Crime Prevention Through Environmental Design by C Ray Jeffery, and Eyes on the street by Jane Jacob to improve safety conditions. Safety is an important parameter in the planning of Resilient city, Age friendly city, Child friendly city, Sustainable neighbourhood, Smart city Mission India etc. Since the neighbourhood is the smallest unit in planning, for the study a neighborhood in Kollam city is selected based on various parameters at the urban level. Primary study was conducted for a detailed understanding of the neighbourhood and to identify various safety issues. The analysis part is divided into the neighbourhood and its characteristics, perception of safety and the distinct aspects of a safe neighbourhood. Issues were mapped and various strategies for safe neighbourhoods for Kollam city developed.

KEYWORDS: Safe Neighbourhood, Perception of Safety, Urban Safety

1. INTRODUCTION

The most accepted definition of safety is “safety is the freedom from harm, injury or loss.” According to Maslow’s hierarchy of needs it is one of the second most basic human needs. The world has been rapidly urbanizing, it is expected that the cities will hold 68% of the world population by 2050 (UN, 2018). So, there is a need to design safe places for the present population and for the future population (Welle, 2015). A well-managed city will meet people’s basic needs and make them feel safe, included, and respected (WHO, 2015).

A sense of safety can be considered as one of the necessities of life that can be experienced at various levels, such as safety at home, safety in neighborhood, safety in city, national security and international security (Aalbers and Rancati, 2008). Neighborhood plays a key role in safety inside home and personal safety (Torres, 2017). Neighborhoods are a key piece in understanding and management of cities as urban planners, be it as a natural way in which communities organize themselves (Cooley, 1909).

2. METHODOLOGY

A deductive approach is used to study the physical characteristics and urban atmosphere of a safe neighborhood. For this purpose, the three elements are investigated. The three foci of the study are neighborhood and its characteristics, perception of safety and the various aspects of a safe neighborhood.

Primary Study was conducted through in- depth expert interviews, online survey to find the safety issues in Kollam city, field study and survey of the residents of the selected neighborhood. Based on the study analysis and inferences recommendations and proposals were made.

3. LITERATURE REVIEW

By 2050, 68% of people are expected to live in cities, particularly in developing countries (WHO, 2020). Urban management will play a key role in defining the quality of life in the coming year (Safe city index, 2019). A key element of this will be security to the people.

Sustainable development goals also highlight various safety aspects to be achieved by 2030 such as access to safe food, drinking water, sanitation and medicines, safe quality learning environment, safe women, and girls etc.

3.1 Need for safety in urban planning

Different concepts such as Resilient Cities; Sustainable Neighborhood; Age friendly Cities, Smart City Mission, India, Child friendly city; Infants, Toddlers, Caregivers- friendly Neighborhood (ITCN); Women & Girl Safe spaces; Making cities and public spaces safe for all women and girls; "Healthy cities; Good health is good politics Toolkit for local governments to support healthy urban development" addresses the need for a safe environment and a safe neighborhood.

Figure 1: Neighborhood unit by Clarence Perry 1929. , Source: The neighborhood unit adequacy: An analysis of the case of Gaza, Palestine.

3.2 Safe Neighborhood

Safety is subjective, achieving this is specific to the community and the individuals and it is a measure of economic development (Aggarwal, 2016). Safety is considered a fundamental need by residents in neighborhoods (Sakip et al., 2013). The ultimate aim of city planning for both new and old towns is to create a safe, organized, and healthy place of work and home for the residents (Faroud et al., 2013).

Neighborhood forms the smallest unit in the city (Meenakshi, 2011; Collison, 1954; Treasure coast regional planning council, 2004; National Geographic Society, 2012). Neighborhoods should be designed to achieve social quality of life (Faroud et al. 2013). The importance of planning neighborhood units was brought in after the first world war with the adoption of automobiles (Lee et al. 2018). During this time, an average of one child was killed in road accidents, thus making safety a major concern.

In the 20th century, after the world war, the emergence of car-oriented development created a new feeling of insecurity (Acierno et al., 2009). Neighborhoods are successful if the environment provides a safe, healthy, good quality of life and sense of community (Amrutha, 2016). Safety is an indicator for residential satisfaction (Sakip et al., 2013).

3.3 Different theories of Safety in Urban Planning

a) Jane Jacob and safety in public space

Jane Jacob studied the relationship between public space and safety and developed the concept “eyes on the street” in (Pacheco, 2015). Jacobs proposes that neighborhoods with active sidewalk life are typically the safe neighborhoods, and those with

Figure 2: Defensible Spaces, Source: MDPI, 2019

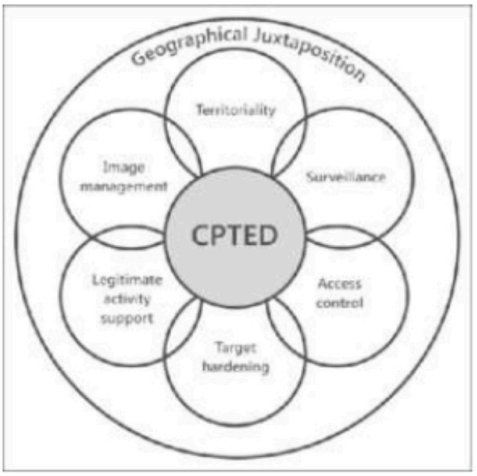

Figure 3: CPTED Principles, Source: https://www.researchgate.net/figure/The-seven-crime-prevention-through-environmental-design-CPTED-principles-Source_fig1_281604957

nearly deserted sidewalks are the ones that are unsafe (Eaker, 2008). The most effective way to make the street safer is by the unconscious effort of the people. Streets where people do not use their sidewalks, such as in neighborhoods where people do not socialize with their neighbors, are those where crime is invited. The criminals know the streets where no one keeps a watch on the neighborhood, and those are the ones they target (Eaker, 2008)

b) Defensible space by Oscar Newman

Defensible space is a principle of crime prevention developed by architect Oscar Newman in the 1970s (Steventon, 2010). According to him, defensible space is a residential area, and the inhabitants are the key agent in ensuring safety. Both society and physical elements are the part of a successful defensible space (Pallida, 2016).

c) Crime Prevention Through Environmental Design (CPTED)

Developed by criminologist C. Ray Jeffery in the 1960s. Crime Prevention Through Environmental Design (CPTED) is a set of design principles to reduce crime and increase building security. Built environment is designed to prevent crime and reduce the damage caused by natural disasters.

Table 1: Aspects of Safe Neighborhood, Source:Author generated based on Literature Study

	Aspect of Safety	Perception of Safety
1.	**Quality Of Outdoor Light And Safety**	• Street lighting and surveillance from housing provide the opportunity for people to monitor the neighborhood. • Dark public space often generates feelings of fear in people (Loukaitou-Sideris, 2006). • People can accept lower lighting levels when social safety is not threatened (Boomsma and Steg, 2013).
2.	**Street And Safety**	• Frequently traveled streets are places where residents can enjoy scenic views as part of their daily lives (Volcano Heights Sector Development Plan, 2013). • Passive surveillance in the form of entrances and windows facing pedestrian paths support eyes on the street and improve safety.
3.	**Community And Safety**	• The perception of being supported and sense of community have an impact on feeling of safety (Zani et al., 2001). • Fear of the crime has an effect on a community's ability to develop social connections as people who are fearful might limit their social contact (Ross, 1993). • Sense of community plays a limited role in reducing negative impacts of safety (Zani et al., 2001). • Maintenance of houses and gardens can also influence the perception of safety (Foster and Giles-Corti, 2008). • Some of the fear generators are graffiti, social disorganization, litter, lack of neighborhood cohesion, presence of undesirables, beggars, prostitutes, and drug addicts (Nelson et al., 2001). • Increase in vacant houses (PD & R, 2014; Torres, 2017). • Caste is one of the predominant factors in the formation of urban neighborhoods (Bharati et al., 2019; Hazlehurst, 1970, Hansen, 2001; Thoks et al., 1969; Gould, 1965; Lynch, 1967). • Segregation in neighborhood affects the diversity (Bharati et al., 2019). • Heterogeneous communities are less discriminating than homogenous communities formed based on race, ethinic groups etc. (Ihlanfeldt and Scafidi, 2002; Bharati et al., 2018). • Mixed land use allows services to be accessed within the community, thus strengthening safety and allowing a mix of income levels in the neighborhood (Amrutha, 2016). • Compact and well-connected places are safer compared to a large area that is spread out. To make a city safer there is a need to avoid urban sprawl.
4.	**Social cohesion and neighborhood safety**	According to UNDP, 2009: • Exclusion of a group • Minorities will become more insecure if they are being victimized because of their ethnicity, gender, culture or religion.
5.	**Crime and neighborhood safety**	• Fear of the crime has an effect on a community's ability to develop social connections as people who are fearful might limit their social contact (Ross, 1993).

d) Broken Window Theory

Broken window theory is a criminological theory introduced in a 1982 article by social scientists James Q. Wilson and George L. Kelling (Kelling et al., 1986). Broken window was used as a metaphor for neighborhood disorder. This theory states that crime emanates from disorder and vice versa.

3.4 Aspects of Safe Neighborhood

From the literature study, the various aspects of a Safe Neighborhood are Perception, People, quality of light, street safety, community, social cohesion, crime and neighborhood disorder. (Table 1)

4. SELECTION OF NEIGHBORHOOD

The 47th District Collector of Kollam B. Abdul Nasar launched the Safe Kollam project on 2nd October 2019. The project focused on five aspects taken from Gandhi's perception of life: Safe Environment, Safe Water, Safe Food, Safe Road, and Safe Children.

Since the Safe Kollam Project was an important project, Selecting a neighborhood had more potential for studying the safety parameters.

Two alternate definitions of neighborhood are census tracts and neighborhood clusters (Mujahid et al. 2007). Census tract are subdivisions of a country having an average population of 4000 people (US department of commerce, 1980). Neighborhood clusters are spatially contiguous block groups (Mujahod et al. 2007).

In order to study the issues and impacts of the composition of socio- economic status, urban forms such as land use, open space, buildings, and density census tract have been adopted to study (Yunmi et al. 2015). By doing so future risk can be reduced and future benefits can be enhanced. It also helps to

Table 2: Site Selection Criteria, Source: Author, 2020

SL no:	Ward No.	Ward names	Residential concentration Index, 2020	Proximity to CBD
		 Figure1: Kollam Division map. *(Source: Kollam Town planning department, 2020)*	 Figure1: Residential concentration index of Kollam city, 2019. *(Source: Kollam Town planning department, 2020)*	 Figure1: Commercial concentration index of Kollam city, 2019. *(Source: Kollam Town planning department, 2020)*
1	1	Maruthadi		
2	12	Thevally		
3	13	Vadakumbhagam		
4	15	Uliyakovil		
5	17	Kadappakada		
6	18	Koikal		
7	19	Kallumthazham		
8	20	Mangadu		
9	21	Arunttimangalam		
10	24	College division		
11	25	Palkulangara		
12	26	Ammanadada		
13	27	Vadakkevila		
14	28	Pallimukku		
15	29	Ayathil		
16	33	Manakkadu		
17	38	Thekkumbhagam		
18	42	Mundakkal		
19	43	Pattathanam		
20	44	Contonment		
21	45	Udayamarthandam		
22	46	Thamarkulam		
23	47	Pallithottam		
24	48	Port		
25	50	Kaikulangara		
26	51	Thangassery		
27	52	Thirumullavaram		
28	55	Kannimel		

<0.5	1- far
0.5-1	2- moderate
>1	3- Near

identify the threats and issues in the neighborhood. To study at the neighborhood level, ward becomes the most useful level of analysis (Bharati et al. 2019).

The neighborhood for primary study was selected based on the comparison of residential concentration index, 2020, proximity to the CBD and by overlapping the city division boundaries (2011 and 2019) for understanding the trend in the study area. From Table 2 Kadappakada, Pattathanam and Cantonment Divisions satisfy all criteria and hence- Pattathanam is selected for primary study.

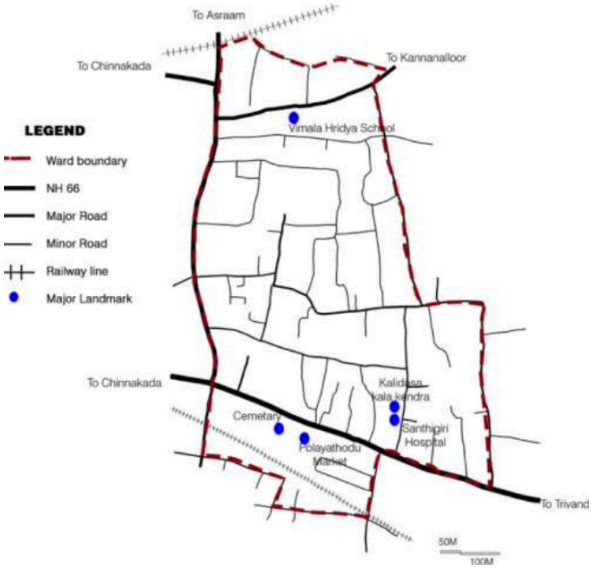

Figure 4: Base map of Pattathanam neighborhood, Source: Author generated Based on Google map, 2020; Google Earth, 2020; Wikimap, 2020

5. PRIMARY STUDY

5.1 Online Survey at the city level

An Online Survey was conducted to identify the safety issues at the city level, and to consider these issues in the selected neighborhood.

Results from the online survey:

- Social order has more impact on the respondents than physical order.
- Discrimination was not a major issue in the city and had less impact on the safety issue
- The major safety concerns were solid waste management, traffic, and road accidents; Pollution, religious and political intolerance, drugs, gender- based violence, water shortage

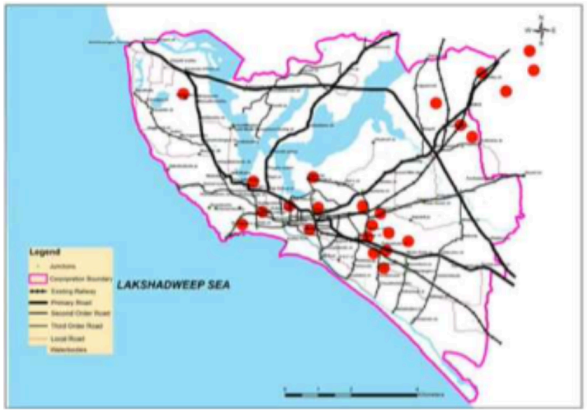

Figure 5: Location Map of online respondents from Kollam, Source: Authored Prepared based on Google form, 2020

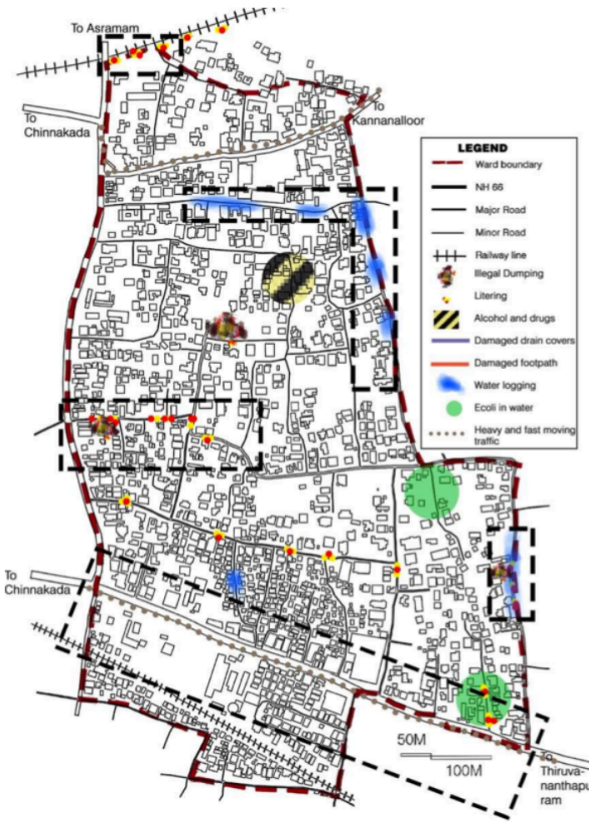

Figure 6: Unsafe neighborhood conditions in Pattathanam, Source: Author prepared based primary Study, 2020

Figure 7: Photographs of littering and traffic, Source: Primary Study conducted by Author, 2020

during summer, pedestrian facility, and Road accidents.

- LGBT and Road users are more vulnerable compared to another user group. The survey suggests that Kollam city is a safe city for Women, Children and Elderly people.
- Daytime is considered safer to walk alone. Perception of safety varies on the basis of gender.

5.2 Primary survey and study in Pattathanam

Primary survey was conducted in the neighborhood through convenient and snowball sampling.

Details of Primary survey

- Number of respondents- 40
- Number of Female respondents- 33
- Number of Male respondents- 7

From the primary study it is found that that:

i. Residents feel safer in a heterogeneous community.
ii. In a homogeneous community minority often feel discriminated against; in Pattathanam it is on the basis of religion and income.
iii. Frequently travelled streets and places such as places of worship, shops, workplace, and friends' houses influenced the perception of safe neighborhood boundaries.
iv. Acquaintance with the local people was simultaneously related to frequently using a place.
v. The feeling of being discriminated against was found in elderly people.
vi. Neighbors of the same age group influenced safe neighborhood boundaries for youth.
vii. Duration of stay in a neighborhood has a positive impact on the perception of a safe neighborhood only for the homemakers.
viii. Maintenance of house and premises affected the safety inside the houses.
ix. For the male respondents frequently, travelled places determined the boundary.
x. Ancestral home, living with family and relatives living nearby are other factors that increased one's perception of safety.
xi. Ownership of houses and the fear of being homeless prevented a respondent from mingling with the neighbors.

5.3 Issues

i. Waste management is the major problem; particularly at the peripheral area since the boundary has access from major roads.
ii. Most of the issues are connected to waste management such as smell, stray dogs, difficulty in walking, mobility, mosquitos etc.
iii. Duration of stay affected the perception of safety, longer the duration increased the sense of safe place.
iv. Stronger the functioning of the residents association, the more the people interacted and shared the same value.

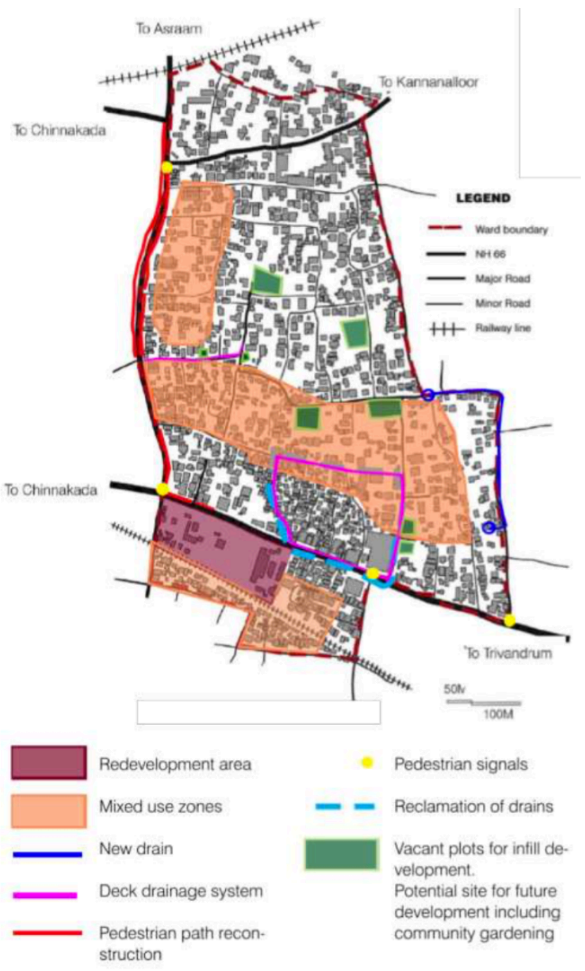

Figure 8: Proposal for Pattathanam neighborhood, (Source: Author, 2020)

v. Most of the people avoid crossing the busy roads and travel by private vehicle or auto rickshaws.
vi. Vacant plots are either used for dumping waste or for parking of vehicles.
vii. The neighborhood is not active during the noontime and is not safe for children and women to walk alone.

5.4 Inferences

For a neighborhood to be safe the built environment should encourage the people to frequently use the place and streets should be walkable. A neighborhood should be heterogeneous, so that people from diverse groups are welcomed to live in the neighborhood.

Perceived safe neighborhood and social cohesion are interrelated, the stronger the social cohesion larger the boundary of perceived safe neighborhood boundary. Ancestral origin, relatives and friends living within the neighborhood increased the sense of safety within the neighborhood.

6. OBJECTIVES FOR SAFE NEIGHBORHOOD

Based on the Primary Study the following objectives are derived for achieving safety in Pattathanam:

i. To Create a sense of ownership of public spaces in the neighborhood so that people take responsibility for their neighborhood.
ii. Safe access and movement of both people and vehicles by providing safe and integrated streets.

Figure 9: Proposed development along the National highway, (Source: Author, 2020)

iii. Advocacy and awareness building for addressing perceptions and guarding against environment decay.
iv. Creating a quality infrastructure to make them more robust to increase the perception of safety.
v. Good urban management and monitoring to ensure the progress and perception of safety inside the neighborhood.

7. STRATEGIES FOR SAFE NEIGHBORHOOD

The following strategies are proposed for safety in Pattathanam Neighborhood:

i. Create Pathways to Maintain Safe housing for all in Pattathanam.
ii. Citizen and Community Participation of residents, neighbors, local leaders, developers, and local bodies throughout the process of designing change for Pattathanam.
iii. Reclaim and repair blighted and abandoned areas within the neighborhood by using infill development strategically.
iv. Promote the creation of mixed-use neighborhoods that support the functions of daily life: employment, recreation, retail, and civic and educational institutions.
v. Vibrant local economy and guided growth.
vi. Safe, sufficient, and reliable water, solid waste management, and drainage inside the neighborhood.
vii. Streets and public spaces as places of shared use. Neighborhoods should have an interconnected network of streets and public open spaces.
viii. Prioritizing pedestrian needs by providing necessary street furniture.
ix. Neighborhood to be compact, pedestrian-friendly, and mixed- use with many activities of daily life available within walking distance.
x. Community activities and program to educate people about the responsibilities as a resident in Pattathanam.

8. CONCLUSION

Pattathanam is one of the popular neighborhoods in Kollam city because of the proximity to CBD and other important locations. Over the years a considerable number of investments in the form of shops, houses, and office spaces have taken place. Being one of the prime locations in Kollam city is necessary to make Pattathanam one of the safest places to live. To make Pattathanam a safe neighborhood it is essential to meet different strategies that address the safety of different user groups, housing, neighborhood, land use, and services and streets.

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THEME 02:

Design for Social Innovation

The culture of designing, in general, is reduced in some extent to a habitual pattern, where the designer follows the process as a ritual. The technology available to us today coupled with innovative thinking can help to redefine the design processes to better respond to the ever-changing demands of the market.

A discussion on the multitude of possibilities offered by today's technology may effectively lead to efficiency and innovation, including collaborative practices

Theme Chairs

Prof. Alessandro Biamonti

Associate Professor, School of Design,
Politecnico di Milano

Prof. Alessandro Biamonti is an architect with PhD in Industrial Design & Multiedia Communication. As Associate Professor at the School of Design, Politecnico di Milano, he coordinates the Research LAB LABIRINT (Laboratory of Experimental Habitat). He's Rector's Delegate for International Relationship with India for Politecnico di Milano, and member of the International Relation Committee of the Design Department.

Prof. Biamonti is associated with TMU University of Tokyo (Japan), Faculty of Design KTU of Kaunas (Lithuania), visiting researcher at DML of Ritsumeikan University (Japan) and the Scientific Committee of the Center for Design Studies of UEMG (Brazil).

His work deals with the anthropological aspects of the discipline, specially focused on Spatial and Interior Design. Therapeutic Habitats for Alzheimer No-Pharmacological Therapies, the role of Contemporary Ruins in our Urban Environments, as well as the knowledge impact related to culture of food, are key-topics of his researches.

Sandeep Sangaru

Sangaru Design Objects

Sandeep Sangaru is a multidisciplinary designer, educator, entrepreneur, wanderer and a nomad by nature. He studied Industrial design specialising in Furniture design from the National Institute of Design, Ahmedabad with a background in Mechanical Engineering.

To mention a few, he is a proud Recipient of the Red Dot Design Award- Best of the best 2009, The Design for Asia-Grand Award and the gold Award 2011, The British Council's Young Creative Entrepreneur Award - Design for Social Impact in 2012 and the recent JSW+AD Craft Prize for Contemporary Craftmanship 2020.

His work is informed by a significant commitment to local material and local knowledge. He loves to capture, communicate and create, through his work of collaborative experiments with different communities practising the craft of handmade in India and around the world. To make all these explorations tangible he founded Sangaru Design Objects which co-creates working with craftsmen, he relooks and innovates ways of working with the age old but relevant traditional methods of making by hand that connects a human way of living with local resources.

Along the way, as a team they are creating new knowledge, innovations and markets to inspire the younger generation to practice and disseminate these sustainable traditional methods.

Workshop

Nikhil Kunnath is the Founder and Designer at KOL Crafts, a startup for bamboo sustainable products. He did his Masters' degree in Mobility and Vehicle Design from IDC, IIT Bombay. He has served as research associate at IIT Bombay on Human Powered Mobility. He is a member of the Kerala Forest Research Institute Bamboo & Cane cluster (KFRI).

Kunnath has keen interest in sustainable products using bamboo, lifestyle products, interior design products and furniture

Nikhil Kunnath
Founder & Designer, Kol Crafts

Giant Grass Bamboo Centre established in 2013, is specialised in construction of Bamboo structures, interiors using bamboo panels and furniture explorations with bamboo. They have been key to bringing together skilled artisans to the forefront to facilitate bamboo explorations.

Muhammed Sadique
CEO, Giant Grass Bamboo Centre, Wayanad

Design Thinking in the Discipline of Architecture:
Inclusion as a Design Prerogative

Amrita Madan
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ABSTRACT: : Architectural Design Pedagogy has quite often suffered from a critical disconnection with not only the ongoing discourse in higher education, but has also been removed from strategic and revolutionary changes that have become a norm in other fields, be it Design Thinking, Innovation or Disruption. No real alternative models have appeared and the discipline is in a state of inertia. Design Thinking, while having its roots in the architectural process, has shifted the focus away from the exclusionary 'designer' to the inclusionary 'user', from creation to negotiation. Yet, the ADP has not considered the implications of the shift. This paper explores why and how Design Thinking and innovation, as understood in the business world, could be practiced in Architectural Design process such that the studio could not only become more inclusive and more interdisciplinary but also reconsider the overall aim of the educational apparatus. The paper delves into why inclusion does/ should matter in architecture, and how practice can provide for the academia to move out of its present path and incorporate the real. How would such a process change the way we practice in the profession? Taking a critical approach, the paper tries to align seemingly disparate entities of human-centered, socially-driven and creative place-making processes to derive a set of actionable targets that could trigger further thought. The research intends to, hence, highlight possible practice-driven scenarios towards an inclusive curriculum, which engage with the changing roles of the architect in the making of space.

KEYWORDS: Design Thinking, Architectural Design Process, Practice-Pedagogy Gap, User Experience, Roles of the Architect

1. INTRODUCTION

The evolution from design to design thinking is the story of the evolution from the creation of products to the analysis of the relationship between people and products, and from there to the relationship between people and people. (Brown, 2019, p. 47)

Peter Rowe, in his seminal work, coined the term Design Thinking under the Architectural design process (hereon referred to as ADP) as a set of (individual) decisions that designers take in action (Rowe, 1987). The reference set of these decisions is a constant push and pull between the 'framed' problem and the context where the building would be built, the designer's personal attitudes, the possibilities of fabrication – technologically or materially, etc. In Rowe's narrative, the end user did not appear, in more than a cursory way. Over the years, many narratives or interpretations of Design Thinking have emerged, in different fields, such as Management, Information Technology, etc. that tend to focus on different aspects (Dorst, 2011).

In the business world, Design Thinking (hereon referred to as DT) is an approach used for practical and creative problem-solving. Its primary focus is that of harnessing and creating user experience and originally comprised, to quite an extent, of the methods and processes that (architectural) designers used. It is relevant to say that, in business, the process of creative problem-solving is closely linked to innovation, which, in turn focuses on user experience, both cognitive and emotional (Razzouk & Shute, 2012). In redesigning the MBA curriculum at the Harvard in 2011, Datar, Garvin and Cullen considered the lack of real-world understanding such programs were providing its graduates, creating a "gap between theory and practice" (Datar, Garvin, & Cullen, Rethinking the MBA: Business Education at a Crossroads, 2011). In turning towards DT, their attempt was to equip the future managers with tools and techniques that allowed them to recognize, ideate, solve and implement these problems differently. DT in business education, and as it was eventually used in other disciplines, was hence, an attempt to balance the knowledge and the practice components of the discipline by making the process more explicit and less tacit (Beckman & Barry, 2007) (Al-Sayed, Dalton, & Hölscher, 2010). Interestingly, course curriculum is also a product, which would ideally go through the process of DT to attain previously unconsidered outcomes.

In an attempt to close the loop, the aim of this paper is to consider what the ADP, in education and in practice, might have to learn from the now evolved DT process, as applied in Management. We consider the following objectives:

1. Comparing and contrasting the processes of DT with ADP
2. Analysing and deducting the components and sequences of both processes
3. Correlating, in a broad sense, the possible implications of DT within ADP

This can be looked upon as a process of breaking the cognitive fixedness – functional fixedness, structural fixedness – what we all have as architects. The contention of this paper is that if the ADP could evolve a way to focus on user experience in a more explicit and central way, as did Business Education, it might be able to emerge in a more purposeful and innovative form. In this short discourse, the methodology used is that of comparing the processes of the two domains to find divergences and convergences between the two approaches to come up with a mutual re-learning strategy. This work uses available data and analyses it in an iterative process, as a 'grounded theory' approach. Further, we discuss the integration of practices of inclusion that could potentially re-trigger and re-align DT into the architectural process, bring in efficiency in the broader sense of the term.

2. THE ARCHITECTURAL DESIGN PROCESS

In the recent past, Engineering, Architecture, and their allied disciplines have struggled with a perceived gap between academia and practice (Zoltowski, Buzzanell, Brightman, Torres, & Eddington, 2017). Attempts at reducing this gap have taken the shape of emulation of practice within education through juries; creating alternative real-life scenarios that acknowledge the socio-cultural situations such as the design-build, or simply by considering academia as a service to the profession. On the other hand, a closer look at Architectural pedagogy shows us that it has, for a long time, proceeded as a practice of acculturation of the learners that nourishes elitist approaches and results in the veneration of the 'star architect' as a bountiful creator of form (Webster, 2011) (Lawson, 2002). This exclusivity is further heightened by the nature of the higher educational apparatus, which primarily produces 'consumers' of culture rather than 'producers' of culture (Stevens, 1995), also setting apart the 'creator' of the space from the 'user' of the space. In an overall sense, the ADP has been understood as one of four stages – assimilation, general study, development and communication (Lawson, 2002).

- The assimilation stage involves collecting information, both generic and about the posed problem. In most academic cases, the ingredients of this stage are site (Location, Shape, etc.) and program, and are mostly 'prescriptive'.
- The next step of general study would comprise of understanding the problem which is done through case analysis of similar programs or problems and such, leading to establishing the 'concept'.
- The development stage tends to be iterative or a reflection-in-action and is based on decision making, which implies choosing one solution over the other. This is a linear activity and works on 'sifting' rather than 'collecting' and is, hence, 'exclusionary'.

Finally, the communication stage is about making the decisions known to other stakeholders such as clients and other consultants on the job.

In each of these stages except the last, and there is a closed-yet-repetitive loop of analysis, synthesis evaluation that the designer goes through. Despite the loop, the overall process is mostly practiced as linear.

While this is known and accepted, what is not clarified is how does a designer know how to move from one stage to the other or even within the loop. Architectural design education, wherein the student is asked to 'create' before being able to 'get information', is contrary to the inherent human learning process, as one needs to practice it to learn (reflection-in-action). Creating before practising leads to 'abstraction', a disconnection with the practice of the subject, and a process of distancing from reality that would need reconsideration. (Salingaros & Masden II, 2010). Cross (2001) proposes that this knowledge is not only gained from reflection-on-action, it is inherent in the objects we create, and hence, can be gained by using the objects, by making and reflecting on the objects, or by being instructed in them, a "designerly way of knowing".

Rowe's architecturally driven Design Thinking considered a range of episodic, nebulous, indeterminate or slightly defined, individualistic, designer-based, representational understanding of how a problem is understood by the designer (Rowe, 1987). Around the same time as Rowe's work, came another seminal work that has long since become the reference point in architectural education – that of Donald Schön (Schön, 1987). As in Rowe's work, in Schön's interpretation of the reflective practitioner, the user does not appear – it is only the designer, the creator and their engagements with the world, having an individual artistry at their core (Schön, 1987). Reflection-in-action as defined by Schön has its very roots in finding, identifying and responding to the element of surprise that might occur when one

deviates from a pre-determined path, by chance or by error. The start of the process is, however, an application of routine understanding to the problem at hand (Schön, 1987, p. 28), though it is supported by a cognitive flexibility that can help us acknowledge previously unidentified 'needs' and rethink the strategies accordingly.

The nature of the design problem for architects is not only predictable but also mostly known before the solution is attempted (Dutton, 1987). The role of the architect is interpretative – that which gives form to an existing set of concerns, prescriptive rather than descriptive, and self-gratifying – that which allows the architect-designer to pursue problems in which they are already interested (Lawson, 2002, pp. 87, 112). The Architect is expected to contribute in problem-framing to some extent, but the client-architect relationship is not governed by this. Additionally, there is an inherent gap, especially in projects of public nature, between the end users and the architects. In the tripartite relation between the architect, the client and the user, the user is mostly marginalized, making the designer's task more difficult. Traditional projects in academia have a further gap – here, even the client does not exist, and the student-architect operates in a sense of void. To this extent, any attempt to 'bring' in the 'user' into the process is going to broaden the gap. Instead, the process has to be reconsidered, and along with it, the roles of all its participants – the architect, the client and the user, and its innovative and operational frameworks (Madan 2002). Hence, it would seem that the core of integrating flexibility and diversity of use into the architectural artifact lies in the renegotiation of the process rather than the product. Such a renegotiation cannot exist without re-defining the roles of its participants or integrating other participants – whether human or technical into the mix. In redefining the role of the architect, Kattien professes action over drawing, process over product, collaboration rather than individualism, implementation rather than speculation (Kattein, 2015). This segregation works in contradiction with including more, doing more. It once again leaves aside key components that could allow us to think differently. Considered within the purview of implementation rather than speculation, it is evident that architects have limited perchance in 'framing' the problem, being bound by operating within a given problem.

Additionally, as it is taught (and, to some extent, as it is practised), the process of architectural design puts forth some critical exclusions. It favours

- Prior knowledge over new knowledge (other than a unique design outcome) – these are predispositions/ perceptions that reinforce the same mindset
- Typologies that exclude other typologies/ materials etc. that exclude large sections of society
- Urban settings rather than any other settings
- Standardization of approaches/ learning styles/ people/ goals
- An architect who can be everything so that everyone else is left out - a designer/ an engineer/ a technologist/ a historian/ a sociologist/ etc.

3. THE DESIGN THINKING PROCESS AS TAKEN UP BY THE BUSINESS WORLD

Design Thinking (DT) is understood as an approach to innovation that can be integrated into all aspects of life – be it business, society or such (Brown, 2019). This strategy of innovation is based on combining designers' skills with technological advancements and economic viability. By default, this process is meant to be human centric and inclusive – it is based on the fact that everyone can design (Cross, 2011) and that the 'design' cannot be left to designers alone, as it is all pervasive in our everyday society (Brown, 2019).

As is the case for the Architectural process, DT in Management also comprises of four phases – clarify, ideate, develop and implement (Datar, Design Thinking & Innovative Problem Solving, 2021)

- Clarify stage comprises detailed research focused on users where the assumption is that the exact requirements are unknown, and that for any transformative innovation, there is a need to discover latent needs using empathy. Discovering needs is more about identifying what are called as latent needs or frustrations and uncertainties that are abstract or emotional more than they are functional by asking open ended questions. This stage provides a comprehensive overview of the context of the yet unknown problem, and is, hence, 'inclusive' and 'exploratory'.
- Ideate stage consists of guiding and evaluating the ideas in order to create a set of design principles. These are not fixed principles, and vary from project to project, situation to situation and designer to designer. They are generally understood as attributes that respond to the user needs that have been identified, and the premise is that the more general the principles are, the more innovative would be the outcome. This stage hence is 'pre-conceptual' and 'descriptive', and need to be more structured than not.
- At the Develop stage, the distinction is clearly made between preliminary ideas and concepts. Concepts are evolved as a collection or a combination of complementary ideas. These concepts go through a more critical and incremental approach of rapid testing and prototyping to understand feasibility, viability and desirability. Feasibility refers to future or

projected functionality. Desirability refers to what makes sense to people and for people, whereas the viability component is essentially economic in nature.

- Then Implement, communicating the value of something so novel such that the users/ clients accept the product or are open to the product. The result of this communication is taking the outcome into a production stage.

3.1 Themes and Essentials/ Techniques used in each stage:

Some of these include:

- Elaborating the context of the problem is understood as a process in itself. A common tool used in DT for this is the Rick E Roberson's AEIOU framework (Hanington & Martin, 2019). The AEIOU framework categorizes observations as activities, environments, interactions, objects, and users, giving insight into people's relationships with the environment, activities conducted within it, exchanges between people, things and artifacts, etc.
- Systematic inventive thinking (SIT) – SIT includes tools to break cognitive fixedness, i.e., the tendency to approach problems or ideas in a previously known and traditional way. The tools are based on listing the attributes of the existing situation and then applying these patterns one by one. Some possibilities are:
  - Subtracting something that's essential within the situation.
  - Adding a copy of an existing resource but with a change that creates values.
  - Task unification which includes adding another task to the current resource, thereby creating multiplicity of uses (e.g. Airbnb, Uber, etc.)
  - Changing the sequence of activities within what is an already known process, etc.

Interestingly, the tools and techniques of DT allow for imagining new possibilities within existing situations, while working within a box and avoiding ideas that are too far out there, and involve integration rather than segregation. The ideas of multiplicity of uses and such things have always been there in architecture. These strategies might help us yield newer forms with contemporary interventions.

4. DISCUSSION: KEY CONSIDERATIONS FOR THE ADP WITH RESPECT TO DT

Users and Empathy: The ADP, in education and in large scale projects, identifies the user in a very generic sense, closing avenues for establishing practices of empathy. Till the user is left out of the equation in the education scenario, true integration between practice and academia will not happen. Live projects and Design Build are some paradigms that are trying to address this concern (Folić, Kosanović, Glažar, & Fikfak, 2016), yet very few focus on the aspect of empathy, mostly correlating to the formal experience of the 'build' aspect rather than the 'social' (Gaber, 2014). Contrastingly, in the DT approach, the boundaries of separation between the user and the creator are blurred through the process of empathy. It is understood that Innovation is best when it addresses real human needs.

The ADP might benefit by making efforts to include embodied spatialities within its core, which might in turn redefine the realm of architecture or rather the start point (Madan & Iyengar, 2019) or incorporate varied strategies that bring fore the understanding that architectural space is for the living.

Nature of the Process: The understanding that ADP is cyclical, iterative and can start anywhere is a myth, whereas in effect it usually either starts at ingredients (site, program, etc.), and moves on to concept, or directly starts at the concept, in a linear fashion. This is exclusionary by default – leaves behind people as well as ideas, as mostly the 'concept' tends to be based on the 'want' rather than a 'need'. In the DT approach, concept follows empathy. There is a finite start point – people and their needs understood through empathy. The rest of the process circles back as and when needed, whereas the actual back and forth is between abstract (clarify and ideate) and concrete (clarify, develop and implement). The ADP needs to be more thematic rather than conceptual.

Finding the 'job to be done' rather than accepting or assuming: One key factor of the DT approach is that of re-framing the question asked or rather re-framing the problem. This allows the designer to think differently, incorporating more or diverse ideas that can lead to innovation. It also allows space for all kinds of divergent and convergent processes.

Real: Management education incorporated DT in an attempt to bring in the real. They did this by making the user the core. In Architecture's attempt at the same, strategies such as design-build are effectively trying to capture the same intent – bring the real world into academia. Yet, such integrations have not affected the process of design, especially in the paper-based design approach (Tepavčević, 2017).

Inclusion vs. exclusions: The DT approach is structured around practices of inclusion. Empathy, task unification strategies during the ideate phase, the process of task segregations based on diverse teams with convergent or divergent strengths, interdisciplinarity and the testing approach are all inclusive by nature. Contrastingly, ADP's conceptual and typological approaches and its predetermined programmatic, renders it exclusionary. There is a need to make it more impact-oriented rather than typological.

5. CONCLUSION

In whichever form the roles of the Designer/ Architect get defined or modified in the years to come, an inherent implication of the ideological shift that has led to the end of the starchitect is that architects are in service of humanity. This reversal of the expert-subject relation of architect-user forces one to reconsider the process of design itself. In this reversal, the expert is the user, whereas the designer/creator is simultaneously the informed spectator and responsible actor as in the Design Thinking approach. This is not an attempt at neutrality. Rather, it is an acknowledgement that user intervention is key to the architect's nonlinear process of design.

Policy and Domain Knowledge – A case for Multidisciplinary approaches: Architectural education, in its current form in India, seems to be at loggerheads with multidisciplinarity and inclusion, creating barriers in terms of who can be architects (access), who can teach future architects (domain expertise vs. multidisciplinary practices), who can use the spaces that we (are learning to) create (users), etc. A few questions that arise out of this are: If everyone can design, shouldn't architects be able to learn from others outside the discipline? Where is the place or point at which domain knowledge is needed in the pedagogical journey of a student-architect? Where is the need for incorporating interdisciplinarity?

Inverting this mindset to a more inclusive one creates a series of queries, be it from the perspective of the faculty imparting an inclusive mindset, the students learning to be more inclusive or gathering tools to develop an inclusive approach, or the architect professional practicing inclusion as a principle in their projects, no matter in which form.

Kat Holmes brings an interesting point to the fore (Holmes, 2018). She talks about the power that is bestowed on designers to remedy exclusion – who can and cannot participate in a space, a design or an ideological premise is very much up to the designer, creator, and thinker. By creating designs, and designers, who are more inclusionary than exclusionary, by creating processes that allow for more participation, more engagement, or by creating techniques that are structured around the needs to people, and by extension, on the needs of all living, we will make our built environment richer, more diverse and more accessible to all.

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Pliancy of Water Hyacinth in Making Compatible Interior Products

Nature's threat to opportunity

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ABSTRACT: Water hyacinth (Pontederia crassipes) is an exotic aquatic weed that originated in Amazon basins. It was introduced to India as an ornamental plant due to its lilac flower. But with a rapid growth rate, this plant became invasive causing environmental issues in many parts of India including Kerala. When the water bodies are choked with water hyacinth, it adversely impacted the aesthetics, biodiversity, and tourism revenue. The government attempted efforts to control the growth of water weeds, methods such as physical removal, chemical, and biological control, but each of them has failed miserably. This paper is intended for the search for efficient systems eradicating the weed through its utilization of it, making nature's threat to opportunity. Quantitative research with experiments is the methodology adopted. Efforts to make a compatible architectural product were done by using different ratios with water hyacinth as the main raw material. Five different samples are made and conducted relevant tests based on IS:2095 1996, IS 2542(part II), IS 2380 (part XVI),1997. These samples are then compared with the existing materials available in the market to standardize the product. Different experiments have been still going on regarding water hyacinth products, but this has not been explored much in the field of architecture. So this paper fills the gap in parallel research conducted on the same topic and the data observed could be used for further research purposes. The possibility of creating water hyacinth bio-boards is successful with comparable strength. Different samples have the potential for different applications as interior architectural products. Thus, from the study and further experiment, it is concluded that the water hyacinth bio-board is a compatible, sustainable and cost-effective interior non-load bearing building material.

KEYWORDS: Invasive, Exotic , Utilization, Bio-board.

1. INTRODUCTION

Water hyacinth is an invasive free-floating aquatic plant that clogs the water surface due to eutrophication. It affects water flow and blocks sunlight thereby increasing the BOD (biological oxygen demand) and creating issues for aquatic life totally. This scenario could adversely impact the aesthetics, biodiversity, and in turn tourism revenue. This has been a great ecosystem issue in many countries including India. Attempts to control or remove the water hyacinth incur high costs and labor and the effect is just temporary due to rapid growth. Believed to have come to India as an ornamental plant, this is causing huge environmental and economic issues all around the country. The need to deal with the water hyacinth problem is immediate in Kerala where most people near the water body depends on tourism for their income. Estimates show that more than 0.2 million hectares of water bodies in Kerala are infested with aquatic weeds (Koutika and Rainey, 2015). Among all the water bodies, Vembanad lake is prone to this spread and in turn affects the economy badly (Dr. G. Nagendra Prabhu, Associate Professor, PG Department of Zoology and Principal Investigator, CRAR). Disease-spreading vector species of mosquitoes breed freely in static waters. The decomposition of the dead plant's results in an obnoxious smell decreasing the clarity of water and depletes the dissolved oxygen content of the water, making it unsuitable for human use. Local fishermen have found it impossible to cast their nets into water covered with dense mats of these weeds. Thus the rapid growth is not only a biodiversity problem but also a social and economical issue (Rahmawati, Haryanto, & Suharyatun, 2018). The annual economic loss due to the proliferation of this water weed in lakes and water bodies in the state would be to the tune of hundred crores (Dr.Biju Kumar, Department of aquatic biology and Fisheries, University of Kerala).

Research on the Development of Biodegradable Board using Water Hyacinth at the Department of Agricultural and Biological Engineering, University of Lampung, Bandar Lampung, Indonesia; they successfully produced water hyacinth bio-boards under experimental conditions but only the bending stress and tensile stress was tested and studied. Research on Microstructural and Thermo-Physical Characterization of a Water Hyacinth Petiole for Thermal Insulation Particle Board Manufacture at the Department of Construction and Technologies in Architecture, Portugal studied the botanical structural details of water hyacinth thereby the properties it possesses. Its potential applications in different fields have been studied but not a proper study in the field

of architecture has not been reported yet. Centre for Research on Aquatic Resources (CRAR), Alappuzha has undertaken various studies regarding the water hyacinth and was successful in making different usable products.

The researchers have realized that the only hope of removal of weeds lies in the economic utilization of these 'natural resources' by economically viable techniques – the concept of eradication through utilization (Limboonruang, & Phun-Apai, 2018). In fact, many researchers across the world have been striving to make use of these aquatic weeds for creative purposes. So in this research paper, study, exploration, and experimentation on the possibilities of water hyacinth as a raw material in the field of architecture have been made, and further checking the properties to implement other physical properties to the bio board made making it viable.

1.1 Aim

To utilize water hyacinth to produce bio-board using different biomass ratios and analyze the properties to produce a compatible product.

1.2 Objectives

- To experiment in making a bio board using water hyacinth as the main raw material, thus finding out the possibilities of cost-effective and viable architectural products.
- To test and study the properties of the product made.
- To inculcate another substantial method to reduce eutrophication.

1.3 Methodology

Quantitative research with experiments was the methodology adopted. As part of the literature study, the collection of secondary data with respect to water hyacinth was carried out. An appropriate method for the utilization of water hyacinth was identified as to produce bio-board which has the potential to replace the existing material used in different context for construction.

The experimentation process consists of the production of the different samples with water hyacinth as the main raw material, using different ratios and binders at various pressures and sizes. Five samples have been made: four samples with synthetic resin as a binder and one made with rubber resin as a binder. The manufacturing of the samples has to be followed by testing (as per IS 2542, IS 2095, and IS 2380) and standardizing. Flexural strength, density and water absorption were investigated. These values could be analyzed and numerical schemes were applied for comparative analysis for each sample, thus arriving at a comparative conclusion and application of the product. Physical properties which the bio board lacks could be identified and further could be enhanced.

1.4 Scope

- To find out an application of water hyacinth as raw material in the architectural field.
- An innovation that could help to reduce the eutrophication within the Kerala context.
- Production of bio-board in small scale with standard sizes.
- This paper educes other researchers doing parallel topics.
- The findings provide an incremental perspective of research and thus the research process could be carried out further

1.5 Limitation

- The bio-board should be tested for fire resistance too, which the test condition was only available at CBRI,IIT Roorkee , this could be incorporated only in the future research of the same.
- Due to time constraint, enhancement of the properties has not been done.

2. LITERATURE STUDY

2.1 Origin, morphology and dispersal

P. crassipes as a plant having an individual rosette with an erect, free floating, stoloniferous and perennial herb bearing a whorl of 6-10 sequentially produced succulent leaves on short vertical stem (Limboonruang, & Phun-Apai, 2018). The species has become a widespread pantropical weed and is recognized as the world's worst aquatic weed (Holm et al, 1977). The species gained attention as an ornamental plant because of its attractive purple flower and more than a century ago, it was first introduced from South America into North America during the late 19th century. Thereafter spread to different tropical and subtropical areas of the world (Limboonruang, & Phun-Apai, 2018).

The seeds are produced in large numbers and are contained in capsules, each capsule containing up to 300 seeds and area viable for 5-20 years (Matthews et al., 1977). The rapid infestation is mainly due to

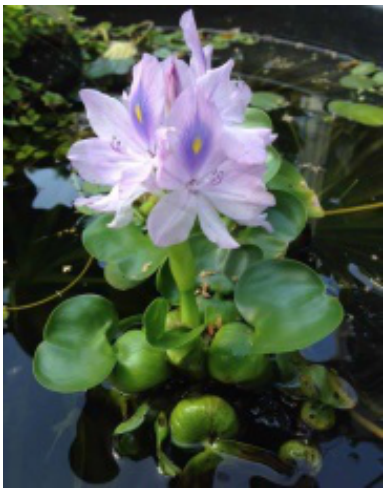

Figure 1 Water hyacinth. Source :Author

vegetative reproduction which the water hyacinth has rapid propagation. It is the morphological characteristics of the weed that make to colonize various habitats in a short span and is well adapted to expeditious distance dispersal (Wilson, Holst, & Rees, 2005).

It is one of the most productive plants in the world (Fernández, et al., 1989). It can double its size within five days and a mat of medium sized plants can contain 2 million plants per hectare (Kunatsa, et al., 2013) and its population can double in as 12 days (Herfjord, Osthagen, & Saelthun, 1994).

The water hyacinth plants can withstand both high acidic and alkaline conditions, but more effervescent growth is supported by neutral water bodies (Gopal, 1987).It is successful owing to their life-cycle and survival strategy that gives it a competitive edge over other species (Méthy, Alpert, & Roy, 1990).

2.2 Positive aspects

This species can remove cyanide from water because of its high biomass production (Dixit, Dixit, & Goswami, 2011). Its enormous biomass production rate, its high tolerance to pollution and its heavy-metal and nutrient absorption capacities permit its use in wastewater treatment ponds in mining areas of its native continent, South America (Ebel et al, 2007). It absorbs heavy metals, organic contaminants, and nutrients from the water body (Kunatsa, et al., 2013).

P. crassipes can be used as a substrate for compost or biogas production and the byproduct of this can be used as fertilizer (Sannigrahi, Chakrobortty, & Borah 2002). This also be used in agro-industry and industry and is also used as animal feed (Gunnarsson, & Petersen, 2007).

2.3 Effects on biodiversity

The mat formed by the water hyacinth reduces dissolved oxygen a situation called anoxia. Besides suppressing the growth of native plants and negatively affecting microbes, water hyacinth prevents the growth ad abundance of phytoplankton, this in turn decrease the food availability in water thus affecting the abundance of zooplankton. This decreases the water quality, thus threatening the life of aquatic species (Rodrigues, Odero, & Hayombe, 2014).

Figure 2 A result of anoxia condition. Source: Research gate

2.4 Effects on economy

The weed affects fisheries and related commercial activities, functioning of irrigation canals, navigation/ transport, hydroelectric programs and tourism. The formation of dense mat disrupts socio-economic and other activities boat and ship navigation, in turn restricts access to water for recreation, tourism and fisheries. This drastically affects the living of people who depend on all these aspects (Fernández, et al., 1989).

2.5 Impact on mankind

The decrease of water quality encourages mosquitoes, snails and other organisms associated with human illness, including malaria, schistosomiasis, encephalitis, filariasis and cholera (Sannigrahi, Chakrobortty, & Borah 2002).

3.EXPERIMENT

- Collection of water hyacinth and removal of roots. (Figure 3)
- Wash the rest of the portions with water and cut the leaves and stems into small pieces and boil this in hot water for 15 minutes until the color of water changes into slight yellowish green, this represents the starch is drained to the water. (Figure 4)
- Drain the water and transfer the boiled pieces of water hyacinth into a blender for conversion into pulp.
- Excess water should be squeezed out from the pulp and the extract formed is dried for few minutes.
- Coconut husks are added in different ratios(water hyacinth: coconut husk fiber -[4:1][4:1.5][4:2]) to this extract and mix thoroughly(bio board with water hyacinth alone as raw material is also made) shown in Table 1.
- This could be then molded by adding binders (here synthetic and rubber resins are separately used for different samples).
- This could be poured to the mold layer by layer of 0.5 cm and apply pressure after each layer and after the final layer, apply pressure and finishing

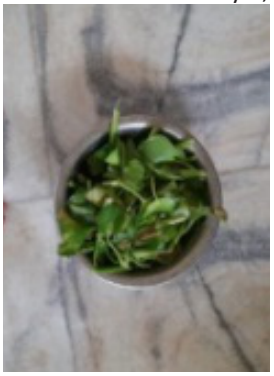

Figure 3 Collection of water hyacinth Source: Author

Figure 4 Cutting and grinding to pulp Source: Author

could be done.

- This could be then dried under sunlight for 3 continuous days, but the curing process persist for 4 days after the sun dry. So after 7 days, the samples are ready to undergo tests.
- 15cmx15cmx1.5cm mold is used in this research, to obtain samples of IS Code test standard sample size of 15cmx15cmx1.2cm (decrease in thickness due to evaporation).

Table 1 Samples Source : Author

Sample	Composition
Sample A	Water hyacinth alone as raw material
Sample B	Water hyacinth and coconut husk as raw material in the ratio 4:1
Sample C	Water hyacinth and coconut husk as raw material in the ratio 4:1.5
Sample D	Water hyacinth and coconut husk as raw material in the ratio 4:2
Sample E	Water hyacinth alone as raw material with rubber as binding agent

4. TESTS AND RESULTS

4.1 Bending stress

This test is conducted as per IS:2380(Part XVI)-1997. Five samples have been tested using Universal Testing Machine(UTM). The sample was placed in the roller support provided.The loads were observed and noted the readings which showed a stable deflection, shown in table 2.

Table 2 Stress calculated Source : Author

Sample	Load(UTM)	Stress = Load/Area
A	0.72 kN	400 kN/m2
B	0.96 kN	533.3 kN/m2
C	0.6 kN	333.3 kN/m
D	0.56 kN	311.1 kN/m2
E	0.6 kN	333.3 kN/m2

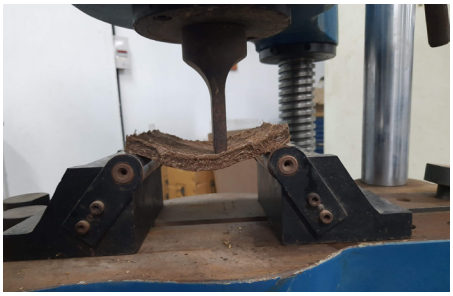

Figure 5 Application of load Source : Author

As per IS code the sample should withstand a load of 0.34kN. All the five samples have passed the test. Out of the samples with w:h ratio of 4:1 have the maximum bending stress. It is clear from the above table, that upon increasing the coconut husk ratio, the bending stress decreases. The sample with rubber as binding material(water hyacinth alone as raw material) have same bending stress of 4:1.5 (w:h) sample. Graphical representation of the same is given below in figure 6.

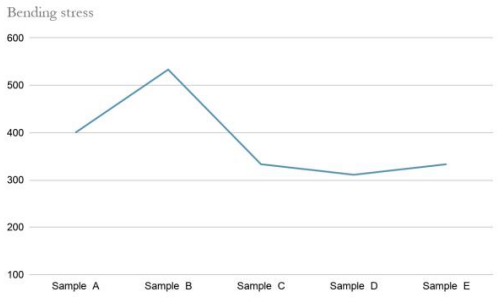

Figure 6 Bending stress graph Source : Author

4.2 Density

Density of a material is the mass of a unit volume of a material substance. Mass of each sample is observed by weighing the dry mass and the density is then calculated by using the formula,

Density = Mass/Volume

where, volume is (15x15x1.5)x10^-6 m3

For density calculation as per IS Code, dry weight should be observed, shown in table 3.

Table 3 Density of samples Source : Author

Samples	Net weight	Density
A	0.122 kg	361.15 kg/m2
B	0.13 kg	385.18 kg/m2
C	0.114 kg	337.78 kg/m2
D	0.112 kg	331.85 kg/m2
E	0.1 kg	296.3 kg/m2

From the graph, it is clear that the density of the sample decreases upon increasing the ratio of coconut husk. The lowest density is observed for Sample E, i.e with rubber as binding agent. From the observation, it is clear that the bio-board is a less dense material.

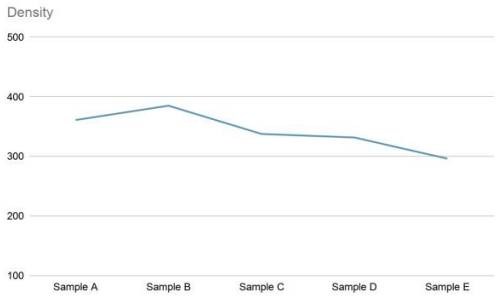

Figure 7 Density graph Source : Author

4.3 Water absorption

This test is conducted as per IS:2380(Part XVI)-1997. Oven dry method is adopted for this test. The specimen is submerged in water for 24 hours and the weight is measured. After the submersion all the specimens are dried in an oven at 103 degree Celsius and the specimens are cooled; the weight after drying is measured. Water absorbed (shown in table 4) can be calculated by using the formula,

Water absorption = [(X-Y)]/Y]x100
Where,
X-Wet weight of the specimen
Y-Dry weight after oven drying

Table 4 Water absorption of samples Source : Author

Samples	Wet weight (X)	Dry weight (Y)	Water absorption percentage
A	0.148 kg	0.122 kg	21.3 %
B	0.154 kg	0.13 kg	18.5 %
C	0.133 kg	0.114 kg	16.7 %
D	0.129 kg	0.112 kg	15.2 %
E	0.113 kg	0.1 kg	13.0 %

As per IS code, water absorption shall be less than 15 % in 24 hours.From the observation it is clear that only the sample with rubber as binding material(Sample E) falls under this category. Upon addition of coconut husk the water absorption decreases, this implies that the material becomes less porous. Highly porous sample is the sample with water hyacinth alone as the raw material.

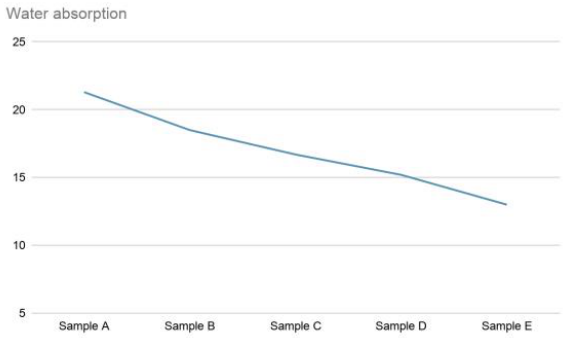

Figure 8 Water absorption graph Source : Author

5. COMPARATIVE ANALYSIS

The samples are not brittle in nature. They all withstand a load of 0.34kN in UTM which is the base standard load for bio-board without fail. No sample showed any crack, despite undergone deflections upon applying load. Thus could be inferred that the samples could be applied as non-load bearing interior material like partition walls, false ceiling etc.

Due to the microstructure of the species used, even though coconut husk is added to three samples, the low density property reflected in the product too. The use of rubber as binding agent further reduces the density of the sample. Less bulk density implies porous or cellular materials. It could be applied for thermal insulation and sound proofing (which need to be tested further) .

Looking to the water absorption percentage apart from the sample made with rubber as binding agent, only Sample D is near to the critical value(water absorption of bio-boards should be less than or equal to 15% in 24 hours). The rest of the samples cannot be applied in the areas where the presence of water could be there, this property could be enhanced further by reagent application. Sample E crossed all the tests conducted. Comparative analysis is shown in table 5.

5.1 Sample A

Sample with the second most load withstanding property among other samples. Porosity is comparable with other samples except Sample E, thus it is not suggested to apply where thermal insulation is necessary. High water absorption rate make it unfit to apply near water presence areas in the interior

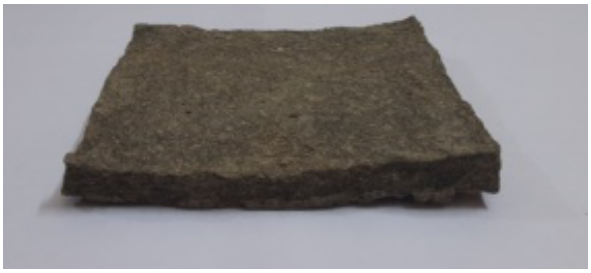

Figure 9 Sample A Source : Author

5.2 Sample B

Sample with the most load withstanding property among other samples. Less porous, thus it could not be applied where thermal insulation is necessary. Since the water absorption percentage is less than 15% make it unfit to apply near water presence areas in the interior.

Figure 10 Sample B Source : Author

5.3 Sample C

Sample with comparable load withstanding property. More porous than Sample A and B. Water absorption percentage is comparatively low, but it is still above 15%,thus this sample is inappropriate in the areas of water presence.

Figure 11 Sample C Source : Author

5.4 Sample D

Least load withstanding property among other samples. Lower density and water absorption rate is 15.2%,thus this could be used in areas of humidity or water presence by adding some natural agents which could reduce the water absorption rate.

Figure 12 Sample D Source : Author

5.5 Sample E

Same load withstanding property as of Sample C.

Low density and high porosity. Water absorption percentage is low, making it to withstand exposure to water. This property could be further enhanced with use of natural agents that reduce water absorption.

Figure 13 Sample E Source : Author

Table 4 Water absorption of samples Source : Author

Samples	Stress (kN/m2)	Density (kg/m2)	Water absorption Percentage
A	400.0	361.15	21.3 %
B	533.3	385.18	18.5 %
C	333.3	337.78	16.7 %
D	311.1	331.85	15.2 %
E	333.3	296.3	13.0 %

6. CONCLUSION

This paper dealt with the economical idea of an attempt to eradicate the invasive water hyacinth utilizing it as an architecture interior material.

- Potenderia crassipes(common name: water hyacinth) is an aquatic weed that forms a mat on the surface of water causing threat to aquatic ecosystem in many parts of world including India. Many eradication methods have been adopted but none succeed. Thus the main aim of the research is to make a compatible interior product from water hyacinth, thus employing the method of eradication through utilization and to find out the area of application of the material by comparing with other parallel materials available in the market. For this quantitative research with experiment is methodology adopted.
- This not only has impact on biodiversity but also affects economy and human values, by creating hindrances for the living of people who depend on water tourism, fishing etc, and causing many water borne diseases since it is the house for many dangerous vectors. Apart from the negative impacts it also has some applications like photo-remediation, fertilizer, animal feed etc.
- Five samples have been from water hyacinth pulp under experimental condition. These samples have been tested as IS 2542, IS 2095 and IS 2380 and the observation and analysis are made on all the tests. Thus properties of these have separately identified.
- A comparative study of all the samples have been made regarding the tests conducted. All the samples where crack free and undergone deflections in UTM, with different loads and no sample is brittle in nature. Density of the dry mass of the samples have been observed, with highest and lowest density being Sample B and Sample E respectively. Only Sample E have water absorption percentage less than 15%.Thus it could be inferred that all the samples are viable as an interior material.

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Inclusivity of Student Introvert Personality in Potential Study Spaces

A case of College of Architecture Trivandrum, Kerala, India

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ABSTRACT : Over the last 20 years, there has been a major push to form group-oriented spaces in educational learning environments that encourage collaboration, interaction, and conversation. Campuses and workplaces have been from time immemorial; inarguably designed for extroverts and their need for simulations. These designated study environments could overwhelm people on the opposite end of the I-E spectrum, the introverts. Architects and designers ought to craft learning environments which will support and engage a far wider demographic of students. This paper aims to suggest design considerations for non-typical potential study spaces in campus environments to be inclusive and sensitive to the requirements of a student with an introverted personality. The three-fold methodology inclusive of - a) Identifying potential study spaces through a set of parameters that impact introvert's comfort; b) Qualitative survey of identified introverted students analysing quality of potential study spaces; c) Suggestion of introvert-inclusive design considerations as an approach that provides insights into characteristics of ideal inclusive study spaces in campuses for students with introvert personality. This paper attempts to shape and integrate inclusive design strategies into future study space prototypes in campus environments.

KEYWORDS: Introvert, Personality, Occupant Comfort, Study spaces, Campus

1. INTRODUCTION

Ashna is an architecture student who loves art and design and often enjoys the quiet escape of sketching with her headphones on. On a personal level, she has a shy nature, a solitary learning style, and often prefer to solve problems on her own. Apart from the rigorous academic program there are many times that Ashna feels overwhelmed by the demands of the week, with studio hours of peer discussions, presentations, and other group activities, all she wishes is to recharge with some music and art in solitude.

Like Ashna there are many such introverts who yearns an oasis in the walls of their campus; a place filed with complex personalities of youth seeking to find a place for themselves. Most institutes and workplaces are designed for extroverts and their need for simulations. Even architects and designers promote and encourage extroversion by designing open spaces and inducing placemaking around every corner in a campus design. As a counterstatement what can be done about the remaining spectrum of the I-E personality? What about the Omniverts who may have a more ambivalent attitude to social interactions? Or the introverts like Ashna that could find such engagements exhausting?

Campus design primarily focuses on core teaching and learning spaces. However, transitional, or peripheral spaces have the potential to be study spaces and research has been done to convert these spaces into group learning or collaborative learning spaces, but this alienates individual learning spaces to the walls of a classroom or a library.

This paper takes the case of the College of Architecture Trivandrum (CAT), Kerala, India a secluded and private campus that enrolls 5 batches of 120 students each under the architecture program forming a close-knit community of a population of 600. The lush green campus integrated with the concept of "green buildings" has many interesting transitional spaces that act as activity or leisure spots for students to mingle in between their classes. An interactive campus with student work exhibits and group installations, events etc make these spaces buzzing with activity at different seasons of the academic year.

Understanding the need for and importance of learning about spaces for introverts in such a dynamic environment, this paper aims to understand the characteristics of unrealised study spaces which makes an occupant of introvert personality comfortable in order to help architects and designers to create more inclusive learning abodes.

2. METHODOLOGY

2.1 Stage One - Identifying the potential study spaces in CAT campus.

Identifying the various intended and unrealized study spaces in CAT campus, based on the parameters derived from literature review.

2.2 Stage Two – A personality test

Using the Eysenck's Personality Inventory (EPI), a random sampling of sixty students of the final year batch in CAT campus is given a personality test to classify them as an Introvert or/and Extrovert based on the percentage of extraversion. The final year batch was chosen as sample population based on the most time spent on campus grounds, with lower batches being subjected to remote learning during covid. A person is classified introvert, according to the test if the E score of extraversions is between (1-12). Based on this, three ranges of people are identified namely: Introverts (1-12), Omniverts (12), Extroverts (12-24).

2.3 Stage Three – Identifying the design considerations of potential study spaces inclusive of introverts.

A photo elicitation method to let the introverts choose between different study spaces in the campus to determine correlation between the three aspects of space, personality and comfort. These photographs were analysed alone and with conjecture to the photo elicitation questionnaire.

3. LITERATURE STUDY

3.1 Identifying potential study spaces

Hanan (2013) mentions that learning is a social activity occurring as much outside the classroom as within it. Through the case study of a campus in Indonesia the respective parameters were identified from the conclusions of the above-mentioned literature reference - Visual access; Proximity to classrooms; Anthropometry (back support); and Greenery. In research from Wang (2020) Chinese university campuses were taken as templates and observation of out-of-class spaces on selected university campus was done. The data was assessed and analyzed by interviewing and questionnaires. The identified parameters are - Seating type and arrangement; Enclosure/ privacy; Sunlight/ lighting; and Wi-Fi.

3.2 Identifying personality types

Sinurat (2018) points out the distinctiveness of the learning style between students who are introverted and those, who are extroverted. Introvert students prefer to study alone while the extroverts prefer to participate and study in groups. The researcher uses the Eysenck Personality Inventory (EPI) by Hans Eysenck to understand the students' personality traits, whether they are introvert and/or extrovert and their percentage of extroversion. The test is a standard test devised by psychologists Hans Jürgen Eysenck and Sybil B. G. Eysenck. Each question features a binary response 'yes' or 'no'.

3.3 Correlating behavioural patterns to personality

In a study to test if personality influenced participants' lighting preferences (Heydarian, Pantazis, Wang, Gerber, & Becerik-Gerber, 2017), findings were that extraverts prefer having high levels of light (either electric light and/or simulated daylight). As people score higher on the extraverted scale, they are significantly more likely to choose to have all the shades open.

3.4 Quality of built environment and their relation human comfort.

Shin (2015) emphasizes on the role of the human agency to strive towards achieving an optimal condition of satisfaction and comfort in any given environment. Human actors within the setting optimize their relationship to the given environment through environmental modification, behavioral adaptation, normative adaptation, and withdrawal and such optimization processes are continuously modified by the goals and purposes of their actions in relation to the socio-physical environment in which those actions occur. Design practitioners in field can provide necessities and increase the level of user satisfaction by skillfully manipulating the physical structure of a given place. The goal is to empower the building users by providing maximized opportunities for optimizing social and physical dynamics.

4. DATA COLLECTION

4.1 Photo Cataloguing

Potential study spaces were identified based on the derived parameters Visual Access; proximity of classrooms, Anthropometry (Back support); Greenery; Sunlight; Wi-Fi; Seating type; Enclosure/Privacy through photo cataloguing. The 4 main spaces identified are canteen top floor, lightwells, 5 stones and cubes (Figure 1 a, 1 b).

4.2 Personality Test

Out of the sixty students, 36 (60%) were identified to be introverts and the scale of extroversion of each student is also measured.

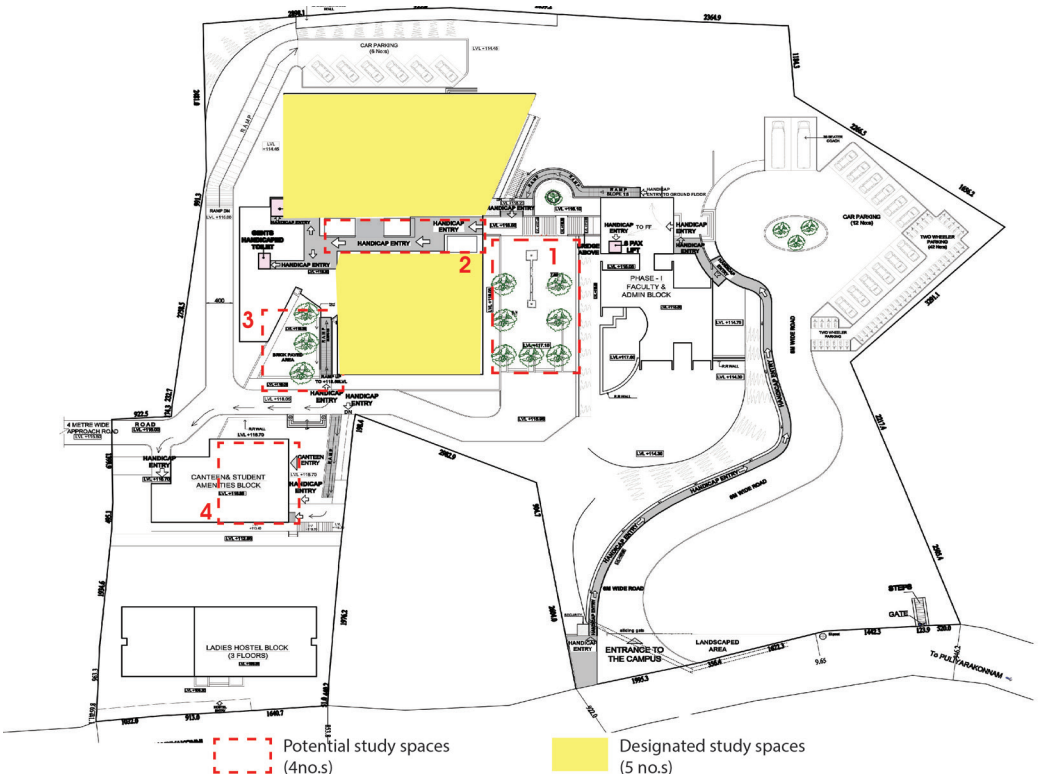
4.3 Photo elicitation questionnaire

This questionnaire consists of two sections, a general section containing questions regarding the narrowed down populations ideal study spaces and its characteristics.

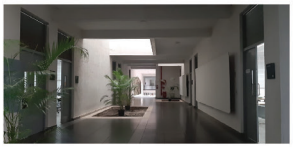
Out of the thirty-six introverted students and their responses on preferred study spaces and their spatial qualities, the main points observed are: 100% prefer spaces with good natural lighting and greenery. 88.9% prefer spaces with privacy or enclosure are the students' choices: 33.3% chose canteen top floor, 27.8% chose lightwell, 22% chose five stones, 16.7% chose cubes.

4.3.1 Top floor of the Canteen –

Chosen by 33.3%, this space is a well-lit, semi enclosed space with views to the academic block, hostel and a distant scenary of mountains (Figure 2). Based on the responses and observations it was




1. 5 stones


2. Lightwells


3. Cubes


4. Canteen top floor

Figure 1: a) Photo cataloguing b) spaces. Source: Author

noticed that both introverts and extroverts use the space differently.

The extroverts tend to gather around near the entrance stairway and overlook the parapet to the more active sides of the campus while the introverts prefer being hidden from the direct view of the entrance and looking at the quieter view of the mountains.

4.3.2 Lightwells –

27.8% chose the lightwell (Figure 3) where Introverts preferred the corner lightwell away from direct view of the circulation in corridors and buffered by a potted plant. Meanwhile the extroverts chose the lightwell with views to the cubes, canteen, and the corridors.

4.3.3 Cubes–

The cubes overlooked by the lightwell, and canteen is an interesting choice taken by only 6.7% of the introverts mainly due to its inactivity in the mornings. Here again as shown in figure 4 (lightwell +cube elevation) a smaller area is opted by the introverts where even when there is activity the cubes near the main paths receive all attention and 'somehow you can be invisible in plain sight' a student mused.

4.3.4 Five stones area –

22.2% chose this 'quiet and calming place' as their potential study space. On observation it was noticed that this space (Figure 5) is rarely visited by extroverts as it doesn't overlook other parts of the campus and the ones who do spend time here, do so in a specific area overlooking the paths and the stairs. While an introvert on the other hand spends time on the lawn space hidden by vegetation, against the intended seating which now acts as a backrest and buffer from direct visual access.

5. INFERENCES

5.1 Broad Overview

Out of the eight parameters identified from the literature references these were the main parameters preferred by the introverts questioned.

5.2 Natural lighting

Lighting is one of the key parameters for an activity like studying. The National lighting code recommends a minimum of three hundred lux lighting in a study space. What seems like a secluded dim-lit introverted space may not be what is preferred by introverts. The resultant data suggests that 100% of the introverts prefers a space with natural lighting. The

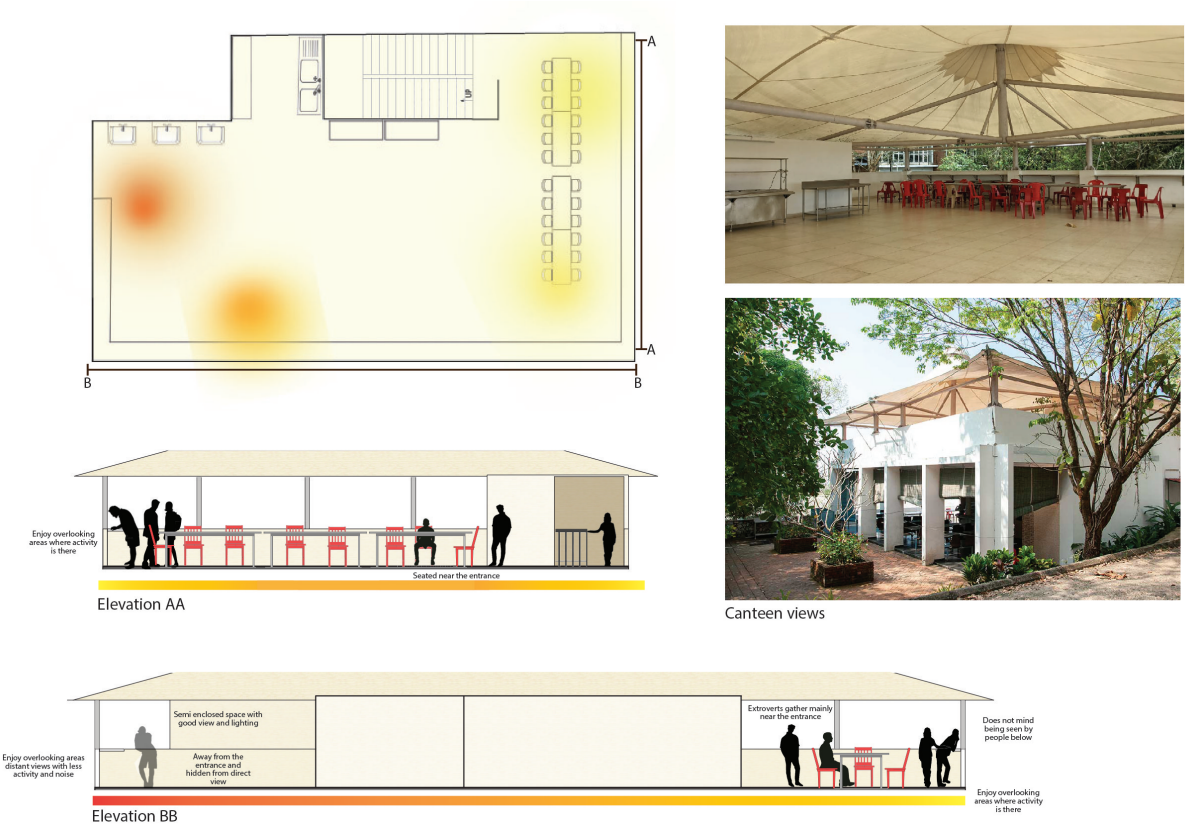


Figure 2: Canteen top floor documentation. Source: Author

Figure 3: Lightwell documentation. Source: Author

top floor of the canteen can be chosen as a prime case study for this parameter. With openings to all sides this space is well lit throughout the day. The low parapet wall and the lean pillars holding the tensile roof structure above offers scenic views to the skyline outside campus.

5.3 Greenery

With various shades and tints of green, the campus environment is elevated to a meaningful location by the form and texture of different plants and trees. 100% respondents prefer a study space with frondescence present. 22.2% people chose the five stones space due to the greenery present or the shade or privacy provided by the plants. These plants do not just add to the aesthetics and calming environment, leafy shrubs can function as a visual buffer providing privacy. Taller plants and trees can be used as a shield from the sun as well as prying eyes from the upper floors. Lawn spaces can double over as noise absorbers while providing comfortable seating in these gardens of zen.

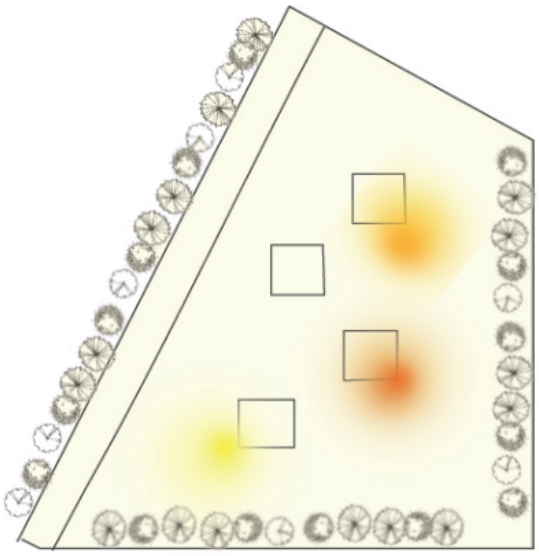


Figure 4: Cubes plan color graded. Source: Author

5.4 Seen and unseen

When asked about privacy 80% preferred a private or enclosed space but a good percentage also preferred spaces with visual access. The cubes area can be taken as an example to explain about the seen and unseen factors an introvert prefers. It is a space that is not too open and wide that it is exposed but at the same time there is a level of privacy but the dominant factor that would attract introverts here is not the perception of privacy it is the visual access to both the academic block, canteen, and the path between them. Such spaces enable them to prepare themselves for a social encounter and gives them a sense of control or territory over the space.

Another interesting finding is that while both the canteen top floor and the lightwells, offer a vantage point of the action below, in the case of the canteen, as one is equally exposed to the users below an introvert would rather choose to view the distant scenery away from the bustling activity on the other

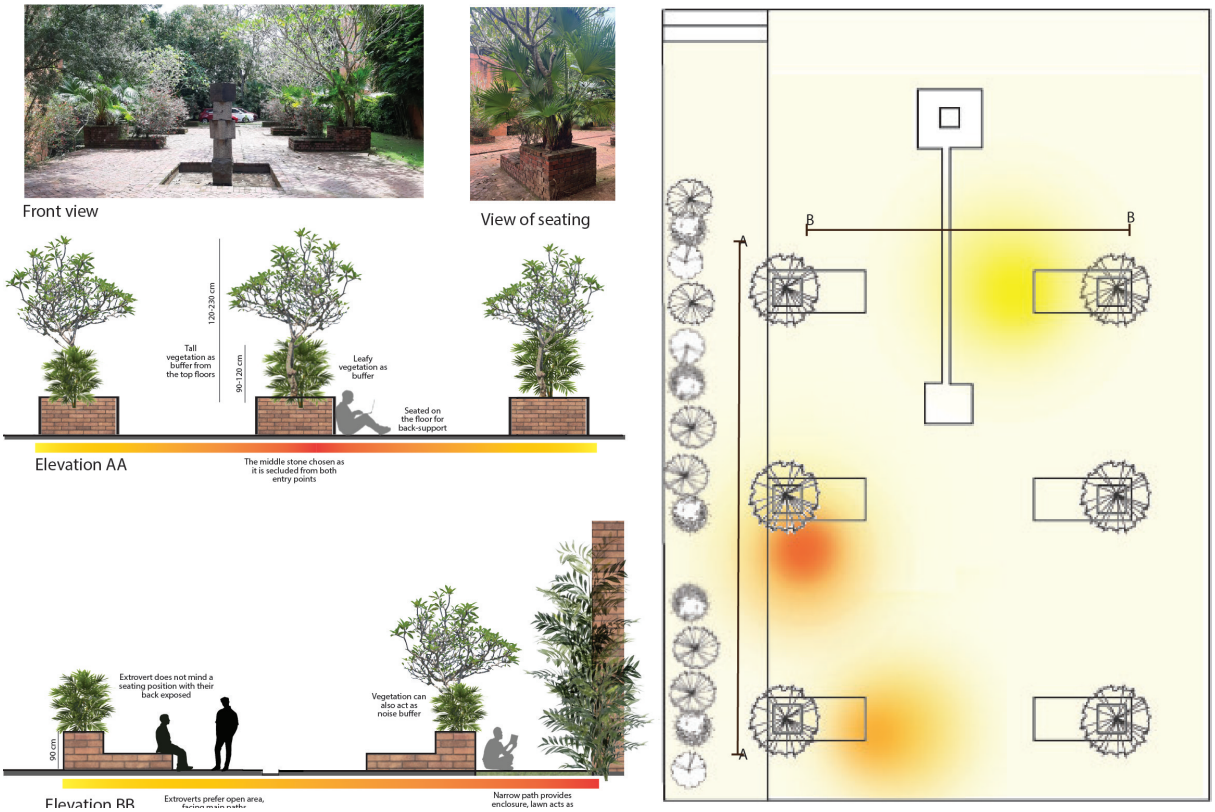


Figure 5: 5 stones documentation. Source: Author

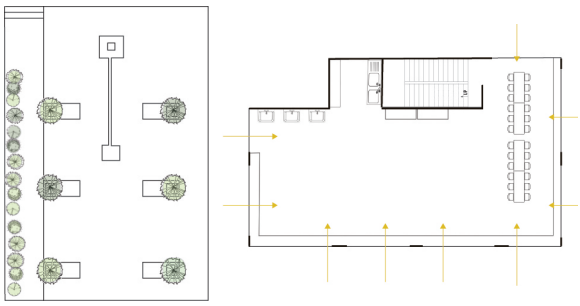


Figure 6: a) Greenery in five stones b) Lighting in canteen. Source: Author

side. The lightwells, on the other hand has a voyeuristic character which does not reveal the user above directly to a person sitting below – which an introvert prefers.

5.4 Seating

Any space that has the potential to be a seating space has the potential to be a hide out. The study shows that a conventional seating space or furniture is not necessary for a space to be used for studying.

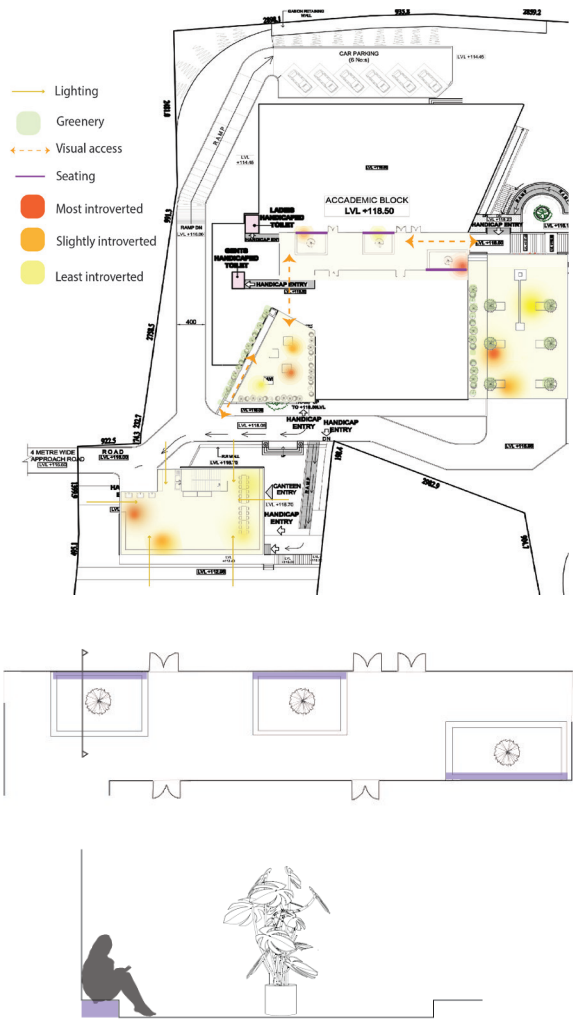


Figure 7: a) Visual access from cubes, b) Seating in lightwells. Source: Author

Students are at ease sitting on the edge of a space with something behind them. Anchor points for sitting include free-standing columns, walls, and trees. Spaces like the lightwell where one can lean against the wall and have visual access to the corridor is thus a natural choice of comfortable seating space. The wall and floor material also factors into the comfort of seating in these edges like how the lawn space in 5 stones coupled with the seating behind acts as the perfect floor seating.

5.5 Comparison matrix

A comparative analysis was done with the identified spaces, the main parameters and the specific locations chosen based on sub parameters (Table 1).

Table 1: Comparison matrix. Source: Author

Space	Main Parameter	Location	Sub Parameters
Canteen	Natural Lighting	Corner	Privacy
		On Furniture	Back support
		Adjacent to a wall	Scenic view
		Close to entrance	Proximity to classroom
Light-well	Seating	Adjacent to a wall	Back support
		Adjacent to a plant	Privacy
		Corner	Away from noise
		Close to entrance	Visual access
Five stones	Greenery	Built element	Back support
		Adjacent to a plant	Shade, privacy
		Close to entrance	Proximity to classroom
Cubes	Visual Access	Close to entrance	Visual access
		Built element	Back support
		Corner	Privacy

5.6 DESIGN STRATEGIES

Based on the literature and case study, combined with user opinion, spatial design strategies that can be implemented to create introvert inclusive study spaces in campus environments are:

- Incorporating properly functioning courtyards or lightwells or semi open spaces with openings to all sides, which remain as a light and ventilation source throughout the day.
- Creating voyeuristic spaces where one can see but remain unseen through play of heights, using

vegetation as buffer or providing such spaces in corners or areas away from the direct line of sight between two places or a path.

- Integrate greenery into design and add a variety of plant buffers which can function as visual barriers, shade, noise buffer or just a calm soothing environment.
- Comfortable seating should be provided in combination with a visual access to the surroundings. Seating need not be furniture or intended spaces as shown in the study and can be a comfortable step, a ledge or against a column for back support is adequate. The orientation of the seating can also be arranged to divide up larger, more open public spaces into smaller, shielded areas that provide solitude and shelter. Students can be in these more intimate spaces and feel socially protected without sacrificing their sense belonging to the larger group.
- These spaces should be embedded across various parts of the campus as proximity to classrooms is a parameter with moderate preference response due to factors like noise or accessibility.
- Providing Wi-Fi routers and charging ports beside these suggested spaces to attract more students who prefer studying with electronic devices in.

6. INTROVERT-INCLUSIVE STUDY SPACES

One of the most pioneering ideas that results from personality research offers the idea that individuals often choose certain situations in order to fulfil certain internal needs and desires (Murray, 1938; Snyder, 1983). So, when a particular personality type is idealised by society, the other individuals are robbed of the choice and excluded from the world created to cater to only a percentage of the population's needs.

An active and healthy campus is one that facilitates improved opportunities in built and social environments to enable students of all personalities to be inclusive in campus within their comfort zones.

For the main spaces, like classrooms, campus design factors like occupant comfort, lighting or productivity are thoroughly researched. However, it is also crucial to examine ancillary areas in terms of comfort or personality preferences. Through relevant literature references the study identified a standard personality test to narrow down the sample population and found eight main parameters to recognize the four potential study spaces with which a photo elicitation interview was conducted. The results showed why the chosen spaces were important to the respondents and what additional parameters could turn these potential study spaces into spaces of retreat for these forgotten users – the introverts. From the data collected a spatial mapping and color grading was done to narrow down the specific locations in each of these spaces and the sub parameters with which these spots were chosen.

Overlaying the layers of literature study, user opinion, and the observational study of the spaces led to the formation of results which can be applied to campus planning and design through integrating spaces with the main parameters like lighting, greenery, visual access and privacy, seating etc., These considerations may be able to manifest a more inclusive campus environment that can finally help bring the introverts into the loop. These results are helpful for more than just understanding how people differ from one another in their behavioral patterns. These and other studies can serve as the foundation for a typology of spaces, which should be followed by field research to determine how these types are distributed in actual campus settings. Furthermore, these findings represent a critical step in understanding the influence that inclusive settings can have on students' academic, social, and emotional wellbeing during these developmental years of life.

Regardless of where a student falls on the introversion/extroversion spectrum, by using this method and carefully stacking the different design

Figure 8: Features that invites an introvert and or an extrovert in C.A.T campus Source: Author

considerations present in the public and private areas on a campus, we may encourage the development of a positive social identity and a sense of belonging.

Finally, our work should inspire the creation of personality-diverse, inclusive campus designs that provide a wide range of indoor and outdoor areas that help connect, engage, retreat, or unwind — resulting in a new sort of environment that celebrates both introverts and extroverts alike.

7. SCOPE FOR FURTHER RESEARCH

The data sample presented here is subject to several limitations. First, the study is based on a single campus, affiliated to one university and it should be generalised by having sample surveys taken from student introverts of several institutions. Data collected from a larger sampling size can offer more depth or add more legibility to the findings. Secondly, the sampling currently has been taken from a single batch's perspective based off their five years at college, it should rather cover all batches in order to have a general view of the campus potential study spaces and the way introverts can connect. Lastly, there may be differences in cultural perspectives based on the geographic context. Also, different institutions can be studied to offer a wider insight into identifying design strategies for inclusive campus planning.

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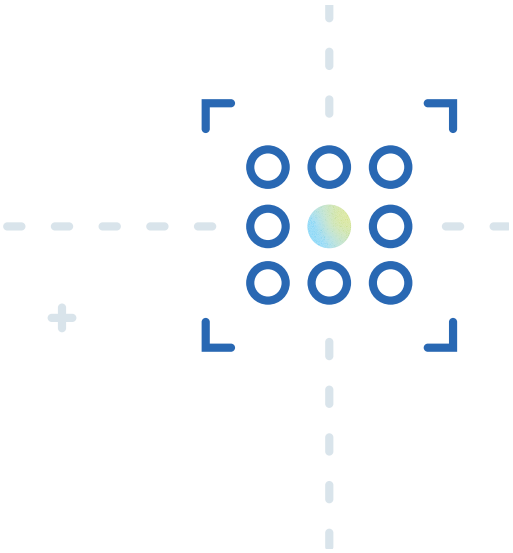

THEME 03:

Conservation & Documentation of Built Heritage

Built heritage embodies traditional and vernacular architectural practices of a region. Traditional architecture is a highly refined combination of codified building crafts. On the other hand, vernacular building methods and materials are rooted in deep understanding of geography, climate, social structure and resource optimization. For the same reason, often, they are the best examples of inherent building performance.

There is a need to record, disseminate and revive the potential of such knowledge systems. The convention aims to throw light on such dimensions of built heritage.

Theme Chairs

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Dr Sanghamitra Basu, a retired Professor from the Department of Architecture & Regional Planning, IIT Kharagpur, is an Architect (B Arch (Hons.JU, Kolkata), Urban Planner (SPA, New Delhi) and Masters in Conservation Studies (IAAS, York, UK. Recipient of DANIDA fellowship and Charles Wallace Fellowship.

She has over 38 years of experience in teaching, research guidance and consultancy projects in the fields of settlement planning, heritage studies and participatory planning, preservation of historic areas, quality of life, housing and neighbour-hood planning

She is currently the Architect Member of Heritage Conservation Committee, Kolkata Municipal Corporation, and is also serving as an advisory member for the Scientific Council of ICOMOS India.

Prof (Dr.) M Kailasa Rao

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Prof (Dr.) M Kailasa Rao is a Professor & Dean, School of Planning and Architecture, Vijayawada with expertise in Architecture and Heritage Conservation. He is also the Director of 'Kailasa Rao Associates', architecture and heritage management consultants.

He is an expert on diagnostic techniques in evaluating traditional Indian built environment using state-of-art technology for his exploration. His expertise includes the use of LiDAR, Infrared, and Drone platforms for digital documentation and 3D mapping from small relics to large cities with great level of accuracy and precision.

He was the recipient of Dr T M A Pai endowment Chair for Architectural Conservation 2013-14 for documentation of Kalyani Chalukya Temples, Karnataka, India. He has also received Research Grant from Archaeological Survey of India (ASI) on numerous heritage conservation projects including Sannathi Stupa, Chaturmukha Basadi - Gerusoppa, Mirjan Fort etc.

Dr. Rao's PhD from Manipal University revolved around 'Architectural Pedagogy from the Examples of Traditional Indian Temple- from Form Generation Concepts to Completion.'

He holds various positions as Member of the National Monuments Authority (2022), member of Academic Senate of SPA, Vijayawada, and INTACH Convenor.

Rural Built Form

An Approach to Occupation Based Rural Housing in Andhra Pradesh, India

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ABSTRACT: Architectural theory and history have traditionally been preoccupied mainly with the study of monuments. They have emphasized and fascinated with the work of men of genius, the unusual and the rare (Rapoport, 1969). Research and studies of the built environment, more so rural settlements, where people lived in multitude over time, have not received the due attention. Occupation is one of the important factors which influences the built form and there are not many studies from India focusing on addressing the issue from a perspective that is specific on occupation. The research aims to envisage the provision of occupationally driven housing for better living for rural households in the state of Andhra Pradesh, India. The researcher had adopted descriptive, exploratory and explanatory research methods on the basis of requirement. The results focus on suggesting guidelines for formulating appropriate built form for rural settlements through documenting the rural built form.

KEYWORDS: Rural, Built Form, Housing, Occupation, Design

1. INTRODUCTION

Over the past many decades, anthropologists have been taking a detailed look along with other individuals at the built form in rural regions, particularly the houses that are being constructed and those that are already in existence, which are occupied by people (Vwa, 2013). There are varied questions that emerge from this observation. Questions such as; why is there a variation in the built environment? What is the manner of variations and what are the factors that influence built forms? (Zagroba, 2017) Practitioners of design, including landscapers, planners as well as architects have been equally engaged in deliberating such questions along with social and behavioral scientists who are concerned about the interaction of humans with their environment. Nonetheless, a social theory of recent times has been concentrating more on temporal as well as spatial dimensions of human behavior (Savchenko & Borodina, 2017). Such developments emphasize the fact that a review on this topic is very much required.

2. LITERATURE STUDY

Saad (1991) have made an attempt to gain insight into the influence of various factors on the indigenous dwelling forms of three clusters of ethnic groups in the north-eastern part of Nigeria. The factors that accounted for the house forms include physical environment, climate, economy, social organisation, religious beliefs, symbolism, technology, materials and historical circumstance. The ancient values of the culture are depicted from the architectural designs which have been further considered as the identified element in the cultural aspect evolving the homogeneity of culture and architecture across the world of architecture (Bemanian et al., 2010). In the past decades, the human communities have transformed from the primitive form into collective patterns of activities and settlement in the small communities. One of the studies have revealed that the inhabitants have been associated with these communities for longer duration and has been considered this place with memories and meanings (Elshater, 2015).

Jayasudha (2016) opined that culture and climate plays a vital role in Vernacular architecture. This is revealed through the analysis of vernacular architecture of Manapad. Its architecture reflects the sensitivity to its unique culture from the settlement level to an individual built form level. Architecture can be defined as designing of these spaces or built environments that aims to fulfil functions of the users (Charitonidou, 2020). One of the studies has revealed the architectural aspects of Iranian architecture evolving the Islamic culture ruling society (Askarizad, 2017).

Previous studies conducted having significance to the architecture of rural housing in India (Tulsi et al., 1994; Acharya, 1927; Singh, 1957; Mukerji, 1976; Sinha, 1969; Mitra, 1966; Mukerji, 1962 and outside India (Kniffen, 1936; Jordan, 1978, 1966; Robert, 1974; Winberry, 1977; Stone, 1965). These studies have focused on how culture has influenced the built environment with specific to size, shape and detailing including climate sensitivity. The earlier studies on the cultural impact on the architecture of rural housing and how cultural practices and behavior associated with it has been evolved and the occupational aspects and its influence on the built form is completely neglected. Therefore, it is necessary to investigate the occupation on the rural built form.

2.1 Occupation

Built spaces or environment would comprise of definite material components, particularly a base, which enables one to view their boundaries and is looked upon as a whole, caters to functions of humans in terms of habitation, circulation or shelter and is purposely appropriated or built by humans to cater to such functions (Bartuska, 2007).

Elizabeth (2020), merged detailed microdata from the Occupational Employment Statistics survey with establishment founding dates from the Longitudinal Database, which allows us to estimate the occupational and wage distributions of employees by the founding dates of their employing establishments.

Aruna (2018) pleads for concerted action to conserve the tangible heritage of iconic sari weaving clusters in India. Handloom weaving is an ancient and highly skilled craft. Weavers' homes which also function as their artisanal workshops represent a unique typology of dual-purpose vernacular architecture. The author also discussed the significance of this architecture, its close links with the traditional craft of handloom weaving, and the results of a pilot project to safeguard this valuable built heritage in the historical town of Chanderi in India.

Study by Seulki & Lim (2020) aims to understand the mechanisms of occupation and happiness—measured as life satisfaction—considering wage, internal working environment, and external occupational prestige as influencing factors. We will also examine whether these factors have different effects depending on gender.

Tyler (2021) examines the extent to which the monetary returns to college majors are influenced by selective migration and occupational choice across locations in the US. To quantify the role of selection, I develop and estimate an extended Roy model of migration, occupational choice, and earnings where, upon completing their education, individuals choose a location in which to live and an occupation in which to work. Agius & Hussey (2015), Fassier (2016), Harrington (2001), Vikari (2011), Meredith et. al., (2015), Michelle (2016), Pierre (2016), John (2017), Huacheng (2017), Hiram (2020) dealt with health-related studies with respect to occupation and its patterns.

As per the Literature review it is evident that there are various studies and research which dealt with aspects like health, mobility, gender, economics, wage difference, migration etc., with respect to occupation and there is a dearth of studies related to occupation and built form and also specially with respect to rural form at international level and also Indian scenario.

2.2 Research Gap

While previous research has considered culture as a whole, it is deemed that occupation practices are two major constraints that are essential to have an impact on the building forms.

Figure 1: Velnuthala Village and Case Study Areas, Source: Google Earth image (accessed 2018)

In nutshell, the following are the three important aspects leading to this research gap: a) neglected studies on rural housing b) more studies are focused on cultural influence and there was no availability of literature and studies on occupational influence on built form c) failure of design for rural housing and settlements by respective government schemes and agencies.

3. CASE STUDY AREA – VELNUTHALA VILLAGE

Velnuthala is located in Krishna district in the state of Andhra Pradesh with a population of 828 (Census, 2011) with total number of 164 households (figure 1). Velnuthala belongs to the plain agriculture type where maximum number of people are cultivators and the rest opted for working as non-agricultural labour. The built form of the settlement is guided by accurate bend of water body as shown in figure 1.

3.1 House 1: Velnuthala Village

House, Household and Economic character

The house (V1H1) corresponds to case study of first house in Velnuthala village (First Case study village, figure 2). The house is around 80 years old with six members (4 male and 2 female) in the household and is situated in 310.3 Sq mts plot area, with a built-up area of 111.39 Sq Mts. The family cultivates 8 acres of land, where the 4 family members out of six are involved in the activities related to occupation at different intervals of time. The major income is derived from agricultural occupation with annual income of Rs. 5,20,000/- to 6,40,000/- per annum. The increase and decrease in the annual income depend on the rainfall and the effect of natural calamities like cyclones, rainfall, availability of water etc., The other income source is from the dairy products like milk and ghee, which ranges from Rs. 60,000/- to 1,50,000/- per annum. The part of the annual income will be used for the investment on seeds, tools, labor etc., for the next season of cultivation.

Activity space: Household Activity Space (HHAS)

The plot consists of four blocks - main block, kitchen, granary and cattle shed. The main block consists of four rooms, which are used as bed room or multipurpose room and surrounded by verandah on

all the four sides. The verandah is a multiple activity zone, used for temporary storage of grains, agricultural tools and gathering spaces. The other three blocks are the kitchen, granary storage and cattle shed. The house is a kutcha house and has thatched roofing, walls made of mud and timber, flooring made of mud and the doors and windows are made of local wood.

Occupational Activity Space (OAS)

Occupational Activity Space (OAS) is the study of spaces influenced by the activities related to occupation i.e., agriculture as primary occupation, dairy products from cows and buffaloes as the secondary occupation and source of income. The granary storage block in the site is exclusively used for storage of grains and used for the complete year. The bullock carts are used for transportation and ploughing is done by bullock drawn ploughs.

3.2 House space used for both HHAS and OAS different time in a day as well as seasons.

There are spaces which are used for various activities during different intervals of time. The verandah acts as a space for cooking and interaction with family members, friends, relatives and other people during day time and the same space is used for sleeping during the night. The multipurpose room in the main block is used storage of grains, storage of agricultural tools and is converted in to space for eating and sleeping. The rural households have designed spaces with multiple uses, without any compromise in the functional aspects of each and every activity.

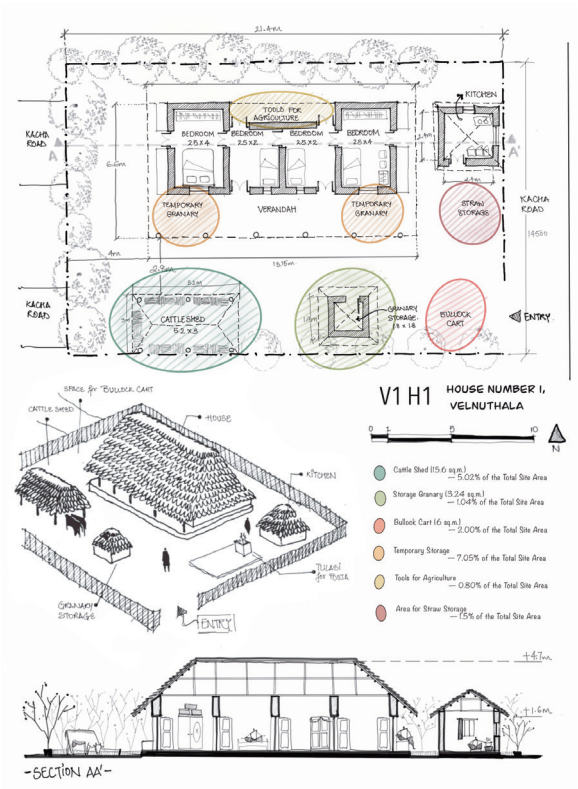

Figure 2: Household Activity Space and Occupational Activity Space of House 1 in Velnuthala, Source: Author

The cattle shed accommodates two bulls and two buffaloes. The bulls are used for transportation and ploughing, whereas the buffaloes supply the food and milk products along with manure and fertilizers. Besides the tools used for agricultural purposes are stored in these cattle sheds, verandahs and rooms. The grains are also stored in verandahs and rooms,

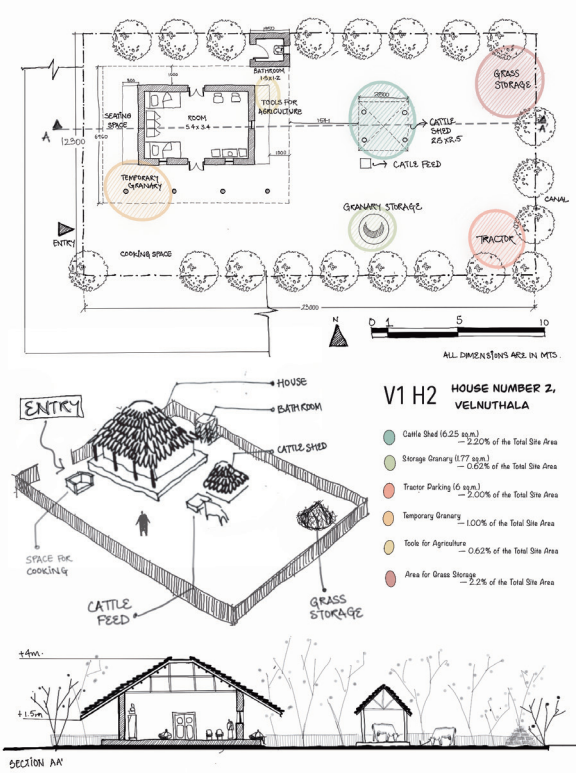

Figure 3: Household Activity Space and Occupational Activity Space of House 2 in Velnuthala, Source: Author

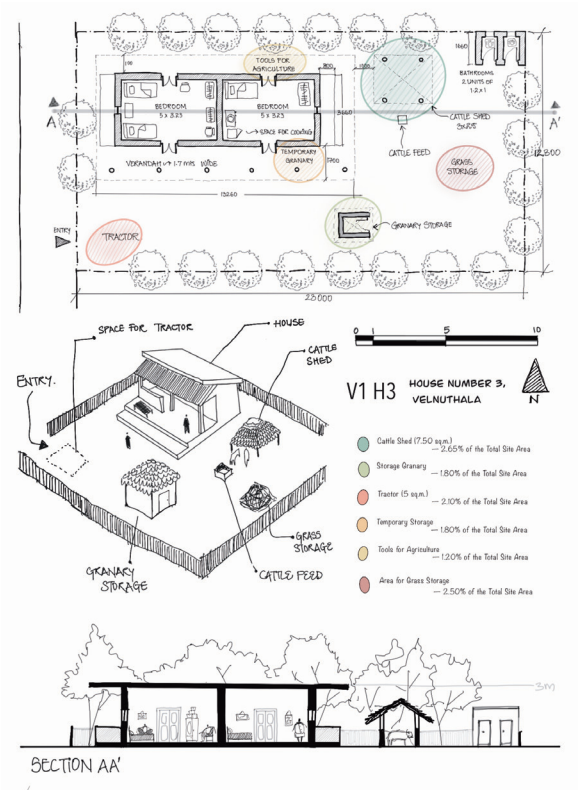

Figure 4: Household Activity Space and Occupational Activity Space of House 3 in Velnuthala, Source: Author

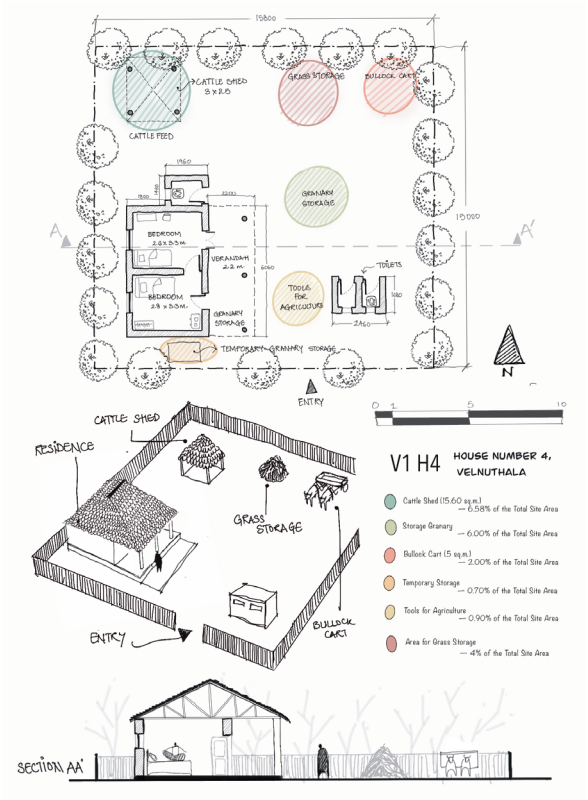

Figure 5: Household Activity space and Occupational Activity Space of House 4 in Velnuthala, Source: Author

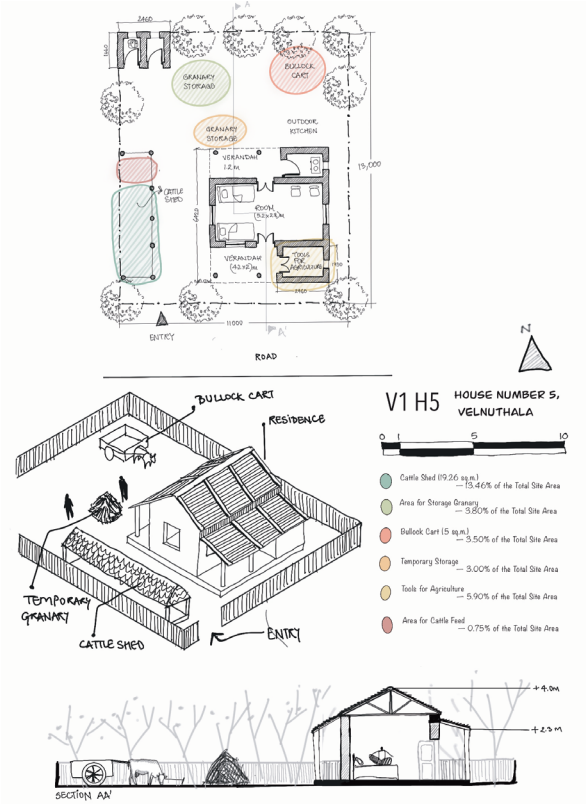

Figure 6: Household Activity Space and Occupational Activity Space of House 5 in Velnuthala, Source: Author

when there is shortage of space in granary blocks or during the season where the grains have to be stored for short intervals of time before selling the grains. As per the survey, it shows that 17.8% of the site area is dedicated for occupational purposes and 10.4% of the built-up area is dedicated for the occupational activities. The figure 1 shows the existing plan as per the survey including the number of blocks, the spaces used exclusively for the occupational purposes at the site level and also shows the spaces used for occupational activity in the main block along with a view and section. Granary storage becomes an important integral part any agricultural house. The major activity related to agriculture is divided between the house and the fields, which are 0.5 Kms away from the house.

3.3 House 2: Velnuthala Village

House, Household and Economic character

3.4 Generic typology of the houses and deviations or variations of house designs in Velnuthala Village

The houses V1H1, V1H2, V1H4 as shown in the figures 2, 3, 5 shows the houses and house forms of almost 80 years old which are vernacular in character with traditional building materials and techniques. The common built form observed in the houses with agriculture as the major occupation is that, the plots are divided in to three to five blocks; the main block, kitchen, granary store, cattle shed and toilet. The space within the site and also main block is also used for the agricultural tools and equipment like bullock carts, tractors, ploughs and other equipment used for cultivation. The granary storage unit forms as a predominant character in all the rural households in this village. The coordination of these blocks for various day to day activities is an interesting pattern in the rural households.

Most of the houses have evolved through ages based on the occupational requirement, whereas the new house which was built with modern materials was a single or double roomed house as shown in figure 3. The main block of the house was the resultant of Indira Awaas Yojana (IAY) scheme. The government has provided only two rooms of RCC. But the people added the additional blocks like cattle shed, granary store, verandah etc., at a later stage to meet various requirements including spaces required for activities related to occupation. The final derivative is like V1H3 (case study of first house in Velnuthala village), where the verandah is extended with asbestos roofing, the cattle shed is added and built with traditional building materials, the granary unit is also added later as per the requirement. The example of the house which was built under IAY scheme doesn't reflect the spatial requirements of an agricultural based household. The common typology of houses observed in this village are V1H1, V1H2 and V1H4 which are evolved based on the needs of the household and occupational space requirements. V1H3 is an example of house in modern context, but converted into the need based requirements of the user (occupation based i.e.,

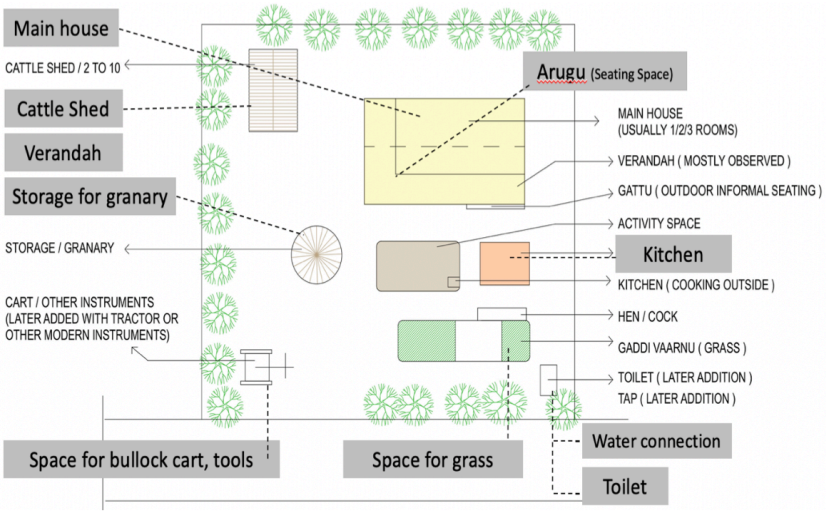

Figure 7: Components of general house typology: occupation – agriculture, Source: Author

agriculture as the occupation). V1H5 as shown in the figure 6 is exclusive house in the village, the house with the same needs and requirements, except the house is made of Mangalore tiled roofing.

4. DISCUSSION AND CONCLUSION

The following are the common components observed and mapped in the village households with agriculture as occupation as shown in figure 7. It shows the spatial arrangement of various activities integrating with day to day activities and its utilitarian profiles, where it is clear to understand the influence of occupation related components in built up area.

a. Main house: Three data sets related to the agricultural land holdings versus number of rooms were identified and arrived among four villages. The first set of households have agricultural land holdings from 1 acre to 30 acres, the second data set of families have leased land holdings, whereas the third data set are the agricultural labor.

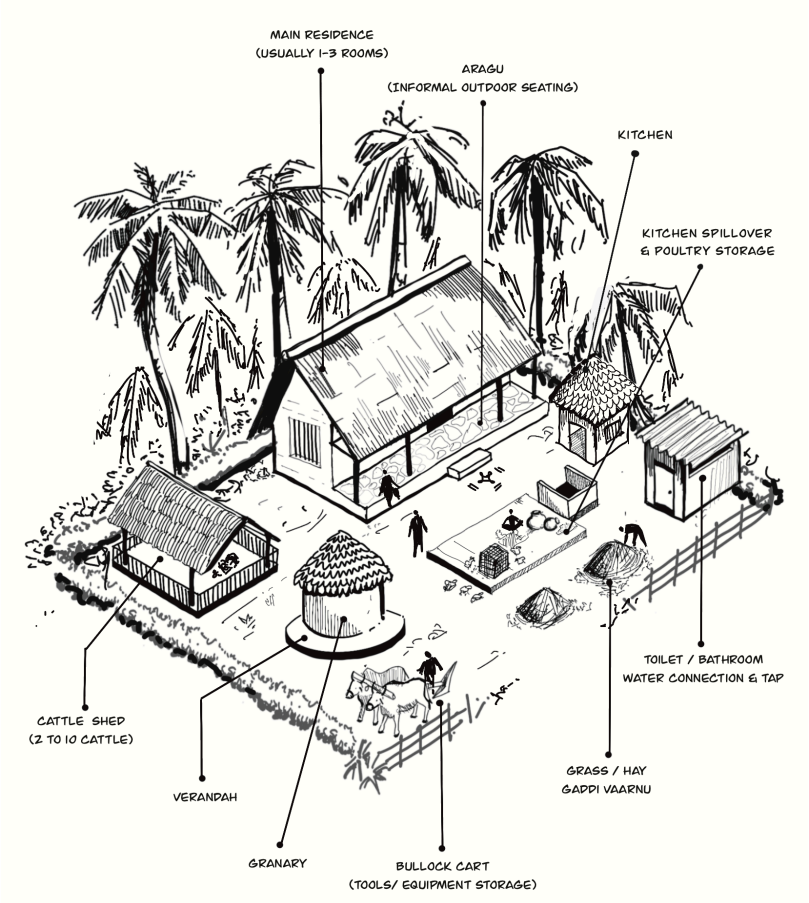

Figure 8: Generic House with occupational pattern as agriculture, Source: Author

As per the study and analysis, it was observed that the economic status of the occupants reflected in number of rooms in main block (house) i.e. one room to four rooms. This main house has other areas like verandah, Pooja space other than the above-mentioned rooms. This is also related to the ownership of land (number of acres owned by a family). The main house also have space for storage at loft, mostly in living areas, where it is easily accessible from living spaces or entry spaces. i.e., the space under the roof. This space is exclusively used for storage of empty grain bags and lighter tools used for agriculture. The same has been elaborated further for understanding occupational influence on built form.

b. Storage for granary: This is a dedicated space, where grains are stored either to sell at regular intervals or to store the required grains for the family. It is also observed that there is a barter system existing in villages Velnuthala and Mukkollupadu The granary storage units are either circular or cube or cuboid in form.

c. Verandah: As per case studies it was observed verandah was part of all houses. The verandah is usually in the front part of the house and in four houses of total 20 cases, it was observed that another verandah exists in the rear side of the main building. Verandah is a semi open space where OAS like storage of grains and tools for agriculture , display for grains were observed. It was also observed that the same space is used for HHAS like sleeping, cooking and other informal activities.

d. Cattle Shed: This is a thatched semi open structure, where cattle are placed. The number of cattle owned by a family depends on the ownership of lands and economic status of the family. This space accommodates cattle along with necessary vessels for their food. The fodder for the cattle are also stored in the cattle shed.

e. Space for bullock cart, tools: It has been observed from the data sets that the bullock carts, plough and other tools required for agricultural farming are placed in open space usually in the front yard of the house. The size is again proportionate to number of acres owned or leased by a family. This space is slowly replaced for parking of tractors and other advanced tools required for farming.

f. Kitchen: There is an enclosed room, which is not directly connected to the main house. The cooking happens in two places, one is in the inner enclosed room/space and they also have an outdoor/open space in front of the kitchen, where major cooking happens. Enclosed kitchen is only used during rainy season. This space acts as an interaction space, which connects the main house and kitchen. The complete family can be visible from this space.

g. Hay Stack (Gaddi Vamu is the local term in Telugu language): As per the study it has been observed that hay is stacked in open spaces. Hay is used as feed for the cattle, for making ropes for tying granary, hay and bullock carts. The hay is also used as roof covering for thatched houses ranging up to 38% in Velnuthala, Mukkollupadu and Bodiguda villages. The space becomes empty by the end of the season.

h. Toilet: It was observed that toilet was a later addition in the site. The toilet is usually built at rear side of the house and is always detached to the main house. The size of the spaces varies depending on the size of the family, number of acres owned or leased by a family.

i. Time and space: The activity starts at 4.00 am with feeding the cattle, preparation of feed for cattle and necessary arrangements to go to field. The housewife and members of the family becomes part of the early morning activities either in the kitchen or verandah.

Figure 8 indicates the generic house pattern observed with agriculture as main occupation and the spaces required for occupational spaces and other house hold activities. This will act as an indicator for basic spatial requirements necessary for agricultural based households and way forward for the design process

The specific design requirements of each occupation, however, differ from one occupation to other. The study, therefore, also attempted to develop guidelines to be followed in providing occupation-specific housing facility to the selected occupations which will pave the way to draw the attention of architects and planners for specific needs of the communities from the perspective of their occupation.

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A Comparative Analysis of Built Forms and Materials Used in Toda and Kota Settlements in South India

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ABSTRACT: Traditional built form plays a major role in achieving higher human comfort by using available local bio resources as building materials. The method of construction techniques is another important aspect which helps the built form to be more responsive to the climatic conditions. The traditional built form structures are the identity of tribal community that enhances the quality of living without affecting the environment and satisfy the people needs. Hence this makes the humans to survive with ease in the different environments. This study focuses on the comparative analysis of built form of tribal settlements of chosen ethnic communities of TODA and KOTA settlement in the region of Nilgiri Biosphere Reserve, Tamil Nadu. The objective of the study is to explore the difference between the housing-built forms and its cultural influence. The study helps to document the available bio resource materials and skillful techniques of construction involved. The systematic study analyses the building components of wall, flooring and roofing structure and structural stability to cope up with the prevailing climatic conditions. The outcome of the thesis study helps to get a complete knowledge of the cultural influence along with the sustainable material & technology involved in the construction process.

KEYWORDS: Bamboos, Plant resources, constructions methods, barrel vaults, Todas, Kotas

1. INTRODUCTION

Shelter or house has always been the basic need of humankind. In the olden days, the nomads were residing inside dense forest area and their inhabitance depended upon the available natural resources for shelter, food and water, where they have been protected from the worst climatic and weather conditions (A.John De Britto et al, 2015). Over the decades, mankind has carved out nature and reorganized its needs and requirements. Thus, the primitive architecture of the built forms or the structure had a very high-level of performance responding to local climatic conditions and remarkable understanding of available local building material used with detailed knowledge (James Marston Fitch & Dainel P. Branch, 1960). Houses and its built form have determinants involving location, climate, material, construction technology and strong connection with socio-cultural & economic aspects (Amos Rapoport, 1969). The term vernacular Architecture is the “Native Science of Building” (Paul Oliver, 2006), presumably influenced by human behavior and environment. This architecture is environmentally responsive and culturally expressive. The identified tribal settlements in Nilgris district - Todas and Kotas possess a rich tradition of ecological knowledge providing a vital connection to establish a habitual harmony between people, climate and built form. The documentation of these two settlements is done in order to present differences between the housing-built forms and how it is affected by their cultural influences. Tribal communities of Toda and Kota in Nilgiris district represent the vernacular architecture of sub-tropical highland climate. Each case study was carried out in two different locations under same climatic conditions. The study focuses on the settlement and houses of these tribal communities and analysis have been done on their built form parameters.

The study explored the comparison of both tribal communities about the influencing factors of built form in settlement planning as well as inhabitants. The study helps to understand the available Bio-resource materials and skill full techniques of construction involved. The systematic study analyses the building components of wall, flooring and roofing structure and structural stability to cope with the prevailing climatic conditions.

2. METHODOLOGY

The ethnographic, architectural findings and the related visuals used in this article are based on fieldwork conducted in two different settlements in the Nilgiris district of Tamil Nadu state. Collection of ethnographic and architectural data was done by participating and observing the daily activities of the selected tribes, interviews and conversations, photography, measured drawings (on-site), sketches and other forms of visual notes. Two intermediate persons helped and provided the information and assistance in understanding the history and culture of the selected tribes.

3. STUDY AREA

Nilgiris District located on the western side of Tamil Nadu state has an altitude ranges between 900m and 2636m MSL. Summer seasons are pleasant with temperature ranging from 10°C to 25°C and during winter temperature ranges from 5°C to 21°C. The Nilgiris has a huge forest cover that influences the natural environmental conditions of the region and it belongs to the biodiversity hotspot of Western Ghats and Sri Lanka (IUCN 2021). The dynamic seasonal changes bring out pleasant weather conditions in different versions of the place which is appreciated by tourists throughout the year. The entire region has steep topography which makes it high altitudinal orogenesis. The major soil types are sandy loam, red loamy soil and black soil can be seen in the river bed areas. The area is prone to landslides and soil erosion due to heavy rain (Saurabh kumar Mishra et.al,2020).

4. SOCIO CULTURAL FACTORS OF TRIBAL COMMUNITY

4.1. Toda settlement

Todas are a small group of people belonging to primitive tribes in Nilgiris District. The Toda are the least populated pastoral group inhabiting who have the tradition of a polyandrous marriage system. The settlement consisted of six to seven huts to form an irregular cluster patterns, along with the cattle shed for the sacred animal buffalo nearby. The open pockets between the houses serve as a venue for Toda's social and cultural expressions. It has been used for interaction, daily activities, Performing arts, rituals and other cultural activities such as marriage, death ceremonies and festivals etc. Todas maintained the sanctity of the temple by placing the stone (called an obstacle stone) near the temple where women are forbidden or prohibited to go beyond that. Evidently, one hut has been retained in the (Manjakal mund) village. Each hut is surrounded by loosely packed stones in a circular form. The entrance is a very small exceptional means of protection from wild animals. The Toda hut is basically rectangular in plan of size 5.5m in length x 2.7m wide & a pent-shaped oval in form of height of 3m. The entry to the house is through a square opening size of 0.9m wide x 0.9m height as it reflects their religious culture of lowering the torso and head in front of the god. No other openings were found in the hut. On each side of the doorway is a raised platform, equivalent to a veranda or thinnai (built–in seat), a semi-private area that served as a gathering place for men and women and enhances the interaction between them. The front facade of the hut wall is covered with stone and it depicted their religious symbol "buffalo horn". The entire structure is elevated 0.3m from the ground level. In traditional huts, the material and construction of the Toda houses of bamboo fastened with rattan and straw. The front and rear of the cottage are usually

Figure 1:Traditional huts of Toda community. Source: Author

made of dressed stones (mostly granite). Thick bamboo sticks curved to form a barrel vault structure. Thin bamboo sticks are tied closely and parallel to each other at the top of this frame. Half- cylindrical barrel vault shaped structure is constructed of wooden planks, bamboo, reeds and grass. Either end is walled by planks set vertically placed. The dried grass or is stacked over the frame as a roof covering.

4.2.Kota settlement

Kotas are musicians and excellent craftsmen having mastery over iron working. Traditionally, their distribution in the Nilgiri District is confined to seven villages.

Each village has three Keri (rows of houses) known as Kizhkeri, Nadukeri and Melkeri. Members living in the same Keri are considered a brotherly clan and hence no marriages are permissible. Keri exogamy is noteworthy among the Kotas. They have elaborate ritual practices of their own. Kotas worship their family deities (Rajan and Sethuraman, 1991). In each Keri (street),5-6 houses were arranged in a linear pattern, with open space in the front yard. The open space is mainly provided for occupational activities such as carpentry & pottery work, interaction, children's play and all other ceremonial activities. An old-fashioned Kota house called 'pai' was traditionally thatched huts. The existing Kota houses were built 100- 150 years

Figure 2: Traditional huts of Kota community. Source: Author.

ago, characterized by the linear arrangement of houses with slope roofs and covered raised platforms for interaction and sleeping. The spaces were divided by central axis opening which leads the entrance to the rear end. The housing layout consists of a front room, containing a raised platform on the left for sitting and sleeping and a hole in the floor for pounding.

A kitchen is located to the right of the front room and contains a wood stove along the wall opposite the arched entrance, and a back room for bathing. Each room and parts of each room have particular names and functions. The walls have special crevices for oil lamps and wood.

Other articles are often stored in rafters above the kitchen. In the past Kota's had no toilets and special huts were built for women to stay in while menstruating. Some of the newly built houses represent remodeled houses of the older type. The material which is used for the construction is mud and

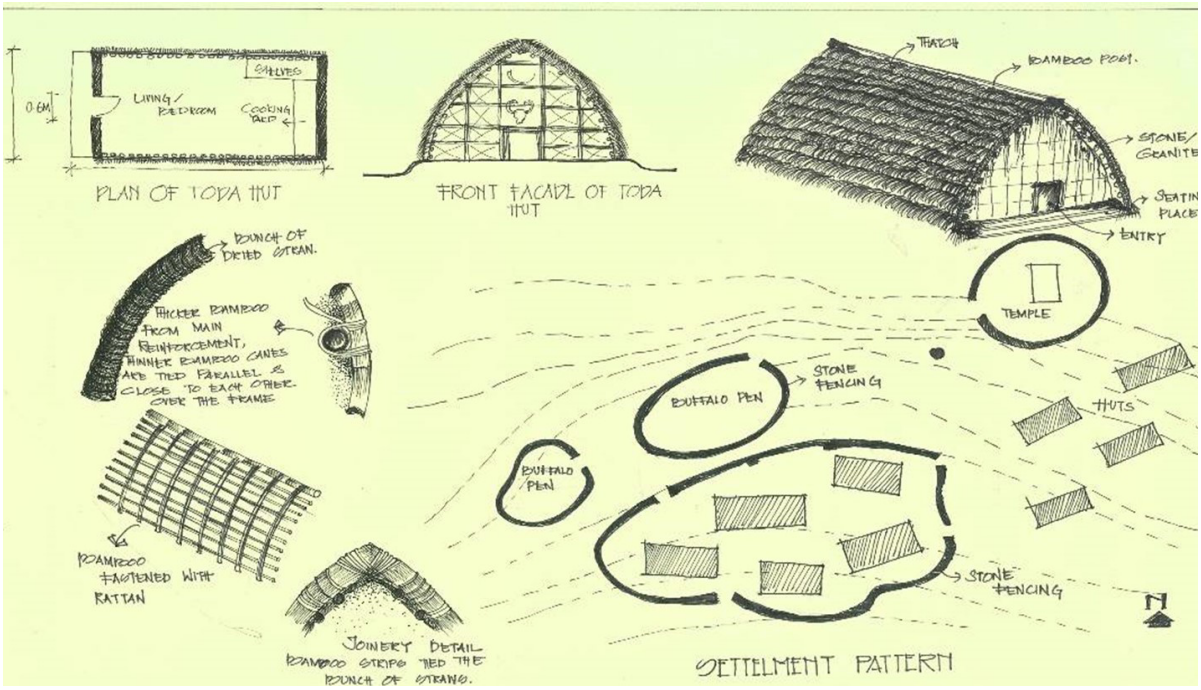

Figure 3: Settlement plan and typical layout with construction details of Toda settlement at Manjakal. Source: Author

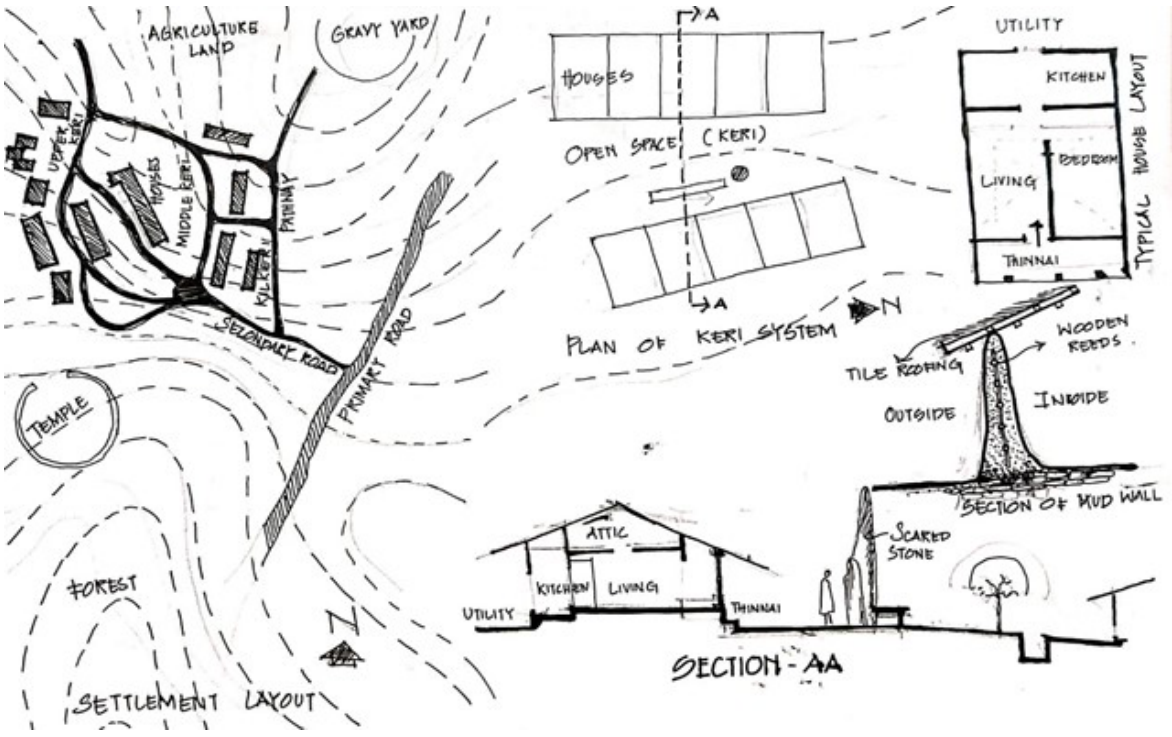

Figure 4: Settlement plan and typical layout with construction details of Kota settlement at Sholur. Source: Author

Table 1: Comparison between the influence of socio-cultural aspects of Toda and Kota Tribal communities. Source: Author

Strategies	Characteristics		Socio cultural influence	
	Toda	Kota	Toda	Kota
Geography & location	Manjalkal mund	Sholur Kokkal	Originated in the Nilgiris district. Toda community spreading nearly 60 villages (munds) located in the various parts of the Nilgiris district.	Originated in the Nilgiris district. These communities are confined to seven villages in Nilgiris district.
Settlement pattern	6-7 huts scattered with open pockets.	7-10 houses arranged in linear pattern having sharing walls.	Polyandrous marriage system with sparse population.	The single lane of houses arranged in a linear pattern belongs to a clan.
Street pattern	No street-cluster of open spaces	3 types- Upper/middle/ lower Keri	The hierarchy of open spaces found in the settlement are utilized for social interaction and other day to day activities and religious gathering.	Classification of people clans based on the street system (upper/ middle/ lower Keris) which is reflected in the topography of the settlement. The streets (Keri) will act as open space and separate open space is provided to perform rituals.
Orientation of the built form	East west direction	East west direction	The temple is isolated and oriented towards E-W axis with the entrance facing towards the west. So all the houses were facing towards the temple entrance (i.e.) east direction.	The temple isolated from the settlement and the linearly arranged houses are oriented towards E-W directions.
Spatial analysis	Single / multipurp ose	Private/ open & semi private different purposes.	The plan of the hut is rectangular in the shape of about 5.5m X 2.7m It possesses all the spaces for activities like cooking and sleeping, together in a single space. It has a separate storage and fireplace inside the hut. All other activities are performed outside the hut. Window openings are less opening and the only source of access to the built form is through an entry of size 0.9M x0.9M	Traditional Kota hut is a rectangular space accommodating veranda space as buffer between living and open space. Then it leads to a kitchen and a utility space in the back yard. The bedroom is located adjacent to the living area. It has a separate attic space for storage at the lintel level. The secondary opening to the veranda is of size 0.6MX0.6M. There is visual connection between the entrance and the back yard entry
Built form	Half barrel vault	Pitched roof	It takes the simple barrel vault roof along the rectangular shape taken from the ground level which is unique to Toda community.	As the houses arranged in a linear pattern it forms the common pitched roof for a single clan. This shows the reflection of the unity of the clan
Scared space / scared element	Reflection of scared animal of buffalo horns in the entrance of the houses	No symbolism at exterior/ scared stone placed in the upper Keri	Toda life revolves around their cattle since dairy farming and dairy products are their only source of livelihood. The main source of income is based on the dairy products of Buffalo. So the people worship buffalo as God and believe that it is a sacred animal. The houses and the temple reflect the buffalo horns engraved on the front facade	Inside the home there is a small Niche for lighting
Walls	Thicker wall made up of bamboo	Thicker mud walls constructed with wooden reeds as reinforcement	The extensive use of locally available natural material bamboo as walls and rear sides are covered with stone slabs and mud flooring. It is the self-supported structure by its unique form. The abundant resource of mud in the local region is used for wall construction. Internally the local timber is supported as the structural member. Locally available regional materials are bamboo, straw, grass, mud, stones etc.	
Floors	Mud flooring	Mud flooring		
Material	Bamboo & canes	Mud / reinforces with wooden reeds		

Table 2: showing the comparison between the influence of Climatic conditions of Toda and Kota Tribal communities. Source: Author

Strategies	Characteristics		Climatic influence	
	Toda	Kota	Toda	Kota
Geography & location	Manjalkal mund	Sholur Kokkal	Both the settlement falls under the same climatic zone, the subtropical to temperate experiencing cool weather throughout the year.	
Settlement pattern	6-7 huts scattered with open pockets.	7-10 houses arranged in linear pattern having sharing walls.	The arrangement of houses forms a cluster pattern that ensures compact planning which restricts the cold breeze and prevents heat loss during the day and night time.	The houses are arranged in a linear form sharing a common wall is called a row house. This concept of planning also ensures the protection of heat loss and doesn't allow cool air inside the house.
Street pattern	No street-cluster of open spaces.	3 types- Upper/ middle/lower Keri	Lack of mutual shading. There are no defined street patterns instead open pockets lead the path way for movement around the settlement.	The open space is exposed to sun radiation which absorbs more heat and naturally forms a solarium space. It allows the maximum heat radiation to absorb and radiate during the night time which keeps the occupant warm.
Orientation of the built form	East west direction	East west direction	The orientation of the built form enhances the maximum of Solar radiation & allows the absorption of heat, which makes the occupant comfortable thorough out the day.	
Spatial analysis	Single / multipurpose	Private/ open & semi private different purposes.	There is no hierarchy of spaces found as it serves as multipurpose spaces exposed to the sun light directly. Since the entry is the only opening that receives the lighting during the day time. The occupant experiences the low lighting inside the hut due to the absence of opening	There is a hierarchy of spaces that serves different purposes. Due to the hierarchy, the house receives indirect lighting.
Built form	Half barrel vault	Pitched roof	The barrel vault helps to increase the speed of the cold winds quickly as the surface is smooth. Barrel Vault roofs and absorbs more solar radiation during the day and dissipates the heat during the night. The roof form helps to drain the rainwater. This would be the appropriate form for this climatic condition.	The pitched roof is very common but highlights that it connects more than 7-10 houses on a single roof. It makes the rainwater to quickly drain off. They form such a way that allows solar penetration inside the buildings in the front and backyard and provides a warmer space for all kinds of household activities during sunny winter days.
Walls	Thicker wall made up of bamboo	Thicker mud walls constructed with wooden reeds as reinforced structure.	The walls were constructed with lightweight structures and the thickness of the Bamboo wall is around 0.3metres and the stone wall is around 0.45metres which has a high thermal mass that stores heat during the day and is radiated at night.	The walls were constructed with mud reinforced with wooden reeds of thickness around 0.45metres as sharing walls of all the houses. This concept of sharing walls reduces the exposure to cold winds and retains the heat during the night with minimum loss to the environment.
Floors	Mud flooring	Mud flooring	Mud is mixed with indigenous stabilizers such as straw, plant extract, cow dung & molasses laid for flooring and smoothening the surface.	
Material	Bamboo & canes	Mud / reinforces with wooden reeds.	The entire built form is constructed with Bamboo, cane and dried grass stacked over this as thatch and it is closely packed to minimize the infiltration of air movement.	The material used for the construction is earthen material as a primary element and support structure is the locally available plant material.

wooden reeds for reinforcement; adopted methodology of wattle and daub follows a row house pattern.

5. DISCUSSION

The comparison evaluates the positive attributes of the built form influence in socio-cultural and climatic conditions. The built form of the Toda community is a self-sustained structure when compared with the Kota built form. Though the growth pattern of the settlement of Toda and Kota is different, both settlement satisfies the community's need and create a comfort zone in responding to their climatic conditions. It ensures the lifestyle, customs and other religious aspects. Though both the architectural built forms clearly reflect the sensitivity towards the natural environment as well as to the cultural beliefs of the people, the Toda hut stands for the unique form of its character and attracts the utilization of natural bio resources of bamboo, canes & straw in an efficient way. It creates the connection between the spatial relation of people with built form & topography. The analysis finds the highlight of traditional built form closely linked to socio-cultural, psychological, environmental and aesthetic values.

6. CONCLUSION

In the above discussions the settlement planning built structure has a strong influence on their socio-culture and adopted the prevailing weather conditions as shown in table.1 and table.2. The study found that traditional built forms of Toda and Kota communities were built with available natural resources like Bamboo, cane, dried grass and mud which are more sustainable. The policymakers or the designers should always consider the settlement's traditional values along with the socio-cultural and geographical factors while designing or proposing the houses to the tribal community. The settlements should be retained with existing traditional values and concentration should be on protecting the tribal settlement from being exploited in the name of tourism. Sensitising and promotion of construction activity which will lay path to the future generation that will enact as social and cultural reforms of both the indigenous communities.

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Application of Digital Tools in Heritage Documentation

A Case Study of the Sacred Ensembles of the Hoysalas

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ABSTRACT: Digital documentation of historic structures is one of the ways to engage with history. Documentation is a critical tool and the first step towards conservation of cultural heritage. Advancements in technologies are opening up new ways of data capture, processing and representing historic structures. Image-based documentation can provide clarity and offer additional information. Scaled-visual information can play a key role in ensuring stakeholders to gain better understanding of the characteristic heritage elements. Contextualized photographic digital documentation methods can be efficient. This paper utilizes the case study of 'the Sacred Ensembles of the Hoysalas' to emphasize the benefits of combining manual methods with digital tools. Cavalcade of sculptural ornamentation and architecture of the Hoysala craftsman is recognized by UNESCO as a World Heritage of Outstanding Universal Value. It is unrealistic to measure and draw them; nor, it is affordable to laser scan the structures by smaller organizations. We customized the traditional methods with digital tools to produce scaled images and architectural drawings. Using the benefits of photography and photogrammetry, made the process faster and affordable. The team evolved to contextualize the following methods to generate the architectural drawings - (i) Manual documentation (ii) Imaging methods (iii) Combination of Manual documentation & Imaging methods. The rationale of utilizing one of the three methods, depended on effectiveness to the context to be documented. This paper elaborates the potential of digital documentation with the Hoysala temples as the contextual case example; in addition we attempt to understand the theory, principles and field work of digital tools in heritage documentation.

KEYWORDS: Digital Documentation, Photogrammetry, Hoysalas, Imaging Methods, Measured drawing.

1. INTRODUCTION

Documentation is a critical tool and the first step towards conservation of cultural heritage. Utilization of structured visual imagery can widen and offer clarity in conservation practice. Documenting South Indian temples is naturally complex, with the exceptionally intricate sculptural artistry, on its walls, gopurams and vimanas. It is not viable to measure and draw them, within the given time; nor, it is cost-efficient to scan the structures with available resources. This is the junction, visual imaging methods including photography and photogrammetry can aid. The photogrammetric method makes the process both fast and affordable with available tools. The task in hand was to document three Hoysala temples, namely: Chennakesava temple at Belur, Hoysaleswara temple at Halebidu and Kesava temple at Somnathpura, all recognized as World Heritage by UNESCO; this documentation was done for the nomination dossier through INTACH Bengaluru. Due to the intricacies of the temple complexes, the documentation team decided on developing a composite model of documentation using visual imagery.

Tailored photographic digital documentation methods are efficient; and especially in combination with manual methods of architectural documentation. Complex dense iconography and elaborate ornamentation of these temples are indeed the most vulnerable subjects. There is always a significant gap in the required information in the conservation practice. 'Scaled-image-based' information can play a key role in ensuring various stakeholders to gain clear understanding of the characteristic elements and can offer the crucial data, closing the gap.

2. SACRED ENSEMBLES OF THE HOYSALAS

Hoysalas ruled parts of Karnataka between 10th and 14th centuries. They are well known for their development of art and architecture in South India. The Hoysala rulers have built more than 100 temples that are surviving today, spread around the state of Karnataka. Incredible attention to detail and craftsmanship are some of the distinct features of their temples. Chennakesava Temple at Belur, Hoysaleswara Temple at Halebidu and Kesava Temple at Somnathpura are three well-known Hoysala temples, "which exhibit an amazing display of

sculptural exuberance"; these three temples formed the cardinal part of the nomination submitted to the UNESCO World Heritage List, called the 'Sacred Ensembles of Hoysalas'. The World Heritage dossier describe the temples as

'The Hoysala era is one that contributed enormously to the development of several creative fields as well as spiritual and humanistic thought. During their reign, the Hoysalas built more than 1500 temples all across their empire of which only a little over 100 survive today. Art historians recognize the exceptionally intricate sculptural artistry of the Chennakeshava temple at Belur and the Hoysaleswara temple at Halebid to be among the masterpieces of South Asian art making the name of Hoysala synonymous with artistic achievement.'

Justification of Outstanding Universal Value - The 'Sacred Ensembles of the Hoysala' represents the pinnacle of artistic and cultural accomplishments of the Hoysala Empire that reigned from the 11th to the 14th Centuries CE largely in present day Karnataka in southern India. The properties also represent a cultural value and respect for the pluralistic spiritual beliefs of Vaishnavism, Shaivism, and Jainism and contributed to their development. The sacred and the spiritual intersected with ordinary people and daily lives in numerous ways.

Date of Submission: 15/04/2014
Criteria: (ii)(iii)(vi)
Category: Cultural Heritage
Submitted by: Permanent Delegation of India to UNESCO
State, Province or Region: Karnataka
Ref.: 5898

3 HERITAGE DOCUMENTATION AND RATIONALE

This paper is an effort towards attaining a comprehensive approach of analytical and digital photogrammetric methods, combined with photographic, manual measure drawing and other visual methods, with the purpose of finding the best solution for mapping, surveying, architectural documentation, restoration and conservation of built heritage. The benefit of combining closing-range photogrammetric methods with other traditional documentation methods, is that it provides a solid technical documentation of the built environment as a basis for technical rehabilitation or conservation planning, both quantitative and qualitative.

In the developing regions, such as India, it is common to see the employment of traditional documentation methods, including manual measurement and drawing, whenever a heritage conservation project gets started. With the nomination dossier, documenting the sculptural and ornamental complexes of the Hoysala temples, with traditional methods was arduous. With the modern buildings, the advantage of using photogrammetric methods may look pointless; and easy to be able to represent with basic architectural drawings. On the contrary, the elaborate work by the hoysala craftsmen naturally make the traditional documentation methods look herculean. Documenting the temples through digital methods, such as photogrammetry, makes it beneficial; besides, it is easier to understand and visualize an orthophoto, (i.e., scale rectified) in place of a technical architectural drawing, with lines, measurements, etc.,. On the outset, the orthophotos can give the color information, texture, material as seen by us. This determines the advantage of using photogrammetry over traditional manual methods. At the same time , it would be beneficial to understand both manual and digital methods of documentation. Context, site topography and other local conditions pose challenges in documenting built heritage; besides, no two temples are similar. Inclusive utilization of alternative methods can amplify the efficiency, minimize the hurdles and negotiate the errors. Optimizing the available resources and understanding the documentation methodologies (both traditional and digital) can prove useful in the process of recording the spaces.

Case studies and internal deliberations, aided the team to contextualize the available methods to produce scaled images and architectural drawings. Broadly the methods can be divided into three types,

I. manual documentation
II. imaging methods
III. combination of manual documentation and imaging methods

Laser scanners could have been utilised for the purpose of documenting the Hoysala temples.

The decision of utilizing these above three methods, depended on their effectiveness upon the context to be documented; time and cost were the primary driving factors to choose these methods over laser scanners. Hence this paper is limited in its elaboration about the manual, digital imaging and digital photogrammetric methods.

3.1 Manual documentation

This first method is completely traditional, through manual documentation. The spaces are measured, using basic manual & laser measuring tools, sketched, drawn and drafted to produce the architectural drawings. Manual documentation is a default option for the surfaces, without undulations. Measuring manually gives a tactile understanding of spaces; this gives us a basic framework of overall limits of the site, that can be referenced with the photogrammetric results for accuracy. This was primarily used in drawing the ground floor plan, basic surfaces and smaller details. Enough measurements of the site and topography were taken along with triangulated information.

3.2 Imaging

Visual Imaging is often underused in the conservation documentation; it is nevertheless used in every junction, giving a basic idea of the space. We were employing the imagery methods to create 'scaled' information that can change the documentation process comprehensively. Imaging methods make use of multiple cameras, lighting and related tools, in achieving the desired results. The key to produce the required data is in contextualizing the tools that are available in reference to the space we are dealing with. With South Indian temples, the imaging methods had to be varied for changing circumstances; the influx of devotees, officials, etc., moving in and out of the temple complex throughout the day, adds to the complexity. Some of the spaces could be under construction, while other spaces neither had enough room to move around, nor sufficient light to capture their facades. Some parts were camouflaged by scaffolding and some were close to vegetation. Narrow spaces were documented with super-wide angle (canon 14mm f/2.8) lenses; dark spaces made use of artificial light sources and tripod; taller vimanas and gopurams made use of drones to document them. Apart from the images taken for stitching and photogrammetric rendering, the images of the spaces, the sculptural panels and details were taken with appropriate focal lengths aiding the understanding of documentation. Telephoto lenses (canon 135mm f/2 lens & canon 400mm f/5.6 lens) were used to minimize the perspective errors, wherever there was enough space to move back; macro lenses (canon 100mm macro f/2.8) were used to document the details and other relevant conditions of the temples.

3.2.1. Aerial Photogrammetry

A. Gopuram (Belur) and Vimana (Somnathpura) of the temples are tall and were captured with the drone/ UAV (Unmanned Aerial Vehicle) to build the digital model. Both the structures required between 100-200 images for the model to be built. Electric wires and vegetation from the sides make the process tricky. The photogrammetric process gets into trouble, with depleted visual access, reflective surfaces or even with the stark shadows. The photogrammetric method may not always result in accomplishing the scaled images replacing the drawings; but it certainly assists in profiling the same from their dense clouds.

B. Site mapping is usually done by creating sequential aerial images captured with UAV (Unmanned Aerial Vehicles)/drones from the above. All the three temple complexes were mapped with the aerial images. In aerial photogrammetry, images are taken in rows and columns, with 50% of spatial overlapping between the consecutive images. These images (between 200-400 images) were stitched digitally, to generate ortho-mosaic photo-maps of the sites; these photo-maps have much larger resolution and information, than the freely available google earth platform. The ortho-mosaic photo-maps were geo-referenced through GIS platforms, to be used as site plans.

3.2.2 Close range Photogrammetry

The walls of the hoysala temples with intricately beautiful relief sculptures, the reflected ceiling of the interior temple complexes utilizing photogrammetric methods in achieving the scale rectified images. These ortho-photographs embedded with scaled information and template, were directly used as replacement over traditional drawings. With dark interiors, the data capturing process was aided with artificial lighting (electronic flashes) and tripod. Some of the typical columns were documented through this method. The front door panel of the sanctum sanctorum was documented through the close range photogrammetry method, to achieve a high resolution data. We were able to acquire the ortho photographs, in order to achieve drawings.

3.2.3 Giga Pixel Imaging/ Photo Stitching

Some of the elevation panels of the Hoysala temples were documented with gigapixel imaging. This method stitches sequential images shot with the telephoto lens (canon 400mm f/5.6 lens). With enough distance at disposal, one set of images (24 images) were taken and stitched. This method using longer focal length lenses can comfortably negotiate the optical errors, which is common with photography. The stitched images are close to the orthographic outputs.

3.3 Combination of manual documentation and imaging

Section through the temple complexes utilizing both manual and photogrammetric methods is achieving the scaled drawings. Manual methods were used in getting the basic measurements and distances in synchrony to the floor plans. Photogrammetric method was used to achieve the sectional profile through the temple complex of shrine and mandapa. Both the methods are later referenced against each other in ensuring the accuracy of the drawings. With varying light conditions, and surface distances, photogrammetry methods come with snags.

In addition to the above methods, the spaces were captured with a 360' degree camera. This provides an immersive perception without actually being to the temples. Though this virtual walk can never be the same as being at the temples, it can give a sense of it. With pandemic situations and limited physical access to our journeys, these virtual walks can be an added attraction.

4 CASE EXAMPLES WITH THE ARCHITECTURAL DRAWING OUTPUTS

4.1 Site Plan - Halebidu Hoysaleswara Temple (Fig. 1) One image is the survey drawing, while the second is the ortho-image map (Fig. 2), generated from aerial

Figure 1: Site Survey plan - Halebidu Hoysaleswara Temple. Source: INTACH Bengaluru Chapter

photogrammetric survey. On comparing these two files, we can deduce the following. Though both files are trying to satisfy similar needs, i.e., to show the overall site conditions and topography, they are starkly different in their appearance.

- The survey drawing is made up of CAD lines, contours, basic infrastructure network, services, dimensions and captions. The ortho-image can show the site like a photo, though it is a scale rectified material. The ortho-image shows color, material, texture and other photographic qualities, clearly differentiating between the building, landscape, pavements, road and other aspects.
- The CAD drawing works with mono-dimensional depth, while the ortho-image can be zoomed to the last bricklayers.
- Ortho-image gives a clear temporal record of the site on a given date and time; this can be useful in long term monitoring and analysis of changes at the site. CAD survey drawing may establish larger physical changes, (of something more than 5m x 5m in scale), while aerial mapping can show most of the visible information as a record.
- Survey drawing shows the manual errors, unable to establish the symmetry, otherwise seen in the ortho-image-map.

Ortho-image provides vast levels of information for the conservator or planner to analyze further; survey site drawing may require multiple levels of interpretation to be able to analyze.

4.2 Inner Reflected Ceiling plan - Chennakesava Temple Belur

This image (Fig. 4) represents a hybrid representation of the central bay, located in front of the sanctum in the Chennakesava temple. The inner ceiling bay is intricate and carved out of stone. The amount of craftsmanship is a perfect example of Hoysalas expertise in temple building. Under traditional conventions, a team would take multiple photos aiding them to draw the ceiling in CAD. The ceiling is in visual symmetry, allowing the draughtsman to trace and mirror, making it look trivial, in disregard to the human artistry on stone. Our team decided to show the ceiling both in drawing and image, for better comprehension of the space, while conservators will have different layers of understanding to be analyzed.

4.3 Elevation drawings - Kesava Temple Somnathpura

The following two representations (Fig. 5) are of the South elevation (in ortho-image) and the West Elevation (in CAD drawing), at the Kesava temple, Somnathpura. Ortho-image elevation is an outcome of multiple photographs, eliminating the optical errors that are common in photos.

The ortho-image allows us to understand the depth and detail of the sculptural ornaments in its elevation; the CAD drawing doesn't allow us to comprehend aspects like, the stone color, depth of sculptures, stellate form or the material texture.

Figure 2: Ortho-mosaic photo-map - Halebidu Hoysaleswara Temple Complex Source: Author

Figure 3: Ortho-mosaic photo-map - Halebidu Hoysaleswara Temple Source: Author

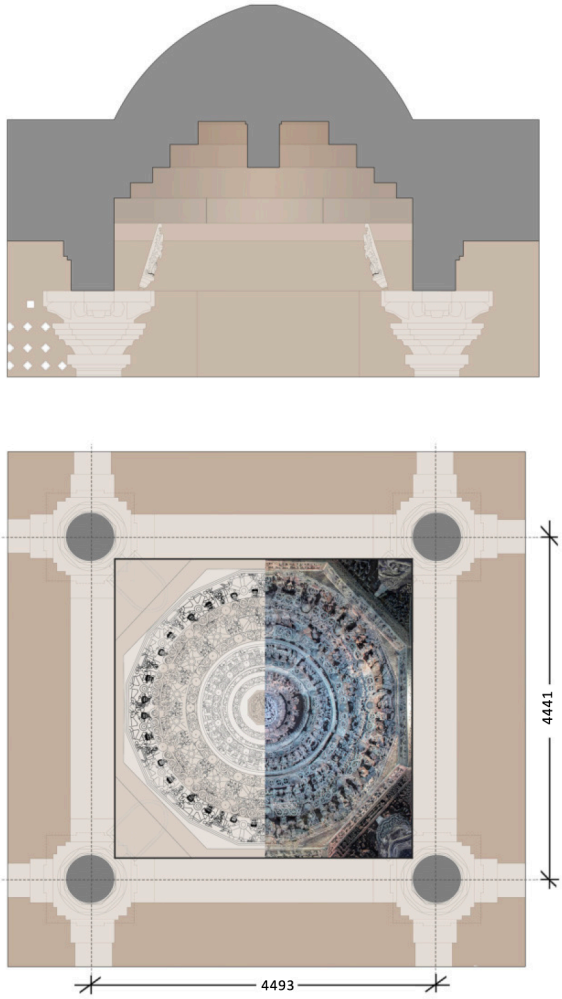

Figure 4: Hybrid Ortho-mosaic cum CAD drawing of Inner RCP - Belur Chennakesava Temple Source: Author

- The ortho-image is a gigapixel photo that can be zoomed into the face of a sculpture anywhere in its representation. The CAD elevation doesn't give any such detail.
- This 3-D data can allow the conservator to analyze the condition of the stones in greater detail, facilitating quantification and solving real time issues towards better conservation/restoration outcomes.

4.4 Reflected Ceiling plan - Kesava Temple Somnathpura

The representation of the reflected ceiling plan in an ortho-image would be self-explanatory is appreciating the utility of photogrammetry in heritage conservation. This representation concedes exceptional direction in enlightening us with the data it gives. To manually measure these ornamental material is impossible from the ceiling, while taking

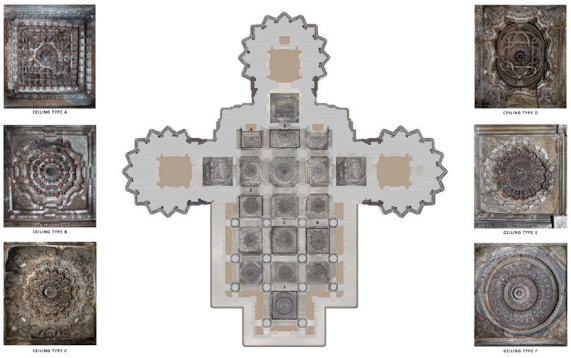

Figure 6: Ortho-mosaic RCP of Somnathpura Kesava Temple Source: Author

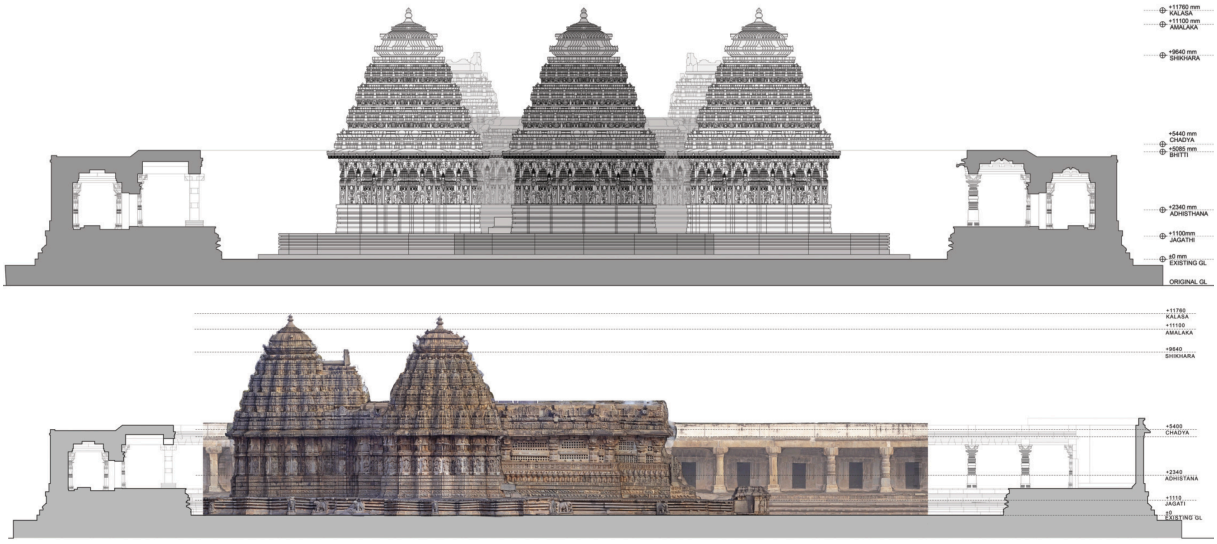

Figure 5: Top: Ortho-mosaic photo elevation of North Elevation. Below: CAD Drawing of West Elevation Somnathpura Kesava Temple. Source: Author

multiple photos from the ground lying down can provide us with the below information after processing. Conditional assessment from enlarged parts of the image, analysis, diagnosis, etc., can happen comfortably from anywhere with this ortho-image.

5 CONCLUSION

One has to understand that digital tools are both a boon and a curse. Digital documentation becomes a meaningless activity, if it is not processed and converted into transferable knowledge. Photogrammetry and other digital methods of documentation have the potential to facilitate the conservation processes. They may not give exhaustive ready-made solutions, but reduces the human errors, increases the depth to the details, simplifies with visual understanding and acts as a bridge among the stakeholders of built heritage. The process needs to look into the basic tool requirements and the general skill or expertise expected from the staff to undertake documentation. Apart from the skill development that we have seen in the paper, there are other aspects such as standardization of equipment, digital data management and creating a documentation manual for heritage conservation projects, in the developing regions shall be the next steps.

IMAGING & DOCUMENTATION TOOLS USED

A. DSLR Cameras - Canon 5D Mark IV & Canon 5D Mark III

B. Digital Camera - Sony RX II

C. 360 Camera - Ricoh Theta Z1

D. Lenses (All Canon) - 14mm f2.8, 24mm f2.8, 35mm f1.4, 50mm f1.4, 100mm macro f2.8, 70-200mm f2.8, 400mm f5.6

E. UAV/ Drone - DJI Mavic pro 2 & Phantom 4

F. Software: Photogrammetry - Agisoft, Metashape, Meshlab. Photography - Adobe Photoshop, Adobe RAW

G. Accessories: Godox electronic flash, Manfrotto tripod, LED Torch & Colour checker. Measuring tools, laser tool, Sketchbook notes.

SITE ACCESS COURTESY:

Archaeological Survey of India

DOCUMENTATION TEAM

Maniyarasan Rajendran, Ragul Ravichandran, Ahlam, Sahana & Swathy for INTACH Bengaluru

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Value-Based Assessment of Built Heritage

A Study of Historical Markets in Bengaluru

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ABSTRACT: Heritage is our inheritance from the past, what we presently experience and what we must preserve and conserve for the future generations. Heritage can broadly be categorized into cultural and natural heritage and cultural heritage can be further classified into tangible and intangible heritage. Built heritage is an integral part of the tangible heritage of any place comprising of historical monuments and sites, objects, artefacts, structures, areas and precincts that are of historic, archaeological, architectural, aesthetic, social and cultural significance. Heritage values are aspects or characteristics attached to the qualities of a place or object by individuals or communities. These values act as a tool to make informed decisions about an object or place and help in discerning the level of significance of an asset. They also aid in understanding the origin and evolution of a place and identify who values it. Bengaluru as a place has been in existence since 9th century AD as depicted in the hero stone inscriptions found in the Panchalingeshwara temple at Begur, a suburb of Bengaluru. It was officially established as a market fortress town in 16th century AD by Kempe Gowda I, an able vassal of the Vijayanagara dynasty. Due to its strategic location in the Indian sub-continent, the city has historically been a major center of trade and commerce and all important South Indian kingdoms from the Cholas to the Marathas and even the British set up bases in this region. The rich mercantile heritage of the city has undergone considerable transformation owing to years of interventions by various stakeholders and is slowly fading under the light of new development. This paper traces the origin of Bengaluru as a 16th century market fortress town and discusses the different values that can be attributed to the heritage markets (pre-colonial and colonial) and highlights their character and significance to the city.

KEYWORDS: Heritage listing, mapping, heritage values, value assessment, Bengaluru heritage

1. INTRODUCTION TO BUILT HERITAGE AND ITS SIGNIFICANCE

Built heritage is an integral part of the tangible heritage of any place consisting of historical monuments and sites, objects, artefacts, structures, areas and precincts. In most cases, it is the only surviving evidence that helps in tracing the history, lifestyle, cultural practices and building traditions of a place.

The factors that define the significance of built heritage can vary from the surroundings and settings, association to important personalities or events in history, originality of the building design and construction techniques, relation to archaeology and socio-political context.

2.VALUE-BASED ASSESSMENT OF BUILT HERITAGE

Assessing the values of a heritage building helps in understanding its significance and enables an informed decision-making process regarding any change to its built fabric. A heritage building may be considered valuable based on its historical context, utilitarian purpose, personal association, unique architectural character or cultural landscape and distinctive natural features etc. (Historic England, 2015). These values have been classified into different categories for better understanding and clarity. A heritage building/monument/site can have an outstanding universal value (OUV) that is important for the citizens of the entire world or can have locally significant values. This paper will be focusing on some of the locally significant heritage values.

Historical Value refers to the importance of a property to the history, archaeology, architecture, engineering or culture of a community, region or nation. Archaeological or Evidential Value refers to the potential of a precinct/building to yield evidence of past human activity. Architectural or Aesthetic Value derives its importance from the special architectural character, materials and building traditions. Social or Communal Value is associated with the community or group of people from a specific background who have a unique connection or collective experience with a place or building.

3. AIM AND METHODOLOGY

The main aim of the paper is to understand the significance of the historic markets of Bengaluru and how they add value to the mercantile heritage of the city. The primary research method adopted for this paper is qualitative in nature. The desk-based research was assisted by collecting data through libraries, archival and online resources.

Firstly, a historical review of Bengaluru's origin and the factors that led to the development of different types of markets was conducted.

Secondly, four chronologically and architecturally important markets were identified and a case-study approach was adopted. A site and photographic survey were conducted to study the architectural styles of the identified markets.

The process of evaluation of the heritage values of the market precincts is based on INTACH's Charter for Conservation of Unprotected Architectural Heritage and Sites in India (INTACH, 2004).

4. TRACING THE HISTORY OF BENGALURU AS A MARKET FORTRESS TOWN AND A MAJOR MILITARY AND ADMINISTRATIVE CENTRE

Bengaluru, the capital city of Karnataka, situated in the geographical center of the Indian peninsula, has played a crucial role in shaping the history of southern India (Annaswamy, 2003). The first mention of the term 'Bengaluru' can be traced back to a hero stone inscription, illustrating the Battle of Bengaluru in the 9th century AD during the reign of the Ganga dynasty (Sharma, 2016). The Cholas and Hoysalas succeeded the Ganga and governed this region for a significant time period. But it was during the rule of the Vijayanagara dynasty, that Bengaluru emerged as an important fortress town (Figure 1). Kempe Gowda I, a feudal chief of the Vijayanagara kingdom is considered as the founder of the city. He was a visionary and prudent commander, who acknowledged the critical location and commercial potential of Bengaluru and decided to make it his capital. He built a fortress market town in 1537 AD called as 'Pete' or 'Pettah', which refers to a market town in Kannada. In 1565 AD, the Bahmani Sultanates of Bijapur defeated the rulers of Vijayanagara, after which Bengaluru became a major military base and later flourished as a commercial hub.

The Mughal army was stationed in Bengaluru for three years after which it was purchased by the Wodeyars of Mysore in 1690 AD. They had a keen eye on this town owing to its ideal location in a valley guarded by hill fortresses providing favorable conditions for a secure environment for trade and military purposes.

Hyder Ali, a commander in chief in the Mysore army, became the de facto ruler of this region once he rescued this territory from constant attack. His secular outlook further encouraged Bengaluru to grow as an industrial and commercial centre. His son, Tipu Sultan, inherited the town and is known to have strengthened it as a defense headquarters (Sharma, 2016). By the end of the 18th century, Bengaluru was a formidable fortress town and a major trading and manufacturing centre. The fourth Anglo-Mysore War (1799 AD), marks the official shift of power to the British, who were captivated by the salubrious climate of Bengaluru and transferred their military capital from

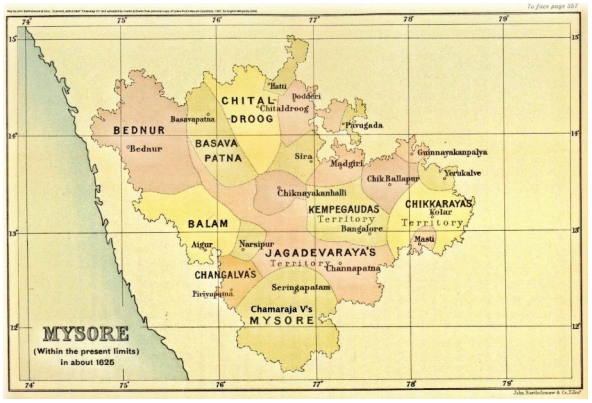

Fig 1: A 17th century plan of Mysore with Bengaluru highlighted, Source: (Rice, 1897)

Srirangapatana to Bengaluru in 1807 AD. The British set up a cantonment to the north-east of the Pete (Figure 2) and it quickly developed to become the largest civil and military station in South India with a flourishing administrative and residential centre (Jayapal, 1997). The settlement of the English troops attracted traders and merchants from the nearby districts and the new English culture and habits paved way for different types of markets and commercial establishments. Trade connections with other parts of British India, which was previously curtailed due to political differences were now actively encouraged and amendments in the economic policies and revenue system had an overall positive impact on the trade and commerce in the city. Thus, Bengaluru emerged as a city with various layers of history and different roles under different rulers, and continues to remain a strong administrative and commercial capital in the country.

5. HISTORIC MARKET BUILDINGS /PRECINCTS IN BENGALURU

For centuries now, public markets have been an inherent feature of the historical landscape of any city and have served as important nodes where people gathered to engage in social, cultural, religious and political dynamics (Tangires, 2005). The evolution and

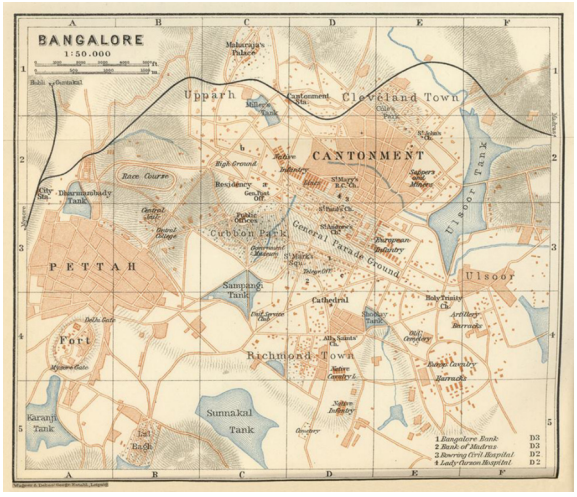

Fig 2: An early 20th century map showing the Pete and Cantonment in Bengaluru, Source: (Baedeker, 1914).

design of markets is influenced by various factors like favorable geographic location, local merchant population, culture and traditions of a place and the variety of goods available for trading (Romano, 2015).

From the historic timeline of Bengaluru, it is evident that public markets have been an indispensable component of the historical landscape of the city. The establishment of a fortress market town by Kempe Gowda I and his subsequent invitation to traders from all over the country to set up their business here, was the first radical measure that ushered the development of Bengaluru into a significant commercial capital.

As specified in the methodology, the study of the historic markets was carried out based on their chronology. The four case studies selected, are categorized into two broad spectrums: that of pre-colonial (16th century) and colonial period (19th and 20th century) (Figure 3). The pre-colonial period focuses on the fortress market town. The colonial period is divided into permanent and indoor and outdoor/street markets. Each category is explored by describing their history, material-built forms exemplifying varied architectural styles and distinct cultural traditions.

Pre-Colonial Era Market (16th Century)

The Pete was arranged in a mud fort of elliptical shape with a ratio of 1:2 with two main streets running north-south and east-west, namely Dodda-pete Road (renamed as Avenue Road) (Figure 4) and Chikka-pete road respectively, the intersection of which formed the town square, called as Dodda-pete square (Figure 5). This fort had eight gates with drawbridges and was enclosed by high rampart walls and a deep ditch or moat with hedging (Figure 6). Many historians like Fazlul Hasan, believe that this layout of the town was based on medieval treatises like the Manasara and Mayamata. Within this military domain was a thriving economic enterprise composed of twenty sub-petes, each of them named after the commodity sold in that locality and occupied by the community trading them. This formed an intricate system of zones based on the mercantile arrangement as can be seen in Figure 7. Each guild of craftsman resided in these designated

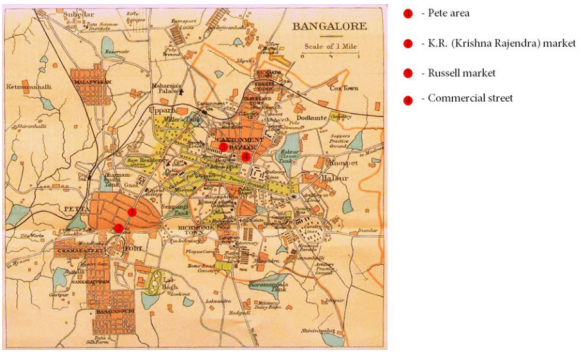

Fig 3: Early 20h century map of Bengaluru highlighting the 4 markets chosen for the study, Source: (Murray, 1924).

Fig 4: An archival photograph of the Dodda-pete Road, Source: (British Library, 1890).

Fig 5: One of the edges of the market square today, Source: (Author).

Fig 6: The Pete area as planned by Kempe Gowda I, drawn by Robert Home in 1791, Source: (Sharma, 2016).

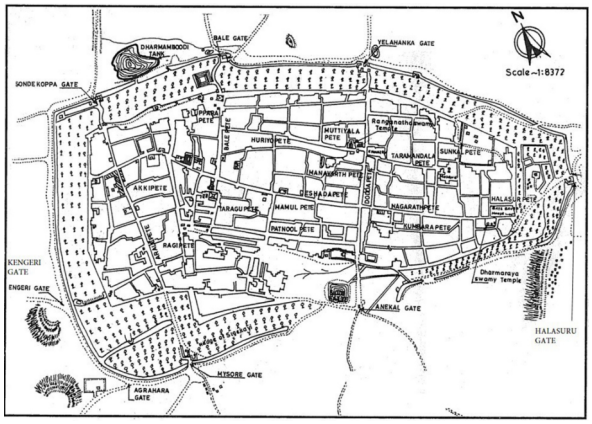

Fig 7: The organisation of the sub-petes within the Pete, Source: (Annaswamy, 2003)

Fig 8: The Mohan Building,Source:(Author)

Fig 9: A typical shop front house. Source: (Author)

sectors, around the temple of their guardian deity and engaged in trade from their shop fronts and workshops.

Though today most of the built structures have not survived, some remaining buildings showcase the vernacular architecture of that time as seen in Figure 8. The decorative cornice, embellished parapets and eaves boards and the typical shop front houses (Figure 9) are nestled in the interior streets of the region and the religious structures of each community like temples and dargahs highlight the architectural significance of the market town. The neighborhood can also be considered as an assemblage of cultural practices, for example, the venue for the annual Karaga Mahotsava, one of the oldest festivals of the city celebrated by the Tigala (horticulturalists in the local language) community, is the Dharmaraya Swamy temple located within the Pete.

Colonial Era Markets (19th Century)

a. Krishna Rajendra or City market, Kalasipalya

This is one of the oldest permanent and indoor markets in Bengaluru selling fresh vegetables, fruits, flowers and all sorts of goods. The site on which the present-day market stands, was once a part of the Anglo-Mysore battlefield of the late 18th century. The area where the market now stands was close to a large

Fig 10: The public space with the fort walls on one side, Source: (British Library, 1860)

water body called Siddikatte that lay between the Pete and the fort and acted as a buffer zone between the areas (Figure 10) (Arunin 2012)

Maintaining the sanitation and hygiene in the old market premises had become an uphill task for the authorities and hence it was decided to build a new market in the same location. The new market designed by the Chief Architect of the Mysore State - S H Lakshminarasappa and Mumbai-based architect EW Fritchley, inspired from the Stuart Hogg market in Kolkata and the Victoria Hospital in Bengaluru opened in 1921. The building with its open square space, arched colonnades, tower-like structures topped with mansard roofs and ornate railings, clock tower, jack arched roofs represents the magnificent European classical style of architecture (Figure 11).

Fig 11: A view of the front facade of K.R. market, Source: (Author)

It was renamed as Krishna Rajendra market in 1946 in honour of Krishna Rajendra Wodeyar of the Mysore dynasty. In 1997, the city corporation constructed a modern concrete building in the open square to accommodate more shops (Figure 12).

The market precinct was a part of the Anglo-Mysore war in the old city and later functioned as an outdoor market representing the past military and economic character of the space. Its past association with notable personalities of the Kempe Gowda and Wodeyar family and the Anglo-Mysore war symbolizes its historical significance. The design of the market buildings, both old and new, have strong architectural values and today they stand as an ornament in

Fig 12: Aerial view of the modern concrete building constructed in the open square, Source: (The Bengaluru Live, 2021).

Bengaluru's cityscape. Even today, traders and farmers gather in this traditional setup to sell their produce and the kind of relationship that exists between the merchant and the customer, shows the social importance of the arena.

b. Russell Market, Shivajinagar

The growing size of the Bengaluru cantonment resulted in an increased demand for household needs and everyday necessities of the British and hence a general bazaar was setup in the vicinity in the 1850s called as New Market, which had a clock tower and a square called as Billi Akki Palli (White rice market) (Figures 13) (Jayapal, 1997).

Fig 13: The clock tower and open arena in front of the New Market, Source: (Luxembourg, 2018)

This market was reconstructed in 1927 to provide better facilities and the building which stands today is named after T B Russell, the then President of the municipal commission and was inaugurated by Hajee Sir Ismail Sait, a well know philanthropist. W H Murphy, an executive engineer of the municipal council is credited for its Indo-Saracenic architecture (Figure 14). The extensive front façade with arched panels has a central entrance marked by buttressed piers with octagonal 'chhatris' (dome-shaped pavilions) on top. The building has square blocks at the end with a high parapet and a squat dome with finial surrounded by four domiciles (Issar, 1998).

The present-day market stands on the site of an earlier market and open arena in the Cantonment depicting the past economic value of the area. Its

Fig 14: Indo-Saracenic architecture of the Russell market, Source: (Author).

historical connection to important people of the city municipal like TB Russell, Hajee Sir Ismail Sait and WH Murphy highlights its associational value. The market building is a combination of Hindu and Islamic architecture with a square and central rising tower demonstrating strong architectural significance. The market shops are run by third generation owners comprising of a culturally vibrant section of the community hailing from different backgrounds who work in harmony with each other and serve a loyal clientele.

c. Commercial Street, Shivajinagar

The Commercial Street shopping zone is located between Kamraj Road and Jumma Masjid Road and includes the by-lanes of Dispensary Road, Ibrahim Street, Veera Pillai Street, Jeweler's Street, Narayan Pillai Street and Lakshmi Mudaliar Street. Set up in the early 19th century, these streets were occupied by merchants who supplied provisions to the British army stationed in the cantonment (Figure 15). The area comprised of residents from different cultural backgrounds and the Tamil Mudaliar community was one such group which dominated the region. Most of the area was owned by Rai Bahadur Sir Arcot Narayanswamy Mudaliar, a wealthy businessman and noted philanthropist and hence the streets are named after his family members. The stores are famous for

Fig 15: An early 20th century view of Commercial Street Source: (Luxembourg, 2018).

textiles, garments, hosiery, shoes, hardware, artefacts, stationery, gold and silver jewellery.

Though most of the older buildings have been replaced by modern extensions, one can still find the typical shop front houses personifying a mix of South Indian vernacular and European architecture (Figures 16) (Rizvi, 2013). Apart from being a major commercial haven, the locality also has important religious structures, with significant cultural heritage and exhibits harmony among the diverse communities, which have been plotted in Figure 17 along with some of the renowned establishments.

Fig 17: Map of Commercial Street shopping zone, Source: (OpenStreetMap, 2018)

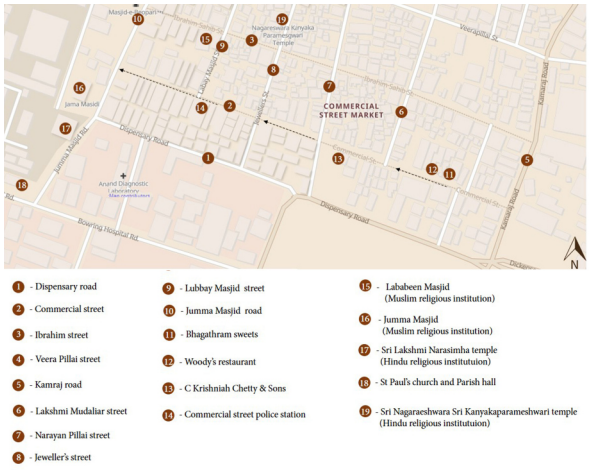

Fig 17: Map of Commercial Street shopping zone, Source: (OpenStreetMap, 2018)

The Commercial Street shopping arena is located in the Cantonment zone where once the British army was stationed which has vital historical value. The area is occupied by an eclectic mix of people from varied backgrounds who form an important part of Bengaluru's community. Apart from the linear arrangement of shops along most of the streets which accentuates the streetscape, there are remnants of typical shop front houses which represent a blend of European and vernacular architecture.

1.1 APPRAISAL OF THE SIGNIFICANCE APPRAISAL OF THE SIGNIFICANCE OF THE MARKETS

From the previous section, it is clear that public markets played a significant role in shaping the image and cityscape of Bengaluru and that markets do not form a single entity. On the contrary, they are heterogeneous spaces, offering varied provisions and performing contrasting roles in different localities. Heritage values have been assigned to these (as shown in table 1), based on the historical facts and data collected of these markets, their association to important personalities, their built architectural styles and cultural practices.

From about a decade, the Bruhat Bengaluru Mahanagara Palike (BBMP), the city corporation, has been striving to take up regeneration projects in the historic market precincts in Bengaluru. In 2017, the Smart City proposal of Bengaluru was approved by the Ministry of Urban Development (MoUD), under the Smart Cities Mission, and was incorporated as a Public Limited Company as per the rules of the Government of India in 2018. The Vision of the Bengaluru Smart City Limited (BSCL) is **"Livable Bengaluru- Healthy, Connected & Vibrant".** Under the Smart City scheme, many projects were finalized and the redevelopment of K R Market junction, Rejuvenation of Russell market zone, Facelift of Commercial Street and few parts of the Pete area are some of the important projects. All of the projects focus on improving the market precincts by providing better services and infrastructural facilities.

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The K R Market project was proposed in 2020 to ensure smooth connectivity of traffic – both vehicular and pedestrian, by integrating transport hubs within the area and to promote business and tourism of the historic neighborhood. The proposed redevelopment plan consists of construction of new public infrastructure like toilets, drinking water points, play area for children and management infrastructure like traffic islands and refuge areas for emergency situations.

A similar rejuvenation scheme with multi-layered interventions and strategies was proposed for Russell Market zone in 2020. The recommendations include a pedestrian plaza, walkway to the integrated mobility hub, organized spaces for vendors, dedicated loading

Table 1: Table discussing the heritage values of the identified historic markets, Source: (Author)

SL No	Name of the market	Evidential Value / Archaeological Importance	Historical Value / Historical Integrity	Associational Value	Aesthetic Value / Architectural significance	Communal/Social Value or Intangible cultural context
1	Pete area	Yields substantial evidential value of past human economic activity, the earliest settlement pattern in the city and constitutes an important historic core of the city.	Bears proof to significant historical events like the foundation of Bengaluru with its historic centre and and its establishment in 1537 AD demonstrates its historical value.	Bears proof to significant historical events like the foundation of Bengaluru with its historic centre and and its establishment in 1537 AD demonstrates its historical value.	The planning, organisation of the spaces and layout of streets within this fortress township has valuable spatial and townscape characteristics.	The co-existence of generations of a diverse trading society for more than 450 years in the same locality indicates the social value of the space, which acts as a source of identity for them.
2	K.R. market	The market precinct was a part of the Anglo-Mysore war in the old city and later functioned as an outdoor market representing the past military and economic character of the space.	The market was set up in 1921 and forms as important part of the historic landscape of Bengaluru.	Its past association with notable personalities of the Kempe Gowda and Wodeyar family emphasizes its associational value.	The design of the market buildings shows an influence of European architecture and the contemporary building constructed in the late 20th century indicate strong aesthetic values	Even today, traders and farmers from the bordering districts gather in this traditional setup to sell their produce and the kind of relationship that exists between the merchant and the customer, shows the communal importance of the arena.
3	Russell market	The present day market stands on the site of an earlier market and open arena in the Cantonment depicting the past economic value of the area.	The market was set up in 1927 and forms a significant element of the historic landscape of Bengaluru	Its connection to important figures of the city municipal like TB Russell, Hajee Sir Ismail Sait and WH Murphy highlights its associational value.	The market building is a combination of Hindu and Islamic architecture with a square and central rising tower demonstrating ample design value and architectural importance.	The market shops are run by third generation owners comprising of a culturally vibrant section of the community hailing from different backgrounds who work in harmony with each other and serve a loyal clientele.
4	Commercial Street	The Commercial Street shopping arena is located in Cantonment zone where once the British army was stationed and is surrounded by Infantry and Cavalry road which has vital archaeological value.	The Commercial Street area was set up in the early 1900s to meet the growing needs of the Cantonment and since then has become an integral part of the historic core of Bengaluru.	The Commercial Street area was occupied by merchants and traders from different cultural backgrounds. The Tamil Mudaliar community owned most of the area and hence many streets in the area are named after members of the community.	Apart from the linear arrangement of shops along most of the streets which accentuates the streetscape, there are remanants of typical shop front houses which represent a blend of European and vernacular architecture.	The area is considered as a shopping haven by the citizens of the city and vendors hailing from different cultural backgrounds have been working harmoniusly from years. The area comprises of many religious institutions and creates a secular atmosphere within the space.

and unloading bays, defined circulation pathways and structured parking for the customers.

Commercial Steet, the city's popular retail hot spot got a facelift under the Smart City project in 2021. The storm water drains, water pipelines, electrical lines of the British era were repaired and replaced with new ones wherever necessary. The road was then laid with wider footpaths and patterned colored cobblestones and is now completely pedestrianized.

All the projects are still underway and it is yet to be seen if the projects pan out as per the proposals, without harming the heritage value of the market precincts.

6. CONCLUSION

The review of the four traditional markets illustrates their contributions in shaping the image and growth of Bengaluru as a mercantile city. The descriptive analysis of the markets outlines the various layers of history, culture, traditions and unique built heritage of the markets. The evaluation of the significance of the markets highlights the rich cultural, historical and architectural value and diversity they bring to the city. This assessment of the markets has been taken into consideration while proposing the new urban conservation projects like the smart-city projects in the vicinity of their setting. The public infrastructure projects at the historic markets have been proposed with minimal impact on the heritage value of the market precincts and all the new designs sensitively blend into the character of the market spaces. Thus, value-based assessment of built heritage is a very important tool towards heritage conservation and should be the first and foremost step to be carried out in any large-scale heritage listing and urban conservation projects.

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Influence of Dutch Colonialism in the Architecture of Kerala:

A Case of Palatial Buildings of the Fortified Settlement of Tripunithura

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ABSTRACT: : Thripunithura, the historic capital of the kingdom of Kochi in Kerala, holds a significant place in the historical timeline of the Dutch colonial occupation of Kerala. The Dutch influence was prominently evident in the architectural style of the facades of Dutch palaces established in the late eighteenth century, characterized by pitched roofs, sash windows, Doric pseudo columns, and decorated friezes, cornice- moldings, and eave boards. The paper aims to study and analyze the facades of the palatial buildings of the fortified settlement of Thripunithura and to identify the elements that portray the influence of Dutch colonialism in the area. The historic and architectural context of Dutch rule in Thripunithura and their alliance with the Cochin kingdom are examined through expert interviews and a review of related literature. A visual survey aided the identification of sixteen palaces within the fortified settlement with Dutch architectural characteristics. Information regarding architectural character, function, significance, and present condition are collected primarily through site visits, documentation, sketching, and preparation of inventories. The documented façade elements of these palaces are comparatively analyzed to understand the degree of Dutch influence from the core to the periphery of the settlement. The analysis enabled the mapping of the proximity of the influence within the fort and the degree of transformations on the facades.

KEYWORDS: Dutch influence, heritage zone, façade elements, heritage character

1.INTRODUCTION

The Dutch East India Company left behind certain important monuments as vestiges of their occupation of the land of Kerala. Few of the palaces in Tripunithura, former capital of the kingdom of Cochin were the contributions of the Dutch. The study was initiated by understanding the history of Dutch in political, socio-cultural and architectural aspects in Kerala. The historic relation between Dutch and the Cochin kingdom were also studied to understand the context. The rapid growth of the settlements, urban pressures, incompatible additions and alterations and monument-centric conservation policies are leading to a loss of Dutch identity in Tripunithura.

The aim of the research is to document and critically analyze the facades of Malikas or palatial buildings of the fortified settlement of Tripunithura to identify the elements that portray the influence of Dutch colonialism in the area and to promote urban conservation. The objectives of the research are to study the history of Dutch colonialism in Cochin, to understand the influence of Dutch in the architecture of Tripunithura, to identify elements of the palatial building facades that reflect the influence of Dutch colonialism and to map the proximity of this influence from the initial settlement area. The methodology of the research is divided into four phases. The initial phase involved the study through secondary sources to understand the history of Dutch colonialism in Kerala, the typical Dutch architectural elements and through books, websites, publications and interviews of experts in the field. The second phase consisted of pilot visual survey and photo documentation to identify palaces with Dutch influence. Further details of the identified palaces were collected through detailed documentation of facades, sketching and architecture inventory preparation. A comparative analysis is conducted of palace facades with identified Dutch elements in the third and final phase. A zone based map of Tripunithura Fort area is prepared to map out the identified palaces of various time periods.

2. DUTCH COLONIAL ARCHITECTURE

Yulianto Sumalyo details the characteristics of Dutch colonial architecture in Indonesia which is a unique mix of western and eastern architectural styles. Local influences suitable to the tropical climate was adopted in the buildings. This can also be seen in Tripunithura.The buildings were multi-storied surrounded by verandahs to allow for cool interiors, saddle roof construction, with numerous doors and windows. (Sumalyo, 2002).

The Dutch influence was prominently evident in the architectural style of the facades of Dutch palaces established in the late eighteenth century, characterized by pitched roofs, sash windows, Doric pseudo columns, and decorated friezes, cornice-moldings, and eave boards. The Ammathampuran kovilakaom at Thripunithura, Krishnavilasom palace at Ernakulam, Shakthan Thampuran Palace at Thrissur, Kalikkotta palace at Thripunithura are having the prominent Dutch characters (Thampuran, 2018).

3.TRIPUNITHURA HERITAGE ZONE

The case study chosen for the research is Tripunithura fortified settlement because the dominance of Dutch was prominent in Cochin Kingdom during 1600-1800 B.C. The Centre for Heritage, Environment and Development, an institution under the Kochi Municipal Corporation, has declared Tripunithura Fort area as a heritage zone. The influence of the colonization of Dutch is visible in the buildings of Tripunithura Heritage Zone.

After the defeat of the Portuguese in 1663, the Dutch annexed Kochi, and since then the Dutch East India Company became the patrons of the Cochin rulers. (Menon, 1911). Tripunithura has been the capital of the kingdom of Cochin since 1790 CE. (Thampuran, 2018). The Dutch East India Company's patronage continued till 1805 CE until the death of Shakthan Thampuran. This period was followed by the era of the British Protectorate from 1814 CE (Bristow, 1959). Although many warehouses and bungalows built by the Dutch were destroyed in 1806 CE by the British for 'strategic reasons". Similarly, many bunglows, malikaas or palaces built during the Dutch time period in the Tripunithura Heritage zone, are subject to transformations in the facades due to lack of adequate studies and research in this field.

The Poornathrayesha temple forms the focus of the zone, with the city growing outwards from the temple. It had a wall which separated the royal part from the other parts of the city. (Katakam, 2006). The Fort area is enclosed by 4 gates along the cardinal directions, centered by the temple. The statue marks the East Fort gate that once existed. The North Fort gate has been reconstructed recently in its original form. Whereas the iron bridge marks the location of the West Fort gate that once existed. The area that was once occupied only by the Royal family now has only 65 palaces, some in good condition and some others in a state of disrepair, interspersed between multistoried buildings, shops and other concrete structures. The roads vary in width and nature from 4m up to 15m.

At Thripunithura, the Dutch influence was prominently visualized in the architectural style of Malikas or royal palaces. Historic buildings were converted and renovated by the Dutch and given to the kings as some beautiful assets. Most of the palaces in Tripunithura were the contributions of the Dutch.The style of architecture of Maalikas are a blend of traditional Nalukettu of Kerala and Dutch colonial characteristics. (Thampuran, 2020)

4. IDENTIFICATION AND DOCUMENTATION

The study began with a visual survey of the palace buildings inside the fort to identify the buildings with Dutch facade elements. From the visual survey, 16 palaces were identified showing the required characteristics within the streets near the temple namely Temple Road, Kalikotta Lane, and Fort Road. Detailed documentation of the façade and architecture inventories were prepared to study the palaces in the fort. The characteristic features identified for analysis of facades were number of floors , width to height ratio of the façade, floor to floor height, floor to roof height, number and style of openings, plinths, roofs, wall to window ratio, columns, eaves, additional features and alterations, and material palette. A tabular comparative analysis of the identified palatial buildings highlighting its characteristic features is detailed in Table 1, 2 and 3.

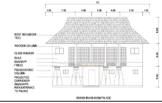
The identified Dutch features are as follows:

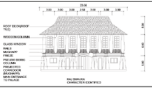
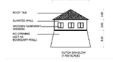
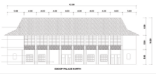
1. Number of Floors: Most of the palatial Buildings are found to be two-storeyed. Kalikotta Palace and Deepthi Palace are found to be the Dutch prominent characters which are found in one-storeyed structures.
2. Width to height ratio of façade: Facade ratios vary with the length of the building and are symmetrical with the elements used in the façade.
3. Floor to floor height: It ranges from 3m to 5m in most of the palaces. Kalikkota palace is used as a recreational center so as to the public gathering the building works in a single floor itself.
4. Floor to roof height: The ratio is proportional with respect to the floor to floor height ratio in order to attain visual perception the roof height ranges from 3m to 8m to attain proportion to the whole building.
5. Openings: Large openings with glass sashed windows, coloured glass sashed windows are found in most of the palace which represents the colonial character to the building.
6. Plinth: Plinth Height of the Buildings is decided by the façade through which the user is accessed into the building. Lint heights are found to be 1m, 60 cm to the building which are facing to the road directly.
7. Roof type: Pitched roofs with slope ranging from 30-35degree are provided in order to increase water flow during the rainy season. The projected roof about 60- 100cm of the building itself acts as the sunshade.
8. Wall to window ratio: In most o the palaces the façade is divided into two different layers: Ground floor consist of minimum openings and first floor with maximum opening and a corridor adjacent to

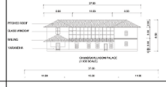
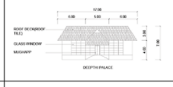
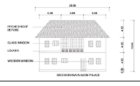
it.The large wall to window ratio gives ambient light into the building from outside and which will not affect the privacy of the interior spaces.

9. Column Spacing: Columns are found in different ways: Large double pseudo- columns in the façade which are in a space of min 3m and max distance of 5m between them. The large columns in the façade and the less number of openings in the ground floor façade are prominent Dutch façade characteristics.
10. Eaves: The eaves are projected from the roof so as to reduce the dripping of water into the building during the rainy season which is 15- 20 cm from the edge which is made up of wood.
11. Alterations and additional features: Pseudo arches are found in some of the façade. Additions and alterations are made in some of the palaces without understanding the façade material and design features, metal brackets and metal roofing and changes to the structure replacing the pitch roofs to the flat roof etc. reduces the characteristics of the structure.
12. Material Palette: Most of the facades consist of mainly with plastered walls, wooden railings, wooden sashed window with glasses and wooden casement windows the natural color palter of the buildings are visible no also which makes them still the traditional structures.

Table 1: Table showing facade charcteristics of Thripunithura Palaces
Source Author

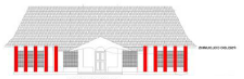
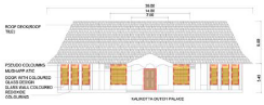
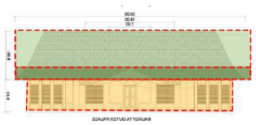
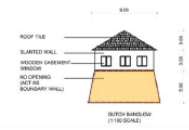
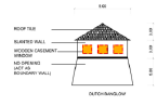
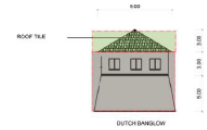
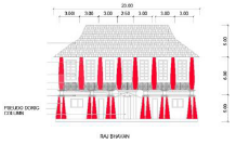
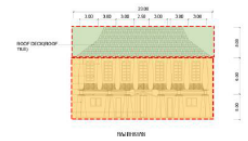
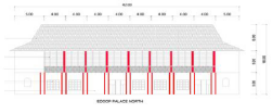
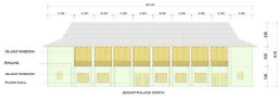
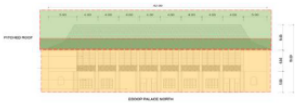
Parameters	Lakshmi Vilasom Palace	Mangalalayam Palace	Lekha Nivas	Subadhravilasom Palace	Lakshmithoppu Palace	Prakashamandiram Palace
Photograph						
Drawing						
Number of floors	2	2	2	2	2	2
Width to Height ratio of Facade	3:1	37 : 15	1 :1	30 :15	9 : 4	27:10
Floor to Floor Height	3m	3m	5m	5m	6m	3.5m
Floor to Roof Height ratio	2: 1	2: 1	2: 1	2: 1	2: 1	2: 1
Openings	Wooden casement windows Wooden sashed glass windows Wooden Doors,Wooden sashed glass doors, Venttilatiors	Wooden casement windows Wooden sashed glass windows Wooden Doors Venttilatiors	Wooden casement windows Wooden sashed glass windows Wooden Doors	Wooden casement windows Wooden sashed glass windows Wooden Doors,Wooden sashed glass doors, Venttilatiors	Wooden casement windows Wooden sashed glass windows Wooden Doors Venttilatiors	Wooden casement windows Wooden sashed glass windows ,Wooden Doors
Plinth Level	60cm	60cm	45cm	60cm	45cm	1m
Roof type	Pitched roof	Pitched roof	Pitched roof	Pitched roof	Pitched roof	Pitched roof
Wall to window Propotion (floor wise)	Ground Floor - 60% First Floor -75%	Ground Floor -70% First Floor -90%	Ground Floor -40% First Floor - 95%	Ground Floor - 30% First Floor - 70%	Ground Floor - 60% First Floor -80%	Ground Floor - 90% First Floor -60%
Coloumn spacing	--	1m	5m	4m	3m	3m
Eaves	1m	1m	1m	1m	60 sm	60 cm
Additional features	Unsympatheic addition of structural elements like metal sheets etc...	Brick Bracket sunshade	--	Unsympatheic addition of structural elements like metal sheets and concrete extension of front entry area etc...	--	Unsympatheic addition of structural elements like metal sheets and concrete extension of front entry area etc...
Alterations and additions	Entrance is extended unsympathetically with metal elements	--	--	Unsympatheic addition of structural elements like metal sheets concrete roofing etc...	--	Unsympatheic addition of structural elements like metal sheets concrete roofing etc...
Material pallete	Wood, Concrete, Plastering glass , metal sheets	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass, metal sheets	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering, glass, metal sheets

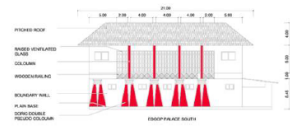
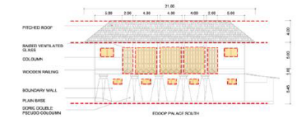
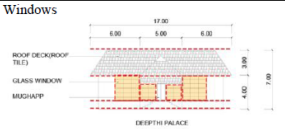
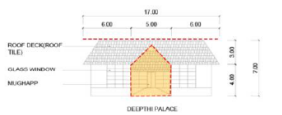
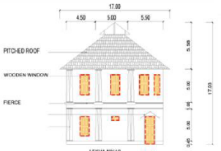
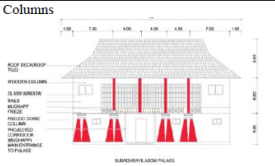
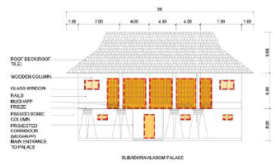
Parameters	Amba Nivas	Raj Bhavan	Kalikkotta Palace	Dutch Banglow	Edoop Palace (N)
Photograph					
Drawing					
Number of floors	2	2	1	2	2
Width to Height ratio of Facade	5 : 4	23 : 16	3 : 1	9:11	43 : 16
Floor to Floor Height	3.5m	5m	--	5m ,3m	5m
Floor to Roof Height ratio	2: 1	2: 1	1: 2	2: 1	2: 1
Openings	Wooden casement windows Wooden sashed glass windows Wooden Doors	Wooden casement windows Wooden sashed glass windows Wooden Doors Venttilatiors	Wooden sashed glass windows Wooden sashed glass Doors	Wooden casement windows	Wooden casement windows Wooden sashed glass windows Wooden Doors,Wooden sashed glass doors, Venttilatiors
Plinth Level	1m	30cm	20cm	60cm	60cm
Roof type	Pitched roof + Flat roof	Pitched roof	Pitched roof	Pitched roof	Pitched roof
Wall to window Propotion (floor wise)	Ground Floor - 60% First Floor - 85%	Ground Floor - 40% First Floor -90%	Ground Floor - 50%	Ground Floor - no opening First Floor - 30	Ground Floor - 60 First Floor -90 %
Coloumn spacing	--	3m	2m	--	4m
Eaves	60cm	1m	1m	60cm	1m
Additional features	Wooden rafters and mettalic sheets eaves are provided in the first floor sunshade level.	Padippura and Flooring are rased to same floor level	--	--	Unsympatheic addition of structural elements like metal sheets etc...
Alterations and additions	Changes in pitch roof and sun-shade devices .Material change	Unsympathetic addition of metal elments into the structure	--	--	Unsympatheic addition of structural elements like metal sheets etc...
Material pallete	Wood, Concrete, Plastering	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering	Wood, Concrete, Plastering glass

Parameters	Edoop Palace (S)	Chandravilasom Palace	Deepthi Palace	Eashwaraseva palace	Sree krishnavilasom Palace
Photograph					
Drawing					
Number of floors	2	2	1	2	2
Width to Height ratio of Facade	5 : 4	3 : 1	17 : 7	23: 10	20 : 13
Floor to Floor Height	5m	3m	4m	3m	4.5m
Floor to Roof Height ratio	2: 1	2: 1	2: 1	2: 1	2: 1
Openings	Wooden casement windows Wooden sashed glass windows Wooden Doors Venttilatiors	Wooden casement windows Wooden sashed glass windows Wooden Doors	Wooden casement windows Wooden sashed glass windows Wooden Doors	Wooden casement windows Wooden sashed glass windows Wooden Doors	Wooden casement windows Wooden sashed glass windows Wooden Doors Venttilatiors
Plinth Level	60cm	1m	60cm	45cm	60cm
Roof type	Pitched roof	Pitched roof	Pitched roof	Pitched roof	Pitched roof
Wall to window Propotion (floor wise)	Ground Floor - 75 % First Floor - 20%	Ground Floor - 60% First Floor - 85%	Ground Floor - 70%	Ground Floor - 60% First Floor -90%	Ground Floor - 40% First Floor - 60%
Coloumn spacing	4m	2m	2m	3m	2m
Eaves	1m	1m	60cm	1m	1m
Additional features	--	Structural renovation is over	--	--	--
Alterations and additions	--	Structural is stabilised using concrete and reinforcement	--	--	--
Material pallete	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass , R.C.C	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass	Wood, Concrete, Plastering glass

4 . CASE STUDY ANALYSIS

The study attempted to identify and comparatively analyze the Dutch colonial architectural influence in the palace facades of the fortified settlement of Tripunithura. The identification is conducted through visual survey, inventory preparation and facade documentation. The palace façade characters and elements of 16 palaces within the Fort were documented and have been analyzed in a comparative manner.

Kalikkottta Palace	**Dutch Bungalow Palace**	**Raj Bhavan Palace**	**Edoop palace (N)**
250 Years : Kalikota palace is one of the primary Dutch characterised building inside the fortified settlement with prominent Dutch characters like double columns, decorative glass sashed windows, high pitch roofs with different slopes, windows which extend to plinth to eaves level and a integration with the Kerala traditional gable structure in the front.	300Years: Dutch fort characterised palace structure. The building stands distinct from the rest of the palaces being a single storied 3-roomed structure resting upon a 3m high ground floor completely filled with mud. The sloping & tiled high pitched Dutch roof rests upon 4 ½ ' thick walls. A steep wooden staircase leads up to the room in the center	300 Years: The 3m high roof of the double storied 'maalika' reveals Dutch influence. However the building is done in traditional Kerala architectural style. The walls are 2' thick & the internal doors are a combination of glass panelled folding door & wooden hinged door (using ancient Tower bolts).	The double storied 'maalika' built in traditional Kerala architecture displays mixed influences. The 1st floor southern elevation is enveloped in long sash windows & perforated screens of British colonial influence whereas the east elevation counterpart has sash windows & louvers of Dutch influence. This long & linear structure running along the road is in disrepair & is separated into 4 parts.
Columns  Wall to window ratio  Wall to Roof Ratio: High Pitched Roof with different slopes.  	Fort character  Wall to window ratio  Wall to Roof Ratio  	Pseudo-Columns  Windows Walls and openings  High Pitched Roof  	Columns  Wall to window ratio  High Pitched Roof Wall to Roof Ratio  

Edoop palace (S)	**Deepthi Palace**	**Lekha Nivas Palace**	**Subhadravilasom Palace**
120 years: The double storied 'maalika' built in traditional Kerala architecture is in a dilapidated state. Massive rectangular columns 2' thick are found in the ground floor whereas the first floor has round double columns supporting the sloping & tiled Kerala style roof.	Between 100 to 180 years: The main building is a quaint 1-storied palace with a portico with steps leading to it from both sides whereas the 'maalika' follows the typical style observed in the area with its Dutch influenced sash windows & louvers in the 1st floor facade.	110 years: Sash windows on a plain base characterize the first floor facade which is separated from the altered ground floor elevation the presence of the double column also exhibits the influence of Dutch elements	110 years: The double storied Maalika has terracotta tiled sloping roof. Sash windows on a plain base characterize the first floor facade which is separated from the altered ground floor elevation using typical Neo-classical cornice work seen in majority of the palaces.
Columns  Windows  	Windows  Walls and openings  Colours Materials 	Columns  Windows Walls and openings Wall to window ratio  	Columns  Wall to window ratio  

Sl. No.	Name of the palace	Age	Dutch Features	Element	Description
1	Chandravilasom Palace	80 years	Windows Colours Materials		Pillars carved out of single tree trunks separate the sash windows at intervals of 2.5m
2	Eashwaraseva Palace	90 years	Windows Colours Materials		The double storied 'maalika' has an L-shaped plan. The ground floor windows have arched spandrels whereas the first floor has Dutch Colonial sash windows on louvered bases enveloping the entire facade.
3	Amba Nivas	100 years	Windows		Complex consisting of double storeyed Maalika & pond. Sash windows on a louvered base bordering the verandas reflect typical Dutch Colonial influence on Kerala temple architecture of thick stone walls & tiled sloping
4	Sree Krihnavilasom Palace	80- 100 years	Windows		The rectangular block is a double storeyed Maalika. Sash windows on a triangular base bordering the verandas
5	Lakshmi Vilasom Palace	100 years	Windows		Complex consisting of double storeyed Maalika & pond. Sash windows on a louvered base bordering the verandas reflect typical Dutch Colonial influence on Kerala temple architecture of thick stone walls & tiled sloping
6	Mangalaalayam Palace	75 years	Windows		The H-shaped symmetric plan consists of 8 'suites' on either side separated by a large hall. The double storied Maalika displays a facade of Dutch Colonial influence in its long sash windows on a louvered base. The tiled & sloping Kerala style roof on wooden rafters is supported on 2' thick walls.
7	Lakshmithoppu Palace	70 to 80 years	Windows		Precinct consists of 3 buildings built in traditional Kerala architecture in 2 separate plots : 2 double storied 'Maalika' & a single storied 'naalukettu' known as the 'thekke naalukettu'.The first floor facade reveals Dutch Colonial influence in the long sash windows & louvers.
8	Prakshamandiram Palace	90- 110 years	Windows		Complex consisting of double storeyed Maalika . Sash windows on a triangular base bordering the verandas reflect typical Dutch Colonial influence on Kerala temple architecture of thick stone walls & tiled sloping roofs

Figure 3: Comparative Analysis of palaces in Zone 3

From the study and analysis of facades, buildings could be classified under three different zones based on their similarities in facades elements.

Zone 1 consists of Kalikkota lane having palace facades with most prominent Dutch influences. Kalikotta Palace, Dutch bungalow, Raj Bhavan, Edoop Palace (North) has prominent Dutch characters like double columns, decorative long glass sashed windows and louvers, pseudo-columns, high pitched roofs with different slopes, windows which extend to plinth to eaves level and a integration with the Kerala traditional gable structure in the front. The time

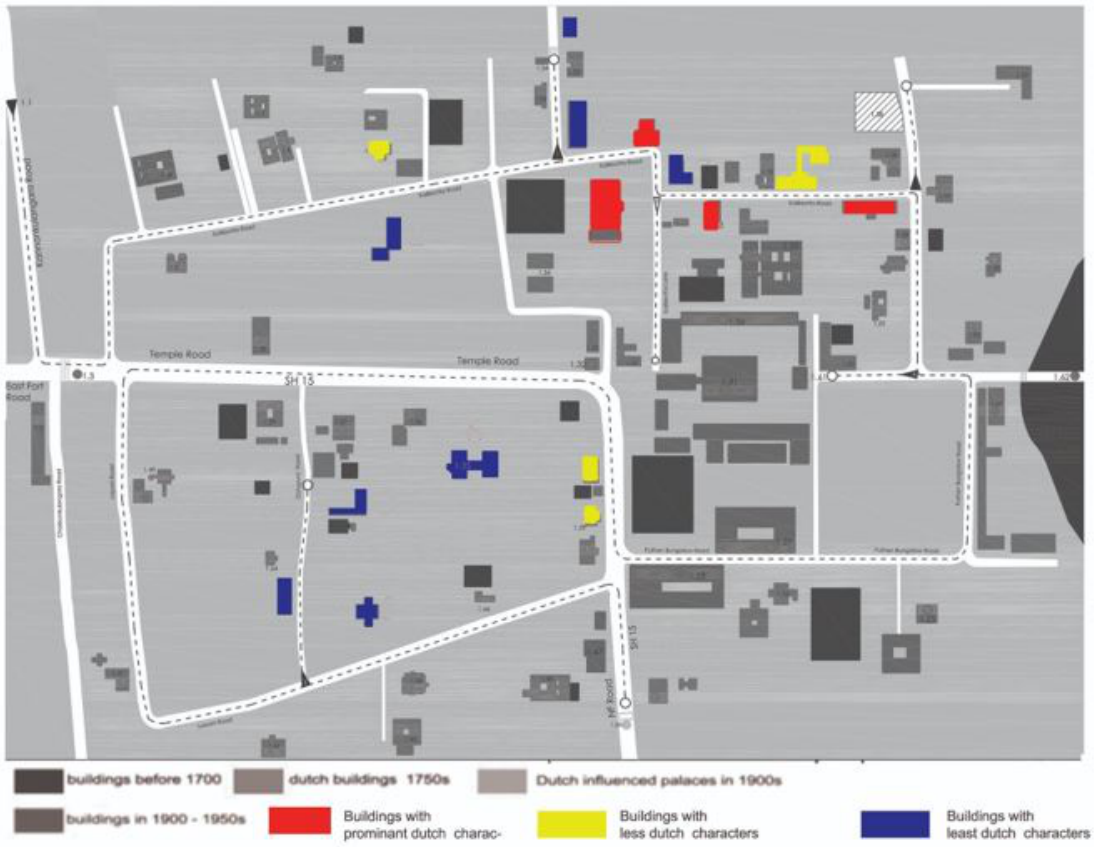


Figure 4: Map of Tripunithura Heritage Zone with palaces demarcated

period of this zone corresponds to the 17th to late 18th century, shown in Figure 1.

Zone 2 is the Temple road or Rajaveedhi Road with palace facades with fewer Dutch elements than Zone 1. Edoop palace (S), Deepthi Palace, Lekha Niwas Palace, and Subhadravilasom Palace

are the examples documented. In addition to Dutch elements, these facades were also influenced by British architectural elements also. The facade elements of glass sash windows and louvers, double half-columns supporting sloping and tiled Kerala style roof are the facade elements identified. Neo-classical cornice work is also observed here. The time period of construction corresponds to the early and late 19th century, shown in Figure 2.

Zone 3 with palaces built in the early 20th century such as Chandravilasom Palace, Eashwaraseva Palace, Amba Nivas, Sree Krishnavilasom Palace, Lakshmi Viasom Palace, Mangalaalayam Palace, Lakshmithoppu Palace, Prakshamandiram Palace has the least Dutch influence. Dutch Colonial sash windows on louvered bases and sloping roofs are the only elements observed, shown in Figure 3.

The palaces of these three zones having similarity in character are colour coded and overlapped on the Tripunithura Heritage Map, as shown in Figure 4. Zone 1 is shown in red, zone 2 in yellow and zone 3 in blue.

7. DISCUSSION AND CONCLUSION

The three zones and palaces identified are mapped in the Tripunithura Heritage Zone. An interesting observation was made that the extent of Dutch influence was observed maximum in the streets closer to the temple and decreased in the subsequent streets (in Zone 2). The influence was least observed in Zone 3 whose proximity was furthest away from the temple.

In a nutshell, it can be concluded that the extent to which the influence of Dutch characters and elements in the facades of the palace buildings are limited mainly in the Kalikkota lane and few of the palace façades during the adjacent time period in the main temple road / Rajaveedhi.

The unique Dutch features of Tripunithura Heritage Zone is facing the threat of incompatible alterations and rapid transformations. To conserve the heritage character of this zone and retain its heritage value, the typical Dutch features of glass sash windows, number and ratio of openings, double columns, and cornices have to be preserved. This study can provide a database of resources for documentation and as a repository for reference in future conservation interventions in the Tripunithura Heritage Zone.

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THEME 04:

Performance of Buildings

Performance based building design approach enhances the efficiency of built environment, and is expected to bring positive changes in the urban realm. Along with the performance parameter, the functionality and aesthetics of built environment is also to be addressed.

Spectrum of performance criteria ranges from energy efficiency, optimization of material resources; occupant comfort, indoor environmental quality, daylighting etc. are to be incorporated into the design methods.

Theme Chairs

Kevin Mark Low

Small projects

Drawing from graduate and postgraduate degrees in Architecture and Art History from the United States, followed by ten years of corporate experience in Malaysia, Kevin established 'small projects' in 2002 and has worked alone since. He teaches and lectures internationally, and his work and writing have been published regionally and in the United States, Japan and Europe.

Low has, over various periods in his life, been professionally involved in writing, environmental sculpture, illustrating, teaching and copyrighting. He has presented papers on building technology at Harvard University and lectured at the architectural department at MIT. Having studied closely with the Aga Khan Foundation; he has earned awards of research grants and fellowships. Low joined GDP Architects and headed their r + d department and special projects division. He currently divides his time between architectural and product designer.

Ken Yeang

Hamzah & Yeang

Ken Yeang, has been a pioneer ecological design since 1971. He founded Hamzah & Yeang in 1977 with Tengku Robert Hamzah, Yeang has completed over 12 bioclimatic eco high-rise buildings, several thousand dwellings (terraced houses), over two million sq. ft. interior design space, numerous eco-master plans and eco-city designs. Hamzah & Yeang's design and built work have been recognised by the over 70 awards received since 1989 that includes Aga Khan Award for Architecture (for the Menara Mesiniaga, an IBM franchise), Prince Claus Award (Netherlands, 1999) and several others.

His areas of interest range from eco-arcitecture, and eco-mimicry to climate responsive passive low-energy, and bio-integration of biotic constituents with the inorganic structure of the built environment.

Dr. ShankhaPratim Bhattacharya

Associate Professor,
Department of Architecture & Regional Planning, IIT Kharagpur

Dr.ShankhaPratim Bhattacharya is presently an Associate Professor at the Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur. He did his graduation in Architectural Engineering from Regional Engineering College Calicut, Kerala (presently, NIT Calicut). He completed his Masters in Engineering (Structural Engineering) and PhD Research from Birla Institute of Technology, Mesra, Ranchi. He received an 'Eminent Architectural Engineer' award by the Architectural Engineering Division of the Institute of Engineers (India) in 2015.

His interests span across building science, thermal comfort and building energy modelling, vulnerability and disaster risk assessment

Workshop

Vishal Garg, Professor at Plaksha University,Punjab. He was heading the Centre of IT in Building Science in International Institute of Information Technology, Hyderabad.

He is the recipient of the inaugural Dr. Arthur H. Rosenfeld Urban Cooling Achievement Award. He is actively involved in supporting the formulation of national-level policies and standards and implementation of building energy codes in India, and was made a Fellow of IBPSA in 2019. He has worked on several large international projects in the area of building energy efficiency.

He is interested in building energy simulation, cool roofs, building automation and controls, and smart buildings.

Dr. Vishal Garg
Professor, Plaksha University, Punjab

An Architect and Technology Consultant for buildings, Milind Mantravadi has overall 18 years of experience in building design, Security, IBMS, and IOT based smart design. He was course coordinator and Assistant Professor at the University School of Design – Mysore University. He has gained deep understanding of sustainable urban development and how smart technology and urban analytic can be combined to create solutions for smart buildings and cities of the future.

In 2020, Milind was appointed as a Subject Matter Expert (SME) for a National road map policy for Smart Energy Management System adoption in mass homes in India to optimise energy load in the residential sector.

He founded GREEN MATRIX in 2018, a consultancy design firm which provides designs in the field of technology and sustainability.

Milind Mantravadi
Green Matrix

Thermal Performance of RCC Roofs Retrofitted with Alternative Insulation Materials:

Context of Naturally Ventilated Residential Buildings in Kerala

Sneha Sara Varghese, Naseer M.A., Joshima V.M.
Department of Architecture and Planning, National Institute of Technology Calicut, Kerala

ABSTRACT: The building sector accounts to 33% of electricity consumption in India, with commercial and residential sectors contributing 25% and 8% respectively; a major portion of which is accountable for space heating and cooling, to provide thermal comfort to its occupants. Usage of insulation materials on building envelope is considered as an effective way in reducing the buildings' total energy requirements. With the rising concern for climate change, the incurrence of heat waves is causing an increase in the day-time temperature, which further raises the energy requirement for space cooling. Majority of the residential buildings in Kerala have adapted locally to this concern by using an extra protective layer of sheet roof structure above their existing RCC roofs, following the market trend. This shows the need for a more effective and efficient retrofit measure using an insulation material, to achieve better thermal comfort and to help reduce the space cooling energy consumption and the resulting carbon emissions. This study discusses retrofitting RCC roofs of naturally ventilated residential buildings, focusing on alternative unconventional insulation materials; through identification of natural materials, locally and readily available in the market, and their scope for thermal insulation purposes, in the warm humid climate of Kerala. Effective utilisation of locally available materials would also help in economic improvement and eco-friendly environment generation; and thereby help in achieving sustainability goals in the building sector. Kerala, being a coastal state abundant with coconut trees; the study focuses on the scope of coir based materials for thermal insulation. Experimental work is done to study the material thermal properties, and Design Builder software is used for simulating the retrofit design cases. Thermal performance of RCC roofs retrofitted with coir-based materials are hence derived.

KEYWORDS: Thermal Insulation materials, Thermal performance, Retrofit, RCC roofs, Coir, Sustainability

1. INTRODUCTION

Heat transfer from outside to inside a building takes place through the building envelope, by conduction, convection and radiation. Building envelope integrates the exterior building skin and roof which comprises of opaque components and fenestration systems (Rashmi, 2020). The transfer of heat by conduction in a building envelope is dependent on the conductivity of materials used in the facades exposed to solar radiation (Kylili, & Fokaides, 2017). As different materials have different conductivity, they have different resistance to conduct heat. Lesser the materials' resistance, greater the heat transfer and greater the thermal discomfort, and hence greater the need for energy for space cooling.

In India, electricity consumption by building sector is increasing at a relatively faster pace. Residential sector having the second biggest electricity consumption in the country, has an annual growth rate of 6.7% over the past decade (Joshima, Naseer, & Lakshmi Prabha, 2021). This increase in demand for electricity can be attributed partially to the increasing need for heating and air conditioning equipment.

Thermal property of the materials used in a building structure helps determine the thermal performance of the building envelope (Rashmi, 2020). Hence, proper building envelope design, especially appropriate selection and application of insulation materials is important to minimize the energy usage, as it helps reduce energy consumption for heating and cooling, thereby ensuring energy savings. It also helps maintain comfortable indoor environment for its occupants, to help improve their health and productivity, and also limits the negative environmental impacts from the building sector. The materials chosen for building insulation are characterized by their heat-transfer coefficients, which depends on a low value of thermal conductivity, which is the ability to block heat transfer through the building structure, mainly roofs and walls (Kumar, & Suman, 2013). Thus, usage of proper insulation strategies is an effective way in achieving energy efficiency, as it brings substantial savings in cooling and heating energy, reduces greenhouse gas emission

and ensures thermal comfort of the occupants (Streimikiene, 2020)

Among the building envelope components, the biggest contributor of heat gain is the roof, as it is exposed constantly to overhead solar radiation (Azmi & Ibrahim, 2020). In warm areas, concrete roofs cause adverse indoor conditions by transferring the most heat to the interiors. The heat gain through the exposed RCC roofs can be reduced by covering them with roofing sheet, tiles, or other covering materials. The focus should be on materials with high value of thermal resistance, that would reduce heat transfer by a considerable amount. According to Census Data of India (2011), for residential buildings in Kerala, concrete is the most commonly used material for roofs. And following the market trend, a majority of the residential buildings in Kerala are seen using a layer of sheet roof structure above their existing RCC roofs, to reduce direct heat transfer into the building. But a proper understanding and selection of roof covering material to be used is needed, rather than just following the market trend. The increasing contribution of construction activities to GHG emissions, and the rising concern for climate change, calls for the need for sustainable development. With sustainable development and proper selection of an insulation material in need, it is important to initiate activities that limit the use of our natural resources, and to look into effective utilisation of naturally and locally available materials, with the scope to be used as insulation materials. Kerala state, with its immense availability of natural resources, has great scope for their utilisation, for building and construction related activities, thereby helping in reducing the huge investment in the construction industry and resulting carbon emissions. Thus, focus should be on locally available, unconventional and innovative building materials, and feasibility in their utilization as sustainable insulation materials, in Kerala.

Kerala is rich in rice husk, cotton fibre, tapioca stalks, coconut husk, pineapple leaf fibre and banana fibre which are extracted from paddy, cotton, tapioca, coconut palms, pineapple and plantains respectively (Lekshmi & Subha, 2011). All of the former listed are natural fibres that are sustainable building materials. Natural fibres are abundant locally, inexpensive, and help ensure that natural resources, particularly renewable ones, are used to their full potential. Of all these organic fibres, coconut husk is the most widely available and cheap byproduct of the coconut industry. Kerala, with its abundance of coconut trees, provides 60% of the total supply of white coir fibre in the world (Coir Board, 2022). Due to the material's wide availability, the building sector has the option of using it as a natural composite. Coir fibre reinforced cement has been used as a low-cost roofing material, according to studies (Lekshmi & Subha, 2011). Hence, with its abundance and the existing scope of being used as a roofing material, the scope of the natural fibre as an insulation material is further investigated.

This study thus intends to evaluate the thermal performance of RCC roofs retrofitted with different roof coverings under ambient conditions, focusing on coir-based material as a sustainable insulation material, in the context of Kerala.

The paper is organized as follows: Section 2 covers literature study on thermal insulation, conventional insulation materials, and review on sustainable building insulation material selection. Section 3 discusses the methodology based on which the study proceeds, and the design cases of roof retrofitting. Section 4 provides discussion of the results and thermal performance of the design cases, comparative analysis of the thermal performance of the design cases is compared and analysed. Section 5 finally concludes about scope of using coir as a sustainable thermal insulation material.

2. LITERATURE STUDY

2.1 Thermal Insulation

Thermal energy is the energy that flows due to a temperature difference, to a body at a lower temperature, from a body at a higher temperature (Vijjapu & Tiwari, 2022). This flow of thermal energy is heat. Thermal insulation is a materials' ability to slow the rate of heat transfer into or out of a building via conduction, convection, and radiation, due to the materials' high thermal resistance (Al-Homoud, 2005). The amount of net heat transferred through a building envelope determines the thermal response, which in turn determines the energy required for cooling and heating of the building that is needed to provide favorable thermal comfort conditions for its occupants (Kumar & Suman, 2013). Thus, the choice of an appropriate thermal insulation material, helps reduce heat flow and is an effective strategy to help reduce the energy demand of buildings.

Thermal conductivity, density, specific heat capacity, and thickness are the mass properties of a building envelope that have a significant impact on its thermal performance (Joshima, Naseer, & Lakshmi Prabha, 2021). Thermal conductivity (k-value) is the property of a material that is used to measure its effectiveness in conducting heat. Induced by a unit (1 K) temperature difference across the sample, thermal conductivity is the rate of steady state heat flow (W) through a unit area of homogeneous material that is 1 m thick in a direction perpendicular to isothermal planes (ASTM Standard C, 1997). It helps measure the effectiveness of an insulation material. A material is considered to be an insulator if it has a low thermal conductivity (W/m K), a high thermal resistance R-value (m2 K/W), and a low thermal transmittance U-value (W/m2 K). The ability to compare the efficacy of various thermal insulation materials quantitatively is made possible by the knowledge of their thermal conductivity values.

Other main parameters used for thermal insulation material characterization includes properties like density and specific heat. The relationship between a substance's mass and volume is described by its density. The amount of energy needed to raise a mass's temperature by one degree is known as specific heat. A higher value of specific heat capacity indicates a greater thermal energy storage system. Thermal diffusivity is another measurable parameter of heat transfer. It evaluates how well a material conducts thermal energy in comparison to how well it can store thermal energy. Rapid heat transmission is related to high diffusivity.

2.2 Thermal Insulation selection

Proper choice of insulation materials is crucial, for the construction of new buildings and the renovation of existing ones. The decision of selecting a material for insulation is based on evaluation of parameters that are used for characterization of the material (Figure 1). Parameters include thermal properties like thermal conductivity, specific heat, and density. Other parameters under consideration include resistance to fire, and water vapour absorption and transmission, and compressive strength, along with the materials' durability, cost, ease of application, CO2 emission factor, etc (Al-Homoud, 2005). These parameters are ranked and valued according to the context of application, and the final selection is made. The most important parameter gets the largest weight factor. When considering thermal performance (as the basic selection criteria), thermal resistance of the material is the most crucial characteristic. As the context of application changes, the most important parameter also changes, with respect to that specific context. Hence it is important to identify and prioritize the basic selection criteria based on context of application, initially itself.

The choice of insulating material also depends on its effectiveness and economic value, which depends on: local climatic conditions at building site, the type, function, shape, size, and construction of the building, the component of the building to be insulated (roof, wall etc.), type and cost of the insulation used (including material and installation costs), type and efficiency of cooling system used, the type and value of energy saved (cost of energy used), and the maintenance cost (Al-Homoud, 2005)

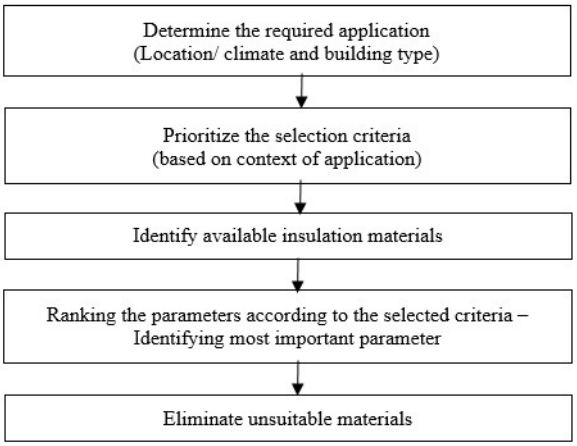

Figure 1: Thermal Insulation selection process.
Source: Al-Homoud, 2005

2.3 Conventional insulation materials

Insulation materials can greatly reduce the average energy consumption. Thermal comfort is improved in buildings that use optimal thermal insulation, at less and operating costs (Kumar & Suman, 2013). The amount of energy that can be saved by employing thermal insulation depends on the type of building, the climate where it is located, the type, thickness, and placement of the insulating material. They can be installed either during construction stage or can be integrated post construction in existing structures. The position of the insulation material within the structure of the building may have an impact on how well it performs during transient heat flow (Kylili & Fokaides, 2017). For roofs, the insulation material can be positioned above or below the slab, whilst it can be applied to the interior or exterior for wall surface. For both systems, it can also be placed at the building element core, inserted between the internal and external material surfaces.

There are different types and forms of insulation materials available in the market. The selection and use of an appropriate type and form of insulation material depends on its physical, thermal, and other characteristic properties as well as the context of its application (Kylili & Fokaides, 2017). Building insulation materials are found in varying types depending on their chemical composition, as:

- **Inorganic insulation materials** are those materials that are produced from abundantly available, non-renewable, naturally existing minerals. Examples include cellular materials like calcium silicate, and fibrous materials like glass, rock wool etc.
- **Organic insulation materials** are those materials that are chemically processed from natural resources and fossil fuels. They are based on biodegradable and regenerative resources. Examples include fibrous materials like cotton, wood pulp, cane, and synthetic fibres, and cellular materials like cork, foamed rubber, polystyrene, and other polymers.
- **Metallic or metallized reflective membranes** are those materials that reduce heat transfer by radiation, in the form of reflective paint, reflective metal shingles, or foil-faced surfaces.

These above mentioned types of insulation materials are usually available in different forms like loose fill that can be foamed or sprayed in-place, mineral fiber blankets in the form of batts and rolls, rigid boards or blocks, reflective materials etc. (Al-Homoud, 2005).

All of these above different types and forms of insulation materials are listed as conventional materials, which have been used traditionally. These are the main insulation materials available in the market and used in construction. They are widely used, yet not entirely sustainable.

2.4 Sustainable Insulation materials: Shift to unconventional materials

The emphasis of the sustainable development approach in the construction industry focuses on environmentally friendly, organic, locally available, natural, renewable, and recyclable building materials that do not impair human health, and have less harmful effects on the environment [5]. The scope of these natural materials to be used for insulation of buildings, to ensure sustainability of buildings and constructions, is important, keeping thermal performance as one of the main selection criteria for building insulation. Sustainability assessment, when choosing building insulation materials, can assure optimal performance and also help minimize long-term effects on society and the environment (Cetiner & Edis, 2014). The assessment considers sustainability factor, as the most important criteria. While considering sustainability factor, the most important parameter that determines insulation selection is related to material availability, since the use of local materials helps in reduction of economic and environmental impacts, and also helps in reduction of GHG emissions. The assessment also considers thermal performance focusing mainly on thermal insulation properties, along with considering technical, economic and environmental properties of the material also.

With the market being dominated by different types and forms of conventional insulation materials, there is the need for alternative, new, and unconventional materials to be used for building insulation, to develop more environment friendly buildings, amid the widespread concerns for sustainability and climate change (Viel, Collet & Lanos, 2019). The use of insulation materials made from natural resources, which can aid in the decarbonization of construction activities, is taken into consideration. Such unconventional insulation materials have the scope of being made from natural sources including agricultural wastes, recycled materials, and waste products from other processing sectors (Streimikiene, 2020). The use of such natural biological materials which are locally available, with similar or lower costs, along with having physical and mechanical properties comparable to that of conventional synthetic materials is considered. According to sustainability criteria, favorable environmental impact including CO2 emissions and health impact is also looked at. Other criteria like resistance to fire and water vapour diffusion, are properties which can be analyzed and enhanced using additives or other systems.

Recent studies have shown that characteristics of insulating materials made from biological fibres are similar to that of traditional insulation materials (Streimikiene, 2020). Hence, there is scope for natural materials, especially residues and by-products of agricultural sector, to be used as alternative to conventional insulation materials.

3. METHODOLOGY

The stages involved in the study are shown in Figure 2 below.

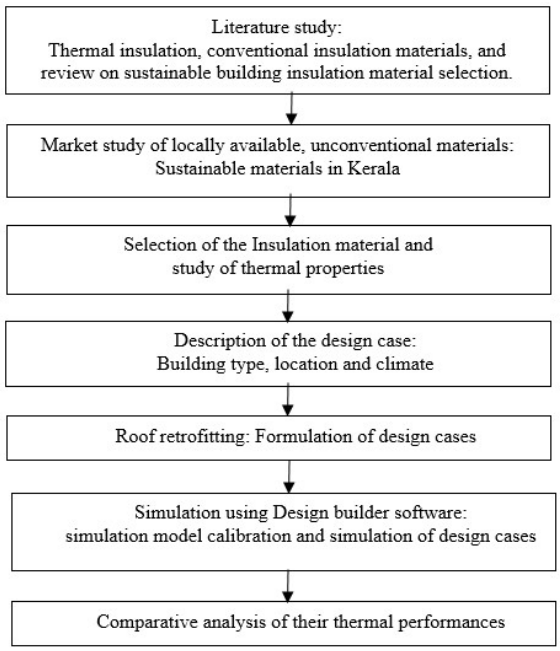

Figure 2: Methodology of the study. Source: Author

3.1 Sustainable material study: Context of Kerala

The material study is concerned with the use of agricultural by-products and residues, and having no conflict with the planting and harvesting of food crops. Kerala is rich in natural fibres like coconut husk, cotton fibre, banana fibre, straw, pineapple leaf fibre, rice husk and tapioca stalks, all of which form a part of sustainable materials [8]. These by-products are the major sources of agro-based bio-fibres, and can be considered as sustainable building materials for the construction industry, and suitable for various industrial applications. Effectively and efficiently utilizing these locally available natural fibres would benefit the state's economy and also help create an eco-friendlier environment (Lekshmi & Subha, 2011). Their scope to be used for thermal insulation purpose is considered.

3.1.1 Coir fibre

Coir is a natural fiber which is the fibrous husk of coconut. Due to Kerala's abundance of coconut trees, 60% of the white coir fibre consumed worldwide is produced there, making coir the state's greatest cottage industry (Coir Board, 2022). Coconut husk is

the cheap residue available abundantly from coconut production. When fully mature coconuts are harvested, the fibrous layer which is separated from the hard shell by the process of de-husking, is then beaten into fibre. This versatile, coarse, natural fibre obtained is coir. The mature brown coir fibres are stronger but less flexible than fibres such as flax and cotton. It is the only natural fibre that can withstand being damaged by salt water, and is comparatively impervious (Coir Board, 2022).

Figure 3: Transformation of coconut into coir fibre. Source: Coir Board, 2022

Studies have shown that, the construction sector has a lot of potential for utilising coir fibre as a natural composite, with the immense availability of coconut trees in the state. Coconut husks are used to make high strength, high density board materials, without the use of chemical binders. These boards have properties, which are comparable to those of commercial wood based panels (Lekshmi & Subha, 2011). They are available in different densities and thickness.

3.1.2 Market study

Market study was conducted on different coir boards available, and their scope to be used as an insulation material is investigated. Following are the 6 different coir boards available in market, listed out based on their density and thickness.

Figure 4: Coir boards available in the market. Source: Author

Table 1: Coir boards types available in market. Source: Author

Sl. no	Density (kg/m3)	Thickness (mm)
1	208	6
2	160	8
3	75	8
4	60	12.7
5	174	8
6	75	38.1

3.2 Testing for thermal properties

3.2.1 Sample preparation

The 6 coir boards identified from market study were collected. Samples were prepared into circular shaped pieces of size 50-70 mm diameter (Figure 5) for testing for thermal properties. Two circular pieces (of same size) were prepared for each coir board type; with a minimum thickness of 2mm for each circular piece. Type 6 coir board was not selected for testing for thermal properties, because of its large thickness. Samples of the remaining 5 coir boards were prepared for testing.

Figure 5: Samples prepared in circles. Source: Coir Board, 2022

3.2.2 Testing for thermal conductivity

The testing for thermal properties was done in a 'Hot-Disk Apparatus' shown in Figure 6. Two circular pieces (of same size) of each material was used for the testing (Figure 7).

Figure 6: Hot Disk – Thermal Constraints Analyser device. Source: Author

Figure 7: Setting up device for testing. Source: Author

The values for thermal conductivity, thermal diffusivity and specific heat for each type of coir board is obtained from the testing (see Table 2 below).

Table 2: Thermal property values tested of coir samples. Source: Author

Sl. no	Material		Thermal Conductivity (W/mK)	Thermal Diffusivity (mm^2/s)	Specific Heat (MJ/m^3K)
1	Coir 1	208 D 6mm thick	0.08757	0.4242	0.2064
2	Coir 2	160 D 8mm thick	0.0839	0.3468	0.2421
3	Coir 3	75 D 8mm thick	0.06123	0.2703	0.2265
4	Coir 4	60 D 13 mm thick	0.06155	0.7242	0.08499
5	Coir 5	100 D 8mm thick	0.08401	0.4644	0.1809
6	Coir 6	-	-	-	-

3.3 Design Case

3.3.1 Prototype model room

Climate of a place, and the buildings' thermal design and usage are the three main factors that determine thermal performance of any building. Kerala has a tropical wet climate according to the Koppen system and a warm, humid climate based on the Indian climatic zone map (NBC, 2016). Relative humidity varies from 70-90%. Mean temperature reaches a maximum of 32'C, during summers. Ventilation is a factor that mainly determines thermal comfort. Heavy rainfall is another element of consideration. In this climate, roof of buildings is constantly exposed to intense solar radiation. For residential buildings in Kerala, concrete is found to be the most commonly used roofing material, as per Census Data of India, 2011. This study focuses on RCC roofs of residential buildings in warm humid climate of Kerala.

The design case is based on a model room of dimensions 3m x 3m x 3m, with a sloping RCC roof, to represent the residential buildings in the scope of our study (see Figure 8). The pitched roof is taken to be sloping along N-S direction. It is a naturally ventilated room, with one door and two windows. Other construction details are given in Table 3 below.

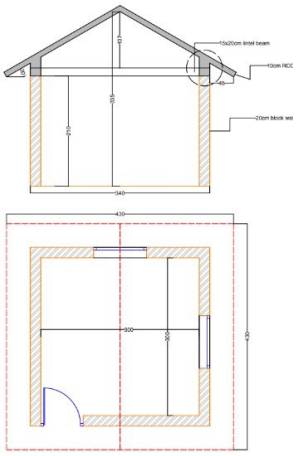

Figure 8: Prototype model room: Plan and Section. Source: Author

Table 3: Construction details of the model room. Source: Author

Building element/ work	Detail and Specification
RCC floor beam	Floor beam of size 20 x 45cm using 20mm reinforcement.
Masonry work	Masonry work using approved, good quality 8" Solid concrete blocks for construction of 20 cm thick walls. Openings left for a door and 2 windows.
RCC lintel:	Lintel beam of size 15 x 20cm, using 12mm reinforcement; given over door and window openings.
RCC roof slab (1:1.5:3)	10cm (4") thick concrete slab; using 8mm reinforcement @ 15cm spacing
Plastering work	Plastering of Internal and external faces of all masonry walls, with cement mortar 1:6; floated hard & trowelled, to get a smooth finish.
Door	Fixing of Flush block board door, 25mm thick, with one side frame.
Window	Window openings with a frame of 25 X 25 X 6 mm angle, and covered with GI weld mesh 25 X 25 X 2.6 mm.
Painting	Applying a coat of primer; and then two coats of exterior grade emulsion/ distemper for external/ internal wall surfaces respectively;

The model room is placed on the terrace of a 3-storey building, to consider the maximum incident solar radiation on a hot, summer day.

3.3.2 Roof retrofitting

Roof is an important element of the building envelope that can help cut the heat flow, as they it is continuously exposed to intense solar radiation. The roof insulation functions to insulate the building against the flow of heat from outside to inside during the day. Insulation material can be used for roofs of new constructions and also for retrofitting existing roof structures, to bring energy savings in the buildings operational phase, by reducing energy consumption. The insulating materials' position within the building structure is another important aspect to be considered (Al-Homoud, 2005). The insulation material for roofs can be positioned below slab or slab top or can also be placed at the center of the building component (Kylili & Fokaides, 2017).

The study focuses on retrofitting of existing residential buildings with RCC roof, with an insulation material, to enhance thermal comfort. For roof retrofitting cases, placing insulation in the exterior surface of existing RCC roof structure, has proven to be the most effective, as seen in previous studies (Joshima, Nazeer & Lakshmi Prabhu, 2021). Hence, the study focuses on retrofitting cases of RCC roof, with insulation material placed outside.

3.3.3 Formulation of design cases

The design case for retrofitting of RCC roof includes the introduction of an insulation material (layer 1) above the existing concrete slab (layer 0).

The insulation material considered is the coir fibre board. From the testing of thermal properties of the coir board samples; thermal conductivity value is seen to range between 0.061 to 0.083 W/mK. Two types of coir board, each of thermal conductivity 0.061 W/mK (Coir 3) and 0.083 W/mK (Coir 2) is taken up for design case.

There is another top layer of roofing material which is either roofing tile or roofing sheet (layer 2), placed above the insulation material. All these above layers have air gaps in between. The design case of retrofitting of RCC roofs in the study includes the following layers as shown in Figure 9.

Layer 0: Existing concrete slab

Layer 1: Coir board as insulation material

- Coir A: Density 160D and thickness 8mm (k=0.083 W/mK)
- Coir B: Density 75D and thickness 8mm (k=0.061 W/mK)

Layer 2: Different roofing materials

- Roofing sheet: GI roofing sheet of SA 0.525 (thickness 3.5mm); k= 72 W/mK
- Roofing tile: Clay roofing tile of SA 0.525 (thickness 20mm); k= 0.83 W/mK

Air gap in between: An optimum air space thickness of 50 mm, is used for the design cases.

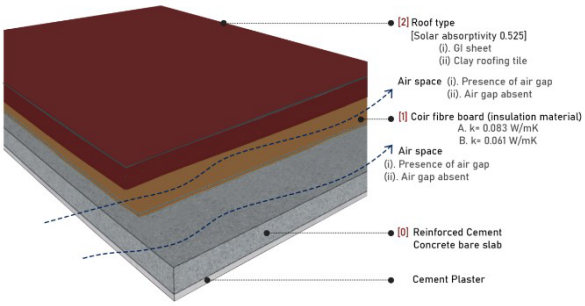

Figure 9: Roof section: formulation of Design cases. Source: Author

The four design cases of RCC roof retrofitting formulated by varying the coir board type and roofing material type, while keeping the air gap constant (50 mm), is as listed below:

- Coir A + roofing sheet
- Coir A + roofing tile
- Coir B + roofing sheet
- Coir B + roofing tile

The thermal behavior of reinforced cement concrete roofs, with coir as an insulation material and different roof coverings (roofing sheet or clay tiles), is studied under ambient conditions, and their thermal performance is analysed and compared using simulation in design builder software.

3.4 Simulation

3.4.1 Design builder software

Design Builder software is used in this study to run simulations of one base case (for calibration) and four design cases of roof retrofit. The climatic file of Mangalore (12.9' N, 74.8'E) representing a warm humid climate was chosen for simulation. Simulations were run for summer design period from the 1st of March to the 31st of May.

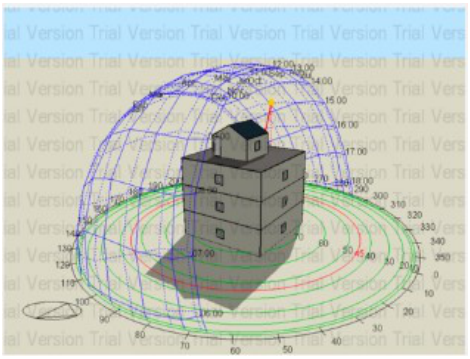

Figure 10: Model room set up in Design builder software. Source: Author

3.4.2 Simulation model calibration

Calibration is a major element in the simulation evaluation process. It is the process of estimating and adjusting parameters of a model, to help improve the agreement between data set of the model and its output. Following are the conditions that have been met, which confirms that the simulated model is calibrated:

- Hourly RMSE less than 30% and Hourly MBE between +-10%.
- Monthly RMSE less than 15%, and Monthly MBE between +-5%.

The simulation model is hence proved to be calibrated. The four design cases listed above are then simulated using the Design Builder software to study the performance under transient conditions and the thermal performance of all the simulated cases are then compared.

Table 4: Model Calibration dataset. Source: Author

	Hourly NMBE	Hourly CV RMSE
T-outdoor air	-2.73	8.69
T-indoor air	4.25	5.22
T-ceiling surface	6.68	7.82
T-roof top	6.46	9.63

4. ANALYSIS

The incident solar radiation (in kW) during the design period from March 1st to May 31st is plotted to find the day with the highest incident radiation (Figure 11). It is seen that the initial half month of March is seen to have the highest range of value. From another detail comparison, March 4th is found to be the day with the highest incident solar radiation.

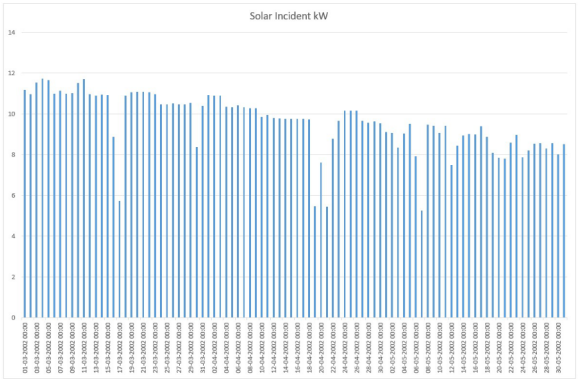

Figure 11: Evaluation of incident solar radiation during the design period from March 1st to May 31st. Source: Author

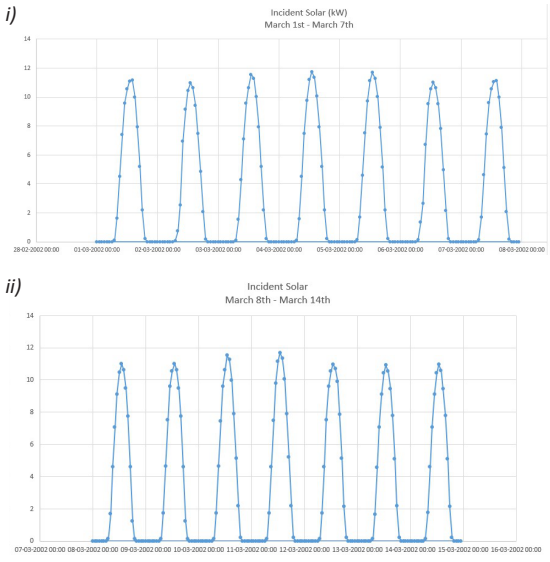

Figure 12: Evaluation of incident solar radiation during (i) March 1-7 and (ii) March 8-14. Source: Author

4.1 Parameters for analysis

The parameters selected for the comparative evaluation are the internal surface temperature of the roof (T_{si}), decrement factor and time lag. The building envelope's ability to store and dissipate heat is defined by its thermal inertia, which is determined by important thermal performance parameters like Decrement factor and Time lag (Asan, 2006). The heatwave amplitude ratio between a building envelope's inner and outer surface is represented by the term 'decrement factor' (f) (Manu, et al., 2016). The decrement factor is calculated for all four design cases based on equation (1).

$$f = (T_{si\,max} - T_{si\,min}) / (T_{so\,max} - T_{so\,min}) \qquad \textit{Equation (1)}$$

Time Lag (φ) denotes the interval of time between the peak of the surface temperature inside ($T_{si\,max}$) and the peak of the surface temperature outside ($T_{so\,max}$) that occurs within a 24-hour period (Manu, et al., 2016). The time lag is calculated based on the equation (2).

$$\varphi = t(T_{si\,max}) - (T_{so\,max}) \qquad \textit{Equation (2)}$$

4.2 Comparative analysis of thermal performance

Comparative analysis is done by comparing values of the selected parameters for the base case and for all the design cases. For detailed comparison, 3 different cases of air gaps (in the roof structure) is also considered for each of the 4 design cases (Figure 13):

- Presence of 2 air gaps (below and above insulation material),
- Presence of 1 air gap (below insulation material), and
- No air gap.

Firstly, the base case is considered. It is the case of the existing RCC roof, with no insulation material nor any roof covering. The inside (T_{si}) and outside (T_{so}) surface temperature are noted and is compared with that of a design case with an insulation material and roof covering (Figure 14). The ceiling temperature of

Figure 13: The 3 cases of air gaps: (i) Presence of 2 air gaps, (ii) Presence of 1 air gap, (iii) No air gap. Source: Author

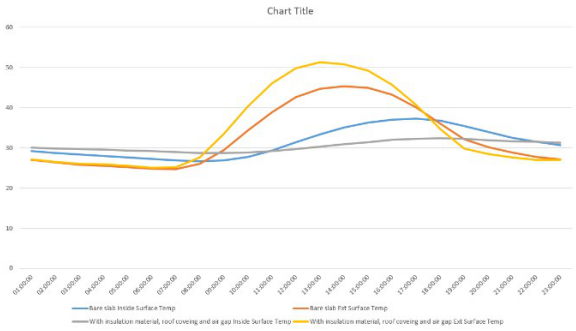

Figure 14: Comparison of T_{si} and T_{so} of base case and design case. Source: Author

Figure 15: Comparison between Tsi and Tso for each design case based on variation in presence of air gap. Source: Author

Figure 16: Comparison of the 4 design cases based on:
(i) Presence of 2 air gaps,
(ii) Presence of 1 air gap,
(iii) No air gap
Source: Author

the design case is lower than that of the base case, which shows the effectiveness of the former in dampening the outside high temperature.

Secondly, all the possible design cases are considered. For each design case, inside surface temperature (T_{si}) and the outside surface temperature (T_{so}) is plotted (see Figure 15). It is observed that the rooftop heats up more quickly, achieves its peak temperature about noon, and then cools down more quickly to return to its initial temperature profile. The ceiling retains a similar surface temperature all through the day, even during the peak hours of high outside surface temperature. The roof covering and the thermal insulation has brought a significant reduction in ceiling temperature when compared to the exterior roof surface. All four design cases follow a similar pattern in temperature distribution (between T_{si} and T_{so}), even within the different cases of air gaps.

For further comparison of the thermal performance of the 4 roof design cases, the inside surface temperature (T_{si}) of all the 4 variants is compared with each other, for each case of air gap (Figure 16).

It is seen that for all the 3 cases of air gaps; the inside surface temperature reaches a lower value when using clay tiles as the roof covering, as compared to using roofing sheet. While comparing the two coir boards, it is seen that there is only slight variation in the inside surface temperature. Out of two coir types, Coir B gives a slightly lower value of T_{si}, when compared to Coir A. The lowest T_{si} is seen in the case of Coir board B, with clay tiles as roof covering.

Analyzing the different cases of air gaps; it is seen that the inside surface temperature reaches the lowest value in the presence of 2 air gaps (for all 4 design cases). There is considerable difference, and the Tsi reaches a higher value in the case of no air gaps. The values of decrement factor and time lag calculated using Equation (1) and equation (2) respectively is given below in Table 5.

The highest decrement factor of 0.325 indicates the inefficiency of (Coir type A + roofing sheet + no air gap) in reducing the high-temperature variations on the inside surface. The low value of decrement factor of 0.144 as seen for (Coir type B + roofing tile + two air gaps), shows a higher level of efficiency and effectiveness in reducing the peak temperature's transmission through the roof. The design cases with no air gap is seen to have the highest values of decrement factor. While, the lower decrement factor values in the case of presence of air gaps, shows that they are more efficient. While focusing on design cases with presence of air gaps, it is seen that the decrement factor is lower for Coir B as compared to Coir A. This can be associated with the lower value of thermal diffusivity of coir board B (0.2703 mm2/s) than board type A (0.3468 mm2/s), that resulted in the lower value of surface temperature.

Table 5: Values of Decrement factor and Time lag of all the design cases. Source: Author

Design case	With 2 air gaps		With 1 air gap		No air gap	
	Decrement factor	Time lag	Decrement factor	Time lag	Decrement factor	Time lag
Coir A + roofing sheet	0.139	5 hours	0.182	5 hours	0.325	4 hours
Coir A + roofing tile	0.148	5 hours	0.188	5 hours	0.310	4 hours
Coir B + roofing sheet	0.135	5 hours	0.172	5 hours	0.281	5 hours
Coir B + roofing tile	0.144	5 hours	0.179	5 hours	0.276	5 hours

5. CONCLUSION

The study discusses the comparison and analysis of thermal performance of RCC roofs under ambient conditions, retrofitted with different roof coverings, focusing on coir-based material as a sustainable insulation material, in the context of Kerala.

The first phase of the study deals with a market study of unconventional and locally available materials in Kerala, and identifies coir as a sustainable material and its scope to be used as an insulation material is looked into. Different types of coir fibre boards available in the market are identified and they are tested for thermal properties. The second phase includes framing of the 4 design cases based on two types of coir boards with different thermal conductivity and same thickness, and two types of roof coverings (roofing sheet and clay roofing tiles). Each of these cases were considered under 3 different scenario of air gaps (within the roof structure); namely 2 air gaps, 1 air gap and no air gap. The third phase deals with simulation of the design cases. Design builder is the software used for simulating the retrofitted design cases, for naturally ventilated residential buildings, during the summer period, in Kerala. The simulation model is initially calibrated. The four design cases are then simulated using the software. The day with the maximum incident solar radiation within the summer design period is identified for further analysis. The thermal performance of all simulated design cases are then analyzed and compared based on parameters like inside surface temperature (T_{si}), decrement factor and time lag.

It is seen that roof covering plays a major part in reducing the inside surface temperature as seen in the analysis. The contribution of clay tiles as roof covering helps reduce the ceiling temperature much lower than while using roofing sheet. The type of coir board used hasn't made much of a difference because of the similar thermal conductivity of both coir board types used. But coir board B, with k value 0.061 performs slightly better than board A, as seen in the slightly lower value attained for inside surface temperature.

Air gap is another significant factor determining the thermal performance. The presence of air gaps within the roof structure has helped achieve lower inside surface temperature.

The best option for thermal performance would be a combination of coir board with lower value of thermal conductivity, clay tile as roof covering, with the presence of air gaps within the roof structure.

The result of the research gives a better understanding in developing thermally efficient roofing solutions using unconventional, locally available materials of a place, rather than conventional materials following the market trend. The study of thermal performance of existing RCC roofs, retrofitted with coir fibre, as an insulation layer and another layer of roof covering, with air gaps in between, is focused only on naturally ventilated buildings, in the warm humid climate of Kerala. This work is also focused on a broader future study on the real time field experiment, of retrofitting of RCC roofs using coir as an insulation material considering an experimental model room, as a prototype for naturally ventilated residences. This work has considered only the thermal properties of coir for analysis of thermal performance, while other parameters like moisture and fire resistance has not been considered. The latter parameters have the scope of being modified using additives, which becomes another interest of future study. The scope of other natural fibres available in Kerala, to be used as insulation material, can also to be further investigated and compared.

ACKNOWLEDGMENT

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Performance Analysis of Green Roofs for Retrofitting Existing Buildings of Tropical Warm Humid Climate

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ABSTRACT: Kerala, located at the southernmost tip of the Indian subcontinent between 8.2" and 12.8" north latitudes and 74.8" and 77.5" east longitudes, has an altitude angle nearer to normal due to its location. The most critical façade in a building in Kerala would be the roof, contributing to occupant discomfort, increased usage of air conditioners, urban heat island effect etc. In recent years Kerala has been experiencing high temperatures, heat waves and drastic floods. The thermal discomfort of occupants inside the buildings is increasing, and various studies predict a more frequent occurrence of heat waves and floods. According to the United Nations, cities account for roughly 75% of global energy consumption and 80% of greenhouse gas (GHG) emissions. Considering the rapid urbanization that India is undergoing, a model of positive urbanism is required to improve occupant comfort by cutting down on CO2 emissions and energy consumption. With the maximum radiation exposure in a building, the roof plays a crucial role in energy consumption and occupant satisfaction. Hence the design, material composition and thermal and energy performance of the building roof are crucial. The study analyzed user response surveys in Municipal corporation areas of Kerala to understand the roof systems used and their performance concerning thermal comfort. The green roof is not a regularly used system in Kerala. The paper investigates the possibility of retrofitting the unshaded concrete roofs of houses in Kerala as green roofs to improve occupant comfort and thereby reduce the energy consumption of houses in the region. Physical and simulation models of the green roof were prepared, and the performance was analyzed using the building performance simulation software Energyplus.

KEYWORDS: Thermal Comfort, Energyplus, Green Roof, Building Retrofit, Kerala, Building Energy

1. INTRODUCTION

Kerala is situated between north latitudes 8°.17'.30" N and 12°.47'.40" N and east longitudes 74°.27'47"E and 77°.37'.12"Eat the southernmost tip of India is a fully electrified state with over 1.5 lakh consumers and is expecting 38,756 million units (1 unit= 1 kWh) of total power consumption by 2026-27, of which, as per the current trends, approximately 50% will be in the residential sector (51.18% as in 2016-17(KSEB, 2020). Hence the residential sector alone will be spending around 20000 million kWh of electricity per year in another five years.

Kerala falls under India's warm and humid climatic zone and therefore displays a varying range of temperature and humidity throughout the year (refer to Figures 1 and 2). The humidity values fluctuate rapidly for various climatic reasons, even on the same day. These varying thermal conditions create thermally uncomfortable indoor conditions inside built spaces. Thermal comfort, which is part of the indoor environmental quality of indoor spaces, is an important parameter which can affect the health, productivity, cognitive performance and overall quality of life of the building occupants (Nair et al., 2022).

Heat transfer through the roof and the radiant heat retention properties of the roofing material play a very crucial role in determining the thermal comfort inside the built spaces of Kerala. Creating a thermally comfortable indoor environment is the biggest challenge architects face in the tropical belt (Kabre, 2010).With almost 1.5 lakh domestic customers and the higher per capita income and standard of living that the state has, more people resorting to air conditioning will drastically change the state's energy expenditure pattern.

The traditional roof system of Kerala consisted of wooden rafters overlaid with Mangalore tiles over a wooden ceiling. The enclosed attic space acts as insulation in itself, thus improving the roof's performance up to 3 times (Dili et al., 2010). With the change in the matrilineal system of the family to that of nuclear families and the availability of concrete as a cheaper material and labour option concrete, terraced houses became popular in the Kerala region. Also, due to industrialization and globalization, there was a drastic change in the usage of building materials. Reinforced concrete (RCC) terrace roofs have become the popular roofing option in most parts of India. The

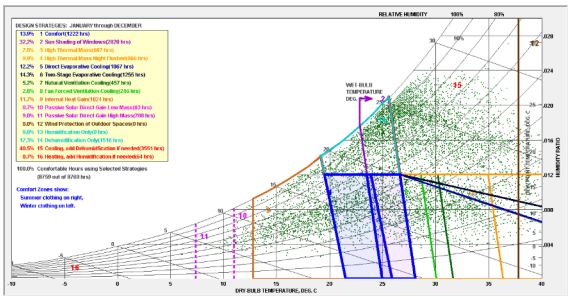

Figure 1: Psychrometric Chart for Trivandrum, Kerala.
Source: Climate consultant software

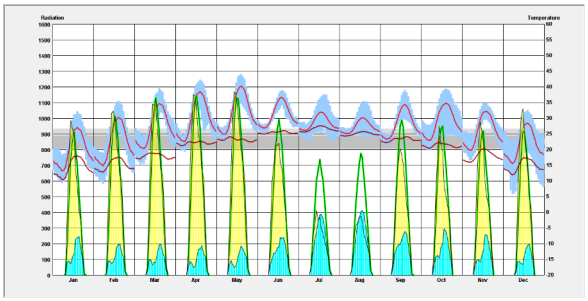

Figure 2: Monthly Diurnal Averages.
Source: Climate consultant software

use of materials like concrete which has higher embodied energy, heat penetration coefficient and varied material properties like thermal conductivity, heat capacity, surface emissivity etc., has eventually resulted in higher indoor air temperature and is also contributing to the heat island effect in the urban environment (Hong & Lin, 2014). Renowned architect Laurie Baker introduced the use of filler slab reinforced concrete slabs, which perform better than the conventional RCC slab due to the air packets between the tiles (Sengupta, 2008).

Whitewashing (White reflective painting) is one of the simplest solutions which people of the region incorporate, which reduces the roof surface temperature by 7.5 degree Celsius (Dornelles et al., 2011). Proper shading of the roof is also an effective solution. Parasol roofing, i.e. addition of an external ventilated roof skin over the main skin is one of the most viable solutions for indoor temperature moderation used in the region. Simply put, a parasol roof acts as an umbrella, shading the main roof from solar radiation (Sadevi & Agrawal, 2019). Urban greening is a prominent practice that can be considered in thronged cities to reduce the effects of the increasing environmental changes and increase the thermal comfort inside buildings. Green roofs (GRs) are a form of urban greening that can be implemented in overpopulated and crowded cities like that in Kerala, where the population density is very high. The terraced concrete rooftops of Kerala are mostly left open at the time of construction but later, as the thermal discomfort increases are roofed by Parasol roofing (aluminium roofing). Green roofs can be an efficient alternative to unshaded or metal sheet roofed terrace roofs of Kerala. Green roofs (GR) consist of a vegetative layer grown on some medium, i.e. water/soil etc. and protected by insulation and waterproofing layers. The two types of green roofs are extensive and Intensive green roofs. Extensive green roofs with a shallower layer of greenery and ease of maintenance will be a preferable option for retrofitting unshaded concrete roofs. Extensive green roof also won't cause an excess load on the structural system of the existing building (Li & Yeung, 2014; Poptani & Bandyopadhyay, 2014).

Green roofs are widely used worldwide for the insulation of buildings roofs (Oberndorfer et al., 2007), as it provide steadier outside roof temperatures in winters and summers (Tian et al., 2017). Green roofs absorb lesser radiation when compared to other conventional roofs and induce a cooling effect through the evapotranspiration of plants and irrigation.

The GRs mainly regulate the indoor thermal environment by insulation and shading of building components (Sailor, 2008). The insulation effect is dependent on factors like foliage density, the density of the substrate and other thermal properties of the roof system (Sailor, 2008).

1.1. Variables affecting green roof behaviour

There are various parameters which affect the thermal performance of the green roof (Kokogiannakis et al., 2014; Kolokotsa et al., 2013; Santamouris, 2014).; which are:

- Solar geometry and orientation of the roof determine the surface temperature of the roof; and hence the heat penetration inside the building
- Thermal capacity, Heat penetration coefficient and thermal lag of the materials used to form the green roof system regulate the indoor ambient temperature and the sensible heat released by the roof
- Outdoor ambient temperature and air movement determine the heat transfer coefficient between the atmosphere and the roofing material
- Other factors include evapotranspiration from leaves, moisture content of the soil, irrigation and evaporation rate etc.

Tropical regions with high temperatures and high humidity levels need passive solutions to reduce internal heat gain and create thermally comfortable conditions. Green roofs being a passive design strategy, have the potential to regulate the indoor thermal environment of tropical areas effectively. However, not many quantitative studies have been carried out in this regard in the tropical context.

The paper analyses the performance of a typical green roof in Kerala's warm and humid conditions and compares its thermal performance with the conventional RCC roof in Kerala. This research mainly

focuses on the material properties of the green roof system and its ability to regulate indoor ambient temperature.

2. METHODOLOGY

A survey was conducted to analyze the types of roofs found in Kerala and the occupant's thermal comfort. A simulation-based comparison (using Energyplus as a simulation engine) of a green roof and a regular RCC flat roof has been made. The variations in heat gain of a green roof with a regular roof are assessed using a physical model study. The study compares the unshaded concrete flat roof in which the mainstream respondents of the survey are staying (which also represent the majority of houses of Kerala) to "Green Roofs", which are not a popular option in Kerala. The two options were compared in terms of their U values, Indoor ambient temperature, outdoor temperature and thermal lag across various time periods.

2.1 Description of the building used for the simulation.

- A base case- with a 12.5 cm RCC roof with cement plaster on both sides
- A green roof with a 5 CM vegetation layer, soil layer 8 cm thick, wooden sheathing 2 cm thick, Jute layer of 0.5 cm thick, tarpaulin sheet 0.3 cm thick with 12.5 cm RCC slab and cement plaster

The above-mentioned models are analyzed using the Open studio Application 3.4 version. The open studio runs the analysis on Energyplus software as a rear engine to simulate various building conditions. The Sketchup plugin for Openstudio was used to model and simulate both GRs and normal RCC flat roofs. Energyplus is one of the most accepted open-source building energy simulation software and is based on fundamental heat balance principles DOE(2015).

Table 1: Properties of design case Green roof model used for simulation. Source: Author

Name	Units	RCC	Brick Wall	Wood Sheathing	Jute Bag	Tarpaulin Sheet
Roughness		Medium Rough	Medium Rough	Medium Rough	Rough	Medium Smooth
Thickness	m	0.125	0.2	0.12	0.005	0.003
Conductivity	W/m-K	1.046	0.54	0.12	0.068	0.33
Density	Kg/m3	2300	1500	800	190	1350
Specific Heat	J/Kg-K	657	840	1300	1360	1674
Thermal Absorptance		0.9	0.9	0.9	0.9	0.9
Solar Absorptance		0.7	0.7	0.7	0.7	0.7
Visible Absorptance		0.7	0.7	0.7	0.7	0.7

Table 2: Properties of Base case RCC Flat roof model used for simulation. Source: Author

Name	Units	RCC	Brick Wall
Roughness		Medium Rough	Medium Rough
Thickness	m	0.125	0.2
Conductivity	W/m-K	1.046	0.54
Density	Kg/m3	2300	1500
Specific Heat	J/Kg-K	657	840
Thermal Absorptance		0.9	0.9
Solar Absorptance		0.7	0.7
Visible Absorptance		0.7	0.7

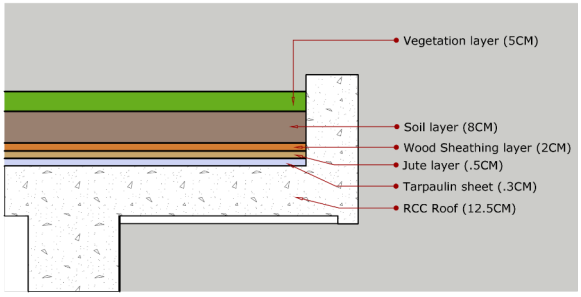

Figure 3:Green Roof detail used for simulation. Source: Author

2.2 Description of the Online- survey conducted

An online survey was conducted among 93 respondents using the purposive sampling technique in the survey monkey platform with an equal number of respondents from the three Municipal corporations of Kerala, i.e. Trivandrum, Cochin and Calicut. Here the researchers used their own judgement in the process of selecting representative samples from the population. The questionnaire consisted of 8 multiple-choice questions and one question based on a likert scale rating.

The survey has been designed with the objective of understanding the level of comfort in houses with various roof types. The data was used to conduct an independent sample test using SPSS to identify the significant difference between the levels of comfort associated with each roof type.

2.3 Description of the Physical model study conducted

A physical model-based study was conducted to understand the time lag of both the unshaded concrete flat roof and the green roof. An RCC roof 12.5 cm thick with cement plaster on both sides and a green roof with plants 5 cm thick, earth layer 8 cm thick, wooden sheathing 2 cm thick, Jute 0.5 cm thick,

Table 3: Independent sample test between roof type and level of comfort inside the house

Independent sample test		Levene's Test for Equality of Variances						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Uncomfortable inside your house	Equal variances assumed	2.69	0.105	-1.80	71	0.07	-0.612	0.338
	Equal variances not assumed			-1.60	17.43	0.12	-0.612	0.381

tarpaulin sheet 0.3 cm thick with 12.5 cm RCC slab and cement plaster on both sides were constructed, and the thermal lag was measured using a T- type thermocouple.

3. RESULTS AND ANALYSIS

By analyzing the survey results, the mainstream respondents stayed in concrete terraced houses with no shading, and 66% of occupants responded that they felt uncomfortable during summer. It is also noticeable that not even a single respondent is living in houses with green roofs. Most of the contemporary houses in the region have concrete roofs, flat or sloping. The indoor temperature, especially in the upper-storey rooms, is beyond the levels of comfort and people who can afford to resort to air-conditioning. As per the survey results, in Kerala, more people are trying to air-condition at least the bedrooms. Such later additions can be seen in many houses in the region. Also, as per the survey, occupants resort to modifications and retrofitting to the building, which was not planned earlier at the design stage of the buildings for achieving thermal comfort. The modifications include aluminium roofing, air conditioning, the addition of coolers and fans, the use of reflective paints, etc., which affects the building aesthetics and increases the expenditure for thermal satisfaction inside the building. When one bedroom is air-conditioned, there is a critical transition in energy expenditure from 80Watts for a ceiling fan to a minimum of 1000 watts for an air conditioner.

Table 3 shows the results of the independent sample test of respondents residing in residences with different types of roofs and their level of comfort in their houses. The sample results show no significant difference in their comfort level under the three types of roofing. All categories of respondents are of the opinion that they are uncomfortable during peak summer. The respondent's level of comfort toward different roofing systems has been shown below with their mean and standard deviation (Refer to Table 4). Respondents residing in spaces roofed with terracotta tiles have a mean score nearer to 3.00, which is 2.7, which shows that they are uncomfortable during monsoon. Even though the temperatures are low compared to summers, the discomfort during the monsoon period can be tagged with the high humidity experienced in Kerala during monsoons.

Table 4: Mean Score and Standard Deviation of type and level of uncomfortable inside the house. Source: Author

Roof type	Comfort status	N	Mean	Std. Deviation
Concrete roof, (Not shaded)	uncomfortable	59	2.1017	1.09379
Metal sheet	uncomfortable	20	2.05	1.14593
Terracotta tiles	uncomfortable	14	2.7143	1.32599

Kabre (2010) identified the major roof systems in Trivandrum (Table 5) and calculated the U value of

Table 5: Roof systems of the region with U Value. Source: (Kabre, 2010)

No.	Roof System	U-value (W/m2K)
1	Mangalore tile (15 cm) on wooden rafter, wooden ceiling.	1.83
2	Filler slab (100 cm) cement renders both sides (12 cm).	3.94
3	Fish clay tile (10 cm,2 layers) on wooden rafters.	4.88
4	Reinforced Concrete (100 cm) 12 cement renders (12 cm) air gap (25 cm) Mangalore tile.	1.96
5	Aluminum sheet (26 gauge) Air cavity (600 cm) wooden ceiling (20 cm).	1.49
6	Funicular shell, lime concrete (100 cm), gravel concrete (50 cm), cement render (12 cm)	2.45
7	Reinforced Concrete slab (100 cm), cement render on both sides (12 cm).	3.62
8	Mangalore tiles (15 cm) Reinforced Concrete rafters.	5.29
9	Ferro cement channel (25 cm).	3.86
10	25 Clay tiles (25 cm) cement vermiculite (1:6,125 cm) Reinforced Concrete (50 cm) lime concrete (50 cm, brickbats) broken ceramic tiles.	1.4
11	Red mud polymer.	4.98

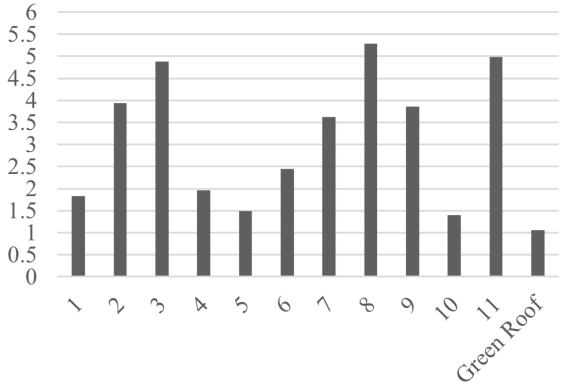

Figure 4: Comparison of U value Roof systems of the region with U Value (source: (Kabre, 2010)) vs design case green roof

different roof systems based on onsite measurements. The 'U' value of the RCC roof was used as the base case, and the indoor ambient temperature for all months was simulated in the open studio. The RCC roof was then retrofitted to create the green roof, which is the design case for the study with a 5 CM vegetation layer, soil layer 8 cm thick, wooden sheathing 2 cm thick, Jute layer of 0.5 cm thick, tarpaulin sheet 0.3 cm thick. Table 5 shows that the U value of the green roof system calculated using Energyplus software is lesser (R= 0.9430 m2K/W, U-value = 1.06 W/m2K) than all the conventional roof systems used in the region, and hence green roofs can be suggested as a possible alternative and also retrofit the unshaded concrete roofs of the region.

Figure 5 explains the indoor ambient temperature of both the base case and the design case on the summer solstice's hottest day in the year (June 21). The outdoor dry bulb temperature marked the annual maximum, 36 degrees Celsius during the afternoon hours, with the average highest outdoor temperatures reported between 2 PM and 5 PM. During the hours with the highest outdoor temperature, the base case has an average indoor zone air temperature of 40.7 degrees Celsius, and the design case, the green roof, has an average indoor temperature of 38.2 degrees

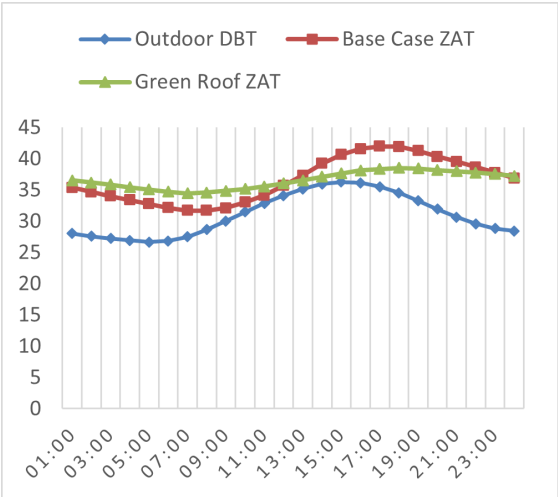

Figure 5: Performance of Green Roof vs Concrete Roof on the summer solstice (June 21). Source: Author

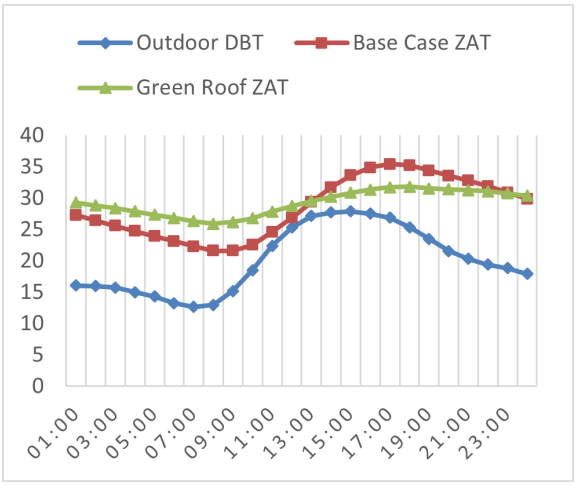

Figure 6: Performance of Green Roof vs Concrete Roof during winter solstice (December 22). Source: Author

Celsius. This shows a drop of around 2 degrees, which should be acknowledged when considering the passive nature of the green roof, suggesting GR as a possible alternative to the concrete roof in summer.

Figure 6 explains the indoor ambient temperature of both the base case and the design case on the coldest day of the year, the winter solstice (December 22). The outdoor dry bulb temperature marked the annual minimum, which is 12.7 degree Celsius during the morning hours. The average of the highest outdoor temperatures was reported between 2 PM to 5 PM (27.9 degrees Celsius). During the hours with the lowest outdoor temperature, the base case had an average indoor zone air temperature of 22.3 degrees Celsius and the design case, the green roof, maintained an average indoor temperature of 26.8 degrees Celsius. The green roof can stabilize the indoor zone air temperature at most of the peak temperature points across the year. The green roof can reduce the indoor ambient temperature in the summer and prevents heat loss during the winter. Proper optimization of various parameters, such as the

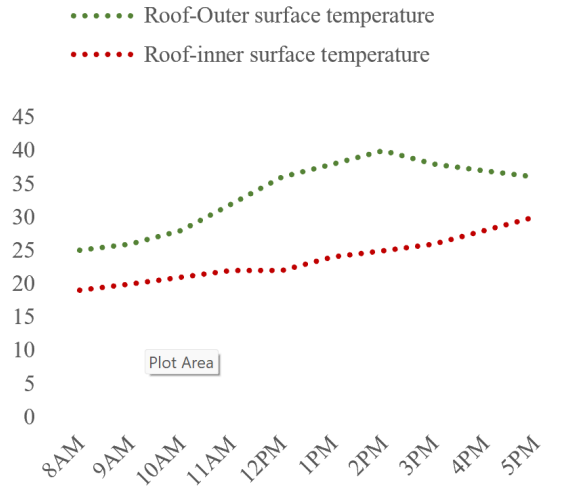

Figure 7: Surface temperature data of RCC roof slab model. Source: Author

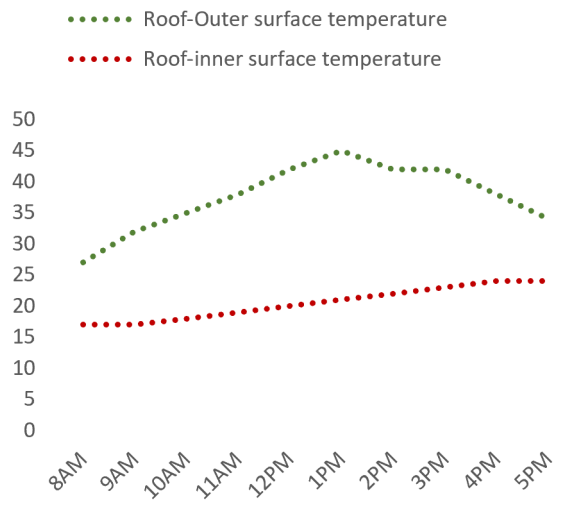

Figure 8: Surface temperature data of green roof slab model
Source: Author

composition of materials in green roofs, could result in better performance of the green roof.

The time lag and decrement factor of both the base case and the design case was also studied in order to predict how much radiant heat will be emitted by the roofing material during the lowest temperature hours. A physical model of both the design case and the base case was constructed in the laboratory. A digital voltmeter was used to calibrate the data. A time lag of 3 hours and a decrement factor of 0.75 was obtained for the base case (Figure 7), and a time lag of 4.5 hours and a decrement factor of 0.55 was obtained for the design case, which is the green roof (Figure 8).

4. CONCLUSION

The building occupant survey response data reveals that most occupants were uncomfortable with the mainstream roofing options available in the Kerala region, especially in peak summers. The occupant's comfort and energy consumption of the buildings should be considered and analyzed in the initial planning and design development stage to ensure the building sector's sustainability. Building retrofits in the form of aluminium roofing, reflective paints etc., were implemented to satisfy the occupant's thermal comfort at a later stage, which in most cases, did not go well with the architectural character of the building and resulted in more expenditure for thermal satisfaction. The extensive green roofs have good aesthetic features and thus go well with most contemporary built forms. The simulation and thermal lag study using a physical model show that the extensive green roof performs better than the RCC roof and can be used as an effective retrofit solution to reduce the cooling load. Further studies on evapotranspiration, irrigation, various plant types suitable for extensive roofing and also life cycle analysis of green roofs in tropical regions should be done to completely assess the performance of green roofs and identify the complete potential of green roofs for retrofitting existing buildings of tropical warm, humid climate.

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Thermal Performance and Cost-effectiveness of Roofs

An Investigation on Urban Residential Buildings of Kerala

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ABSTRACT: This study explores the thermal efficiency and cost-effectiveness of commonly used roofing systems in urban residential buildings of Kerala. A representative one square-kilometer area in Trivandrum, the capital city of Kerala is considered for the study. The roofing systems present in the area are identified through satellite imageries and field survey. The nine roofing types identified are assessed for its thermal performance (i) based on its thermal properties such as U-value, decrement factor and time lag, (ii) thermal performance index (TPI), and (iii) its impact on cooling load. The cooling load (KWh) is then converted to INR using the rate slabs provided by KSEB and is compared with the cost of construction to understand the monetary efficiency of each roofing types. It was observed that the base case - Exposed R.C.C flat-roof performed the worst with TPI of 72.82%, and highest annual cooling load of 3415 KWh. The roofing type, R.C.C flat-roof with white painted (Case-5) is found to be having the lowest pay-back period, while Vegetated R.C.C terrace roofs (Case-6) showed the lowest cooling load and has the second lowest payback period. From the study it is also found that the burnt clay surfaces showed the lowest mean peak outside surface temperature and the lowest mean peak inside surface temperature was found on wooden films. In the common scenario of choosing roofs with low initial expenses, the study throws light on its thermal performances and payback periods.

KEYWORDS: Cooling load, Cost-efficiency, Payback period, Roofing systems, Thermal performance

1. INTRODUCTION

India's goal of reducing Green House Gases(GHG) by 33% to 35%, from 2005 levels by 2030, can be met by improving energy efficiency or lowering energy demand. India's building sector is the second-largest consumer of electricity, accounting for nearly 30% of overall power consumption. According to a survey on electricity consumption in India, the use of energy for indoor heating and cooling will expand to more than five times its current level by 2030. Increased use of decentralized-room-based air conditioning devices for thermal comfort is one of the major factors driving this significant increase in electricity consumption, (BEE, 2019, p. 2). In view that a building's roof is the most heat gaining element on it, studies pertaining to the effective reduction of heat gain through roofs are indispensable (Madhumathi, Radhakrishnan, & ShanthiPriya, 2014).

The census data of 2013 shows that the roofing trend in Kerala is heavily moving towards G.I/Metal/ Asbestos sheets/Concrete which constitutes 58.64% of residential roofing types in Kerala. While Hand/ Machine made roof tiles are occupying only 36.71% of the houses and Grass/Thatch/ Bamboo/Wood/Mud/ Polythene is occupying only 3.25% (NBO, 2013, p. 107). The cost effectiveness, durability of the material and lastly the suitability of the material in the climate are the criteria that lead to their preference among people. These most used roofing materials are also seen among the list of materials with high Carbon emissive production nature, high production of chemical by-products that are hazardous in nature and high embodied energy.

This study focuses on the thermal performance and cost effectiveness of the roofs that are prevalent in urban Kerala. A roof with high thermal performance and low pay-back period is supposed to be the most desirable one. This investigation will include the construction cost of the roof types and their operational cost dedicated to cooling the space (Considering the climate of Kerala, warm-humid), to understand the feasibility of the roofing in long run from its payback period.

2. MATERIALS AND METHODS

Roof types for the study were identified from the representative location in the capital city of Kerala. The identified roofs were thermally evaluated using empirical methods, site measurements and simulation; later, findings were compared to validate the methods. In the empirical method of thermal performance evaluation, U-value of the roofs were calculated using thermal conductivity and thickness of each layer of materials. Specific heat capacity and density of the material is also looked at for a better understanding of its thermal properties. Using site measurements, time-lag, decrement factor and thermal performance index was found out for the selected roofs. Further, the roof types were simulated in Design Builder to obtain its cooling load requirements in Kerala climate. The cooling loads were then converted to Indian National Rupees (INR) using Kerala State Electricity Board (KSEB) price slabs and compared with the worst performing case to identify savings in cooling expense (Wan Iman Wan, Royapoor, Wang, & Roskilly, 2015). These savings were then

equated with the roof construction expenses to determine its payback periods.

2.1 Identification of roof types

Roofs were identified from a representative urban neighborhood in Trivandrum called Vellayambalam with the help of site inspection and google earth study. More than 14 types of roofs were identified from the study area. Approximately one square kilometer of urban area was considered for identifying the roofs. The prevalent roofs in the urban area of Trivandrum were identified to be R.C.C Flat-roofs (40%), Metal sheet roofs (43%), Burnt Clay tiled roofs (11%), White painted RCC roofs (1%), Vegetated roofs(1%) and Others(4%), as depicted in Figure 1. Others included composite roofs, tile floored terraces, photovoltaic roofs, R.C.C pitched roofs(exposed), sheet roofs of PVC and other materials.

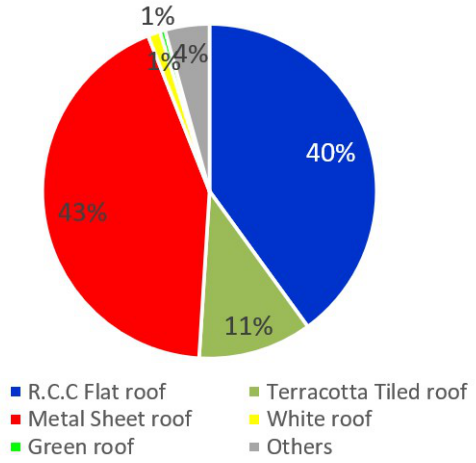


Figure 1: Roofing types in Vellayambalam.

From the identified roof types, nine were selected for the study as they form a significant portion of the total roof types found in the study area. They are taken as cases for further study in this paper;

Case1 . - R.C.C Flat-Roof
Case2. - R.C.C Flat-Roof with Gypsum False Ceiling
Case3. - R.C.C Flat-Roof terrace with G.I Sheet Roof Cover
Case4. - R.C.C Pitched Roof with Terracotta Tile Embed
Case5. - R.C.C Flat-Roof White Painted
Case6. - R.C.C Flat-Roof with Terrace Garden
Case7. - Clay Tiled Roof with Wooden Attic
Case8. - G.I Sheet Roof with Wooden False Ceiling
Case9 - Terracotta Tiled Roof over R.C.C Terrace

2.2 Thermal evaluation of roofs

The identified roofs were subjected to thermal performance evaluation using three methods. (i)An empirical method using the calculations provided by ECBC for compliance checking, (ii)thermal performance index, decrement factor and time lag using the site measurements taken during February and March months and (iii)by cooling load simulations using the software Design Builder.

In empirical methods, the roof's thermal performance was analyzed using U-Value(W/m2K), calculated from the resistance of materials, as shown in equation(1);

$$U=\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}+\ \ldots\ldots\ldots\ldots\ldots+\frac{1}{Ro}+\frac{1}{Ri} \quad (1)$$

Where,
R1, R2, R3… - thermal resistance(m2K/W) offered by each layer
Ro- thermal resistance offered of air film outside the section
Ri- thermal resistance of air film inside the section.

Resistance 'R' of the material was found by equation(2);

$$R=\frac{d}{\Lambda} \quad (2)$$

Where,
R-thermal resistance of the material
d- thickness of the material in meters
Λ-thermal conductivity(W/mK)

Density and Specific heat capacity of the material was also looked at as to understand the thermal performance better. Materials with high density and high specific heat capacity also has high thermal mass. This results in the storage of heat during day hours (Geetha & Velraj, 2012). In the site measurement method, surface temperature variations of the selected roofs were measured using Testo440 thermocouple and infrared thermometer for a time span of 19 hours (5:30AM to 12:30AM) for 7 days. The measurements taken were then used to find decrement factor, time lag and thermal performance index to understand the thermal performance of the roofs. Decrement factor(μ) signifies the heat loss of the material as it travels from its one end of the section to other. The value obtained is between 0 and

Figure 2: Testo440; Controller(left), Thermocouple probe(middle) & MCP; Infrared thermometer gun(right), Source: Photographed by author

1. Value 1 signifies that the material has zero loss of heat while transmitting and the outside peak surface temperature equals the inside peak surface temperature, equation (3).

$$\mu = \frac{Ti.max}{To.max} (3)$$

Where,
Ti.max -peak inside surface temperature
To.max -peak outside surface temperature

Time lag is the time taken for the inside surface temperature to reach its peak after outside surface temperature reaches its peak. It was found using the equation (4).

$$T_{lag} = T_{To.max} - T_{Ti.max} (4)$$

Where,
TTo.max-hour at which outside surface temperature reach its peak(h)
TTi.max-hour at which inside surface temperature reaches its peak(h)
TLag–time lag(h)

The Thermal Performance Index formulated by Chitrarekha Kabre was used for the study as it includes monthly mean air temperature to calculate the TPI values, thus simultaneous measurements can be avoided in the site studies. Mean air temperature is part of the equation (5) to compensate difference in environmental conditions that may arise while taking measurements from sites in different microclimate conditions (Kabre, 2010).

$$TPI^* = \frac{\Delta tc.max - \Delta tc}{\Delta tc.max - \Delta tc.min} x\ 100 (5)$$

Where,
Δt c-Excess of Ceiling temperature over Mean air temperature
Δtc.max-Average maximum excess of Ceiling temperature over Mean air temperature
Δtc.min-Average minimum excess of Ceiling temperature over Mean air temperature
TPI* -New Thermal Performance Index by Chitrarekha Kabre (Kabre, 2010)

2.3 Analytical study

Analytical study was done using Design Builder 4.5.0.148 which uses the Energy Plus simulation engine for its heating/cooling load calculations. The default thermal properties of materials were used for simulation and for a material unknown to the software, values were obtained from secondary data and inputted. Weather data of Trivandrum, Kerala, India, was used for the simulation. Floor area and occupancy of the model was set to 74.32 sq.m and 4.4 people respectively (Department of Economics and Statistics, 2012). Plan aspect ratio was taken as 1:1 to negate any influence of orientation on the modelling. Occupancy hours were set to 17 hours (16:00 to 9:00) on weekdays (Monday to Friday) and 24 hours for weekends. Metabolic factor was considered as 0.90, considering the activities of the space, being light office work/ standing/walking. HVAC is assumed to be supported by split AC with a coefficient of performance (COP) of 5. The light power density and equipment power density was taken as 5W/m2 for the residence (Grondzik & Alison, 2019). Further, the thermal performance was studied using cooling load obtained from simulation under the set base conditions.

2.4 Cost analysis

Cost analysis was done in four steps. First step was to convert the cooling load energy (KWh) calculated from simulation into Indian Rupee (INR) using Kerala State Electricity Board (KSEB) rate slabs thus finding the annual cooling expenses, as shown in Table 1. Second step was to find the savings in cooling expenses by each roof cases by comparing it with the base case. Third step was to find the construction cost of each roof types based on current market rates. The fourth and final step was to compare the construction expenses of each roof with the savings in cooling expenses it achieves, to find the payback period of the roofs.

Table 1: KSEB rates as on February 2022, Source:www.kseb.in (Tariff at a glance, 2022)

UNITS (KWh)	RATES (INR/KWh)
KSEB	**Telescopic slabs**
0-50	2.9
51-100	3.7
101-150	4.8
151-200	6.4
201-250	7.6
Flat slab	
>250	5.8

For the convenience of calculation Flat slab was considered. KSEB telescopic slabs are applied for energy consumption occurred during a period of two months. As the study obtains only the annual cooling load electricity, it is logical to follow flat slab prices.

For calculating the construction costs, the average household floor area of urban Kerala, 74.32 Sq.m was considered (Department of Economics and Statistics, 2012). For this floor area, the market rates (February 2022) were obtained for its roof construction which was later used for the calculation of the payback period. The comprehensive rates including labor, material and transportation taken for the study were obtained from various vendors and contractors who worked in Trivandrum, rates are as shown in Table 2.

Table 2: Roof constructions works and their market rates on February, 2022, Source: Primary study

WORKS	COMPREHENSIVE RATES (INR)
R.C.C, 2% reinforcement, 1:1.5:3	1149 Rs/Sq.m
Gypsum False Ceiling, 15mm, Al. channels	125 Rs/Sq.ft
G.I Sheet Roof, 18-gauge, MS truss and pillars	140 Rs/Sq.ft
Terracotta Roof Tile, pasting on RCC	77.5 Rs/Sq.ft
White Roof Painting	20 Rs/Sq.ft
Green Roof	500 Rs/Sq.m
Wooden floor, 20mm with joists, no rendering	300 Rs/Sq.ft
Mangalore pattern roof tile on MS truss	180 Rs/Sq.ft

RESULTS AND DISCUSSIONS

3.1 Site measurements and empirical study

When the Mean interior surface temperatures of the studied roofs where compared, it was understood that case1, RCC flat-roof has the highest peak temperature of 38.3oC at 17:30 and case7, Terracotta roof tile with wooden attic showed the lowest peak ceiling temperature of 33.7oC at 15:30, as shown in Figure 3.

Due to materials of lower specific heat capacity and thermal mass, case7 roof doesn't store heat as much as the RCC roof types which created hotter environment during the night hours. Roofs case7 & case8 which had wooden attic and ventilated air gap has a time lag of 1 hour and 2 hours respectively while that of the others varied from 4 hours to 5 hours. Studying the Exterior surface temperatures, it was understood that the roofs with terracotta roof tiles showed lower peak temperature readings (47.6oC, Case7 and 55.1oC, Case4) compared to the metal sheet ones(59.2oC) and exposed RCC ones, as shown in Figure 4. Usage of lower peak exterior temperature roofs may help in the reduction of urban heat island, which needs to be studied further.

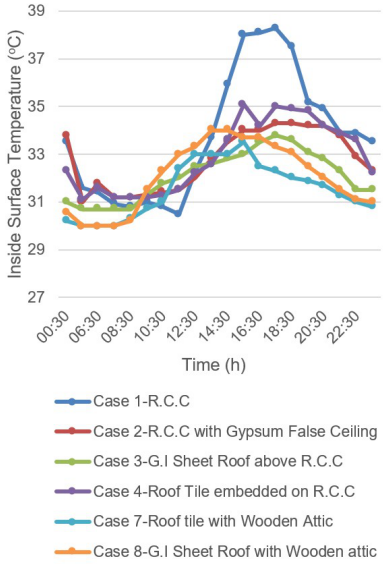


Figure 3: Interior surface temperatures of roofs

Further, the thermal performance index was calculated using equation (5) with the monthly mean outdoor temperature of 29.6oC found out from the site measurements. From comparison of empirical methods and site measurements, it was understood that the Case7 performed better in heat transmittance, which is lower among the studied group with a U-value of 1.2W/m²K as shown in figure 5. This can be attributed to the lower thermal conductivity of material layers and the ventilated air insulation in the attic as shown in table 3.

In congruence with the empirical method, TPI value was also found highest in Case7 with 91.78%. RCC flat-roof performed worst with the highest U-value of 2.97W/m²K and a TPI of 72.82%, as shown in Table 3 & Figure 5.

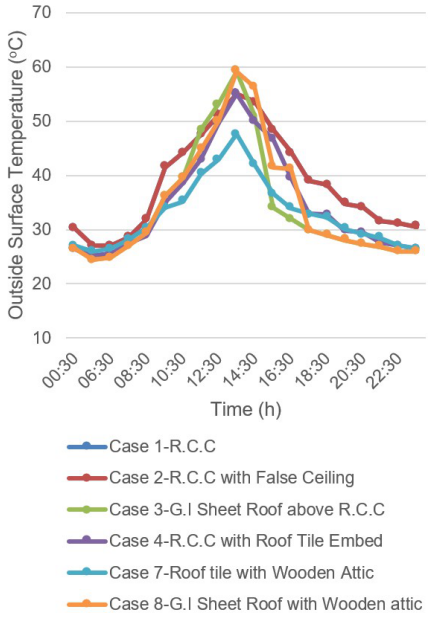


Figure 4: Exterior surface temperatures of roofs

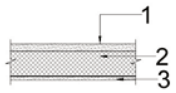
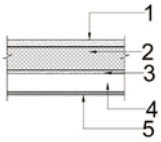
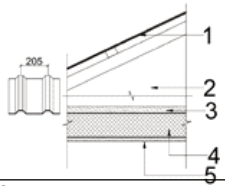
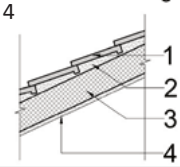
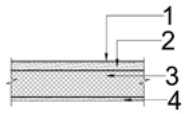
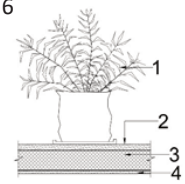
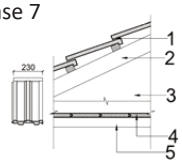
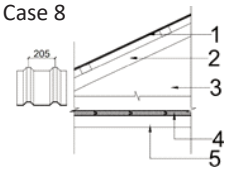
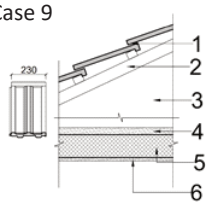
Time lag was found lowest in Case7(1 hour) and Case8(2 hours) in the measured roofs and the highest was 5 hours in Case2. Decrement factor was found lowest in Case3, RCC roof with GI sheet covering, which means that even though the outer layer is heated up-to 59.2oC, the peak inner layer temperature is only 33.8oC with a difference of 25.4oC. Highest decrement factor is for both Case1 and Case7 as 70% of the outer surface temperature is transferred to innermost layer, as shown in Table 3.

3.2 Analytical study

When the results of the simulations were compared, it is understood that the Case6, Vegetated roof showed the lowest cooling electricity load of 1504KWh, followed by Case3 and Case9 with cooling electricity load around 1567KWh, Figure 5.

As expected, Case1 showed the highest cooling electricity load of 3415KWh. The second worst performance in cooling load was Case8 with 2002KWh, followed by Case5 and Case7, Figure 5.

Table 3: Thermal performance of roofs, Source: Primary

Roof section	Layers (Outside to inside)	Density (Kg/m3/)	Specific heat (J/Kg.K)	U-Value (W/m2.K)	Decre-ment Factor	Time lag (h)	TPI* (%)
Base Case (1) 	1. Cement plaster - 30mm 2. R.C.C - 100mm 3. Cement plaster - 15mm	1. 1762 2. 2288 3. 1762	1. 840 2. 880 3. 840	2.97	0.70	4	72.82
Case 2 	1. Cement plaster - 30mm 2. R.C.C - 100mm 3. Cement plaster - 15mm 4. Air cavity - 75mm 5. Gypsum - 15mm	1. 1762 2. 2288 3. 1762 5. 612	1. 840 2. 880 3. 840 5. 950	1.70	0.62	5	88.30
Case 3 	1. G.I Sheet 2. Air cavity. - 150cm 3. Cement plaster - 30mm 4. R.C.C - 100mm 5. Cement plaster - 15mm	1. 7850 3. 1762 4. 2288 5. 1762	1. 470 3. 840 4. 880 5. 840	1.25	0.57	4	90.07
Case 4 	1. Terracotta tile - 20mm 2. Screed - 30mm 3. R.C.C - 100mm 4. Cement plaster- 15mm	1. 1892 2. 1646 3. 2288 4. 1762	1. 880 2. 880 3. 880 4. 840	2.71	0.63	5	85.7
Case 5 	1. White paint film 2. Cement plaster - 30mm 3. R.C.C - 100mm 4. Cement plaster - 15mm	2. 1762 3. 2288 4. 1762	2. 840 3. 880 4. 840				
Case 6 	1. Leafy plants 2. Cement plaster - 30mm 3. R.C.C - 100mm 4. Cement plaster - 15mm	2. 1762 3.2288 4. 1762	2. 840 3. 880 4. 840				
Case 7 	1. Terracotta tile - 20mm 2. Wood rafter 3. Air cavity. - 150cm 4. Wood floor. - 20mm 5. Wood joists	1. 1892 4. 720	1. 880 4. 1680	1.20	0.70	2	91.78
Case 8 	1. G.I Sheet 2. Mild Steel truss 3. Air cavity - 1500mm 4. Wood floor - 20mm 5. Wood joists	1. 7850 4. 720	1. 470 4. 1680	1.32	0.61	1	90.97
Case 9 	1. Terracotta tile - 20mm 2. Mild steel truss 3. Air cavity. - 150cm 4. Cement plaster - 30mm 5. R.C.C - 100mm 6. Cement plaster - 15mm	1. 1892 4. 1762 5. 2288 6. 1762	1. 880 4. 840 5. 880 6. 840	1.21			

3.3 Cost analysis

After converting the cooling load to cooling expense, the savings of each roof were compared. These savings were then tallied with the construction expense of the roofs to find out the period taken for the return of investment. From the exercise it was found that the Case5, White painted RCC roof has the lowest payback period of 1.87 years, attributing to its low initial cost compared to the rest. Roofs with wooden attic showed highest payback periods (Case7 and Case8) due to the high cost of the construction of wooden attic, as shown in table 4.

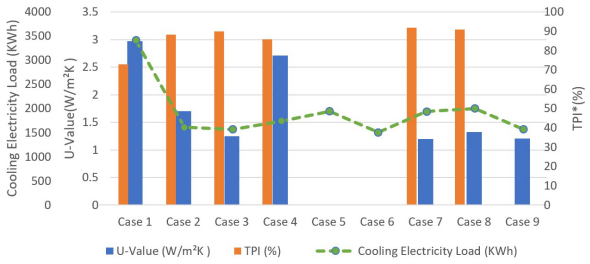


Figure 5: U-value, TPI and Cooling load of the roofs

Table 4: Cost analysis of the roofs, Source: Primary study

Case	Construction cost (INR/ 74.32sq m)	Annual cooling load savings (INR)	Additional construction expense from Base-case (INR)	Payback period (years)
Case1	85409	0 (Base-case)	0	—
Case2	185409	10463	100000	9.5
Case3	197409	10718	112000	10.4
Case4	147410	9697	62000	6.4
Case5	101400	8550	15990	1.87
Case6	122570	11083	37160	3.35
Case7	384000	8572	298590	34.8
Case8	352000	8195	266590	32.5
Case9	229400	10718	143990	13.43

4. CONCLUSION

From the study, it was noticed that the RCC flat-roof performed the worst in all three methods and hence it was kept as a base case for the study. Adding a layer of terracotta tile over this roof only reduces the U-value by 8%, but reduced cooling load by 51%, increased time lag by 1 hour and increased thermal performance by 13%. The other roofs which had lower U-Values (around 50% of RCC flat-roof) also had cooling loads similar to the one with terracotta layer. Hence U-value is not reliable for analyzing the thermal performance of roofs with different layers of materials. Adding air insulation significantly reduced U-value of the roof compared to adding a dense material layer.

Further, time lag was seen greater for roofs with thick and denser section and was lower for roofs with wooden layer instead of RCC. Buildings where day times are occupied denser roof sections can be recommended and where night time occupancy is preferred, lighter sections can be used to reduce cooling load.

It was observed in the site measurements that roofs with terracotta outer layer had lower outside surface temperatures and can be recommended as a strategy to reduce UHI intensity.The cost analysis study showed white painted RCC roof having the lowest payback period. A builder looking for the cheapest solution for reducing cooling load can opt for this roof type. An RCC roof with fully covered vegetation layer seems to be the most feasible roof type, as it has the most cooling load savings and the second lowest payback period.

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Optimization of Classroom Design for Improved Comfort: Warm & Humid Climate

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ABSTRACT: The comfort condition of the classroom users has a direct impact on their productivity level. And thus, it has become a major concern of the designers to enhance the visual and thermal comfort conditions of classroom spaces. This study presents a case of multi-objective optimization of classroom design for enhanced visual and thermal comfort. A representative classroom layout (the Indian Standard Recommendations for Basic Requirements of School Buildings in 1978) in warm humid climatic conditions was chosen for the analysis. Four design variables – building orientation, window to wall ratio (WWR), glazing material type and shading device were considered and a parametric analysis of the same using the Responds Surface Method (RSM) was carried out. The visual and thermal performance of the developed cases in the parametric setup was assessed with the help of the simulation tool Rhino and plug-ins such as Honeybee and Grasshopper. The results obtained from the parametric analysis were considered for the optimization computation with the objectives, (1) thermal comfort- in Predicted Mean Vote (PMV) scale, the value tends to 5 for comfort (2) Visual comfort- in Useful Daylight Illuminance (UDI) scale with value in the range 70% -100% and tending to 100 % for comfort. The optimized output for the considered case was observed to be (6.38 mm clear laminated glass, 65 cm horizontal shading device, 40% WWR and N-S orientation). This study put forward a methodology for design optimization projects for architects and designers. The study needs further refinements with the inclusion of more design variables.

KEYWORDS: Optimization, Parametric Design, Thermal Comfort, Visual Comfort

1. INTRODUCTION

In Architectural design, it is complicated to consider the building integration, inhabitance requirements and the environmental conditions influencing the building (KobraGharouni Jafari, 2020). The comfort condition of the classroom has direct impact on its user and their productivity level therefore; classroom design should pay attention on occupant comfort and performance (Manoj Kumar Singh, 2018). A parametric design approach is used to evaluate the four design variables in classroom design for enhanced visual and thermal comfort.

Students in primary school spend 70% of their time inside the classroom than in other areas and they do not perform adaptive activities such as adjusting the set point temperatures, opening and closing the windows, or adjusting the CLO value on their own (Erica Hinckson, 2015) (Manoj Kumar Singh, 2018). The creation of an environment in which students feel more awake and pay more attention to the information delivered in the lecture contributes to the quality of learning (Henk W. Brink, 2020). When discussing learning efficiency, it is more complete and objective to consider thermal comfort in the context of enhancing indoor environmental quality, which includes visual and auditory comfort (Haiqiang Liu, 2021). Earlier studies show that poor indoor air quality, poor thermal, acoustic and visual conditions affect learning quality and students' mental and physical health. High temperature and low ventilation in a classroom indoors affect the performance of occupants (Miguel Ángel Campano-Laborda, 2020). Large form coefficients, inadequate envelope insulation, and a high window-to-floor ratio all have an adverse impact on the thermal comfort of classrooms (Haiqiang Liu, 2021). Orientation, optimal window-to-wall ratio, space organization, solar shading, and building shape are architectural design characteristics that have a significant role in optimum thermal comfort (Z.S. Zomorodian, 2013).

Day lighting is one of the major aspects which focus in indoor environmental quality in buildings. Several studies have proved that optimum daylight increases student's productivity and improve performance (Haiqiang Liu, 2021). Day lighting is important in biological effects - on the production of cortisol, a hormone that regulates the day-night cycles as well as the student's concentration (Yun-Shang Chiou, 2020). The shade devices comprised of horizontal or vertical blades can increase daylighting uniformity and it will help students' well-being in classroom learning (Simone Secchia, 2015) (Yun-Shang Chiou, 2020).

There are many studies done in the field of thermal and visual comfort analysis in various building sectors. This represents the importance of thermal and visual comfort in educational institutions, and how it affects the student's performance. Over the years climatic condition and environment keep changing which makes this field of study unending.

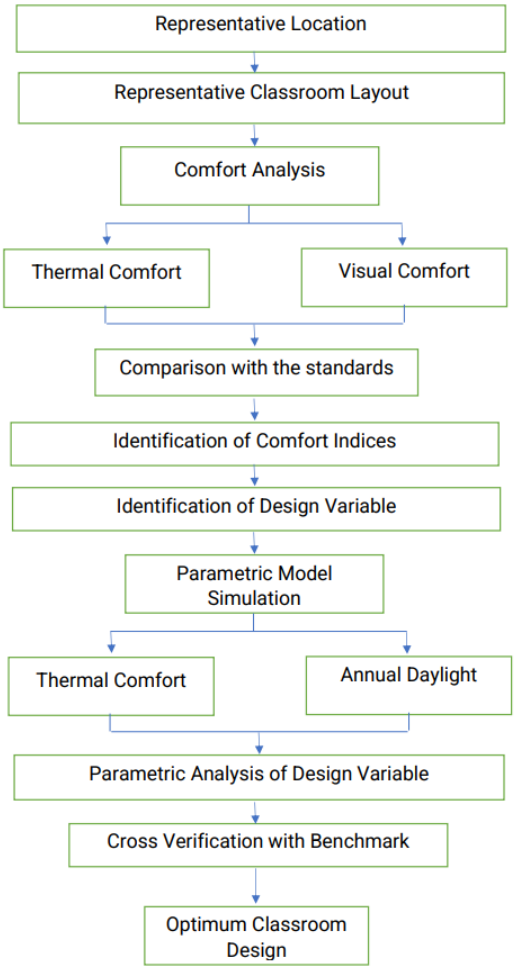

Figure 1: Methodology. Source: Author

There are specific standards (Department, 2019) (Department G. o.-P., 2017) followed by designers without considering the occupant's visual and thermal comfort. This paper attempts to provide guidance for architects to select the best possible design variables which improve thermal and visual comfort for a primary classroom.

2. OBJECTIVES & METHODOLOGY

Many studies discuss thermal and visual comfort evaluations in various spaces and climatic conditions independently. A combined study of both thermal and visual comfort is necessary to meet the inhabitants' comfort needs and there is no research till date, available for the optimized solution for thermal and visual comfort in warm and humid climatic conditions.

This research aims to develop an optimum classroom design and the result shows a Methodology for optimum classroom design for enhanced thermal and visual comfort in a warm humid context. The objectives are:

- To identify the visual comfort and thermal comfort indices in the classroom design.
- To identify design criteria for improved comfort levels in classroom.
- To evaluate the thermal and visual comfort in the representative classroom layout.
- To develop optimum classroom design for enhanced comfort levels.

Figure 1 shows the methodology chart to develop an optimum classroom design for enhanced thermal and visual comfort in a warm and humid climate zone. Primarily, a representative location and a classroom layout was selected and comparison with the standards, thermal and visual comfort analysis was done through background study. Then, widely used design variables and indices for thermal and visual comfort had to be identified from the literature study. Most commonly used simulation software (Grasshopper) is utilized for the parametric modeling

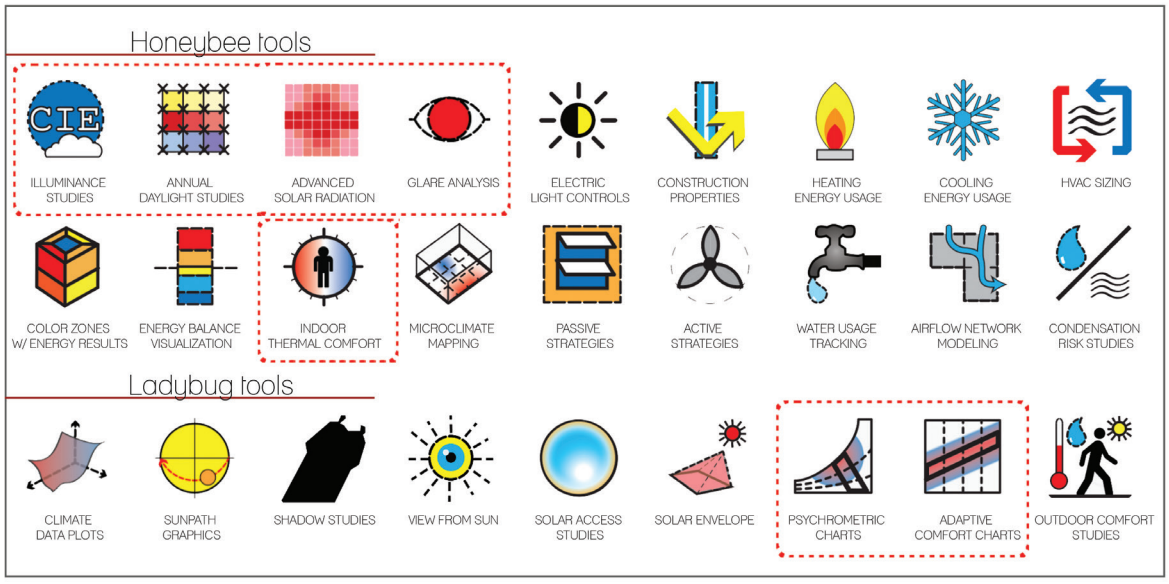

Figure2:Grasshopper-Plug-ins-Tools. Source: https://www.ladybug.tools/

linked to Rhinoceros 3D. Finally, the conditions in parametric analysis of design variables were cross verified with benchmark.

2.1 Software Program for Model Design

One of the most commonly used software in this field is Grasshopper, which is a graphical algorithm editor that serves as parametric modeling, linked to Rhinoceros 3D and helps designers with no formal scripting background to generate parametric forms quickly. In this research, three-dimensional parametric modeling of a primary school classroom was developed in Rhinoceros with the aid of the Grasshopper plug-in tools (Figure 2). Grasshopper plug-ins, Ladybug and Honeybee were used for performing environmental analysis and calculating daylight illuminance, energy consumption and visual and thermal comfort. In calculating Useful Daylight Illuminance (UDI) and Predicted Mean Vote (PMV), Honeybee and Ladybug, which is the most valid simulation tools, along with Radiance, Daysim, Therm and Open studio are used. For the evaluation of thermal and visual comfort, the required Trivandrum epw file was download from the Energy plus website (Climate.OneBuilding. Org, n.d.) and imported to the ladybug plug-in in Grasshopper.

2.2 Classroom Layout

The Indian Standard Recommendations for Basic Requirements of School Buildings (Institution I. 8.-I., 1978) in 1978 specified the basic plan for a primary classroom as a rectangle of 7.3 m x 6.1 m with window openings on two sides (Figure 3). A representative classroom layout is used as a base model for thermal and visual simulations.

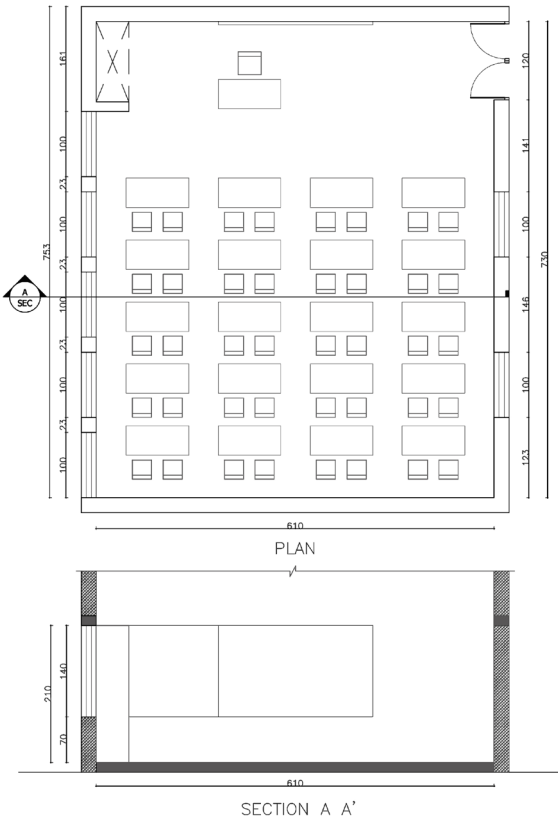

Figure 3: Classroom layout plan and section. Source: Author

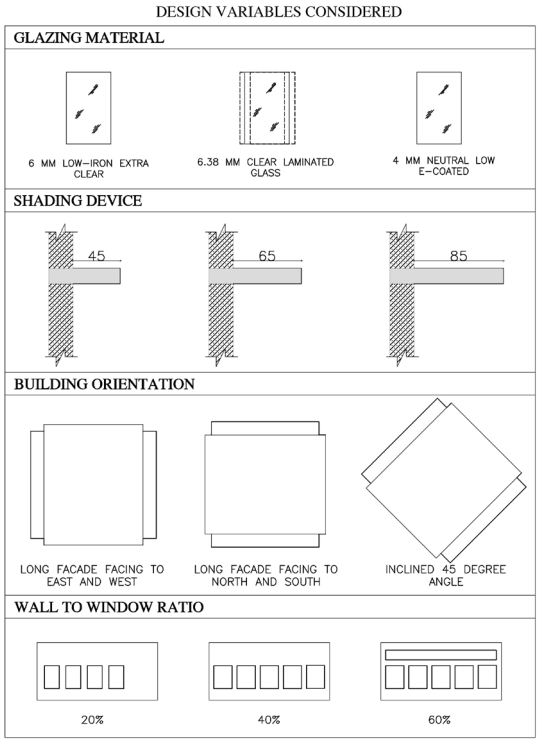

Figure 4: Design Variables Considered. Source: Author

2.3 Design Variables & Indices

Students in primary class do not take adaptive actions on their own, so non-take adaptive actions are considered for possible design variables. Window glazing and number of windows are influencing design variables for a reflected daylighting evaluation in a school (Ai, 2010). Shading devices and windows has indispensable role to enhance the visual comfort in a building design (Varendorff A, November 2012). Visual comfort parameters such as shading devices and glazing material used are considered in previous studies, but architectural parameters such as orientation of building and wall to window ratio are not. So the said parameters should also be correlated with visual parameter. The design variables considered are limited to building orientation, Wall to Window Ratio (WWR), glazing material and shading devices. Three conditions (low, mean and high) of each design

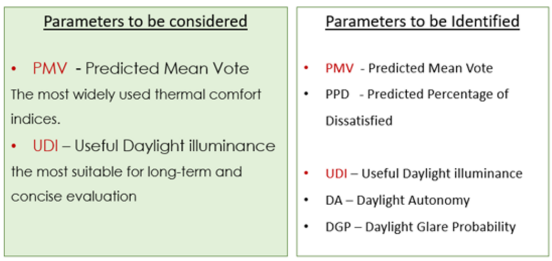

Figure 5: Considered Indices. Source: Author

variables are built to develop the cases for optimization process held in a parametric model so as to analyze the thermal and visual comfort of the representative layout (Figure 4).

The most often utilized thermal comfort metrics are the Predicted Mean Vote (PMV) and Anticipated Percentage of Dissatisfied (PPD). PMV is an index for evaluating thermal strain between the body and environment that assigns a comfort rating with the help of a seven-sensational scale and PPD is the expected percentage of people who are unsatisfied with each PMV (Z.S. Zomorodian, 2013).

From the visual comfort indices, in the frame of early design and optimization processes, the evaluation of glare through DGP (daylight glare probability) is difficult to generalize and UDI is suitable for evaluating the visual comfort illuminance in a time series (Salvatore Carlucci, 2015). The considered indices for thermal and visual comfort can be analytically investigated by using the grasshopper plug-ins (Figure 5).

2.4 Annual Daylight Simulation – Useful Daylight Illuminance (UDI)

The visual comfort index, Useful Daylight Illuminance, is calculated for the annual daylight simulation of a classroom layout. The Useful Daylight Illuminance (UDI) values are the percentage of time when the active occupancy hours is received between 100 and 2,000 lux. For simulation, the average percentages of time during the active occupancy hours are considered (March 15th, 9 a.m. to 3 p.m.), when the test point receives between 100 and 2000 lux (hours in a working day of school without calculating the lunch break and interval break). The higher value of UDI in the range of 70% to 100% has greater visual comfort in a space when the value considering the activity period is between 100 and 2,000 lux (I. Acosta, 2016).

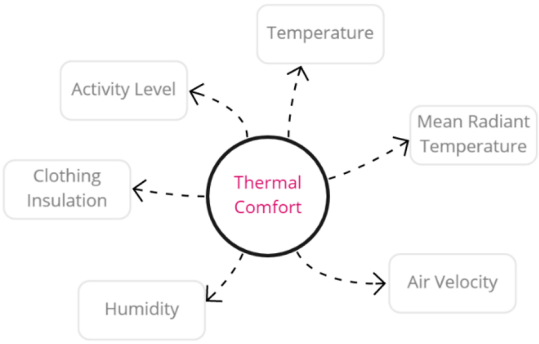

Figure 6: Thermal Comfort Parameters. Source: Author

2.5 Thermal Comfort – Predicted Mean Vote (PMV)

The Predicted Mean Vote (PMV) is to predict a group's vote using a seven-point thermal sensational scale (Figure 6). PMV is a seven-scale value for the simulation, with 5 as the neutral value for thermal comfort, decreasing values represent cooling and increasing ones represent heating which is used to evaluate the thermal comfort in a primary classroom zone.

The Predicted Mean Vote values are from continuous data collected hourly between 9 a.m. and 3 p.m. on March 15th. For simulation, the clothing insulation of 0.7 (clothing for long sleeves shirt and pants), the metabolic rate of 1.1 met for a seated person and the air velocity of 0.1 m/s is considered (Figure 7).

2.6 Optimization

The final sector of the study deals with the impact of design variables on a classroom design with the help of Design of Experiments (DOE). A parametric analysis of design variables is carried out using Response Surface Method (RSM) to examine their impact on thermal and visual comfort in a classroom. Among the two designs available in RSM, Central Composite Design (CCD) and Box-Behnken Design (BBD), CCD is used in the present study since it has a wider scope in the application.

Four independent design variables for a classroom design, orientation (long facade facing to North-South direction, East-West direction and inclined to 45-

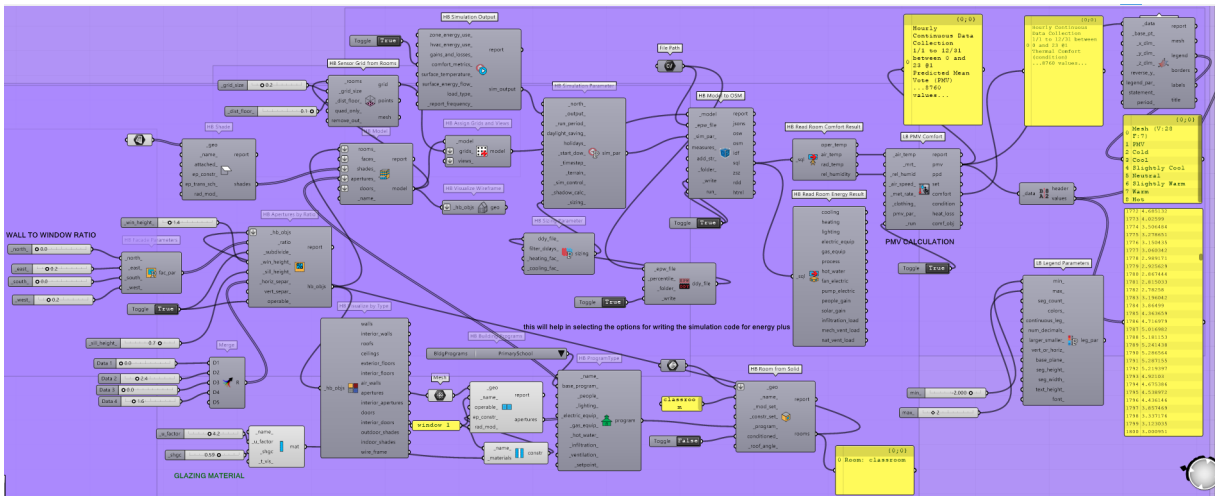

Figure 7: PMV Simulation (Source: Author generated using Rhino Grasshopper Simulation Software)

degree angle), WWR (20%,40% & 60%), shading devices (ranging 45 cm to 85 cm), and Glazing material (6 mm Low-iron Extra Clear glass, 6.38 mm clear laminated glass, 4 mm neutral Low-E Coated glass) have been considered. Considering the number of factors, by using CCD, the total experiment run has been reduced to 25 saving considerable time and effort. Each of the combinations is simulated in grasshopper software for thermal and visual comfort analysis. Later, statistical analysis was carried out to understand the relative impact of each design variable for an optimum classroom design.

3. STUDY AREA

3.1 Location

Thiruvananthapuram is taken as a case example of warm and humid climate conditions which is also a prominent educational centre (Figure 8). The required Trivandrum epw file was downloaded from the Energy Plus website (Climate.OneBuilding. Org, n.d.) and imported into the ladybug plug-in for the evaluation of thermal and visual comfort.

3.2 Climate Data

According to the climatedata.org website, April is the warmest month of the year, with an average temperature of 26.9°C in the Trivandrum district. For improving the occupant's comfort in an extreme condition of discomfort, the peak temperature time period is considered. April and May are considered the hottest months throughout the year, but primary schools have summer vacations during this period. Therefore, the next hottest month (march)is considered for the simulation. March 15 is the warmest day, according to the climatic data available for the previous year, current year, and next year (2021, 2022, and 2023, respectively) (AccuWeather - Thiruvananthapuram Kerala, n.d.).

4. RESULT & DISCUSSION

The representative base model recommended by the Indian Standard Recommendations for Basic Requirements of School Buildings is simulated in the rhino grasshopper tools. The simulation results are shown in table 1. The PMV and UDI output of 25 cases are developed from different options of design variables. The results of the optimization program are ideal if the value tends to 5 for thermal comfort in the Predicted Mean Vote (PMV) scale and the value in the range of 70%-100% and tends to 100% for visual comfort in the Useful Daylight Illuminance (UDI) scale. The results are:

1) Design variable for optimum thermal and visual comfort in the Kerala summer season.

For a primary classroom design, possible design variables for non-take adaptive actions such as orientation, WWR, shading, and glazing material are taken to achieve optimum visual and thermal comfort. According to the ideal values of thermal comfort and visual comfort, case 10 is the most optimum design variable to consider for a classroom design in the Kerala summer season (Table 1). Table 1 shows that the long facade oriented in a north-south direction with a 65 cm sunshade and 40% WWR with 6.38 mm clear laminated glass as window glazing materials are the ideal design variables for the optimum thermal and visual comfort in the Kerala summer season. The optimized result shows the indoor PMV scale as neutral when the outdoor PMV scale is in warm conditions and the UDI value is the maximum (99.9%). To achieve the best visual and thermal comfort in the summer, a primary classroom should be oriented to a long facade facing north-south direction with a 65 cm sunshade and 40% wall window ratio with 6.38 mm clear laminated glass window glazing.

2) Optimum design variables for reducing heat gain with maximum UDI.

Case17 shows that the next ideal case for the optimum thermal and visual comfort is when the building facade is oriented in the North-South direction with 4 mm neutral Low-E Coated glazing material and 20% of WWR with 45 cm sunshade length. Cases 6 and 22 show that the classroom inclined at a 45-degree angle with a 45 cm shading length and 20% of WWR with 6 mm Low-iron Extra Clear or 4 mm neutral Low-E Coated as glazing material are the next ideal cases. Reducing the heat gain while having a minimum useful daylight illuminance, can be achieved through the window design with 20% of WWR with a 45 cm shading length.

3) Low visual comfort and poor thermal comfort.

Case 15 shows that the classroom with 60% WWR oriented to the east west direction with 65 cm of shading has a poor effect on the occupants' thermal and visual comfort (Table 1). For a window design in a primary classroom, using 6.38 mm clear laminated glass with 60% of WWR and oriented to a long facade facing east-west direction with 65 cm of shading on windows causes high thermal gain with low useful daylight illuminance.

4) Optimum design variable for high obstruction factor around the classroom design in warm and humid climate.

Cases 3, 4, and 20 show that the design variable has the maximum UDI (Table 1). The longer facade of the classroom is oriented in a north-south direction with an 85 cm long sunshade and 60% WWR with 4 mm neutral Low-E Coated or 6 mm Low-iron Extra Clear as glazing material has the maximum Useful Daylight Illuminance in warm and humid climate. For a north-south (Long Face) oriented classroom which is surrounded by vegetation and buildings, the optimum design variables to consider are the 60% of WWR with the 85 cm shading length for maximum UDI without compromising thermal comfort.

Table 1: Simulation Results. Source: Author

Experiment cases	Glazing material	Shading size	WWR	Orientation	Thermal Comfort	Visual Comfort
					PMV	UDI
Case 1	6 mm Low-iron Extra Clear	45 cm	20%	long façade facing to North and South	5.05156557	90.74074074
Case 2	6 mm Low-iron Extra Clear	85 cm	20%	long façade facing to North and South	4.94314943	82.5462963
Case 3	6 mm Low-iron Extra Clear	45 cm	60%	long façade facing to North and South	5.46279257	97.25
Case 4	6 mm Low-iron Extra Clear	85 cm	60%	long façade facing to North and South	3.82027986	98.10185185
Case 5	6 mm Low-iron Extra Clear	65 cm	40%	long façade facing to East and West	5.91029814	86.90740741
Case 6	**6 mm Low-iron Extra Clear**	**45 cm**	**20%**	**inclined 45 degree angle**	**5.18599443**	**91.88888889**
Case 7	6 mm Low-iron Extra Clear	85 cm	20%	inclined 45 degree angle	4.81284557	86.64814815
Case 8	6 mm Low-iron Extra Clear	45 cm	60%	inclined 45 degree angle	6.36247657	81.21296296
Case 9	6 mm Low-iron Extra Clear	85 cm	60%	inclined 45 degree angle	6.02873557	84.60185185
Case 10	**6.38 mm clear laminated glass**	**65 cm**	**40%**	**long façade facing to North and South**	**4.98625643**	**99.93518519**
Case 11	6.38 mm clear laminated glass	65 cm	20%	long façade facing to East and West	5.205603	86.96296296
Case 12	6.38 mm clear laminated glass	45 cm	40%	long façade facing to East and West	6.13176414	84.03703704
Case 13	6.38 mm clear laminated glass	65 cm	40%	long façade facing to East and West	5.867441	86.90740741
Case 14	6.38 mm clear laminated glass	85 cm	40%	long façade facing to East and West	5.67474357	89.31481481
Case 15	**6.38 mm clear laminated glass**	**65 cm**	**60%**	**long façade facing to East and West**	**6.80483686**	**73.7037037**
Case 16	6.38 mm clear laminated glass	65 cm	40%	inclined 45 degree angle	5.44821357	93.40740741
Case 17	**4 mm neutral Low-E Coated**	**45 cm**	**20%**	**long façade facing to North and South**	**5.051566**	**92.5**
Case 18	4 mm neutral Low-E Coated	85 cm	20%	long façade facing to North and South	4.94314943	85.64814815
Case 19	4 mm neutral Low-E Coated	45 cm	60%	long façade facing to North and South	5.46280443	95.4537037
Case 20	4 mm neutral Low-E Coated	85 cm	60%	long façade facing to North and South	5.36551	97.92592593
Case 21	4 mm neutral Low-E Coated	65 cm	40%	long façade facing to East and West	5.767441	86.90740741
Case 22	**4 mm neutral Low-E Coated**	**45 cm**	**20%**	**inclined 45 degree angle**	**5.18595071**	**91.88888889**
Case 23	4 mm neutral Low-E Coated	85 cm	20%	inclined 45 degree angle	4.81284557	86.64814815
Case 24	4 mm neutral Low-E Coated	45 cm	60%	inclined 45 degree angle	6.62272986	81.21296296
Case 25	4 mm neutral Low-E Coated	85 cm	60%	inclined 45 degree angle	6.02873557	84.60185185

Excellent Case Best Case Good Case Poor Case

5) Design variable for optimum thermal and visual comfort in the Kerala monsoon season.

The available daylight illuminance in indoors is considerably low during the monsoon season. In cases 9 and 25, the result shows that the design variables can achieve the heat gain increase with maximum UDI (Table 1). The result shows that the classroom facade of 60% WWR with an 85 cm long sunshade oriented at a 45-degree angle has the high illuminance in indoors. 6 mm Low-iron Extra Clear and 4 mm neutral Low-E Coated are the glazing materials used for the window design. A classroom design with 60% of WWR and an 85 cm long sunshade length which is oriented at a 45-degree angle can achieve visual comfort in the Kerala monsoon season.

5. CONCLUSION

An ideal classroom design plays an indispensable role in occupants' comfort and performance. This study focuses on thermal and visual comfort variables to balance the occupants' comfort in a primary classroom. The paper put forward a Methodology for optimizing classroom design for enhanced thermal and visual comfort in the warm humid context which can act as guidance for architects to select the best possible design variables for a classroom design. A representative base model is identified and the four design variables for thermal and visual comfort indices are considered for simulation. For optimization, the calculation of PMV and UDI for 25 cases, which is developed from the different conditions of four design variables, is placed in a representative base model by using parametric modeling techniques.

The study result shows that the classroom design, oriented in a north south direction with a 65 cm sunshade and 40% WWR with 6.38 mm clear laminated glass window glazing are the design variables to be considered for optimum thermal and visual comfort in the Kerala summer season. For reducing heat gain with minimum UDI for a classroom design, the window design with 20% of WWR, a 45 cm shading length and 6 mm Low-iron Extra Clear or 4 mm neutral Low-E Coated glazing material. The classroom with 60% WWR oriented to the east-west direction with 6.38 mm clear laminated glass as glazing material and 65 cm of shading on windows has a poor effect on the occupants' thermal and visual comfort. The longer facade of the classroom, oriented in a north south direction with an 85 cm long sunshade and 60% WWR with 4 mm neutral Low-E Coated or 6 mm Low-iron Extra Clear as glazing material has the maximum Useful Daylight Illuminance without compromising the thermal comfort. The classroom design with 60% of WWR and an 85 cm long sunshade length which is oriented at a 45-degree angle are the design variables to achieve the heat gain increase with maximum UDI in the Kerala monsoon season. Further scope of the study includes the addition of different design variables like projected walls, different types of facades, and shading designs and uses any other layout type that is listed in standards or the latest design for classroom arrangements. The same methodology can be used for different climatic conditions to achieve an optimized space design to improve thermal and visual comfort.

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ESTIMATING THE ENERGY-SAVING POTENTIAL IN OFFICE BUILDINGS IN WARM-HUMID CLIMATE:

Implementation of ECBC Envelope Measures

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ABSTRACT: The importance of constructing buildings that cause minimal harm to the environment has been prevailing since the mid-1900s. Green building technologies are improving, which can help to prevent further depletion of natural resources and harm to the environment. The relationship between the inefficiency of existing building envelopes, which continue to be harmful, and the various alternatives that can be used is briefly examined in this study. This research will look into the topic of energy savings through alterations to the building envelope, including what it is, how it is done, and how it can reduce environmental impact. The importance of international rating systems such as the IGBC in addressing the issue will also be investigated. Furthermore, the ECBC standards mentioned in the rating system serve as a guide to limiting the impact and it prescribes the techniques and methods to consider. The paper aims to compare the three energy efficiency performance levels of ECBC concerning envelope U-factor in office buildings in Kerala and estimate energy saving potential.

KEYWORDS: Green buildings, retrofitting, ECBC, energy efficiency, building envelope, u-value

1. INTRODUCTION

Sustainability, the concept of 'Green,' and environmentally friendly options have become increasingly popular in recent years. Buildings that are energy, water, and resource-efficient are the future of architecture, as they can help to control climate change, reduce greenhouse gas emissions, and conserve natural resources. Green building rating systems were created to educate, encourage, and assist teams who come forward as the need and scope of such buildings grew.

In India, The Bureau of Energy Efficiency launched Energy Efficiency Building Code (ECBC) in 2017 to provide a set of standards and assist in energy-efficient construction. The Indian Green Building Council (IGBC) is the most widely used and respected green building rating system in the country. IGBC refers to the Energy Conservation Building Code for the standards. These efforts assist us in achieving our goal of global sustainability.

2. THE RESEARCH AREA

The research aims to establish the importance of building envelope measures prescribed in the Energy Conservation Building Code to attain energy efficiency in an office building in Trivandrum, Kerala. The potential reduction in electricity consumption caused by changes in u-values of the building envelope will be examined

The concept of energy-saving can be used as a tool to reduce environmental impact. The Energy Conservation Building Code describes three energy performance levels that can be achieved by adhering to the standards prescribed. The study will address these subjects per the building envelope measures. Finally, recommendations for reducing the electricity consumed will be discussed.

2.1 Methodology

To understand the major literature published on the topic a review of research papers is conducted. This helped to evaluate the energy consumption sources in commercial buildings. It brings us to the conclusion that the building envelope can play a big role in energy saving if altered.

Later on, the ECBC performance levels the three energy efficiency performance levels namely, ECBC compliant, ECBC plus (+), and super ECBC, are reviewed. An office building with minimum requirements for ECBC compliance, in Trivandrum, is selected for further study. A simulation model is created using Design builder software by inputting all the actual conditions like equipment number, lighting fixture, air conditioning, occupancy, etc. U-values specified in the building envelope category in ECBC will be assigned to the model. The model will be used to test and find the results of change in energy consumption with respect to electricity with change in the U-factor.

To conclude the research recommendations of materials which can be used to achieve the desired u-value are specified. The study will shed light on the significance of the building envelope and U-factor for

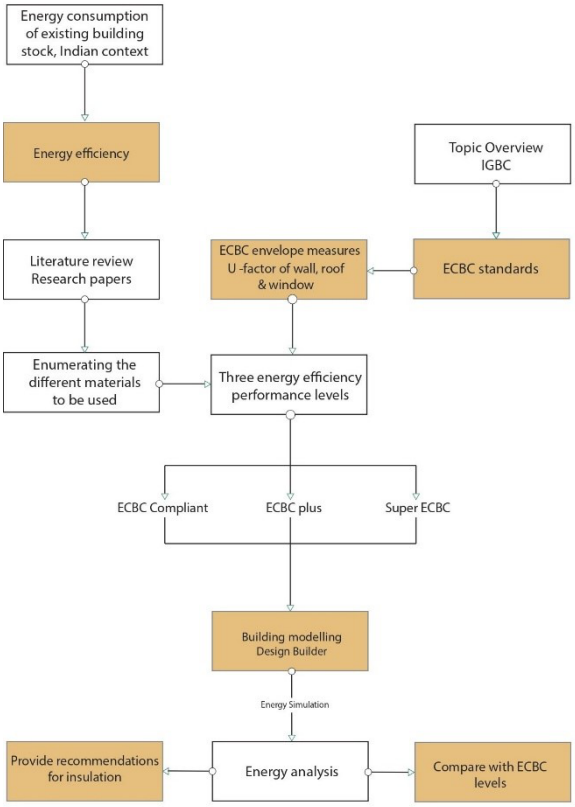

Figure 1: Methodology of the research. Source: Author

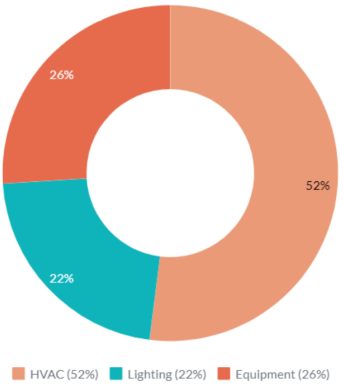

Figure 2: Breakup of total electricity consumption. Source: Author

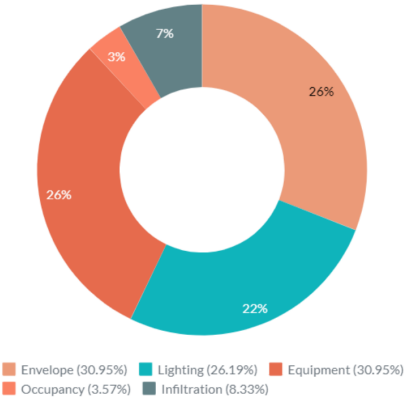

Figure 3 Breakup of causes of HVAC consumption. Source: Author

achieving energy efficiency in buildings, which can further aid in reducing greenhouse gas emissions. The lack of specific case studies to refer, to regarding the possible technique is a limitation.

3. LITERATURE REVIEW

In his report, the author Ruparathna, states that around 40% of the energy is used by the world's buildings, which also account for one-third of all greenhouse gas emissions (GHG) (Ruparathna, 2016). The authors stress the importance of energy efficiency and the need for converting the existing building stock to energy-efficient ones. Being in a tropical climate zone, India requires heating and cooling all year long to maintain a comfortable indoor environment. The load on mechanical heating and cooling can be reduced by designing the envelope according to the climate, selecting appropriate materials, and sizing fenestration and shading devices.

Out of the total energy consumed by a conditioned building, 52% comprises the heating and cooling load (Bano, (2016)). HVAC systems are conditioned to respond to the amount of heat present indoors. The building envelope is the major reason for indoor heat gain. Therefore, the selection of appropriate materials plays a vital role in reducing the cooling electricity load thereby reducing the pressure on natural resources.

According to the statistical report, it was found that the total built-up area of conditioned commercial buildings is increasing tremendously in Trivandrum. This can lead to stress on natural resources. Thus, this study focuses on the energy-saving potential of an office building in Trivandrum, with the implementation of building envelope measures prescribed in the Energy Conservation Building Code of India.

4. DATA COLLECTION

A live case study was conducted to review the ECBC performance levels and to estimate the potential energy savings with each category of levels. An office building in the Trivandrum district was selected to evaluate its energy-saving potential.

Building details:

Building name: Keerthi & Bhavana Architects
Location: Vazhuthacaud, Trivandrum, Kerala
Area(approx.): 465sqm
Number of floors: 2 HVAC system
Centralized Connected load: 152kWh
Occupancy: 45 Office working days- 6 days/week
Office working hours- 7 hours/day

4.1 Actual conditions

The building is facing in North-East direction an arterial road abuts the site. It is an architectural firm constructed in 1994. The construction materials include conventional brick(230mm), RCC, sand, coarse aggregate, and clear glass with a metal frame. It is a framed structure with internal partitions converted into half walls with glass walls extending will the roof.

The actual electricity consumption in the building was taken to validate the consumption in the model. Table 1 shows the average electricity bill amount and the total average electricity consumption per month and year. The list of all the equipment along with its number and energy consumption is given in Table 2.

Table 1: Actual electricity consumption. Source: Author

Electricity bill/ month	Rs.5000(approx.)
Avg consumption/month	625kWh(approx.)
Avg consumption/year	85000kWh(approx.)

Table 2: Equipment list. Source: Author

Equipment	Numbers	Energy consumption/hour
Tube lights	33	20 watts
Fans	18	40 watts
Centralized A/C	372sqm	25 ton
Computers	40	170 watts

4.2 Simulation process

Steps involved:

i. Creating a model in design-builder.
ii. Assigning u-values of actual materials.
iii. Assigning the number of electrical equipment and air conditioning.
iv. Simulate the model to get the actual energy consumption data.
v. Now, u- values for different performance levels are assigned one by one.
vi. Comparing the results

4.3 Simulation inputs

The walls and roofs of the office building were first modelled using architectural drawings prepared after the case study. However, the thickness of cement plaster was assumed to be 12.7 mm, as is standard practice. The positions of the Lights, fans, and computer are depicted in the electrical plan. The number of equipment was entered according to Table 2. The u-values of conventional materials (Table 3) such as brick were taken from standard guidelines, such as IS codes and SP41. ECBC prescribes u-vales for Opaque external wall, roof, and vertical fenestration under the building envelope measures of the three performance levels, namely ECBC, ECBC+, and Super ECBC.

Table 3: Input U-Values. Source: Author

Envelope	Wall	Roof	Window glass
Material	Brick	Concrete	Clear glass
Thickness	230mm	150mm	6mm
U-Value	2.38	3.25	5.8
R-Value	0.42	0.3	0.17

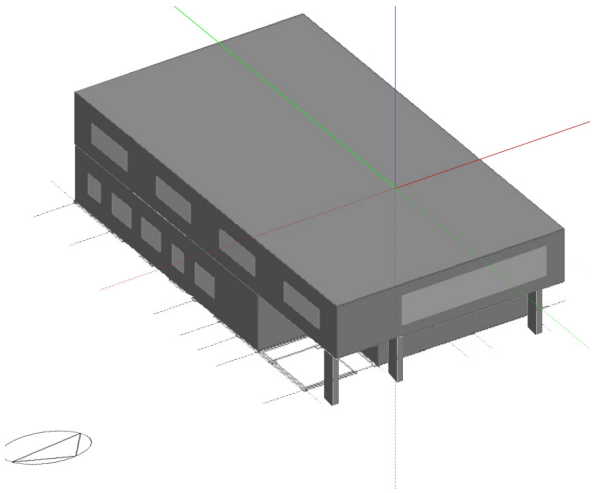

Figure 4: Model in Design builder. Source: Author

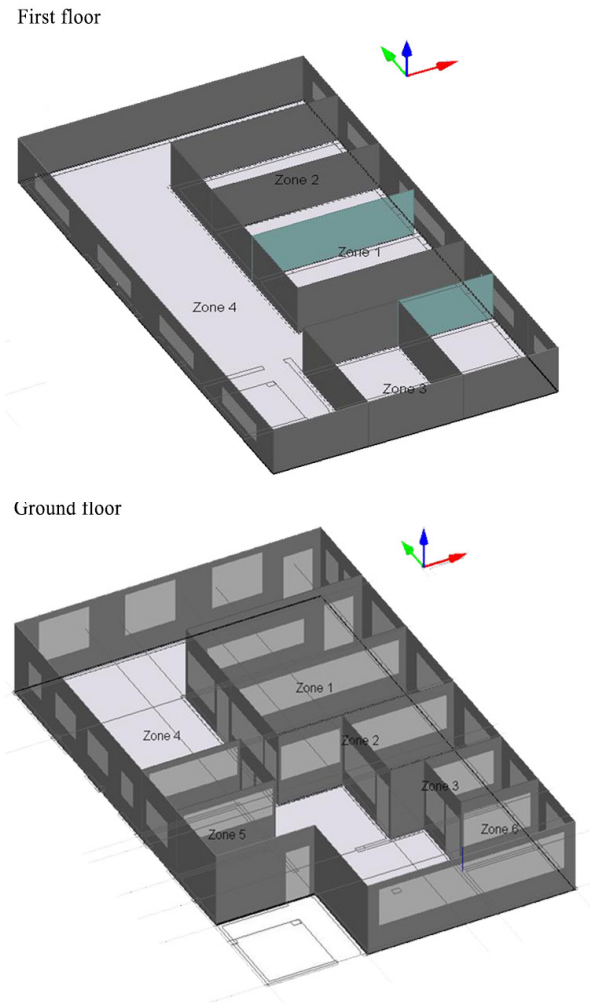

Figure 5: Interior arrangement from the model. Source: Author

Table 4: ECBC U-value for envelope. Source: ECBC

Building envelope	Wall	Roof	Window
ECBC com	0.4	0.33	3
ECBC +	0.34	0.2	2.2
Super ECBC	0.22	0.2	2.2

5. RESULTS

Monthly data of outdoor dry bulb temperature, inside air temperature, general lighting, mechanical ventilation, solar gain of windows, room electricity, heating, cooling electricity, etc are obtained. Figure 6 depicts the actual electricity consumed as per the electricity bill acquired from the office and the simulated electricity consumption. There is a visible reduction in indoor air temperature (Figure 7), which is desirable in the reduction of cooling electricity of the office building, shown in Figure 8.

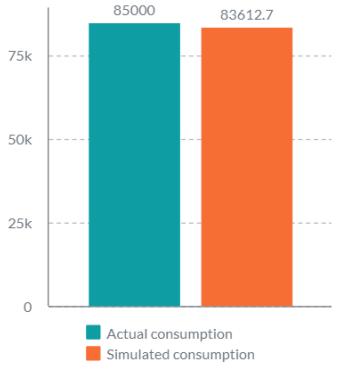

Figure 6: Actual electricity consumption. Source: Author

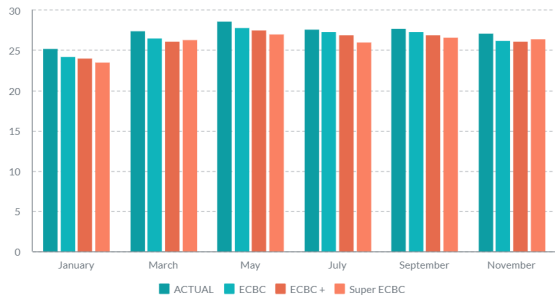

Figure 7: Monthly average inside air comparison. Source: Author

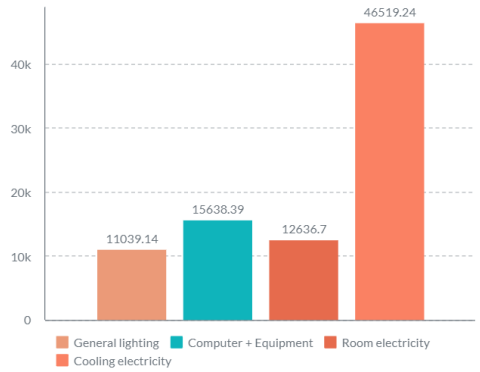

Figure 8: Consumption of electricity as per model. Source: Author

The results show that the super ECBC standard u-values can achieve the greatest reduction in energy consumption. Figure 9 depicts the reduction in energy consumption as a result of the various standards.

6. INFERENCE

According to the study, changing u–values of the building envelope can reduce energy consumption

Table 5 Result comparison. Source: Author

ECBC Performance levels	Actual	ECBC compliant	ECBC +	Super ECBC
Energy consumption	46519.2	36052.41	33726.44	31377.3
Percentage decrease	–	22.50%	27.50%	32.50%

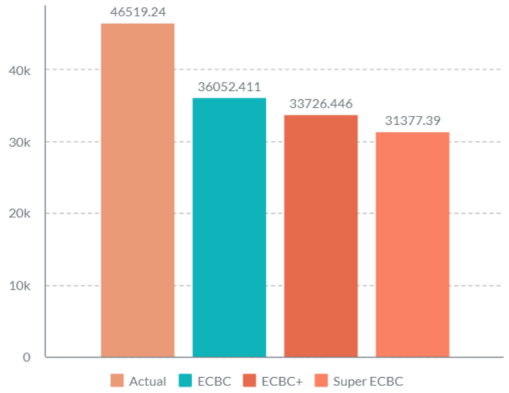

Figure 9: Consumption of electricity and cooling electricity as per model. Source: Author

in an office building by about 30%. The ECBC compliance of the office building's walls, roof, and glass was achieved by changing the u value of each according to the standard. The value of cooling electricity is the parameter that is used to compare the two. Table 5 shows the comparison of simulation model results with the actual consumption.

The results show that the super ECBC standard u-values can achieve the greatest reduction in energy consumption. Figure 9 depicts the reduction in energy consumption as a result of the various standards. The energy consumption in the office building as per the model was 83,615.7kWh per year. The total cooling electricity from the simulation results equals to 46,519.24kWh per year.

As shown in Figure 9, the electricity consumption data from the simulation of the building in actual condition indicates that the highest consumer is the

Table 6: Recommendations for insulation materials Source: Author

Envelope type	ECBC level	u-value	MATERIAL	THICKNESS(mm)
WALL	ECBC	0.4	Expanded polystrene	80
			Blown fibre	80
	ECBC +	0.34	Urea formaldehyde foam	100
			Insulation board	77
	super ECBC	0.22	Polyuthane foam	100
ROOF	ECBC	0.33	Insulation board	60
	ECBC +	0.2	Extruded polystrene	120
	super ECBC	0.2	Insulation board	120
GLASS	ECBC	3	High performance glass	4-8.
	ECBC +	2.2	High performance glass	4-8.
			Double-glazing (air-filled)	8
	super ECBC	2.2	High performance glass	4-8.
			Double-glazing (air-filled)	8

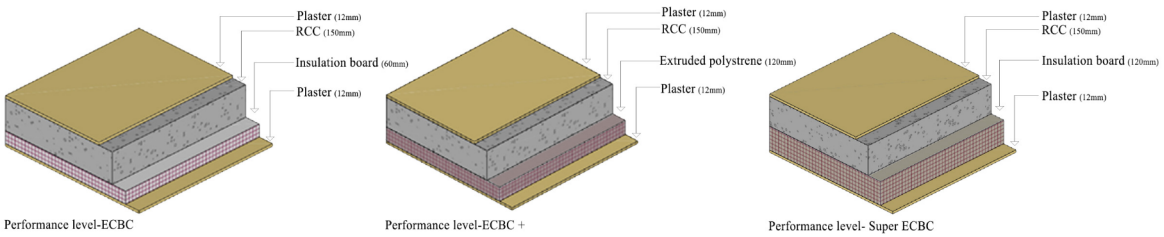

Figure 10: Illustrations of insulation in the roof. Source: Author

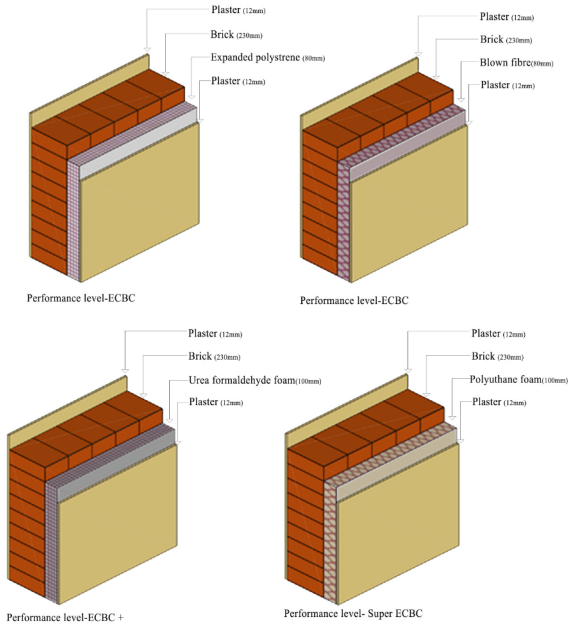

Figure 11: Illustrations of insulation in the wall. Source: Author

HVAC system (cooling electricity). Out of the total cooling electricity, the first performance level, ECBC compliant, reduced by 10,0466.8kW per year which is a 22.5% reduction. The second performance level, ECBC + reduced 12,793.8kWh per year which is a 27.5% reduction. The last performance level, super ECBC which assures to reduce the maximum consumption, reduced to 31,377.39, which is a 32.5% reduction in electricity consumption.

7. CONCLUSION

The task of this report was to find out the energy-saving potential which can be achieved using the ECBC envelope measures in office buildings. The study established the connection between the u-values of the building envelope to the amount of energy consumed by the HVAC system in the building. Finally, the result draws to the fact that an office building with about 5000sqft of area can reduce up to 15000kWh of energy.

7.1 Recommendations to achieve the envelope standards

The ECBC envelope u values can be achieved through the use of different materials in construction and also by using different methods of insulation in walls and roofs. The choice of glazing type proves to be very efficient in reducing the heat gain in the building.

To summarize, the building envelope u-values can alter the amount of heat entering the building thereby decreasing the amount of electricity spent in cooling the indoor environment.

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Planning For Low Carbon City In Climate Change Hotspot Area Of Kerala:

For a Climate Resilient Future

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ABSTRACT: Climate change has become a global concern nowadays influencing human survival. Urbanisation has created many serious problems including increased carbon footprint in cities. Since carbon dioxide is a major greenhouse gas, the increase in the concentration of carbon dioxide in the atmosphere can lead to global warming and result in climate change. So it is necessary to tackle the climate crisis by reducing carbon footprint and moving towards a sustainable and climate resilient future. Low carbon city is a city that comprises societies that consume sustainable green technology, green practices and emits relatively low-carbon or Green House Gas as compared with present-day practice to avoid the adverse impacts of climate change. Kerala State Action Plan on Climate Change identified the major climate change hotspot districts in Kerala using Composite Vulnerability Index. Palakkad has a higher composite vulnerability index and is considered as climate change hotspot district in Kerala. The study tries to understand the anthropogenic causes of carbon emission, its impact on climate change, the calculation of carbon emission, and the low carbon concept. The literature case study was conducted to find out the various low-carbon planning interventions that can be adopted to reduce carbon footprint. Palakkad Municipality, the first order settlement in the Palakkad district is the most urbanized city in the district. The sources of carbon emission in Palakkad Municipality are analyzed based on a household survey. Finally, strategies and recommendations are formulated for low-carbon city planning.

KEYWORDS: Low Carbon, Carbon footprint, Climate Change

1. INTRODUCTION

Climate change poses a hazard to every country on earth. Global warming and climate change are being caused by an increase in CO2 levels in the atmosphere. During the last United Nations Conference on Climate Change in Madrid, the 2020 Climate Risk Index was unveiled. India with a Climate Risk Index of 18.17 is ranked fifth among the list of countries (Countries Most affected by Climate Change, 2022). India committed at the 26th Conference of Parties to achieve zero carbon emissions by 2070. (Hindustan Times, 2021). The significant climate change hotspot districts in Kerala are identified using a composite vulnerability index that combines social and economic vulnerability indexes and environmental vulnerability indexes. (Department of Environment and Climate Change, Government of Kerala, 2014, p. 39). In Kerala, the Palakkad district is regarded as a climate change hotspot because of its higher composite vulnerability index. Planning a low-carbon city in Palakkad can boost life quality, resilience, and efforts to combat climate change.

The study aims to develop strategies and recommendations to reduce carbon emission in Palakkad Municipality. For this, four research objectives have been outlined. First objective is to comprehend carbon emission, low carbon concept and carbon emission calculation. Second objective is to understand the techniques to achieve low carbon emission by means of case studies. Third objective is to assess the existing condition of Palakkad by calculating the carbon emission and conducting household survey. Finally based on the analysis, strategies and recommendations are developed.

2. LITERATURE REVIEW

The literature study was conducted to better comprehend carbon emission, the low-carbon concept, and carbon emission calculations.

2.1. Carbon emission and climate change

The increase in the concentration of greenhouse gases directly correlates with the rate of climate change and global warming. Most often, greenhouse gases are carbon dioxide. (Ali, Ahmad, & Yusup, 2020, p. 1).Both natural and man made sources produce CO2 emissions. Rising CO2 emissions were strongly impacted by the speed of urbanization. (Ali, Ahmad, & Yusup, 2020, p. 1). More than 70% of the world's energy demand and a similar amount of CO2 emissions come from urban areas. (Bai, Zhang, Yang, Wei, & Yu, 2021, p. 1).

Limiting the rate of warming is the best action the world can take to combat climate change. When we are able to reduce emissions due to technological breakthroughs and lifestyle changes, this will be doable. (Henson, 2011).

2.2. Low carbon city

Low emissions of greenhouse gases, primarily CO2, are referred to as "low carbon."(Wenyao, 2010, p. 1). A

city that uses sustainable green technology, engages in environmentally friendly activities, and emits relatively little CO2 in comparison to current practice is referred to as a low carbon city. (KeTTHA, 2011, p. 11).

2.3. Carbon emission calculation

A framework for identifying, calculating, and reporting city greenhouse gas emissions is provided by the Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC). (Sotos, Fong, Doust, Schultz, Marques, & Deng-Beck, 2021).

2.3.1 Inventory Boundary

The GPC cannot be used by cities unless they have established an inventory boundary. Any geographic boundary is acceptable for the GHG inventory. (Sotos, Fong, Doust, Schultz, Marques, & Deng-Beck, 2021, p. 10).

2.3.2 Sectors of City GHG Emissions

Stationary energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) are the sectors of city GHG emissions (Sotos, Fong, Doust, Schultz, Marques, & Deng-Beck, 2021, p. 10).

2.3.3 Emission Methodology

The most common methodological approach to calculate greenhouse gas emissions is

Emissions = AD X EF (1)

Activity data (AD) is a numerical indicator of the amount of activity that contributes to GHG emissions. The mass of GHG emissions in relation to a unit of activity is measured by emission factor (EF). (Sotos, Fong, Doust, Schultz, Marques, & Deng-Beck, 2021, p. 52).

3. CASE STUDY

To comprehend spatial planning strategies that can be used to lower carbon emissions, the case study of Shenzhen was chosen. The case study of Meenangadi Gram Panchayat in Kerala aids in the study of carbon emission calculation techniques.

3.1 Shenzhen, China

Shenzhen is one of the Chinese cities that experienced fast urbanization. Numerous problems, such as energy shortages, elevated CO2 emissions, etc., have been brought on by the rapid urbanization. In order to achieve sustainable growth, Shenzhen includes the concept of Low Carbon City into urban planning.

Shenzhen's master plan was based on a multicenter-cluster-belt urban form. Density zoning separated the city into the ecological reservation area, the peripheral urban area, and the kernel urban area. Ecological reservation areas are capped at a moderate level of development intensity. Development is permanently prohibited on the territory that is included in the Basic Ecological Control Line. The development of neighborhood parks and urban parks is based on the Shenzhen green system plan. (Jia, 2009, pp. 1-4).

By installing solar panels on homes and solar water heating systems on public buildings, sustainable energy use is promoted. Four power-generating and garbage-incineration plants in Shenzhen can burn 5,450 tones of domestic waste per day and produce 700 million KWH annually. (The story of Shenzhen, 2019).

The growth of public transit has been proposed by the Integrative Traffic Plan. Encourage the use of new energy vehicles and hasten the development of pedestrian and bicycle traffic systems are other measures adopted. (The story of Shenzhen, 2019).

Table 1: Total emission of carbon from transportation in Meenangadi. Source: (Thanal, 2018, p. 21)

Vehicle Type	Total No	AACD	EFCO2(Kg / km)	CO2 in tones
Two Wheeler	1990	6300	0.0324	406.1988
LMV or Motor Car	1160	12600	0.149	2177.784
Auto rickshaw	315	33500	0.1322	1395.0405
Passenger Bus	50	100000	0.328	1640
Goods Carriage	27	63000	0.5375	912.2875

Table 2: Total emission of carbon from energy in Meenangadi Source: (Thanal, 2018, p. 23)

	In Tonnes	EF	CO2 in tonnes
Bio degradable waste	1457	0.541	788.24

Table 3: Total emission of carbon from waste in Meenangadi. Source: (Thanal, 2018, p. 24)

Source	Sector	EF	Consumption	CO2 in tones
Electricity	Domestic	0.81	9534.2703	7722.76
	Commercial	0.81	2569.67	2081.44
	Industry	0.81	789.45	639.46
	Others	0.81	198.80	161.03
Firewood	Domestic	2.9	3366.76	1279.36
Lp Gas	Domestic	0.37	413.28	1198.51

3.2 Meenangadi, India

Meenangadi is a carbon neutral Gram Panchayat in Kerala. Transportation, Energy, Waste, and

AFOLU sectors were assessed for GHG emission profile of Meenangadi.

The total carbon emission from various sectors in Meenangadi is 33,375.099 tones. Trees and

Plantations in Meenangadi sequester 7425.22 tons of carbon. The excess carbon in Meenangadi is 11,412.57 tones. (Thanal, 2018).

4. METHODOLOGY

5. CLIMATE CHANGE HOTSPOT AREA OF KERALA

Palakkad is one of the four districts in Kerala that are considered to be hotspots for climate change, cording to the State Action Plan on Climate Change (SAPCC) of Kerala 2014. The agriculture industry is particularly hurt by adverse weather conditions.(Department of Environment and Climate Change, Government of Kerala, 2014).

Table 4: Total emission of carbon from livestock in Meenangadi Source: (Thanal, 2018, p. 26)

Livestock Type	Total No	EF (enteric fermentation)	EF (manure management)	Total CH4 emission	CO2 in tonnes
Cattle	3763	38.83	2.7	156277.39	3281.825
Buffalo	280	66.15	3.3	19446	408.366
Goat	1376	4.99	0.22	7168.96	150.548

Table 5: Total emission of carbon from irrigated paddy in Meenangadi. Source: (Thanal, 2018, p. 26)

	In Sq meter	EF	CH4 in tones	CO2 in tones
Paddy	2565709	11	28.22	593

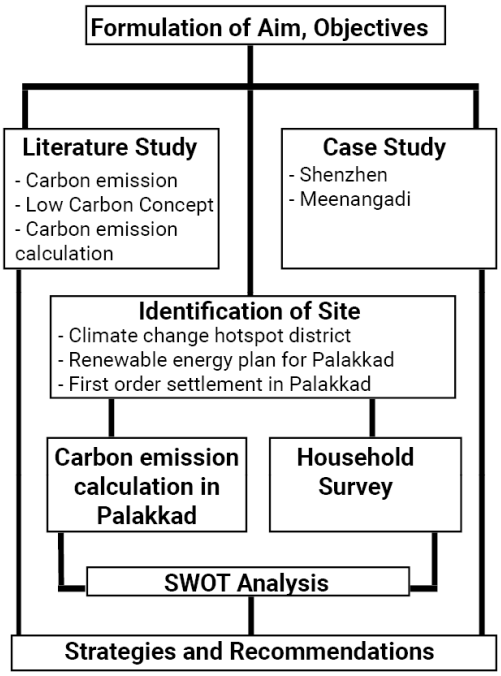

Figure 1: Methodology. Source: Author generated on May 2022

The World Institute of Sustainable Energy (WISE) and WWF-India worked together on a project study titled Renewable Energy Plan by 2030 for the Palakkad District in Kerala. The key finding of the study is that by 2030, renewable energy sources can supply 47.7 of the district's total energy, including all of its electricity.(WWF-India, 2015, p. 1).

Palakkad Municipality show urban character and is first order settlement. (Department Of Town And Country Planning,Government of Kerala, 2011). Since more activities are concentrated in Palakkad Municipality, the greenhouse emission is also comparatively higher.

Table 6: Total emission of carbon from transportation in Palakkad. Source: Road transport year book 2019, Palakkad Bus Operators Association, KSRTC Bus stands Palakkad, Auto rickshaws association Palakkad

Vehicle Type	Total No	AACD	EFCO2(Kg / km)	CO2 in tones
Two Wheeler	1990	6300	0.0324	406.1988
LMV or Motor Car	1160	12600	0.149	2177.784
Auto rickshaw	315	33500	0.1322	1395.0405
Passenger Bus	50	100000	0.328	1640
Goods Carriage	27	63000	0.5375	912.2875

Table 7: Total emission of carbon from energy in Palakkad Source: KSEB office Palakkad, Gas outlets in Palakkad

Source	Sector	EF	Consumption	CO2 in tones
Electricity	Domestic	0.81	76072212	61618.49
	Commercial	0.81	65104566	52734.698
	Industry	0.81	4339326	3541.854
	Others	0.81	4496736	3642.356
Firewood	Domestic	2.9	3366.76	36511.0296
LP Gas	Domestic	0.37	800080	296.02

Table 8: Total emission of carbon from waste in Palakkad Source: Municipality office, Palakkad

	In Tones	EF	CO2 in tones
Bio degradable waste	10950	0.541	5923.95

Table 9: Total emission of carbon from livestock in Palakkad Source: Veterinary Hospital, Palakkad

Livestock Type	Total No	EF (enteric fermentation)	EF (manure management)	Total CH4 emission	CO2 in tones
Cattle	1136	38.83	2.7	156277.39	1386
Buffalo	130	66.15	3.3	19446	224
Goat	1193	4.99	0.22	7168.96	154

Table 10: Total emission of carbon from irrigated paddy in Palakkad Source: Master Plan Report Palakkad

	In Sq metre	EF	CH4 in tones	CO2 in tones
Paddy	2086900	11	28.22	504.37

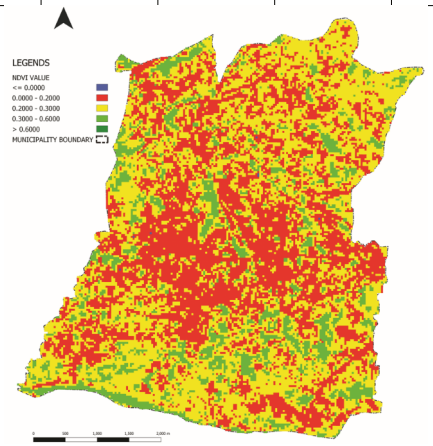

Figure 2: NDVI image of Palakkad Municipality, Source: Author generated on May 2022

6. CARBON EMISSION IN PALAKKAD MUNICIPALITY

Transportation, Energy, Waste, and AFOLU sectors were assessed for GHG emission profile. Equation (1) is used for calculating the carbon emission. The total carbon emission from various sectors is 458361.3853tones.

Note: NDVI image (Figure 2) is generated in GIS. The red colour denotes buildings, yellow shows light vegetation and green colour denotes thick vegetation. The total green area in Palakkad Municipality is 6km2.

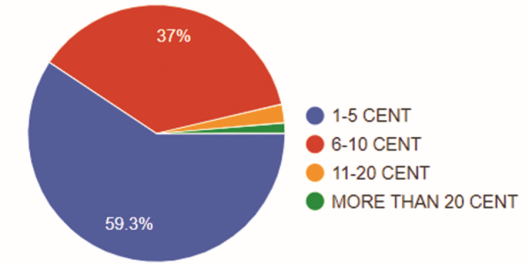

Figure 3: Survey results – plot area, Source: Household Survey conducted on May 2022

7. HOUSEHOLD SURVEY AND ANALYSIS

Total no of responses: 500 households

Sampling Technique : Random Sampling.

7.1 BUILDING

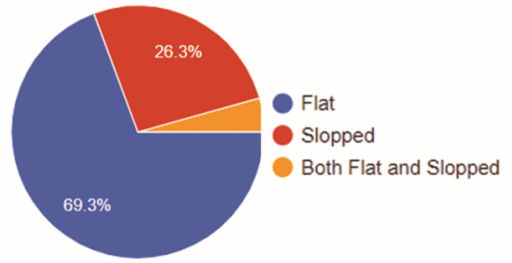

Figure 4: Survey results – Roof of houses, Source: Household Survey conducted on May 2022

The plot area of houses and roof type are analyzed in building sector.

Most of the houses has an area of 1000 sq ft. and situated in a plot area of less than 5 cent. There is minimum setback for houses and lacks space for vegetation (Figure 3). 70 percent of houses have flat roof and has potential for green roofing (Figure 4).

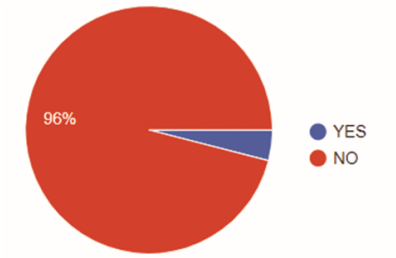

Figure 5: Survey results- use of solar energy, Source: Household Survey conducted on May 2022

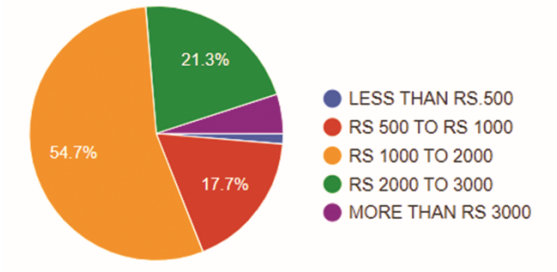

Figure 6: Survey results- electricity consumption, Source: Household Survey conducted on May 2022

7.2 Energy

The use of solar energy by households and the electricity consumption of households are analyzed in household survey. There is a heavy dependence on

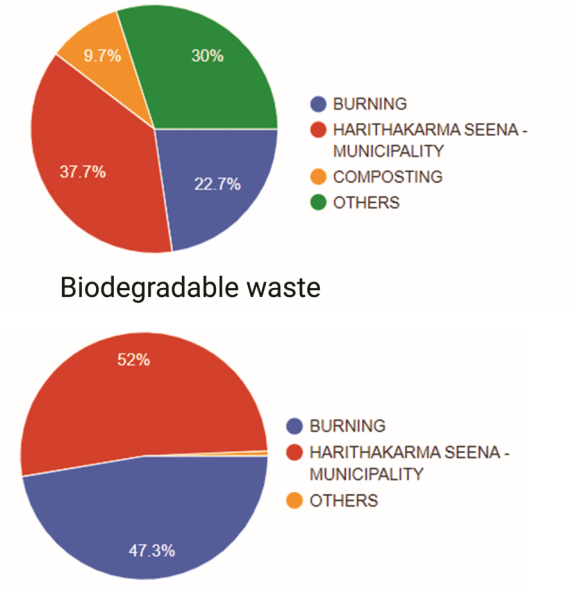

Figure 7: Survey results- biodegradable waste management, non-bio degradable waste management, Source: Household Survey conducted on May 2022

non conventional source of energy (Figure 5). Most of the households use more than 200 units of electricity (Figure 6). Use of Air conditioning adds to the energy consumption.

7.3 Waste

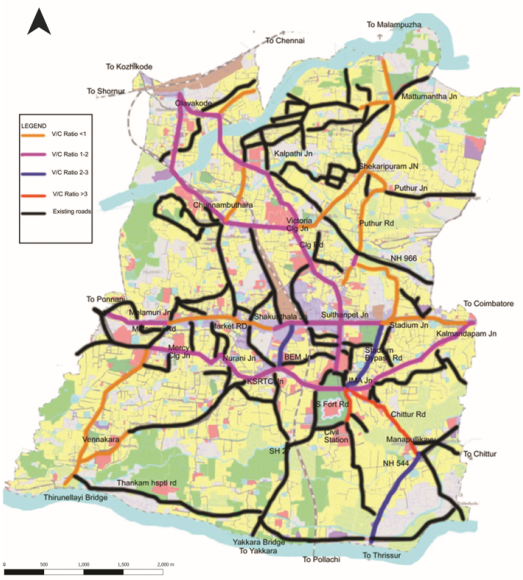

Figure 8: Map showing volume capacity ratio of roads in Palakkad, Source: Author generated with reference to Master Plan report of Palakkad town 2031.

The waste is not treated properly. Waste is dumped near market road, bypass and near railway stations (Figure 7).

7.4 Transportation

Most of the houses in Palakkad Municipality have vehicle ownership. Two wheeler vehicles are high compared with four wheelers. Volume capacity ratio (Figure 8) exceeds 1 in most of the major roads.

8. SWOT ANALYSIS

8.1 Strength

Palakkad has strong potential for the development of renewable energy resources as per Renewable energy plan.

8.2 Weakness

There is lack of green spaces for carbon sequestration. Renewable energy is not utilized due to lack of awareness and initial cost. Lack of public waste bins results in dumping of waste near road sides and streets. Pedestrian pathways are lacking in areas such as college road.

8.3 Opportunities

Vacant agricultural land can be converted to solar farms, agrivoltaics and urban parks. Flat roofed buildings have the potential for making green roofs.

8.4 Threat

Transportation sector has highest carbon emission. Since Palakkad is well connected to Coimbatore and major cities in Kerala, pollution from intercity and interstate vehicles are also high.

9. STRATEGIES AND RECOMMENDATIONS

9.1 Agrivoltaics

Agricultural land is the most suitable for solar farms in terms of efficiency. Hence the uncultivated crop land can be converted to agrivoltaics. Converting 70 hectares of land to agrivoltaics produce 18,104,000 KW electricity. Also 14664 tons of carbon emissions are reduced.

9.2 Rooftop Solar Panels in Public Buildings

Solar panels can be installed on the roofs of Municipality Office, Civil Station and KSRTC bus stand. It produces 333229 KW electricity annually.

9.3 Solar street lighting

Street lights along the roads should be replaced with solar panels. It will help to reduce approximately

Figure 9: Map showing location of new urban parks in Palakkad, Source: Author generated on May 2022

1500 tons of carbon emission.

9.4 Urban Parks

As part of AMRUT Mission, urban parks are proposed in residential area. Planting more trees in the proposed parks can increase carbon sequestration. The total area proposed for new parks is 3.17 acre. Planting 1.5 acre with tropical trees helps to sequester 57 tons of CO2 annually.

9.5 Green Roofs

Residential land area is 12.05 km2. Since most of the houses have minimum setback, it is assumed that buildings in Palakkad utilize maximum coverage according to KMBR, and then available roof top area is 7.23 km2. According to household survey, 70

Figure 10: Map showing location of proposed public waste bins, Source: Author generated on May 2022

percentages of houses have flat roofs. Hence the total flat roof area is 5 km2. So the total carbon sequestrated by converting the entire flat roofs into green roofs is 47500 tones CO2.

9.6 Electric auto rickshaws and buses

Electric auto rickshaws and buses can be introduced. Government need to provide financial assistance at the initial stage.

9.7 Charging Stations

For auto rickshaws and private buses, charging stations can be introduced near Stadium Bus stand and Olavakkode railway station. For private vehicles, charging station is proposed near CSI working women's hostel.

9.8 NMT

Clear, unobstructed footpaths of 2m width are proposed on college road and market road. Dedicated parking spaces with well designed cycle stands should be provided for cycles near transit stations.

9.9 E waste bins in public places

E waste bins can be installed on public places such as bus stands, railway stations, market road and major junctions.

10. CONCLUSION

Reducing the carbon emission helps to enhance the quality of life of people in Palakkad and address climate change. From the emission calculations, energy and transportation sectors are the major contributors to carbon emission. Strategies and recommendations are formulated under energy, green cover, transportation, waste management sectors. The proposed action plans results in nearly 25 percentage (energy:5%, transportation : 4%, green cover: 15 %, waste: 1.2%) decrease in carbon emission.

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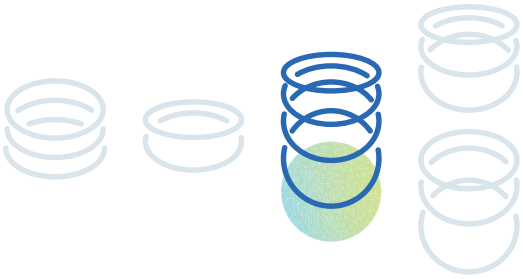

THEME 05:

Green Platform: Pedagogy, Process & Policies

We find ourselves in a multifaceted global crisis which is systemic (interconnected and interdependent) and non fragmentable in nature. Green compatibility of the decisions, regulations and policies taken worldwide and a social defence in case of violation of this grassroot democracy is a need of the hour.

The six principles of green politics, namely social justice, ecological wisdom, grass-roots democracy, non-violence and respect for diversity should be integrated at various scales into the regulations, rating systems and processes worldwide to generate a global standard.

Theme Chairs

Guruprasad Rane

Co-Founder, Bhoomija Creations

Guruprasad Rane completed his architecture studies from L.S.Raheja School of Architecture, Mumbai in 2002, Guruprasad Rane started working with Habitat Technology Group, a Non Governmental Organization working in Shelter Sector in India.

At HTG he worked on Tsunami Rehabilitation Projects and gained experience in Mud, Bamboo and other cost effective Construction Techniques. In 2012 he and his colleagues form ASF-India and became part of ASF-Int network. Previously he served as a board member for four years between 2012 and 2016

Jaigopal Rao

Managing Director, & Principal Designer,
Inspiration Architects

Jaigopal Govinda Rao is the managing director and principal designer of Inspiration Architects. He has worked with Laurie Baker and drawing inspiration from his style he also focuses on designs on ground realities and complexities offered by Indian subcontinent.

He is a Member of Special Advisory Group, State Finance Commission Government of Kerala, State Planning Board and Kochi Corporation Master plan committee.

Deepa Rani R

Associate Professor,
College of Engineering Trivandrum

A graduate in Architecture from College of Engineering,Trivandrum and Masters in Building Technology and Construction Management from IIT Madras, she developed interest towards Building Science through the various projects undertaken at IIT Madras.

As an academician cum researcher, in building science, she always had an inclination towards social and environmental sustainability where building plays a major role.

Analysis of Carbon Sequestration by Mangrove Wet-lands to Offset Carbon Emissions from House-hold Sectors:

A Case Example: Akkulam

Induja R Raj, Aysha S
College of Engineering Trivandrum

ABSTRACT: Around the planet, a revolution is unfolding. There's a lot going on throughout the world, from Extinction Rebellion protestors protesting in the streets in the UK to Greta Thunberg's 'Climate Strike. Wetlands contain substantial amounts of carbon. When a wetland is lost, it implies the loss of that particular carbon sink, but it also means that the carbon stored in that wetland is released. The area of Kerala's undistributed mangroves has been reduced to 250 hectares, despite the fact that the potential area is roughly 2670 hectares (KFRI). This research aims to study Carbon emissions from the household sector and how mangroves help in the Carbon sequestration giving a way to analyses the depleting mangrove cover over Akkulam Veli-lake, and how rapid anthropogenic activities have hit the environment. 13 different residential zones were identified and classified as a valley, ridges, coastal and plain lands along the periphery of Akkulam Veli lake. A field survey was conducted to analyze the various household activities that lead to Carbon emissions which included carbon emissions from electricity consumption, transportation and other fuel consumption for cooking such as LPG, Wooden pellets, Natural gas etc. Depleted mangrove areas and existing mangrove cover were also analyzed during the field survey.

Different software, such as the CURF tree carbon calculator, tree plantations, eco matcher, urban forestry carbon sequestration worksheet, My CREST Carbon sequestration calculator, etc., were used to analyze carbon sequestration capacity of mangroves and compare the carbon emission values. The findings showed that the existing mangroves are able to sequester the carbon emissions from the 13 different zones. So Akkulam being a high potential area for Urbanization bringing back the lost potential mangrove stretch would lead to reducing the drastic carbon emissions that contribute to Climate Change. And therefore, prototypes are put forward to give importance to safeguarding, conserving, and increasing these wetlands' value.

KEYWORDS: Wetland conservation, Mangroves, Carbon emissions, Carbon Sequestration

1. INTRODUCTION

The new phase of the industrial revolution has a drastic effect on nature and over the years the accumulation of Carbon dioxide has been unprecedented. Since the Industrialization, human activity has increased the concentrations of greenhouse gases in the atmosphere, enhancing the radiative forcing from CO2, methane, tropospheric ozone, CFCs, and nitrous. The quantities of CO2 and methane have increased since 1750 by 36 per cent and 148 per cent, respectively, according to research released in 2007. (Forster, 2007). All the data point to a single fact that anthropogenic activities had made a radical consequence on the entire planet and thus it remains the fundamental duty to safeguard nature to safeguard the very existence of every living being. The considerable amount of carbon stocked in wetlands is released into the atmosphere once these wetlands are converted to main lands. Wetland soils are the best long-term carbon sinks because they keep carbon locked up as long as they are intact and wet (Twilley R, 2019). Kerala is recognized for its own wetlands and is one of India's greenest states. Kerala has over 217 wetland areas, together accounting for about a fifth of the state's total land area. Kerala's unique wetland environments include marshy and waterlogged places, sizable polders, lakes, and the Myristica Swamps in the Western Ghat woods.

Salt-tolerant mangroves are common in tropical and subtropical intertidal zones around the world. Although very productive, these are also incredibly sensitive and fragile. Due to a large number of aerial and subsurface rhizomorphs present, they provide a highly good soil binding geotextile. This gives the plants a very solid anchoring that enables them to withstand the waves. Protection of mangrove vegetation is essential due to its rich biodiversity, importance to the survival of specific communities, economic status, and significance to coastal stability and projected global warming and sea-level rise scenarios.

Field surveys were conducted to analyze the potential mangrove extent and the lost mangrove cover over the years and the reason behind the threats is the low land value.

The focus of this paper is to portray the importance of wetlands and establish a prototype to safeguard the blue and green (Water and land) area required for carbon sequestration thus conserve the existing mangroves and recover the potential for mangroves.

The study area is limited to indigenous people living in the ridges, valleys, plains and coastal areas near the Akkulam Veli lake region. Only household carbon emissions from energy consumption, transportation and fuel are been surveyed. Potential area identification is based on research published research papers and the live survey. The residents' permissions were taken into consideration during the field survey. Therefore, the study's primary variables such as similar contextual environment, resident numbers, number of floors, floor area, etc. are limited.

India pledged to achieve carbon neutrality by the year 2070 and to cut its emissions at the 2021 United Nations Climate Change Conference (COP26) summit (Pandey, 2021). The first step in accomplishing this goal is the establishment of a market for carbon credits. The Energy Conservation (Amendment) Bill, 2022, was approved by the Lok Sabha, paving the door for the creation of carbon credit markets. To maintain a smooth carbon trading system in the nation, the bill suggests developing a local "Carbon Credit Trading market" and giving Indian government entities the authority to issue Carbon Trade Certificates.

The state government of Kerala has taken several steps to safeguard mangroves around the state. One such program was carried out by the Haritha Keralam Mission, which after the successful implementation of the "Pachathuruthu" initiative to turn surplus or abandoned land of various government ministries into small woodlands, launched "Mangrove Pachathuruthu." Mangroves for the Future (MFF), a project organized by the International Union for Conservation of Nature (IUCN) in India, is another effort to safeguard coastal livelihood.

2. METHODOLOGY

The topic was analyzed and the potentials of wetlands were studied as an initial part of the methodology. Different sources of carbon sequestration were recognized from the household sectors. Case studies were done to solidify the study and defining the area of study.

The whole study was divided into 3 different Phases.

- Phase 1- Background study: focused on understanding the topic and its potential.
- Phase 2- Literature study and Study area: Literature studies on carbon sequestration and importance of mangroves were studied. From the field study conducted potential and lost mangrove stretch were identified.
- Phase 3- Analysis and inference: Carbon emissions from the household sectors were identified and the mangrove stretch needed to sequester the emissions were calculated. Based on the calculations for the carbon sink, a set of prototypes is determined to enhance the value of wetlands.

2.1. Study area

The study area covers the areas in and around Akkulam Lake which is located in the western portion of Thiruvananthapuram along the southwest coast of India. The lake covers an area of about 0.76 km2 and is situated between 8°31' 14" and 8°31' 52" north latitudes and 76°53'12" and 76°54'6" east longitudes. It is a linear lake lying almost perpendicular to the seashore, with the western part abutting against the sealine. It is separated from the shoreline by a sandbar during the non-rainy season which used to occur naturally. The green cover of Akkulam, which is home to a variety of fishes and migrating birds, is dwindling as a result of rash and reckless construction and a cynical attitude on the part of authorities. Indigenous communities were identified to understand how the lake acted as prime source of income and are categorized into different zones. The study focuses on the evaluation of carbon Sequestration of Mangroves-wetlands of Akkulam wetlands. See the figure 1 given below.

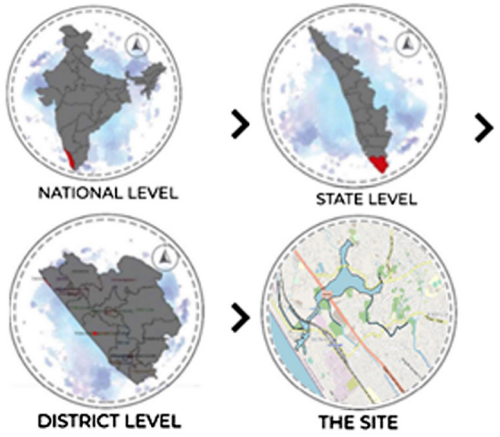

Figure 1 :Site location, Source: By author

2.2 Need for the Study

The area of Kerala's undistributed mangroves has been reduced to 250 ha, despite the fact that the potential area is roughly 2670 hectares (P. K. Muraleedharan,K. Swarupanandan,V. Anitha , 2009). The vegetation's distribution has drastically diminished, and it is currently classified as endangered in Kerala. Coastal systems are under increasing population and exploitation pressures, with approximately 40% of the world's population living within 100 kilometers of the shore (Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe,, 2007).

The commercial exploitation of raw materials, as well as land reclamation for agriculture, aquaculture, and housing, among other things, pose a threat to the state's mangroves. The conventional and present methods of resource use within the mangrove system

have undergone significant changes, which has an impact on the system's depletion.

The Veli Akulam Wetlands are focused as it is one of the prevalent environmental wetlands that are being encroached upon and choked by the expanding urbanization around it. Table 1 shows the increase in built-up areas over the years.

Table 1. Land cover of Vegetation, Barren land and water bodies, Source: (P. Arulbalaji, 2020)

Year	Vegetation		Built-up land		Barren Land		Water Bodies	
	(km^2)		(km^2)		(km^2)		(km^2)	
	%		%		%		%	
1998	125	86	10.5	7.3	7	4.9	1.5	1
2000	112	77.8	25.4	17.6	5.5	3.8	1.5	0.8
2019	71	49.3	67.5	46.9	4.5	3.1	0.93	0.6

Main land use changes starting from the east side of the lake portion and from the coastal area. The lake area was 46.37 ha in 2003 and it has shrunk by 40.77ha in 2011 and by 39.38 ha in 2019. See the figure 2 given below.

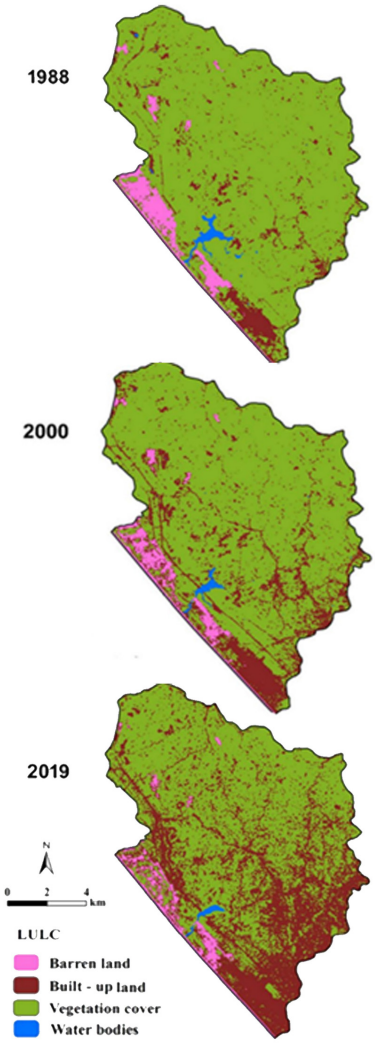

Figure 2: Land cover map 1988-2019, Source: P. Arulbalaji, 2020

About 39.6% of the built-up land has been increased during the period 1988–2019.

Defining the boundary and emphasizing the potentials of regaining wetlands thrive the need to safeguard them.

Gulls, Waders, Terns, Plovers, Shanks, Herons, and Darters are all known to breed and nest in the wetlands. There are four original species of mangroves discovered in Veli Akulam Lake, when there were once 10 species and eighteen subspecies, some of which were listed as endangered species. Because of the brackish water and mangroves, it is an excellent spawning area for a variety of fish.

Akkulam, which is under threat of extinction and is being suffocated by the growing urban growth around it. The identified potential cover of mangroves is shown in figure 3 and existing mangroves are shown in figure 4 to understand the lost mangrove stretches.

Figure 3: Potential mangrove spots in and round Akkulam Veli lake, Source: By author

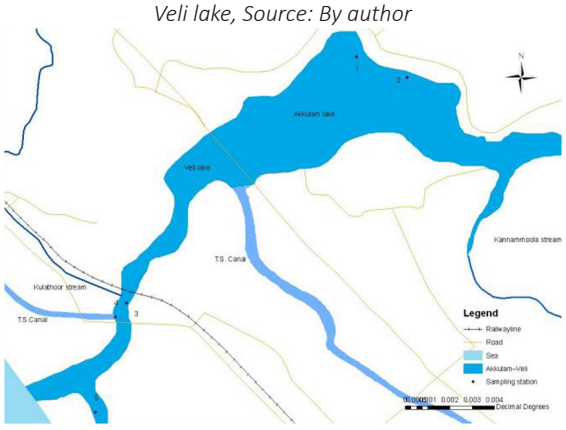

Figure 4: existing mangroves stretch, Source: Moses SA, 2018

3. CRITERIA FOR SELECTION OF DIFFERENT ZONES

The Zones are identified based on the geography of the terrain classifying it as plains, coastal, valley and ridges in and around Akkulam Veli lake where the indigenous settlement were prominent. The settlements of these zones were once depended on the Akkulam-Veli lake, refer figure 2. Their change in pattern of livelihood were considered major factor to identify the threats of the degrading Akkulam-Veli

wetland. Changes occurring like land use change, soil character change, vegetation cover reduction, increasing of built-up area and population are contributing on lake shrinkage over the years. Encroachment occurs near the lake portion, reducing the lake area.

Table 2: Different Zones classified according to the graphical profile. Source: By author

Sl No	Zones	Profile
1	Pothuvilputhan Veedu Colony	Valley
2	Kattela	Valley
3	Kims	Valley
4	Karimanal	Valley
5	Karottuvila	Ridge
6	Oruvathilkotta	Ridge
7	Karikkakom	Plains
8	Arashumudu	Plains
9	Prashanth Nagar	Plains
10	Friends Nagar	Plains
11	Kochuveli	Coastal
12	Veli	Coastal
13	Poundukadavu	Coastal

3.1 Changes in Wetlands of the region

Industrial and other anthropogenic activity has encroached on agricultural lands and wetlands endlessly. The natural landscape has been significantly altered by the ongoing development of industries and communities.

Wetlands in and around the lake region have clearly changed over the years causing a severe threat to its entire ecosystem. Unplanned urban corridor is also one major cause for this change. See figure 5 below.

Figure 5: Wet-land changes over the past two decades, Source: Google earth

The wetlands were converted to main-lands over the years. It was also in this region, which is now disappeared, that mangrove variety was identified. The fish variety of the lake is also impacted by the loss of mangroves and wetlands.

The degree to which two mangrove species—Sonneratia caseolaris and Cerbera odollam—are under anthropogenic stress in a tropical coastal lake system The dangers to mangroves were attributed to anaerobic causes, organic pollution, and salt issues.

Four true mangrove species and fourteen mangrove associates were identified in the Akkulam-Veli Lake stretch. Only Two species are left in the region. Depletion of mangroves affected the existence of fish diversity and bird diversity. (Many fish and birds depending upon the mangroves) and it will affect the quality of water in the lake that will lead to the drastic growth of water hyacinth. Potential Mangrove cover identified is 4.3 ha which is equal to 43000 m2.

4. CARBON SEQUESTRATION AND HOUSEHOLD SURVEY

Mangroves sequester 179.6 g Corg m2a1 per unit area and around 15 Tg Corg a1 globally which emphasis in conserving them (Alongi, 2020). Mangroves store only 4% (range 1.3–8%) of the carbon sequestered by terrestrial ecosystems, implying that they represent a modest contributor to global C storage and sequestration.

Accordingly, the potential stretch calculations are as follows:

Potential Mangrove cover is 4.3 hectors which is equal to 43000 m2. Which states that mangroves in this potential area can sequester about 7,77,22,800 g Corg m2a1 which is equal to 4,300 tons of CO2.

Capacity of existing mangrove stretch of 1.9 hector to sequester carbon is 1900 tons of CO2.

Carbon emissions from the household sectors are calculated and are as follows:

Carbon emissions from the household sectors are calculated and are as follows:

- Electricity: - A total of 127.7 tons of CO2 is emitted every year from the consumption of electricity alone.
- Fuel consumption: - A total of 43.5 tons of CO2 is emitted every year from the consumption of fuel (both petrol and diesel) alone.
- Cooking Gas and wooden pellets: - A total of 0.12 tons of CO2 is emitted every year.

5. RESULTS AND PROTOTYPES

Total CO2 emitted from the house hold sector is 171.32 tons to the atmosphere.

Potential Mangrove cover can sequester about 7,77,22,800 g Corg m2a1 which is equal to 4,300 tons of CO2. Capacity of existing mangrove stretch of 1.9 hector to sequester carbon is 1900 tons of CO2. Which infers that the mangroves have the potential to sequester CO2 emitted from the household. This analysis states that the potential region also has the ability to sell their carbon in the world market introduced after the Kyoto Protocol and Paris Summit, thus the value of a wetland increases and its conservation demand increases.

Table 3:Different Grading system,

Grade	CO2 sequestration
Grade A	1-100 tons
Grade B	>100 tons

Various steps have been set as a prototype for safeguarding these wetlands by providing value and incentives for wetland conservation as the main challenge we face today is the conversion of wetlands

to main lands. Few such prototypes include categorization of wetlands into two Grades; GRADE A and GRADE B, according to which the incentives are provided. See table 3

With respect to these grades various incentives are provided to the owner. It is as follows:

- Reduction in land tax
- Reduction on stamp duty during transaction
- Reduction in electricity tariff for the owner (carbon selling – buying systems)
- Benefits in TDR to conserve the wetlands.

Different incentives for each item under each grade are shown in table below.

Table 4:Different Grading system and their incentives

Items	Grading system	
	Grade A	**Grade B**
Reduction in land tax	50% reduction	25% reduction
Reduction on stamp duty during transaction	1% reduction	0.5% reduction
Reduction in electricity tariff.	10% reduction	5% reduction
TDR benefits	10% addition concession in FSI	10% addition concession in FSI

6. CONCLUSIONS AND DISCUSSIONS

The study aim was to find the potentials of mangroves to sequester the CO2 and aims at conserving these ecosystems. The alarming urbanization leads to unethical encroachment to these wetlands as the land vale to these lands still remain low. The low economic generation from these lands attempts to the owners to sell them or convert them to dry land to increase the land value. A proper economic generation along with incentives will encourage people to safeguard these ecosystems.

An understanding of wetlands and their carbon sequestration wide opens one to the world market of Carbon selling by which one can generate a revenue out of it. Currently, carbon is traded internationally in exchange for carbon credits, which contribute to a global reduction in emissions. The carbon trade certificate encourages businesses and nations to spend in environmentally friendly initiatives and activities that benefit nature, such as reforestation etc.

The potentiality in increasing the incentives and opportunities to sell carbon in the international market would enhance the wet-land values and considered as treasured lands with revenues. Once these wetlands can generate an income of their own, people who acquire these lands will hesitate to sell it or convert them to mainland thus could be safeguarded from further deforestation.

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Impact of Urban Morphology on Vehicular Carbon Dioxide (CO_2) Concentration

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ABSTRACT: Air pollution is a major problem that affects cities' livability, resilience, and long-term viability. It has a direct impact on health and comfort, as well as an increased risk of morbidity and mortality. Vehicular traffic is a major source of carbon emissions, which contributes significantly to air pollution. Changes in morphological factors will help to mitigate the negative consequences of poor air quality. As a result, thorough research into the effects of various morphologies on urban ventilation and carbon concentration due to vehicles is critical. In recent decades, computational fluid dynamics models have been frequently employed to examine the impact of urban morphology on urban ventilation. However, most of the studies are concentrated on idealistic building layouts, with little extensive exploration into the effect of actual urban morphologies. In this study, Local Climate Zone (LCZ) - an effective land classification system for urban studies, were analyzed for its impact on vehicular carbon concentration and subsequent microclimatic effects. Three LCZs, namely LCZ-2, LCZ-5 and LCZ-9A representing high density, medium density and low density respectively were analyzed for its microclimate, traffic flow and carbon concentration using calibrated instruments. It is observed that among the three selected LCZs, LCZ 9A has the least CO_2 content and LCZ -2 has the maximum. The study throws light into the impact of urban built morphology on vehicular carbon concentration. This type of research can be helpful for practitioners and urban designers, especially during the early stages of planning, to identify places that may be prone to poor air quality owing to motor traffic without having to undertake expensive simulations.

Keywords: Air Pollution, Carbon Emission, Local Climatic Zones (LCZ), Urban Morphology, Urban Ventilation

1. INTRODUCTION

Analysis of the urban environment is a fascinating and active field of study, and major strides have been achieved in improving our understanding of how morphological factors impact and even moderate the micro and macro climate. The growth of cities, lead to increase in vehicular traffic and emissions, which ultimately leads to a decrease in air quality and harm to human health. An increased traffic rate in Thiruvananthapuram city affects the air quality as the vehicles boost carbon dioxide concentration.

The major contributor to global warming is widely reported to be the growth of carbon dioxide (CO_2) emissions from human activities (Han et al., 2018, Wang et al., 2019c, Xie et al., 2017). Mainly, the combustion of fossil fuels through different human activities in cities is noted as the key source of global CO_2 emissions (Wang et al., 2014, Yao et al., 2018). Numerous health impacts from CO_2 exposure might be experienced. These include convulsions, coma, hypoxia, sweating, tingling or a pins-and-needles sensation, headaches, dizziness, restlessness, and a tingling or pins-and-needles sensation (Wisconsin Department of Health Services (2022).Literature shows that urban areas generate more than 67 percent of the global energy consumption and emit more than 70 percent of the worldwide CO_2 emissions despite covering about three percent of the earth's surface (Fragkias et al., 2013).

Currently, studies are done or being done on urban forms and CO_2 emissions (Mi et al., 2017, Shan et al., 2016b) and on the relation between vehicular pollutants and meteorological parameters (V S Bachtiar et al. 2018). However, not much work is being done on the impacts of urban morphology and vehicular air pollution. This research intends to study the impact of LCZ (Local Climate Zone) morphology on vehicular CO_2 concentration in streets. This proposal will aid decision-making in designing any urban area to reduce the concentration of vehicular CO_2, reduce the trapping of heat in urban setups and benefit human health as well as infrastructure.

2. LITERATURE REVIEW

A detailed survey of literature has been done on the studies related to LCZs, urban morphology and vehicular carbon emissions. The related terminologies also have been discussed below.

2.1 Urban morphology

Urban morphology refers to the study of the form of human settlements at various scales in order to comprehend its spatial organization, character, and development process (Patrick M.Schirmer, 2015). The words "morph" and "logy" are the roots of the word

“morphology”, which refers to the logic of form perception. These investigations into the physical characteristics, structures, proportions, and deformation of objects and their constituent parts have been carried out in a variety of domains (Pinzon Cortes,2005).

The term "urban form" refers to the primary physical components of a city, such as its streets, squares (the public space), street blocks, plots, and buildings, to name a few. Goethe, a German writer and philosopher who focused on biology in several of his works, is credited with coining the term "morphology." For the study that studies the essence of shapes, Goethe coined the term "morphology." The generic and abstract nature of morphology, despite its classification as a branch of biology, allowed for its usage in a variety of contexts, including the study of towns in central Europe around the end of the 19th century. Studying the physical part of an urban space is thought to be the most appropriate way to define the overall image of character because its physical nature and organization are the most apparent and long-lasting aspects.

2.2 Local climatic zones

The term "Local Climate Zones" refers to a system of 17 groups, 10 of which can be considered urban. The system's initial intent was to provide a framework for studies on urban heat islands by enabling the standard sharing of temperature information throughout cities (Stewart and Oke, 2012). Its universality has significant benefits since it enables systematic comparisons between global studies of intra- and inter-urban heat islands (Bechtel et al., 2019a). It offers a platform for information sharing, describes the parameters of the urban canopy in the processes of the urban ecosystem and supports model applications, particularly for cities with weak or insufficient data infrastructures (Stewart and Oke, 2012). This approach seeks to be impartial (incorporating quantifiable and measurable aspects essential to surface thermal climate), inclusive (representing local landscapes in a sufficiently general manner to avoid inherited regional or cultural biases), and standardized. Within the canopy layer, each class aims to have generally uniform air temperature. By thresholding 10 geometric and 7 surface cover criteria, they defined 17 LCZ classes (Table 1).

2.3 Vehicular air pollution and carbon dioxide

Atmospheric pollution in developing countries throughout the world is often severe and constantly increasing since the rate of increase in air pollutant concentrations in developing countries like India is faster than in industrialized countries(Bhaskar & Mehta,2010). After industrialization, the concentration of CO_2 rose by 43% due to the burning of fossil fuels and deforestation n (NOAA, 2017).The primary cause of air pollution, according to research, is roadside dust. Daily deposits and accumulations of primary and secondary particles from many anthropogenic and natural sources are mixed with hazardous compounds from vehicle emissions and exhausts(Amato et al., 2009).The traffic volume on the road and their speeds are among the non-exhaust emission sources of pollution (Chen et al., 2006a).

According to data from the Ministry of Roadways and Transport, there were 0.3 million registered automobiles in the nation in 1951 and 253 million in 2017. For the past ten years, the country's registered vehicle growth rate was 10.1%, above the national highways' 5.54% CAGR. Depending on the chemical makeup of the fuels, the quantity of CO2 emitted by the burning of 1 L of gasoline and 1 L of diesel fuel varies, but it is roughly 2.36 kg and 2.60 kg, respectively. With minor amounts of CO, CH_4, NO_2, SO2, HC, and PM, road transport accounts for 243.82 Tg of CO_2 emissions in India, or 94.5% of total emissions (Badrinath et al.,2007).

2.4 Urban heat island

Cities have become densely inhabited urban environments with less greenery and more impermeable surfaces as a result of rapid urbanization. When compared to their rural surroundings, urban areas have greater air and surface temperatures because of the loss of vegetation, which increases the amount of heat stored in the ground layer and building fabrics, (Oke, 1982). Urban Heat Island (UHI), a phenomenon, has grown to be a problem for the quality of densely populated urban areas (Wong and Yu, 2005).

UHI is a measure of the overall microclimate changes brought on by modifications to urban surfaces (Landsberg, 1981). According to Akbari et al. (2001), UHI refers to locations where the natural vegetation has been gradually replaced by structures like roads and buildings and where air temperatures tend to be higher than in their rural surroundings. Another definition of UHI says, urban heat island is a result of micro-climatic differences brought on by "man-made" interventions and changes to the environment (Kolokotroni et al., 2006). UHI occurs throughout the day and night, but its peak intensity is reached 3 to 5 hours after sunset (Oke, 1987) which is due to the fact that cities are unable to cool down since a large portion of the heat is retained in the roadways, buildings, and other structures.

2.5 Acronyms:

EO	Earth Observation
LCZ	Local Climatic Zone
MP	Morphological Parameter
SVF	Sky View Factor
BSF	Building Surface Fraction
ISF	Impervious Surface Fraction
UHI	Urban Heat Island
PM	Particulate Matter

3. METHODOLOGY

In the chosen study location – Thiruvananthapuram city, clusters in distinct LCZs were identified based on the morphological zone properties prescribed by Steward and Oke (Table 1). LCZ 2, LCZ 5 and LCZ 9A representing high, medium and low built density respectively were considered for the detailed analysis. Hourly CO_2 concentration was measured on the road side area of these three LCZs using calibrated probes/TESTO 420 air quality measurement tool. Along with CO_2 readings, traffic volume and meteorological parameters, namely, air temperature and wind speed were measured. Further, relation between CO_2 and LCZ morphology, CO2 and wind speed, CO_2 and temperature has been analyzed. The same process can be used to investigate the relation between LCZs and vehicular CO_2 concentrations in any location. The methodology adopted for the study is represented in Figure 1.

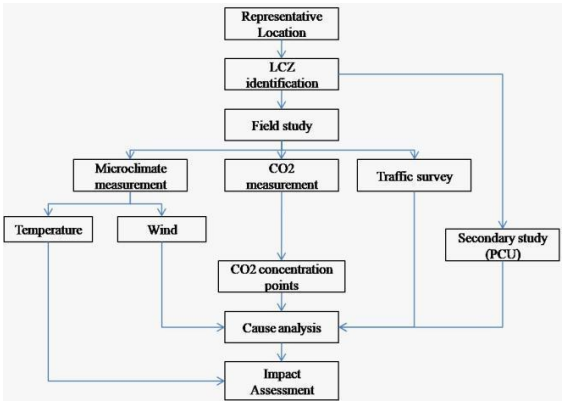

Figure 1: Methodology chart, Source: Author

3.1 Study locations

Three Local Climatic Zones have been selected that represent different morphological parameters. LCZ 2 (Gandhari-Amman Road - Statue Road), LCZ 5 (Press Road - Pulimoodu Road) and LCZ 9A (VellayambalamRoad - Museum Road) (Figure 2, Figure 3) are taken for the study as they represent high density, medium density and sparsely built urban settings respectively.

These three study sites are selected based on the on site measured threshold levels of morphological parameters that define the local climatic zones (Figure 4). These different settings allow us to get the impact of various urban settings on CO_2 concentration as they differ in morphological parameters as well as in meteorological parameters.

3.2 Tools and techniques

LCZ categorization is done based on ten morphological parameters, namely: Sky view factor, Aspect ratio, Building surface fraction, Impervious surface fraction, Previous surface fraction, Height of roughness elements, Terrain roughness class, Surface Admittance, Surface Albedo and Anthropogenic heat output.This study considers the Sky view factor, Aspect ratio and Building surface fraction. On-site, measurements are taken to calculate the above-stated morphological parameters.

LCZs threshold measures are taken from Stewart and Oke (2012). A sampling of CO_2 was done at three

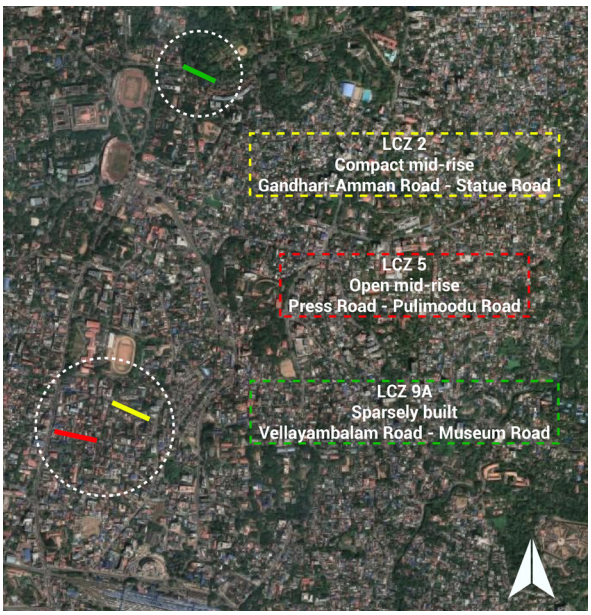

Figure 2: Google map of Trivandrum City highlighting three selected LCZs, Source: Google Maps

Figure 3: Views and street maps of three studied LCZs, Source: Google Maps

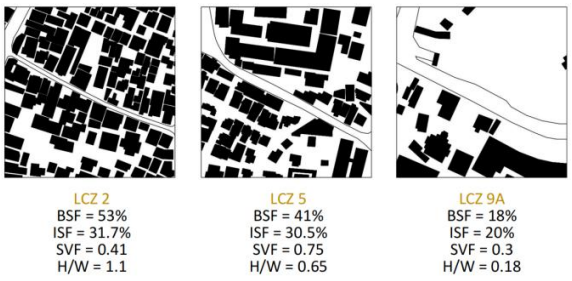

Figure 4: Calculated Morphological Parameters for 3 LCZs, Source: Author

Table 1: Values for geometric and surface cover properties for local climate zones, Source: Stewart and Oke, 2012

Local Climatic Zone (LCZ)		Sky View Factor (a)	Aspect Ratio (b)	Building Surface Fraction (c)	Impervious Surface Fraction (d)
Compact high-rise	LCZ 1	0.2-0.4	>0.2	40-60	40-60
Compact midrise	LCZ 2	0.3-.06	0.75-2	40-70	30-50
Compact low-rise	LCZ 3	0.2-0.6	0.75-1.5	40-70	20-50
Open high-rise	LCZ 4	0.5-0.7	0.75-1.25	20-40	30-40
Open midrise	LCZ 5	0.5-0.8	0.3-0.75	20-40	30-50
Open low-rise	LCZ 6	0.6-0.9	0.3-0.75	20-40	20-50
Lightweight low-rise	LCZ 7	0.2-0.5	1-2	60-90	<20
Large low-rise	LCZ 8	>0.7	0.1-0.3	30-50	40-50
Sparsely built	LCZ 9	>0.8	0.1-0.25	10-20	<20
Heavy industry	LCZ 10	0.6-0.9	0.2-0.5	20-30	20-40
Dense trees	LCZ A	<0.4	>1	<10	<10
Scattered trees	LCZ B	0.5-.0.8	0.25-0.75	<10	<10
Bush, scrub	LCZ C	0.7-0.9	0.25-1.0	<10	<10
Low plants	LCZ D	>0.9	<0.1	<10	<10
Bare rock or paved	LCZ E	>0.9	<0.1	<10	<10
Bare soil or sand	LCZ F	>0.9	<0.1	<10	<10
Water	LCZ G	>0.9	<0.1	<10	<10

a Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere
b Mean height-to-width ratio of street canyons (LCZs 1-7), Building Spacing (LCZs 8-10), and tree spacing
c Ratio of building plan area to total plan area (%)
d Ratio of impervious plan area (bare soil, vegetation, water) to total plan area (%)

Table 2: PCU factors for various types of vehicles on Urban Roads, Source: IRC 106

Vehicle Type		Equivalent PCU Factors	
		Percentage composition of Vehicle type in traffic stream	
		5%	10% or above
Fast Vehicles			
1	2 Wheeler Motor cycle or scooter etc.	0.5	0.75
2	Passenger car, pick-up van	1.0	1.0
3	Auto-rikshaw	1.2	2.0
4	Light commercial vehicle	1.4	2.0
5	Truck or bus	2.2	3.7
6	Agricultural tractor trailer	4.0	5.0
Slow Vehicles			
7	Cycle	0.4	0.5
8	Cycle-rickshaw	1.5	2.0
9	Tonga (Horse drawn vehicle)	1.5	2.0
10	Hand cart	2.0	3.0

Table 3: On-Site measured meteorological parameters, CO_2 concentrations (ppm) and traffic volume (PCU/Hr), Source: Data collected by the author

TIME	CO2 (ppm	TEMP (°C)	WIND (m/s)	RH %	TOTAL PCU/HR
LCZ 2 - Gandhari-Amman Road - Statue Road					
12:00-13:00	350	38.3	0.55	54.2	333.75
13:00-14:00	342	38	1.1	51.3	286
14:00-15:00	378	35.7	0.5	57.2	223.25
15:00-16:00	340	36.9	0.9	49.8	197.5
16:00-17:00	325	35	1.3	45.2	239.75
17:00-18:00	340	33.1	1.34	45.69	191
18:00-19:00	320	31.2	1.3	43.74	150
19:00-20:00	311	29.3	1.7	41.79	167
LCZ 5 - Press Road - Pulimoodu Road					
12:00-13:00	383	40.3	1.45	47	1180.55
13:00-14:00	325	35.7	4.0	60.8	1015.8
14:00-15:00	320	36.3	3.36	56.1	659.95
15:00-16:00	338	37.8	4.05	52.8	712.25
16:00-17:00	350	35.8	3.5	50.2	873.2
17:00-18:00	326	32	3.2	48.1	629.35
18:00-19:00	298	30	3.8	53.2	513.75
19:00-20:00	305	29.2	4.0	54	354.75
LCZ 9A - Vellayambalam Road - Museum Road					
12:00-13:00	420	37.8	4.1	50.9	2187.25
13:00-14:00	374	36.4	4.2	55.9	1771.25
14:00-15:00	390	37	3.5	54.3	1530.8
15:00-16:00	365	35	3.1	57.1	1356.8
16:00-17:00	424	33.8	3.9	59.5	1478.25
17:00-18:00	230	32.7	4.0	60.9	1440.6
18:00-19:00	263	29.2	3.9	55.2	1217
19:00-20:00	280	28	3.6	56	1287

points representing three LCZs, namely Gandhari-Amman Road - Statue Road (LCZ 2), Press Road - Pulimoodu Road (LCZ 5) and VellayambalamRoad - Museum Road (LCV 9A), as mentioned in Table 3. CO_2 Readings are taken using TESTO 440. A sampling of CO_2 concentrations is conducted for measurements 60 minutes apart for 8 hours during the peak vehicular movements of the day.

Meteorological conditions measured are temperature (°C), wind speed (m/s) and relative humidity (%) using TESTO 440. A sampling of stated meteorological conditions is conducted 60 minutes apart for eight hours during the peak vehicular movements of the day, as mentioned in Table 3. Traffic flow volume is measured using the standing observer method using tally sheets to record traffic flow. PCU factor values mentioned in IRC 106 are used to convert traffic volume into PCU (Table 2).

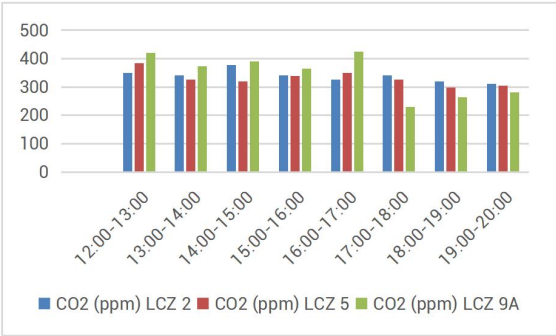

Figure 5: CO_2 concentration (ppm) at different times of the day for three studied LCZs, Source: Author

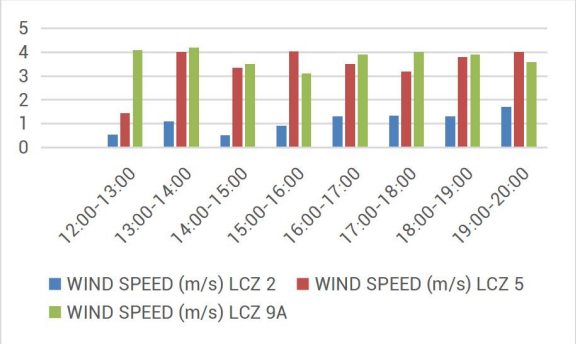

Figure 6: Wind speed (m/s) at different times of the day for three studied LCZs, Source: Author

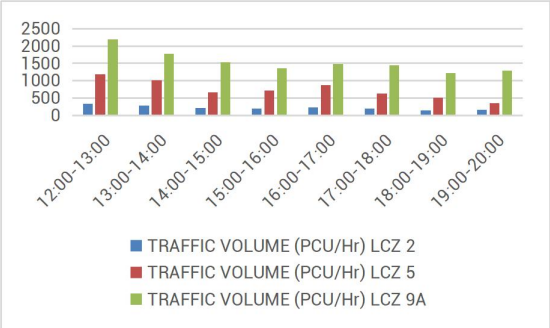

Figure 7: Traffic volume (PCU/Hr) at different times of the day for three studied LCZs, Source: Author

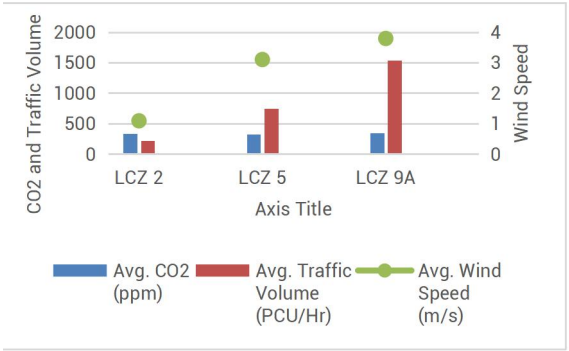

Figure 8: Avg. CO_2 concentration (ppm), Avg. traffic volume (PCU/Hr) and Avg. Wind speed (m/s) for three studied LCZs, Source: Author

4. RESULTS AND DISCUSSIONS

The residence period of chemicals in the atmosphere is influenced by the intrinsic variability in air pollution movement and dispersion, the temporal fluctuation of source intensities, and the filtering and conversion mechanisms in the atmosphere. Variability in the concentration of a pollutant arriving at a receptor is caused by these and other factors.

The three studied LCZs possess distinct properties both in terms of urban morphology and meteorology. These factors affect the CO_2 concentration in different ways. Hence, the CO_2 readings at these three LCZs were distinct (Table 3). After examining the readings, following results were attained.

4.1 CO2 concentration across LCZs

The lowest CO_2 concentrations is recorded in LCZ 9A (least being 230 ppm between 17:00-18:00), and the highest CO_2 concentration is recorded in LCZ 9A (highest being 424 ppm between 16:00-17:00) (Figure 5).From 12:00 PM to 17:00 PM, the CO_2 concentrationsin LCZ 9A are higher than the other LCZs, however after 17:00 PM, this reverses (Table 3). Based on ASHRAE Standards, CO_2 concentrations in outdoor air typically range from 300 ppm to 500 ppm (tolerable/safe).

Therefore, based on the onsite measurements, it is concluded that the CO_2 amount on the roadside areas of the studied LCZs between the studied time period (12:00 PM to 20:00 PM) are safe. This conclusion also means that CO_2 on the studied roads does not endanger human health.

4.2 Ventilation Availability in LCZs

The highest wind speeds are recorded in LCZ 9A (highest being 4.2 m/s), whereas, the lowest winds speeds are recorded in LCZ 2 (Figure 6).

4.3 CO_2 concentration and traffic volume

Generally, traffic volume should be directly proportional to CO_2 concentration, as more number of vehicles will emit more CO_2. But in this case, even when the traffic volume is significantly higher in LCZ 9A, CO_2 concentration is almost equal to CO_2 concentration in LCZ 2 and LCZ 5 (Figure 7).

This result indicates that, there is an impact of morphology and meteorology on CO_2 concentration, which is negating the CO_2 concentration due to traffic volume.

4.4 Impact of urban morphology on carbon concentration

The comparison between CO_2 concentration, traffic volume and wind speed across the three LCZs (Figure 8) shows that, even when the traffic volumes are significantly higher in LCZ 9A, CO_2 concentration is almost equal to the CO_2 concentrations in the other two LCZs and even lower than LCZ 2 and LCZ 5 after

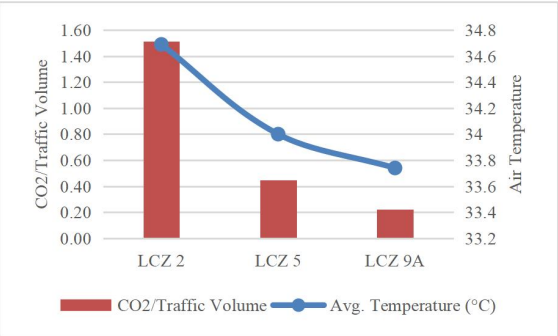

Figure 9: CO2/Traffic Volume and average air temperature (°C) for three, Source: Author

17:00, when the traffic volumes are significantly higher at these particular times (Table 3). Wind speed is found to be the most effective meteorological parameter in dispersing CO_2 among the studied parameters as higher wind speeds take away the CO_2 particles form the roads.

Thus, it is concluded that LCZ 9A can generate higher wind speeds (Figure 6) that, in turn, disperse vehicular CO_2 emissions resulting in lower CO_2 concentrations. This is because the threshold levels of morphological parameters that characterize LCZ 9A (lower aspect ratio, lower SVF and lower BSF) enable it to generate higher wind speeds. This correlation shows the inverse relationship between CO_2 gas concentration and wind velocity passing through the study site. This result is in accordance with V S Bachtiar et al. 2018. Therefore, among the three studied LCZs, LCZ 9A has proven to be the best urban setup for dispersing the vehicular CO_2 concentration.

4.5 Carbon concentration and urban thermal environment

The highest average air temperature is recorded in LCZ 2 (34.69°C), while the lowest air temperature is recorded in LCZ 9A (33.74°C) (Figure 9).

When we divide average CO_2 concentration by average traffic volume, we can get CO_2 per unit traffic volume. Just considering traffic volume, the CO_2 per unit traffic volume for LCZ 9A should have been the highest as this has the highest traffic volume. Whereas in reality, due to morphology, LCZ 9A has the lowest and LCZ 2 has the highest value. Due to morphology which then affects the meteorology, CO2 per unit traffic volume of LCZ 9A is significantly lower. This helps in reducing the heating effect due to vehicular emissions (Zhu et al., 2017). This reduction in vehicular emission and CO_2 concentration, results in reduction of UHI.

It is concluded that LCZ 9A can generate maximum wind speeds, which reduces air temperature and negates the heating effect caused by UHI due to vehicular emissions (Zhu et al., 2017). This increased UHI due to CO_2 concentration also increases the energy consumption in urban areas required for cooling (Oke, 1985).The threshold levels of morphological parameters that define LCZ2 (higher aspect ratio, higher SVF, higher BSF and higher ISF) adds up in increasing the air temperature which is in contrast with LCZ 9A. Along, with these morphological parameters, unlike LCZ 9A, morphology of LCZ 2 is unable to generate higher wind speeds. This reduces the dispersion of vehicular CO_2 which adds up to temperature rise.

5. LIMITATIONS AND FURTHER WORK

The scope of this investigation is to analyze the impact of Local Climatic Zones on the vehicular CO_2 concentration in urban areas. The study is subjected to several limitations, such as inclusion of more LCZs, and meteorological parameters, which may be addressed in the forthcoming research.

6. CONCLUSION

There is diverse perception towards LCZs, urban morphology and carbon emissions in literature. However, hardly any study has attempted involving all the attributes and entities that has to be addressed while examining an LCZ in terms of emissions. Among the studied LCZs, LCZ 9A has proven to be the best urban setup for lowering vehicular CO_2 concentrations. Therefore, it is concluded that the threshold values of morphological parameters that define LCZ 9A should be implemented in designing urban spaces to reduce vehicular CO_2 concentrations. Also, among studied meteorological parameters, wind speed is found to be the most effective meteorological parameter in dispersing CO_2. It is observed that LCZ 9A can generate the highest wind speeds, which boosts CO_2 dispersion, which is in accordance with V S Bachtiar et al. 2018. This will also help reduce the urban heat island effect (Priyadarsini Rajagopalan, 2014) and enhance infrastructure as well as human health. Further, the study can be applied to the designing of urban setups, road networks, traffic design and control, pollution control and meteorological research.

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Toward Zero Energy:

Passive Design Strategies to Achieve Net Zero Energy in Residential Buildings

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ABSTRACT: In the world of modernist technologies and strategies, we often forget the importance of passive sustainability and vernacular design. These designs are specific to the region as they use local materials and resources. Another key aspect of vernacular architecture is that it is related to and is influenced by the local culture and climatic conditions. Thus, they are specific to the areas they are built in and also show characteristic elements unique to the region. However, considering the above statement in light of designing toward net-zero structures, it is important to first understand what the phrase stands for and how this term would hold true, not just in the current world but also in the world to come with all its changes. To state briefly, Net-Zero structures are structures that have zero dependence on fossil fuels as they generally gravitate toward renewable sources of energy to meet their energy demand. This would sound like a solution to a few of the world's greatest problems; pollution, depletion of natural resources, and global warming. Hence, by bridging the passive design technologies and net-zero goals, it would become possible for a developing country like India to achieve global standards of sustainability. Thus, this is a research paper that deals with exploring a contemporary example of the built environment by studying an existing residence in Kerala, to uncover its innate positive elements and means of responding to the local climate while also exploring other additional methods to make the design more sustainable and net-zero directive than it already is.

KEYWORDS: Sustainability, Vernacular, Traditional, Climate responsive, Passive design

1. INTRODUCTION

Architecture at any given point is at its peck. At any given time, Architecture seeks to take into account the regional situation and quite literally is a reflection of its time. That being said, the current situation demands for sustainability. More and more people are concerned with the ever- worsening climatic conditions. Everyone is trying to find a way to save the environment and architects are doing their part too. But the questions that need to be raised are; what of the buildings already built? Is there no saving the existing structures? Or are they merely left as bad examples?

Net zero energy buildings help to produce as much energy as they consume and the energy produced could be a mix of onsite and renewable energy sources offsite. In other words, they use secondary sources of energy that are renewable and minimize carbon footprint (Purushottam, 2022). This is achieved by incorporating climate responsive design and technology interventions. Net zero energy buildings can be achieved by implementing the right strategy, design elements, construction materials and use of the right appliances during the use phase.

Keeping these in mind, the concept of sustainability and Energy efficiency will be explored through an existing residential project built not by any architect but designed by the tenants themselves, just like a vast majority of Pre-existing Structures.

Achieving an reduced energy or Zero energy goal is more convenient for new construction but for a preexisting building, it can be attained through retrofitting, by improving its energy efficiency and using renewable sources for energy generation and energy optimization (Albadry, Tarabieh, and Sewilam 2017; Vora,Rajgor, and Pitroda 2016). Although retro-fitted buildings are more expensive than a new Zero energy building due to restrictions of preexisting building orientation, position, shape and geometry(Joshi, Pathak, and Singh 2014), but various studies suggest that it can be achieved within competitive cost (Albadry, Tarabieh, and Sewilam 2017). Instead of altering the building's structural components and energy supply system, energy consumption can be reduced up to 20–30% by optimizing the operations and improving the Energy Efficiency Measures in a building (Guan, Xu,and Jia 2010; Kneifel 2010). The energy consumed for heating in a conventional building can be saved up to 80% in a Passivhaus (Zeiler and Boxem 2013). Broadly, Zero Energy Building is based on the concept of energy optimization and clean energy generation through sustainable renewable resources (Albadry, Tarabieh, and Sewilam 2017; Feng et al. 2019) hence; Zero Energy Building mainly focuses on balancing the energy requirements to reduce the energy demand and the required energy load generation (Pless and Torcellini 2010).

The term 'sustainability' is often associated with high-rise structures or buildings with a lot of technological interventions and design specifications. But it's often forgotten that our ancestors were sustainable in their own right which is referred to by another term indicating a style called 'vernacular'.

Yet in a way both terms are same but different. The exploration of these two words, their meaning and application with respect to a small-scale project is the core idea of this research. It seeks to understand sustainability in passive design and vernacular elements, as well as tries to integrate possible technologies that are not necessarily 'high-tech' but none the less, are means to make the current project capable of becoming Net-Zero and truly Sustainable.

1.1. Aim of Study

The main case of study for this paper is located in Kannur, Kerala; a contemporary house constructed in a place with warm humid temperature. This case study is chosen with the primary aim of understanding an existing structure in its present site context and how this existing structure can be made sustainable with economical and minimal interventions.

Thus, this study is to understand sustainability at a small scale. On studying a small-scale residential project, this paper aims to analyze where this structure currently stands in terms of sustainability and where it can be taken from there.

By understanding its existing conditions as well as the climatic conditions it experiences along with a traditional case study, this paper explores topics such as shadow analysis, construction materials as well as construction techniques and climate responsive analysis that give in-depth understanding of the site and structure allowing suitable interventions for the betterment of the energy efficiency and sustainability of the existing structure.

1.2. Method of Study

Acquiring the necessary data for this study is done by being on site and taking into consideration the experience of the tenants living on site. The climatic analysis and other case studies have been studied through literature studies and software simulations.

Taking all this information, the paper is structured to achieve the goals of the study. Starting from an overview, a case study of a vernacular building is taken so as to understand the authentic style of architecture followed by study of the main project. The climatic study of the location followed by the construction and material analysis of the project ensures a thorough introduction to the building in focus. This is followed by the detail sustainability analysis of the project at hand.

On completing the analysis, inferences are drawn and observation is made. Leading to a set of architectural interventions that may be applied to attain Net-Zero energy levels and well as improve its current sustainability.

2. A VERNACULAR CASE STUDY

Thai kottaram is the core of the Padmanabhapuram palace complex. This region has tropical climatic with high rainfall. Thai kottaram is a two storeyed structure with a courtyard, built in the 16th century by Ravi Varma. It is one of the oldest buildings in the palace complex. The building is well suited for Kerala's humid climate. The slope roofs aids for drain of water due to rains and the cool breezes passes through the jaalis of the windows.

The building is planned according to Thachu shastra, the science of carpentry and vastu shastra (Fazeli & Goodarzi, 2010). Thai kottaram stands in the brahmasthana, the point where the main axes cut each other, which corresponds to the sacred centre of the Vaastu purusha mandala (Figure 1). This forms the basis of design for the entire palace complex.

Figure 1: Thai Kottaram, Padmanabhapuram Palace Complex, Source: Keralatravels, 2022

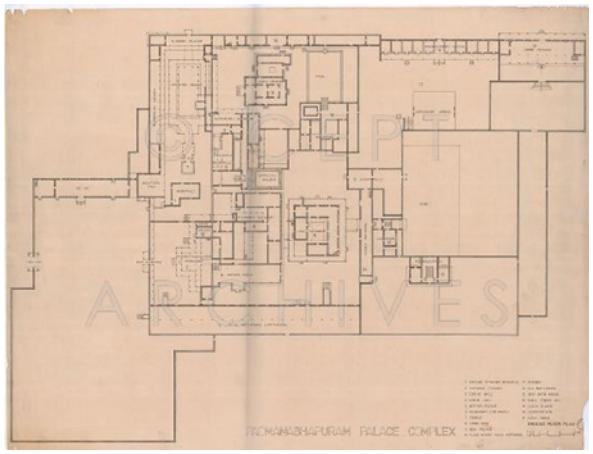

Figure 2: Plan of Thai Kottaram, Source: CEPT Archives, 2014

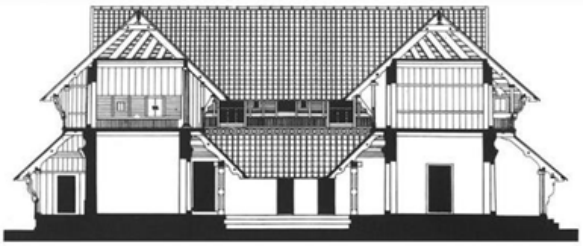

Figure 3: Palace Section, Source: CEPT Archives, 2014

The kottaram have a nallukettu structure, established by four rectangular blocks. These blocks connect to one another by intermediary structure with high pitched roofs and courtyard left open to bring light and ventilation (Figure2 and Figure 3). The courtyard serves as the focal point of interaction between the family and also a pace for various household and religious activities. The internal and external verandas act as a protection from rain and sun. The main entrance to Thai kottaram is through a doorway located in the southern corner of the building. The door opens to Ekantha mandapa, a place used for religious activities. The inner section of the palace opens to a nallukettu with nine rooms arranged around a central courtyard, laid with hewn stone blocks.

The major building materials used include laterite stone, granite stone, wood, clay roofing tile, mud, lime, timber, etc. all the material used for construction are locally available. The palace structure is constructed out of wood with laterite used very minimally for plinths and for a few select walls. The roof structure is constructed out of timber, covered with clay tiles. Significant features of the building include the intricate joinery work, wood work and carvings, and the lustre of the black floor. The mantrasala on the first floor has wooden louvers to admit air and light, that helps to maintain a pleasant temperature indoors. Surface water drainage and sewage disposal is done through an underground system laid towards the south east.

3. CASE STUDY OF CONTEMPORARY HOUSE IN CANNANORE

The project is located in Punnad, Irrity, Cannanore amidst lush green vegetation over a span of 1.57 acres in a rectangular contoured site which can be accessed through a secondary road connecting Punnad and Parayangaad- Uliyil (Figure 4a).

The highest recorded point on the site is 5 meters above ground level while the lowest is 6 meters below ground level where the road level is considered 0.Water is supplied to the entire site from two prominent wells in the site; one dug-step well (16 m depth; 3 m diameter) in the northern end of the site- used for bathrooms, gardening and kitchen purposes; one dug well (13 m depth; 2 m diameter) attached to the residence used for drinking purposes (Figure 4b).

On site vegetation include cashew nut, jackfruit, allspices tree, mahogany, vanilla, pepper, betel nuts, coconut, rubber, mango tree, plantains, passion fruit, papaya, malanga root, neem, amla, turmeric, custard apple tree, curry leaves trees, drumsticks, pumpkins, tomatoes, green chillies, bird's eyes chillies, golden shower, hibiscus, roses, aloe vera, tulsi, marigold, grebara daisy.

Figure 4a: Aerial view along with road network, Source: Author, 2021

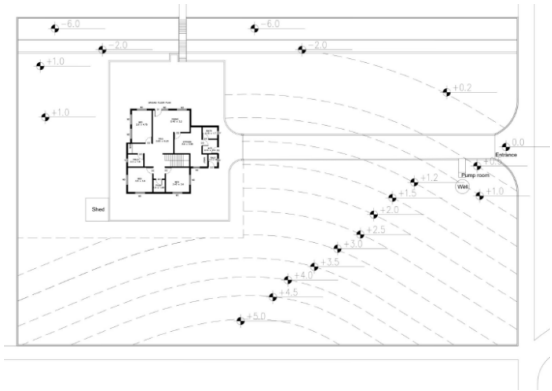

Figure 4b: Site Plan, Source: Author, 2021

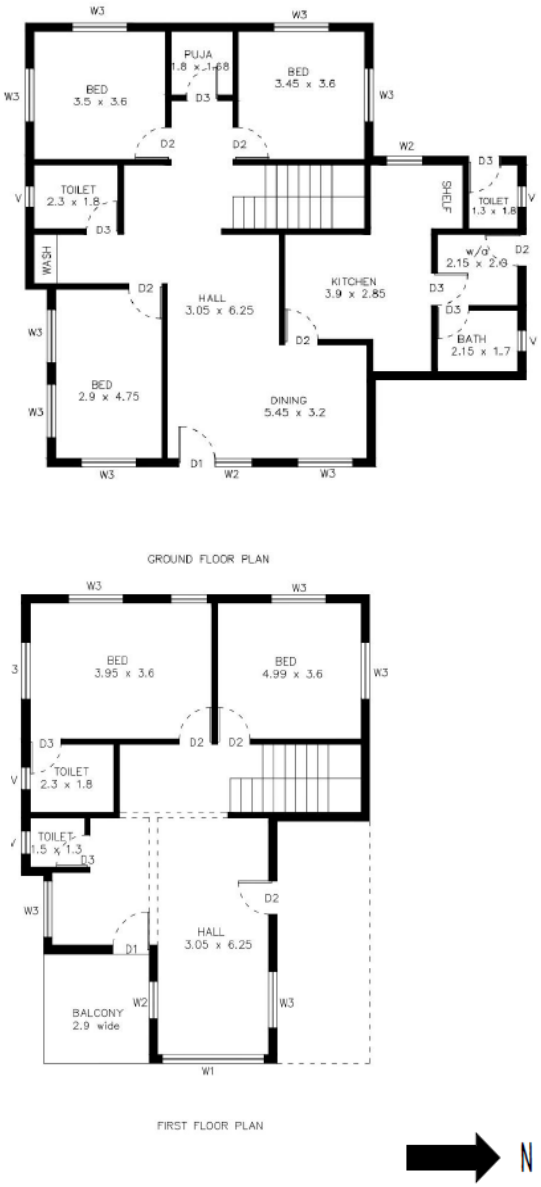

Figure 5a: Plans, Source: Author, 2021

Figure 5b: Elevation, Source: Author, 2021

Figure 5c: 3D view of the house, Source: Author, 2021

The residence was initially built in 1990 but was later reconstructed in 2018 which included addition of the first floor to the initial 3BHK plan (Figure 5a, Figure 5b and Figure 5c). Occupying a total built-up area of 3500 sq ft, this abode houses a living, dining, and kitchen with utility, three bedrooms, one common toilet, one bath and servant's toilet in the ground floor while the first floor houses a hall with common bathroom, two bedrooms and two balconies. There is a fish pond on the rear side of the building and a store for firewood with outdoor kitchen on the southern side of the residence.

4. CLIMATE STUDY

Kerala has a warm humid climate, characterized by the following features:

- Hot and sticky weather
- Continuous presence of dampness
- The air temperature is moderately high, 21 to 32°C, with minimal fluctuations between day and night
- High humidity across all seasons
- Mostly diffused sunlight due to dense cloud cover
- Low speed winds that are variable in speed and constant in direction.

The heat loss in this kind of weather happens through convection or conduction. Since the air is moisture laden, evaporative cooling is not effective to cool bodies down. Some level of comfort can be achieved by outdoor breeze passing through the building and also across the surface of the occupants. As the temperature difference throughout the day is negligible, the walls and roof temperature remain the same as that of the air.

4.1. Temperature

In Kannur, the average temperature is about 26 °C, with April being the warmest month with a maximum temperature of 34.1°C and a minimum temperature of 25.6°C (Figure 6a).In July, temperatures average from 28.9°C to 23°C, making it the coldest month. An increase in the average temperatures has been recorded over the last four years (Figure 6b).

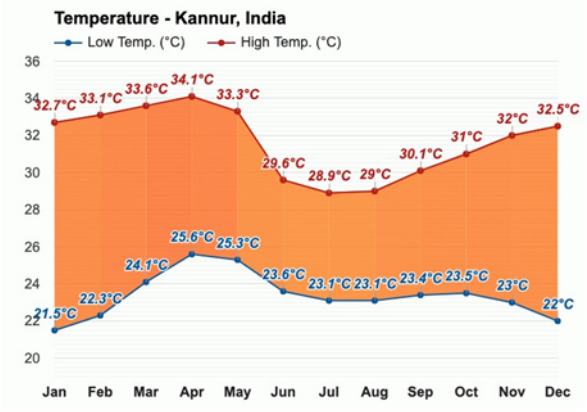

Figure 6a: Annual Temperature, Source: Michaelaschludecker, 2022

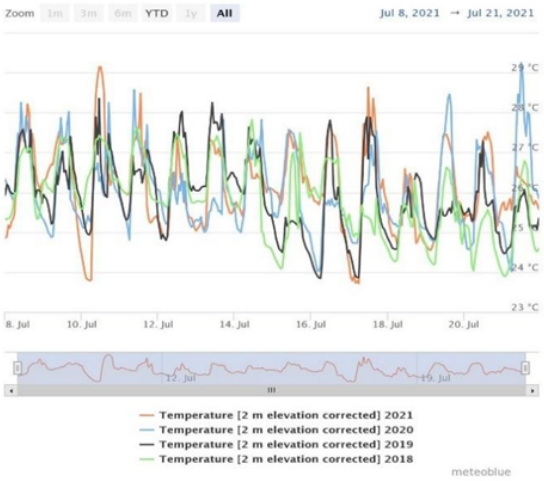

Figure 6b: Temperature at 2m, Source: Michaelaschludecker, 2022

4.2. Precipitation

February is the driest month, with only 0.2mm of precipitation received. The majority of the rainfall happens during June, where precipitation levels reach 1033.5mm.July has the highest number of rainfall days

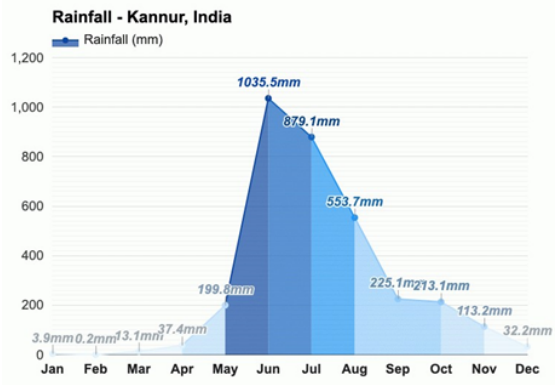

Figure 7a: Rainfall, Source: Michaelaschludecker, 2022

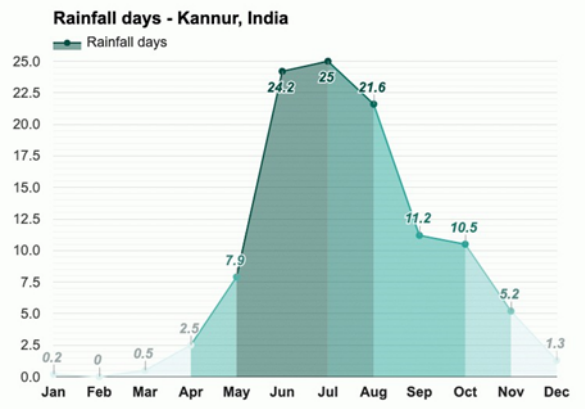

Figure 7b: Rainfall Days, Source: Michaelaschludecker, 2022

with 25 days, whereas February has the least number of rainfall days with 0 days (Figure 7a and Figure 7b). A fall in the average amount of rainfall received has been seen over years.

4.3. Wind

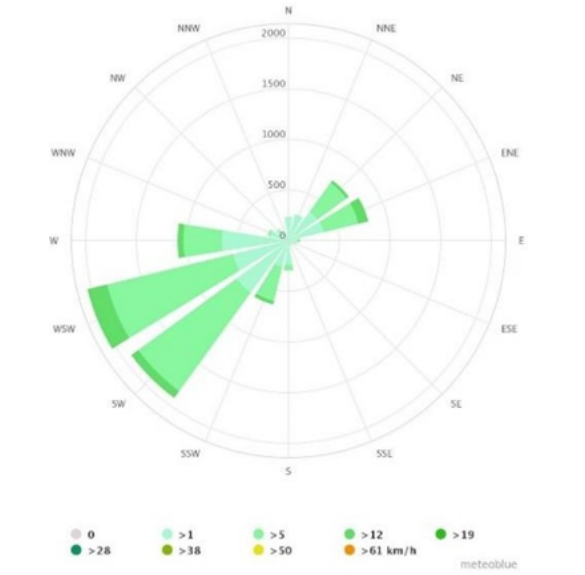

Figure 8a: Wind Direction, Source: Michaelaschludecker, 2022

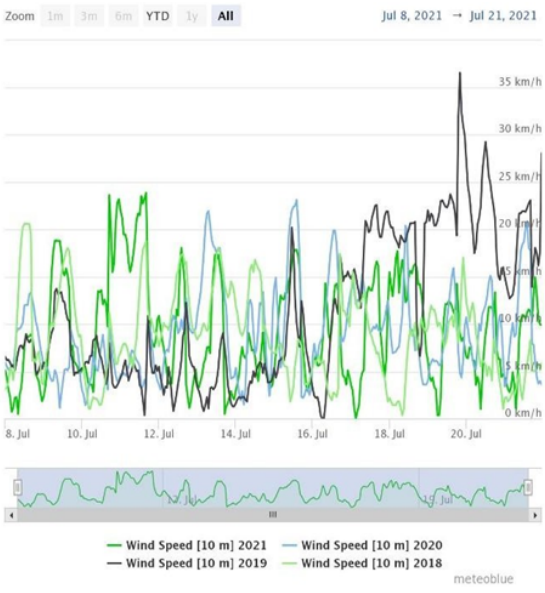

Figure 8b: Wind Speed at 10m, Source: Michaelaschludecker, 2022

The majority of the winds come from the WSW direction for 1040 hours/years and SW directions for 885 hours. The wind speed is an average of 3.6 km/h throughout the year, with March being the windiest, with an average wind speed of 5km/h(Figure 8a and Figure 8b). The average wind speeds recorded at different elevations from sea level have increased over the years.

4.5 Shadow Analysis

A shadow analysis was done to study the shadow pattern on the building within a time frame of 11am to 3pm, on the first of every month, for a year (Figure 9). The house experiences an overheating period during the months of May, June and July, where none of the faces of the house experience any shadow falling on it.

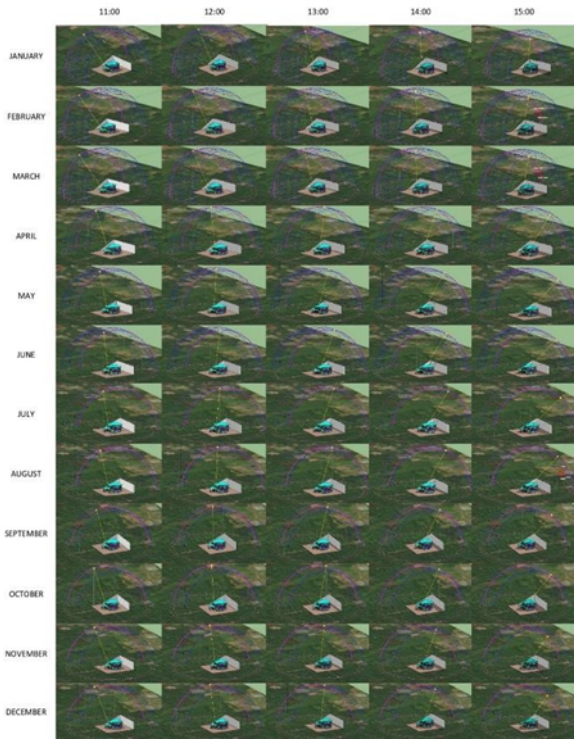

Figure 9: Shadow analysis done for 2021, Source: Author, 2021

5. CONSTRUCTION MATERIALS

In the residential building the major materials used for construction includes laterite blocks, lime mortar and plaster, various varieties of timber (teak, jackfruit, mahogany), flooring is done with vitrified tiles, ceiling uses concrete slab with water proofing. The external wall is made of 3 layers: lime plaster, laterite masonry and wall finish paint. The laterite stone are traditionally used after direct extraction from the naturally occurring sources. Laterite is sieved and mixed with 5% of cement and chemical setting agent. The mixture is then machine compressed to form high density blocks. Usage of laterite blocks reduces the heat within the house. They have lower embodied energy due to use of locally available materials and high recyclability factor. Laterite stones improve strength as they are exposed to sun and weather.

Lime is used for plastering and as mortar in the building construction. Lime is combined with additives to produce lime slurry for mortar and plastering works. It is used as lime surkhi mortar for foundation and masonry wall. Lime mortar provides greater strength to the masonry wall.

Concrete is used in flooring and ceiling slabs. Concrete is noted for its compressive strength, the grades of concrete depend on the compressive strength of the material. Concrete has low tensile strength.

Timber is used for windows, doors, furniture, etc. Teak, jackfruit, mahogany wood sourced locally is used for construction. It is noted for its properties like durability, strength, hardness, workability, appearance, etc. timber is extensively used in Kerala architecture for decorative works, doors, windows, etc.

Windows uses frosted glass; this type of glass diffuses the light passing through it. Its translucent glass and provides privacy to the user while allowing the daylight to pass through.

6. CONSTRUCTION TECHNIQUES

6.1 Initial Construction

Construction of this residence began in the year 1990 which commenced with site clearance for construction of well followed by site purification rituals also known as Bhumi pooja. The site was then cleared for unwanted vegetation and was later excavated for foundation work which was done in rubble. It was backfilled with soil around with plinth and reinforcements were placed for column footings and tie beams as a damp proof course which was later concreted and finished before building the plinth wall in laterite stone. The superstructure for ground floor was constructed in laterite stone, RCC columns were cast and the corners were built in laterite stone after dressing them to required shape and size. Internals were plastered after side levelling and they were built in courses. Internal and external RCC lintel beams were cast and internal columns were filled with concrete. Scaffolding and shuttering for beams and slabs were done proceeded by placement of template frames and reinforcements for openings. Conduits for electrical works were laid and concrete was mixed and poured into floor slabs. Staircase and headroom were constructed. Interiors were plastered with lime plaster and finished with wallpapers and paints, mosaic tiles were fixed onto the floor followed by installation of glass partitions, wall cupboards, kitchenware and bathroom ware. The construction ended in 1992.

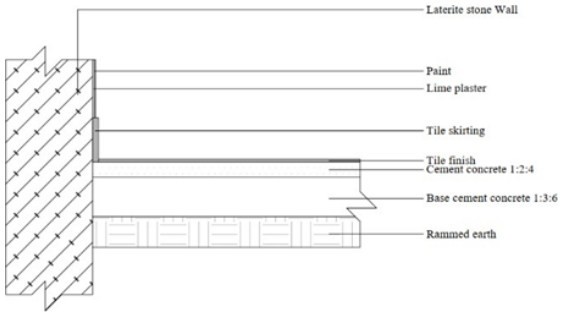

Figure 10a: Floor sectional detail, Source: Author, 2021

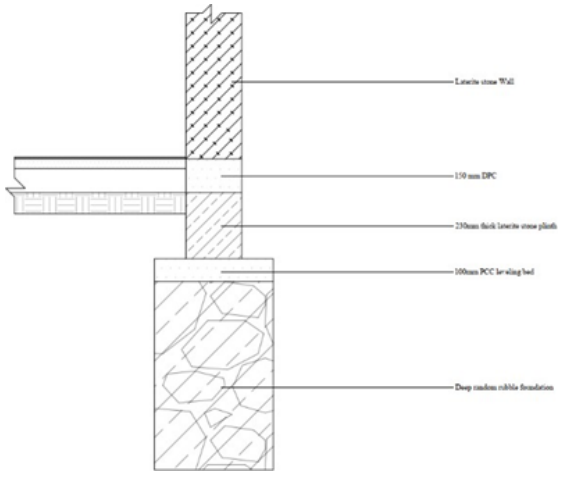

Figure 10b: Foundation detail, Source: Author, 2021

6.2. Reconstruction

The project was reconstructed after 26 years in 2018. This included change in the ground floor plan with addition of another floor making it a five-bedroom residence. The Mangalore tiled slope roof was completed after casting of roof slab and concrete overhangs were made to house water channels. The floors were done in vitrified tiles while the walls were finished in paint.

7. PARAMETERS FOR WARM HUMID CLIMATE

Various design parameters can be considered to make the building climate responsive. They include the following as listed:

- Cross ventilation: Buildings have to be oriented such that it can capture winds passing by in order to achieve air movement throughout the building.
- Openings: openings must be strategically placed such that the winds can be captured into the building and facilitate cross ventilation.
- Building design: buildings built in this type of climate have an elongated plan with a single row of rooms to allow cross ventilation.
- Arrangement of buildings: group of buildings tend to be spread out.
- Buildings are mostly built on an elevated platform to capture air of higher velocities as the air closer to the ground is stagnant due to the ground cover.
- Shading devices: Even though the radiation of heat is lesser than that when compared to hot dry climate, it still is a significant source of heat. Therefore, shading devices should provide good coverage by obstructing most of the sky.
- Material of construction: As the temperature of the walls and roof surface remains the same as that of the air throughout the day, low thermal

capacity materials should be used for construction. Lightweight construction will allow heat transfer from the surfaces of the wall and roof to the atmosphere, thereby cooling the interiors.

- Roof design: by providing a reflective roof and ventilating the space between the roof and ceiling, the roofs can prevent increasing the indoor temperature.

8. COMPARATIVE STUDY BETWEEN VERNACULAR AND CONTEMPORARY RESIDENTIAL BUILDING

Table 1: Comparative study, Source: Author, 2021

Thai Kottaram	Thamburu Residence
Constructed in the 16th century	Constructed in 1990 and Reconstructed in 2018
Located in Padhmanabhapuram palace complex, Thuckalay, Tamil Nadu	Located in Punnad, Irrity, Kannur, Kerala
Traditional Kerala Vernacular architecture	Contemporary Architecture
Thachu Shastra principle	Vaastu Shastra principle
Elements included wooden louvers, Timber jaalis, poomukham, charupaudy, ambalakulam, and nadumuttam	Elements include Meenkolam, well and chajjas
Manglore tile roofing with timber rafters and purlins	Manglore tile roofing with steel rafters and purlins over concrete flat slab
Structure was built with Laterite blocks, timber, granite, clay roofing tiles	Structure was built with Laterite blocks, timber-teak, mahogany and jackfruit, lime plaster, clay roofing tiles, vitrified tiles and concrete
Underground drainage system	Septic tanks (separate compost systems for bathroom and kitchen waste)
Ambalakulam is the primary source for rainwater harvesting	Rainwater harvested in catchments directed towards well
Nadumuttam brings natural light and cross ventilation into the structure	Main source of light and ventilation are the windows and ventilators

9. CLIMATE RESPONSIVE ANALYSIS OF THE PROJECT

9.1. Psychometric Chart

The psychometric analysis for the site was done, by climate consultant software which is indicated by the chart below. This showed that the strategies necessary for 100% comfort were; sun shading of windows, natural ventilation and cooling, Fan-forced ventilative cooling, dehumidification and cooling along with dehumidification (Figure 11).

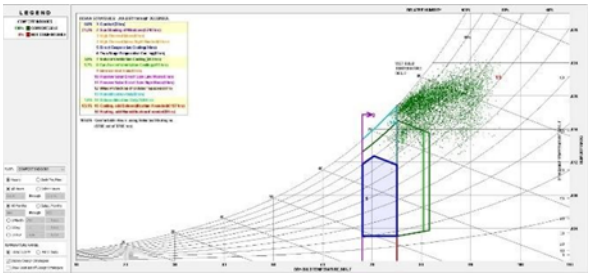

Figure 11: Psychometric Chart, Source: Climate Consultant, 2021

9.2. Mahoney Table

The Mahoney table is a reference table used in architecture to help design climate-appropriate buildings (Elshafei, 2021). It is a table that makes use of air temperature, precipitation, humidity, and wind to get to indicators that eventually derive the schematic design development and provide climate-sensitive design recommendations.

The Mahoney table recommendation includes; orientation such that the long axis of the structure was along the east- west, double-banked rooms thus providing temporary air movement, very small openings 10- 20% of wall area, heavy external and internal walls, heavy roofs having over 8h time-lag, space for outdoor sleeping and protection from heavy rain. Base on the above given Mahoney table, a time-lag analysis for the roof was carried out, which indicated a lime lag of over 8hs through Rhino software (Figure12).

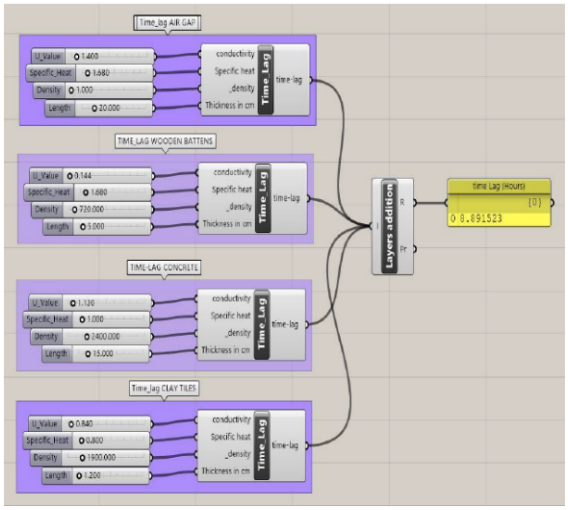

Figure 12: Roof time-lag analysis, Source: Author, 2021

10. POSSIBLE INTERVENTIONS TO MAKE THE EXPERIMENTAL BUILDING NET ZERO

Net zero energy buildings are buildings that make, or supply, their energy through renewable resources, which results in zero carbon emissions. Net zero buildings have zero carbon emissions as these buildings create their own energy through renewable resources.

Table 2: Potential interventions worked out without major structural changes, Source: Author, 2021

Energy Efficiency:	Waste Management:	Building Materials:
1.Passive solar design (Roof overhangs, glass areas)	1.Grey water system (root zone water treatment method)	1.Locally sourced materials timber
2.Active solar design (solar panels)	2.Recycling (bio gas plant)	2.Use of recyclable materials window and door frames
3.Ventilation (windows and ventilators)	3.Low flow taps and showers (latest fixtures)	3.Use of renewable, nontoxic material laterite blocks
4.Efficient lighting (LED lights, latest fixtures)		

10.1. Wind Mill (Standalone Wind Turbines):

They are most effective when placed on top of a hill, away from impediments and turbulence. They are also known as free-standing or pole-mounted. A home wind power generator converts naturally occurring wind power into electricity by utilizing the aerodynamic force of the rotor blades. Small wind energy installations can be connected to the electrical grid (Figure 13). These are referred to as grid-connected systems. A grid-connected wind turbine can help you save money on utility- supplied electricity for lights, appliances, and heating (Home wind turbines - benefits, costs and Requirements 2022).

10.2. Solar Powered Street Lights:

Solar street lighting are less reliant on traditional electricity and the national grid. Solar products are completely dependable for twilight to dawn illumination operations (Industry Today, 2021). Because they are off-grid, they require almost no maintenance and have cheap operating expenses. During the day, the solar street lights (solar panels) absorb solar energy. Solar energy is converted into electrical energy by photo-voltaic cells, which is then stored in a battery. At night, the bulb turns on automatically and drains the electricity stored in the battery. Solar-powered lights, which feature built-in LED, closely mimic sunshine (Figure 14).

Figure 13: Windmills, Source: Paul Brown, 2017

Figure 14: Solar powered street light

10.3. Bio-gas Plant

Anaerobic digestion, a fermentation process in which waste is digested by bacteria to produce methane gas, is used by biogas facilities (Figure 15) (Evans et al., 2020). It can be used as a fertilizer in agriculture. Biogas is a renewable energy source that provides electricity and heat to the local grid. Significant environmental benefits include lower emissions of greenhouse gases such as methane, CO2, and nitrous oxide. It is frequently used as a cooking gas.

Figure 15: Bio-gas Plant, Source: ICCDI Africa, 2019

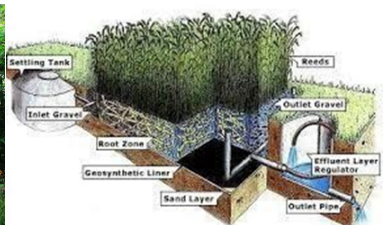

Figure 16: Root Zone Method, Source: ellensharmaschool, 2022

10.4. Root Zone Method:

The root zone/filter plant is a biological filter, where the biological treatment of waste water takes place in a soil volume, which is penetrated by roots. The root network is composed by suitable plant species. It consists planted filter beds containing gravel, sand and soil (Figure 16). The RZWT system utilizes nature's way of biologically processing domestic & industrial effluents. Due to its natural process, there is no need to add any input such as chemicals, mechanical pumps or external energy. This reduces both the maintenance and energy costs (Rootzone Africa,2022).

10.5. Plant as dehumidifier

Humidity-absorbing indoor plants serve a dual purpose by absorbing moisture from the air and bringing the outdoors in (Reducing Humidity in Your Home with Plants. 2020). This is the ability of the leaves to absorb dew, fog, or other forms of vaporous moisture through the stoma. This liquid travels down the roots and into the xylem. For example, Peace Lily, Boston Fern, Orchids, Spider Plant (figure 17), and so on.

10.6. Ventilation

Ventilators are provided near ceilings in the rooms of our houses because the air we breathe out is warm and rises out of the room through the ventilators

Figure 17: Spider Plant, Source: Jay Scotts, 2019

Figure 18: Ventilators near the ceiling

(Figure 18). Cool fresh air rushes into the room through the doors and windows.

10.7. Shading and Window treatment

To control the amount of daylight and thermal energy in the building, we need to reduce the percentage of openings. Timber louvered windows helps in controlling the daylighting entering in and the use of low E glass, it emits low levels of radiant thermal energy (Figure 19a and Figure 19b).

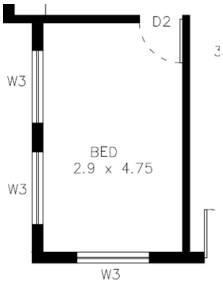

Figure 19a: Bedroom plan, Source: Author

Figure 19b, Timbered louvred windows

11. CONCLUSION

The contextual challenges, carefully selected approaches, and potential answers constitute the meaning of sustainable design. In an interpretative method, this article analyses the sustainability of building and construction services of the chosen project in Kannur, with the goal of developing a viable solution.

By extensively studying parameters such as climate and construction techniques in the existing contemporary structure as well as comparing it with the traditional case study with respect to general interventions seen in warm humid climatic conditions, it can be established that the project is mildly climate responsive and sustainable. Based on site conditions and climate studied, interventions proposed range from standalone wind turbines on site level to change in window design on building level to attain a net- zero energy project.

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Planning Strategies for The Development of Wetland Dependent Livelihood

A Case of Thekkumbhagam Panchayat, Kollam

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ABSTRACT: Wetlands are rich in biodiversity. Wetlands provide several benefits, services and sustain biodiversity that is essential for human wellbeing and prosperity. Wetlands are a source of employment. Several people are dependent on wetland directly or indirectly to earn income from farming, fishing, pisciculture, tourism, travel activities and travel. The study aims to understand the major wetland-dependent anthropogenic activities and identify the threats to the livelihood and housing of the people/communities of the Ashtamudi wetland through the detailed study of Thekkumbhagam panchayat. For the wetland-dependent livelihood development, the role of the existing and developing infrastructure and various facilities on the lifestyle of the people is considered. Based on the exploratory study on Thekkumbhagam panchayat, it helps to identify major livelihood activities such as fishing, agriculture, pisciculture, coir making, and tourism; characteristics of the panchayat, water quality, etc. Further study is conducted through surveys. The survey is based on the livelihood activities, infrastructure facilities, financial requirement, housing condition and related issues. A pilot survey of 13 households was taken from nearby surroundings of the lake. Phone-in survey of seven key informants such as panchayat president, panchayat member, Kudumbhashree members, etc. is taken. Analysis of these responses depicts the lack of facilities and awareness, improper environment management, which push back the people in the panchayat from the fishing and other water-related livelihood and looking for other occupation rather than fishing and farming. On this basis, it is to recommend that improving the existing facilities, increasing the opportunity of value-added products, providing infrastructure facilities related to the livelihood, in cooperation with existing schemes and funding would improve the housing condition and quality of life through environmentally sustainable manner. Further research is needed to identify more factors that can help to improve the ecological stability and wetland conservation that support the livelihood of wetland-dependent communities.

KEYWORDS: Wetland, Ashtamudi Lake, Thekkumbhagam, Integrated livelihood strategy, Housing

1. INTRODUCTION

Wetlands are the transition zone between the dry land and the water body. It is the Eco tone zone with different characteristics other than the water body or dry land. It also serves as the interface between the aquatic and terrestrial ecosystems characterized by hydric soil which may be permanently or seasonally saturated with water. The wetland has distinct characteristics of flora and fauna.

Ashtamudi Lake is situated in Kollam and it is the second largest wetland ecosystem. It is a palm shaped water body with eight eminent arms. It opens to sea through a single outlet at Neendakara from several creeks such as, Kumbalathu Kayal, Kanjirakkottu Kayal, Kandanchira Kayal, Kuripuzha Kayal Kallada Kayal, Thekkumbhagam Kayal, Perumon kayal, and Thevally Kayal. The National Highway (NH 47) is passes through the periphery of the lake. The railway network is also passing along the lake and connected to major towns and village. The boat Jetty is located 3 Km away from the railway station and provide boat services. There are many small and big islands in the lake region which are the major factor which contribute to the beauty of the lake. Ashtamudi Lake is declared as Ramsar site on 2002. The Ashtamudi Lake has maximum depth of 6.4 m at the confluence zone. Ashtamudi Lake is a natural coastal lagoon. The water spread area of the Ashtamudi Lake is found to be shrinking. The foreshore area of the lake is used for coconut plantation and construction purpose it results to the shrinkage of the lake. The use of fertilizer for crops that seeps to lake causes pollution. An increase in the number of houseboats is leading to the direct discharge sewage into the lake.

Thekkumbhagom Panchayat is a traditional village rich in scenic beauty. It is an island which connected by bridge to the main land. This panchayat also contain 10 small islands. The total area is about 20.26 km2 with 5.22 km2 of land area and 15.04 km2 lake areas. Thekkumbhagom is a coastal plain occupied with sand banks and plains. Thekkumbhagom bordered by Thevalakkara on the North, Trikkaruva Panchayat on the East, Chavara and Neendakara on West,

Ashtamudi Lake on the east and Kollam town on the South. Thekkumbhagom is an island is now connected with bridges one from the South at Neendakara and other to the north at Thevalakara.

An exploratory study on Thekkumbhagam panchayat, it helps to identify major livelihood activities such as fishing, agriculture, pisciculture, coir making, and tourism; characteristics of the panchayat, water quality, etc. The survey is based on the livelihood activities, infrastructure facilities, financial requirement, housing condition and related issues. A pilot survey of 13 households was taken from nearby surroundings of the lake. Analysis from the responses depicts that the lack of facilities and awareness, improper environment management, which push back the people in the panchayat from the fishing and other water-related livelihood and looking for other occupation rather than fishing and farming. recommend that improving the existing facilities, increasing the opportunity of value-added products, providing infrastructure facilities related to the livelihood, in cooperation with existing schemes and funding would improve the housing condition and quality of life through environmentally sustainable manner.

2. THEKKUMBHAGAM PANCHAYAT

Thekkumbhagom Panchayat is a traditional village rich in scenic beauty. The total area is about 20.26 km2 with 5.22 km2 of land area and 15.04 km2 lake areas. Thekkumbhagom bordered by Thevalakkara on the North, Trikkaruva Panchayat on the East, Chavara and Neendakara on West, Ashtamudi Lake on the east and Kollam town on the South. Thekkumbhagom is an island is now connected with bridges one from the South at Neendakara and other to the north at Thevalakara.

Thekkumbhagom is a community of 10 island surrounded by the Ashtamudi lake and also rich in natural beauty. Thekkumbhagom is a coastal plain occupied with sand banks and plains. The slope is from West – East to South – North. Moving from south to west the slope increases. Out of the total (5.22 km2) land area in which 85 % of it are sandbank and 15 % of lower plains.

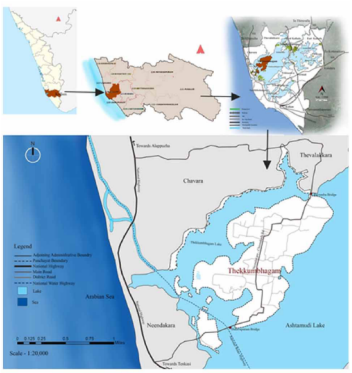

Figure 1: Location map of Thekkumbhagam Source: (Author generated with reference of Google map using GIS)Panchayat

2.1 Features

The maximum temperature in summer is 34.0°C and the minimum temperature in winter is 21.0°C. Majority of the months in a year are dominated by sufficient rainfall. The most common type of soil in the Thekkumbhagam is coastal alluvial soil mainly because the region is surrounded by lake and adjacent to sea. The water quality changed by the construction of bridge, it also led to the depletion of fish species. The use of oil fueled speed boat for local transportation also a source of water pollution. The area adjacent to the lake is affected by the flood during heavy rainy season. The slope is increasing away from the lake side. The topography feature depicts that the panchayat is more prone to flood. Flood level is maximum of 5 cm. There is no severe effect due to flood. This area is moderate drought prone. Thekkumbhagam panchayat come under CRZ I and CRZ III category. The protective buffer zone of 50m is provided around. Thekkumbhagam is within the RAMSAR cited catchment area and 12km buffer zone area.

2.3 Population

As per 2011 census the total population of this panchayat is 16937 (Figure 2). Compared to other panchayat in the Chavara block the lowest population is in Thekkumbhagom panchayat. It may due to the topographic character.

As from the graph it shows about 2% of population growth from 1991 to 2001, which keeps slighter change in numbers of population in 2011.

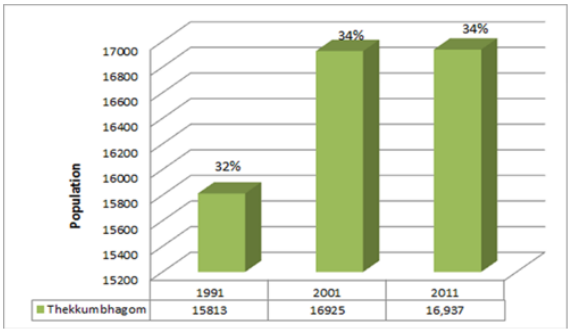

Figure 2: Population of 1991,2001,2011(1991,2001,2011 Census) Source: (Ministry of Home Affairs, Govt. of India)

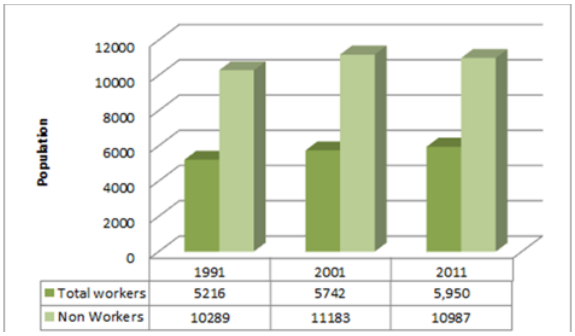

Figure 3: Comparison of workers population 1991,2001,2011 Census) Source: (Ministry of Home Affairs, Govt. of India)

2.4 Occupation

The major occupation In Thekkumbhagam is poultry farming, agriculture, fishing, and coir making. The people are engaged more in other works rather than agriculture and farming. New generations have less interest in fishing and farming. About 70% of the population is engaged in government jobs (Figure 3).

2.5 Land Use

43% of the total geographic area of Thekkumbhagam panchayat lies under water which justifies the water related activities (Table 1 and Figure 4). 7% of the total geographic area is utilized for agriculture crops. Paddy cultivation is not practiced in the panchayat because of the salinity of the water, hence upland paddy cultivation is rarely practiced in the panchayat. Traditional homestead type of cultivation is seen. Highly scattered residential settlement patterns feature ribbon development along the major road corridors. Settlement pattern is concentrated in the water edge and main road corridors. Commercial development is less and is confined to the major road corridors and junctions.

Table 1: Land utilization breakup of Thekkumbhagam panchayat Source: (Author generated with reference of Google map, Land use map using GIS)

Land Use	Area(in ha)
Agricultural fallow land	0.1
Agriculture crops	150
Built up area	665
Paddy converted land	2.7
Waste land	350
Water body	885

Figure 4: Thekkumbhagam Land use map Source: (Author generated with reference of Google map, Land use map using GIS)

2.6 Housing Condition

Comparing the year wise details of constructed and completed buildings; more residential buildings were constructed in 2006-2007 whereas the non-residential buildings were constructed less in 2006-2007. The semi- pucca and pucca house type of housing in panchayat.

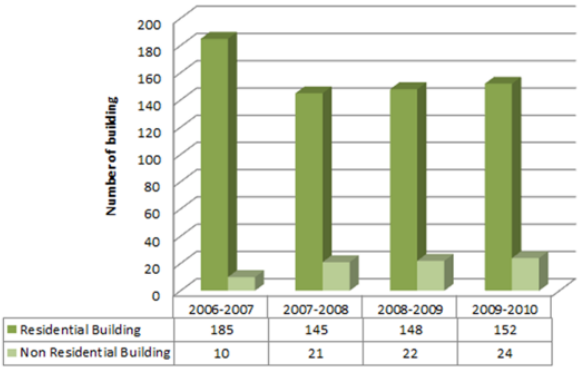

Figure 5: Comparison of residential and non-residential building 2006-2010 Source: (2020,Author, Panchayat Primary survey,)

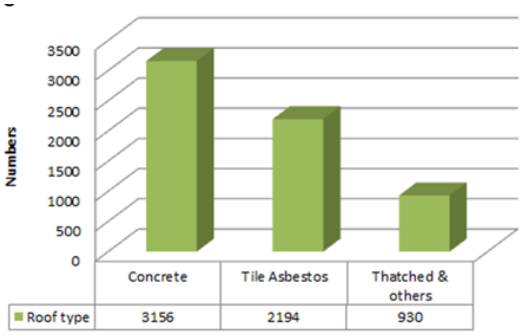

Figure 6: Roof type Source: (2020,Author, Panchayat Primary survey,)

2.7 Livelihood activities

The major occupation of Thekkumbhagom panchayat is Agriculture, fishing, Animal husbandry and coir making. Traditionally they practice fishing as their livelihood. Due to the lack of facilities and concern from the authorities the fishing community has been isolated and marginalized.

The figure 7 showing the study of livelihood activities in the Thekkumbhagam Panchayat. Analysis of water-dependent activities, their issues, infrastructure required and lacking for further development.

Traditionally they practiced fishing as their major livelihood activity. Large amounts of income are generated from fishing. Traditionally practiced occupation is coir making from coconut husk, but it seems to decline due to high labor work and less profit. Traditional retting method is not practiced, instead they import the processed fiber for coir made from different places. The coir products are made according to the order by the customer or bulk production as by different companies. The members

of Kudumbhashree unit are also engaged in the coir making. Two Kerala coir societies are presently active in the panchayat which provide more help for the workers. The traditional coconut husk retting is completely stopped. The fiber used for coir making is imported from Alappuzha, Tamil Nadu, and some other region either by makers or by customers. The lack of labour, and increasing in the labour charge threatened the coir industry. There is not enough profit for the workers from selling the product in the market.

The lands adjacent to the lake are not suitable for crop cultivation due to the presence of salt content. Several fallow lands are there which are kept as vacant. Government provides financial assistance for the cultivation of crops. Grow bags, seed kits, crop protection equipment, compost, and other grants are provided to support agriculture. The grow bag for organic farming is provided by the Krishibhavan for all, especially for the low lying residents.

The figure showing the analysis of livelihood activities in the Thekkumbhagam Panchayat. Analysis of water-dependent activities, their issues, infrastructure required and lacking for further development.

An income of approximately 5000-7000 rupees is earned as monthly income for fishing and coir making. Agriculture is not practiced for commercial purposes. Coir making is in its decline stage. The coir is produced based on the order placed by the customer.

Livelihood activity	Water Quality	Space required	Infrastructure required	Lacking
Agriculture	The region is slightly alkaline. Water have high electric conductivity	Land suitable for farming	Fertilizers,Storage space	Unaware of new technology
Animal Husbandry	The region is slightly alkaline	Rearing	Cattle shed cage for hen, duck etc.	Lack of interest in farming for commercial purpose
Fishing				
Boat fishing	High hardness,Depletion of oxygen, Presence of sulphide High temperature	Maintenance and construction of boat for fishing. fishing net. Landing etc	Landing centre, Market facilities Boat, Net	Insurance or subsidy for the fishermen Landing centreMarket facilities
Chinese net fishing	Turbidity is normal high temperature,BOD is high	For setting the cheenavals fishing equipment in the lake	Boat facilities,fish net.storage facilitieswaiting shed. Electricity	Susidy or grants, Pollution control in water
Clam fishing	High hardness,Depletion of oxygen Presence of sulphide High sulphide High temperature	Storing the catchesPlacing the read Dumpingthe waste. storing the shell,Processing the meat for exporting	Landing centre, Market facilities Boat. Net	Insurance orsubsidy for the fishermen. Landing centre,Market facilities work place for processing
Pisciculture	Water Temperature is high , BOD is high	For setting the cage or boundaries for culture the fish Maintenance of cage net etc	Waste disposal, cage construction Storing facilities	Work place, Marketing facilities Storage facilities
Coin Making	Depletion ofoxygen High concentration of nitrate	Storing the coconut fiber. retting the fiber. Processing the fibre. storing the coin	Machine or equipment for making coir from fibre resting place for workers electricity	Marketing facilities lack of demand profit
Tourism	Presence of Sulphate, Phosphate,Nitrate, High Total dissolved solid	Developing as tourism centre	Boating service, Accomodation, Amenities	Awareness

Figure 7: Study of livelihood activities Source : Author

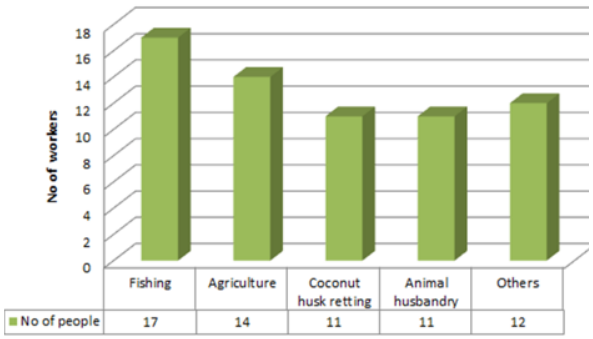

Figure 8: Livelihood activities
Source: (2020,Author Primary survey)

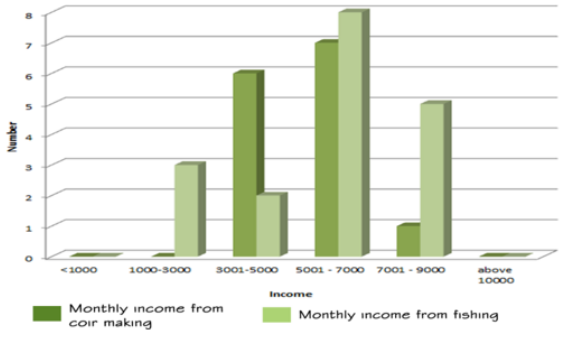

Figure 9: Monthly Income of Fishing and Coir making
Source: (2020, Author, Primary survey, Panchayat)

	STRENGTH	WEAKNESS	OPPURTUNITY	THREAT
LIVELIHOOD				
Fishing	A large portion of the population is engaging in fishing based occupation.	Fishing sector is treated as a marginalized section. Decline of water quality.	Positive response towards the fishing jobs. Fishing is the major income for the population. High scope.	Destruction in the fish species. New generation people are more attracted to the Government Jobs.
Boat Fishing	Almost all are engaging in boat fishing	Maintenance of boat and fish net. Ownership of boat	Positive response towards boat fishing.	Using of fuel in the boat depleting the water quality.
Chinese net fishing	The fishermen who resides near the lake side practising chinese net fishing. Amethod to catch large amount of fish	Maintenance of fishing equipment,security. Natural disaster affect the equipment badly.	Wide variety of fishes are available	Exploitation of small fish. Using of unscientific method.
Clam Fishing	High demand on market and income generating sector. Exporting to different region. The shells is used as raw materials in industries.	After the construction of the bridges and disposal of untreated waste from industries and other declining the resources	Well established local marketing network Work for both women and men.	Poor water quality
Coir Industry	Traditionally practising occupation. Availability of raw materials.	Inhibition towards coir making sector because of high labour charge and low profit.	Positive response towards coir making.	High labour work & chargeHusk retting cause water pollution.
Agriculture	An agarian base of the people	Inhibition towards agricultural sector. Lack of profit. Lack of facilities.	Positive response towards agarian job. Easement of transportation	Salt content in the lake water. Lack of irrigation facilities. Fallow land.
Tourism	Rich natural senic beauty attaract the tourist.	lack of awareness and facilities	Positive environment for developing as a tourist centre. Economic growth. Regeneration of traditional activity	Water Pollution.
Animal Husbandry	Environmentally suitable for duck farm, cattle rearing etc.	Lack of Interest.	Availability of land.	No profit.

Figure 10: SWOT Analysis of livelihood activities Source: (2020, Primary survey, Panchayat)

2.8 Analysis

CRZ rule violated buildings can be seen near the lake region, which are categorized as an unauthorized building. Some of the areas nearer to the lake side are flooded annually and they turned out to be fallow land.

The wastes are collected by the Panchayat. No enough spaces are there to dispose of the wastes within the panchayat. The collected wastes are

disposed of in the nearby Panchayat (Chavara & Neendakara) disposal area/shredding unit. Water is supplied from the Sasthamcotta Lake. In addition to that there are two tube wells placed within the panchayat for public use. The water is supplied irregularly. No specific water supply schemes. The fish catches and other made products are sold in the local market within the panchayat and the market nearby panchayat.

Market facilities are not sufficient. It gets flooded during rainy season. The people are actively engaged in MNREGA, Kudumbhashree (NHGs) etc. they also engage in planting mangroves near lakeside. Upland paddy cultivation, scattered vegetable cultivation, grow bag etc. are the agricultural practices. Several training programme is conducted by the Krishibhavan. Initial cost for the Chinese net is very high. Not all household has boat with proper facilities for fishing. No any schemes are available for providing financial assistance. Fisheries department providing subsidy, loans for the pisciculture for the fishermen. Exporting of clam meat, prawn, crabs are the main income of the Panchayat. The coir industry is facing huge destruction due to non-availability of husk fiber, high labor charge and nonprofit. Reluctance of livestock farming is due to the improper waste management system. The main government offices, hospitals, shops and market are located adjacently in a ward of the panchayat, which is act as a node. No facility for higher education.

3. STRATEGIES

Strengthen the resilience and capacities of wetland dependent livelihood communities in regulated and environment friendly manner. Promoting the use of innovative technologies, technical skills and financial services that contributes to the nutrition and livelihood security of the people/ communities that depend on Ashtamudi Lake along with considering the sustainable use of resource, environmental protection and biodiversity.

The strategy formulated for Thekkumbhagam Panchayat is envisioned in 3 phases. The development is focus on the major livelihood activities are:-

- Fishing- Boat fishing, Chinese net fishing, Clam fishing
- Pisciculture
- Agriculture
- Coir Making
- Livestock Farming

The strategies based on the type of intervention are –

Livelihood Facilities – The strategy includes physical or spatial intervention of infrastructure facilities and management. The locations identified for the spatial proposals are based on the analysis of available maps, data and primary study.

Governance/Fiscal – The proposal for which the schemes of government and the fund allocated for the same be required.

Policies/ Strategies - Intervention and regulatory in proposing schemes which are largely intangible & require longer time to make an effort.

Utilizing the natural resources available in the panchayat and developing the livelihood, housing condition of the people without over exploiting the resource. Resource depletion can negatively impact the livelihood of the local wetland dependent communities. The related and mutually supported strategies with inland fishing as the major focus, and lead to the integrated livelihood strategy for the wetland dependent communities by adapting the overall ecological character of the wetland so as to optimize the outcomes of livelihood and will act as a

Sector	Existing condition	Who were benifited	Issues/Lack of facilities	Who were affected	Existing Schemes
FISHING	Availability of wide variety of fish species One Landing centre with less facilities Exporting of clam crab etc yield high income	Fishermen, fish catch seller, fishing equipment manufacturers, fishproduct exporter,Houshlds resides near the lake Industries used clam shell as raw materials	Overexploiting of fish resource, Fishing equipments Disposal of waste into the lake Lack of conservation of clams, and other fish species Lack of landing centre, market facilities Insurance and subsidy Processing unit	Inland fishermen, fish sellers, Industries, fish product exporters etc. Local peoples of the panchayat	Loans, grants & subsidyfrom fisheries department Schemes for providing help for the chidrens of fishermen Fishermen village scheme
PISCICULTURE	Farming of mussels, pearlspot fish, shrimp. etc Fisheries department provide facilities Exporting of clam increases the income and demand	Fishermen engaged in fish farming fishermen near the lakeside. Exporters	Availability of cage for farming Availability of workmens for the maintainence of cage net and other related facilities.Poor water quality	Fish farmers, exporters, Fish species	Providing assistance equipments and fishes for fish culture NFDB CMFRI (Fisheries Department)
AGRICULTURE	Increase of fallow land Decrease of paddy cultivation Homestead cultivation Lack of awareness Intercrop cultivation	Farmers who engaged in farming Local residents	Salinity of water Lack of awareness lack of interest of new generation. Unavailability of water suitable for farming Natural calamities Marketing facilities	Farmers side near the lakeside Local People depend on cultivated crops	Farmers side near the lakeside Local People depend on cultivated crops
COIR MAKING	Production in smallscale according to the demand	Women and who engaged in work Kudumbhashree workers	This industry facing destruction because of high cost for fibre Unavailability ofla bours High labour charge Non profit	Coir making depended housholds	Loan and subsidy from Coin society workers, Kudumbhashree workers &MNREGA
LIVESTOCK FARMING	Mainly engaging in farming for domestic use. Duck dairy farming is income generating sector	Livestock farmers, Fishermen who engaged in duck farming	Lack of rearing space . Lack of profit	Livestock farmers, Fishermen who engaged in duck farming	Kudumbhashree unit schemes, Local Government scheme, Widow pension beneficiary
TOURISM	Two resorts are functioning for tourism Boat service along the lake	Tourists, resort workers, local people near the resort	Resource are not been properly used for tourism, lack of facilities	Fishermen	DTPC Schemes
HOUSING	Majority houses are concrete, tiled and asbetos roofed houses with electricity and sanitation facilities	Local people	Land less and houseless communities, lack of destitute homage Household near the lake side are vulnerable to the natural calamities	Household near the lake side	Life mission scheme, Fishery village schemes, Flood relief fund
SOCIAL INFRASTRUCTURE	Health facilities such as ayurveda, homeopathy allopathy, sidha are available, Aganawadi in reachable distance	Local people	Lack of required facilities for health sector, Need of Palliative care	Local people	MLA fund. MP fund for the panchayat
PHYSICAL INFRASTRUCTURE	Street light in all wards, connectivity with major junction, waste collection	Local people	No space for waste disposal and composing availability of drinking water, lack of public toilet facilities	Local people	MLA fund. MP fund for the panchayat, Kollam Lions Club

Figure 11: Analysis of livelihood activities

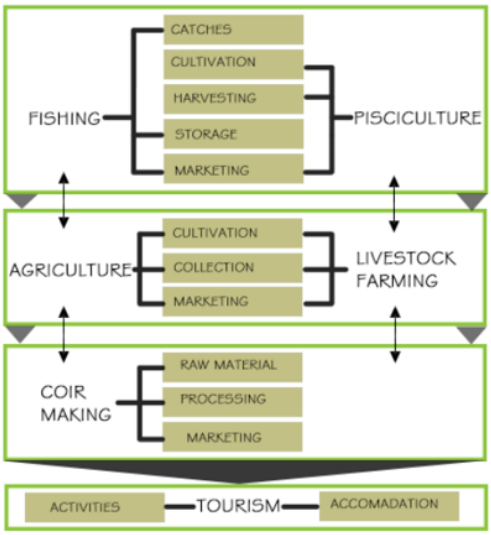

Figure 12: The core of livelihood development. Source: (Author generated 2020)

generator of a quality housing condition. This will lead to the development of new infrastructure facilities, commercial centers, and also will generate new employment opportunities.

Integrated livelihood strategy focus on -

- Connecting all livelihood activities that depended on wetland by reducing the over exploiting the resource.
- Enable conservation and management of wetland resources.
- Infrastructure facilities and financial requirement for the improvement of livelihood and housing
- To encourage the rural based tourism sector in the panchayat through fishing and other artisanal activities.
- This will lead to the development and active involvement in different livelihood sectors and would initiate the requirement of newer infrastructure. Also generate more income and employment opportunities by proper concern from the authorities.
- Thekkumbhagam panchayat will be known as an artisanal livelihood depended on their ecological character of wetland.

3.1 Recommendation

3.1.1 Infrastructure facilities

Proposal for the fish land facilities: Facilities that required are- Workshops, Net repair areas, Fisher men's facilities, Open storage and parking, Ancillary services, Utilities, Ice production, Cold storage, Refuelling, Landed products, Shore processing, Safe mooring area, Provision for the basic utilities and boat servicing.

Ancillary enterprises that can be promoted are: Fish net making and repair, Cage culture and pen culture fish near the lake stretches, Mussels/Clam/ Oyster farming, Development & marketing of fish products. Breeding and marketing of ornamental fishes, Cultivation of bamboo, Crab fattening Ornamental fish culture, Rice cum fish farming Value added products from fishing

3.1.2 Ecological importance of Mangrove farming

Awareness and Empowerment

1. Training, soft skill empowerment for all the natives. Enhance the coordination and cooperation of fisheries with the other sector concerned with rural development & water resource management.
2. Selection of the target group for the micro finance programme should be based on poverty and income level of household.
3. Improve the participation of women in aquaculture.

Coir making

1. Promotion & incentive programs are for coir making sector the panchayat. Provide financial support for the workers and coir society. Promote coir-value added products making and marketing.
2. Geo textiles, Organic manure, Coir wood Coir particle board

3.1.3 Community based resource management

The community should have the responsibilities to protect their fishery resource from poaching, over fishing, illegal fishing and other activities. Promote ecotourism activities and water resource management system. Divide into different zones.

ZONE 1 - No fishing allowed.
ZONE 2 - Fishing in particular time of a year (Caught fish equally shared among members).
ZONE 3 - Fishing is allowed all year.

The financial supports for the community are from ecotourism boat rentals, venture, competition, annual sale of catch, sale of catch from fishing competition.

3.1.4 Development of Agriculture

Enhance the agricultural production & income of farmers. Mapping of agricultural land, monitoring the demand and supply.

Risk mapping and remote sensing, Provision of weather insurance scheme for the farmers, Improve the soil fertility; control the use of agricultural pest control, improving water management in the agriculture sector, Promotion and incentives programs for coconut plantation, Cultivation of Bamboo, Existing fallow lands to be taken as lease for paddy cultivation under panchayat land lease program, Training and awareness for the agriculture practices.

3.1.5 Development of Livestock farming

Existing barren land taken for cattle rearing, Insurance scheme for the farmers.

3.1.6 Development of Tourism

Promoting ecotourism for the Panchayat under DTPC, Eco friendly boats travel along the lake side, Live fishing and other village activities enhance tourism.

Figure 13: Proposal framework.
Source: (Author generated 2020)

3.1.7 Development of Integrated farming

Panchayat level incentives program me on integrated farming in households, especially economically weaker sections. Under state government integrated farming management

3.1.8 Other Infrastructure facilities

Provision for the inland roads, bunds, drainage systems, culverts in wherever needed, take proper measure for mitigating the natural inundation or calamities in inland areas, Provision of biotin or biogas plants in all households. User friendly composting and recycling method. Efficient use of waste resource by adopting R3 (Reduce, Recycle, Reuse) strategies, Assistance to the maintenance for the dilapted houses especially near the lakeside, Provision of rain water harvesting for water collection and recycling of wastewater especially for irrigation purposes, Provision for waste collection and treatment facilities, Construction of a sewage treatment plant, Existing fallow land can be used as Open public space or park for the panchayat, Use of Renewable energy technologies.

3.1.9 Housing

The construction houses are with basic amenities like a multipurpose room, kitchen, bedroom and toilet for the homeless people. And also, provide prefabricated septic tanks along with toilet facilities to the household that lack sanitation facilities.

3.1.10 Recommended Phasing

PHASE - 1

- Training, awareness programme and empowerment programs in livelihood sectors.
- Integrated farming units for each household.
- Barren land to be used as rearing area for cattle.
- Fallow land to be utilized for cultivation.
- Planting of Mangroves.
- Introduction of cage/pen fish culture.
- Promotion of Bamboo cultivation.

PHASE - 2

- Development of landing center.
- Improve the market facilities and direct collection of agro, livestock products.
- Empowerment and skill development training.
- Development of value added products.
- Development of existing markets.
- In cooperation tourism in the village activities such as fishing, coir making. Etc.
- Integrated livelihood system.
- Construction and maintenance of houses.
- Provision of basic infrastructure and amenities.

PHASE - 3

- Development of collection and processing units.
- Accessibility of insurance and other schemes to all members of the panchayat.
- Development of tertiary jobs such as marketing, exporting management. Etc.

4. CONCLUSION

The study is about the wetland depended livelihood mainly focus on the Thekkumbhagam panchayat along the Ashtamudi lake. Thekkumbhagam is a traditional village rich in biodiversity and scenic beauty. The geographic condition and topography of the panchayat is suitable for nature dependent livelihood activities. The panchayat itself have the potential to develop employment opportunity and income from the ecosystem. But it not utilized in an efficient and sustainable manner. The resources get depleting due to unscientific practice, effluents from industries, dumping of untreated wastes into the lake.

The major livelihood activities of the Thekkumbhagam panchayat are fishing, agriculture, coir making, livestock farming. Due to the use of unscientific method unawareness, lack of facilities and lack of proper concern from the authorities the new generation loss interest and looking for other jobs. Through this study helps to understand the impact of lake on the livelihood of the communities and for the future development of the area in a sustainable way to bring about the maximum benefit to the community as socially, economically and environmentally. To summarize there is a need of improving the existing condition, infrastructure facilities, developing of value-added products, introduction of integrated farming system, improvement of housing condition, development of tourism. As a whole Thekkumbhagam panchayat will be known as an artisanal livelihood depended on their ecological character of wetland.

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