Proceedings of The 3rd International Conference on Smart Villages and Rural Development COSVARD 2020

07-08 December 2020
Webinar

Editors:

Dr Hemanta Doloi
Prof Atul Bora

The University of Melbourne
Victoria 3010, Australia

Smart Villages Lab
Culture • Construction • Capacity • Community

3rd International Conference on Smart Villages and Rural Development (COSVARD 2020) hosted by the Smart Villages Lab (SVL) of the Faculty of Architecture, Building and Planning of the University of Melbourne.

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Preface

A very warm welcome from the conference Convenor and the Chair to all the attendees and stakeholders of COSVARD 2020 conference.

Having had success in first two COSVARD conferences under relatively normal environments, the COSVARD 2020 was required to be held in a year like no other. Ravaged by the global pandemic and at the time of not only global but national borders restrictions across many countries, hosting an international conference was not an easy task. Yet, 21st Century's technology coupled with competence and enthusiasm of the participants from across the globe made it all possible to successfully host COSVARD 2020 as a Webinar.

COSVARD2020 Webinar provided a global platform for researchers, policy makers and industry professionals to share relevant knowledge and examples from practice associated with new forms of rural development. With over 40% of world's nearly 8 billion population still living in rural and ever-increasing discrepancies between urban and rural, the role of COSVARD for building necessary capacities and mobilising required effort for reducing the gap of urban-rural divide is pivotal. With three consecutive years of COSVARD, a visible roadmap has already been laid for building the much needed capacity underpinned by relevant knowledge and theories in a new form of rural development widely known as "Smart Villages". Smart Villages is a relatively new concept where multiple interrelated dimensions are integrated for developing rural communities with a bottom up approach. In smart village creation, data-driven and context specific solutions are at the center of intervention planning and management. Traditional top-down approaches where decisions on interventions are based on the grand national and state level public schemes, proven to be ineffective in terms of delivering direct benefits to the community targeting their needs and requirements at the grass-roots levels.

Through the COSVARD conference, numerous new ideas are being shared and debated among the academia, practitioners and public officials across a range of different issues associated with the community development. The research and development initiatives at the Smart Villages Lab (SVL) at the University of Melbourne striving to narrow the gap between urban and rural communities. With increasing popularity globally, it is our intention that COSVARD becomes a yearly event for creating necessary awareness of this area of critical need among the broader international community, expanding engagements with potential future partnerships from other parts of the world, especially developing economies and harnessing funding opportunities for conducting sustained research and expanding disciplinary knowledge.

Like the previous two years, the scope of COSVARD 2020 conference was again within five broad themes, 'Rural Housing', 'Rural Infrastructure', 'Rural Economy', 'Sustainability' and 'Smart Governance'. A "Smart Villages Poster Competition" was also incorporated in COSVARD 2020 to promote emerging design ideas in Smart Villages.

Under the Rural Housing theme, the key focus was on housing affordability, low-cost housing, materials selection, energy and water solutions, sanitation, reusability and recycling of waste, skill development, environmental design, disaster resilience and other relevant topics.

The focus of the Rural Infrastructure was on construction and maintenance of roads and other forms of infrastructure, access to education and health care, provision of services, including energy, potable water, waste and sewage management, creation of public spaces, ICT applications and operations, and other related topics.

Rural Economy section was to deal with the building social capital, micro and community-led finance, income generation, farming support, crop selection and improvement, market access, pricing, various forms of tourism and other related topics.

Sustainability theme focused on Environmental, Social, and Economic sustainability of all aspect of rural development.

Finally, Smart Governance section comprised the research and development associated with the Information Communication and Technology (ICT) and data-driven solutions, machine learning applications, alternative forms of governance and other relevant topics.

The research papers received from broad audience across all five themes were accepted for COSVARD 2020 following the double-blind review process. The scientific committee of the conference comprised over 30 experts from diverse disciplinary background recruited globally. A total of 18 final papers and three posters were included in the conference proceedings. Eight selected keynotes were presented by eight distinguished academic and professional members with relevant background. The keynotes presenters were Prof Mark Burry, Director Smart Cities Research Institute from Swinburne University of Technology, Mr Samir Baruah, Top Cooperate Banker from Assam, Prof KN Satyanarayan Director of Indian Institute of Tirupati (IIT Tirupati), Prof KC Iyer from Indian Institute of Technology Delhi (IIT Delhi), Mr Adithya VS from TVASTAGroup Chennai India, Prof Atul Bora, Principal Assam Engineering College, Assam; Dr Arvind Phukan, President of the Core Professional Group for the Brahmaputra (CPGB), USA and Dr Pranjal Phukan from Guwahati, Assam.

Last but not least, I sincerely appreciate the support, dedication and commitment of every single member of the scientific committee and a few other distinguished colleagues in reviewing the papers for the conference. Without their selfless support and good wishes, COSVARD 2020 would not have been possible.

With warm regards

Associate Professor Hemanta Doloi
Convenor and Chair (COSVARD 2020)
Director (Smart Villages Lab)

Message from Co-Chair

At the outset, I wish to thank everyone involved in organising COSVARD-2020 as a Webinar.

Assam Engineering College, being the local organising partner, involved in collaboration with University of Melbourne for organsing this 3rd International Conference on Smart Villages and Rural Development (COSVARD2020). COSVARD conference is one of the most significant outcomes of the ongoing collaborative research project between the University of Melbourne and Assam Engineering College with a focus of upgradation of skills in construction sector of the state. The construction sector has a strong multiplier effect on all other sectors of economy and therefore attempt has been made to engage all stakeholders to make the collaborative venture a grand success.

Unlike the previous two years, 2020 being a pandemic year, hosting an international event was not an easy task. However, with the availability of the IT-based conference management systems, the organizing committee rather took COSVARD 2020 as a unique opportunity to reach out more widely and facilitated participations for audience from a wider geographical boundaries.

COSVARD 2020 was organized with a vision for sharing intellectual knowledge and wisdom of experts committed for upgradation of skills in the construction sector of the places of high need such as the state of Assam, and states in India and abroad and to disseminate the information to all stakeholders involved in construction sector with a focus to facilitate creation of smart and sustainable villages and cities.

As Skills in Construction, Information Communication and Technology (ICT), Smart and Sustainable Village and Cities, Sustainable human settlements are embedded to each other, the theme of this annual conference is chosen to continue a healthy debate among the participating experts and stakeholders of diverge background.

Our message is clear. ‘Smart Village’ will never happen without ‘Sustainable Construction Practices’. Therefore, improvement of capacity in this sector is taken up to create smart and sustainable villages, cities and towns in the state as well as in the world.

I wish the COSVARD will become a truly international event with the above stated mission in years to come.

With warm regards to all the delegates participated in COSVARD 2020.

Dr Atul Bora
Conference Co-Chair
Principal, Assam Engineering College

Committees and Partners

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Dr Atul Bora AEC (Co-Chair), Assam Engineering College
A/Prof Robert Crawford, The University of Melbourne
Dr Hannah Robertson, The University of Melbourne

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Swinburne University of Technology, Australia

COSVARD 2020 – 3rd International Conference on Smart Villages and Rural Development

Organized by
Smart Villages Lab, The University of Melbourne
and
Assam Engineering College, Assam, India

Online Webinar
Date: 07 - 08 December 2020

Webinar Link:
Please click the link below to join the webinar:
https://unimelb.zoom.us/j/83222179841?pwd=YndtbEF5eEJVOVQ1U1BIeXgvZXdDZz09
Webinar ID: 832 2217 9841
Password: cosvard20

Final Program Schedule

Agenda for Opening Ceremony and Inauguration
Day 1 - Monday 07th December 2020
2:30pm (AEDT*) – 4:00pm (AEDT)
9:00am (IST#) – 10:30am (IST)

*Australian Eastern Daylight Time #Indian Standard Time

Anchored by: Dr Purobi Patowary (Assam Engineering College)	
2:30pm (AEDT) 9:00am (IST)	Welcome and Introduction **[A/Prof Hemanta Doloi, Chair]** Director, Smart Villages Lab, The University of Melbourne
One minute prayer showing respect for the Departed Soul of the Ex-CM of Assam Tarun Gogoi who pioneered the Smart Villages vision and provided unconditional support in our mission	
2.40pm (AEDT) 9:10am (IST)	Welcome Speech **[Prof Atul Bora, Co-Chair]** (Principal, Assam Engineering College)
2.50pm (AEDT) 9:20am (IST)	Inaugural Address, COSVARD 2020 **[Prof Dhiraj Bora]** Vice Chancellor, Assam Science and Technology University, Assam, India]
3:00 pm (AEDT) 9:30am (IST)	International Perspective **[Prof Mark Burry, AO]** Swinburne University of Technology, Victoria, Australia
3:10 pm (AEDT) 9:40am(IST)	National Perspective, COSVARD 2020 **[Mr Samir Baruah]** Top Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, NE
3:20 pm (AEDT) 9:50am(IST)	National Perspective, COSVARD 2020 **[Mr Mrinal Talukdar]** Journalist, Film Maker, Author and Social Worker
3:30 pm (AEDT) 10:00am (IST)	International Perspective **[Assoc. Prof Robert Crawford]** The University of Melbourne
3:40pm (AEDT) 10:10am (IST)	Assam Perspective **[Dr Arvind Phukon]** Past Rotary District Governor Ph.D,.D.I.C.,P.E.,D.Sc. (Honorary), President/Founder, Core Professional Group for the Brahmaputra (CPGB), Former Professor of Civil Engineering, University of Alaska, Anchorage, USA, CEO/Founder , Phukan Inc., Consulting Engineering Company, Anchorage, Alaska (USA)
3:50 pm (AEDT) 10:20am (IST)	International Perspective **[Dr Hannah Robertson]** The University of Melbourne
3:55 pm (AEDT 10:25am (IST)	Vote of Thanks **[A/Prof Hemanta Doloi]**
Technical Session starts at 4:00pm (AEDT) 10:40am (IST)	

Technical Session

Time	Day 1 - Monday 07th December 2020	
4:10pm (AEDT) 10:40am (IST)	**Keynote 1: Prof Mark Burry, AO, Director (Smart Cities Research Institute)** **Swinburne University of Technology, Victoria, Australia** *"Smart Village Digital Twins: First Steps to Meeting the Challenges"*	
4.40 pm 11:10am (IST)	**Session 1: Housing - Resilience**	
	Chair: A/Prof Robert Crawford	**Authors**
Paper 1	Design and fabrication of a flood proof house to overcome the flood hazards in rural areas of Assam, India	Manash Bhuyan, Imran Hussain Ahmed, Bappi Chamua, Manash Jyoti Medok, Raju Ronghang, Mousumi Gogoi *Assam Engineering College, Assam, India*
Paper 2	Ideation of Smart Village: A Framework to Make Indian Villages Self-Sustained	Navneet Munoth, Ekansh Jain *Maulana Azad National Institute of Technology, Bhupal, India*
Paper 6	Lack of Rural Infrastructure: The Impact on Economic Development, A Case Study of South Salmara region, Assam.	Noin Rifatul Khair Mazumder, Imtiaz Hussain *Assam Engineering College, Assam, India*
5.40pm (AEDT) 12:10pm (IST)	**Break**	
5.50pm (AEDT) 12:20pm (IST)	**Session 2: Housing – Design**	
	Chair: Dr Hannah Robertson	**Authors**
Paper 5	Thermal Analysis of Local jute-fiber as cavity insulation for tropics	Rezuana Islam, Sajal Chowdhury, Shajib Paul, Mofassera Jahan, Sumiaya Sultana, Angshuman Roy, Sadman Ali, Nazneen Sultana Nisu, Rahela Tabassum *Chittagong University of Engineering & Technology (CUET), Chittagong, Bangladesh.*
Paper 4	Creating Smart Villages through context specific workshops	Hemanta Doloi *The University of Melbourne, Australia*
Paper 7	Sustainable Livelihood Approach to Remodel Munda Homestead: Case Study of Shaymnagar, Satkhira	Simita Roy, Shuvra Das, Anirudva *Bangladesh University of Engineering and Technology (BUET), Bangladesh*

Paper 8	Research Methods to investigate occupants' domestic environmental experiences for EXD framework	Sajal Chowdhury, Masa Noguchi, Hemanta Doloi *The University of Melbourne, Australia*
7:10 pm (AEDT) 1:40pm (IST)	**Break**	
7.45pm (AEDT) 2:15pm (IST)	**Keynote 2 (revised):** **Mr Samir Baruah,** Top Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, NE *"Rural Development – need for a collaborative effort"*	
8.15pm (AEDT) 2:45pm (IST)	**Session 3: Infrastructure**	
	Chair: Dr Manjuri Hazarika	**Authors**
Paper 9	A Water Supply and Sanitation study of the Sundarbari village around Jalukbari, Assam	Sudeshna Purkayastha, Rimpi Sharma *Assam Engineering College, Assam, India*
Paper 10	Bamboo as a resource in making villages smart	Bipasha Das and Nayanmoni Chetia Jorhat Engineering College, Assam, India
Paper 13	Bankfiltration as water source: A case study of Phuentsholing, Bhutan	Medalson Ronghang, Partha Jyoti Sarma, Mun Mun Basumatary, Subham Shekhar Roy, Gitanjali Wary *Bineswar Brahma Engineering College, Assam, India*
9.15pm (AEDT) 3:45pm (IST)	**End of Day 1**	

	Day 2 - Tuesday 08th December 2020	
2:30pm (AEDT) 9:00am (IST)	**Keynote 3: Prof KN Satyanarayan, Director (IIT Tirupati)** *"Smart Villages - Role of Academic Institutions"*	
3.00pm (AEDT) 9:30am (IST)	**Session 4: Sustainability**	
	Chair: A/Prof Hemanta Doloi	**Authors**
Paper 14	Smart Rural Hub: A resilience approach in Bangladeshi 'Char' communities	Nabeela Nushaira Rahman[1], Md. Obidul Haque[2], Hassan Md. Mainul[3] [1,2] *BRAC University, Bangladesh* [3] *Premier University Chittagong, Bangladesh*
Paper 15	Implementation of alternative affordable materials in sustainable rural housing design	Md. Obidul Haque[1], Bibi Ummay Tasnim Munzarin[1], Shaswati Saikia[3] [1,2] *Premier University Chittagong, Bangladesh* [3] *Kaizen Architecture & Design Studio, Bangladesh*
Paper 18	Multiculturalism and Socio-cultural integration in the bottom-up approach to rural housing: A multi-case study in Assam, India	Velyne Katharpi and Hemanta Doloi *The University of Melbourne, Australia*
4.00pm (AEDT) 10:30am (IST)	**Break**	
4.15pm(AEDT) 10:45am (IST)	**Keynote 4: Prof KC Iyer (IIT Delhi)** "*Infrastructure, connectivity and growth of India*"	
4.45pm(AEDT) 11:15am (IST)	**Session 5: Infrastructure**	
	Chair: Prof Jayanta Pathak	**Authors**
Paper 11	A Smart Bi-Parametric Approach for Homogeneous Delineation of Rural Roads	Eddula, Sai Vighnesh, Peraka, Naga Siva Pavani, Biligiri, Krishna Prapoorna *Indian Institute of Technology Tirupati, India*
Paper 12	LCA Framework for Utilization of Excavated Granulates in Pavement Systems	Aman Singh, Avishreshth Singh, Krishna Prapoorna Biligiri, B. J. Ramaiah *Indian Institute of Technology Tirupati, India*
Paper 16	An evaluation of performance and well-being of users through biophilic indicators - A review	Anita Kavathekar, Shaila Bantanur *BMS School of Architecture, Bangalore, India*

5.45pm (AEDT 12:15pm (IST)	**Break**	
6.00pm (AEDT) 12:30pm (IST)	**Keynote 5: Prof Koshy Varghese (IIT Madras) in association with Adithya VS and Pranjali Kanchi** "*Affordable Housing Through 3D Printing*"	
6.30pm (AEDT) 1:00pm (IST)	**Session 6: Smart Villages Poster Design**	
	Chair: A/Prof Krishna Prapoorna	**Authors**
Poster 1	Deconstructing PMAY-G: ICT 4 Nation Building	Harshal Kate[1] and Garima Jain[2] [1]*Indian Institute of Technology Delhi, New Delhi, India* [2]*World Resources Institute (WRI) India, New Delhi, India*
Poster 2	The revival of the tribal community by concept of S.M.A.R.T Village: A case of Sabar Tribe of Jharkhand, India	Nazish Abid[1], Ressal Ansari[2] and Ginelle Lopes[3] [1, 2] *REVA University Bangalore, India* [3] *XXI Architecture Pune, India*
Poster 3	Flood resistant housing in Assam	Dhiman Thakuria and Dhiman Kaskyap *Assam Engineering College, Assam, India*
7.30pm (AEDT) 2:00pm (IST)	**Break**	
7.45pm (AEDT) 2:15pm (IST)	**Keynote 6: Prof Atul Bora, Principal (AEC) and Director (Technical Education)** *"Linking Skill-building and Employability with the Roadmap for a Sustainable State"*	
8.15pm (AEDT) 2:45pm (IST)	**Keynote 7: Dr Arvind Phukan, USA** *"Design of Smart Villages in India – some reflections"*	
8:45pm (AEDT) 3:15pm (IST)	**Special Talk: Dr Pranjal Phukan**, D.Litt.(Hons), CEng, M.I.E, F.I.P.E, M.I.I.E, FMERC *"Startup opportunities, job creation and income enhancements in Smart Villages"*	
9.00pm (AEDT) 3:30pm (IST)	**Best Papers and Posters Competition Results** **Closing Remarks**	
9.15pm (AEDT) 3:45pm (IST)	*Remark by the Chairs* **- End of Conference -**	

Keynotes Speakers and topics

1. Prof Mark Burry, Director Smart Cities Research Institute from Swinburne University of Technology
    - *Smart Village Digital Twins: First Steps to Meeting the Challenges*

2. Mr Samir Baruah, Top Cooperate Banker from Assam
    - *Rural Development – need for a collaborative effort*

3. Prof KN Satyanarayan Director of Indian Institute of Tirupati (IIT Tirupati)
    - *Smart Villages - Role of Academic Institutions*

4. Prof KC Iyer from Indian Institute of Technology Delhi (IIT Delhi)
    - *Rural Development, construction and project finance*

5. Mr Adithya VS from TVASTAGroup Chennai India
    - *Affordable Housing Through 3D Printing*

6. Prof Atul Bora, Principal Assam Engineering College, Assam
    - *Linking Skill-building and Employability with the Roadmap for a Sustainable State*

7. Dr Arvind Phukan, President of the Core Professional Group for the Brahmaputra (CPGB), USA
    - *Design of Smart Villages in India – some reflections*

8. Dr Pranjal Phukan from Guwahati, Assam
    - *Start up opportunities, job creation and income enhancements in Smart Villages*

Prizes

Research Papers

1st Prize

Velyne Katharpi and Hemanta Doloi, “Multiculturalism and Socio-Cultural Integration in the Bottom-Up Approach to Rural Housing: A Multi-Case Study in Assam, India”, The University of Melbourne, Victoria, Australia

2nd Prize

Sai Vighnesh Eddula, Naga Siva Pavani Peraka and Krishna Prapoorna Biligiri, “A Smart Bi-Parametric Approach for Homogenous Delineation of Rural Roads”, IIT Tirupati, India.

3rd Prize

Medalson Ronghang, Partha Jyoti Sarma, Mun Mun Basumatary, Subham Shekhar Roy and Gitanjali Wary, “Bank filtration as water source: A case study of Phuentsholing, Bhutan”, Bineswar Brahma Engineering College, Kokrajhar, Assam, India.

4th Prize 1

Simita Roy[1], Shuvra Das[2] and Anirudva Bhowmik[1], “Sustainable Livelihood Approach to Remodel Munda Homestead: Case Study of Shaymnagar, Satkhira”, [1]Bangladesh University of Engineering and Technology (BUET) and [2]Chittagong University of Engineering and Technology (CUET), Bangladesh.

4th Prize 2

Nabeela Nushaira Rahman[1], Md. Obidul Haque[2] and Md. Mainul Hassan[2], “Smart Rural Hub: A Resilience Approach in Bangladeshi ‘Char’ Communities”, [1]BRAC University and [2]Premier University Chittagong, Bangladesh.

Design Posters

1st Prize

Nazish Abid[1], Ressal Ansari[2], and Ginelle Lopes[1], “The revival of the tribal community by concept of S.M.A.R.T Village: A case of Sabar Tribe of Jharkhand, India” [1]School of Architecture REVA, University Bengaluru and [2]XXI Architecture, Pune, India.

2nd Prize

Harshal Kate[1], and Garima Jain[2], “Deconstructing PMAY-G: ICT 4 Nation Building”, [1]Department of Management Studies, IIT Delhi and [2]World Resources Institute (WRI) India.

3rd Prize

Dhiman Jyoti Thakuria and Dhiman Kaskyap “Flood resistant housing in Assam” Assam Engineering College, Assam, India.

DESIGN AND FABRICATION OF A FLOOD PROOF HOUSE TO OVERCOME THE FLOOD HAZARDS IN RURAL AREAS OF ASSAM, INDIA

ManashBhuyan[1], Imran Hussain Ahmed[2], Bappi Chamua[2], Manas Jyoti Medok[2], Raju Ronghang[2], Mousumi Gogoi[3]

[1]Faculty, Industrial & Production Engineering Department, Assam Engineering College, Jalukbari, Guwahati-781013, Assam, India. Email ID:manash800@gmail.com, manash.ip@aec.ac.in
[2] 8th semester student, Industrial and Production Engineering, Assam Engineering College, Guwahati, India.
[3] Faculty, Mechanical Engineering Department, Assam Engineering College, Guwahati, India.

Abstract – *In Assam, about half of the total population is landless and lead a miserable floating life during flood. In this study an attempt was made to design a low-cost floating house suitable for people in low lying areas in Assam which are greatly affected by flood. Considering the reasons above an attempt was taken to make a low-cost floating house that would be stable and durable. Floating house is a unique mechanism of living on a buoyant platform without the fear of sinking and get afloat with the rising ups and downs according to the water level. It is not a house boat, but an actual house that's designed to float. Thus, a design of a flood proof house is made to provide shelter and stocked all the basic requirements during flood for the people. Different types of modern constructional materials are used in modernize floating structure and providing all the amenities required in this house. The Dutch technology consists of a floating concrete container that can be used as a lower level or cellar. The Canadian technology consists of a square container turned upside down and filled with polystyrene, an unsinkable structure. Switzerland architects design floating house on a catamaran pontoon which consists of 98% plywood from locally sourced birch. In the study, the design of house is done in Solid-works. There are three alternatives designed out of which one is selected and showed in this paper. All the faults are minimized in the final design and prototype fabrication of the proposed design is executed. Cost analysis of the house is calculated so that it can be affordable for below poverty line people. In this study, the proposed model of the house has been designed to act as a safe house during flood. It functions as a normal house and as the water level during flood rises the house is lifted due to the buoyant force. With the help of proposed model one can easily get rid of the situations which are visualized during flood.*

Keywords: *Flood proof house, Low cost house, Prototype fabrication*

1. Introduction

Flood is defined as the condition in which land is submerged in water which is normally used to be dry. Due to different natural phenomena like rainfall lasting for a longer period of time, monsoon season, tropical cyclones or a large amount of rapid snowmelt flood situation can occur in rivers or other drainage. In urban areas due to improper drainage system sometimes due to high precipitation water can accumulate on the streets and maybe sometimes comes back into the building through sewers pipes when rainfall is higher than the drainage capacity. The condition of flood can get worsen in the case of major infrastructure failure like dam failure etc. The consequence of flood can be devastating which includes loss of life and financial losses. It damages the building, roads, bridges etc. affecting the normal life.

Therefore, the need to adopt effective countermeasure against these disasters especially flooding the concept of Amphibious House has been adopted here. It refers to structures that will function both in land and water in response to flood in low lying areas. This configuration allows the houses to rise with the floodwater, mitigating the damage caused by the seasonal flooding

The main advantage of this idea is that it is an economical solution for flood mitigation and also prevents an ongoing inconvenience to residents as well as creating a significant impediment for the elderly and others with impaired mobility. From literature it is observed that researchers made flood proof poultry houses to safe poultry firms during flood season (Ali 1995 and Suman 2007). Some researchers developed low cost floating houses and the design is stable from engineering point of view (Ishaque 2014: 49-57).

2. Design Calculations

Design calculation is a method of identifying and eradicating the problems in a process, to identify the important factors as well as existing interactions which determine the performance characteristics of the proposed design.

2.1 Mechanism Used

Buoyancy: Buoyancy is the upward force exerted by a fluid that opposes the weight of an immersed object. Buoyancy is the phenomenon stated by Archimedes, which says the object experiences the upward force when it is completely or partially submerged in a liquid.

Using area, height and volume the formula is:

$F_b = \rho \times g \times h \times A$

F_b denotes the buoyant force

ρ denotes the density of the liquid

h is height, A is surface area.

2.2 Design Data

Table 1. Dimensions of the House

Sr. No.	Component	Measurement (Feet)
1	Length	10
2	Breath	7
3	Height	7

Table 2. Dimensions of the Drum

Sr. No.	Component	Measurement (cm)
1	Diameter	59.5
2	Height	102

Table 3. Dimensions of the Bamboo

Sr. No.	Component	Measurement (mm)
1	Diameter	80

2.3 Design Calculation

2.4.1 Bamboo

As per the data calculated the weight of a 24 feet (7.310m) bamboo is between 15 to 20kg. So the average approximated weight is 17 kg.

Weight of bamboo for 1 meter of its length =2.32 kg

Circumference of the bamboo of radius 0.08 m (80 mm) = 2×π×r = 0.5 m

2.4.2 House

As it is calculated that the circumference of the house to be 0.5 m
No. of bamboo required along the length of the house =3.0488/0.5=6.096
6.1 number of bamboo of length 7ft or (2.1336m) will be required along the length of house i.e. 6.1 × 2.1336 = 13.015m of bamboo along the length

Similarly, along the breadth 7ft or (2.1336m) for length of 7m

$$= \frac{2.1336}{0.5} \times 2.1336$$

= 4.27×2.1366
= 9.11m of bamboo

Now total bamboo required in meter = (2×9.11) + (2× 13.015) = 44.25 m (145.18ft)

2.4.3 Drum

Now, volume of one drum =π× r²×h
= 0.284 cubic meter

We know that buoyant force is equal to the volume of the water displaced. And here the volume of the water displaced is equal to the volume of the 10 drums.

Buoyant force = $\rho \times g \times h \times A$
= 1000×9.81× (10×.284)
=27860.4 N (2840 kg)

3. Design Models

3.1 Accepted Design Model with Compressed air balloon.

The proposed design with dimensions is shown in Fig.1-5 below.

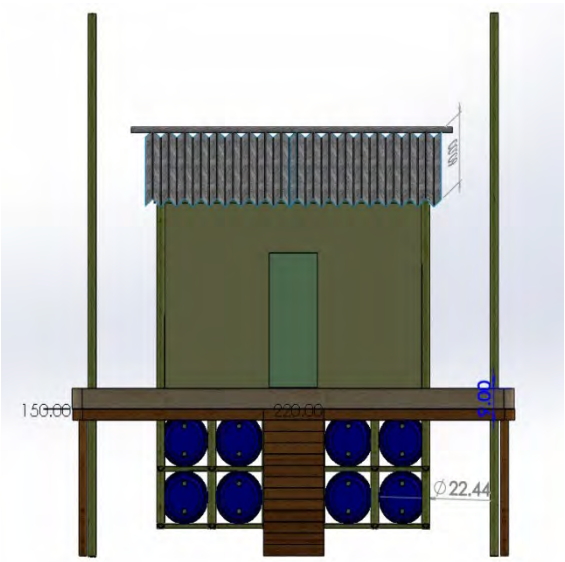

Fig 1 Front View

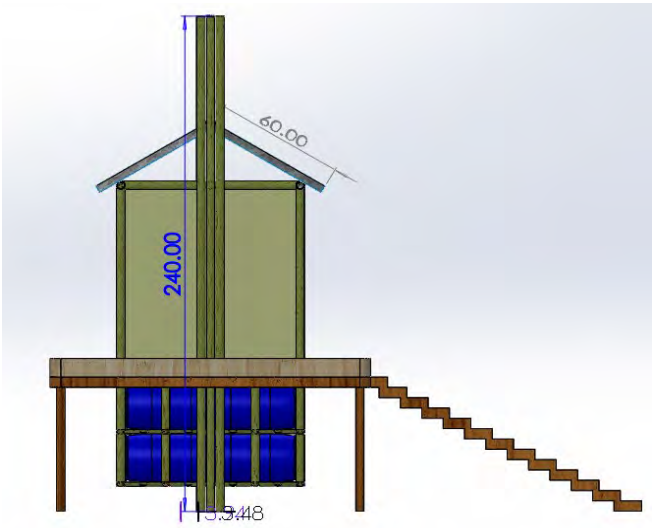

Fig 2 Side View

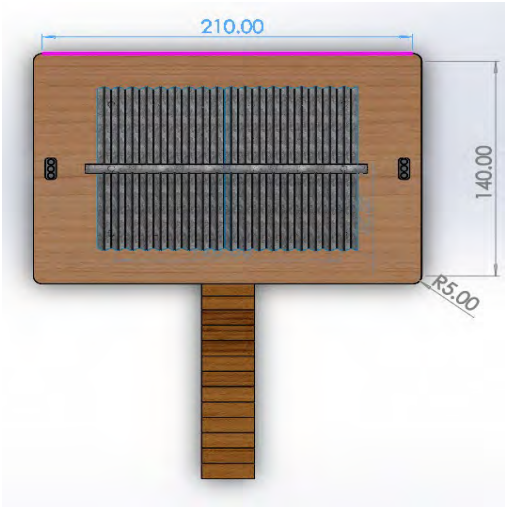

Fig 3 Top View

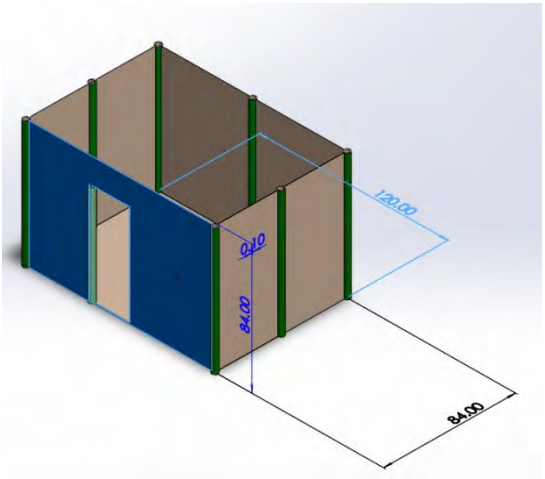

Fig 4 Room Dimension

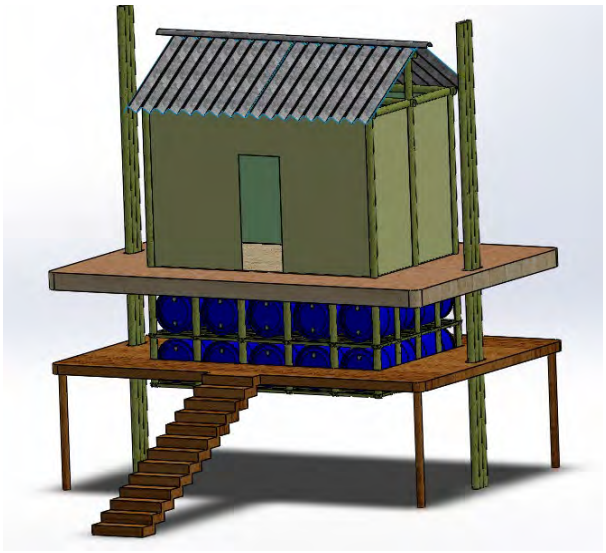

Fig 5 Floating View

4. Prototype Fabrication

Fig.6. Side View of the prototype model.

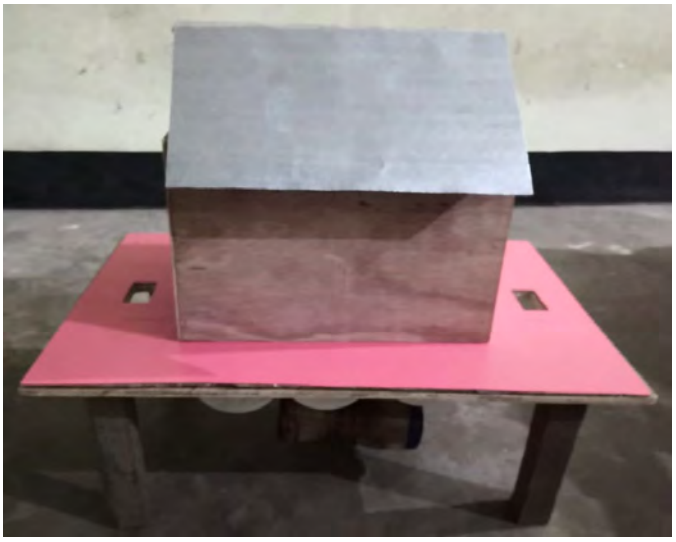

Fig. 7. Front View of the prototype model.

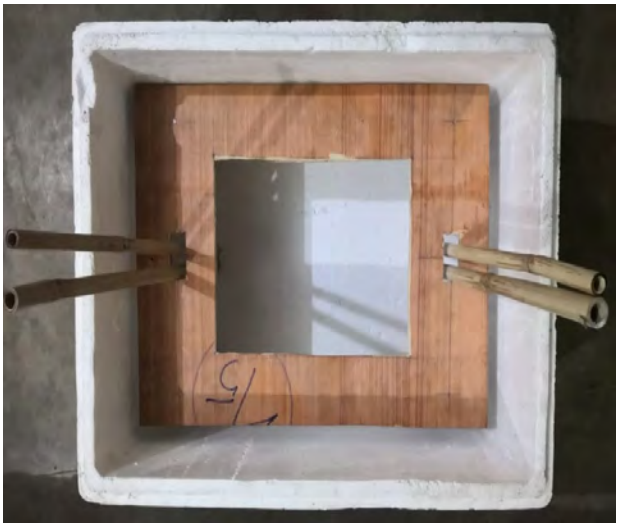

Fig.8. Top View of the prototype model base.

Fig.9. Top View of the prototype model.

5. Analysis of the Proposed Design

Buoyancy is the upward force exerted by a fluid that opposes the weight of an immersed object. It is caused due to the differences in pressure acting on opposite sides of an object immersed in a fluid. The direction of the net force due to the fluid is upward. Buoyancy is the phenomenon stated by Archimedes, which says the object experiences the upward force when it is completely or partially submerged in a liquid. When the drums attached to the frame of the house are immersed in water, it creates buoyant force which lifts the house during flood. The house is also supported by two guideways so that the house doesn't get carried away in flood. Guideways are used mainly to keep the house in a fixed position and allowing the house to move in only vertical direction. The prototype model shown in Fig.6-9 is worked efficiently as according to the proposed design. When water pour in the cage the house automatically rises up with the help of drums and not displaced because of the guideways attached in the prototype. Furthermore, the stairs are attached with the bottom of the house just because to prevent damage of the stairs when it goes up during flood.

5.1 Cost estimation

Considering the economic condition of floating people an investigation was carried out to find a suitable building material which has economic, viable and durable. So that, variable fencing, roofing and floating materials were considered to estimate the cost. Estimated cost for a Bamboo Fenced floating house is shown in Table.4 which is developed with the help of literature (Ishaque 2014: 49-57).

Table.4 Estimated Cost for Bamboo Fenced Floating House (Ishaque 2014: 49-57)

Materials	Quantity	Rate	Price (Rupees)
Fencing			
a) Bamboo pillar	3 pieces	Rs.60/Pieces	180.00
b) Bamboo Mat	6 Nos.	Rs. 100/mate	600.00
c)Timber for door(1) and window(2)	1.5 cft	Rs.1200/cft	1800.00
d) G.I. wire	1.5 kg	Rs.60/kg	90.00
Roofing			
a) Bamboo frame	1 piece	Rs.200/piece	200.00
b) Screw	1 kg	Rs.100/kg	100.00
c) CI-sheet	1 ban	Rs.2450/ban	2450.00
a) Ceiling	1 No. (10'×7')	Rs. 100/chatai	100.00
b) G.I Wire	1 kg	Rs.60/kg	60.00
Flooring			
a)Wooden Frame	2.3 cft	Rs.1400/cft	3220.00
b) Bottom frame of bamboo mat	3 pieces	Rs.150/Pieces	450.00
c) bamboo mat	1 No.((10'×7')	Rs. 100/mate	100.00
d)Nails	1.5 kg	Rs.60/kg	90.00
e)G.I. wire	0.5 kg	Rs.60/kg	30.00

Float			
a)Drum	10 Nos	Rs.500/Drum	5000.00
Labour cost			
	1 labour/day(4 days)	Rs. 250/day	1000.00
	1 carpenter/day(3 days	Rs. 350/day	1050.00
Miscellaneous cost			1000.00
Total Cost			17520.00

5.2 Methodology

An amphibious floating structure was designed to use it as a flood shelter with all the amenities so that one can meet their natural need during flood. To float the structure an assumption was made that drums should be provided in such a way that it will remain in complete balance. However, local materials were selected to design the floating house. In the present study a 'Middle class' family was considered as the family in the rural areas who has enough earnings to run the family easily for the whole year. Mostly its source of income is from agricultural products. The family was considered of five member's family. It consists of father, mother and three children. For design consideration their approximate body weights were considered as 60 kg, 55 kg, 40Kg, 15 kg and 10kg i.e. the total is 180 kg. To provide sanitation facilities a floating toilet must be hinged in such a way that stability of the floating structure does not hindered.

Considerable incoming loads in the house

For design purpose the weights are considered as given below:

Table.5 Estimated incoming load in the House

Sl. No.	Particulars	Weight
1.	The total weight of the family members	180 kg
2.	Weight of food (one month)	250 kg
3.	Weight of seed of different crops	200kg
4.	Self-weight of the structure	200 kg
5.	Weight of stored drinking water	75 kg
6.	Weight of the utensils, cloth and others	200 kg
7.	Total weights	1105 kg

6. Conclusion

The designed flood proof house can easily be constructed from locally available materials and it can be done economically. It may be used in the flood hit areas where the people can easily afford to build such facility at a low cost. The design is estimated to support a weight of about 2000 kg. The facility can easily support the family including the basic

requirements for survival during the flood. For some additional comfort the roof of the house can also be fitted with solar panels for illuminating the house and connecting electrical appliances.

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IDEATION OF SMART VILLAGE: A FRAMEWORK TO MAKE INDIAN VILLAGES SELF-SUSTAINED

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Abstract:

In India as per the census 2011, 68.84% of the total population live in villages or rural areas, and out of 6,00,000 villages, 1,25,000 villages are undeveloped so there is a need for the emerging concept of the smart village for the redesigning and advance tech-supported building these villages. Lack of employment and infrastructural services in Indian villages leads to severe migration from villages to cities. Thus the need for 'Ideation of smart village' in the current scenario seems to be more important as consistent migration from villages to cities is resulting in the form of concrete jungles. The present challenges in Indian villages can be addressed with the modern infrastructural solution available. And hence approach for developing a smart village will be precisely focused on availing the necessary services required. Also, the primary aim of this study is to preserve the original characteristics of Indian villages. The most appropriate method to build a Smart village is to identify the locally available practical solutions for the problems. Adopting the methodology of traditional village planning supported with modern technology available in the form of ICT and IoT will result in the development of a smart village which will not only be sustainable but also self-dependent. The study proposes the smart innovation supported by the local parameters for Indian villages. There will be practical recommendations for having a better infrastructural service for villages. The results from this study may be replicated by other villages of India who are also facing similar planning problems.

Keywords: *Smart Village, Urbanization, ICT, Sustainability, Rural Development*

1 Introduction

In India, too much discussion and consultations are taking place everywhere to build smart cities but there are very few discussions to build villages/rural areas smart and sustainable. Located outside the jurisdiction boundary of cities and towns, a rural area is a geographical area that consists of a settlement (also popularly known as 'lal dora' in some parts of India) and land apart from the settlement area demarcated by the revenue boundary. Any settlement situated outside the town/city boundary having a maximum population of 15,000 can be considered as a village of rural areas where the predominant source of earning a livelihood is agriculture and allied activities like horticulture, sericulture, pisciculture, pottery, cottage industry, etc. In short, it can be said that all settlement area which is not in compliance with any definition of the urban area falls in the category of rural area. India being an agrarian country where rural area dominates the statistics, 'smartness' as a concept to develop rural settlements is not even pondered about. Plentiful of the country's rural population lives in nucleated villages which can be described as shapeless in terms of forms of settlement. According to the 2011 census, India has approximately 6, 38,588 rural units, and 68.84% of the total population resides in those rural units whereas, on the other hand, 31.16% of people reside in urban areas (Beg, 2018). Considering the Indian context in terms of diversity of culture, climate, ethnicity, topography, etc. the policymakers should focus on the grass-root level, and hence, the rural area in the heart of the nation should be the center of attention. Many rural areas lack even the basic facilities and employment opportunities because of which large scale rural to urban migration is being observed resulting in rapid urbanization. This is not only creating 'ghost' villages but is also becoming unmanageable for urban local bodies for facility provision. Hence, to dodge the accompanying problem with large scale migration, the villages themselves can be smartened up to provide basic facilities like education, technology, employment-generating activities, etc. In the same path of thought process, Mahatma Gandhi also versioned that "The best, quickest and most efficient way is to build up from the bottom. Every village has to become a self-sufficient republic". The emergence of information and communication technology has provided means for an effective and faster communication, efficient storage, retrieval, and processing of data, and exchange and utilization of information to its users, whether the individuals, business groups, or

governments (Mukherjee, 2011). Hence Information and technology can be used as a powerful tool for rural development and if used properly it would be helpful to solve problems at grass root levels and enhance development opportunities.

2 Problem and Challenges

It is seen that planners and decision-makers in developing countries have great opportunities and challenges at the same time to avail of well-equipped infrastructure in rural settlements and villages. Worldwide cities are facing are the problem of rapid growth and urbanization. Presently more than 48% of the total population of the world is living in urban areas which were only 3% at the beginning of the 19th century (Kumar, 2017). Continuous population growth and the absence of basic services in rural areas are the main cause for the migration of rural population to urban areas resulting in the shortage of housing and infrastructural services in those areas. The development of physical social infrastructure in rural areas is strongly required for the development of people also. Since people of villages are changing their occupation from agriculture to different sectors because of insufficient opportunities therefore less agriculture production is recorded in recent years (Kale, Varpe, Chothave, & Borse, 2017). Although the Government has launched various schemes and programmes in the direction of rural development and their betterment the rural population is not much aware and get benefitted from those schemes and programmes. Therefore framework to bring transparency between the government and rural communities needs to be developed as a foremost step in the direction of the smart village.

3 The vision of the Government of India

In India, the Ministry of Rural Development is the nodal Ministry for carrying most of the rural development and welfare activities in rural areas. This Ministry has a vision for the sustainable development of Indian villages through a multifaceted strategy by increasing livelihood opportunities for poverty eradication, providing social safety, and developing infrastructure facilities to promote (About the Ministry, 2020). This vision is supposed to improve the quality of life in rural areas and to reduce the developmental segregation in the most underprivileged section of society. To accomplish the objective of rural Upliftment, the Government of India defined various aims in this direction. It aims to

provide basic housing and homestead to BPL households and social aid to the disabled and needful groups in villages. It also includes capacity building and skill development along with inviting discretionary agencies to involve themselves in this noble cause of rural development. Rural connectivity through all-weather roads and restoration of depleted productivity of the land is also the main concern for the government of India (Gupta & Gautam, 2018). The government of India is also focusing on the development of skills, education, banking facilities, health, rainwater harvesting, and conservation of water bodies, electricity, waste disposal, affordable housing, open defecation, internet connectivity, cooking gas, social protection and public engagement activities in rural areas.

4 Government Policies and Schemes

The Government of India has a wide spectrum of policies and schemes to provide employment, well-equipped infrastructure, a better quality of life and poverty alleviation (About the Ministry, 2020). Over the years, the Government of India has launched various policies and schemes to fulfill the requirements of rural areas. Some of the major programmes operated by the Government for rural development are listed below-:

i. National Rural Livelihoods Mission (NRLM) for poverty alleviation and employment generation.
ii. Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) to strengthen livelihood security.
iii. Shyama Prasad Mukherjee RURBAN Mission.
iv. Pradhan Mantri Awaas Yojana or Housing for All to provide affordable housing for economic weaker section of society.
v. National Social Assistance Programme (NSAP) for a social pension.
vi. Pradhan Mantri Gram Sadak Yojana (PMGSY) for the construction of quality roads.

5 Impacts on Demography, Environment, and Quality of Life

Seventy percent of the total Indian population lives in villages; major problems being faced in rural areas are illiteracy, poverty, discrimination, language dominance, resistance to change, citizen's awareness, and infrastructure problems such as electricity, communication, transportation, and lack of knowledge about new technology. "Smart Village" can be used as a metaphor for "Smart City", which brings basic amenities,

infrastructural sustainability with overall development in the rural areas (Johnson, 2016). There can be multiple ways to enhance the Quality of life in rural areas. Whether they are inhabitants from the middle-income or lower-income group, every small facility provided will result as a boom for them. Better health facilities in villages will reduce maternity complications. Information and communication technology will make primary education smarter and digitized (Shukla P. Y., 2016). Infant mortality rate and maternal mortality can also be reduced by proper supervision of pregnant women and education awareness about child delivery (Zavratnik, Kos, & Duh, 2018). Internet accessibility in the village will provide quality education and will help to reduce the school dropout rate. Rural migration can also be reduced with the help of the smart village concept by developing self-help groups to boost the local economy. Establishment of a community center in villages will also play a vital role to bring inclusivity in the village by acting as a focal point for basic medical services, emergency response, infrastructure, agriculture, and community participation ensuring the overall development.

6 Case Studies

Smart Village: Punsari, Gujarat

The study of Punsari smart village is taken to understand how the existing situation of any village can be modified with the help of modern technological interventions for the holistic future development of rural areas. Punsari village is located 80 km away from the state capital Gandhinagar in the Sabarakantha district of Gujarat state. This village houses 6000 villagers.

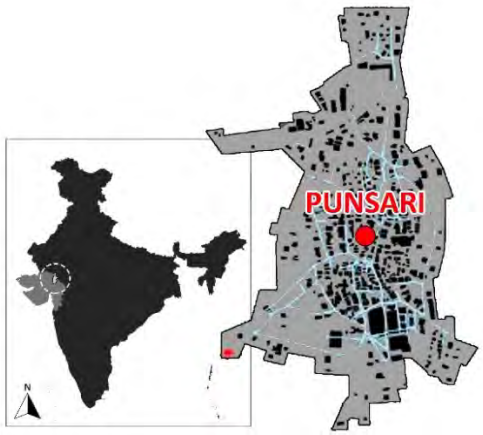

Figure 1. Location of Punsari Village

All the basic infrastructure services are available in this village which makes it an ideal village. In the process of development, the rural characteristics of this village remained intact. Villagers are still involving in farming and community engagement can be seen in this village. This is the perfect example to unify technology and rural development without disturbing the authenticity of the village which is important for the balanced growth of the country (Bhagat, 2017). GIS analysis tools have been used to propose different initiatives regarding the social and physical development of the village. Some major strategies adopted to develop Punsari as a smart village is as follows:

i. This village has a 66kV sub-station for power supply. And electricity is produced from the collected waste.
ii. Schools of the village have advance infrastructure and facilities including CCTV cameras, Air Conditioners, and projectors.
iii. 120 waterproof speakers are installed in this village for effective communication.
iv. Underground drainage and sanitation system have been provided.
v. Reverse Osmosis plant has been
vi. Panchayat has installed a Reverse Osmosis (RO) plant in 2010 to supply clean drinking water to the village people.
vii. This village has door to door waste collection service.

Smart Village: Harisal, Maharashtra

Harisal village in the Amravati district of Maharashtra is another glaring example of a smart village. Earlier mobile connectivity and communication networks were unable and high infant mortality rates, unemployment, school dropouts were common problems in this village (Ranade & Lodhe, 2015). In recent years, the Government of Maharashtra and Microsoft have signed a memorandum of understanding to develop this village as a smart village through a comprehensive framework. They adopted an IT-enabled framework for the development and PPP model for the transformation of this village. The essential interventions were revolved around three core pillars: to ensure last-mile access, provision of technology and infrastructure, and to foster a sustainable ecosystem.

Figure 2. Location of Harisal Village

The following strategies are adopted in the implementation of the digital village Harisal project in Harisal-:

i. Formation of Digital Village Harisal Committee with 20 qualified youth from the village itself for seeking suggestions, monitoring the work progress, and capacity building for services being provided under the project.
ii. Backend Computerization of offices as per schemes and capacity building of the employees for the usage of software systems.
iii. Setup of VC studio in Gram panchayat for regular interaction with citizens and review and monitoring of the project.

7 Technological Interventions for Smart Village

The circumstances and difficulties in developing urban and rural areas are because of the varying constraints and opportunities. Numerous scientists accept that the overarching innovations produced for the smart city could likewise be helpful for the smart village idea. One promising innovation like Geoinformatics could likewise be valuable for villages while changing rural villages into the smart village (Tripathi, Singh, & Kumar, 2012). Geoinformatics advancements can assume a truly unmistakable part inside the organization and execution of ICT in the "Smart Village" as decision support systems. It'll likewise help in recognizing framework bottlenecks and gaps, thereby improving information investigation and observing, while at the same time upgrading suitable specialized and innovative abilities, advancing normal practices and practices positive for the conviction of village and community development (Zavratnik, Kos, & Duh, 2018).

Accessible distinctive spatial and non-spatial layers are regularly joined and incorporated to encourage examination and settle on the least complex choice. Ongoing improvements in GIS, GPS, remote sensing, web-administrations, and area-based administrations and advances can uphold creative answers for the board, administration, and resident interest rehearses consistent with Smart Village objectives. Geospatial Information and Geographic Information frameworks (GIS) are basic segments for building brilliant smart villages during an essential way that maps the physical world into a virtual environment (Atieno & Motur, 2014). GIS-based arranging and decision support networks permit organizers and consequently the village to proficiently make and picture effective situations and decide their potential effects on future land use designs and dependent on employment trends and projections.

8 Findings and Discussions

The fate of India lies in changing over every village into a smart village. The idea of the smart village will give the population the similar benefits that they derive from the metropolis. This will nullify the pull factor of the cities and reduce migration to urban areas. People in the future will contribute tremendously to the development processes and appreciate conventional agricultural practices with the utilization of modern innovations. It is necessary to realize the functional needs for self-sustained energy, clean water, and waste management, in rural areas. The villages which have basic infrastructure, Information, and communication technology solutions will enable connectivity between communities and provide remote access for E-Learning, E-Health, and E-Business, which will further catalyze socio-economic growth.

9 Conclusion

Based on the above study it is clear that there is excessive pressure on urban infrastructure due to the migration of rural people in search of better living opportunities, thus the idea of making a smart village is more plausible in the present context. Smart Villages won't just lessen this movement yet, also inundate the population stream from urban to rural areas. ICT/IT and GIS are building stones of the framework that will induce the entire process of smart development in rural areas (Shukla P. Y., 2016). Every village is an interesting model and having various issues and circumstances. It might be hard to

actualize a similar model of village development for all the towns (Phahlamohlaka, Dlamini, Mnisi, Mashiane, & Malinga, 2014). An effective planning, detailed strategy, and monitoring and execution system for all activities is required to utilize the information and communication tools for rural development. Benefits of the smart village efforts are foreseen to be tremendous and this concept has the potential to uplift the grass-root level of the country, hence adding a feather in the overall development of India.

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Lack of Rural Infrastructure: The Impact on Economic Development, as a case of South Salmara District, Assam

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Abstract

Infrastructure is the basic equipment that is needed for a country, region to function properly. It is the underlying foundation that undergirds the structure of the economy. Infrastructure contributes to economic development by increasing productivity and services, which enhance the quality of life. Rural areas tend to lack sufficient roads that would increase access to agricultural inputs and markets. Poor infrastructure hinders communication, resulting in social isolation among the rural people. This paper discusses how the lack of rural infrastructure impacts the economic development of a region as a case of South Salmara District of Assam. A case study comprised of detailed research and surveys in the region explores the concept further. The survey approach comprising mainly quantitative methods employed in collecting and analyzing data. Purposive sampling technique was employed and survey questionnaire was used to collect data for the study. The study concludes that quality of infrastructure in the region is very poor that has a negative impact on the lives of the people. Findings reveal that several factors contributed to the economic stagnation of the region. The study recommends that government should give more consideration to the rehabilitation of the infrastructure, assign substantial budget to rehabilitate the infrastructure, which would promote the economic development of the region.

Key words: *Rural Infrastructure, Economic Development, Roads, Electricity, South Salmara District.*

1. INTRODUCTION AND AIM

1.1. Introduction

Infrastructure is the basic equipment that is needed for a country, region, or organization to function properly. It is the underlying foundation or basic framework that undergirds the structure of the economy. Infrastructure contributes to economic development by increasing productivity and providing services, which enhance the quality of life. (Akinyosoye 2010)

Majority of the people in the world lives in rural areas where the level of public infrastructure is low. Rural poverty is often a product of poor infrastructure that hinders development and mobility. Rural areas tend to lack sufficient roads that would increase access to agricultural inputs and markets. Without roads, the rural people are cut off from technological development and emerging markets in more urban areas. Poor infrastructure hinders communication, resulting in social isolation among the rural people. Such isolation hinders integration with urban society and established markets, which could result in greater development and economic security. Moreover, poor or nonexistent irrigation systems threaten agricultural yields because of uncertainty in the supply of water for crop production. Many poor rural areas lack any irrigation to store or pump water, resulting in fewer crops, fewer days of employment and less productivity. Both a lack of roads and insufficient irrigation systems result in greater Work Intensity in many rural communities.

India is the second most populous country in the world with a population exceeding 1.3 billion. 65.97% of the total population lives in rural areas. Provisioning of basic infrastructure facilities for this large section of the population spread across 3.28 million square kilometer of the country's geographical area has been a major challenge.

Transport represents one of the most important human activities worldwide. It is an indispensable component of the economies of countries and plays a major role in spatial relations; helping create valuable links between regions and economic activities, between people and the rest of the world. Among the many importance of transport is its key role in specialization allowing production and consumption of products to occur at different locations. Better transport allows more trade and a greater spread of people. Economic growth has always been dependent on increasing the capacity and rationality of transport.

Agriculture is the main livelihood in India’s villages. Agriculture makes up 18% of the country’s GDP and about 64% of the total population is directly employed in agriculture. Consequently, agriculture remains important to the Indian economy, which in turn depends on the rural infrastructure. Rural roads provide the important connectivity with growing markets adjacent to the rural areas. In India, it has been shown that roads alone account for 7% of the growth in aggregate output of the rural areas. But in rural areas the level of public infrastructure especially roads seems low. Lack of basic infrastructure such paths, trails, bridges and roads and access to transport services makes it difficult for poor people to access markets and services. Poor road access has put nevertheless constraints for rural poor people in terms of access to other social infrastructure such as education and health facilities.

Irrigation is another decisive factor that plays an important role in the development of rural economy. It determines the agricultural productivity of a region. Indian agriculture is still dependent on monsoon. Hence agriculture in rain fed areas, drought prone areas, desert and high hill regions require irrigation. Timely irrigation is critical for Indian agriculture. Irrigation is essential for successful agriculture particularly in the area, where rainfall is inadequate and uncertain.

Assam vestiges some of the poorest regions of the country. Connected to the country through a narrow corridor, the state has always been left out in gaining the attention of the Central Government. With more than 40% of the people living below poverty line, the state is one of the under-developed states in the country. The State is endowed with abundant fertile land and water resources with total geographical area of 78,438 sq. km. of which 98.4 % area is rural. There are about 26247 villages in the state and agriculture is the main livelihood. Agriculture makes the highest contribution to its domestic sectors, accounting for more than a third of Assam's income and employs 69% of workforce. Poor people living in rural areas of Assam are isolated by distance, terrain and poverty from employment and economic opportunities, markets, healthcare and education.

There is clear evidence that rural isolation is associated with low agricultural productivity linked to poor market access and low use of fertilizers and modern agricultural technologies. It is also linked with poor health and low school enrolment. Rural isolation can imprison the elderly and people with disabilities. (Starkey & Hine 2014)

1.2. Aim

The purpose of the study is to investigate lack of rural infrastructure: the impact on economic development as a case of South Salmara region, Assam. The study aims to examine the impact of rural infrastructure on the economic development of the region. Through this survey research we intend to explore the perceptions of the local people regarding the level of infrastructure and the issues and challenges they face. The study further aims to come up with a solution for the economic development of the region.

1.3. Research Questions

To shed light on the problem, the following research questions were addressed:

1) What is the main reason that is obstructing the development of the region?
2) How the lack of infrastructure is hindering the development of the region?
3) What are the economic, socio-cultural and other benefits when a region is well connected with a state of infrastructure?

2. LITERATURE REVIEW

Infrastructure is a key element of poverty alleviation. It often acts as a catalyst to development and enhances the impact of interventions to improve the poor’s access to other assets, e.g., human, social, financial, and natural assets. Its impact is felt both on the economic and social sectors. (Pouliquen 2000)

Sub-Sahara Africa vestiges the poorest region of the World despite the recent noticeable increase in per capital income growth rates of many countries in the region. Thanks to decades of economic stagnation, poor standard of living, ethnic cleansing and tribal wars, political instability and environmental disasters which had left infrastructure development uncared for. Infrastructure are public goods and services that goes into the production process as Complementary inputs for traditional factors of production such as capital, labor and Entrepreneur. They help to increase returns on investment by reducing production cost and improving transition efficiency (Bello & Osinubi, n.d.)

Somalia is a country situated in the Horn of Africa. It is bordered by Ethiopia to the west, Djibouti to the northwest, the Gulf of Aden to the north, the Indian Ocean to the east, and

Kenya to the southwest. Somalia has the longest coastline on Africa's mainland and its terrain consists mainly of plateaus, plains and highlands. The destruction of the country engulfed not only the bridges that link the regions together in economic wise, but devastated roads, water, transportation, education, communication, electricity, hospitals and all that may contribute the development of social infrastructure as well, thus, lack of infrastructure makes the economic development retarded. (Osman & Abdulle, n.d.)

Factors responsible for poor state of infrastructure:

- Lack of resources to undertake infrastructure development.
- Lack of reliable data to determine finance and manpower requirements of project.
- Lack of infrastructure development framework that adequately delineate stage by-stage project requirements in many countries of the region.
- Inadequate planning, mismatch of projects with society needs, and requirements.
- Inadequate supporting institutions and unstable political environments. (Bello & Osinubi, n.d.)

Various factors determine different transport costs across countries. Distance from major markets and other geographical characteristics are only two of these factors. For example, it is estimated that doubling distance increases overall freight rates by between 20 to 30 per cent46, and that landlocked countries face, on average, 50 per cent higher transport costs than otherwise equivalent coastal economies. (Limao and Venables, 2001)

In Costa Rica, a retrospective review of the rural electrification experience through electrification cooperatives indicates that for one of these cooperatives the number of major businesses jumped from 15 to 86 after electrification .Without potable water and sanitation health is at risk. The social and economic impact often goes hand in hand (Pouliquen, 2000).

Poverty reduction requires economic growth which, when accompanied by sound macroeconomic management and good governance, results in sustainable and socially inclusive development (ADB, 1999). Greater access of the poor to education and health services, water and sanitation, employment, credit, and markets for produce is needed. Moreover, the vulnerability of the poor to economic shocks and natural disasters must be reduced to enhance their well-being and encourage investment in human capital and in higher-risk and higher-return activities. Public policy reforms and investment in physical infrastructure will significantly contribute to the pursuit of socially inclusive development (Ali & Pernia, 2003).

The lack of infrastructure is hindering the economic growth in many developing countries. Infrastructure investment has the effects of contributing to increase the productivity and it is expected to contribute to future economic growth in developing countries where infrastructure is still insufficient. Therefore, infrastructure development is one of the most integral parts of the public policies in developing countries. Supporting infrastructure development in developing countries by advanced countries is extremely important field. This can be inferred from the fact that many international organizations such as World Bank and OECD are actively promoting the improvement of infrastructure by providing various support programs to developing countries. However, the precise relationship between infrastructure and economic growth is still frequently debated. Good infrastructure helps to raise productivity and lower costs in the directly productive activities of the economy, but it has to be expanded fast enough to meet the demand for infrastructure in the early stage of development (KIM 2006).

The availability of infrastructure facilities and services as well as the efficiency of such services to a large extent determine the success or otherwise of all other production endeavourers.

Investments in infrastructures such as energy, water, transportation and communication technologies promote economic growth and help to alleviate poverty and improve living conditions in developing countries (OECD, 2006).

3. METHODOLOGY

This section of the paper outlines a brief description of the study area and methodology. The methodology encompasses the research approach, sampling techniques and methods of data collection.

3.1. Study Area

South Salmara Mankachar is an administrative district in the state of Assam. It is located at about 245 km west of Guwahati, in the lowermost part of Assam. The district occupies an area of 568 square kilometers and has a population of 555,114 as per to 2011 census. It is bordered by Bangladesh in the west, Meghalaya in the south-east and river Brahmaputra in the north-west. It is one of the most backward and under developed region in the state. Economic stagnation, poor standard of living, political instability and environmental disasters had left the infrastructure development of the region uncared for. The destruction of the region engulfed not only the bridges that link it with other regions economic wise, but also destroyed roads, water, transportation, communication, electricity, education, healthcare and everything that would contribute to the development of social infrastructure along with the physical ones.

3.2. Research Approach

This study employed a descriptive design. It is quantitative in nature. In analytical research, the researchers have to use facts or information already available, and analyze them to make a critical evaluation of the material. The study was conducted in a survey research approach. The survey approach comprising mainly quantitative methods employed in collecting and analyzing data. Quantitative research approach provides a relation between empirical observation and mathematical expression of quantitative relations. Quantitative research approach is based on already decided and well structured questions whereby all the respondents will be asked the same questions. Thus, the survey design allowed for easy quantification of data on the effects of bad infrastructure in the economic development.

3.3. Study Population and Sampling Procedure

The study population consisted of 50 people from different work background. In this study, purposive sampling technique was employed and survey questionnaire was used to collect data for the study. Purposive sampling is the type of sampling where the researcher uses his/her judgment regarding participants from whom the information was collected. Purposive sampling technique is used in order to choose the respondents believed to have the information concerned the study by using own judgment, and then the survey questionnaire was distributed to the respondents.

4. DATA ANALYSIS

4.1. Profile of Respondents

The profile of the respondents was analyzed and the following tables present gender, age and background.

Table 1: Gender data

Gender	Frequency	Percent
Male	37	74
Female	13	26
Total	50	100

Source: Field Survey, 2020

Table 2: Age data

Age	Frequency	Percent
21-30	11	22
31-40	14	28
41-50	24	48
51-60	1	2
Total	50	100

Source: Field Survey, 2020

Table 3: Background data

Background	Frequency	Percent
Farmer	26	52
Small shop owner	10	20
Student	10	20
School teacher	2	4
Professor	1	2
Engineer	1	2
Total	50	100

Source: Field Survey, 2020

4.2. Assessment of Infrastructure

I. Road

In terms of frequency of road use, the field data revealed that greater percentage (68%) of the respondents use the road on a daily basis, 26% uses the road 3-4 times a week, and the remaining 6% use it once in a week.

Table 4: Frequency of road use

Responses	Frequency	Percent
Uses road daily	34	68
Uses road 3-4 times a week	13	26
Uses road once a week	3	6
Total	50	100

Source: Field Survey, 2020

In terms of assessment of the road network in the district, all the respondents agreed that the condition of roads in the district is bad. Following from this, about 82% of the respondents agreed that the roads are terribly bad and 18% agreed that the roads are moderately bad. None agreed to the point that the roads are good.

Table 5: Assessment of quality of road network

Responses	Frequency	Percent
Road conditions are terribly bad	41	82
Road conditions are moderately bad	9	18
Road conditions are moderately good	0	0
Total	50	100

Source: Field Survey, 2020

On the issue of travelling through the roads, 82% of the respondents agreed that they find it very uncomfortable travelling by the roads in the district, 18% agreed that they find it somehow uncomfortable and none of them agreed that they find it comfortable travelling through the roads.

Table 6: Issues of travelling through the road

Responses	Frequency	Percent
The find it totally uncomfortable travelling through	41	82
They find it moderately uncomfortable travelling through	9	18
They find it comfortable travelling through	0	0
Total	50	100

Source: Field Survey, 2020

In terms of assessment of impact of the road condition in the lives of the respondents, 76% of the respondents agreed that the road condition affects their livelihood directly. 24% agreed that it does not affect their livelihood directly.

Table 7: Impact of road condition on livelihood

Responses	Frequency	Percent
Affects livelihood directly	38	76
Do not affect livelihood directly	12	24
Total	50	100

Source: Field Survey, 2020

II. Irrigation

Certain questions pertaining to irrigation were also asked. Regarding the facility of irrigation provided by the government, majority (64%) said that there is no facility of irrigation provided in the region.

Table 8: Assessment of irrigation facility provided

Responses	Frequency	Percent
There is no facility of irrigation in the region	32	64
There is some facility of irrigation	18	36

Source: Field Survey, 2020

Out of the 50 respondents, the 26 farmers were asked about the ways they water their fields. It revealed that majority of the people use shallow machine purchased by them to water their fields. A small number of people use shallow machine received from the government. Many of them have electric pumps but can hardly use them due to lack of proper electricity.

Table 9: Assessment of ways people use to water fields

Responses	Frequency	Percent
Use shallow machine purchased by them	16	61.53
Use shallow machine received from government	7	26.92
Use manually operated tube well	3	11.53
Total	26	100

Source: Field Survey, 2020

In order to assess the reasons for decline in the agricultural productivity, the following responses were recorded.

Table 10: Assessment of reasons for decline of agricultural productivity

Responses	Frequency	Percent
Lack of proper irrigation facilities	24	92.3
Lack of proper electricity supply	26	100
Unable to use H.Y.V. seeds because to financial constraints	12	46.15
Other reasons	5	19.23

Source: Field Survey, 2020

III. Electricity

In regard of assessment of ways the people use electricity for, the field data revealed that 16% of the survey respondents use electricity when available for irrigation purpose, 28% use electricity for study purpose, and 20% use electricity for business purpose.

Table 11: Ways of use of electricity

Responses	Frequency	Percent
For irrigation purpose	8	16
For study purpose	14	28
For business purpose	10	20

Source: Field Survey, 2020

The respondents also use electricity for common uses in their households. 100% of the respondents use electricity for light and fan. Water pumping is also a common use. A few households has access to running water which they use for drinking purpose and can also store it for 2-3 days for cooking and other household needs.

Table 12: Common use of electricity by households

Responses	Frequency	Percent
Light	50	100
Fan	50	100
Cooking and drinking	12	24
refrigerator	7	14

Source: Field Survey, 2020

The respondents equally stated about the issue of blackout that they face. When asked about the frequency of blackouts, 18% respondents said that blackouts happen more than once in a week, 36% said that it happens once every week, 42% said that blackouts happen more than once in a month, and 4% said it happens once in a month.

Table 13: Frequency of blackouts

Responses	Frequency	Percent
More than once in a week	9	18
Once a week	18	36
More than once in a month	21	42
Once a month	2	4

Source: Field Survey, 2020

In order to assess the average length of the blackouts, the same 18% of the respondents stated that blackout lasts for an average of 6-12 hours, 36% stated that it lasts for 12-24 hours, 42% stated that it lasts for 24-48 hours, and the remaining 4% stated that it lasts for more than 48 hours. The respondents equally revealed that there are also blackouts that last for about 10 days – 25 days or sometimes maybe a month.

Table 14: Average length of blackouts

Responses	Frequency	Percent
6-12 hours	9	18
12-24 hours	18	36
24-48 hours	21	42
More than 48 hours	2	4

Source: Field Survey, 2020

In the light of this, the respondents were asked about the effect of blackouts in their daily lives. 16% respondents said it affects agriculture in watering their fields, 28% said it affects in their studies and office work, 20% said that it directly affects their business and income. 24% said that it also affects cooking and drinking and also water pumping ability.

Table 15: Affects of blackouts

Responses	Frequency	Percent
Affects agriculture	8	16
Affects studies and office work	14	28
Affects business and income	10	20
Affects cooking and drinking	12	24

Source: Field Survey, 2020

5. RESULTS

In view of all the above mentioned, a descriptive analysis of the lack of infrastructure is done and the results obtained are shown in the table below.

Table 16: Descriptive analysis of lack of infrastructure

Statement	Agreed	Not agreed
Lack of infrastructure promotes poor standard of living in your region	92%	8%
Lack of infrastructure encourages economic deficit in your region	92%	8%
Lack of infrastructure brings decline in productivity in your region	78%	22%
Lack of infrastructure is an obstacle to the free trade in your region	76%	24%
Lack of infrastructure promotes unemployment in your region	88%	12%
The education in your region is as desired	30%	70%
Your region is well electrified	16%	84%
The health care in your region covers your needs	24%	76%

Source: Field Survey, 2020

In light of the overall quality of the infrastructure and the problem they face due to it, the respondents were asked about what they think the reason to be that is causing the hindrance to development of the region. In context to that, the following responses were recorded.

Table 17: Reason for hindrance to development

Responses	Frequency	Percent
Lack of government policy and dedicated funds for developing the infrastructure	43	86
Lack of interest of the government to do so	46	92
Corruption	46	92
Due to extensive erosion problem development could not take place	13	26
Problem of land acquisition for construction of roads or any infrastructure projects	6	12

Source: Field Survey, 2020

6. DISCUSSION

6.1. Methods for Improvement

There is a clear need to provide basic infrastructure and social amenities in the rural areas so as to bring India at par with other global superpowers of the world. More importantly, such a development will vastly improve the lives of the Indian population which still struggles with many socio-economic problems such as poverty, hunger, health, illiteracy, lack of skill and modernization, etc.

The following methods can be adopted so as to induce some development in that region.

i. By investing in Infrastructure projects

Infrastructures projects help generate employment and maintain the flow of fund into the economy and helps economy grow thereby touching each and every stake-holder of the economy.

If we focus on developing infrastructure projects in the region, we are actually providing them alternatives. It will create employment opportunities for the local people, give them an alternate income solution, which will help lower farmers' loan burden and will improve their livelihood.

ii. By developing the rural road infrastructure of the region

One of the most important and effective means of inducing development in the region is by developing the road infrastructure of that region. It includes constructing new roads, expanding the existing road network, covering more area, connecting more number of villages. It will help link the communities of that region and their agricultural fields to the main transport system and markets. Improving the rural roads will reduce transport cost and stimulate marketing. This will result in increased production and productivity, crop diversification in that area and increased profitability of the people. A main bottleneck for local economic development is often a limited and poor quality rural road network. This crucial component of rural infrastructure, neglected during the reforms decade, need to be state financed in a time bound manner to prevent the rise in urban-rural disparities in growth and development.

iii. By improving the existing irrigation system of the region and investing in new irrigation projects

Rural economy is heavily dependent on agriculture and agro-based services. Agriculture productivity is largely influenced by irrigation. Today, it is necessary to increase the agriculture productivity of the region; for this irrigation has to be increased. The best method for the development of irrigation system in the South Salmara district can be if we can invest in canal irrigation system. Canal irrigation is more preferred and feasible in places where water availability is never a constraint. The mighty Brahmaputra river flows through South Salmara and henceforth canal irrigation turn out to game changing for the agriculture scenario of the district because of the following reasons:

a. The South Salmara district is situated on the bank of river Brahmaputra. So, source of water for irrigation is never a problem.
b. The district is having almost plain topography, which is suitable for canal irrigation.
c. The demand for irrigation is very great in this part of country as a variety of crops are grown.
d. Type of cultivation is intensive.

Although the concept of canal irrigation is present in the field of irrigation, it has main folding effects on agricultural landscape. They require heavy capital outlay which can be afforded by the Government for the construction to the canal. This leads for bringing about the changes in agricultural landscape. The old cropping pattern is replaced by irrigated crops. The farmers adopt the cropping pattern which is suitable to existing environmental conditions and which may give high remuneration.

Other systems of irrigation that can also be introduced to eliminate the problem of irrigation in that region are:

1) **Lift irrigation –** a lift is installation of pump, at a height close to the river bank that taps water from the river and allows it to reach the field through small channels constructed for this purpose. These can be electrically operated or diesel driven or powered by solar energy. The lifts can also be operated on river banks with jack-well to which the water supply is regulated by construction of small wires.

2) **Tube-well irrigation –** tube wells are considered to be an important aspect of Green Revolution which provide assured irrigation. As compared to surface wells, tube wells

are not only cheaper but, they also relieve our weak and overworked cattle of the great strain of working as well. Where canal - irrigation is likely to give rise to the evil of water logging these are best-sources of irrigation. In view of this, Government has started a phased programme for the construction of tube-wells in U.P., Punjab, Bihar, and Gujarat, since the inception of the first five year plan in 1951.

3) **Tanks -** tanks forms another important source of irrigation. They are found in almost all States. In rocky areas, the availability of underground water is poor as rocks do not suck water, neither well can be dug out nor can canals be constructed. But water can be easily stored in tanks which may either be naturally available or suitably constructed.

iv. By maximizing the supply of electricity and power generation

Electricity's role in improving quality of life in rural areas is quite clear. Electricity has a huge role in agriculture. Due to the irregular supply of electricity and days long blackouts in the region, the people are unable to use electric pumps in irrigation, which leaves them with no other option but to use shallow machines or manually operated watering methods. By maximizing the supply of electricity to each and every village, the people will be able to utilize it in irrigation, power farm machinery, fodder chopper etc., which will result in the modernization of agriculture in the region and also increased agricultural production. In addition to agricultural sector, maximizing the supply of electricity will provide lighting for extended working and studying, which will result in higher education rates. It will also give the people the ability to use electricity in household appliances to save time and effort, to refrigerate medicine and food etc. However, to make this electricity available for the people to use, it should be made affordable for them.

A much safer and comfortable life is offered with the access to electricity. It has the ability to transform rural economies.

v. By undertaking and implementing long term measures to mitigate the problem of bank erosion

Erosion is another important factor that has affected the lives of the people of this region considerably. Bank erosion by the river Brahmaputra in this region is very extensive. People lose 1000s of hectares of land every year due to erosion. People lose house, properties, agricultural lands and become homeless. This is one of the most important reasons that contribute to the cause of the region being underdeveloped. By taking appropriate measures to deal with this problem at the earliest, it will help the people of this region to settle without the fear of their house and properties being washed away by the river and they are able to engage in any kind of activities to earn their livelihood, which in turn will contribute to the economic development of the region. Preventing erosion of land, properties will attract developmental activities too. Some common and effective measures to prevent bank erosions are riprap revetment, use of sacks filled with sand or sand-cement mixture, gabions, articulated concrete mattresses, etc.

vi. By investing in educational institutions

Education is the primary tool that can contribute to holistic growth of the nation. While the urban areas of India have 85% literacy rate, presently, in rural areas, it's as low as 69%. This is a hindrance to the socio-economic development of the country, and primarily stems from a lack of schools and basic educational infrastructure in villages. This calls for a major investment in

educational institutes and free schooling in rural areas so as to bring the citizens at par with the literate populations of the country.

6.2. Benefits of a Developed Infrastructure System on a Rural Economy

Infrastructure plays a crucial role for not just the country's economic growth but also its progress in human development. There is a clear need to provide basic infrastructure and social amenities in the rural areas so as to bring India at par with other global superpowers of the world. More importantly, such a development will vastly improve the lives of the Indian population which still struggles with many socio-economic problems such as poverty, hunger, health, illiteracy, lack of skill and modernization, etc.

1) **Rural road infrastructure:** It provides mobility and connectivity to people living in rural areas. It also provides the much needed boost to agricultural activities by making available water, seeds and other raw materials to the farmers. By improving connectivity, rural roads also enhance employment opportunities for the rural people in non-agriculture sector, thereby, increasing livelihood opportunities. Rural roads also ensure that the rural areas are served with better public services and all the benefits offered by the state reach the far-flung areas easily. They can even provide access to education and health services.

   Therefore, improvement of rural road seems to be a clear means by which large numbers of people might acquire the opportunity to participate in the market economy and thereby raise themselves out of poverty (Oraboune 2008). Good transport infrastructure is a necessary condition for economic growth and poverty alleviation, but transport investments alone cannot address the problems of the poorest households. (Starkey & Hine 2014)

2) **Irrigation infrastructure:** Agriculture is the backbone of Indian economy. The availability of assured and timely water supply is an important condition for modernization of agriculture. In a country like India, where annual rainfall is scanty and uncertain, irrigation is the only input. Considering the agrarian nature and over population in our country, self sufficiency in food grain production, irrigation is given top priority. Irrigation development is of great importance to India from following points:

   i. In the first place, this is the best way to prevent famines which has occurred at varying intervals of time over several centuries.

   ii. To end the uncertainty of water from rainfall, permanent irrigation works on an adequate scale accompanied by commercial farming are necessary.

   iii. It will improve production level and agricultural productivity.

   iv. Irrigation is a sine qua non for converting subsistence farming to commercial farming. It has been estimated compared to the yield of crops in lands without irrigation; the yield on irrigated land will be more than two times.

   v. Irrigation facilities enable the farmers to grow two or three crops in a year which helps to maximize agricultural output.

   vi. Irrigation helps to grow money crops / commercial crops like sugarcane, cotton, tobacco and fruits which are of great value to the national economy.

vii. Since irrigation projects are generally labour intensive works, these help to create employment opportunities. This is very important in the context of the almost chronic problem of unemployment in the country.

Finally, irrigation will promote the all-round economic prosperity of the country. It will promote the agricultural development, trade and industries. Thus, in turn, irrigation will increase employment opportunities in the country. (Koli 2006:3-6)

3) Urban cities are already saturated and are on the verge of population collapse. Most of the urban migrants belong to the rural regions. Improved rural infrastructure will reduce population migration into already congested urban cities.

4) Will help achieve 100% literacy rate in the country.

5) It will reduce the gap between the rich and the poor and equitable distribution of resources.

6) Will help eradicate nation-wide health issues.

7) Infrastructure scheme also brings about a change in the mindset of the people.

7. CONCLUSION

The findings of the study indicate that the quality of infrastructure in the region is very poor and that has a negative impact on the lives of the people of the region. The study finds evidence of the effects of bad roads on transportation and lives of the people in the South Salmara district. It also finds that irrigation facility in the district is almost nil. The study reveals that one of the main reasons for the quality of the infrastructure in the region is due to the negligence of the government and the competent authority to work towards its improvement.

There is no doubt about the benefits good infrastructure can bring to the South Salmara district. The nature of infrastructure in the South Salmara region was the major issue affecting its developmental activities. Successive governments and decision-makers need to improve the policies with regard to infrastructure in the district to accelerate the needed development the district deserves.

The study aimed to explore lack of infrastructure; the impact on economic development. The findings of the study proved that lack of infrastructure holds back economic development raises unemployment and promotes poor standard of living. While the above discussed methods won't change the rural economy within a fortnight, but if implemented with proper planning it would definitely boost the economy within a few years.

8. RECOMMENDATIONS

The study recommends that government should give more consideration to the rehabilitation of the infrastructure, assign substantial budget to rehabilitate the infrastructure in order the people live in distance places get an opportunity to develop their economy. The government should encourage private building companies to build roads, irrigation system and come up with rules and regulation to prevent default risk.

The government must always follow up on reports to check whether projects being implemented are done properly. Standards assessments should be the number one priority. Routine monitoring and evaluation can be built into road infrastructure investment policies to ensure that roads construction carried out by contractors are properly done. When the roads and irrigation system are good, it will bring more development into the District and last longer.

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THERMAL ANALYSIS OF LOCAL JUTE-FIBER AS WALL INSULATION FOR TROPICS

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Abstract: From the beginning of the 20th century, cavity insulation materials have become widely used to minimize building heat transfer rates to provide comfort and energy efficiency. This study is aimed to examine the thermal quality of jute fibers as cavity insulation for the tropics. In this study, 0.4×0.4×0.4 m3 and 0.3×0.3×0.4 m3 rectangular glass models forming cavity in-between were prepared. The model represents the reduced scale of usable indoor space. The experiment was conducted by heating the outside surfaces of the glass box. The obtained results identified a significant decrease in indoor air temperature (minimum of 0.6°C and a maximum of 3.4°C) of the enclosed space using jute-fiber as cavity insulation material. The application of jute-fiber as a cavity insulation material can lead to environmentally sustainable and financial advantages.

Keywords: *Indoor environment, Thermal insulation, Jute-fiber, Tropical climate*

1 Introduction

Air temperature (AT°C) of the environment is increasing day by day due to rapid climate change(Raman, Mande et al. 2001; Alam and Chowdhury 2011; Chowdhury, Ahmed et al. 2015). As a result, the indoor temperature is rising tremendously (Perez-Garcia, Lippke et al. 2007; Chowdhury, Ahmed et al. 2015). Worldwide an annual rise of 3.3°C per century is predicted by the Intergovernmental Panel on Climate Change (IPCC 2007). Studies on climatic parameters indicated a significant increase in temperature in a tropical climate like Bangladesh (Rahman and Alam 2003; Huq, Reid et al. 2004; UNDP 2007). This will directly affect the indoor thermal environment resulting in subsequent pressure on heating-cooling energy demand(Rahman and Alam 2003; ASHRAE 2010).

Thermal insulation is one of the most effective ways to prevent heat gain or, conversely, loss between indoor and outdoor as insulation helps reduce the amount of heat penetration on a warm day as well as reducing heat loss on a cold day (Aspiras and Manalo 1995; Engelmann, Kalz et al. 2014; André Pina 2017). Hence provides a comfortable indoor temperature compared to the outside for its occupants and results in a positive impact on heating and cooling energy savings. An energy-efficient building can help reduce 30% or more on the cost of energy than a conventional one (Jollands, Waide et al. 2010). Studies showed that using local materials in modern ways can reduce indoor temperature (Santamouris, Pavlou et al. 2007; Omer 2008; Sakka, Santamouris et al. 2012). Bangladesh is a tropical country with different types of houses that evolved in response to that region's climatic condition. These houses are believed to be thermally comfortable, but with the increasing temperature worldwide, these house's functionality regarding comfortable indoor will be threatened in the future. There are different local materials available in rural Bangladesh that can be used as an effective cavity insulation material. But the study sought to evaluate the performance of jute-fiber as a cavity insulation material, one of the cheapest locally available materials in rural Bangladesh, hoping that the findings will be similarly applicable to other tropical countries to Bangladesh.

2 Problem Statement

Typically, in a tropical region like Bangladesh, a traditional mud-brick wall (12.7-25 cm thick) is used as an outer envelope (Chowdhury, Ahmed et al. 2015). Generally, due to direct sunlight on the east-west exterior walls, excessive heat is formed (Raman, Mande et al. 2001; Perez-Garcia, Lippke et al. 2007). Again the trend of using manufactured material in rural areas introduces a new dimension to the problem. These materials create an unhealthy & uncomfortable indoor environment due to high heat gain (Mallick and Ali 2004), which is very risky for human health (Chowdhury, Ahmed et al. 2015). In Bangladesh today, approximately 40.7% of the overall residential energy use is only consumed for cooling and heating purposes(Mallick and Ali 2004; Ayers and Huq 2007; Ghailane, Ahamat et al. 2020). But, it is possible to control the room's indoor temperature using thermal insulation (Aspiras and Manalo 1995; Chowdhury, Rasul et al. 2008; Kymalainen 2008; Engelmann, Kalz et al. 2014; Pallubinsky, Schellen et al. 2016). Although there are many types of thermal insulations, this study focused on jute-fiber which is an indigenous substance available in the region.

3 Objectives of the Study

The study aimed to evaluate the thermal performance of jute-fibers as cavity insulation material for the tropics. This research also aims to explore the application of insulation properties through a range of parametric simulation studies that will allow a practical design approach to reduce heat gain indoors in the tropics.

4 Scope and Limitation

This research entirely focused on evaluating local jute-fiber's thermal performance as an effective cavity insulation material, especially for warm, humid tropical climates like Bangladesh. As a result of using local content, the indoor surface temperature of an enclosed space is reduced but may reduce the cost regarding the use of cavity insulation materials. However, a more detailed experiment will be required to introduce the jute-fiber as a local insulation material for multiple cavity air-gaps. The limited-time and scope of the current research studied a range of parametric simulations considering AT instead of operative temperature (OT). Again, to validate the results obtained, further research is needed considering various attributes and design factors (i.e. OT, HVAC system, energy consumption, surface layering, and material properties) that may affect the indoor thermal environment.
Moreover, in the future, more characteristics of this material will be needed to explore, such as resistance to pressure, heating, water vapor, fire and sound insulation, etc. For a real-field application of the findings, applicability of jute-fiber from cost-effectiveness, fire safety, etc. Perspectives, which are beyond the scope of this research, is needed to be assessed and hence considered as the future research extent.

5 Methodological strategy and experimental setup

Insulation materials are usually produced from inorganic materials (Farhan, Khamidi et al. 2012; Vakiloroaya, Samali et al. 2014; Costes, Evrard et al. 2017; Roque and Santos 2017). In recent years, these materials rarely use as building insulations due to the suspicion of health risks (Aspiras and Manalo 1995; Matusiak 2006; Kymalainen 2008). Thus, it is essential to investigate the potentials of organic-based materials as cavity insulation. As organic-based insulation, jute-fiber was chosen because of its availability in the local area of Bangladesh. The experiment was conducted to determine the effectiveness of local jute-fiber as an insulation material for the wall.

For this experiment, two glass boxes of different dimensions were prepared (Fig.1 & 2). The measurement of the outer box is 0.4×0.4×0.4 $m^{3,}$ and the inner box is 0.32×0.32×0.4 m^3 leaving an air gap of 0.08m in-between the boxes. Assuming the box as a room, the two glass surfaces, with an air gap in-between them, act as a cavity wall. Glass material was used for its better heat conductivity.

An initial diagram was developed according to the above figures (Fig.1 & 2)—cavity space between two glass boxes was created to fill it with local jute-fiber (Fig.3). The cavity space was filled with jute-fiber in such a way that there was no air gap. Otherwise, inside air would act as a heat conductor. Then from the box's outer side, heat is provided on all four sides of the box using a heat source, as shown in Fig.4.

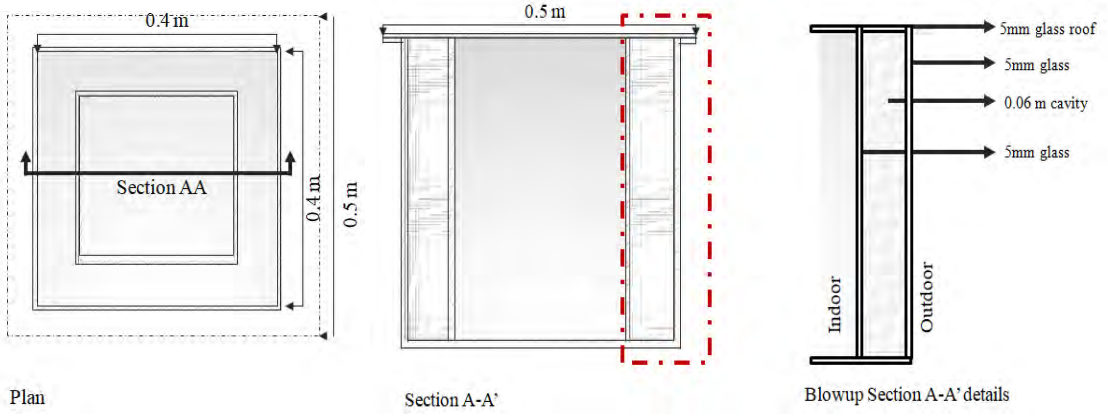


Figure 1: Experimental plan and sectional blow-up

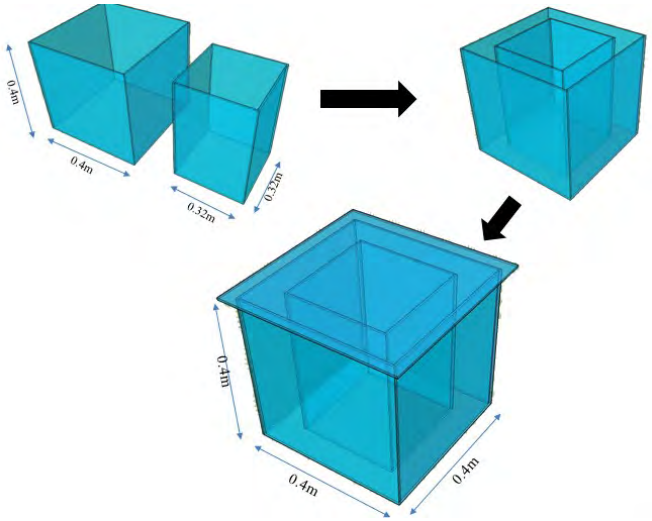


Figure 2: Experimental glass box modeling strategies

Figure 3: Local jute-fiber (sack) (top) and the cavity filled with jute-fiber/sacks (bottom)

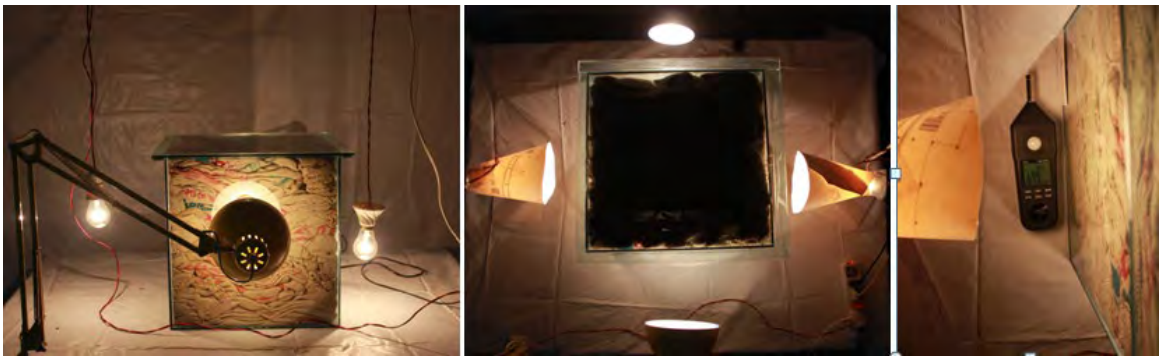
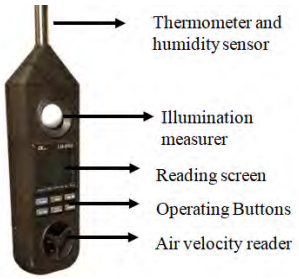


Figure 4: Heating the outer surface of the box with a heat source

After proper setup, physical measurements of AT and relative humidity (RH) were taken using Environmental Quality Meter for both inside and outside the box. Again, the box's surface temperatures (both inside and outside) were measured using MT4 Laser Non-Contact Thermometer. Instrument details are listed in Table.1. Then, the surface temperatures of the box's four heated surfaces were calculated to identify the temperature differences between the inside and outside of the box.

Table 1: Instrument used and their properties

Name	Environmental indicator	Accuracy	Instrument
MT4 Laser Non-Contact Thermometer	Surface temperature	98% (range 0-750°C)	
Environmental Quality Meter	▪ Air temperature ▪ Humidity ▪ Airspeed ▪ Light ▪ Sound ▪ Thermocouple	±5%@calibrated wavelength 633 nm / 1 mW (range: 0 ~ 40°C, 80% non condensing, maximum)	

The measurement of AT and RH was taken at a 15 minutes interval for three hours simultaneously for several days. Deviation in AT and RH between inside and outside was quite visible. At last, a range of simulation studies was carried out by 'EnergyPlus' with the open studio plug-in for the calculation of monthly indoor thermal environment following local climate conditions and internationally defined indoor thermal standards (Mishra, Usmani et al. 2012; Chowdhury, Ahmed et al. 2015). The average indoor thermal

conditions obtained from the field study were considered to validate and compare simulation results.

6 Result analysis and Discussion

The experiment of the first-day was conducted for about an hour. The initial outer AT of 23.9°C and the inner AT of 23.6°C were identified (Fig.5). The outer AT reached 27.6°C in an hour while the inner AT was increased by 1°C and became reached 24.6°C. The difference in AT between inside and outside was about 3°C. The indoor RH was higher than the outdoor (Fig.6).

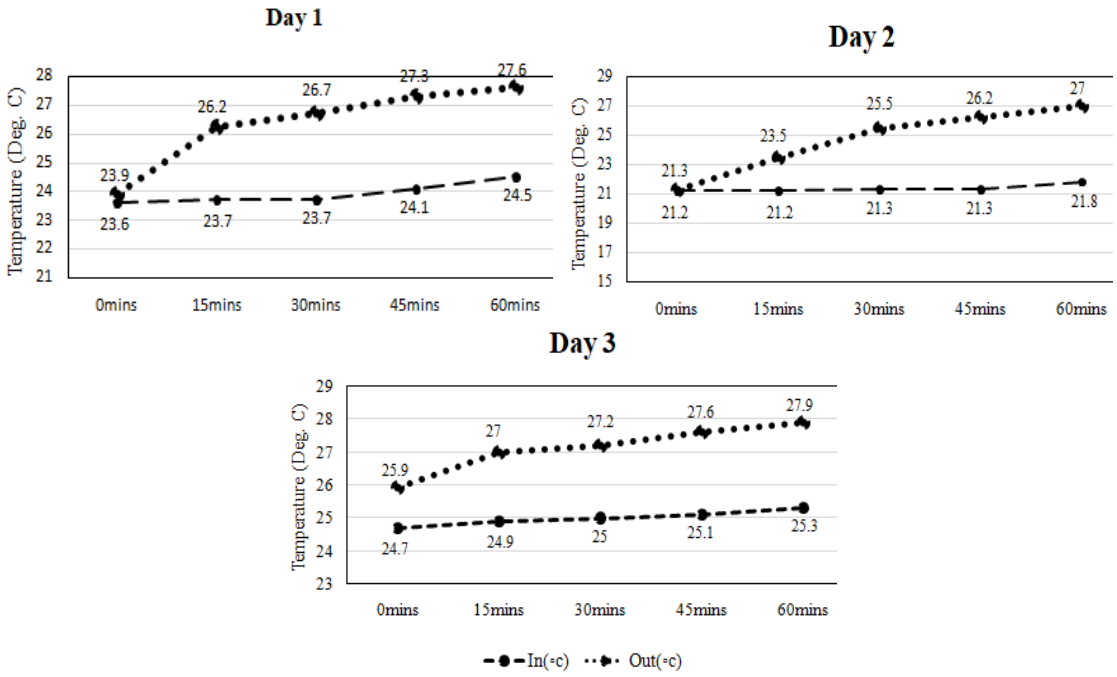
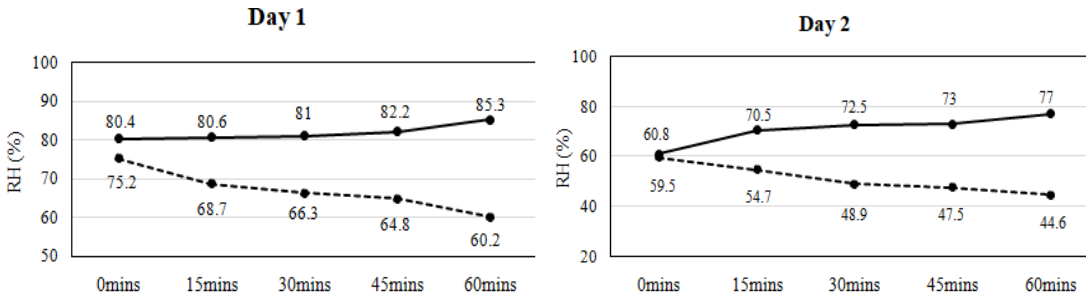


Figure 5: AT (°C) profile for three days of experiments



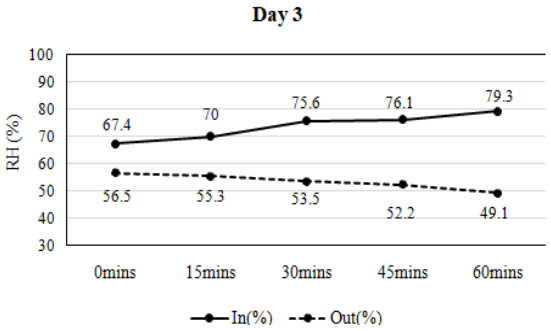


Figure 6: RH (%) profile for three days of experiments

On the second-day experiment, it was identified that the external AT increased by more than 6°C in an hour while the internal AT increased by less than 1°C from its initial condition. The initial AT was 21.2°C, and after an hour, it was increased to 21.8°C. The outer RH was continuously decreased with the increase of AT but the inner RH showed increasing values with time. From the third-day experimental condition, a similar result was identified, which is presented in Fig.5. In all cases, a difference of nearly 15-25% of RH between the outdoor and indoor of the experimental box was identified (Fig.6). The experimental data obtained and differences calculated for the three days of experiments are presented in Table 2.

Table 2: Data comparison for three days of experiments

		Initial (°C)	Final (°C)	Difference (°C)	Comparison
Day 1	Outdoor temp.	23.9	27.6	+3.4	26.5%
	Indoor temp.	23.6	24.5	+0.9	
Day 2	Outdoor temp.	21.3	27	+5.7	10.5%
	Indoor temp.	21.2	21.8	+0.6	
Day 3	Outdoor temp.	25.9	27.9	+2.0	30.0%
	Indoor temp.	24.7	25.3	+0.6	

For measuring the surface temperature, the glass box surfaces were marked as A, B, C, and D (Fig.7), respectively. With the thermal monitoring tools, measurements of the outer and inner surface temperatures were taken at an interval of 15 minutes. Initially, the exterior surface temperature was 26°C, and after the first 15 minutes, it became above 32°C while the inner surface temperature remained almost unchanged. After 30 minutes, the outside temperature reached nearly 42°C and the inside surface temperature (27°C) increased by 1°C. When the outside temperature was around 70°C, the inner surface temperature was ranged between 32-35°C on all three days of the experiment.

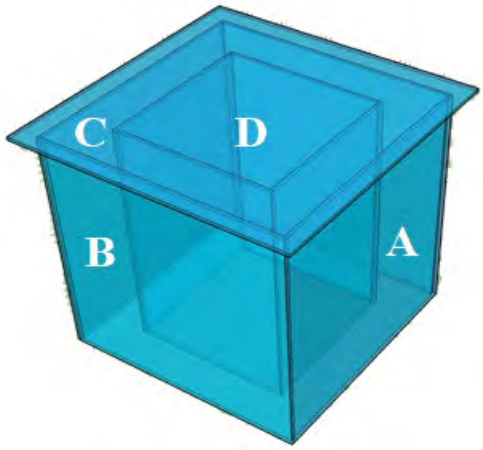
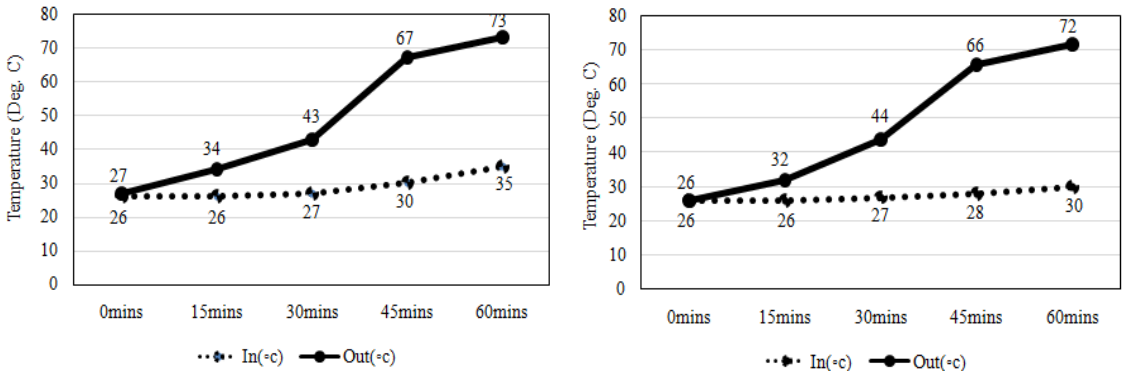


Figure 7: Surface marking as A, B, C & D

Fig.8 illustrated the obtained experimental data for both external and internal conditions. From the experimental data, it is observed that the fluctuation of the indoor surface temperature was very little (nearly stable) and lower than the exterior surface temperature. The variation of the outer surface temperature was high (Fig.8).

For predicting future climatic scenarios, a three-dimensional energy model similar to that of the experimental model was developed for parametric simulation studies by EnergyPlus and Open Studio Plug-in. Monthly evaluation of indoor thermal condition was conducted for two different cases: i) cavity keeping unfilled and ii) cavity filled with jute-fiber as building insulation. The simulation results identified that jute-fiber could reduce excessive indoor heat penetration as a cavity insulation material, thus creating a better thermal environment throughout the year (Fig.9 & 10). These experimental and parametric simulation studies focused exclusively on local jute-fiber performance as a wall's cavity insulation material. Some problems related to the experimental space were not identified, i.e., various variables and design parameters. A further comprehensive study will be required to assess the indoor air quality, parameters of the indoor climate, HVAC system, energy consumption, the surface layering, the material properties that affect the indoor thermal environment, and the risk reduction for safety(Mishra, Usmani et al. 2012; Vakiloroaya, Samali et al. 2014; Chowdhury, Ahmed et al. 2016; Roque and Santos 2017).



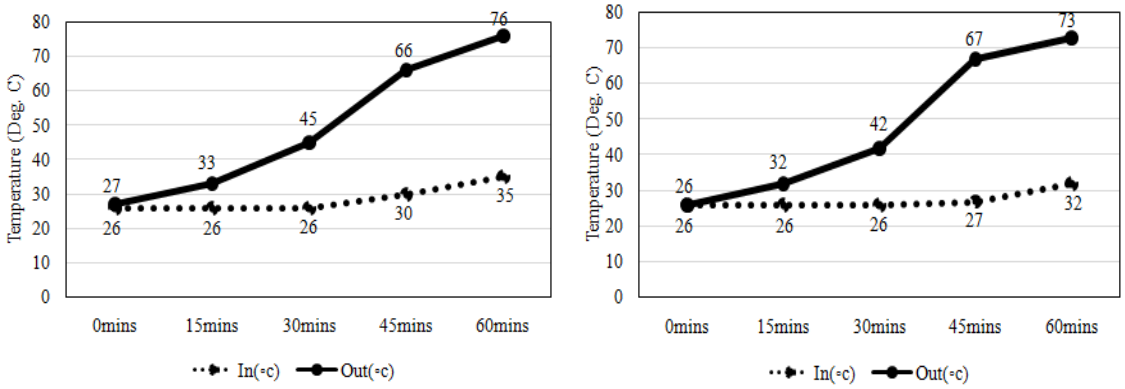
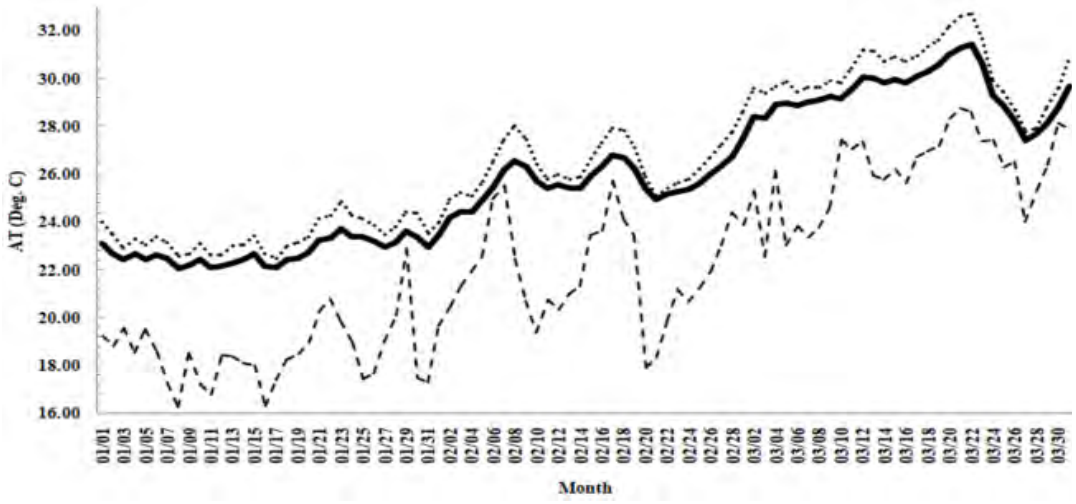
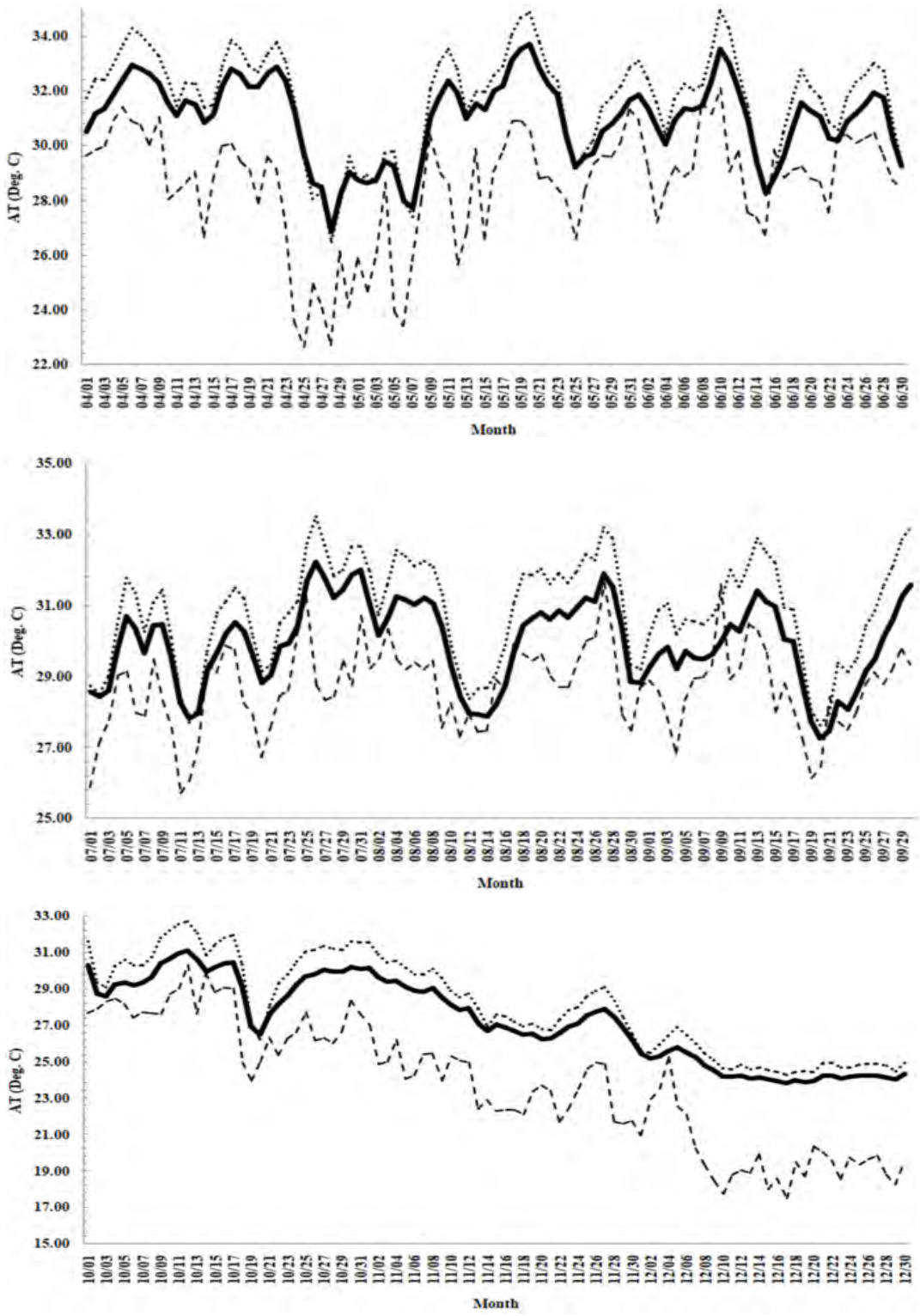


Figure 8: Surface temperature profile of A, B, C & D (left to right respectively)

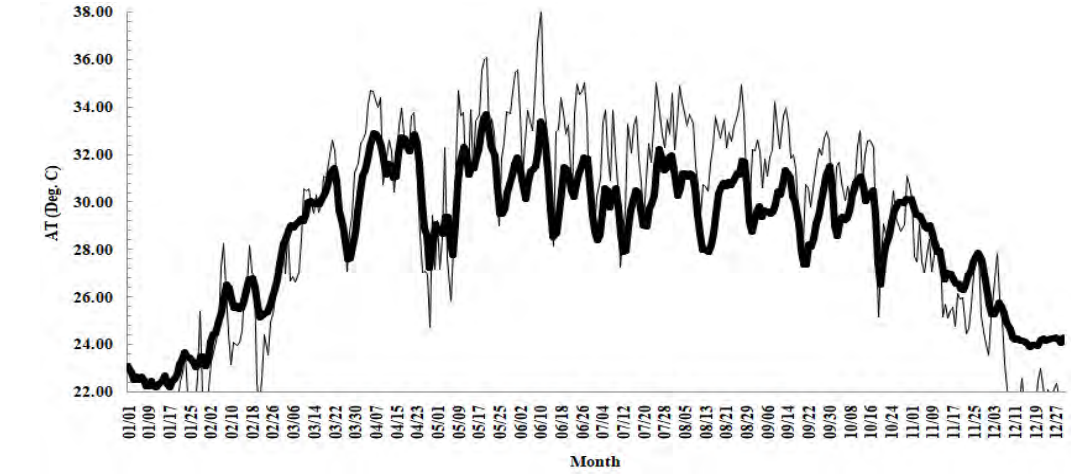
The numerical analysis revealed that indoor thermal conditions predicted almost a very high-risk situation for a non-insulation case from April to July. Jute fiber as insulation material was not a high-risk situation. The lower (comfortable) status increased nearly two times higher from non-jute (insulation) to jute (insulation) for the experimental enclosed zone (Fig.9).

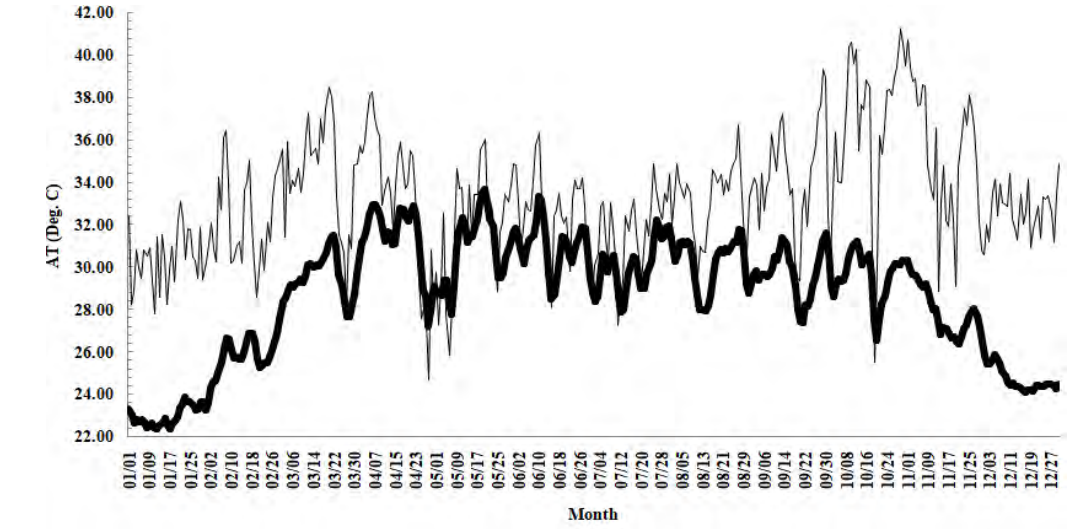


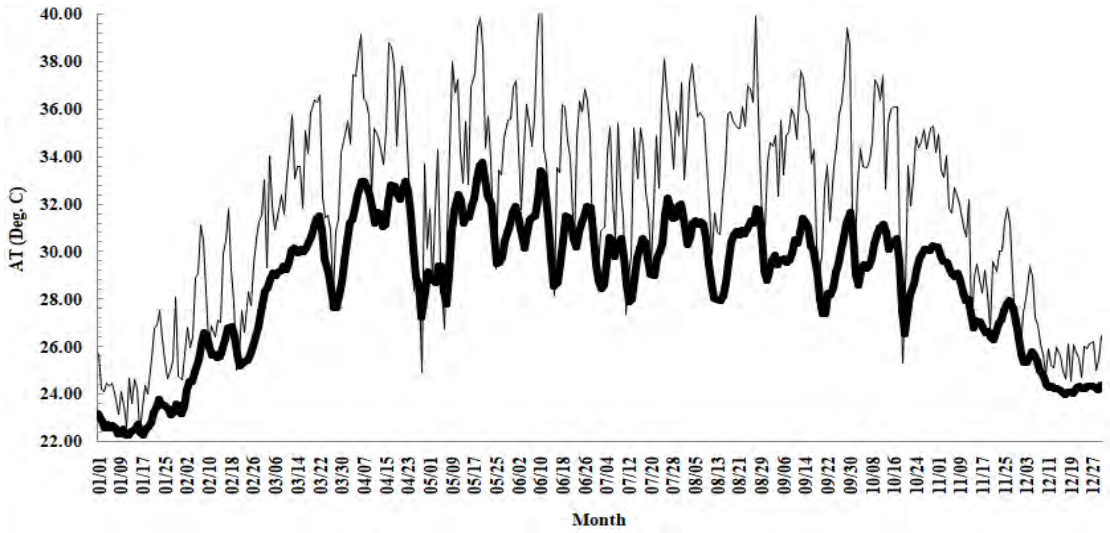


Indoor AT (~~non-jute~~) Indoor AT (jute) ——Outdoor AT – – – -

Figure 9:Yearly AT profile of Jan-Mar, Apr-Jun, Jul-Sept, Oct-Dec (top to bottom respectively)


AT (Deg. C)
Month


AT (Deg. C)
Month


AT (Deg. C)
Month

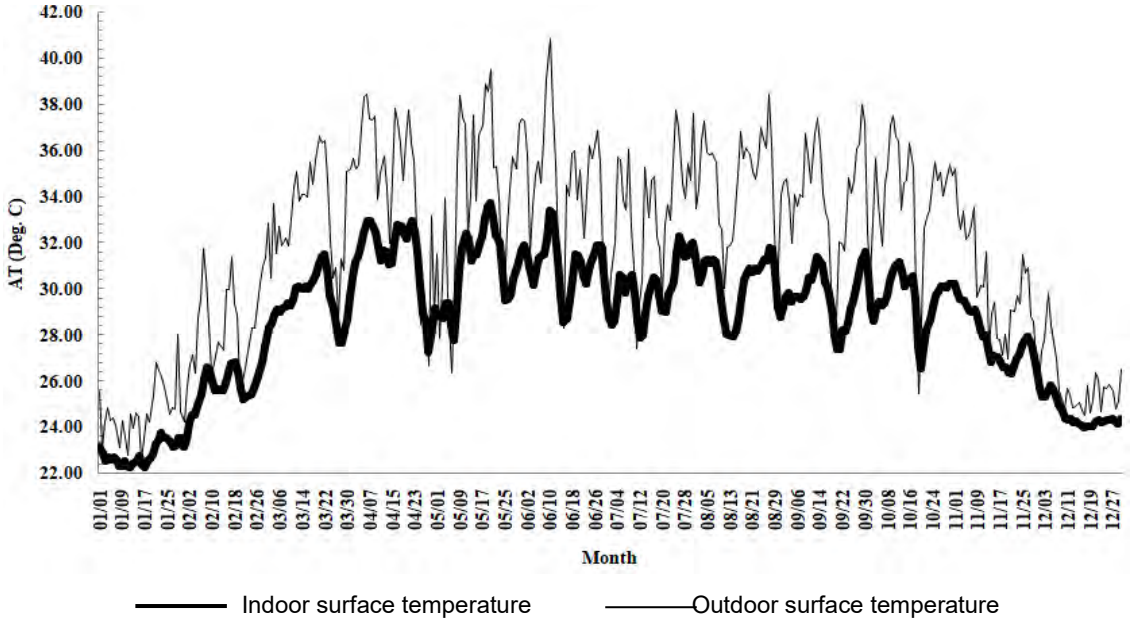


Figure10: Wall surface temperature profile: North, South, East,& West (top to bottom respectively)

The parameter of 'EnergyPlus' (version 8.1.0)and the Open studio Plug-in 1.3.0 integral to Google Sketch-Up 8 was used to forecast indoor thermal conditions. A range of simulations have been conducted for parametric studies to explore the active indoor environment approaches with insulation properties. Observations of simulated thermal performance resulting from the change in parameters and material characteristics allow a design approach to reduce heat gain indoors. Finally, proposals for the design of exterior walls concerning local climate have been analyzed.

The following equations (1-4) were used in this analysis to measure the thermal properties of test materials (Chowdhury, Ahmed et al. 2015; Chowdhury, Ahmed et al. 2016).

Conductivity, $k= \{ms(dT/dt)d\}/D(T_1-T_2)\ Wm^{-1}K^{-1}$ (1)

Specific heat, $C_p = Q/\{m(T_1-T_2)\}\ Jkg\text{-}1K\text{-}1$ (2)

Thermal resistance, $R = L/k\ m^2KW^{-2}$ (3)

True density, $d = (W_1-W_2)/V\ g/cm3$ (4)

Table 3 shows the simulation values conducted in the study model with local materials for parametric studies.

Table 3: Parameters for Energy Plus simulation

Parameters	Specifications
Location	Dhaka region, Bangladesh
Geographical Location:	
i) Longitude	90.25° (North)
ii) Latitude	23.95° (East)
Time Zone	+6 GMT
Simulation period	January-December (Condition: Summer (high temperature &humidity))
Sky Model	Clear sky
Calculation option	Standard
Units of Dimensions (Length, areas, etc.)	Metric (SI) (m, cm, etc.)
Units of Photometric Dimension	European (SI) (lux, cd/m2, etc.)
Elevation	9m
Orientation	Front Elevation facing South
Plan Shape	Rectangular
Total number of floor	1
Simulated floor	Building Zone (Typical)
Floor to Floor Height	3.5 m (7.0 m for the two levels)
Floor Area	0.4×0.4 m^2
Floor Dimension	0.4 m ×0.4 m
Window Area	No Window
Solar Absorbance (for exterior surfaces)	0.55 for external walls (Light color) 0.35 for the roof (light color)
Occupancy Density	Not Applicable
Lighting level	Not Applicable
Electric equipment	Not Applicable
Glazing	The single panel of glass with an aluminum frame (refl. 0.92)
Construction Type	ASHRAE 90.1 non-Res.
Natural Ventilation	Not Applicable
Zone Ventilation Flow rate	Not Applicable
Room Air Distribution Model	Not Applicable
Ventilation Control Mode	Temperature (off/on)
Design Flow Rate	(No Air Changes/Hour)
Air gap thermal resistance	0.13~0.50 m^2kw^{-1}
Calculation Method (Design flow rate)	Air Changes/Hour
Leakage Component Name	Surface Object
Zone construction	Roof: Plaster (1:5)+ RCC (1:2:4)+ Plaster (1:5)
	Floor: Plaster (1:5)+ RCC (1:2:4)+ Plaster (1:5)
	Wall: Brick wall, Plaster (1:5)+ Brick + Plaster (1:5)+ air gap +
	Jute sacks + Plaster (1:5)+ Brick + Plaster (1:5)
	(construction pattern has been changed alternatively)

Mechanical ventilation	None
Output variable	AT (ºC), MRT (ºC), OP (ºC), RH (%)
Schedule Type Limit	Fraction/ Continuous
Fraction Radiant	0.3~0.4
Output Variable Dictionary	Regular
Output Schedule	Hourly
Heat balance algorithm	Conduction transfer function

The deviation with experimental values was not respectively the same at all times. A different factor depends on this deviation. Temperature fluctuations, material density, and porous quality (Uvsløkk 1996; Chowdhury, Ahmed et al. 2015) were the main factors. The transient method applied was highly temperature-dependent. Present experiments and studies have been conducted based on their optimization algorithms and implementations in real-time based on field observation, scheduling, comfort requirements, and indoor control strategy. Such models can extend and create uncertainty through the environment and other control algorithms.

7 Conclusions

This experiment represents the surface thermal performance of an enclosed space by utilizing jute-fiber as cavity insulation material. From this particular experiment, the following findings have been illustrated:

- The temperature differences between the indoor and outdoor wall surfaces were a minimum of 0.6°C and a maximum of 3.4°C.
- The fluctuation of the indoor surface temperature was very little (nearly stable) and lower than that of the exterior surface higher temperature.
- The indoor thermal condition is predicted as a very high-risk situation for a non-insulation case from April to July. With the jute-fiber as a cavity, insulation helps to improve the high-risk condition. The lower (comfortable) status increased nearly two times higher from non-jute to jute (insulation) for the enclosed zone.

As the research focused on reducing the indoor surface temperature of an enclosed space using locally available material as cavity insulation that will help reduce the expenditure for heating/cooling in rural areas. Therefore, a further extension of the research considering various attributes and parameters that this study presently lacks, jute-fiber can be used as an efficient architectural insulation strategy to create affordable rural houses while guaranteeing sustained growth for building smart communities.

Acknowledgments

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CREATING SMART VILLAGES THROUGH CONTEXT-SPECIFIC WORKSHOPS

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Abstract: *Smart Villages is a relatively a newer concept for developing rural community with necessary amenities and enabling empowerment by leveraging the unique potential in location specific contexts. While the research conducted at the Smart Villages Lab (SVL) of The University of Melbourne has resulted in a new Smart Villages model, the key concepts are yet to be tested empirically for realising the benefits at the community levels. The Smart Villages Workshop is one of the key enablers for disseminating the findings of Smart Villages research. The Smart Villages Workshop is a platform for joining hands of like-minded individuals from academia, industry and community and progressively elicit context-specific ideas for promoting smart solutions for communities in one or many aspects bounded by the Smart Villages concepts. By workshopping the range of ideas with the involvement of multitude of stakeholders across multiple settings, not only are the research findings practically implemented but also new ideas are brainstormed and the underlying knowledge is captured for a continuous development of a new body of knowledge in the field. In this paper, detailed processes of conducting Smart Villages Workshops is presented. The processes will enable the participants to work on context-specific themes of the selected villages or any geographic localities. Focusing on the existing situations, potential and opportunities for progressive development, the workshops will contribute to making master-plans for practical implementations.*

Keywords: *Smart Villages Workshops, Smart Villages Implementation, rural development*

1 Introduction

With over 40% of the world's population now living in rural areas, there is global interest in research associated with the creation of "Smart Villages" to address the ever growing urban-rural divide. In a state like Assam where 86% of the 35 million population still lives in very rural areas, the need for smart interventions is even greater in an attempt for rapid upgradation of the community. Smart Village research being undertaken in Smart Villages Lab (SVL) at the Faculty of Architecture, Building and Planning of the University of Melbourne has been exploring rural community development, practices and relevant policies with a focus on community-centric planning of affordable housing, infrastructure, sustainable development and growth, community empowerment and other issues related to the creation of Smart Villages. The idea of smart villages is highly significant for not only to appreciate the potentials of the rural community for contributing to the local and national economy but also stemming the migration to the already crowded cities for seeking better economic opportunities (Doloi *et at* 2019a).

While Smart Villages could be a novel concept enabling the rural communities to modernise and establish at the same level as the urban counterparts, unlike traditional development models, the concept promotes a complete new bottom-up approach. In the bottom-up approach, the community takes a leading role and the needs and requirements of the grass-roots level people take the precedence in planning of the interventions in the development modalities (Doloi *et al* 2019b). One of the key enablers is thus the process of engagement of the grass-roots level community for contributing towards their own plans of development. Such development plans are based on their immediate needs and priorities in reference to an available benchmark being applicable in the location specific context. In order to engage the relevant local community for imparting in collaborative discussion forums, contributing ideas for achieving common objective in a particular village context and develop sustainable outcomes, appropriate framework is required (Doloi and Donovan 2020). The framework needs to facilitate the collaboration, generate interests and provide a clear roadmap for realising the values being created out of the entire community engagement exercise leading the creating a smart village. In this paper, for the first time, the author aims to establish the Smart Villages Workshop as one of the key enabling framework for engaging rural community in the villages especially in an Indian context.

2 Why Smart Villages

Smart Villages is a relatively new concept that refers to the processes of supporting rural community with context-specific solutions and empowered by harnessing the potentials within them. Depending on the community size, location and underling potentials, level of smartness in the upgradation processes may vary from one community to the other. The rationalisation of the Smart Villages is summarised in the following few points.

- Majority of the population live in villages with less than standard living conditions
- Some of the basic facilities like electricity, running water, road connectivity, playgrounds, library, banking and medical assistance are not readily available even at a convenient proximity from the villages in most cases
- The lack of the conveniences in the village is also a reason for lack of opportunity for income generation and independencies among the community
- Arranging better living conditions for the rural community results in stemming migration to the cities which removes the burden of continuous adaption due to increased population in already overcrowded cities

- Retention and reflection of the rural culture, rural eco-system, social settings including history, heritage and value is highly crucial in the digital waves and rapid transformation process so that the rural areas are points of attraction for urban communities. Such trends will provide the opportunities for supporting rural economies and enabling empowerment among the rural communities.

3 Broad areas of focus in Smart Villages design

While designing a smart village, context-specific considerations are highly significant. "Smart solutions" is a relative term and one solution does not fit all. For instance, in a place where people are relatively poor and struggles to earn a regular income, some sort of steady and accessible income source could be one of the smartest solutions for that community. Similarly, in a place where clean water is not available, any sort of localised solutions for securing a potable water supply system could be one of the smart solutions in its own right.

In the development process of a community, an integrated approach is required encompassing a range of fundamental necessities and needs. Some of these necessities may include:

- Income generation ideas and potentials
- Education and skills – needs and development
- Agriculture – needs, potential and development
- Housing – needs, potentials, skills and development
- Energy – needs, requirements and potential for alternative sources
- Waste – current practice, improvement potentials
- Water and sanitation– current practice, improvement potentials
- Transportation - needs and development
- Health and wellbeing - current issues, existing facilities, improvement potentials
- Environment – current issues, improvement potentials
- Governance - needs and development

In any attempt for developing community in the smart villages, emphasis should be placed on in all of the above areas so that a holistic development model can be established for the target communities. An idealised Smart Villages model and interconnected areas are shown in Figure 1 below.

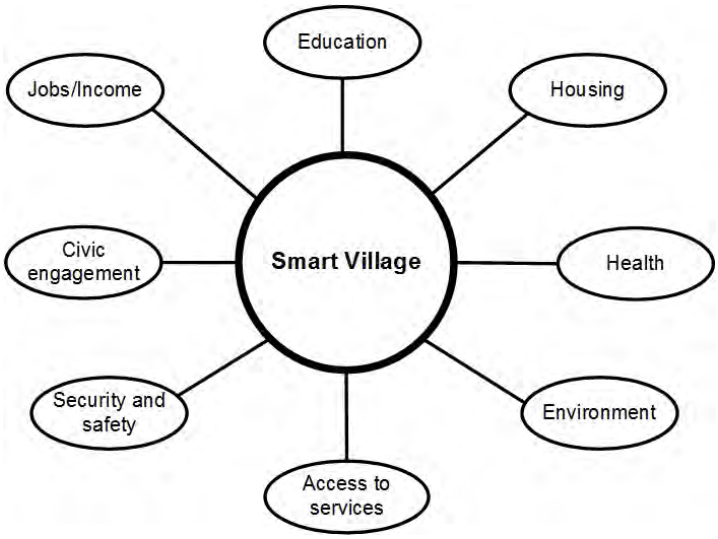

Figure 1: Idealised Model of a Smart Village

(*Source: Doloi et at 2019a: Planning, Housing and Infrastructure for Smart Villages, Routledge, UK*)

In order to develop action plans across all these interconnected areas, every aspect needs to be explored. The action plans must be developed with practical and feasible implementable strategies with clear potential for showing results on the ground. The Smart Villages workshop is one of the very first steps to explore each of these areas as individual modules and develop practical and implementable strategies with the help of Special Interests Groups (SIG) within the participants.

4 Scope of the workshop

4.1 Significance

The University of Melbourne, in partnership with the Government of Assam, has been conducting research on "Smart Villages" for creating shared capacities for addressing the ever growing urban-rural divide in Assam. Under the purpose-built research entity, Smart Villages Lab (SVL), the researchers in the Faculty of Architecture, Building and Planning at the University of Melbourne have been exploring rural community development, practices and relevant policies with a focus on community-centric planning of affordable housing, infrastructure, sustainable development and growth, community empowerment and other issues related to the creation of Smart Villages. With an initial focus on housing and infrastructure sectors, the project aimed to foster relevant knowledge for augmentation of community development practices including collaborative capacity building in construction management. Involving large groups experts including wider stakeholders' participations across multiple levels in the community, the project is expected to result in creation of technical and intellectual knowledge required for sustained growth of rural villages in cross-cultural contexts.

4.2 Aim of the workshop

The aim of the workshop is to design practical and implementable solutions to solve real-world problems in the context of specific communities. One of the key concepts of the Smart Villages workshop is the grass-roots level community-specific idea elicitations with a bottom-up approach. A typical schedule of a workshop comprises three full day activities including site visits, final presentations and award ceremonies. Based on the expertise and interests, the participants are required to form the Special Interest Groups (SIG) to work in one specific area or theme within the case study villages.

For instance, in a selected village, some of the key issues could be dilapidated public temple, muddy local roads, ill-maintained local park or unused cultivated lands etc. Taking into consideration of interests and expertise associated with each of these issues, the Special Interest Groups (SIG) will need to work one selected issue with necessary depths and breaths and devise feasible solutions through the workshops.

As all the specific issues in a given village are not possible to ascertain at the beginning, workshops on individual modules may be difficult organised. However, with a first workshop on a particular village, numerous issues will emerge. Depending on the scale of such issues, the needs for the individual modules-based workshops will come into surface where size of SIG will grow to tackle the issues in depths and breaths with appropriate action plan. The action plan will need to be implemented for realising the benefits and empowering the community.

The workshop on the same village may need to be conducted more than once. The master plan developed in the first workshop will form the basis for extending the scope and knowledge in the subsequent workshops. Any field-based implementation records need

to be updated on the master plan over time. A natural custodian of the master plans developed through the Smart Villages workshop would be the local coordinating institution and the materials should be carefully kept either in the library or in the office of the principals.

By way of participating in one or more modules in the workshop, the participants are required to be part of a Special Interests Groups (SIG) and share their academic, professional or visionary knowledge and ideas for understanding the context-specific issues and devise implementable solutions.

The solutions from the SIGs are then integrated to develop master plans for specific villages with clearly defined scope, cost and budget, source of funding, execution timeline including control, monitoring, operations, impacts and realisation of benefits.
Objectives include:

By way of participating in one or more modules in the workshop, the participants are required to:

- select one or more specific village(s) with clear demarcation of boundaries as case study
- contribute their ideas, render their academic and professional services focusing on the key areas of development in the selected village
- explore individual areas and devise range of feasible solutions considering specific contexts
- contribute towards development of the master plans at the village levels by integrating the best possible solutions from all the interconnected areas
- develop execution, monitoring and control and completion plans including funding and cash flow considerations
- establish clear roadmaps ensuring short, medium and long term outcomes and meeting the development target of the entire community.

4.3 Setting up the workshops

Smart Villages Workshops are conducted in partnerships between the local collaborating institutions and the Smart Villages Lab (SVL) at The University of Melbourne, Australia. A local coordinator or a coordination team is required to be formed at the collaborating institution for conducting the workshops with all supporting facilities and resources. The lead coordinator at the facilitating institution requires to establish the targets and objectives of each workshop based on the location or village being considered and preliminary understanding of the immediate needs and requirements of the community concerned.

4.4 Qualifications and roles of the participants

The success of the workshop depends on how the like-minded and relevant groups for participants are being recruited and how it facilitates generating interests with genuine participations and undertakings for tackling real issues in the context of the subject village. Thus, setting-up of clear objectives, curbing the scope in one or two deliverables, clarity in instructions and ambience are some of the key factors for promoting positivity and getting them engaged with respect to the interests and expertise among the participants.

Ideally the participants for Smart Villages workshops should be drawn from a range of roles associated with the specific locations of the villages including relevant jurisdictions. Example of some of the participants are:

- senior level students of the coordinating institution(s)
- academic staff members of the coordinating institution(s)

- representatives (e.g. headman) from the case study villages
- office bearers from the local governments
- officials from local banks
- other professionals from community such as planners, engineers, volunteers from NGOs
- teachers from local schools
- representatives from municipality
- representatives district offices

4.5 Key processes of the Smart Villages Workshops

This section discusses about some of the key processes for steering the workshops and undertaking the necessary investigations for deriving the outcomes. In order to deriving practical and feasible solutions to the problems, the processes should be based on relevant scientific principles. Thus both theoretical underpinnings and applicability in practice are important considerations while exploring the processes in a particular village context. Seven key processes are briefly discussed below:

1. Establishing the context

Setting up the context is one of the very first processes in Smart Villages workshop. Under this process, some of the key considerations include identification of the village(s), geographical boundaries demarcating the village(s), number of houses, size of population, land area and type and other demographic information. Contexts also include the considerations under which a particular issue may be listed such as environmental, social, economic and so on.

2. Understanding the World-Views of the village

Under this process, SWOT analysis (e.g. Strength, Weakness, Opportunity and Threat) of the selected contexts should be undertaken. SWOT analysis helps in not only to understand the context well but also identify the internal and external factors associated with both risks and opportunities of the issues being considered under each context.

Adopting the Soft Systems Methodology (SSM) (Doloi 2011, Checkland and Scholes 1990), the world views of the specific contexts under the selected contexts should be evaluated and picturised using the Rich Pictures required by the SSM method. The Rich Pictures include all the actors and functions and their causal relations in directional line diagrams. Based on the Rich Picture and by undertaking necessary analysis (e.g. CATWOE analysis as required by SSM), concept maps are developed with a clear identification of actors and processes. This concept maps will then add significant input in the process of developing master plans of the selected site.

3. Identification of the issues

Upon developing the Rich Picture and concept maps on the selected contexts through SSM, range of underlying issues are identified. The issues are then categorised for aligning the interests and expertise of the SIGs among the participants. Examples categories may include *streetscape and beatification*, *restoration of places of culture and heritage significance*, *education and skills*, *roads and drainage*, *agriculture*, *job creation and income growth*, *safety and security*, *health and well-being*, *water and sanitation*, *waste management* etc. Once the issues are identified, necessary action planning including benefit analysis will need to be undertaken (Ackoff 1984, Cazorla *et. al.* 2013, Carmemark et al 1976).

4. Role and Responsibility Analysis

One of the important processes in any development planning is the identification of role and responsibilities of the stakeholders who directly or indirectly support the project and contributes to make it happen. Based on the identified stakeholders and their associations with respect to project planning and implementation, responsibility planning is conducted and appropriate responsibility matrix is designed to highlight the activities, authorities including communication formalities over the project lifecycle.

5. Effort-Analysis

Effort analysis process entails the effort in terms of man-hours required to perform the project activities from a practice context. Effort plans are contingent of the resources being available at any particular stage of the project. Both effort and resources plans are required to be reviewed and analysed from the financial obligations and cash flow perspective as well.

6. Project-based Execution Planning

Project based execution plan is developed following the best practice processes available in the mainstream literature (PMBOK 2017). The PMBOK Guide provides the guidelines and processes on twelve key knowledge areas required for executing projects. These knowledge areas are scope management, cost management, schedule management, risk management, quality management, procurement management, communication management, human resources management, integration management, financial management, stakeholder management and environmental, health and safety management. Focusing at the master plans levels, relevant plans are required for each of these knowledge areas with respect to the project context.

7. Review and Finalisation of the Master Plan

Under this final process, setting up the milestones against the deliverables and highlighting the objectives to achieve over short, medium and long run is highly critical from execution and controlling aspects of the project. Appropriate documentation archival needs to be setup for timely access of the plans and processes, review and upgrades over time as required.

4.6 Awards and recognition

Awards and recognition is paramount in most projects and the effort expanded over Smart Villages Workshops by the participants is crucial to be appreciated in a formal settings. Upon successful completion of the Smart Villages Workshop, the participants should be awarded with participation certificates issued jointly by the Smart Villages Lab (SVL) of The University of Melbourne and the local coordinating institution. Effort will be made to award the certificates to the participants by organising a closing ceremony in the presence of the eminent members of the participating organisations. Based on the work produced in the workshop, the participants may be invited to contribute research papers or present design-posters at relevant forums such as The International Conference of Smart Villages and Rural Development (COSVARD) organised annually by the SVL.

4.7 Typical schedule of the workshop

A typical schedule of a workshop comprises three full day activities including site visits, final presentations and award ceremonies. Based on the expertise and interests, the participants are required to form the Special Interest Groups (SIG) to work in one specific area or theme within the case study villages.

For instance, in a selected village, some of the key issues could be dilapidated public temple, muddy local roads, ill-maintained local park or unused cultivated lands etc. Taking into consideration of interests and expertise associated with each of these issues, the Special Interest Groups (SIG) will need to work one selected issue with necessary depths and breaths and devise feasible solutions through the workshops.

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5 Conclusion

The process of transforming Smart Villages concepts into a reality is highly significant for not only to demonstrate the applicability of the research but also making an impact with the evidence-based approaches among the community in need. For the first time, a field-based workshop model has been developed for bringing the research into practice. Taking the community at the core of the implementation model, step by step processes for rolling out the Smart Villages Workshop in context-specific environment has been highlighted. The Smart Villages Workshop model put forward in this paper demonstrates the processes of engaging community making master plans of their own need-based development models. The approach not only encourages for bottom-up decision making but also entices a sense of belongingness among the community for making a change in the environment they live in. Drawing the scientific methods such as SSM and Project Management Framework available in the mainstream literature, the Smart Villages Workshop promotes the science-based processes and offer necessary mentorship to both local partnering organisation as well as the participants in professional and community settings. The continuous process of reviewing, morning and upgrading of the master plans resulted from the Smart Villages Workshop will act as a catalyst in leapfrogging the transformation process of rural community especially in the developing economies.

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Sustainable Livelihood Approach to Remodel Munda Homestead: Case Study of Shaymnagar, Satkhira

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Abstract: *Ecological imbalance of the Sunderbans mangrove forest and exposure to long-term effects of climate variability pose significant risks for livelihood of the people living in Bangladesh's South-West Coastal Region. Sea-level rise, permanent inundation, salinity intrusion, and frequent storm surge inundation has become an acute problem in this region. The Munda community, an indigenous forest depended community, is living in Kaikhali union in Shyamnagar Upazila (sub-district) in the coastal district, Satkhira, continually attempts to adapt to these indigenous knowledge of the reactions and counter-reactions to climate change. This paper attempts to overview an idea of remodeling a Munda homestead with the help of a sustainable livelihood framework, achieved through access to a variety of livelihood resources (natural, economic, human and social capital). An ethnographic case study research has been done on the Munda community of the study area to collect the context-rich details about the participants' perception and actions regarding current climatic disasters and in the face of future climate change. With the progression of the study the results show how the livelihood framework and method can be modified in response to the specific contexts of the selected cases focusing the sustainable livelihood generation of a single homestead. Adaptive modification in the livelihood framework inevitably demands remodeling of the domestic spaces and its traditional components. Hence, some indicative design strategies are produced, as an outcome of the field study and context study, which can endure sustainable income generation activities of the Munda homestead and instigate changes towards smart village.*

Keywords: *Munda Community, Rural Homestead, Rural Economy, Livelihood Framework, Sustainable Livelihood*

1 Introduction

The Munda people, the Sundarbans' ethnic community, migrated to Bangladesh about 300 years ago from Nagaland and have ever since been here. They are found in the Shyamnagar Upazila, in Khulna, Jessore, and mostly near the Sundarbans, as well as in Joypurhat. They now live in the Sundarbans mangrove forest, one of the country's most climatically vulnerable areas and depend on its ecology for their livelihoods (Naushad, 2015). Focusing on the settlement history of the Sundarbans, Raja Pratapaditya, the then Zamindar of Jessore, and one of the Bara Bhuyans ,settled the maximum part of his kingdom in 1574 by demolishing the inaccessible forest land of Sundarbans and named the area as “Jashohor” (Jalil,1986). In the British era, the imposed tax enacted by Lord Cornwallis in 1793 played an important role in demolishing the Sundarbans. Since the taxation was fixed the landlord’s interest has increased to produce more by expanding agricultural into the heavily forested Sundarbans. The Sundarbans Commissioner William Dampier noted that about 85,000 acres of land had been deforested and used for agriculture, paddy fields in the region by 1830, and many people have migrated to this region to become a cultivator. (Ghosh D. , 2020). With the continuation of these historical events, the Munda people also start to settle in this area by demolishing the forest land for the sake of the livelihood over the 300 years ago. This natural-resource based community has been largely dependent on the Sundarbans for their livelihood generation and homestead construction. The limited scope of livelihood opportunity because of the salinity of land, leads to the illegal exploitation of the Sundarbans, the active buffer for the country in case of climatic disasters like cyclone.

Besides this human interruption, this ecologically enriched area of the country is currently facing the impact of climate change also. The Zoological Society of London (ZSL) found out in a study conducted in 2012, that the Sunderbans coast was retreating up to 200m (660ft) in a year which will destroy the agricultural activities, shrimp cultivation of the mangrove area (Cornforth, et. al., 2013) Again, the rising sea level combined with higher surface water temperatures and higher salinity levels have presented a concern for the survival of native flora and fauna. The Sundari trees, for example, are extremely salinity sensitive and are under threat of extinction (Ghosh A. , 2015). Loss of the mangrove forest will result in the loss of the protective biological shield against cyclones and tsunamis which may put the surrounding coastal communities at high risk. The recent cyclone, Amphan, occurred on 18 May 2020, clearly showed the Sundarbans’ capacity of being the protective shield for the study area compared to the neighbour country, India. Diversifying the livelihood opportunities of the local community can potentially reduce the illegal exploitation of the Sundarbans resources resulting in a communal resiliency to the impact of climate change and, on the other hand, help the natural growth of the mangrove. With this intention, the paper has selected a natural resource-based ethnic community of Sundarbans as a study group and aims to suggest a resilient homestead based livelihood system which has the capacity to resist, mitigate and prepare for the disaster impacts.

2 Theoretical Background

2.1 Rural Homestead and Rural Economy

Homestead, colloquially known as *'Bhite-Bari'*, has been an integral part of the predominant rural settlement in Bangladesh. As a regional archetype, its physical and functional aspects carry the synthesis of the age-old culture, climate, and nature. (Ahmed, 2012) A common pattern of these homesteads is the arrangements of several single-story rooms (*Ghor*) around a rectangular open courtyard (*uthan*) and a backyard pond with bathing step, regularly used in bathing and cleansing activities. To protect the houses from the annual flood, a common phenomenon in a deltaic flood plain, the pond is initially excavated to collect soil for raising the land of the homestead. Once the land is raised, the main dwelling unit as well as the ancillary structures like kitchen, cowsheds, and granaries are gradually built over time around the central open courtyard. The open court (*uthan*) allows different types of activities like drying clothes and foods, processing agricultural produces, making baskets or household artefacts, cooking, chatting, and other social events.

A homestead can work as a production unit for vegetables, trees, fishes, and animals with an integrated farming system that helps to improve the socio-economic condition of the rural populations (Aysha Akter, 2019). Homestead forest, a diverse array of plants and trees provides food, fuel wood and timber for domestic consumption and sale, and protects the house during cyclones (Inoue, 2014).The Government of Bangladesh is operating a poverty alleviation project through family farming titled ***"Ektee Bari Ektee Khamar"*** i.e. One House One Farm (OHOF) (Programme, 2020).The goal of the project is to alleviate poverty by family farming livelihood and income generation of the underprivileged community. Moreover, engaging woman in these home-based farming activities may ensure their participation in family income generation (Mamun MHA, 2010). National Agriculture Policy (NAP) has recognized the importance of the involvement of women in agriculture and homestead farming in the socio-economic context of Bangladesh and gave emphasis on the skill improvement training and capital supporting programs (Agriculture, 1999).In this way, the rural homesteads can play a key role in creating livelihood scope, empowering women, and contributing to the rural economy.

2.2 Sustainable Livelihood

The International Institute for Sustainable Development (IISD) describes sustainable livelihoods as being "concerned with people's capacities to produce and secure their means of living, enhance their well-being, and that of future generations" (Balgis Osman Elasha*, 2005). In the WCED report, 1978a, livelihood was defined as sufficient stocks and flows of food and money to meet specific needs, livelihood security refers to secure possession or access to resources and income-earning activities, including savings and assets to minimize risk, ease shocks and meet contingencies, and sustainability refers to the long-term preservation or improvement of resource productivity. From the report's point of view, a household can earn the capacity to gain sustainable livelihood stability in several ways- by land, livestock or trees, planting, fishing, hunting or collecting rights, secure employment with adequate remuneration or a variety of activities. (WCED, 1978a). The UK's Department of Foreign and International Development (DFID) has tried to define the "Sustainable Livelihood" as a means of coping with and recovering from stress and shocks and sustaining or improving its capability and properties, both now and in the future, while not diminishing the natural resource base (Chambers, R., & Conway, G. ,

1992). After analysing the definitions of sustainable livelihood, the parameters of sustainable livelihood can be identified as:
Availability of Income source in different periods which is subjected to an assurance of sustainable income with or without unusual disturbance at different seasons of the year (Income stability) with ***Connectivity with different Resources*** and ***Adaptive capacity*** or ***Flexibility*** to cope with the shocks and stresses. These livelihood activities have an impact on the ecology of the context depending on the livelihood resources.

2.3 Livelihood Framework

Sustainable rural livelihood is the system analysis for reducing poverty by empowering the poor to build on their opportunities. IDS published a Working Paper presenting an analytical framework (Fig.01) for sustainable rural livelihoods in June 1998 (Scoones, 1998), in which the sustainable livelihood framework expressed as a question highlighting five elements contexts; resources; institutions; strategies; and outcomes which were applicable to different scales – from an individual to household, to household cluster, to extent community, to village, region or even nation, with sustainable livelihood outcomes of varying levels:

"*Given a particular context (of policy setting, politics, history, agro-ecology and socio-economic conditions), what combination of livelihood resources (different types of 'capital') result in the ability to follow what combination of livelihood strategies (agricultural intensification/ extensification, livelihood diversification and migration) with what outcomes? Of particular interests in this framework are the institutional processes (embedded in a matrix of formal and informal institutions and organizations) which mediate the ability to carry out such strategies and achieve (or not) such outcomes."* (Scoones, 1998)

The Natural Resources Department of DFID opens consultation on sustainable livelihoods and establishes an annual conference of the Rural Livelihoods Advisory Group Natural Resources Advisors which takes Sustainable Livelihoods as its theme and then publishes contributory papers: Sustainable Rural Livelihoods: What Contribution Can We Make? (Carney, 1998). In this article, (Carney, 1998) explained a Rural Livelihood Framework (Fig.02), which explains how livelihood outcomes are produced by livelihood strategies by transforming livelihood system frameworks and processes and accessing livelihood assets in a context of vulnerability.

The sustainable livelihood conceptual framework has been developed to evaluate the performance of the livelihood and environmental management for building resilience in the context of present climatic shocks and stresses and for reducing community vulnerability to future climate change. (Elasha, B. O., et. al., 2005). It is a guide to understand how the household livelihood systems deal with the outside environment under specific frame condition and how the individuals and communities pursue the coping and adaptive measures as a reaction to external shocks and stresses to ensure economic efficiency and income stability.

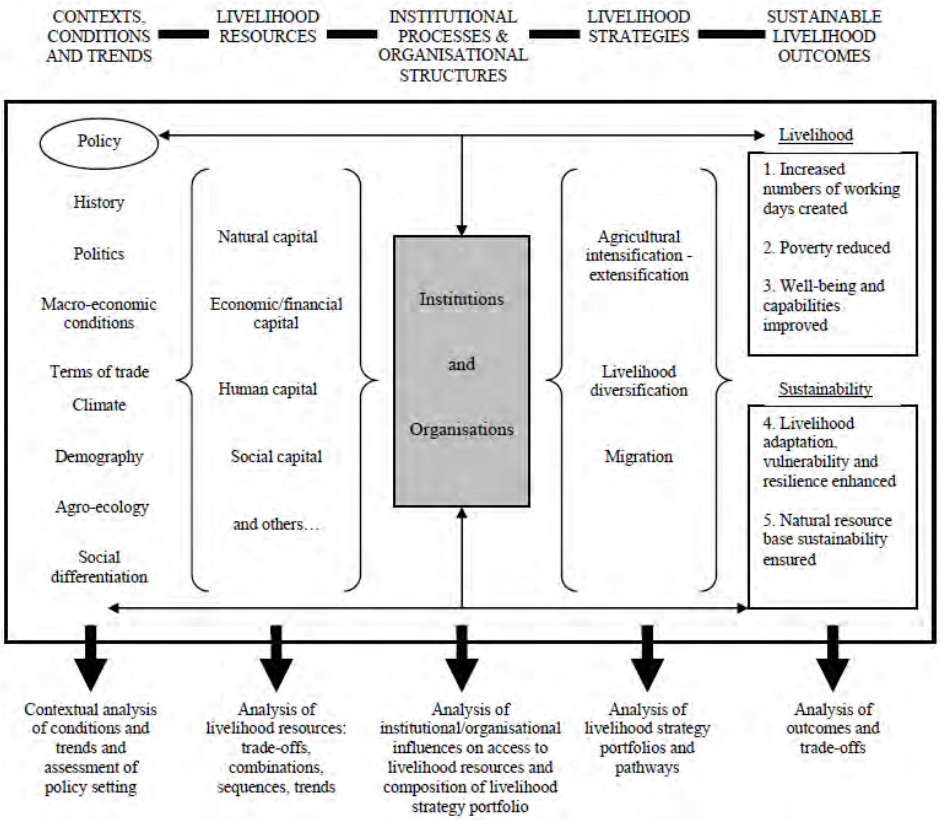


Figure 1: Sustainable Rural Livelihoods Framework by IDS *(Scoones, 1998)*

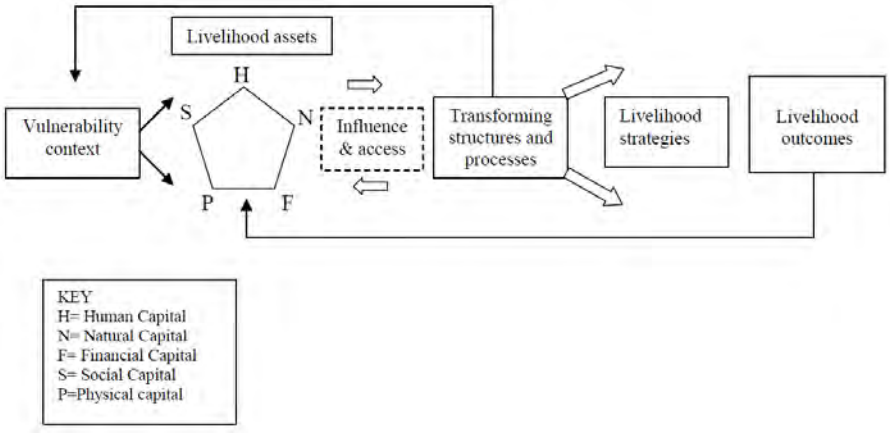


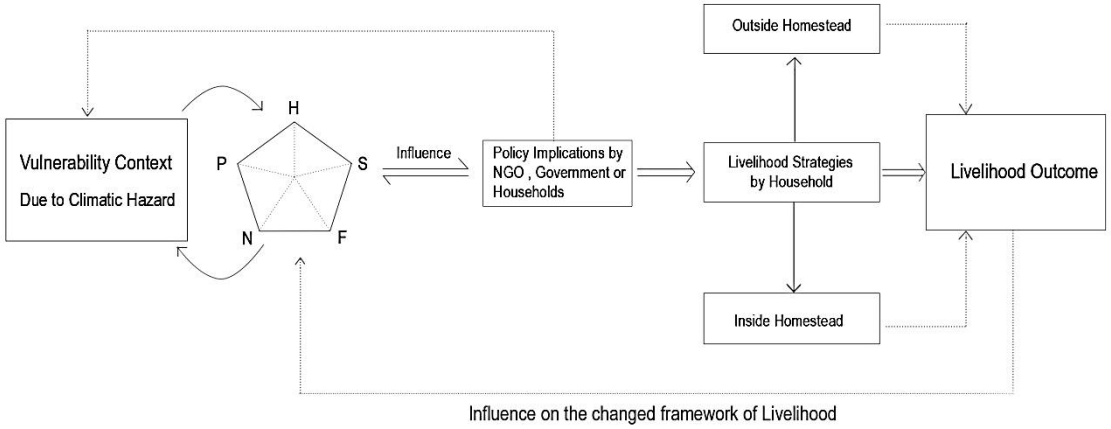
Figure 2: DFID's Sustainable Livelihoods Framework *(Carney, 1998)*

3 Methodology

The research aim is to transform a single Munda homestead by enabling the subsistence structures with coping and adaptive strategies regarding livelihood to deal with external shocks and stresses due to climatic conditions. Selection of this particular community will help the research to understand all the elements of the livelihood framework and the impact of vulnerability context. The aim complies with three objectives, which are:

1) Study of Salient features of Munda homesteads in the study area in relation to its economic and climate resiliency.
2) Finding out the scope of improvements of their homestead with the view of sustainable livelihood (Conceptual model)
3) Design suggestions for remodeling the homestead conditions with a demonstration model using available materials and skills for the *Munda* community.

The sustainable livelihood model of UK Department of Foreign and International Development (DFID) is followed in this research. The notion of the five capitals (natural, physical, human, social and financial) shaped the basic understanding and then a modified version of the livelihood framework (Fig.03) is developed considering the scope of home-based economy options. The paper also has tried to introduce the diversified livelihood model in the context of the study area to make the community people more resilient in the economy in the face of current climatic shocks and stresses and future climate change.



KEY: H - Human Capital; P - Physical Capital; N - Natural; F - Financial Capital; S - Social Capital

Figure 3: Study Framework for Remodeling Munda Homestead in the view of Sustainable Livelihood Framework

To study the salient features of Munda homesteads in the study area in relation to its economic and climate resiliency, the primary data from the field study and the secondary data from the literature study has been considered and after analysing the findings the scope of improvements has been explored to develop a conceptual model in the view of sustainable livelihood. The primary data has been collected through structured and semi-structured interviews and focused group discussion with the community people. As an outcome of the study, this paper will suggest a proposed model for the Munda homestead using available materials and skills.

4 Study Area

4.1 Geographic Location

The study area, this particular research presents, is located in Sabkhali Munda para, Purba Kaikhali, Shyamnagar (22°19.8′N 89°6.2′E) Upazila under Satkhira (22° 21′ 0″ N, 89° 4′ 48″ E) (Fig.04). (Shyamnagar Upazila).The river Ray Mangal, contiguous with this Upazila, defines the India-Bangladesh Border. Lying within the reign of tidal effect, salinity intrusion and natural disasters, Shyamnagar Upazila has been one of the less economically developed part in the south-western coastal districts of Bangladesh. The area, Kaikhali, a union of Shyamnagar, is situated very close to Sundarbans mangrove forest. An essential component of the settlement is the embankment (*bund*), constructed in the 1960's, without which human life is impossible in the lower part of the Sundarbans. The level of village land and agricultural land is lower than the high-tide water level and the human-constructed long bund protects the settlement from high tides and saline water ingress. There are about 1770 Munda inhabitants living in the greater Shyamnagar region, where 44 Munda households are living in Kaikhali. Most of the people rely wholly or partly on forest products.

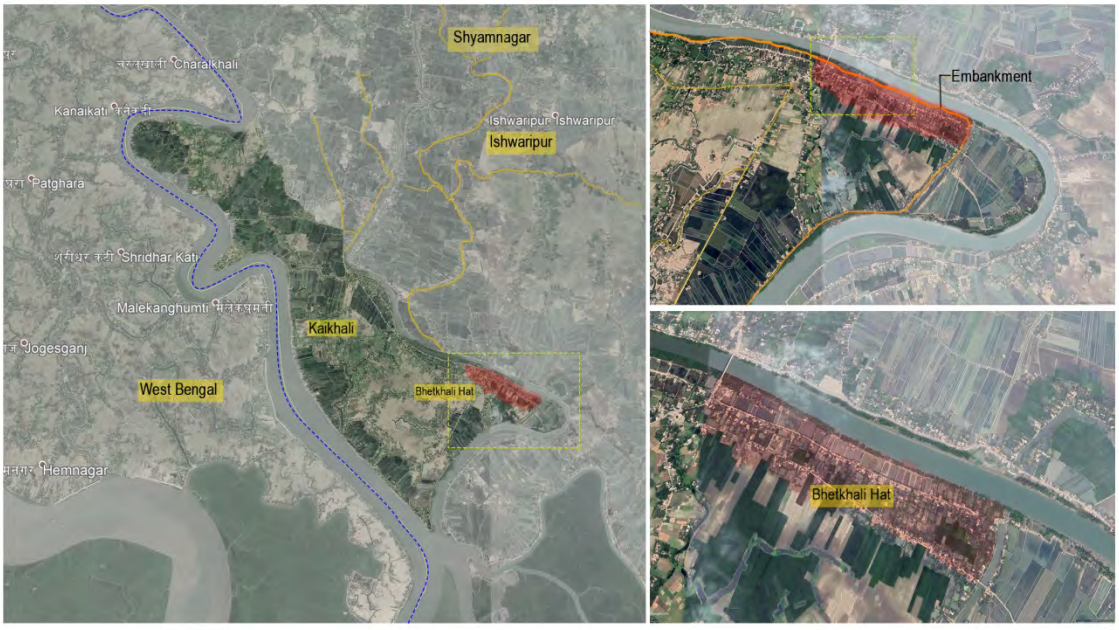


Figure 4: Geographic location of the study area; Embankment; Bhetkhali Hat

4.2 Munda community in Shaymnagar, Satkhira

Munda community is living in scattered areas of Koyra and Dumuria Upozillas of Khulna District, Shyamnagar, Debhata and Tala Upazilas of Satkhira district - all falling within the region of Sundarbans. Being a natural-resource dependent community, they have been utilizing Sunderbans forest since the colonial era and thus they have developed intensive ecological knowledge about harvesting resources in the Sunderbans. However, forest ecology was immensely disrupted and the biodiversity was destroyed due to the unplanned and illegal extraction of forest timbers, animals, and other resources by the

colonial administrator using the Munda community as the labor force (Roy, 2018). At the end of the colonial era, they started to leave their forest-based livelihood and looked for an alternative source of livelihood like rain-fed agriculture or working as domestic labour to well-off Hindu and Muslim families. Long years have passed since they had cultivated their lands given as a gift by their landlords, with the agreement that they could not sell the land. After independence, local land grabbers and political influential had targeted the lands of the Munda people to forcefully occupy them and evict the people from their ancestral property. Despite living in the same land for generations, the Munda people have been fighting for the right of land ownership. Moreover, this region has endured extreme threats from climatic hazards, such as cyclones (which occurred in 1988, 1991, 2007,2009, and most recently 2020), flash floods, drought (1974), the continuing intrusion of salinity into agriculture, and extreme lack of clean water. The long-term consequences of these disasters have put them in a position to earn their living from a wider variety of livelihoods.

5 Results and Discussion

5.1 Munda homesteads in Economy and climate resiliency:

Munda homesteads pattern has a close similarity to their Bengali neighbours' owing to their long association with the mainstream Bengali community and cultural transition. The use of locally available materials and climate responsiveness are the attributes that are strongly present in their homes (Fig.5). In Shyamnagar, the highest water depth recorded was 2.1 to 2.4m and severe inundation for a longer period. The Munda community people build their houses with a high plinth of 1-1.2m to cope with the disaster. In many cases, they use the Sunderbans forest resources, such as forest wood (Sundari, Goran, Pashur) for their housing structure and Golpata, Hogla for making the roof. Some households, of better financial condition, use CI sheets as a more durable roofing material. The season for house building comes just after the harvest time and people use straw annually to rebuild the roof. This practice helps them in two ways: one is to reinforce the measure of structural preparedness for cyclone and the other is to create a new roof with fresh straw. However, during the cyclone, many families leave their homesteads to take shelter in the cyclone center as their houses are not resistant enough to withstand the storms. In the field survey, two cyclone shelters are found in Kaikhali union, which are not well maintained and do not fulfil the requirements of hygiene and privacy. Participants in a group discussion indicated that they would appreciate economic support from the government or NGO to build their own cyclone resilient house so that they would not have to leave their homes during these calamities.

Traditionally Munda man holds a position of earning member and female as a domestic worker and care provider in the family. This kind of social disparity and the gendered role has limited the economic mobility of the Munda female (Roy, 2018). Females' paid-work has always been socially stigmatized, leaving women economically dependent on the husband's earnings. Home-based livelihood opportunities are suggested to play a

significant role in making Munda women more economically self-dependent and socially empowered. Different types of home based farming and economic models are already been used as effective earning source for the Munda homesteads.

A community-based tourism initiative entitled “Promotion of Local Culture in the Sundarbans Impact Zone in Bangladesh through Cultural Eco-tourism and Entrepreneurship”, with Munda Community living in the broader Shyamnagar Region, started in late 2014 with the help of SAMS and an NGO Relief International (RI). Community peoples received financial support as well as training as eco-guides, in services, hospitality, finance and security. The tourists visiting Sunderbans, mostly in December, January and February, are availing accommodation facility in the eco-cottages made within the Munda homestead and all the Munda families involved in eco-tourism are equally sharing the monetary benefits earned from this collective initiative. Consequently, the spatial configurations of the community are changing for adapting the new functional requirements sought by the livelihood opportunities as saline resilient farming, community tourism or home based shops and so on. This process may play an effective role in improving socio-economic conditions of the Munda families ensuring more sustainable livelihood alternatives throughout the year.

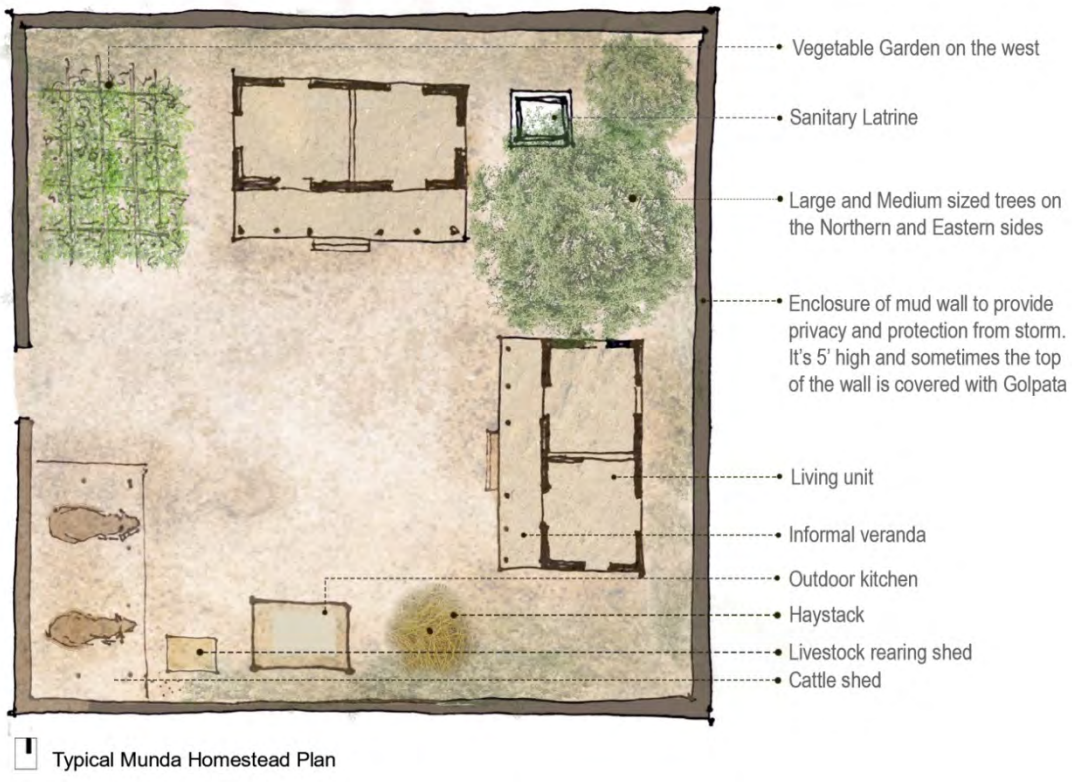


Figure 5: The homestead and settlement pattern analysis taking into account the measure of disaster preparedness.

5.2 Present Livelihood Context

Present Livelihoods of the indigenous Munda community circles around Farming, Rice cultivation, Freshwater fish farming, Shrimp culture, Crab culture, Fishing, collecting

Honey, Wax, Wood, and Golpata from Sundarbans (Fig.6). Saline water shrimp cultivation has become very popular after 1983 for its high demand in the international market and created livelihood opportunities to the community people. As the demand was growing up, most of the people are becoming interested in saline water shrimp culture (Baghda) converting the farmlands into '*Gher*' where saline water is kept reserved by creating Aisles (higher boundary). Thus the salinities had been increasing at an alarming rate in the farmlands which was destroying the fertility of the land. As a result, many *Munda* farmers could not continue rice cultivation and undergone severe financial hardship. The extensive farming systems negatively expedite the processes: infringement of mangroves, the intrusion of salinity, degradation of land, de-stabilization of coastal ecosystems. Moreover, for sudden flood and cyclones, these "*Gher*" get damaged and washed away by floodwater, and shrimp cultivators become economically-

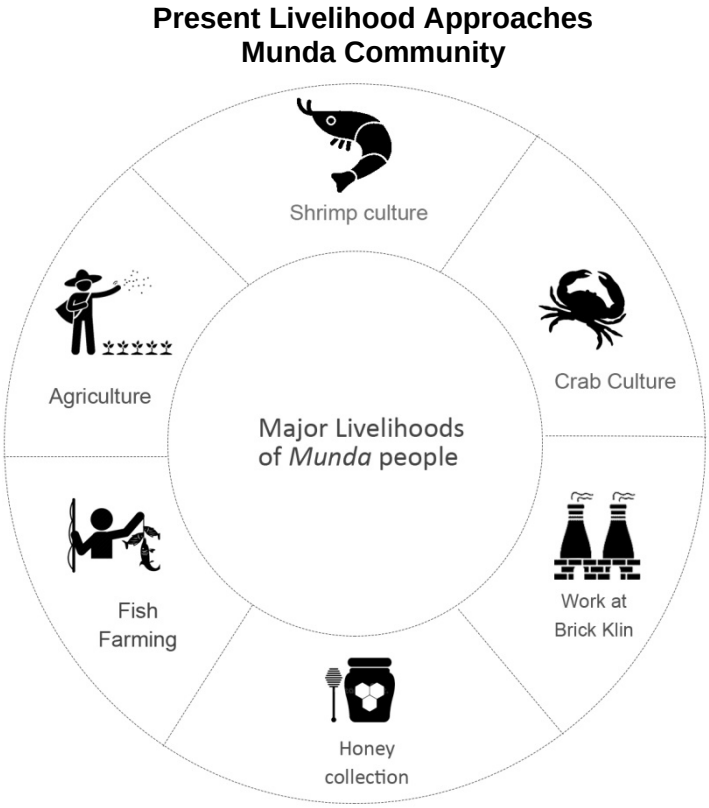
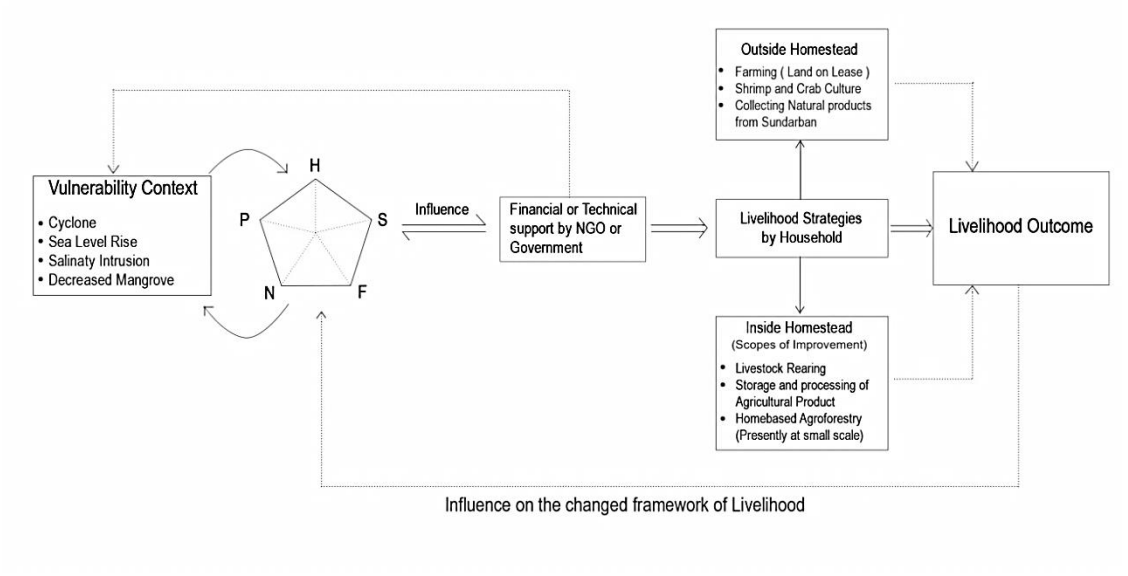


Figure 6: Present livelihood approaches the Munda Community adopted.

devastated as they cannot cut the profit what they were supposed to. All these reasons are associated with the present unstable livelihood condition of the Munda community.

So a close observation of the livelihood of this indigenous Munda Community leads us to the fact that the unplanned distribution of lands for farming and shrimp cultivation creates a diplomatic circumstance among the people to choose their regular profession under the consideration of financial benefits and ecological imbalance of farming land. Moreover this monoculture practice of livelihood and higher dependency on the Sunderbans causes serious damage in the ecosystem of the study area. In addition to that, rearing livestock

including cows, pigs, and goats within their homesteads became an earning option for the *Munda* females in small scale. The existing condition of the livelihood framework has been shown in Fig.07.



Human capital	: Household members (females are not incorporated), active labour (most of the case male based)
Physical capital	: Livestock, equipment, vehicles, houses.
Natural capital	: Access to land (Lease from landowner), forests (collecting timber and non-timber products), water, grazing, fishing, wild products and biodiversity
Financial capital	: Savings/debt, gold / jewellery, income, credit, insurance
Social capital	: Kin networks, group membership, socio-political voice and influence

Figure 7: Existing livelihood framework of Munda Community

5.3 Scope of improvements:

Sustainable livelihood approach can help to reshape Munda Homestead so it can respond to different vulnerability context. Researchers have found from the literature review and field survey that the climatically vulnerable group of people prefers to improve the homestead rather than investing on building cyclone shelters. Investment aided by NGO/government organisation in improving a core house unit in the homestead can help creating disaster preparedness. The attic space (Fig.8) will serve as emergency shelter and safe storage space. The brick foundation and load bearing walls will be the main concern for cost. Rest of the building components including raised mud plinth, door, window, wooden ceiling and roof can be managed from local sourcing.

Immediately after flood, water logging and increased salinity are main threat to agriculture based profession. Engaging local skills, community groups or agencies in making and repairing houses can open new avenues of livelihood opportunities to the local people for the time being. Institutional support and loans on easy terms should be available in this period, so people can repair their shelter and pursue alternative livelihood like collecting

forest resources, making hand-crafted products. A shop (no. 7 in Fig.11) has been incorporated in the homestead so that the household members can sell the home produce and collected timber and non-timber materials from the forest and can ensure additional income for the family.

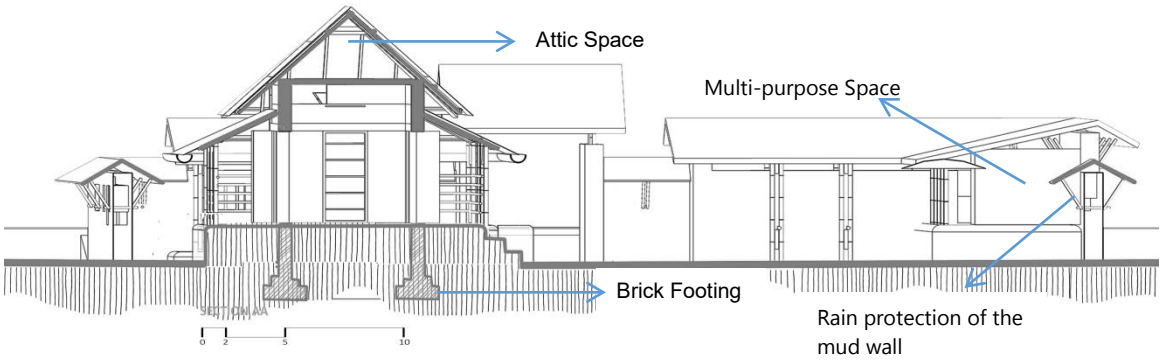


Figure 8: Proposed Homestead Section for Munda Community

In the proposed framework (Fig 10) the paper aims to enrich Human Capital by including the female working domain in the case of livelihood generation parallel to the male family member that was found neglected in the literature research and field survey. The proposed homestead includes the vegetable gardening appropriate in the saline prone areas (space marked as 12, 13 in Fig.11) such as- tower gardening, ring gardening, and *macha*, aquaculture, raring livestock, handicrafts, homestead shops, homestead agroforestry which can be a part of the home-based female working domain as shown in the Fig.11, the spaces marked as 6, 7, 8 12, 13, 14, 15 and 17. As the government of Bangladesh has tried to train the community people with the scope of homestead based eco-tourism, which has also been introduced in the suggestive design. A multipurpose space has been proposed which can be converted into different types of working space depending on the seasons simultaneously this space can be converted as a tourist accommodation during the tourist season of November to February, the space is marked as no. 8 in the Fig.11. A homestead based agroforestry has been proposed (space marked as no. 15 in Fig.11) which can be a windbreaker for the homestead in the event of the cyclone, at the same time an additional source of income also. A pond has been proposed as the source of small scale aquaculture (space marked as no. 14 in Fig.11).

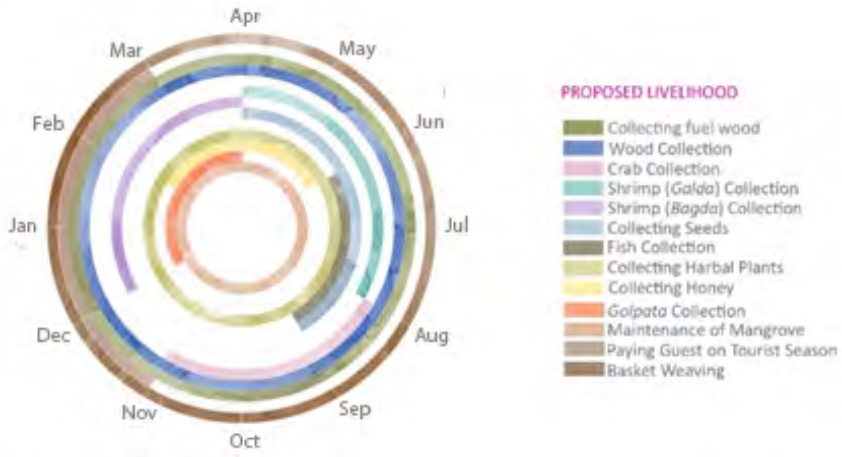
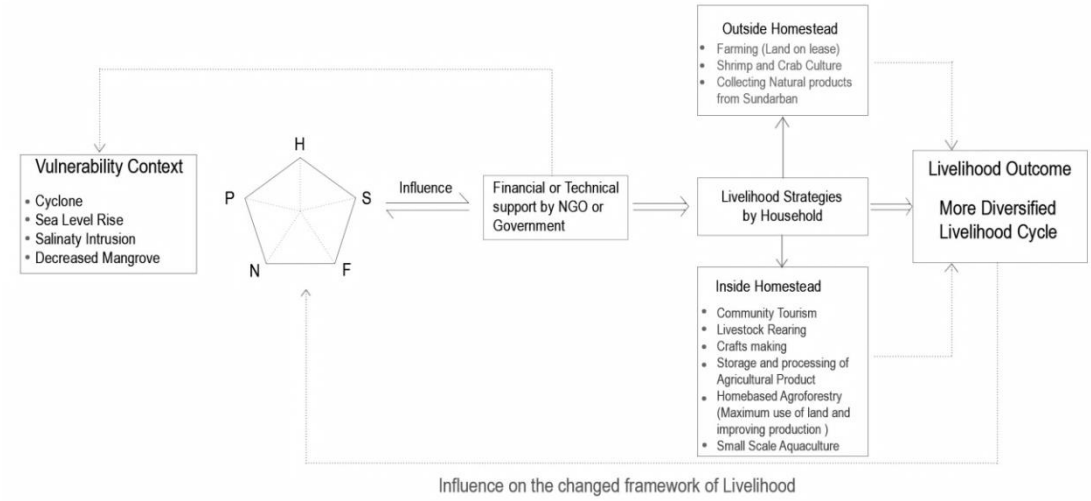


Figure 9: Proposed Livelihood opportunities for *Munda* Community throughout the whole year.

With all these opportunities of livelihood a household can ensure a diversified income generation system which will eventually decrease the dependency on the forest resources. (Fig.9). Subsequently, the mangrove can restore its ecological balance and increase its territory to cope with the current shocks and stresses and the future climate change. The proposed livelihood framework has been shown in the Fig.10, which not only helps the community to build the capacity to responds to and recovers from the impacts of the disaster but also helps to build a climate-resilient smart village with a secured livelihood system.



Human capital	: Both Male and **female members** (**home based agroforestry and crafts making**) as active labour
Physical capital	: **Multipurpose homestead space for income generation**, **Shops**, Livestock, Vehicles, Houses, Pond.
Natural capital	: Kitchen Garden, **Tower garden, Small scale Aquaculture (Shrimp cultivation, fish Farming),** forests (collecting timber and non-timber products), water, grazing, fishing, wild products and **increased biodiversity.**
Financial capital:	**Institutional support , Loans on easy terms ,**Savings/debt, gold / jewellery, income, credit, insurance
Social capital	: Kin networks, group membership, socio-political voice and influence

Figure 10: Proposed Livelihood framework of Munda Community

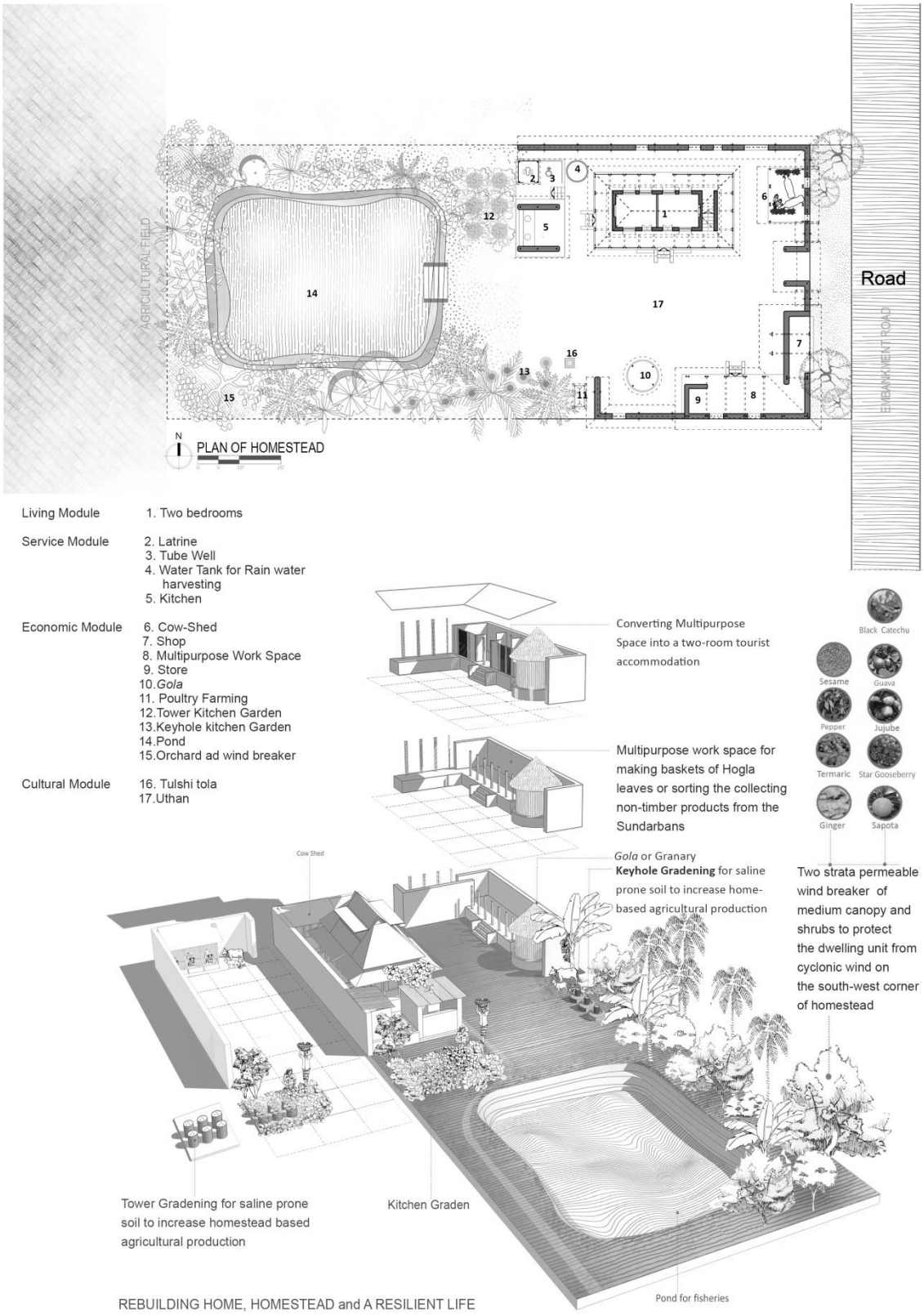


Figure 11: Proposed Model of *Munda* homestead.

6 Conclusion

The over-extraction of the Sundarbans forest resources, the extensive shrimp cultivation with brackish water and the on-going impacts of climate change are continually leading to an imbalance of the ecosystem and precarious existence of the Munda community in the South-West coastal region of Bangladesh. The loss and damage of the physical capital due to climatic disasters like Aila, Amphan, coupled with the damage of natural capital(ecosystem) by human-created distresses is increasingly threatening the livelihood resilience among the households of Munda people as well as the sustenance of the other capitals in the livelihood framework (human, financial and social). Because of these shocks and stresses, the affected community is seeking new livelihood opportunities to cope with and recover from disasters. However, with the findings and proposal of this paper, it indicates that a sustainable livelihood framework with diversified livelihood options focusing on the development of homestead and empowerment of women can help to create a system which acts to respond, cope, recover and transform the lives of the community people. The suggestive spatial changes in homestead and diversification of livelihood cycle can instigate transformative resilience in the communal livelihood strategy, as well as reduce the dependency on the Sunderbans forest which exponentially reduces the risk of ecological extinction because of human interventions.

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RESEARCH METHODS TO INVESTIGATE OCCUPANTS' DOMESTIC ENVIRONMENTAL EXPERIENCES FOR *EXD* FRAMEWORK

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Abstract:

Occupant has holistic experiences in their domestic environments that may affect their health and wellbeing. Nowadays, various research methods are conducting to explore occupants' psychological issues in their living environments. Thus, occupants' domestic environmental experiences need to be examined into architectural design decisions to enhance their health and wellbeing. This study's primary objective is to explore the research methods to investigate occupants' environmental experiences in their domestic living. In this study, relevant literature reviews have been conducted to understand the research methods of exploring occupants' environmental experiences. A series of qualitative and quantitative methodological approaches (mixed-mode) have been considered to triangulate the correlation between occupants' subjective experiences and their wellbeing (i.e., comfortable feeling). Through these research methods, the correlation between environmental design factor (DF), spatial factor (SF) and user context (UC) have been explored in occupants' domestic settings. Structured questionnaire surveys, semi-structured interviews and photo survey techniques have been considered to explore occupants' domestic environmental experience (EXD). For the statistical data interpretations and correlational analysis, the 'Pearson' and 'Association Rules (Apriori)' algorithms have been identified for data mining using SPSS statistics. NVivo will be utilised for the content analysis and image coding to clarify the relationship between DF, SF and UC of occupants according to different domestic environments. Moreover, this methodological approach to exploring occupants' domestic environmental experiences may help develop the notion of domestic 'Environmental Experience Design (EXD)' framework.

Keywords: *Domestic Environment, Environmental Experience, Research Methods, Tools and Techniques*

1. Introduction

The literature studies identify that housing and dwelling environments have been recognised as one of the most prominent settings that may directly or indirectly affect occupants' health and wellbeing (i.e., emotions, feelings and moods) [1]. Occupants' health and wellbeing may be improved by changing or developing living conditions and behaviors related to their household daily experiences and existing physical conditions of domestic environments [1]. Although domestic indoor environmental qualities have been studied extensively before by different research methods, tools and techniques, the research on the occupants' domestic environmental experiences is still insignificant to date in the built environmental design domain [1]. Thus, occupants' domestic environmental experiences need to be examined into architectural design decisions to enhance their health and wellbeing. Therefore, there is a necessity for in-depth studies of occupants' domestic environmental experiences that may affect their wellbeing.

Although various research methods are conducting to explore occupants' psychological issues in their living environments, there is a limitation in investigating occupants' experiences in housing or domestic environments. This study's primary aim is to explore the research methods to investigate occupants' domestic environmental experiences that may contribute to developing the concept of 'Environmental Experience Design (EXD)' methodological framework to enhance occupants' health and wellbeing.

The research investigates outcome solutions to scientific and social problems through objective and systematic analysis [2]. According to the literature, research methods are the strategies or procedures applied in collecting data or evidence for analysis to discover new information and improve understanding of an issue. Different types of research methods use various tools and techniques for data collection [2, 3]. There are mainly three research approaches: (a) qualitative, (b) quantitative, and (c) mixed methods [3]. Here, inquiry procedures are called research designs and specific research methods: data collection, analysis and interpretation approaches [4]. The selection of research methods also depends on the nature of the research problems and the issues addressed. However, researchers' and audiences' personal experiences play an essential role in selecting research methods [3, 4]. The research design contributes a vital role in answering the specific research question according to the research goal. Moreover, research design and methods are closely related where researchers need to make their decisions on how to collect their expected data to answer research questions [3, 4].

2. Identification of Research Gap

From studies, it is clear that in a living condition, occupants' behavior is affected not only by the spatial environment but also by occupants' perceptions, feelings and needs as well as by users' social context [5]. Today's architectural design approaches create a gap between users' spatial needs, demands and architectural design factors along with psychological satisfaction. According to Lawrence (1990), there exists a study gap between two current theories, namely the theory of 'Environmental Deterministic' and 'Social Constructivism' that drive users' experience within space [6]. Here, The environmental deterministic theory based on environmental psychology describes the physical environment's impacts on human behavior. The scope of explanation about users' social, cultural and economic contexts is limited to some extent in this theory. On the other hand, the social constructivism theory describes cultural and social perception as challenging to measure where consideration of built environmental effects is limited [5]. According to the literature, user-centered design between the two spectra derive from the user's physical and psychological experiences and address the user's social, cultural, and environmental aspects (Fig. 1).

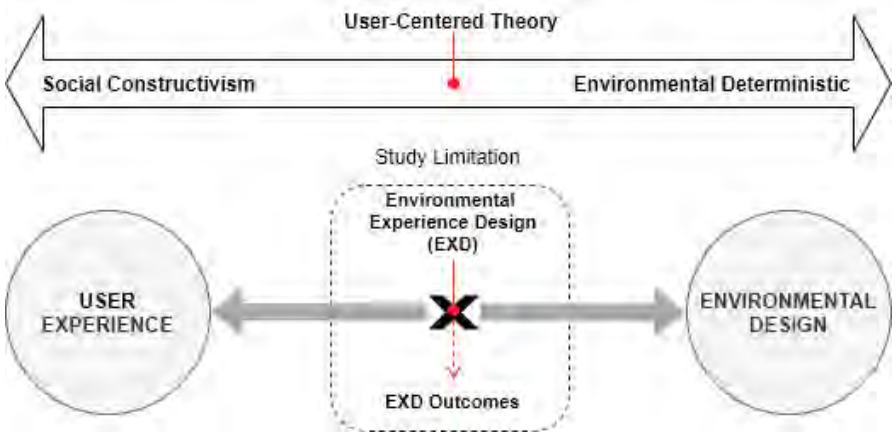

Figure 1. Research gap between '*User Experience*' and '*Environmental Design*' domain.

Architectural design encompasses multidisciplinary disciplines, including human-centered design and decision-making procedures; however, the concept of 'Experience Design' has hardly been applied to architectural design decisions before [7]. Experience design may improve the association between inhabitants' needs and physical settings in the built environment. This new application may change the design concept from a technology-driven idea to a human-centric design decision.

3. Experience Design: A User-Centered Approach

Kling (1977) coined the term 'User-centered Design (UCD),' a person-centric philosophical design approach that focused on the human cognitive interaction with objects, products or things [8]. Later, the concept of UCD became widely popular as 'User Experience (UX) Design' due to the publication entitled 'User-centered System Design: New Perspectives on Human-Computer Interaction' by Donald A. Norman in 1986 at the University of California, San Diego [9]. According to Norman,

> *Human-centered design is a design philosophy. It means starting with a good understanding of people and the needs that the design is intended to meet. This understanding comes about primarily through observation, for people themselves are often unaware of their true needs, even unaware of the difficulties they are encountering. [10]*

Additionally, in the book entitled 'The Design of Everyday Things' Norman expanded the concept of 'Experience Design' in view of the industrial design domain where the author elaborated the concept of human psychology behind design perspective and its' importance in everyday lives considering usability and usefulness [11]. According to the author, experience design is:

> "…*the practice of designing products, processes, services, events, and environments with a focus placed on the quality and enjoyment of the total experience*." [10]

The design needs to interact between people and technology where discoverability and understanding are the two most essential features of the reasonable invention [10]. However, the UX design domain is more human-centered than 'User Interface (UI)' where user thinking, feeling and behaviors are the focal point. In the book entitled 'Design for Experience: Where Technology Meets Design and Strategy', Kim stated that the user is a focal point in experience design. Meanwhile, the design incident is subjective; the humanities and social science theories may cover these issues [12]. According to him, technology innovation theory such as UX/UCD/UI may develop fundamental user experience design logic. However, it's difficult to grasp where to start when it derives from a product or service design [12]. In that case, real design features should be implemented to understand the specific experiential elements.

This term is now widely adopted and UCD/UX definition can be characterised in numerous ways focusing on the user's perspective in the design process based on their needs and demands. For instance, it resulted in difficulties in clarifying user pragmatic needs and demands [13]. In the ISO-standard 9241–210, the user-centered design process has also been endorsed for interactive systems based on people's perceptions and responses [14]. According to the authors, the user-product interrelates with socio-cultural factors in a precise context. Thus, user-centered design raised the philosophical agenda, including users' expectations and experiences. It argued about the clear perception of design usability between end-users, designers and developers, indicating a new emerging design paradigm with many disciplines. Moreover, Thüring and Mahlke draw attention to the perceived instrumental factors, non-instrumental factors and emotional responses

are the three main components of user experience to form a complete decision and regulate user behavior [14]. Finally, the authors mentioned that user experience emphasises perceptions, preferences and emotional responses while using a product or service. To consider these aspects, experience design needs an extended perspective because of human psychological needs that may correlate with the prime design objective's emotional view. In that case, human satisfaction is the core parameter within the interactive design domain.

Referring to Merleau-Pontian than Heideggerian, Pallasmaa believes that an architect's design needs to incorporate with basic human needs of feelings where phenomenological analysis of emotions and feelings is a prominent part of the design. According to Pallasmaa, architectural phenomenology is a purely theoretical approach that captures the essence or interprets human-environmental perception [15]. According to McLellan, functionality, engagement, stimulation, enjoyment and memory are the experience design goals [16]. The book 'The Handbook of Interior Design' also highlights that reflection of human experiences is domineering in indoor living environmental design [17]. A study by Noguchi also projected the concept of 'Environmental Experience Design (EXD)' for aged care facilities in the Australian context [7].

4. Research Hypothetical Construct

An EXD theoretical concept has been developed based on this 'User-centered Design' thematical framework. In this theoretical concept, the user experience's core aspects are concised in three separate components: design factor (DF), spatial factor (SF) and user context (UC). Without understanding occupants' experiences, it may be difficult to identify environmental design solutions to enhance occupants' mental wellbeing or satisfaction. The first component, which concerns environmental design and qualities, deals with the user's needs and demands with existing environmental design aspects. It encompasses indoor environmental elements but also the psychological part of occupants' comfortable feelings. The second component, considering perceived spatial factor focuses on users' spatial experiences and may be linked to user physical, psychological and social needs and demands into their domestic living environments. The last component deals with user contextual factors related to their preferences and restrictions in their living environment that may shape the interaction between design and spatial factors. Thus, this theoretical concept may be applied to extract the 'Environmental Experience Design (EXD)' methodological framework for the domestic environment, as suggested in Fig. 2.

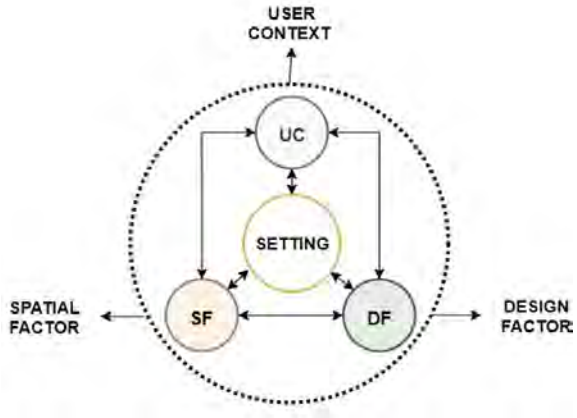

Figure 2. Research hypothetical construct.

5. Research Questions Formulation

Formulating a significant research question (RQ) is essential to exploring an existing ambiguity in specific circumstances or deliberate inquiry areas [2-4]. After narrowing the research subject's

scope and identifying what types of studies have been conducted in the past based on occupants' domestic experiences, primary and sub-research questions will be formulated for further analyses (Fig. 3). In this study, the research question is the following:

What research methods to investigate occupants' domestic experiences (DF, SF and UC) in their living environments to enhance wellbeing?

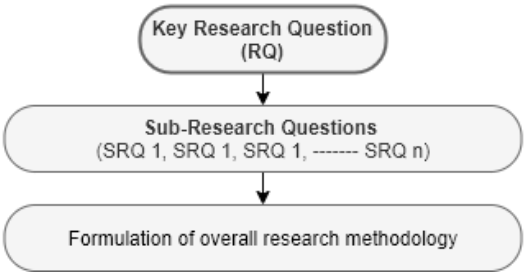

Figure 3. Primary and sub research question formulation.

Based on the research questions, suitable research methodological approaches have been discussed in the following section while considering the study's purpose.

6. Trend of User Experience (UX) and Built Environmental Research Methods

The term 'user experience (UX) design' was developed in the industrial design domain [1]. Here UX that focuses on improving user-product interfaces for usability. The user experience research method indicates creating data and user perceptions [7, 10, 11]. This section identifies the various research methods commonly used in the UX design domain that may influence developing the research methods to investigate occupants' environmental experiences in their domestic environments. The most-frequent research methods used by UX professionals have been illustrated here from the source of UX careers survey reports (Fig. 4).

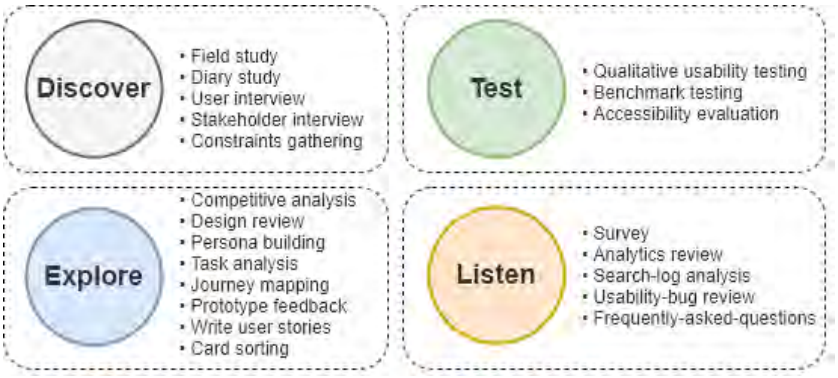

Figure 4. The most-frequent UX research methods.

Figure 5. The most systematic research methods applied in the built environmental researches.

The built environment is a relatively new term and most spatial design settings created by humans are elements of the built environments [18]. The most frequent of the built environmental research consists of cognitive, behavioral, components and emotional aspects. The present trend of existing built environmental research methods is either robust qualitative or quantitative. Nowadays, mixed mode (combined) methods are utilising by researchers in the domain of built environmental researches (Fig. 5).

7. Mixed-mode Research Approach

The term 'mixed-mode' states to develop a research methodology that integrates both quantitative and qualitative data within a single investigation or inquiry. This research integration explores a more comprehensive and interactive data analysis application than the data collected separately by quantitative and qualitative approaches [3, 4].

Mixed methods research initiated in the social sciences research and has recently expanded into the built environmental studies and others [3]. Research methods depend on the functions of research situations where each strategy has its specific approach to collect and analyse empirical data [3]. In this study, to understand research methods of exploring occupants' domestic environmental experiences, a series of qualitative and quantitative methodological approaches (mixed-mode) have been considered to triangulate the correlation between occupants' subjective experiences and their mental wellbeing (i.e., emotions) in existing domestic environments (Fig. 6) [3, 19].

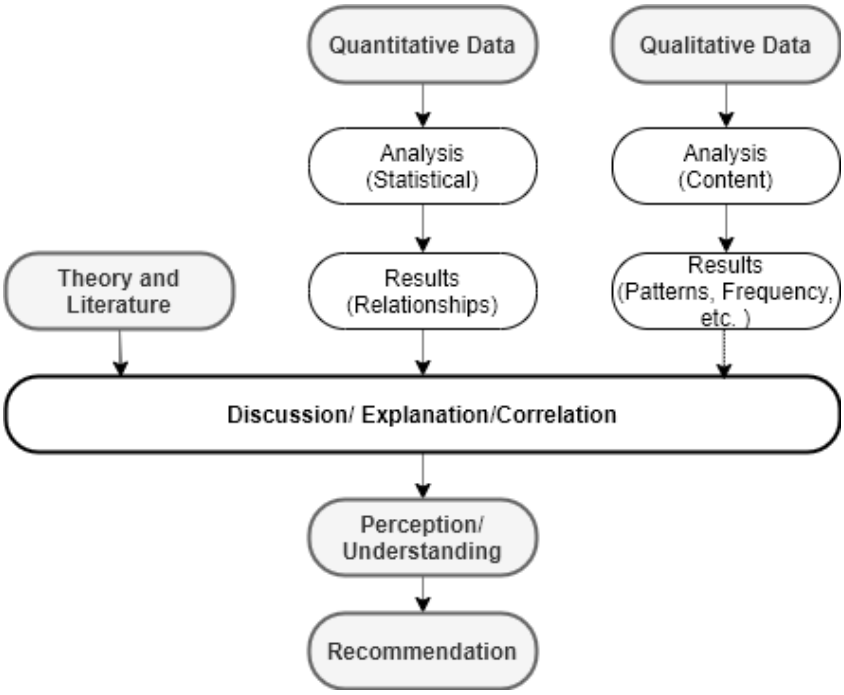

Figure 6. Triangulation of mixed-mode research approach.

Through this research method, the correlational matrix between environmental design factor (DF), spatial factor (SF) and user context (UC) will be explored that may contribute to developing a methodological framework of 'Environmental Experience Design (EXD). In this study, qualitative methods, especially field observations and semi-structured interviews have been allowed the researcher to develop the overall scenario of the occupants' environmental experiences in their existing domestic settings. On the other hand, quantitative analysis using structured questionnaire

survey data will identify the DF and SF's descriptive complements concerning comfortable feeling as occupants' wellbeing.

8. Data Collections Methods

Data collection is one of the most significant phases in directing research that collects information on different variables of research interests [3, 4]. In this study of occupants' domestic environmental experiences, the main research variables are environmental design factor (DF), spatial factor (SF) and user context (UC). Based on these factors, the following methods have been considered to collect data.

a. Literature Review

A literature review is a scholarly survey that is connected to a particular theme or research question [3]. The literature reviews concerning theories related to this research thematic study areas are essential to developing a benchmark and correlational matrix between DF and SF within the built environments. This desk research will help to clarify the notion of occupants' domestic environmental experiences as described above. PubMed, Scopus, Science-Direct, Google Scholar databases and other sources (such as books, journal articles and theses) may be explored to identify the relevant literature based on the thematic study areas.

b. Structured Questionnaire Survey

A structured questionnaire survey is a document with standardized questions for extracting specific information from the respondents [3]. There will be two sections addressing domestic environmental design factors and spatial factors in these structured questionnaire surveys. The participants will be asked straightforward questions based on their existing domestic environments' present conditions, comfortable feeling and future preferences in each section. From the question sheet, participants can understand the specific problem/question. The interviewer put a tick mark or binary (0, 1) or 'yes/no' on the 'Low, Medium, or High' boxes beside each item in the answer sheet according to occupants' responses. The participant will be asked about their experiences on that particular design and spatial factors considering different spaces (i.e., bedrooms, living room, dining room, drawing room, kitchen, toilets, multipurpose, corridor, balcony) in their domestic settings (Fig. 7).

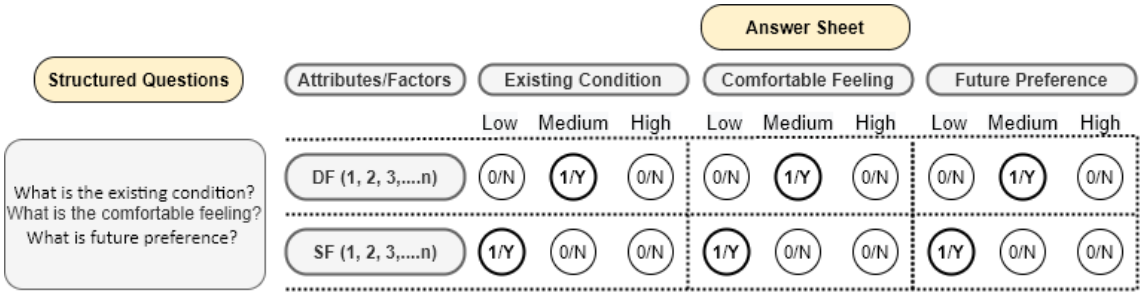

Figure 7. Methods of the structured questionnaire survey.

c. Semi-structured Interview

Here, semi-structured interviews do not strictly follow a formalized list of questions and answers format [3]. The strategy is to listen to the occupants (as interviewees) tell their domestic living experiences using open-ended questions, allowing for a discussion with the interviewee to achieve the goal (Fig. 8). The duration of each interview will be no longer than 30 to 40 minutes for an occupant. In this interview, occupants need to ask their background information,

preferences, restrictions and requests to record their interviews. Occupants may express their daily experiences regarding their emotional responses (positive and negative) in domestic environmental settings. The interviewer encourages interviewees to explain their mental wellbeing status related to different spaces in their daily domestic environments. Occupants may discuss the most recent space-related experiences in their domestic settings and describe their adaptive behaviors. The interviewer is also warming up the interviewee to think about future preferences (needs and wants) and their restrictions on their existing living conditions. Lastly, the interviewee may seek permission to take some photos in their domestic living environments.

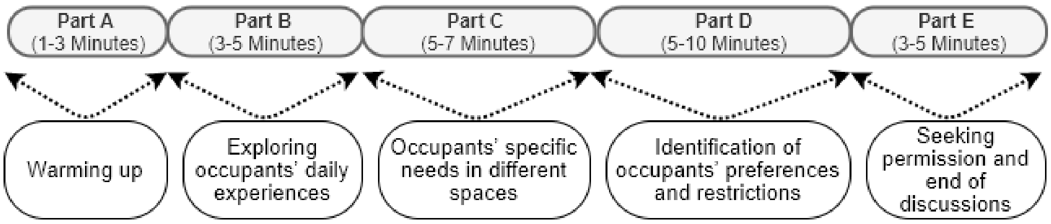

Figure 8. Segmentation of the semi-structured interview.

d. Photographic Survey

The photographic survey is a visual data collection qualitative research method used as a research tool throughout diverse individuals and communities [3, 20]. This research method can filter to explore human-environmental relationships and experiences [3, 4, 20]. Photographic surveys will be carried out to convey information about the occupants' living environments, lifestyle, behaviors and space use patterns or sequences within their existing domestic environments. Photographs will be taken in the different high-density urban dwellings in each case study area, depending on the users' behaviors, space usability and functionality in their residences. This photographic survey's primary purpose is to explore the existing compact living scenarios and occupants' patterns in high-density urban apartments. The photographic survey will be implemented anytime on weekdays or weekends to easily understand occupants' living style in different circumstances in their domestic spaces.

9. Analytical Algorithms:

a. Pearson Correlation Coefficient

Pearson's correlation coefficient (Pearson's *r*) is generally used in statistical analysis (linear regression) to measure how strong a relationship is between two variables [21, 22]. Pearson correlation coefficient (PCC) is a symmetrical algorithm developed by Karl Pearson, which means calculating the similarity of item X to item Y is the same as figuring the similarity of item Y to item X [21, 22]. The initial measures of linear correlation and significance between two variables DF and SF will be extracted from the binary data obtained from a structured questionnaire survey of occupants' present and future domestic environmental conditions and emotional responses by using the 'Pearson' algorithm.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where, n = Total number of respondents, x (Target) = SF/EM (1, 2, 3, ….n) and y (Input) = DF (1, 2, 3, ….n)

It has a value range between +1 and −1. A value of +1 is total positive linear correlation, 0 is no linear correlation, and −1 is an absolute negative linear correlation [21, 22]. The correlation and significance between DF, SF and EM factors of occupants' domestic experiences will be identified from this statistical analysis (Fig. 9).

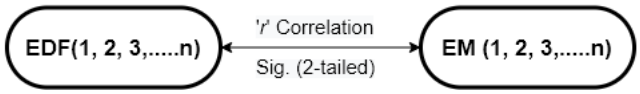

Figure 9. Pearson Correlation Coefficient between EDF and SF/EM.

b. Apriori

Apriori is a statistical algorithm for extracting association rules from data that was developed by Agrawal and Srikant in 1994 [21, 22]. This algorithm discovers frequent item sets from the data and then generates rules from frequent item sets (Fig. 10 and 11). After analysing the correlation by 'Pearson' coefficient (*r*)' and significance, 'Association Rules' can develop the relationship between DF and SF by discovering the most interesting frequent item sets or combinations for 'Mass Customisation' for the occupants to their present scenarios and future preferences. The analytical adjustment will be considered based on confidence (min. 50%), support (80-100%) and lift (+1). Variables in this analysis can be either categorical or continuous. Occupants' emotional (comfortable feeling) and design priority lists of specific spaces in their domestic environment according to their future preferences will help to develop a methodological framework of EXD for the domestic environment that may have a societal impact.

$$\textbf{Apriori} = \begin{cases} Support\ (x) = \dfrac{N_x}{N} \\ Confidence\ (x \rightarrow y) = \dfrac{\text{Support (x, y)}}{\text{Support (x)}} \\ Lift\ (x \rightarrow y) = \dfrac{\text{Support (x, y)}}{\text{Support (x)} \times \text{Support (y)}} \end{cases}$$

Consideration, support (80-100%), confidence (min. 50%), lift (+1)
N = Number of Records

Figure 10. Mathematical modeling of '*Apriori*' algorithm.

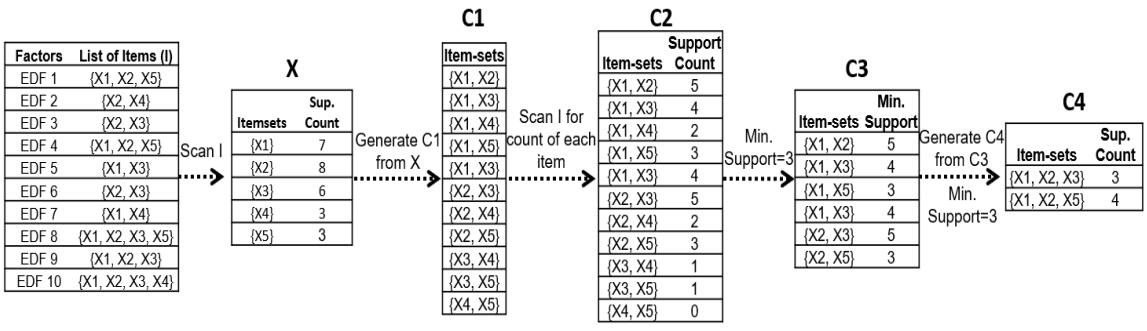

Figure 11. Demonstration of support count in association rules.

c. *Text Mining*

Text and image analysis methods are generally used to extract useful information from many narrative documents. In the text mining methods, word frequency allows to detect trends in the incidence and consider contextual information about the words commonly used in narrations [23]. Tree mapping of text/word frequency can classify and visualise the relationship between different variables. Coding means highlighting sections of text, phrases, sentences or images to describe qualitative data content. Coding helps to bring all types of sources and references together in a single 'node'. In the coding section, 'node' can gather all the responses and information in one place by thematic categorisation. Using a coding chart for a percentage of coverage, visualisation, identifying and developing content becomes easy (Fig. 12) [3, 23].

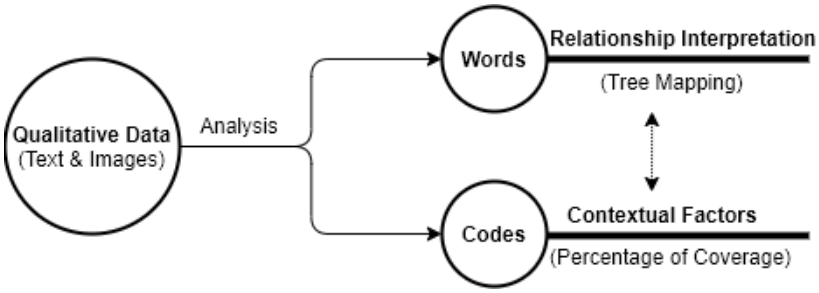

Figure 12. Text and images analysis approach.

10. Quantitative and Qualitative Analytical Tools

a. *Quantitative Data Analysis*

Statistical Package for the Social Sciences (SPSS):

SPSS is a widely used program for statistical analysis in social science. Market, health, education and government researchers also practice statistical data collection, data analysis, data mining, text analysis and data documentation by SPSS. Statistics such as descriptive, bivariate, prediction, correlation and regression analysis are included in the base software. SPSS was developed by Norman H. Nie, Dale H. Bent, C. Hadlai Hull and was initially released in 1968 [21].

IBM SPSS Modular:

IBM SPSS Modeler is a data mining and text analytics software application from IBM. It is used to shape predictive models and conduct other analytic tasks. It has a visual interface that permits users to influence statistical and data mining algorithms and machine learning software without programming. One of its main aims from the outset was to eliminate unnecessary complexity in data transformations and make complex predictive models very easy to use [21].

b. *Qualitative data analysis*

NVivo for Content Analysis:

NVivo is a qualitative data analysis computer software package used across various fields. QSR International produces this software. Australian social scientist Lyn Richards and computer scientist Tom Richards developed this software [23, 24]. NVivo supports qualitative researchers to organize and analyze qualitative data perceptions like interviews, open-ended survey responses, journal articles, social media, photo coding, and web content. NVivo also helps deep levels of analysis on small or large volumes of data are required in research.

11. Overall Research Structure

According to the above discussions, the investigation of occupants' experiences in their domestic settings, this overall research methodological approach may explore the EXD framework for the domestic environment to enhance occupants' health and wellbeing that has been illustrated in Fig. 13. However, this draft proposal of the methodological approach may help explore EXD research and be tested for further application. Hereafter, this method may need to be modified or adjusted after multiple evaluations of occupants' experiences during the study timeline.

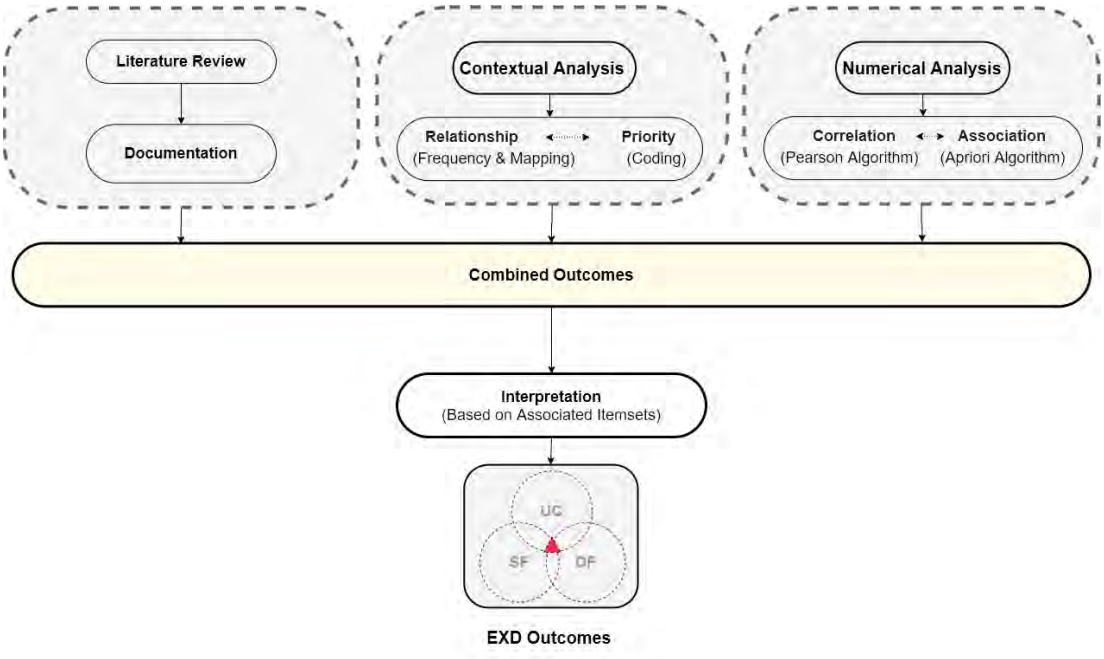

Figure 13. Summary of the overall research methods.

12. Conclusion

Structuring the EXD research methods entails systematising the architectural design decision-making process and selection prioritised of environmental design components that may improve occupants' mental wellbeing. This study aims to develop research methods to investigate occupants' environmental experiences to explore correlations between DF, SF and UC in their existing domestic environments. This overall research approach can help develop the 'Environmental Experience Design (EXD)' methodological framework of domestic environments for rural and urban housing to enhance occupants' health and wellbeing by investigating their living experiences. Subsequently, rethinking architectural design approaches to compact domestic environments into consideration not only housing or dwelling but also other built environmental scenarios that affect occupants' wellbeing before and after COVID-19 will be another concern of this research.

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A WATER SUPPLY AND SANITATION STUDY OF THE SUNDARBARI VILLAGE AROUND JALUKBARI, ASSAM

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Abstract: *This study is carried out to describe the water supply and sewage distribution systems in a rural area of Assam. Their wastes, drinking water quality and sanitary practices is quite inefficient. Various means of technology is used to demonstrate spatial relationships for a clearer understanding of problems and possible solutions. Availability of clean water and adequate sanitation facilities are of prime importance for limiting diarrheal diseases. We examined the water and sanitation facilities of a village in Jalukbari, of State Assam. Places of residence, water storage and distribution, sewage and places where people in the village defecated are mapped and drinking water sources are tested for the same village. Water in the village was found to be micro-biologically affected and unfit for consumption. This paper gives an overview of the existing water supply and sanitary condition in Jalukbari highlighting the burning problems and main issues faced by the area. The paper also suggests various methods for water management for monitoring both water supply and uses of essential measures for proper sanitation. Analysis using direct observations like surveying random houses revealed poor planning, poor engineering design and lack of proper water distribution system causing possible contamination of drinking water and from sewage at multiple sites. Until appropriate engineering designs for water supply and sewage disposal to suit individual village needs are made available, point of-use water disinfection methods could serve as an interim solution.*

Keywords: *Consumption, Sanitation, Disinfection, Contamination, Sewage.*

1 Introduction

Water is an indispensable part of human existence. Water supply and sewerage system are one of the most important constituents of society. With a growing economy and changing lifestyle the pressure on water resources is increasing. Depleting ground water tables and deteriorating ground water quality are threatening the sustainability of both urban and rural water supply in many parts of India. In Assam, mainly the supply of cities that depend on surface water is threatened by pollution, increasing water scarcity and conflicts among users. But among all of them rural areas are the worst affected areas. Lack of knowledge and awareness both are leading to the problem of proper water availability in these areas of Assam.

According to a survey conducted by UNICEF in 2011, water quality is very badly threatened, in rural areas because of poor practices in maintaining cleanliness around the borehole source, and other sources of drinking water. The term water supply goes hand in hand with the term sanitation. In other cases, the water became contaminated from natural or human-caused pollutants such as arsenic, excess iron, fluoride and other substances that degraded the water in some areas. Development of new technology was critical in expanding rural water supply and has played an important, though less successful role in sanitation. So, to improve the condition of today's Assam, we as engineers must try and improve the sanitary condition as well as make sure there is never scarcity of water in our land. The objective of the paper is to assess the current access to and the perceived water quality in the rural areas around Jalukbari, Assam with various types of water supply. The factors affecting the volume of water consumption and preferences to use alternative sources among centralized water supply users need to be identified. In addition, people's satisfaction with the quality of drinking water and the reliability of different services should be evaluated. However, the official statistics on water access per person in the area like Jalukbari do not reflect the complex realities of the current situation, therefore a questionnaire survey should be carried out in villages of Jalukbari and selected households should be interviewed to illustrate the complexity. This paper gives an overview of the existing water supply and sanitary condition in Jalukbari highlighting the burning problems and main issues faced by the area. The paper also suggests various methods for water management for monitoring both water supply and uses of essential measures for proper sanitation.

1.1 Scoping

The scope for this project involves development of systematic clean water supply and proper sanitization overcoming the challenges faced the locals. It needs to be highlighted here that the paper does not address only relevant concerns regarding the water resources and sanitization issue in Jalukbari only. The first is the issue of intersectoral allocation of water resources in all rural areas of Assam facing water scarcity so as to eliminate this problem from root, and also whether this needs to change, given increasing population and the priorities accorded to drinking water by successive governments. For the purpose of this paper, it is assumed that water allocation for Jalukbari will remain the same at best, with a possibility of reduction in the future. The second issue is the link between current population of the area, and water availability. Studies have questioned the availability of water seeing the current situation of the area of study. Various surveys followed by interviews should be taken so that the root cause of the problem is discussed and resolved.

1.2 Content

It has been rightly said that the degree to which a water-supply system and sanitation in rural areas around Jalukbari (Assam), fulfils its public health function varies almost directly with the efficiency and effectiveness of its management. This statement is corroborated by experience everywhere. In the planning of small water-systems and sanitation, it sometimes happens that enthusiastic officials and designers give too little consideration to the management phase of water-supply schemes and to the development of appropriate administrative devices for their smooth operation. Too often, public opinion regards the management function of waterworks officers as a routine job which consists of handling daily occurrences and which grows and expands under its own momentum. This assumption is far from the true facts, as good management of a water system, whether large or small, embraces a number of functions, such as : (1) provision and maintenance of adequate facilities; (2) good and smooth operation; (3) provision of a satisfying service to consumers; (4) efficient maintenance; (5) establishment of sound fiscal methods; (6) development of equitable water rates; (7) efficient organizational structure and procedures; (8) development of technical and financial plans for future expansion; (9) supervision of personnel; and (10) control of equipment and supplies. (Alua Omarova, Kamshat Tussupova, Peder Hjorth, Marat Kalishev 1and Raushan Dosmagambetova26 February 2019), Broadly speaking, the management phase of water supply and sanitation in such rural areas, can be divided into two parts : the first part, administration, deals with organization, records, finances, personnel, and supplies; the second part, operation and maintenance, is concerned with the conveyance and delivery of safe water and sanitation from source to consumers. Both are important and interdependent and must be coordinated to affect a unified and well-integrated procedure. Another significant aspect of management is timing. Good management anticipates rather than follows needs, and maintains alertness in reviewing and revising operations and procedures as appropriate. Moreover, through its public health engineering department of the above mentioned area, the health administration can be of considerable assistance to the communities in giving locally recruited persons the training and managerial experience which they require to keep the system in good operating condition and, what is most important, to ensure that the water and sanitation delivered to consumers is safe and in adequate quantity for personal hygiene and household needs. It is quite logical that, eventually, the actual administrative assistance should be taken over by the municipality itself or some other government agency. However, in this case, which may be an intermediate developmental step, the health administration must keep a prime interest in the operation of the system, beyond the simple function of checking the quality of the water and sanitation delivered to consumers of the concerned area. Finally, the time will come when local technology, facilities, and experience have sufficiently developed to enable the health administrations to resume their traditional role. Perhaps at that time the water system and sanitation in the concerned area will be operating smoothly and there will be local pressure for its continuance. It is important, therefore, that comprehensive assistance be given from the beginning, and not after trouble arises. Proper aid in management is likely to be one of the best preventive measures. According to our ideologies and manifestations, although the management phase of a water-supply system is the last item in the list of steps required for its development, it is most important to be kept in mind by policy-makers and engineering designers during the earliest planning stages. The engineer who makes the preliminary field investigations and designs can, by his decisions, facilitate or complicate future operation and maintenance problems. But searching simply for a solution wouldn’t help much, but the best solution would. The engineer in charge of field investigations and

design controls one of the most important phases, which bears heavily on the future operation of the project. If by diligent work he/she can eliminate a pump, an engine, another piece of equipment, or a treatment process, he/she is thereby removing another possible obstacle to efficient operation. The water-supply and sanitation policy, of which mention has been made previously, is expected to deal, among other things, with this aspect of design. Above all,

- Sanitation coverage needs to be accelerated here,
- Generating a push from the people to get facilities rather than expect the Government to do it (demand-led promotion) is important
- Focusing on intensive education and awareness campaigns to ensure that people understand the need for safe sanitation is necessary,
- There should be improvement in sanitation facilities by providing toilets and latrines that flush into a sewer or safe enclosure,
- Good hygiene habits should be promoted through education, also
- Proper hand washing with soap and water can reduce diarrhoea cases by up to a significant percent.

Overall, an understanding of the operational problems of small water-systems, perseverance in the search for simple solutions, and vigilance in approval of projects are the best possible measures to facilitate management of these systems and, thus, to ensure the fulfilment of their function.

1.3 Significance

India has long faced the challenge of providing safe drink to improve rural water supply, and in the mid-1980s the issue was declared a national priority. As a result, by 2011, 95 percent of Assam's rural population had access to some form of water supply infrastructure. In practice however many systems were no longer functional. The key issue was that systems were designed and constructed by state engineering agencies with little participation from local communities. Here in Jalukbari area of Guwahati (Assam), the main problem is people lacking a sense of ownership, and maintenance. Consumers also treated water as a right to be provided free-of-cost by the government, making systems financially unsustainable. Moreover, a growing population led to the mounting demand for water, with the result that water tables were falling and many water sources were shrinking or drying up altogether. The focus of this research is mainly revolves around all around development in rural areas of Assam which is only possible if there is proper sanitation system, improvement of which, is only possible if there is proper sustainable and affordable water and sanitation services . Open defecation in rural areas is a major problem that perplexes policy makers and civil society alike. India has the largest number of people who practice open defecation (626 million) and the most number of child deaths due to poor water, sanitation and hygiene conditions compared to the rest of the world. So access to proper toilets and at the same time proper sewerage system in Assam is by itself an important aspect that needs to be understood to perverse the beauty of this incredible state. (Jeyanthi Govindarajan, Kalyan Banda, Rajiv Sarkar, Srila Gopal March 2009)

2 Background of the Area of Study

Jalukbari is a locality in Guwahati, Assam, India, located between National Highway 31 and National Highway 37. The town is situated about 12 km to the west of Guwahati, in Kamrup District. Gauhati University, the first University in North East India, has its campus

at Jalukbari. Another attraction is the Saraighat Bridge, the first road cum rail bridge connecting the north and south banks of the mighty Brahmaputra River. K.K. Handique Library, Guwahati University Library, Assam Engineering College and North Eastern Regional Forest Rangers' College are also situated here.It is a beautiful place surrounded with mountains and incredible landscapes.

2.1 History

Sundarbari is a native village near Jalukbari area of Guwahati, Assam. The language spoken here mostly are Assamese, Bodo, Karbi, Rabha, Garo, Tiwa etc.

2.2 Geography

Jalukbari is a village panchayat located in the Sonitpur district of Assam state, India. The latitude 26.11 and longitude 91.83 are the geo-coordinate of Jalukbari. It is located in the UTC 5.30 time zone and it follows Indian standard time (IST). Jalukbari sun rise time varies -38 minutes from IST. The elevation / altitude here is 51 metres, above the sea level. Its Latitude is 26.11 and Longitude is 91.83.

Figure 1: Map of Sundarbari

The above figure (Figure 1) represents the Map of Sundarbari, particularly the area we have selected for our project. The total area of the region is 290,343.90 sq.km (3,125,235.90 sq.ft).

2.3 Population

The population of our dissertation area is almost 1000, with a household number of almost 250, with at most 5 members in a family. So a higher quantity of basic hygiene needs and basic food hygiene needs to be taken care of.

2.4 Economy

The Economy of this area is largely agriculture based with majority of the population engaged in it. The monthly income here for an average family is approximately 10-15000, and which can vary accordingly.

2.5 Institutions and Households

Gauhati University, Assam Engineering College, Government Ayurvedic College, Jalukbari, Sanskrit School are some of the educational institutions located in Jalukbari. Indian Institute of Technology, Guwahati is situated at around 8 km away from Jalukbari. All India Institute of Medical Sciences is going to be set up at Changsari which is 17 km from Jalukbari. Girijananda Chowdhury Institute of Management and Technology is situated at 11 km distance from Jalukbari.

3 Research Methods

The different dimensions of the rural drinking water supply and sanitation to be studied to understand the best practices with the proven experiences in the sector. Hence, the methodological questions those were associated with this become inevitable in order to interpret the social reality. Therefore, an effort was made to formulate the workable ideological understandings of this study.

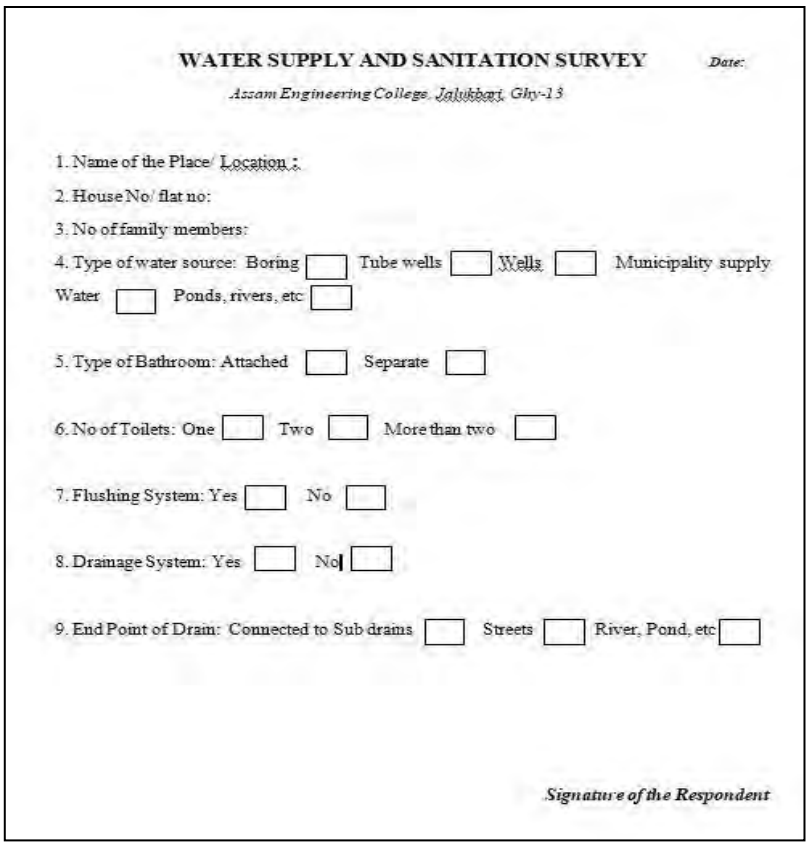
Figure 2: Flowchart of the Research Methodology

4 Field Study / Empirical Study

This study was undertaken in Sundarbari area of Jalukbari which is a district in Kamrup.This covers moderate, medium and extreme habitations and 02.00 percent of the total households of the selected habitations covered.There people use multi-sources of water due to the lack of a stable water supply system in the villages. Households usually classify them based on their purpose for using water. For instance, tap water for drinking, wells for hygiene, rainwater and thawed water for garden irrigation, etc. Even there not proper rainwater harvesting hence making the water not suitable for drinking or cooking purpose.The sanitation system in some of its part is also razing to the ground. There is lack of water making urinals and bathroom filthy as anything. There is lack of proper sewage facilities, so sometimes sewage flows through the street giving it an unbearable view. This chapter provides an explanation of the methods used in this study. First it describes the importance of social and cultural factors in water supply and sanitation development projects and the research methods used in this type of fieldwork in developing countries.Then a literature review presents the references that were consulted for this study and the methods and types of information they suggest to use and obtain to conduct a watersupply and sanitation study. Finally it describes the survey that was used to conduct this baseline study.

4.1 Surveys and Interviews

To get the whole information about the area we surveyed almost 15 houses. For getting the information more precisely we tried to get information from random houses,so that their actual living condition becomes more transparent. We prepared a format of the survey so that we could cover all the basic ideas of their water and sanitation. We tried to make the survey so basic that each and every person could answer the questions, without facing any difficulties.The format of form is shown below:



WATER SUPPLY AND SANITATION SURVEY Date:

Assam Engineering College, Jalukbari, Ghy-13

1. Name of the Place/ Location :
2. House No/ flat no:
3. No of family members:
4. Type of water source: Boring ☐ Tube wells ☐ Wells ☐ Municipality supply Water ☐ Ponds, rivers, etc ☐
5. Type of Bathroom: Attached ☐ Separate ☐
6. No of Toilets: One ☐ Two ☐ More than two ☐
7. Flushing System: Yes ☐ No ☐
8. Drainage System: Yes ☐ No ☐
9. End Point of Drain: Connected to Sub drains ☐ Streets ☐ River, Pond, etc ☐

Signature of the Respondent

Figure 3: Survey Form

4.2 Participants' Observation

The survey was carried out during July-August 2020, in two villages in Sundarbari area of Jalukbari, Assam. Overall, 15 randomly selected households were interviewed. The results revealed that even though villagers were provided with tap water, significant numbers used alternative sources. The households residing mostly near Nijorapur area of Sundarbari have lesser access to proper water supply and sanitation facilities. There were three reasons for this situation: residents' doubts regarding the tap water quality; use of other sources out of habit and suitability; and availability of cheaper or free sources. They also lacked any flushing system or proper hygienic conditions for household sanitation. Another problem concerned the volume of water consumption, which dropped sharply with decreased quality or inconvenience of sources used by households. The ratio of number of family members to number of toilets gives a clear depiction of the importance of proper water supply and sanitation, which lacks in these areas, and that proper care has to be involved. Moreover, people gave a poor estimate to the quality and reliability of water from wells, open sources and tanked water.The paper suggests that as well decentralization of water management as monitoring of both water supply and water use are essential measures. There must be a tailor-made approach to each village for achieving the Sustainable Development Goal of providing rural Sundarbari with safe water and sanitation facilities.

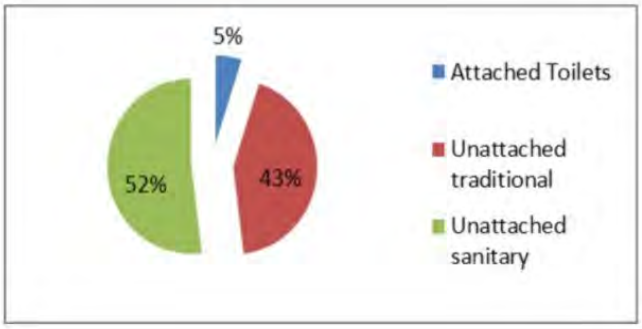


Figure 4: Bar diagram of toilet condition in Sundarbari

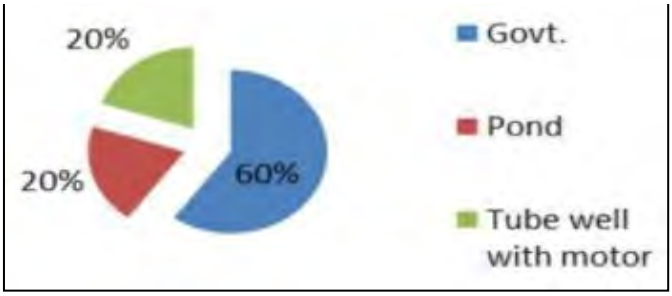


Figure 5: Bar diagram of water supply condition in Sundarbari

Rural people have to use multi-sources due to the lack of a stable water supply system in the village. Households usually classify them based on their purpose for using water. For instance, tap water for drinking, wells for hygiene, etc.
Another problem concerned the quality of water supply and sanitation for the residents from unregistered boreholes and wells in the village. These boreholes and wells were not tested for compliance with the sanitary standards before and during the operation. Also for the proper drainage system, sufficient measures has to be taken to eradicate the depletion of water quality in the Deepor Beel area. In most of the houses with drainage systems, the end points meet in this area, due to which the quality of water decreases drastically. This situation was regarded as highly unsatisfactory, since most of the population also had to use water from Deepor Beel for domestic as well as household purposes. Accordingly sanitation facilities should also be taken care of. (Andrew Wesuta, Edgar Mugema Mulogo, Fred Bagenda Micheal Matte, Moses Ntaro and Richard Apecu 26 February 2019)

5 Literature Review

The sole purpose of this research is to get an overview of the present water and sanitation condition in the rural areas around Jalukbari covering Assam Engineering College. In the last few decades a lot of research have been conducted in this water supply and sanitation domain but only a few have been able to accomplish their goals.

One of the Book that was written in this domain is 'Just Stir Gently: The way to mix hygiene education with water supply and sanitation'. This book provides options and methods for integrating hygiene education with water supply and sanitation projects. Aspects covered include the process of behavioural change; hygiene education planning, implementation program organization; manpower and costs. Illustrations and examples are used to reinforce the text and to give some ideas from "real life" situations. The book is intended primarily for those responsible for the development and implementation of hygiene education components in water supply and sanitation projects. This Book really helps to understand the most important thing that should be considered to make this research successful and that is proper hygiene education in the rural areas. (Marieke T. Boot1991)
Another work that is related with our work is the paper written by S. Cairncross, I.Carruthers, D. Curtis, R. Feachem, D. Bradley and G. Baldwin, Wiley, Chichester in 1980. The tone of this book is set by a sentence in the Introduction: 'It may seem extraordinary but it is often the case that executing agencies, both water agencies and aid donors, are not genuinely interested in knowing the facts of the impact of their activities'. This book is an attempt to show what those agencies would do were they to become more interested in the effectiveness of their work. It is strictly confined to the evaluation of existing village supplies of drinking water; there is virtually no consideration of problems of livestock supplies and irrigation, or of waste water disposal and sewerage in urban areas. It does not attempt to cover hydrology or water engineering. On the whole it is simply written and could be recommended to planning departments. It would also be useful to libraries and some students in rural training institutes teaching preventive medicine and community development. (Andrew Wesuta, Edgar Mugema Mulogo, Fred Bagenda Micheal Matte, Moses Ntaro and Richard Apecu 26 February 2019)

6 Implementation of the Study

6.1 Facts Gathering

A total of 439 houses in Assam have declared open defecation but only 47.7% use improved sanitation facilities according to a survey conducted by NFHS (National Family Health Survey). Improved facilities include proper flushing system which also includes a piped sewer system and a septic tank. Talking about proper Water supply , in Assam out of 6,367,295 households only 10.5% (9.2% in 2001) has tap water, 18.9% (26.7% in 2001) has wells and majority 59.4% (46.9% in 2001) use tube wells for drinking water followed by 11.3 % (14.6%) having drinking water from other sources.(ENVIS Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology2011)

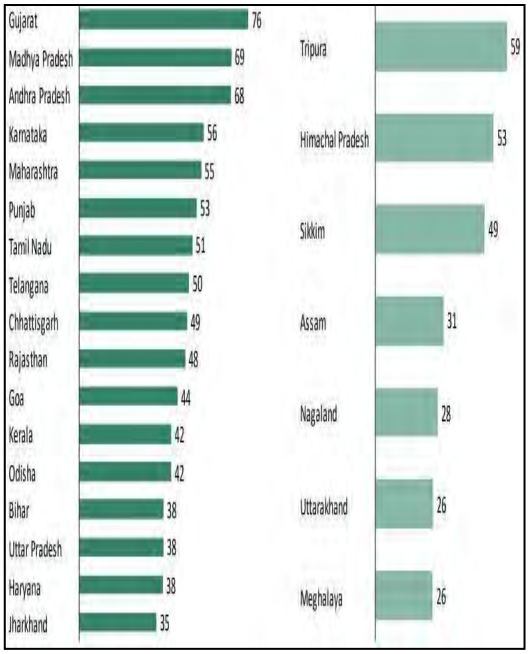


Figure 6: Water index complex

From the above it is quite clear that condition of water supply in Assam is really not good enough to cope up with the other states. Talking about the rural areas they get only 6-7% of the water they get in urban areas. In a recent interview conducted by the prestigious news media sentinel reveals that a water mafia has been operation from Beltola and it has drawing the Groundwater of the neighbouring areas in which Sundarbari along with other areas also comes into picture. Mahananda Das, a resident of Sundarbari, who has been facing drinking-water shortage for many years, said, “We have only been hearing promises and agendas and schemes of the government. Be it the present BJP or the past Congress, all have only shown us dreams. Every time there is a minimal repair to our roads in our area, but after a few days, new pipes are being laid there which further deteriorates the present conditions. The government is only laying pipes for the last 10 years or more, but the problem remains the same.” Echoing on the same note, another resident added, “Buying drinking-water has become a daily affair. The condition has turned so worse that since the past many years, it has been a monthly routine for our family to prepare a separate budget for water.” (Sentinel Assam 2020).

6.2 Evidence Collection

A deep well is one of the major sources water supply in our area of dissertation. More than 100 families depend on this kind of source of water supply. But during winter seasons water level goes down creating a major problem for the inhabitants.

Figure 7: A deep well, situated amidst Sundarbari

Such kind of tanks is also used by the people there. But it has some short comings as the temperature of the water changes along with the atmosphere. So water gets very hot during the summer days and extremely cold during the winter. Otherwise it is very cost-effective water source.

Figure 8: A Syntax Tank

Tube wells are also widely used in the area. It's cost effective and reliable but take a lot labour in drawing water.

Figure 9: A tube well, another major source of water

For some people there, Deepor beel is the main source of water supply. But for some family it is also the end point of their drains or the dumping ground.

Figure 10: Deepor beel

7 Process for Improvement of Water Supply Problems

From our perspective there various ways by which we can improve the water supply condition in the area. The ways includes both traditional and modern. Observing the lpcd (litres per capita demand) of the Households in that area.

According to WHO, the estimates of requirements of lactating women who engage in moderate physical activity in above-average temperatures, a minimum of 7.5 litres per capita per day will meet the requirements of most people under most conditions. This water needs to be of a quality that represents a tolerable level of risk. However, in an emergency situation, a minimum of 15 litres is required. A higher quantity of about 20 litres per capita per day should be assured to take care of basic hygiene needs and basic food hygiene. Laundry/bathing might require higher amounts unless carried out at source.

7.1 Methods

The population of our dissertation area is almost 1000 with a household no of almost 250,with at most 5 members in a family so a higher quantity of to take care of basic hygiene needs and basic food hygiene. There basic water requirement(LPCD) which is 40 litres per capita per day (lpcd) for humans to meet the following requirements.

Table 1: LPCD of an average household

Purpose	Quantity (LPCD)
Drinking	3
Cooking	5
Bathing	15
Washing Utensils and house	7
Ablution	10

With normal output of 12 litres per minute, one hand pump or stand post should be estimated for every 250 persons. There are many ways to improve the safety, permanence, and water quality of traditional hand dug wells. The simplest, but most important improvement to an existing well is the construction of a wellhead consisting of a head wall and a drainage apron. In case of an independent habitation, if their population is less than 250 persons and there is no potable water source within its location, one source of water supply, be it tube wells, shallow wells, municipal supply etc. should be provided.

7.2 How Do We Apply

Keeping in mind that it may be difficult for some household to get a proper boring water supply system as it is very costly so we should keep looking for other alternative sources which safe and affordable at the same time. A source is said to be safe if it is free from physical, chemical bacteriological and biological contamination and conforms to the drinking water quality standards prescribed. The recommended standards acceptable and cause for rejection for drinking water in India by WHO and BIS is as follows:

Table 2: Water quality of an average household

Sl.No.	Characteristics	Acceptable	Cause for rejection
1.	Turbidity (NTU)	1	10
2.	Colour (Units on Platinum Cobalt Scale)	5	25
3.	Taste and Odour	Un objec-tionable	Objectionable
4.	PH	7.0 to 8.5	<6.5 or >9.2
5.	*Total dissolved solids (mg/l)	500	2000
6.	Total hardness (as CaCO3) (mg/l)	200	600
7.	Chlorides (as Cl) (mg/l)	200	1000
8.	Sulphates (as SO4) (mg/l)	200	400
9.	Fluorides (as F) (mg/l)	1.0	1.5
10.	Nitrates (as NO3) (mg/l)	45	45
11.	Calcium (as Ca) (mg/l)	75	200
12.	Magnesium (as Mg) (mg/l)	30	150
13.	Iron (as Fe) (mg/l)	0.1	1.0
14.	Manganese (as Mn) (mg/l)	0.05	0.5
15.	Copper (Cu) (mg/l)	0.05	1.5
16.	Arsenic (mg/l)	0.05	0.05

Keeping in mind the above details the methods should be applied. The water in our area of dissertation has a really rich iron content which is about 1.2 mg/l, (should be below 0.3mg/l) which has adverse effects on health, and so we should try our level best to reduce the iron water and bring the level down to at least 1.3 mg/l which is consumable. So such kind of filters should be applied in water supply system, sand filters are nowadays very popularly in use and are also affordable. Usage of alum in water should also be influenced. Since the economic conditions of the area is not that high so our main aim was to provide facilities affordable for all. The idea of rain water harvesting could also be encouraged.

7.3 Expected Outcomes

The main goal of our dissertation is that water should be available to each and every household in the area of Sundarbari not only available but also the water should be safe and consumable.All people have safe access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Public water points are sufficiently close to shelters to allow use of the minimum water requirement.

Expected results:

- At least 15 Lpcd is available to each household
- Flow at each water collection point is at least 0.130 litres per second.
- There is at least 1 water point per 250 people.
- The maximum distance from any shelter to the nearest water point is 500 metres.

These are the ideal outcomes we expect from our dissertation but again it is not possible to get the exact outcomes because of time constraints and other difficulties faced during the time of dissertation, but we hope that the results will be close enough to our expectations.

8 Process for Improvement of Sanitation Problems

8.1 Methods

- By accelerating sanitation coverage in Sundarbari area.
- Generating a push from the people to get facilities rather than expecting the Government to do it (demand-led promotion).
- Focusing on intensive education and awareness campaigns to ensure that people understand the need for safe sanitation.
- Taking the scheme beyond rural households to rural schools and nursery schools, thereby promoting good hygiene practices.
- Promoting cost-effective and appropriate technologies.

8.2 How do we apply

- Further increasing political will and administrative commitment by identifying and creating local sanitation champions at higher level – for example, through exposure visits and evidence-based advocacy – and addressing key institutional bottlenecks such as by supporting the area to formulate a specific sanitation policy.
- Providing technical support to demonstrate that sanitation can be delivered in a sustainable manner.
- Supporting the strengthening of Sundarbari area and to roll out the successful models to nearby areas, eventually covering the entire region of Jalukbari.

8.3 Expected Outcomes

Sanitation is one of the most important aspects of community well-being because it protects human health, extends life spans, and is documented to provide benefits to the economy. Sanitation (e.g. toilets, latrines, mechanized wastewater treatment) is currently deployed as a way to contain and/or treat human excreta (and in some cases grey water) to protect human health and the environment. In other words, it is the one that separates "human excreta from human contact" in a hygienic manner (e.g. flush toilet, ventilated improved pit latrine (VIP), piped sewer systems, composting toilets, and septic systems). Examples of unimproved sanitation are: pit latrines without a slab and bucket or hanging latrines. Basic sanitation facilities are defined as being used by only one household and may empty on-site or are connected to a sewer system that may or may not be followed by treatment. Many sanitation facilities are however shared in both urban and rural settings. Another expected outcome of sanitation is to safely reduce human exposure to pathogens. Pathogens are excreted by infected individuals and if not properly treated, may present a risk to humans who come in contact with them. These individuals can also be exposed to pathogens through drinking water or eating food contaminated with pathogens found in human excreta.

9 Conclusion

From this study it is revealed that, although a lot of research has been done and a lot of effort has also been put trying to improve the water supply and sanitation of Sundarbari but still a lot still needs to be done to improve the situation. Moreover, it's the women of the household who fetch water for the household and looks after the hygiene and cleanliness of the house. So their education and awareness regarding safe drinking water and clean toilets is very important. Equally important is the awareness regarding the benefits of good health, as the whole i.e. good health can be achieved only by fulfilling the parts. If people are aware of the situated then it will definitely be easier to achieve the goal and create an ideal situation of the water supply and sanitation department. (WHO water, sanitation and hygiene strategy 2018-2025)

Figure 11: water quality of an average household

Safe drinking-water, sanitation, hygiene and management are the main factors for human health and well-being. We as engineers and also as a responsible citizen should try our level best to eradicate the problems as if it's our own and should deal with it more personally. We have tried and given our best to make this dissertation more precise and accurate.

10 Conflicts Of Interest

The authors declare that they have no conflicts of interest.

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BAMBOO AS A RESOURCE IN MAKING VILLAGES SMART

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Abstract: The soul of India lies in its villages, which resulted in the development of Smart Village where "Housing for all by 2022" is the slogan of the government. Traditional houses with sustainable materials such as Ikra, Bamboo, Wood, Kher (Thatch) is common in North-East and has been in use from centuries. Traditional houses constructed with indigenously available material withstood many natural calamities which can be used as models and sources for new technologies to provide a sustainable housing. With a little touch of engineering these materials can have numerous prospects. Even though there are many other locally available materials in this paper bamboo is taken into consideration because of its widespread uses from ancient time. Here, the engineering applications of bamboo for partial replacement of reinforcement in beams and footings have been tried to make the rural houses more sustainable. The performance of bamboo mats for improvement in bearing capacity is also studied. For the purpose of getting better ultimate bearing capacity bamboo grid of Bidirectional (Square) and Tridirectional (Hexagonal) aperture are placed at different depths (0.25B, 0.5B, B, 1.5B) and varied number of layers in the tests for the comparison .Thus the improved performance of various parameters/components of housing is observed by using locally available, sustainable, biodegradable bamboo in engineered way.

Keywords: *Smart Village, PAHAL, Traditional houses, Sustainable, Bamboo*

1 Introduction

India is the second most populated country in the world with nearly 138 crore people which is approximately one-fifth of the world's population. More than 70% of India's population live in villages that are associated with farming and agriculture. Over the past few years, young generations living in villages have been migrating to cities for various reasons such as higher education, better infrastructure, and increase in earning potential. This has lead to negative impact on villages leaving behind an aging population there. Taking this into account, sometimes in 2015 Prime Minister Narendra Modi's Cabinet came up with an idea to upgrade 300 villages to "*Smart Villages*". Smart Village gets its foundation from Mahatma Gandhi's vision of Adarsh Gram (model village) and Gram Swaraj (village self rule/independence). On Gandhi's birthday PM Modi launched Sansad Adarsh Gram Yojana (SAGY or SAANJHI) as a development programme for India. It is a village development plan for Personal, Human, Social and Economic dimensions. A typical village transformed into a Smart village by upgrading the infrastructure and connecting it to the bigger ecosystem.

In the concept of "*Smart Village*", the development of the village shall be based on the five paths: Retrofitting, Redevelopment, Green fields, e-Pan and Livelihood. Dhanora of Dholpur district of Rajasthan is India's first Smart Village. A decision-making need for such

smart village is implicitly recognised at present within Assam by the State Government's 2016 endorsement of the policy framework ***Assam 2030****: Our Dream, Our Commitment* (Government of Assam 2016). *Assam 2030* adopts and adapts the United Nations Development Programme's Sustainable Development Goals (SDG) for the Assamese context to improve the living standards of rural citizens and reduce the rural-urban divide. In Assam, floods being the biggest hurdle in its growth, a non-profitable foundation SEEDS (Sustainable Environment and Ecological Development Society) have built 81 bamboo houses in association with NEADS that are strong and elevated enough to withstand floods.

Housing is the basic need for the human beings along with food and water. It provides shelter to rest and gives protection. Further, housing is a criterion for the development of every individual of a nation. One of the parameters of Human Development Index is the Standard of Living (in other words, Purchasing Power Parity of the individuals) of the people in the country. Therefore, by all the above points, housing has comprehensive scope covering all the aspects of our lives from basic need of every human to the ultimate goal of a nation, Economic Development. With the launch of Indira Awas Yojana (IAY) by the then Prime Minister Rajiv Gandhi in the year 1985 the idea of sustainable housing came into being. With its continuation, Prime Minister of India in 2015 launched a programme "***Housing for All 2022***" under the scheme Pradhan Mantri Awas Yojana (PMAY-G) with the aim to provide affordable housing. The houses provided under the scheme will be eco-friendly, sustainable and economic with the usage of locally available materials. It aims to construct 2 crore houses in 4041 statutory towns and cities of the country by 2022 taking into consideration 75 years of independence of the country. The Ministry with the flagship with United Nations Development Programme (UNDP) and IIT Delhi has undertaken detailed study of 18 states for technical design, construction materials in PAHAL. The same scientific concept utilized optimally in our villages.

In India, Assam is in the north eastern part and shares its border with Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. It has hills, plain lands and river valleys. It spreads over an area of 78, 523 sq. kilo-meters. Barak Hills and the Brahmaputra Valley are its most important landmass. In Assam, maximum people live in rural areas. River Brahmaputra made Assam a very fertile area and it helps Assam to be an agriculturally developed state. Assam contains three physiographic divisions (out of the six in India) - The Northern Himalayas (Eastern Hills), The Northern Plains (Brahmaputra plain) and Deccan Plateau (Karbi Anglong).

The following three have been identified as the main criteria for design of PMAY-G houses for Assam and the state has been divided in to five housing zones –

1. Vulnerability to natural hazards
2. Physiographic and access to building materials
3. Cultural Compatibility

PAHAL[7] considers these criteria while designing the houses for the various zones in Assam. These make the idea of designing the sustainable houses for different economic sections of the people residing in Assam. The attempt made for flood control using knowledge of bamboo that has been a common source of livelihood for village community. At the end, it is not about building homes, but about building the community together.

Figure 1: Proposed housing zones from PAHAL

Table 1: Comparative description of the Zones of Assam

Parameters	Zone A	Zone B	Zone C	Zone D	Zone E
Vulnerability to floods	High (50-75%)	High (50-75%)	Low	Low-Medium	Low (25%)
Vulnerability to storms	Medium	Medium- High	Medium-High	High (speed 50m/s)	High (Near to Bay of Bengal)
Vulnerability to riverbank erosion	Low	Medium to High	Low	High	Low
Forest cover	Negligible	Negligible	75% of area	Medium	Negligible
Elevation	25-50m	75-125m	300-400m	25-150m	25-50m
Resources available	Fly-ash bricks, Bamboo	Bamboo (Chang Ghar)	Bamboo, timber,wood, stone	Fly-ash bricks	Bricks
Districts	Morigaon, Nalbari, Darang	Majuli	Karbi Anglong, DimaHasao, Cachar Hills	Goalpara, Bongaigaon, Barpeta	Barak Valley

In the early phase of the colonial period of the nineteenth century the distinctive housing patterns and materials used for construction earned the then government's attention as it withstood the massive earthquakes of 1897, which rattled Assam with hardly any damages. Even in 1950 earthquake, all the traditional hoses remain unaffected. High roofed, parallel-widened doors and windows, walls and ceilings of wooden frames plastered with mud, parallel wide sky window facilitating cross ventilation are the features of Assam Type Houses. Cities of Jorhat, Shillong, Guwahati have many such houses. Even today, many of them still proudly stand telling stories of civil engineering matching

with indigenous knowledge. Besides being aesthetically dynamic, they prove to be eco-friendly setup with sustainable features for energy, climate and comfort [9]. These are the few houses, which are still gloriously standing to test of time in various parts of Assam.

Figure 2: Assam-type houses

2 Types of Traditional houses in Assam

Ikra house

Ikra house commonly termed as “Assam type house” is widely constructed all over the state. These houses built with locally available materials such as bamboo, wooden planks, thatch etc. To fulfil earthquake requirements of safety a proper beam-column provided. Ikra houses are generally single-storied with brick or stone masonry walls up to 1m above the plinth. The walls consist of bamboo woven with wooden frame plastered with mud and cement. The roofs are of GI sheet supported on bamboo trusses. The superstructure connected to foundation walls using steel angles, flats with bolts and nails [3].

Figure 3: Ikra house

Mud house

Mud is a mixture of water with soil, silt and clay. These traditional mud houses cope with the inimical environmental. It’s a highly important and experimented archetype that exists over the years from generation to generation [3].

Figure 4: Mud house

Chang Ghar

This type of house on raised stilts is commonly found in the Himalayan region especially in dense forests, banks of river. In Assam the tribes of Mishing community live in such houses with flight of 5-7 stairs leading to these houses [3].

Figure 5: Chang ghar

Bamboo house

For the main structural member, bamboo is used in such houses. Here the wall is made of bamboo strips and plastered. Care is required to combat heavy rains. The stilted part is for gentle rains. The roofs are covered with grass which can be replaced later when required [3].

Figure 6: Bamboo house

The performance of traditional houses has been good in the region especially when earthquakes are considered. The damage due to earthquake in Ikra house is on additional stories due to amplification of ground motion along the height. No injury due to falling of light weight debris in Ikra houses. Being flexible in nature these houses do not break due to pressure from rigidity.

3 Bamboo and its Traditional uses

Jati Bah and Bholuka Bah bearing the scientific name ***BAMBUSA TULDA, BAMBUSA BALCONA*** is fastest growing woody plant belonging to grass family. Some of these species grow so fast that one can even see them growing. They are capable of growing 60cm or more in a day and can grow up to 30m or more .They grow in any climatic

condition and soil type, which is major factor for considering it. However, the growth rate depends on the local climatic condition and soil type. It attains maturity after 3yrs of its plantation and it is always advisable to go for matured bamboo for construction purpose. The density of fibres in cross section of a bamboo shell varies with the thickness as well as height. Fibre distribution is uniform at the base than at the top or the middle. In addition, it has been found that although bamboo falls partially in the wooden family yet it has strength which is greater than most of its correlates. The locally available bamboo is one such material which can be easily available and does not need skilled workmanship. Bamboo is a renewable, versatile material with high strength and low weight making it "super plant". It has continuous release of O_2 and absorption of CO_2. Bamboo is being used for construction from time innumerable and currently used as scaffoldings, framing, walls etc. It can be used in various other fields such as toys, furniture, home decoration and jewellery.

Figure 7: Applications of bamboo

With the advantages of bamboo such as sustainability, availability, economy etc being a natural product its durability is a major concern. Bamboo is prone to insects than other trees and grasses due to its high nutrient content. Insect attacks are more if starch content and humidity is more in the culm. The most popular way of treatment of bamboo is with chemical composition of CCB (Copper Chrome Boron) as- Boric Acid (1.5): Copper Sulphate (3): Sodium Dichromate (4).

Figure 8: CCB treated bamboo in RFRI

4 Literature Review

Ahirwar. S.K, Mandal. J.N **(2017)** studied the results of small-scale load tests on sand reinforced with the bamboo grid of different aperture shapes. Two different aperture shapes are used in the bamboo grid viz-hexagonal (tridirectional) and square (bidirectional) form. The effects of the location of the top reinforcement layer, size of

reinforcement, number of reinforcement layers and aperture shape of the bamboo grid were the parameters studied in the experimental investigation. The test results show that the hexagonal aperture bamboo grid provides better performance than the square aperture bamboo grid. The improvement factors in bearing pressure and percentage reduction in the settlement ratio were found 4.3% and 81%, respectively, with the use of hexagonal bamboo grid reinforcement, while these parameters were obtained 3.0% and 68% for the bidirectional bamboo grid reinforcement at the settlement ratio of 7.5%. ***Borah.M, Chetia.N*** **(2016)** concluded that flexural strength of bamboo reinforcement depends on the area of cultivation, type of species and cross-sectional area. An improved flexural performance of BRC beam with the increase in number of days of curing period and increase in the size of bamboo rebar. It recommends using steel stirrups as it improves the flexural as well as shearing capacity of beam.

Ghavami **(2003)** studied the mechanical properties of 6 different types of Bamboo, proper treatment that should be applied to it, the methods that should be employed when ultilizing bamboo as concrete reinforcement. The positive attributes of bamboo are listed supporting its eco-friendly nature. Some negative attributes are also given focusing on its tendency to absorb water. The properties of bamboo were found to be based upon a functionally graded construction, with its most important property being that its ratio of strength to specific weight is 6 times more than steel. Test results showed the ideal value for the percentage of bamboo in concrete to be 3% of its cross sectional area of concrete beam, allowing for the highest applied load, and the necessity for drying and water repellent treatments. This study concluded that bamboo can substitute steel satisfactorily, and that there is a need to establish the characteristic strength of bamboo for design purpose.

Latha. G, Somwanshi. A.B **(2009)** presented the results from the laboratory model tests and numerical simulations on square footing resting on sand. Bearing capacity of footings on geosynthetic reinforced sand is evaluated and effect of various reinforcement parameters like tensile strength, number of layers, layout and configuration of geosynthetic layers on bearing capacity is studied thoroughly. Four types of grid like strong biaxial geogrid, weak biaxial geogrid, uniaxial, geo net are used in the study. Geosynthetic reinforcement is provided in the form of planar layers, varying the depth of reinforced zone below the footing, number of geosynthetic layers within the reinforced zone and the width of geosynthetic layers in different tests. Influence of all these parameters on the bearing capacity improvement of square footing and its settlement is studied by comparing with the test on unreinforced sand. Results show that the effective depth of reinforcement is twice the width of the footing and optimum spacing of geosynthetic layers is half the width of the footing. It is observed that the layout and configuration of reinforcement play a vital role in bearing capacity improvement rather than the tensile strength of the geosynthetic material. Experimental observations are supported by the findings from numerical analyses.

Naznin. F, Chetia. N **(2015)** attempted to investigate the material properties of locally available species- ***BamboosaTulda*** and its flexural performance in beams as tension reinforcement. An average of 440N/mm^2 of tensile strength was determined experimentally for bamboo splints and a better flexural performance observed for beams with more numbers of reinforcements and shear links than those without. The test results i.e. flexural strength of 7, 28, and 45 days were taken into consideration for comparison purpose. Moreover, remarkable reduction in the mid span deflection in concrete beams observed when provided with bamboo reinforcements. Hence leaves an option of using bamboo as potential reinforcement in low cost construction.

PAHAL (2016) gives various options for different housing patterns in various states with a view to provide comfort, disaster resilience and reducing environmental damages. it provides ideas so that sustainable housing is possible with locally available materials.
***Sevalia et al* (2013)** due to high cost of steel and associated corrosion problem attempt was made to use bamboo instead of steel. The mechanical properties- tensile strength, compression strength, flexural strength, modulus of elasticity and failure pattern for both doubly and singly reinforced bamboo concrete beams were observed and tested. Doubly reinforced bamboo concrete beams were found to be more elastic than singly reinforced ones during flexural test. Modulus of elasticity of doubly reinforced bamboo concrete beams were found to be twice than that of singly reinforced beams of bamboo concrete and thereby providing scope for application of bamboo as structural and reinforcement in concrete.
***Syeda.A et al* (2011)** *concluded* that main characteristic of the bamboo which makes it a suitable building material is it's high tensile strength which is equivalent to mild steel at the yield point and very good weight strength ratio making it high resilient against the forces created by the earth quakes and hurricanes. Bamboo can replace 70% of steel and wood used in the construction and reduce the cost by 40%.

5 Studies Performed with Bamboo in the laboratory as well as in real life

Bamboo used in various fields in order to improve/change the conventional procedures. Some of them are
a. Partial or full replacement of steel in concrete beams
b. Use of bamboo mats in improving the bearing capacity of sandy soil
c. Partial replacement of steel by bamboo splints in footing

5.1Bamboo reinforcement concrete beam

Bamboo reinforced concrete stands to be a good option in the sustainable development of civil engineering construction. Many researches has been carried out in this field which helps in understanding that use of bamboo in reinforced concrete has a vast scope.The potential of bamboo as a substitute for steel in reinforced concrete has been studied by many researchers[3]. In terms of tensile strength bamboo, reinforcement is almost same to that of steel but problem arises when ductility is considered. All the samples collected from RFRI (Rain Forest Research Institute), Jorhat an institute under ICFRE (Indian Council of Forest Research and Education). Beams were cast with reinforcement cages prepared with bamboo as longitudinal reinforcement and steel stirrups. The tensile strength as high as 440N/mm^2 is obtained with a sharp peak followed by a sudden fall in the graph due to lack of ductility unlike steel in the testing process [6].

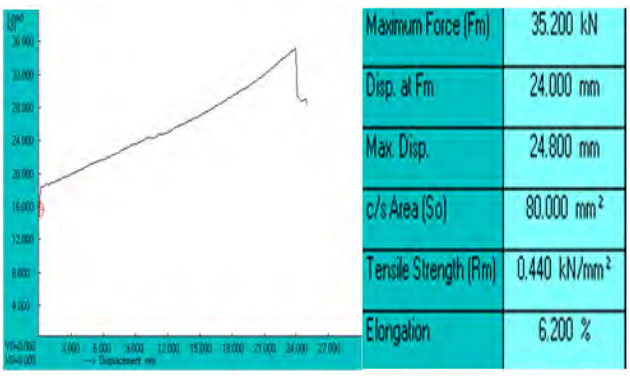
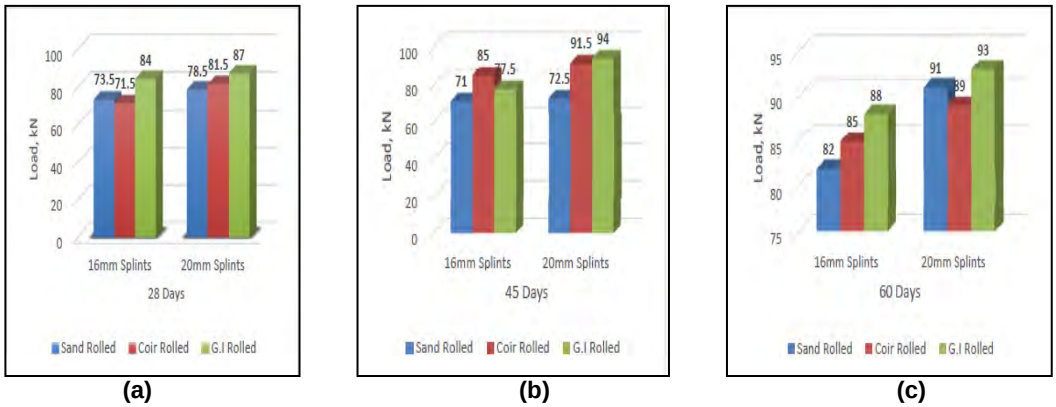


Figure 9: Load vs Displacement curve for 16mm bamboo splints

An improved flexural performance of BRC beam has been observed with the increase in number of days of curing period and increase in the size of bamboo rebar. It is also recommended to use steel stirrups as it improves the flexural as well as shear capacity of beam [4].



(a) (b) (c)

Figure 10: (a),(b),(c)Load v/s Curing period (28 Days;45Days;60 Days)

From literature study, also it is clear that doubly reinforced bamboo concrete beams are to be more elastic than singly reinforced ones during flexural test. Modulus of elasticity of doubly reinforced bamboo concrete beams found to be twice than that of singly reinforced beams of bamboo concrete [8].

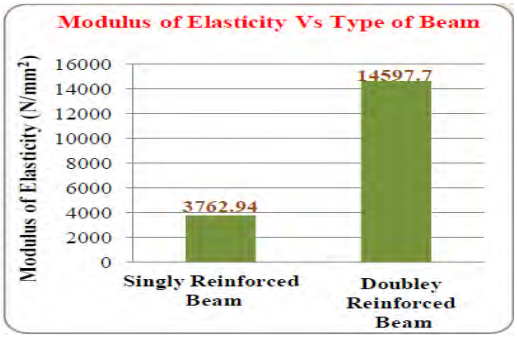


Figure 11: Comparison of Modulus of Elasticity of Singly Reinforced and Doubly Reinforced Beam

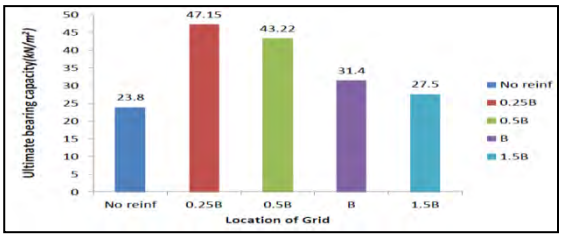
5.2Bamboo for soil improvement

Ground improvement is a necessity due to lack of adequate quality of land available in the present world. Soil reinforcement is such technique available to enhance the quality of soil. Soil reinforcement with bamboo to improve the bearing capacity of the soil is one such technique. An effective use of bamboo depends upon the configuration of mattresses. The parameters studied in this experimental investigation included the effects of the location

of the top reinforcement layer, size of reinforcement, number of reinforcement layers and aperture shape of the bamboo grid. The improvement of bearing capacities due to installation of bamboo layer represented by a non-dimensional factor called "***Improvement Factor***" [2]. The factor defined as the ratio of ultimate bearing capacity of shallow foundation with bamboo layer to the ultimate bearing capacity of shallow foundation without it.

The tests are conducted considering two types of bamboo grids viz square aperture bamboo grid and hexagonal bamboo grid. The study is conducted to observe the results to reduce settlement and bearing capacity. A comparative study is done with and without the bamboo grid. A model footing is placed on medium density Zone III sand and the bamboo grids are at various depths 0.25B, 0.5B, B, 1.5B (where B is the diameter of footing). The load-settlement curve is obtained according to IS: 1888-1982 (Method of load test on soil). In case of bearing capacity of soil, it increases with the insertion of bamboo grid calculated from Improvement factor. For varying depth, the improvement ratio for bearing capacity increases when the difference between top layer and footing is less for both Bidirectional Bamboo Grid (BBG) and Tridirectional Bamboo Grid (TBG). Due to the aperture shape the resistance offered by TBG is more compared to that of the BBG for the same size of the reinforcement. It can be observed that the aperture shape of reinforcement also plays a vital role in the enhancement of load carrying capacity of footing. The settlement observed on the reinforced sand bed with three layers of TBG reinforcement is less as compared to the same number of layers of BBG reinforcement. In case, bearing capacity the bearing capacity is more in three layer of TBG. Thus, it can be concluded that (N=3) of TBG is more effective than (N=4) of BBG.

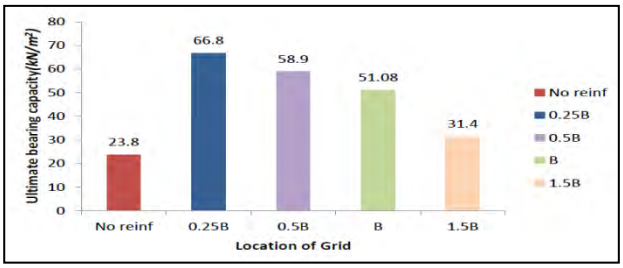
(a)



(b)

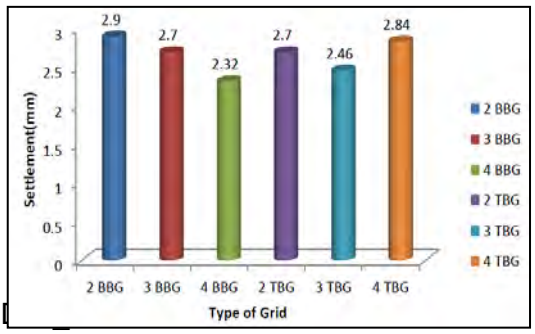
Figure 12: (a) Square aperture bamboo grid (b) Comparison of bearing capacity with location

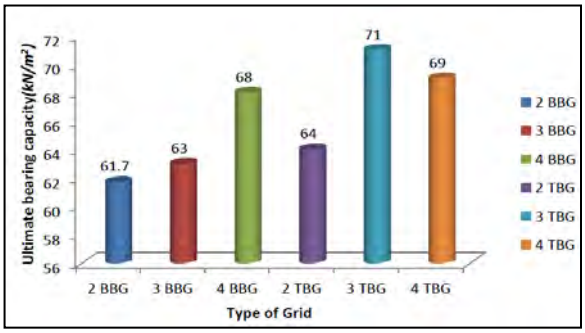
(a)



(b)

Figure 13: (a) Hexagonal aperture bamboo grid (b) Comparison of bearing capacity with location





(a) (b)

Figure 14: (a), (b) Comparison between type of grid with settlement and ultimate bearing capacity

5.3Bamboo as building components in field

In general, traditional Assam type house the load is comparatively low to other buildings such as RCC. This results in low pressure on footings and correspondingly less bending moment, which can be resisted by bamboo reinforced mats. Using the technique a house constructed in Rain Forest Research Institute, Jorhat where all the footing jalis were prepared from treated bamboo splints. The relevant photos are attached in Fig 15.

Figure 15: Bamboo reinforcing mat in RFRI, Jorhat (Courtesy: R.Kalita)

6 Conclusion

Bamboo being easily available in this region of North East India, research to find out its various properties and applications are still going on. In many cases, it can be a good substitute for steel and wood. It is eco-friendly in nature thus helping in maintaining the ecosystem .From the studies, it is apparent that engineered bamboo (properly treated) can be an economic and sustainable solution for many of construction methods/processes such as partial replacement of steel in low cost housing and for many geotechnical appliations.

Acknowledgements

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BANKFILTRATION AS WATER SOURCE: A CASE STUDY OF PHUENTSHOLING, BHUTAN

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Abstract: *The natural water treated through bank filtration (RBF) could be a sustainable alternative to the problematic conventional water treatment schemes of drinking water supply in Bhutan. Based upon a request by the Water and Sanitation Division (WSD) of the Royal Government of Bhutan, the investigation was taken for the technical feasibility of RBF for water supply to the town of Phuentsholing in southwest Bhutan. The borehole logs, riverbed sediments and microbial density of the rivers and groundwater were analysis.*

Result suggests that aquifer thickness is more than 15 m at the riverside, it can decrease to the landward side where the proposed RBF well location, because of the eventual proximity to the base rock of the hill and decrease of saturated aquifer thickness.

The coarse grained floodplain material implies a high hydraulic conductivity and large fluvial boulders deposit but the large impermeable boulders, with finer grained sediments lodged between the boulders can reduce a substantial amount of groundwater flow cross-sectional area. This could also lead to a reduction of the effective hydraulic conductivity from the river side. Consequently, horizontal flow of water towards the well would be reduced. Thus, it has appeared that in such hydrogeological characteristics (limitations of aquifer thickness and hydraulic conductivity) there required at least three wells (abstraction Q = 65 m³/hour per well) to six wells (Q = 35 m³/hour per well) or eventually more vertical wells to meet the demand of 3,000 m³/day (3 MLD) or 125 m³/hour, because an abstraction rate of 125 m³/hour cannot be met from a single well

The water is also expected with no coliforms and a character of glaziers melt water. Hence, RBF is can be installed in Phuenttsholing state of Bhutan Kingdom.

Keywords: *Bankfiltration, drinking water, Sustainable Development, aquifer, hydrogeological*

1 Introduction

The Kingdom of Bhutan has abundant water resources, however accessing them for drinking and irrigation is difficult due to the country's mountainous terrain (Dorji, 2016). Moreover, Bhutan has been identified as exceptionally vulnerable to climate change with the biggest impact expected to be to the hydrological system (Mahanta et al., 2018). Consequently, in a study by the Asian Development Bank (Dorji, 2016), rural drinking water and sanitation and urban water management have been identified as the foremost of five critical areas of water management in the country. In rural areas, communities are dependent on small streams and springs. But as a result of climate change, the quantities of this water are decreasing up at sources. On the other hand, in urban areas water issues pertain primarily to quantity. In this context, with migration from rural areas, municipalities are facing increasing challenges in meeting the growing water demand, both in terms of quantity and quality.

Bank filtration or riverbank filtration (BF/RBF) is a well-proven sustainable water treatment step, which is used at numerous sites as a part of a multi-barrier approach to drinking water supply (Grischek & Ray, 2019). RBF general neutralized the quantity of water through the bank- / bed storage and can thus be considered as an element of managed aquifer recharge (MAR) and Integrated Water Resource Management (IWRM) (Grischek et al., 2019). Many case studies highlighting the sustainable character of RBF from the mountainous Himalayan state of Uttarakhand in North India can be found in the literature. Extensive research and field experiences since 2005 by the HTWD and its partners on the intentional use of RBF in Uttarakhand (compiled in Dobhal et al., 2019) have confirmed that RBF is an ecosystem service due to a high natural removal of pathogens (> 99.99%). It is a sustainable alternative or a supplement to the direct abstraction of surface water and conventional treatment, especially during monsoon because of the high removal of turbidity and RBF wells can be made flood-proof as demonstrated for the case study site of Srinagar by the Alaknanda River in Uttarakhand (Musche et al., 2018).

In the above context and considering that Uttarakhand and Bhutan have similar geographic characteristics and face similar water resources management challenges, especially for drinking water production, it is decided to explore the possibility of applying in Bhutan for water production.

1.1 Study Area

In consultation with the Water and Sanitation Division of the MoWHS, it is proposed to construct a pilot RBF scheme for the Phuentsholing municipality's Amo Chu WTP. The town of Phuentsholing is the commercial capital of Bhutan and adjoins the Indian town of Jaigaon (Figure. 1). The Amo Chu WTP is proposed to be constructed approx. 5–6 km upstream of Phuentsholing town (Figure. 1). The RBF pilot well is proposed to be constructed in the vicinity of the site for the proposed WTP, eventually even within the premises of the WTP if hydrogeological conditions are favourable.

The site is located in the town of Phuentsholing, one of the four major municipalities (Thromde) in Bhutan. It is located in the south western Siwalik foothills of the country on the left bank of the Amocchu River. Details of the location are given in table 1. The floodplain at the proposed site is approx. 500–700 m wide at the site. The main river channel separates into two channels at the start of the meander. The width of the channels at the time of the measurement was found between 30 m and 50 m and the distance from the proposed site for the RBF well to the waterline of the nearest channel was approx. 100–110 m.

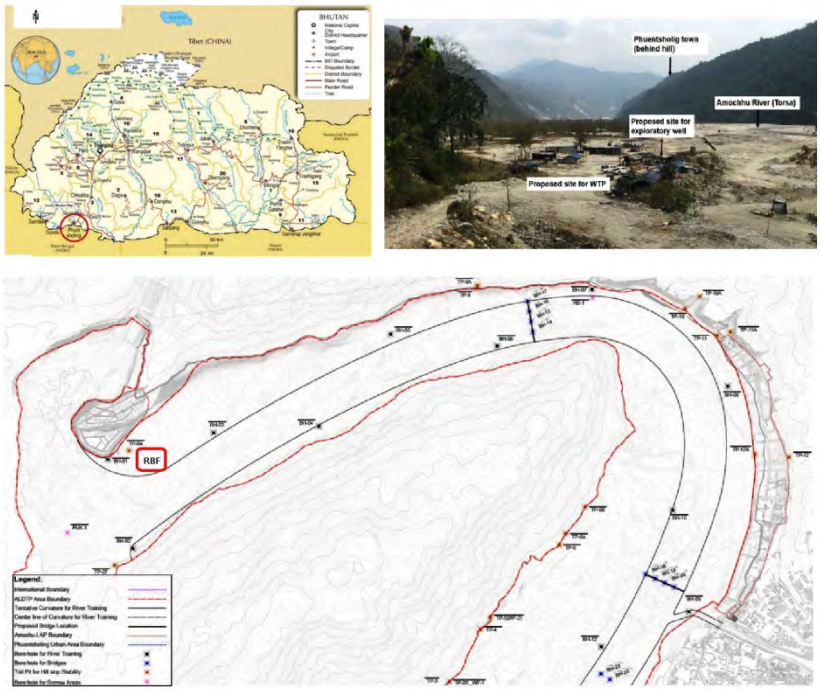

Figure 1: Study area: Location of RBF plant at Bhutan

The site for the proposed water treatment plant and RBF well is relatively flat and the ground surface elevation is estimated to be between 227 and 230 m ASL

Table 1: Description of the study area

Sr.No	Description	-
1	Name of the Location	Phuentsholing
2	Lat & Long	26°52'42.95"N; 89°20'3.55"E
3	Name of the river	Amocchu River
4	Population#	23,925 souls
5	Area Cover	15.6 km²
6	Average annual flow$	297 m³/s
7	Well distance from the river	100-110 m
8	Ground surface elevation	227-230 m ASL
#as per the structural survey 2013 by Thromde 2017; $Dorji, 2016)		

The 358 km long Amochhu River originates in the Chumbi valley in the Tibet Autonomous Region, flows through western Bhutan and enters India (as Torsa River) at the Phuentsholing-Jaigaon border. The Amochhu catchment area is 2,298 km², which is about 6% of Bhutan's total land area (Dorji, 2016).

2 Methodology

The feasibility study for the application of RBF, including the design of the RBF scheme, for the Amo Chu water treatment plant (WTP, capacity 3 MLD) was taken in the first week of March 2020. A team comprises of HTW Dresden and BBEC Kokrajhar visited to select the location for the pilot RBF well(s) and to design the scheme, it is mainly necessary to determine the following crucial parameters:

- saturated aquifer thickness,
- grain sizes of the aquifer sediment
- hydraulic conductivity of the aquifer.
- water quality

Visual reconnaissance and desktop analyses of all accessible literature and information relevant for proposed RBF on topography (topo-sheets,maps), subsurface lithology, surface and groundwater levels and water quality in context to geo-hydraulic conditions, safety against annual monsoon floods, seasonal variation of distance between well(s) and river and also on pathogen and turbidity levels in river water were carried out. The water samples were brought to the laboratory of the waterworks under Water and Sanitation Division (WSD), MoWHS, Royal Govt. of Bhutan for quick determination of bacteriological parameter as per colillert-18 procedures (IDEXX) and grain sizes analysis as per IS:2720 of BIS 2006 at Civil Engineering Laboratory lab of Bineswar Brahma Engineering College, Kokrajhar. Risk-assessment was also performed after Schmidt et al., (2019) for the RBF site.

3 Results and Discussion

3.1 Hydrogeology and Subsurface lithology

The floodplain of the proposed bank filtration site consists of unconsolidated glacio-fluvial deposits of poorly sorted boulders, pebbles and sands that are typically found in piedmont areas (also referred to as Terai) in the foothills of the Himalayas (CGWB, 2014). The visual observation of the sediments in the wide river channel at the site during the reconnaissance indicates that the site has mainly medium-coarse grained sand and gravel (pebbles) to large fluvial boulders (Figure 2). These sediments are similar to at the RBF site in Haridwar by the Ganga River with 22 wells (Uttarakhand, India). The RBF wells in Haridwar have been in operation for more than 50 years and abstract water having sustainable quality and quantity.

Figure 2: A visual estimation of riverbed sediment at the proposed RBF site

From the data from the borehole trail pits dug up to the depth of 15-18 m in the land reclaimed project from the Amochhu floodplain, it revealed that the aquifers consist of very dense greyish brown medium sand with gravel also cobbles and boulders up to a depth of 15m BGL in all boreholes. In BH-01 that is the deepest (18 m) and closest to the proposed RBF site, medium to very dense greyish black sand was found from 15 to 17 m BGL with highly weathered greyish black rock at the bottom (17 – 18 m BGL) detailed given in Table 2. The subsurface material appears to be similar across the floodplain, it can be concluded that the aquifer is unconfined and in direct contact with the river that are both favourable conditions for RBF. Considering this, it can be estimated that the saturated aquifer thickness in close proximity to the river is approx. 15 m. The hydraulic conductivity estimated based on Kozeny-Carman equation from the grain size distribution curve is

found 2.3 x 10^{-3} m/s. Here the effective (d_{10}) grain size is 0.45 mm, suggesting highly porous kinds of aquifer materials.

Table 2: The data of the cell growth and substrate loss

Borehole #, Depth (m BGL)	Ground surface elevation (m ASL)	Depth (m BGL)	Visual description of subsurface material
BH-01, Depth: 18	226.83	0 - 15	Very dense greyish brown medium sand with gravel, cobbles & boulders
		15 - 17	Medium to very dense greyish black sand
		17 - 18	Highly weathered greyish black rock
BH-02, Depth: 15	220.50	0 - 9	Very dense greyish brown medium sand with gravel, cobbles & boulders
		9 - 15	Very dense greyish brown medium sand with less gravel, cobbles
BH-03, Depth: 15	221.37	0 - 15	Very dense greyish brown medium sand with gravel, cobbles & boulders
BH-04, Depth: 15	215.63	0 - 15	Very dense greyish brown medium sand with gravel, cobbles & boulders

3.2 Determination of bacteriological indicator counts

The water sample was collected from the Amocchu and the Omchhu Rivers (a tributary of the Amochhu) and a mixture of water from different wells from the groundwater well field in Phuentsholing town on 4 March 2020. Results in mixed groundwater are satisfactory, although a slightly elevated total coliform counts (13.5 MPN/100 mL) were observed, no E. coli was observed indicating relatively good bacteriological groundwater quality in the town's well field (Table 3). Aesthetically, the water quality of the Amocchu is good and the total coliform and the E.coli counts are comparable to those in rivers at RBF sites in Uttarakhand in India. The counts for the bacteriological indicators are high in the Omchhu River because of the high wastewater input from the town and low flow compared to the Amochhu. The water quality of the Amochhu is also favourable for RBF considering the relatively low bacteriological indicator counts and that the pollution from organic compounds is expected to be low as there are no major industries upstream. Suggesting suitable for bank filtration system if sufficient distance or travel time is maintained between the wells and the river.

Table 3: Total and E. Coli counts in water sample

Sample (number of samples)	Dilution	Total coliform count [MPN/100mL]	E. coli count [MPN/100mL]
Groundwater well field (1)	No dilution	13.5	0
Amochhu River (1)	1:10 & 1:100	15,531 – 52,470	225 – 300
Omchhu River (1)	1:1,000	1,732,900	280,900

3.3 Analysis of Entry-Level Risk-assessment

The entry-level risk-assessment is performed based on science-based procedures derived from previous experiences of the RBF site of Haridwar that has some similar hydrogeological conditions to Phuentsholing (Page et al., 2010; Bartak et al., 2015; Schmidt et al., 2019). In the present study, the main risks are from the unknown parameters saturated aquifer thickness at the proposed RBF well location and the hydraulic conductivity and the risk of flooding during monsoon. Even though the aquifer thickness is at least 15 m at the river, it can decrease to the landward side where the proposed RBF well location is because of the eventual proximity to the base rock of the hill. From a first glance, the coarse grained floodplain material implies a high hydraulic conductivity, which also suggests from the grain size analysis.

Table 4: Risk Assessment Analysis

1.	**Simple assessment (Y/N)**	**Remark**
a	Is the aquifer for the proposed RBF site, to be used for drinking water supply? local floodplain aquifer proposed to be used for RBF and no other abstraction-**Y**	Low risk
b	Is the scale of the proposed RBF scheme larger than domestic rainwater harvesting (RWH)? **N**; no domestic RWH, only natural and induced recharge at RBF site	Low risk
c	Does the source water (river) contain sewage effluent, industrial wastewater or urban stormwater? **Y**; but only in low concentrations because of low impact from anthropogenic factors upstream	Low risk
d	Is the area around the recharge area ever waterlogged? **N**	Low risk
Simple assessment is satisfied if all answers are "No". Then no need to continue assessment because there is a low inherent risk. However if any answer is "Yes" proceed to Viability assessment.		
2	**Viability assessment (Y/N)**	
a	Is there a sufficient demand for water? **Y**; 3,000 m³/day (3 MLD),125 m³/hour (at 24 hour/day operation)	Low risk
b	Is there an adequate source of water available for RBF? **Y**; perennial Amochhu River	Low risk
c	Is there a suitable aquifer for RBF? coarse-grained aquifer at river 15 m thick, aquifer thickness and hydraulic conductivity at proposed well location determined , crucial parameters to be confirmed **Y**	Low risk
d	Is there sufficient space available for RBF and eventual post-treatment measures? **Y**	Low risk
If the answer to any question is "No", then the project is not viable or else it has has a major constraint. If answers are "Yes", then proceed to Guidelines applicability assessment.		
3	Guideline applicability assessment **(Y/N**)	
a	Is the source of water for RBF only from a natural catchment including rural / overland runoff with less human activity and / or snow melt (not much affected by sewage effluent, industrial wastewater or urban stormwater)? **Y**	Low risk
b	Is the aquifer unconfined and not polluted? **Y**, aquifer is unconfined. Water quality to be determined as no groundwater quality data available and no (monitoring) wells exist at proposed RBF site.	Low risk
If answers are "Yes", then monitor / compare quality of water from RBF wells to water quality standard and if any parameters exceed permissible limits, then consider post-treatment measures		
4	Sanitary survey **(Y/N)**	
a	Is there a latrine (unsealed, open-pit), open sewer or leaky sewer or human (open defecation) or animal faeces within the catchment area of, and/or in close to proposed RBF site? **N**	Low risk
b	Are there industrial, transport or agricultural activities generating stockpiles, wastes, spills or emissions reaching the surface of the catchment area of, and/or in close to proposed RBF site? **N**	Low risk
c	Is there proposed post-treatment of water to be recovered? Y (likely), to be confirmed depending onabstracted water quality.	Low risk
d	Does the existence and condition of any barriers around of the proposed RBF site/well prevent short circuit of contaminated water? Appropriate well-head and flood-proofing measures must be implemented	Low risk
Any question answered by Yes needs to be taken into specific account in the Water Safety Plan. Even if not observed, the possibility of these hazards occurring or barriers being breached also needs to be taken into account. Proceed to Aquifer assessment		
5	Aquifer assessment **(Y/N)**	
a	Does river water have low quality; is water turbid, coloured, contains algae, has a surface slick or does it smell? **Y**; mainly high turbidity during monsoon and presence of pathogens	Low risk
b	Are there other groundwater users, groundwater-connected ecosystems or a property boundary within 100m of the proposed RBF site? N	Low risk
c	Is the aquifer known to contain reactive minerals (e.g. pyrite) or is groundwater in this area known to contain arsenic? Does the aquifer contain soluble minerals such as calcite and dolomite? **N,** indication presently, needs to be confirmed.	Low risk
d	Is the aquifer composed of fractured rock or karstic (fissured or cavernous) limestone or dolomite? **N**	Low risk
Any question answered by Yes needs to be taken into specific account during drinking water production from the RBF scheme. Even if not observed, the possibility of these hazards occurring also needs to be considered.		

However, the large fluvial boulders indicate that a substantial amount of groundwater flow cross-sectional area could be reduced (by the impermeable boulders) with finer grained sediments lodged between the boulders. This could lead to a reduction of the effective hydraulic conductivity and consequently horizontal flow of water towards the well would be reduced

Conclusion

The interpretation of data and information from the site and desktop analyses indicate that the proposed site is generally suitable for RBF (Table 4). The risk assessment concludes that there are low inherent risks and further investigations should be pursued to quantify the feasibility of RBF at the project site. Calculation of aquifer capacity, well yield and the number of wells required to meet the water demand of 3,000 m³/day or 125 m³/hour (3 MLD) on continuous well operation (24 hours x 7 days pumping) after judging the present hydrogeological characteristics (limitations of aquifer thickness and hydraulic conductivity) at least three wells (abstraction Q = 65 m³/hour per well) to six wells (Q = 35 m³/hour per well) or eventually more vertical wells would be required to meet the demand because 125 m³/hour is too high to abstract from single well. An alternative to the construction of numbers of vertical well, once could construction of a large diameter caisson well. But the feasibility of a caisson well would also depend upon the aquifer conditions as derived from an exploratory well. Thus, RBF well for water supply at Amocchu River bank of Phuentsholing town could be use for construction of water abstraction wells based on current study.

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SMART RURAL HUB: A RESILIENCE APPROACH IN BANGLADESHI 'CHAR' COMMUNITIES

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Abstract: *Bangladesh slopes gently in north-south direction forming a flood-plain delta, meeting the Bay of Bengal at south and is one of the most vulnerable countries to sea level rise due to climate change as per various reports. The coastal region is also susceptible to cyclones, storm surges and tidal flooding. Webbed by numerous rivers and canals, erosion and accretion of land is also common in the central coastal zone. The southern district Bhola is the largest island in the country consisting numerous river Islands, known in Bangla as a 'char'. Studies show that the communities in these 'chars' are facing threat of displacement and climatic migration in the near future. To mitigate this and increase sustainability, the government has taken up numerous projects. In line with these, this study aims to analyse the local life pattern of the villages in 'Char Kalmi' union of Bhola district and proposes a community hub to address the contemporary needs of the coastal-rural 'char' communities. The focus of this study is to design a community central hub, coined 'Smart rural hub', or SRH, in a modular and replicable approach that will satisfy the community requirements like village market, special schooling and distance learning, aiding NGO's and other voluntary organizations to deliver their services, housing festival gatherings and also act as a cyclone and flood shelter, isolation centre in case of communicable diseases and awareness hub. This multi-objective SRH will be built with used shipping containers with the aim to reduce carbon footprint, provide resilience against cyclones, and aid to socio-economic, ecological and cultural sustainability. The proposal is expected to have the potential to be adopted in other areas of similar context as well to increase community resilience and mitigate climatic migration by ensuring much needed development facilities.*

Keywords: *rural development, 'Char', community hub design, shipping container architecture, coastal resilience*

1 Introduction

Disparity between the development of urban and rural communities has become more apparent as the world dives deeper into the era of technology. Ideas to decrease the gap of convenience and comfort between these communities are emerging worldwide, aiming towards holistic development, without disrupting the natural features of these societies. This research adds to this section of study by addressing the contemporary needs of the coastal-rural river-island, or as known in Bengali – 'char', communities, in the villages of Char Kalmi Union – Char Maya, Char Patanangla, Dakshin Char Mangal, Uttar Char Mangal and Uttar Char Maya (Department of Public Health Engineering (DPHE), 2018) – in the island district Bhola in Bangladesh. This is done by attempting to design a community hub, coined 'smart rural hub' or 'SRH', that is contextual, sustainable, resilient, participatory and cohesive to the socio-economic notions of the area. Here, the word 'smart' denotes the grassroot-level design considerations in rural context for the general well-being of the village community to increase their resilience; rather than meaning technological interventions. The coastal storm surge threats are taken into critical consideration, with the intention of providing an architectural resolution to community needs in 'char' areas by proposing a modular, multi-objective and multipurpose community hub, made chiefly from repurposed shipping containers, that reverberates smart village development ideas.

Bangladesh is prone to natural disaster and faces, every year, floods, water-logging, tornado, cyclone, thunderstorm, river/coastal flooding, tidal-surge, landslides, salinity intrusion, hailstorm etc. due to topographical features and geographic location (Islam 2016). About 12.64% of the entire country's population reside in disaster susceptible areas and among them, 38% have no education and are unaware of disaster threats (Islam 2016). Barisal Division, where the study area – Char Kalmi Union, Bhola – is located, surpasses other divisions in terms of damage from cyclone (78.31%) and storm/tidal surge (31.51%) (Islam 2016). Moreover, the study location is one of the most storm-surge prone areas in the country (Comprehensive Disaster Management Programme (CDMP II), 2014). The inkling to reuse shipping containers for this study came from keeping these facts in mind. Meagre financial revenues and widespread ecological impairment have been produced from a vast amount of administration associated difficulties in the coastal zones of Bangladesh, which has made its population suffer (Islam, Xue and Rahman, 2009). Had good management practices been followed, several of the complications and associated sufferings could be evaded (Hossain 2001). As a consequence of landlessness, deficiency, employ shrinkage amid the deprived and disregarded, river destruction, and natural disasters, hordes of individuals and families migrate to urban areas each day, and often face extreme poverty, (Reza and Rahman, 2019), which is undesirable. Numerous public, private and non-profit organizations have been capitalizing in mitigation actions and inventive resolutions to make affected people and communities more resilient and this study aims with the SRH proposal to aid to this body of knowledge and transfer it to practice in rural areas in the path of smart developments of rural population. The idea is to propose a rural hub, that focuses on capacity building of associated communities, facing environmental calamities, urban-rural disparity and knowledge deficiency, to make them self-dependant, empowered and resilient.

1.1 Aim and Objectives

This investigation aims to generate resilience within 'char' communities facing disasters and urban-rural disparity to build their capacity to tackle their challenges by proposing a

community hub, that embodies the notion of sustainable development, through an architectural solution in the context of coastal 'char' regions of Bangladesh. The specific objectives of the research are:

Table 1: Specific Objectives

#	Description	Method(s)
a	To analyse the problems of 'Char' communities	Literature Review, contextual need analysis
b	To outline the needs of disaster-prone context	Literature Review, survey findings
c	To analyse the use of containers as a resilient and sustainable construction unit	Literature review
d	To establish a 'smart rural hub' design by incorporating environmental, economic and socio-cultural aspects	Analysis of Site, Problem and Literature, Design Proposal
e	To line up the design with the notion of smart villages	Analysis of context, Design features and Discussion

1.2 Scope and Limitation of the study

This paper proposes an SRH design that incorporates the essence of 'Char' communities facing cyclones and storm-surges and is focused on rural lifestyle. With need-based contextual modifications, this design may be deemed appropriate in similar geographical and socio-economic settings. However, the study is limited to the rural practices, social dynamics of 'char' communities and climatic condition of the area. Also as an unbuilt design proposal, the outcomes are yet to be determined and can only be speculated at this moment.

1.3 Organization of the paper

The paper is organized in several parts. First, literature review is presented which consists of background study, problem identification, concept generation, selection of appropriate construction unit and technique, and determining functional aspects of the design proposal. Second come the methodology section where the methods of the research and data collection is described. This is followed by the design proposal, which embodies insights gained from previous studies, professional expertise of the researchers, and most importantly contemporary contextual needs. Finally, the discussion and conclusion at the end to conclude the study with indication towards future applications.

2 Literature Review

This section discusses the literature study of the topic of interest for this paper addressing key points to consider, highlighting different aspects of the research. It presents the researchers' view on the study site, significance of 'char' communities, conception of SRH, reason to select shipping containers and the basis of design functions of the proposed SRH.

2.1 Significance of 'Char' areas, community and the study site

Caused by deposit in a river path or estuary, a 'char' can be defined as an expanse of land encircled by a water body, usually rivers in Bangladesh, and can be of two types – independent of or attached to the riverbank (Banglapedia, 2014). There are more than 300 such sandbar islands or 'chars' in Bangladesh, with a population of about 20 million

(Zaman, 2019) and these areas are among the most deprived regions of the country. The residents of 'chars' are mostly susceptible to extreme scarcity and insolvencies due to delicate atmosphere, inadequate resources, condensed revenue prospects, inaccessibility, and absence of inland organisations and facilities (RDCD, 2011). The government has launched numerous projects for development of these 'chars', namely the Char Development and Settlement Project, however, they are limited still to only the northern part of the country and areas like the chosen study area on the southern part are mostly underdeveloped (RDCD, 2011). People still opt to live in these areas as most of them have no other options and due to the river erosion problem of Bangladesh, these 'chars' provide an opportunity to recover lost habitat (Hessel, 2013). 'Chars' have dynamic properties due to the constant accretion and erosion of it (Sarker, Huque, Alam and Koudstaal, 2003), making life here even more vulnerable to nature.
In this perspective, this study focuses on the development of 'char' communities through the proposed design to significantly bridge the gap between the inland and 'char' life quality in the study site 'Char Kalmi', shown in Figure 1, as well as holistically develop resilience of the village communities.

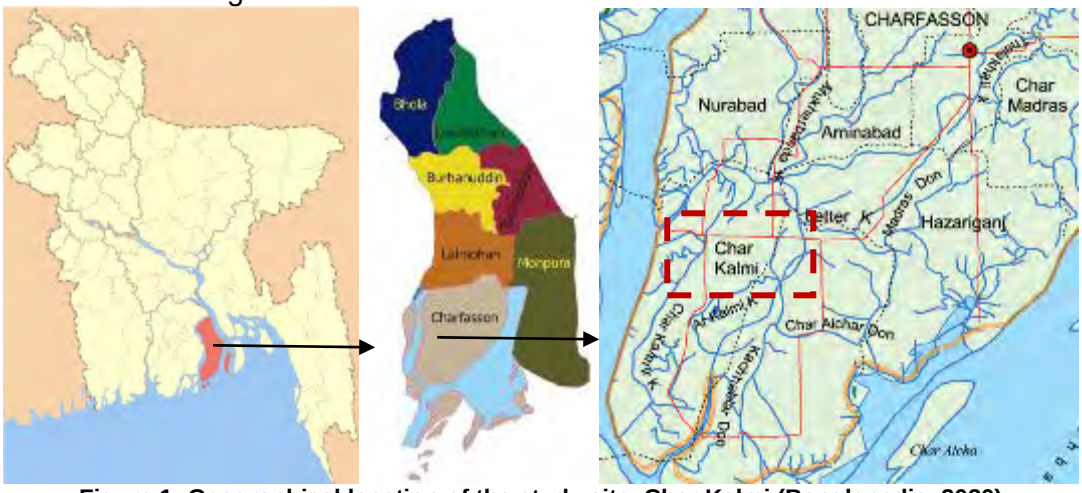

Figure 1: Geographical location of the study site, Char Kalmi (Banglapedia, 2020)

Based on various reports, articles, surveys and studies, some user demands of the site was identified. It has been found that cyclones and flooding have been the major threat to 82% of the population of the site region who are exposed to these; with awareness regarding evacuation, protection and mitigation being as low as 19% among them (Jagnoor et al., 2019). Drowning or being injured is the primary concern for during a disaster while damage and loss of crops and livestock comes in second, causing the perception of natural disasters to become fatalistic among the communities as there is insufficient support for the vulnerable population, and even with the presence of community preparedness practices, there exists lower rate of response from the community to early warning systems (Jagnoor et al., 2019) due to lack of communication and education. A deficient in disaster management and mitigation alertness is therefore identified here. Also identified are the use of improper and risky building materials in the area, like tin which is used in 85% of households, that stems from low-cost, unawareness, and availability (Jagnoor et al., 2019). Furthermore, locals are usually unwilling to evacuate during a disaster due to concerns about their property, livestock, lack of privacy in shelters for women and feeling that shelters are not more adequate than their homes (Jagnoor et al., 2019). However, also identified was the dependency of community members on each other due to trust. As Bhola is one of the regions facing the most storm/tidal surge, above 1 meter (Dastagir, 2015), these concerns are taken into account in this study critically. There are many government policies and projects to

address these issues, but the enforcement of these is another concern in coastal disaster management and preparedness, with most projects still not implemented or abandoned (Islam, Xue and Rahman, 2009).
Therefore, a gap is recognized by the researchers between planning and implementation due to lack of connectivity with the users. Another concern is the overall sustainability issues of Bangladesh, where economic scarcity overshadows the already in effect damage caused by lack of sustainability aiding practices, which pose a great threat to the economy, culture, social dynamics and environmental degradation in the long run (Rahman, 2019). The following are directions for the design gathered from the site conditions:

- Unwillingness of affected population to go to disaster shelters
- Lack of education and awareness on disaster related issues
- Lack of proper amenities for the mentioned rural population as opposed to their urban counterparts
- Cultural privacy issues are not addressed properly
- Building materials are not justifiable and safe
- Lack of proper implementation of government policies
- Lack of sustainable practices

From the above, this study gains ideas to incorporate in the design proposal in order to increase its acceptability and effectiveness to the intended users.

2.2 Concept of Smart Rural Hub (SRH)

Growth centers are a common rural development practice in Bangladesh (LGED, 1995). These are rural marketplaces and transitional municipal hubs that are recognized for making progressive investments by the Planning Commission based on socio-economic factors (Barua, Akter and Jahan, 2015). The impression of an SRH stems from this concept and can be identified as a more inclusive, resilient and sustainable advancement of growth centers by the addition of several features to address contemporary needs of the users. The reason for addressing the issue at hand from this perspective is that it has been proven that growth centers are effective in linking urban and rural economy, resulting in decrease in dichotomy between the communities (Barua, Akter and Jahan, 2015). However, the concept of growth centers is not contemporary and relevant anymore, having a number of problems like lack of utility and infrastructural services, lack of recreational facilities that encourage communities to actively participate in growth centers, lack of proper architectural and structural planning resulting in shortage of storage, shaded areas, internal connectivity, public toilets, waste management and slaughter houses on top of administrative shortages like no control of casual impermanent shops and proper managing body (Mondal and Das, 2010).
In the course of this study, it has been found that Char Kalmi lacks in efficient growth centers for being disconnected from mainland. However, since the inauguration of Maya Bridge in 2015, connecting the mainland with the ‘char’ (The Daily Star correspondent, 2015), the opportunity has widened for the development of this rural zone and this research targets this opportunity by proposing an advanced growth center by proposing the design of a multifaceted and resilient SRH.
The Smart Rural Hub or SRH is essentially a mixture of a growth center or rural market, disaster shelter, socio-cultural community center and educational center. The literature review identifies failures and problems of growth centers and disaster shelters. As mentioned in section 2.1, the rural population is rather demotivated to seek refuge in cyclone shelters for various reasons. One of the main reasons identified is a lack of feeling connected or a sense of ownership with the shelter itself. Also, many cultural

aspects, like privacy of women, provision to shelter livestock, allocation of space, and the overall feeling of abandonment and gloom regarding these shelters are often overlooked; hence the design and purpose of these structures habitually remain unfulfilled. Additional to this, literacy rate of the study site is about 43% whereas the country overall stands at 71% (BBS, 2013) which creates the need of encouragement towards education and this study aims for that by incorporating that facility to the SRH design. Another matter of concern is childbirth, which has improved overall compared to previous decades but remains still a problem in rural areas where maternal and neonatal mortality rates are high, infant and child care education is low and lack of trained childbirth attendants are scarce (UNICEF, 2015); which demands a proper child delivery and maternity unit in the SRH design as well.
This study investigates these aspects and proposes a design that will address these sensitive aspects making it a culturally, socially, environmentally and economically sustainable, resilient, participatory and user-oriented architectural solution.

2.3 Use of shipping containers

The use of shipping containers has aided global economy, but due to the linearity of its lifecycle, it has the downside of gathering of unused ones in many countries. To address this, designers worldwide have taken to upcycling shipping containers to come to a sustainable and minimal waste producing solution. Bangladesh is such a country where these containers can be found in plenty, right after much bigger countries like the U.S.A., India and Canada; but is one of the fortunate countries to have temperate climate that makes the repurposing of these containers easier due to climatic advantage needing minimal retrofitting with the provision of using almost as it is (Bertolini and Guardigli, 2020). The area of study is prone to strong winds and storm surges, and as per government directives, buildings in this sort of coastal regions are required to have strong cross-bracing to suppress force of wind, tie-downs from bottom to top for anchoring and be built in regular volumes (HBR, 2018) – which are all met by these containers. Use of containers allow modular design, which aids in flexibility of design and leaves provision of future extension. Moreover, it is proven that shipping containers aid in reducing global warming factor by 15% and is considered a more sustainable construction unit compared to steel and timber (Bertolini and Guardigli, 2020). It is 35% less expensive than an equivalent measured home built in brick or mortar (Aadhan, 2017) and stronger than traditional bamboo structures. Furthermore, these containers have resale value and can be easily recycled. Also, the objective of participatory design can be fulfilled as the construction method is relatively simple and fast, with the prospect of socio-cultural artwork displayed on the facades.
Therefore, this study finds the containers as a construction unit that is a suitable match for the design.

2.4 Basis of SRH functions

As per the policies adopted by Rural Development and Cooperatives Division, Bangladesh, the key to rural development program is poverty alleviation and empowerment, which is supported by rural infrastructure development, educational progress, rural health service and nutrition, empowerment of rural population particularly of women, self-reliance, child and youth development, culture and heritage preservation, support to elderly people, and many more (RDCD, 2001). In accordance to the above, this study approaches the problem of ‘char’ communities by proposing an evolution of the growth center through SRH. Growth centers all around the world have different definitions and functions based on context but essentially always has a potential for future adaptations and improvements (Wekwete, 1988). It was incorporated by the

government of Bangladesh in the 1980s in the rural development plan and was defined as a rural/village market (LGED, 1995).
In the neighbouring country India, this concept was used as a development strategy, starting more than fifty years ago; they are located based on economic condition of rural areas, focusing on agricultural development and seeking to serve the dense rural population to be economically solvent (Shah, 1974), and are similar to the ones later introduced in Bangladesh.
On the contrary, in the case of Vermont, USA in 1988, growth centers were introduced as a land-use strategy, to attract farmers and other communities, to populate unused areas of the state (VPIC, 2007). The function was agriculture based but also housed ancillary purposes to support an entire community on a relatively disconnected area like health center, child care, educational facilities and public gathering spaces – some of these growth centers later on evolved to modern downtowns or central business districts (CBD) as they became urbanized (VPIC, 2007).
Based on the above discussion, previous literature review, contextual need analysis, and findings of survey on the local population, the researchers of this study decided on the functions to be comprised in the design proposal in Table 2, to address the contemporary needs of the site, which is discussed in detail in the following sections.

3 Methodology

The methodology of this paper follows a mixed approach, incorporating study of the site, literature synthesis, problem identification and analysis, contextual and contemporary needs identification through interviews of users and field experts in addition to the researchers' comprehension. The broad methodology is illustrated in the Figure 2.

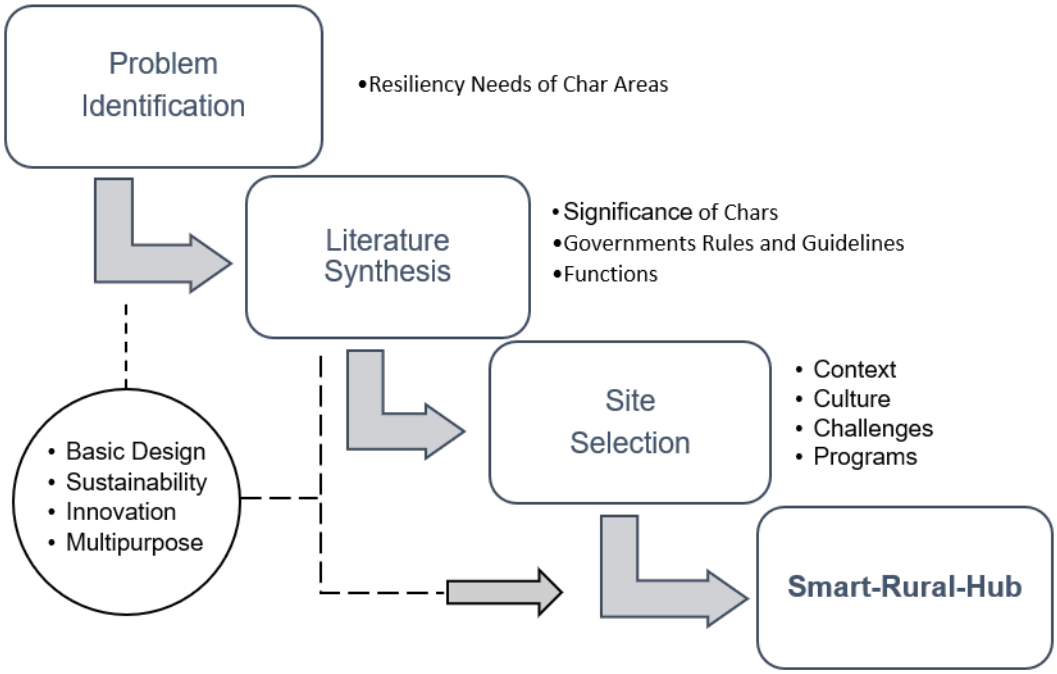

Figure 2: Broad methodology of the study

Specification of the problem was initially directed by identifying the forte, awareness and proficiency of the researchers and was concentrated to rural community development approaches for disaster-prone 'char' communities. This led to the selection of Char Kalmi as the study site and following investigation.

Participatory rural appraisal (PRA), a research method used by non-profit organizations and others involved in the development sector (Hasan, Siddika and Hossain, 2019) has been adopted for this study, along with focus group discussions (FGD), to understand contextual and contemporary needs, problems and acceptability of the design proposal in the mentioned community; with the help of the Postgraduate Programs on Disaster Management (PPDM) department of BRAC University. This survey was conducted in January-February, 2020 on a randomly chosen sample population of 194 people. Figure 3 describes the PRA method applied.

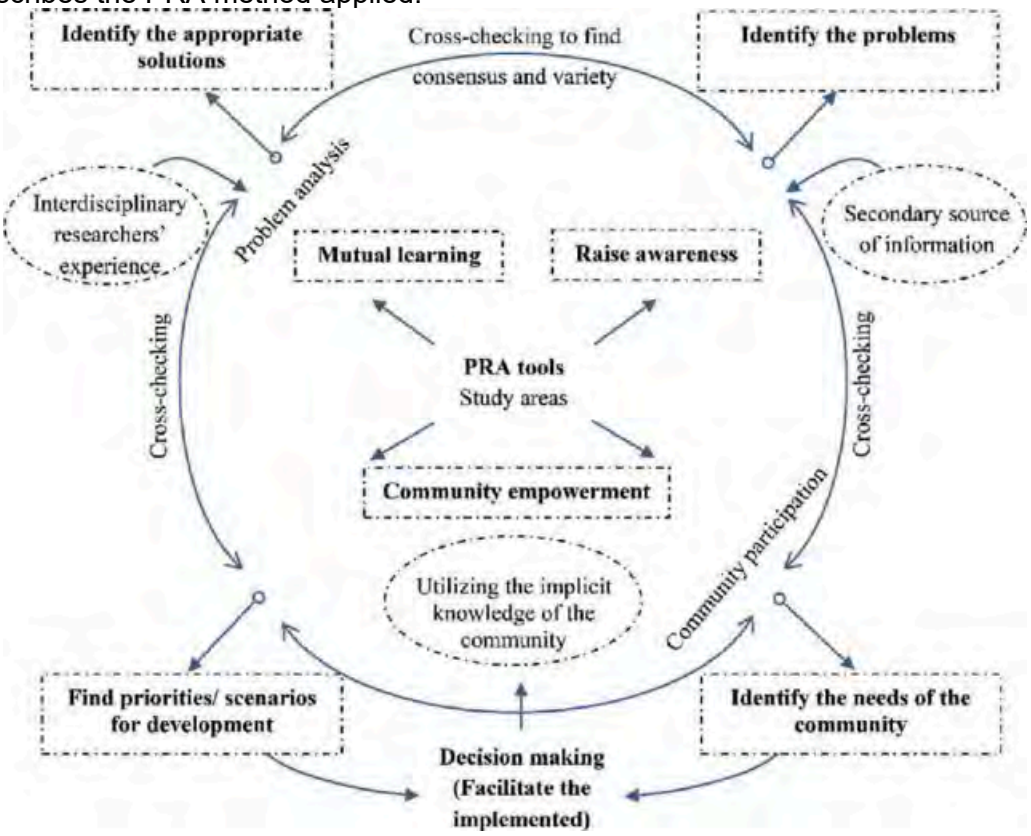

Figure 3: Participatory rural appraisal (PRA) (Al-Qubatee et al., 2017)

Simultaneously, literature survey was conducted to funnel necessary directions towards the design to enable it to achieve the objectives mentioned in Table 1. A gap was found in community participation and motivation towards disaster mitigation and this insinuated a participatory, user-oriented and holistic community development approach towards the hub design development. From the study in Section 2.4, and the results of the PRA survey method, the following functions were incorporated in the design by the researching architects as seen in Table 2.

Table 2: Smart Rural Hub Functions (Broad)

#	Function	Allotted space (%)
a	Rural Market (Dry and Wet markets)	30
b	Education / Disaster shelter	40
c	Health care, day care and religious centre	20
d	Supportive functions	5
e	Administrative functions	10
	Total	100

The functions have sub-divisions in the design and is described in Section 4.

4 Design proposal

This chapter outlines the design proposal with the aid of graphical presentation along with the design features that enable the hub design to be considered smart.

4.1 Design description

The design process commenced with combining gathered site information, contextual requirements date, user-needs and the researchers' perception. The site was selected based on accessibility to ensure easy transportation of containers through water ways during construction and later transportation of produce for the market. It is located near the Maya bridge mentioned in Section 2.2, to enhance connectivity. The design follows courtyard-based arrangement of functions, which is a traditional approach of the region (Aman, Rahman and Zahir, 2016). Figure 4 shows these functions and their locations based on zoning plan.

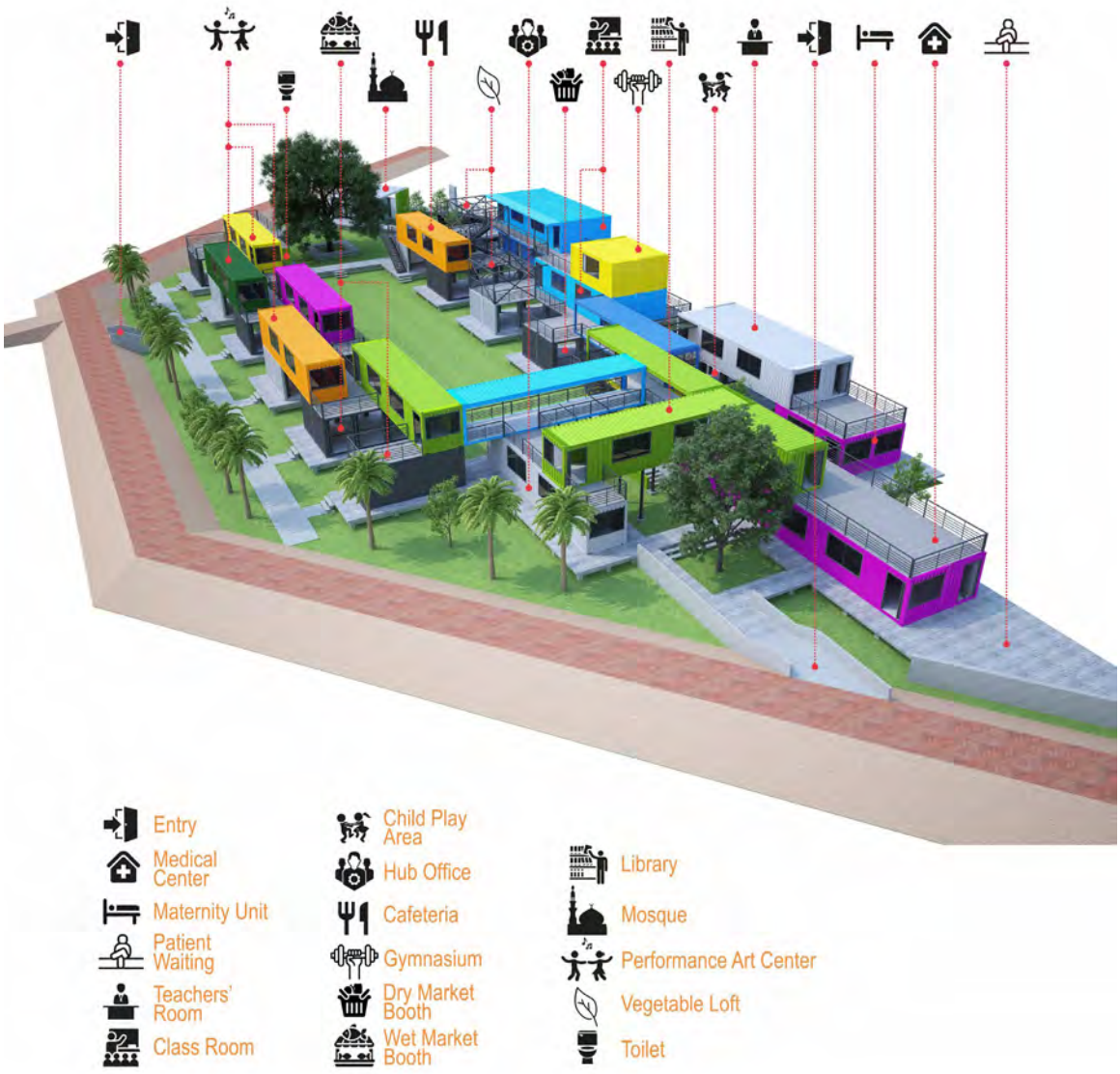

Figure 4: Aerial view of the SRH denoting different functions

Figure 5 shows the ground floor plan of the hub, which is mostly devoted to the market facility. The medical center and maternity unit near the entrance is separated from the rest of the functions to adequately serve the patients and also act as an isolation unit in case of communicable diseases or during a pandemic. The day care center or pre-school section can also be used as a consultation center with different public, NGO and other organization regarding health, sanitation and related awareness issues. Apart from that, administrative functions, such as the hub office, storage spaces, audio-visual room for internet services, are allotted here for better control. Community spaces are provided like mosque, cafeteria, public toilets, open area to encourage community bonding, sense of familiarity with the hub and positive approach towards the establishment.

Figure 5: Ground floor plan

The first floor caters to the educational facility as seen in Figure 6.

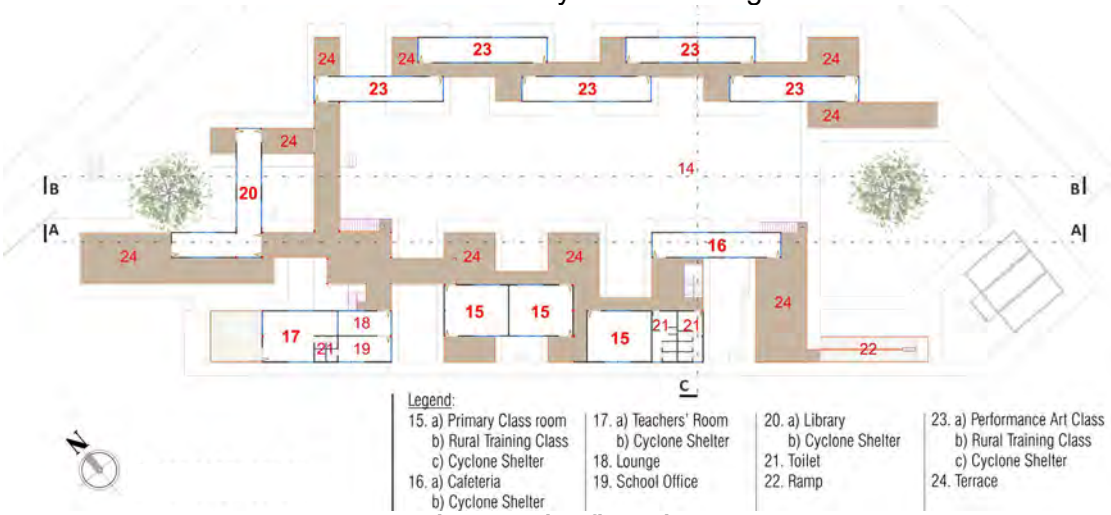

Figure 6: First floor plan

The primary school will run on the first half on every weekday and on the second half, there is facility for after-school activities to keep children positively engaged. There is provision of creative and performative art trainings, elderly education and craft training as well as an open-to-all library to keep the cultural aspect thriving. All of these will be used as disaster shelter when required. The free-flowing planning offers a sense of being unbound, which may positively affect the mental condition of people seeking shelter and also aid in breaking the wind force of cyclones. Figure 7 shows the second-floor plan, housing further convertible class rooms and gymnasium.

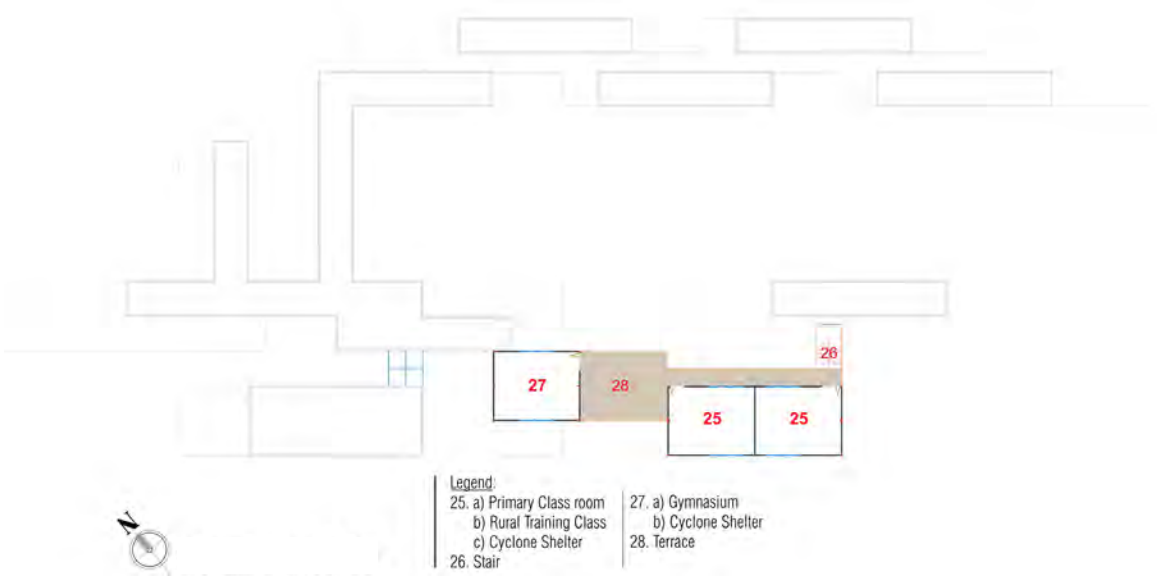

Figure 7: Second floor plan

Figures 8, 9 and 10 show cross section of the hub where the vertical arrangement of the hub functions can be seen. The addition of the ramp (Figures 5,6 and 8) is a key deliberation for the differently able people as well as a socio-economic consideration of mobilizing livestock during a disaster. Also, the raised plinth level is a protection measure against flood, and the hollow space underneath aids in passing of air, thermal cooling and reduces obstruction in the face of stormy winds.

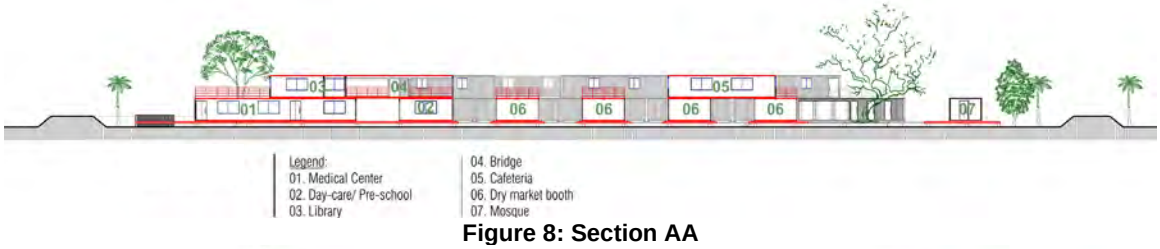

Figure 8: Section AA

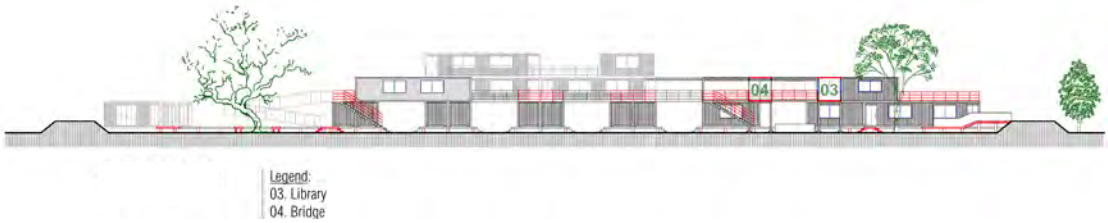

Figure 9: Section BB

Again, these figures show the possibility of isolation during health disasters like the Covid-19 pandemic by isolating blocks with controllable access. The playful arrangement of the structure is not only because of the aesthetic reasons, but also to create spaces of different scales – from intimate to broad – and to provide structural resilience as well.

The vast number of terraces provide the facility of public kitchen garden, which can aid to the sense of belonging and community.

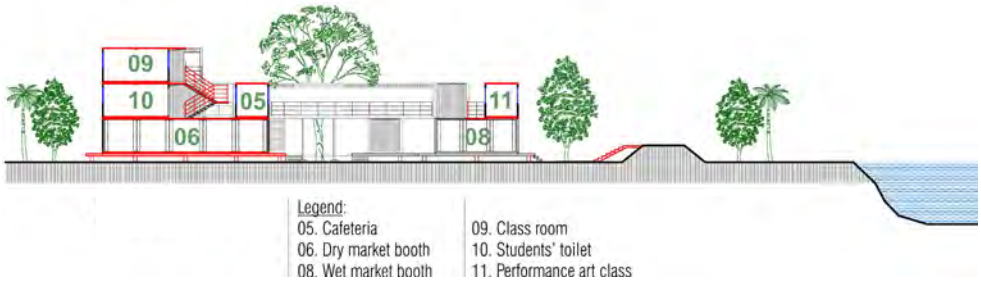

Figure 10: Section CC

4.2 Smart features

To achieve the aim of this study, the features of the SRH are aligned to the concept of smart village. These features are the outcome of literature review, survey reports, contemporary contextual needs, and designers' insights combined together as design directions. Table 3 describes these features.

Table 3: Smart Rural Hub Features

#	Feature	Description
a	Use of shipping containers	Containers are sturdy yet lightweight, ease and rapidity of construction, flexibility of design, room for future modification, novel approach in the region, sustainable, cost effective, fast implementation of design, and has resale value, making it a smart selection of construction unit in this study.
b	Variety of community spaces	The spaces created are of different proportions allowing different people of the community experience them differently but keeping intact the sense of togetherness.
c	Staggered units	The staggered arrangement of units makes the centre architecturally proficient while serving the purpose of storm resilience
d	Contextual functions	The functions are a big consideration for this design and acted as the key guidance in planning. The functions are derived from careful and thorough analysis of the context, PRA results and subsequent identification of key areas to address
e	Disaster resilience	Incorporating disaster shelter in a community hub was decided in order to acclimatize the shelter to its intended users to decrease lack of motivation to seek refuge during disasters.
f	Multi-functional spaces	The multi-use of the majority of the functional spaces allow the hub to be buzzing with activity all throughout the year. It allows room for festivity as well, keeping in mind the cultural notions of the region. It also attends to the problem of scarcity of space in a over-populated country, and adheres to multipurpose open planning as an efficient use of space.
g	Universal Accessibility	The addition of the ramp aids to accommodate universal accessibility for the disaster shelter.

Figures 11, 12, 13, and 14 shows how the researchers visualize the spaces to be if it is constructed.

Figure 11

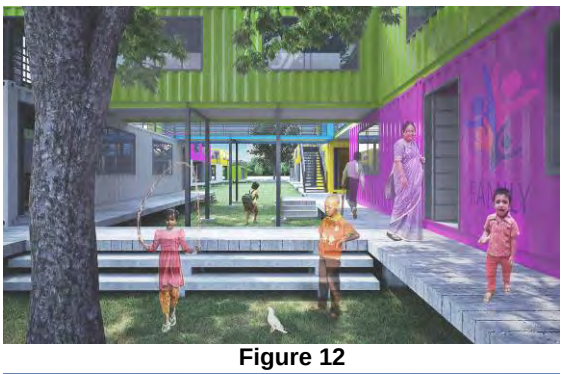

Figure 12

Figure 13

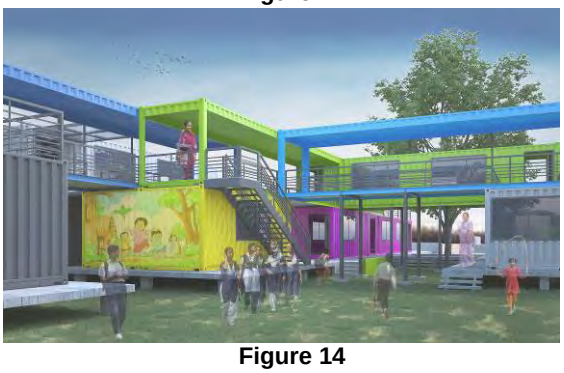

Figure 14

5 Discussion and conclusion

The result of this research, the hub design proposal, is derived from all the studies conducted prior to it. Several of the sustainable development goals (SDG) by the United nations have been addressed in the process like the third goal – good health, the fourth goal – education, the ninth goal – industry and infrastructure, the eleventh goal – sustainability and so on. The disconnectedness of the 'char' regions, along with other contemporary problems are articulated and, if applied effectively, this can shine as a beacon of hope. People living in 'char' areas are habitually resilient as they often have to pass their lives in dynamically changing conditions. The researchers of this study have come to the resolution that they can very well be self-dependant only if some infrastructural support is provided. The proposed design is a result of this resolve, however, its effectiveness is yet to be confirmed as it is yet to be constructed. It has been tried in this paper to coin a new term – Smart Rural Hub – that can be expected to be adopted as the evolved growth centre and has the potential to be accepted as a model for policy makers with contextual adaptation. With careful attention to socio-economic and cultural aspects besides environmental and technical aspects, this design may very well be a novel approach in similar settings and can be considered as a precedent of this branch of development in the rural arena.

"Contemporary practices are trending towards holistic living and can only be achieved by learning from history, tradition and by keeping cultural values thriving" – Haque, Rahman and Zaman, 2019.

The key to effectively address a problem is to gather deep insights of the context – both tangible and intangible aspects – and that is exactly what has been practiced in this study. The journey from problem identification and analysis to the complete design proposal was completely guided by contextual appropriateness and cultural cues. the problem of Char Kalmi union are not typical, neither are they completely unique, which provided the designers a chance to creatively attend to the issues. Initially, the priority was disaster resilience but it, like growth centres, evolved to holistic resilience – encompassing aspects of concern of the community. Heavy emphasis was put on literature review and analysis of information derived from PRA and FGD approaches in order to make the design participatory, socially acceptable and contextually appropriate. In light of that, the objectives mentioned in Table 2 have been attained throughout the paper. It can be predicted that this research, if funded fittingly, can bring about change in community functions of rural areas and the future holds promising success stories focusing the smart rural hubs.

Acknowledgements

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IMPLEMENTATION OF ALTERNATIVE AFFORDABLE MATERIALS IN SUSTAINABLE RURAL HOUSING DESIGN

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Abstract: *There is a search for sustainable and low-cost materials as a substitute for traditional materials in the present situation for the lower-income group people of Bangladesh. Materials that use less energy and have a lesser degrading impact on the environment during its lifetime and provide protection against natural calamities can be defined as sustainable building materials. Headed for making safe, affordable, and sustainable human settlements, the goal of this paper is to explore the provision of low-cost-housing materials prescribed by the House Building Research Institute (HBRI) for the poor community of Bangladesh. Considering the circumstances of low-income group communities, a sample design of the module has been developed where alternative materials are used instead of generally practiced ones like Sand Cement Block, Compressed Earth Block, Ferrocement panel-footing-column-beam-roof and Corrugated Galvanized Iron (CGI) sheet. It is expected that this study becomes a significant part of the overall rural housing development schemes in Bangladesh in terms of material sustainability and affordability along with providing better living conditions for rural communities. Finally, a comparative analysis between the typical existing house and a proposed prototype has been depicted to fathom the efficiency in terms of affordability, durability, availability, environmental impact, and vulnerability which in turn highlights the areas which need intervention and attention from the concerned organizations to make sustainable housing, for the lower-income group people, a reality in Bangladesh.*

Keywords: *Alternative materials, Affordability, Sustainability, Poor community, Sample design*

1 Introduction

Although the majority of Bangladeshis live in rural settlements and most of the dwellings are in rural areas, until now there is no land-use plan and adequate sustainable building materials, affordable for the lower-income group communities, in rural areas of the country. However, recently the Bangladesh Government has addressed this issue and has started taking measures to develop the rural settlements in many aspects. Housing is one of the highest priorities in the Government agenda therefore, the Housing and Building Research Institute (HBRI) an autonomous organization under the Bangladesh Ministry of Housing and Public Works who are researching, developing, and promoting sustainable building materials along with the construction techniques for both urban and rural housing with an aim to achieve government's commitment (HBRI, 2018). Houses in the rural area are mainly constructed of indigenous materials such as thatch, bamboo, grass, straw, jute, CI sheet, golpata, stuck, and mud. The walls are built of bamboo, straw, jute stick, CI sheets, or mud while the roofs are of thatch or CI sheet and sometimes with earthen tiles (Hasan, Ullah, and Gomes, 2000). These materials are vulnerable to nature especially in a tropical country like Bangladesh. On the other hand, from the point of environmental impact, the building sector has a significant effect on the entire environment (Rob, 2014). Currently, over 8000 brick kilns produce around eight million tons of carbon emission per year, and corrugated iron sheet factories contribute another six million tons (Yu, 2008). Exhaustion of fertile topsoil, deforestation, and air pollution caused by these materials are thus, genuine issues to look for alternate sustainable materials for rural housing. This paper analyses the use of such materials for rural housing settlements based on case studies of the living condition of rural communities in Kattoli of Chattogram which is close to the coastal area and exposed to the natural calamities throughout the year. Through this study it is observed that considering the circumstances of low-income group people residing in disaster-prone areas, alternative materials can be implemented instead of generally practiced ones, e.g. F.C. instead of R.C.C.; Sand cement block, Compressed earth block, Thermal block instead of Bricks; CGI sheet or F.C panel instead of CI sheet, etc.

1.1 Aims and objectives

This study aims to analyse the impact of the existing building material in rural communities of Bangladesh in terms of environmental impact, vulnerability to natural calamities as well as agents and affordability for the masses. It also aims to study the impact of the introduction of alternative building materials amongst the rural communities in terms of acceptability, ease of availability, affordability, durability, and environmental impact. The specific objectives are:

Table 1: Specific objectives of the study

	Description	Method(s)
01	To understand the vulnerability of existing housing materials in rural areas.	Physical survey, Literature Review
02	To study the environmental impact of existing building materials in rural areas	Case Study, Physical survey, Literature Review
03	To analyse the affordability of existing rural housing materials and compare it with the affordability of alternate building materials.	Literature synthesis, Case Study

2 Literature synthesis

From the initiation of human settlement-practice, housing form became the symbol of safety and protection for human existence (Uddin, 2007). The native design in rural housing is defined by a unique view of form, function, spaces, material, and construction of the houses among the community (Katharpi and Doloi, 2019). With the grown economic dimension and living pattern of human life, several factors are also reflected in the realm of housing methods that includes affordability, cost efficiency, and sustainability (Uddin, 2007). Certainly, it is difficult and challenging to establish any new material and construction method in the market due to a rigid mindset regarding existing construction methods. It is hard to promote alternative materials and gaining trust among them. Moreover, people want to be on a safer side and unwilling to take any risk with their lifelong savings in new, unknown, and things yet to be proven. However, the cost of materials is a huge issue especially in the poor settlements of Bangladesh. Common people are usually interested in cheaper, handy, yet quality materials (Rob, 2014). All over the world, needs, interests, aspirations, preferences, and abilities depend on society's productions, adaptation, and development of their habitat, making suitable use of materials that are locally available. The knowledge of indigenous practices of architecture and investigating their related implementations is (re)learning the path to planning catastrophe safe models as build back better is extremely helpful, yet additionally to adjust to contemporary ways of life and their development, to regard the neighbourhood condition and culture and to adjust to the specialized and financial limits of neighbourhood populaces (Shelter Cluster, 2018). This paper considers studying and extracting useful information about housing materials for the rural community from their surroundings and affordability. In Bangladesh, there is a figure of such community, but little consideration has been paid to their redevelopment, and the variety of the contextual scenarios they travel through. Thus, it can be an important study if these problems are addressed in a particular context, where living challenges are important to focus on. There is always a gap in search of local material constructed houses for lower-income community people. The research tries to fill the gap with its some material analysis and offer some new thoughts.

2.1 Materials description

Described underneath are some of the alternate materials as prescribed by The Housing and Building Research Institute of Bangladeshis (HBRI) and other upcoming alternate building materials.

Sand Cement Plinth: The plinth can be constructed by stabilizing sand with cement.

- The proportion of mixing ingredients is 1:10 (Cement: Sand).
- The numerous rivers of Bangladesh carry huge quantities of sand. It is locally available and can be collected from anywhere. (HBRI, 2018)

Bamboo and Bamboo Matt: There are nine (9) general and more than thirty-three (33) species of bamboo in Bangladesh, out of which seven (7) are originating from nature in the forest zones and about twenty-six (26) species have been cultivating in the low land (Banik, 2000). Moreover, people of tropical countries especially South East Asia have an affinity in building with bamboo.

CGI Sheet: CGI or Corrugated Galvanized Iron is a building material composed of sheets of hot-dip galvanized mild steel, cold-rolled to produce a linear corrugated pattern in them. CGI weighs light and can be transferred with minimum efforts. Corrugated iron is similar

to roofing by tin (HBRI, 2018). Thus, is highly beneficial in its chances of weathering due to corrosion is less. However, care should be taken to align it in a proper structural angle else it can easily get deformed or blown away by strong coastal winds.

Sand Cement Hollow Block: They are manufactured by combining sand and cement.

- They give a specific texture to the walls.
- They are strong, durable, and require very less finishing
- Reduce the total cost of the project by being less in a dead load of walls

Ferro cement: Ferro cement is ideal for the construction of thin walls as it uses wire mesh in place of steel. It is lighter than concrete as no gravel is used. It is of two types

- **Pre- Cast Ferro cement:** The primary advantage of per cast Ferro-cement is that it can be cast as required and then transported to the site. This leads to quality control, proper time management as well as ease of use in the site. In order to avoid the salinity related issues in coastal regions, pre cast ferrocement materials can be proved to be more preferable.
- **Cast-in-situ:** Cast-in-situ Ferro cement can be applied to construct shells and thin walls as and when required (HBRI, 2018).

Timber: Timber is one of the main building components of housing in a tropical country like Bangladesh. It remains one of the most sought out commodities for low-cost housing in terms of strength and durability.

Bamboo Plastic Composite and Bamboo Wood: Since the availability of bamboo is high in Bangladesh technologies such as bamboo plastic composite and bamboo wood (authors) can be experimented with for building houses. However, at present, they are high end products in terms of costs. If cost can be brought down, they can be excellent products for durable yet sustainable housing (Authors).

Figure 1: Studied materials (Source: HBRI, 2018)

2.2 Construction techniques

Some of the basic techniques used to construct the dwellings with the above materials are as follows:

Plinth: The plinth is generally made up of cement and sand. Such plinths are not vulnerable to getting washed off during the monsoon rains and floods (Figure 3).
Footing: The footing is generally made up of Ferrocement. The footing is inserted into a hole dug two feet below the ground level. Such kind of footing provides stability to the structural members which are essential for disaster-prone areas (Figure 5).
Bracing: Structural bracing is generally done of bamboo and timber. The Ferrocement beam and column support the load. They provide extra stability during natural calamities like storms, earthquakes, etc (Figure 4).
Walls: Walls are usually made of Sand Cement Hollow Block and Bamboo Matt. The hollow brick wall, up to a height of 900mm, shall remain intact even after natural calamities. Post-disaster repairs, if any, of the bamboo matt wall above, shall consume less time and cost (Figure 2).
Roofing: Roofs are made up of Bamboo truss covered with CGI sheets. It is economically viable for a country like Bangladesh because the production is high (Figure 5).

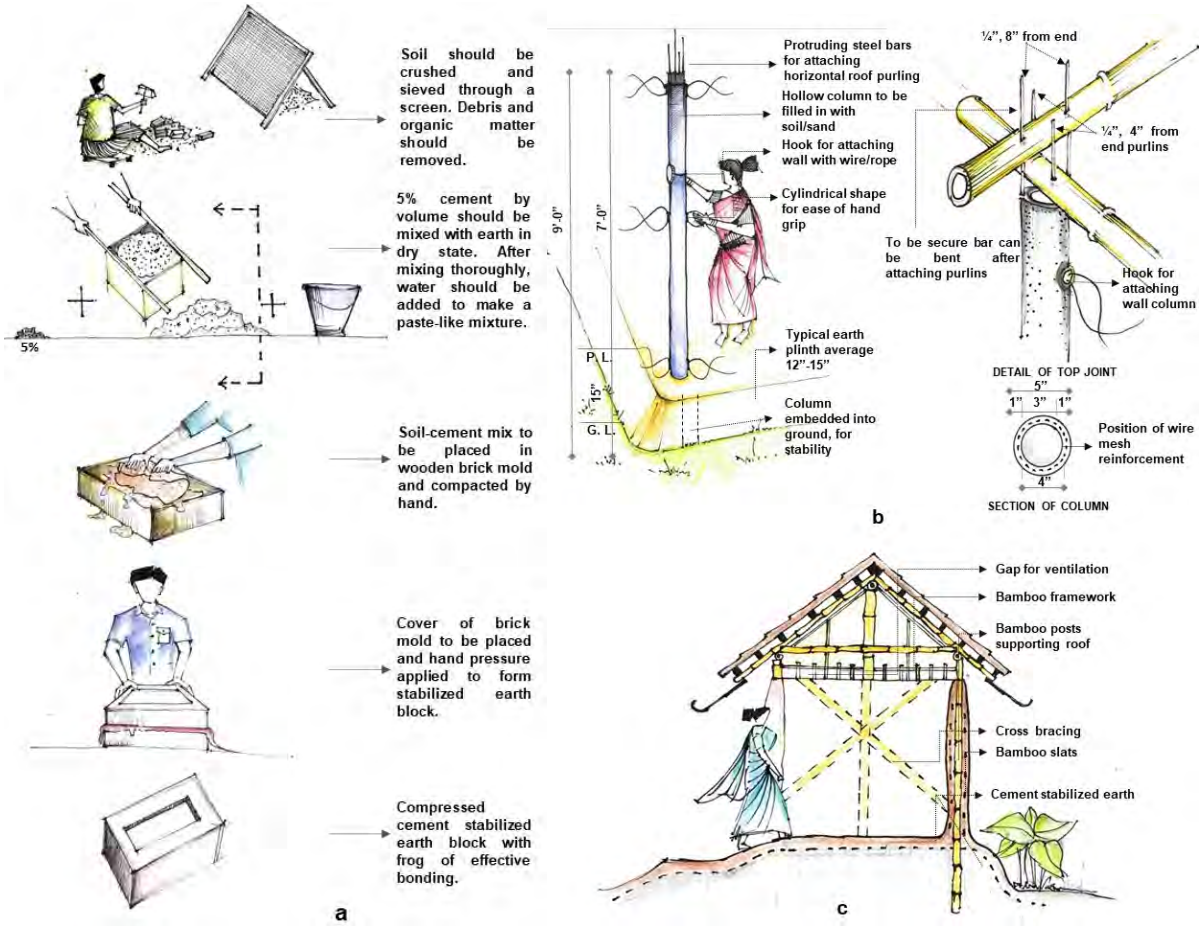

Figure 2: a. Production process of compressed earth blocks. b. Details of hollow RC post and its production. c. Design aspects of building an earthen house. (after, ADPC 2005)

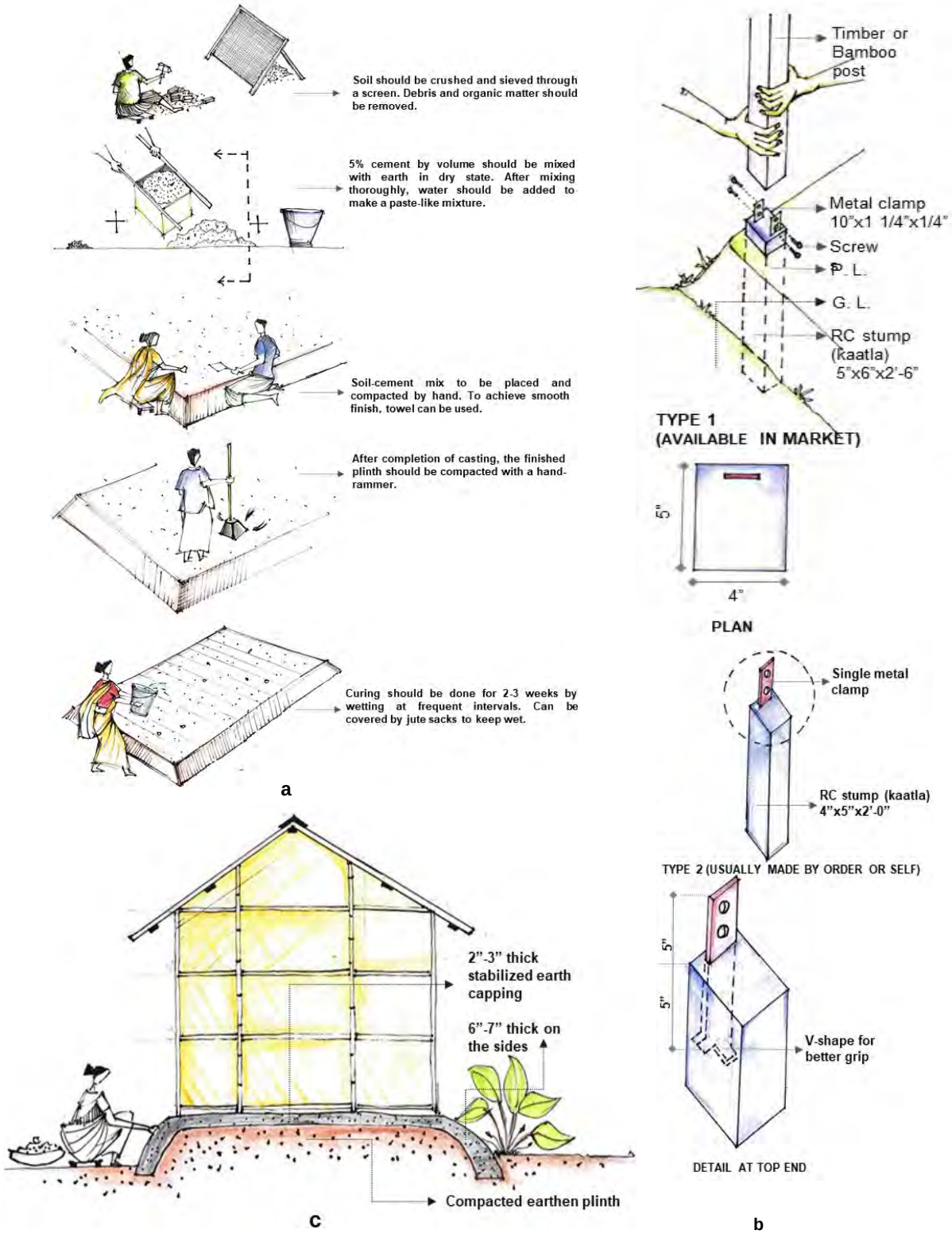

Figure 3: a. Cement-stabilized plinth construction process. b. Details of cement-stabilized plinth. c. Concrete stump for protecting lower end of bamboo post. (after, ADPC 2005)

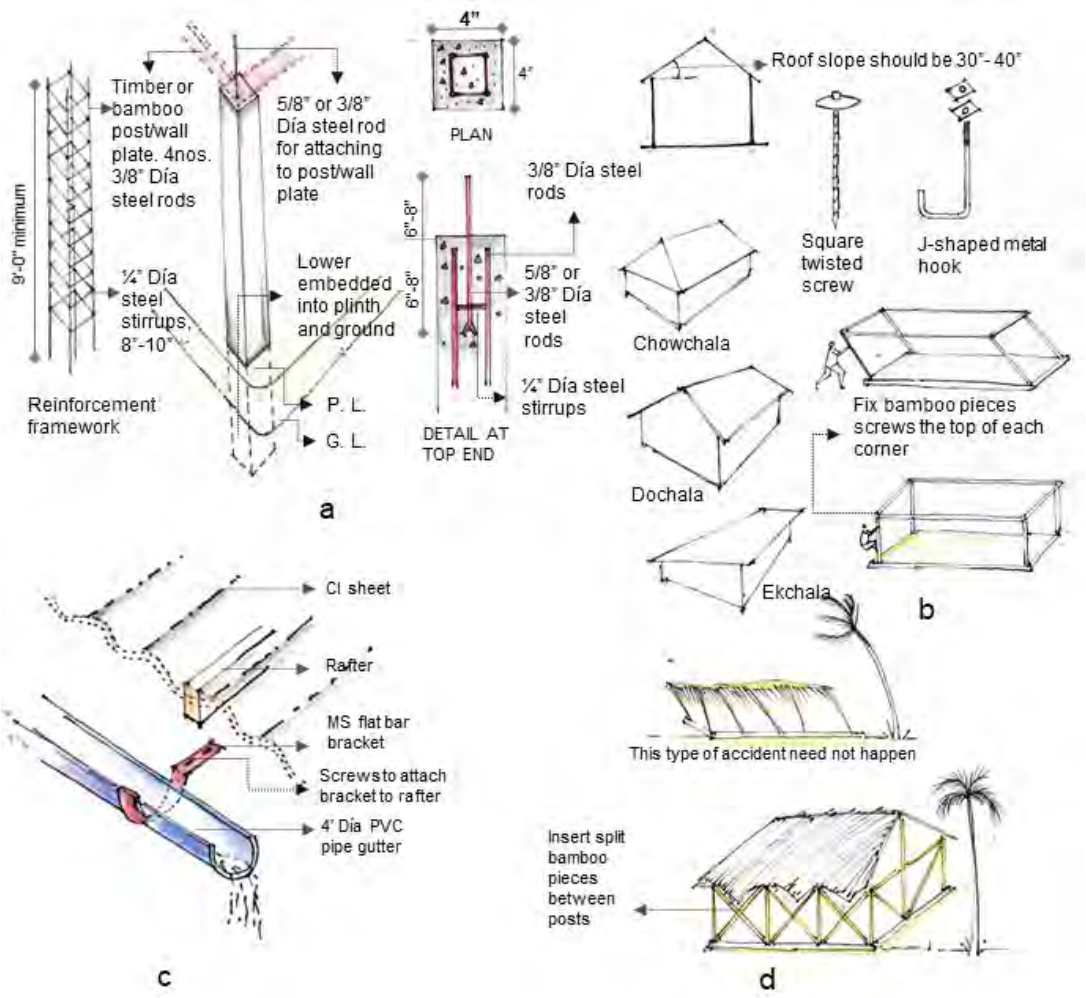

Figure 4: a. Reinforced concrete post b. Basic features of wind-resistant roofing. c. PVC pipe rainwater gutter detail. d. Cross-bracing of bamboo structural frame. (Source: after, ADPC 2005)

Figure 5: Standard house example for coastal area (Source: HBRI 2018)

3 Methodology

This study has been started by addressing the lack of affordable sustainable materials for rural and poor settlements. The literature survey was a key step for this study to understand the significance of alternative materials and the government's guidelines regarding housing development for the poor. A physical survey in a poor settlement of Kattoli, Chattogram took place in this research to attempt a sample house design by implementing a few alternative sustainable and affordable materials along with suitable construction techniques composed from literature synthesis and researchers' experience. The design methods used in the study were firstly architectural design of a single house considering context and users' living pattern and then the overall construction process has been outlined to make it as a sample for the communities similar to the study area.

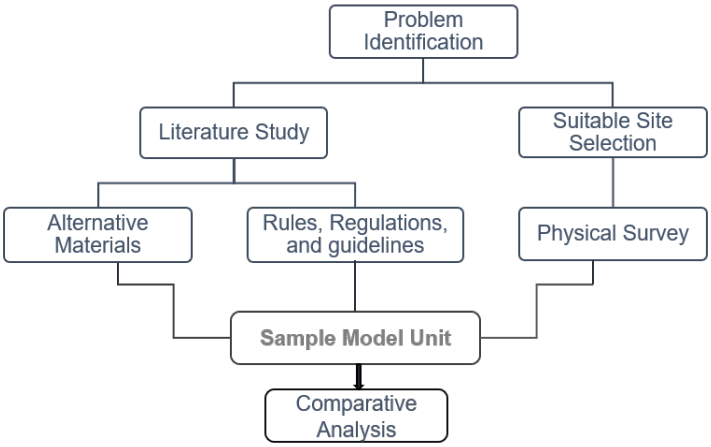

Figure 6: The research framework

4 Sample design proposal

The decisions on proposals are primarily influenced by some criteria (Figure 7). The chosen materials are locally available and affordable to the community. From several case studies and literature surveys it comes up as the best solution achieved for this community housing. Firstly, it will provide the community with a sustainable and low-cost housing within their comfort and adaptive level. Secondly, it will be eco-friendly and labour consumer development centric.

Figure 7: Material selection criteria for the proposed sample design (After, Zhou,Yin, and Hu 2009)

4.1 Proposed site analysis

The survey was conducted physically to examine the existing materials, housing pattern, space use pattern, vulnerability to natural calamities, etc. in the selected area that is Kattoli, Pahartoli in Chattogram.

The site is mostly surrounded by low rise housing, farmlands, factories, a stadium, and some shops. The dwellers are fishermen or industry labours. The essential information was gathered through field study at a prime level through a basic survey. Information was gathered both by physical perception and meeting the people at houses, fields, workplaces, and markets. However, significant data, site map, and climatic information were gathered from books, research articles, and library study. Some of the dwellers are in the conflux of upgrading their livelihood but still, most of them can't afford to adapt upgraded materials that are available in the market. The existing dwellings are vulnerable to natural calamities due to the lack of quality building materials and techniques.

Figure 8: Proposed site, Kattoli, Pahartoli, Chattogram

Figure 9: Existing housing condition

4.2 Existing housing materials of the community

Brick, Bamboo, Iron sheet, Concrete are the materials which are adapted and afforded by the community. At present, they are using the mentioned materials for their houses.

CI sheets: They are used for the walls and roof.
Bamboo: It is the main structural bracing material. The thicker ones are used as columns while the thinner ones are used for bracing. The roof truss and purlins too are made up of bamboo.
Plastic sheets: They are used to create enclosures for toilets; sometimes for walls and ceiling as well.

The durability of the houses constructed of the above materials is very less especially in the disaster-prone areas. At times they may last for few seasons but every season one or the other material needs a replacement; at times due to natural calamity and times due to natural degrading.

Building material alludes to the material which is utilized for advancement purposes. They give the make-up of living spaces and structures including homes. The performed examination guided to the decision towards a need for sustainable building material as referenced in Figure 10 The concluded picture got portrayed below:

- Absence of sturdy housing materials
- Absence in appropriate management process.
- Absence of legitimate integration of materials resulting the vulnerability.
- Poor state of material because of the impacts of intermittent climatic changes.

Figure 10: Existing housing materials (field survey)

4.3 Sample design

Based on the analyses of the literature study and case study an alternate construction technique for houses for people belonging to lower-income economic groups is proposed herein.

Plan: In terms of planning the space includes a multipurpose space and a prayer space. The planning has been done so because most people from the community cannot afford a larger space than the designed module. All household activities like working, sleeping, eating shall be confined within this area. However, a prayer space has been provided as most people residing in the sub-continent prefers having a designated space for spiritual wellbeing (Figure 11).

Footing: The primary footing shall be constructed of Ferro-cement footings which shall be more durable to natural calamities and agents (Figure 5).

Plinth: The plinth shall be of Sand-Cement mixture, as sand is readily available along the numerous river banks of Bangladesh (Figure 3).

Beams and columns: The beams and columns shall be made up of hollow Ferro cement beam-column, which are light weighted, durable, and are easy to work with (Figure 5).

Walls: They shall be made of hollow sand cement blocks up to a height of 900mm. There after they shall of bamboo matt and bracing (Figure 2).

Roof: The truss members shall be of bamboo while the covering material shall be the CGI sheet (Figure 5).
Ceiling: Bamboo ceiling shall be provided to insulate the dwelling from heat and it shall be used for their as storage (Figure 2).
Door and Windows: The Door and Windows are shall be of Timber (Figure 5).

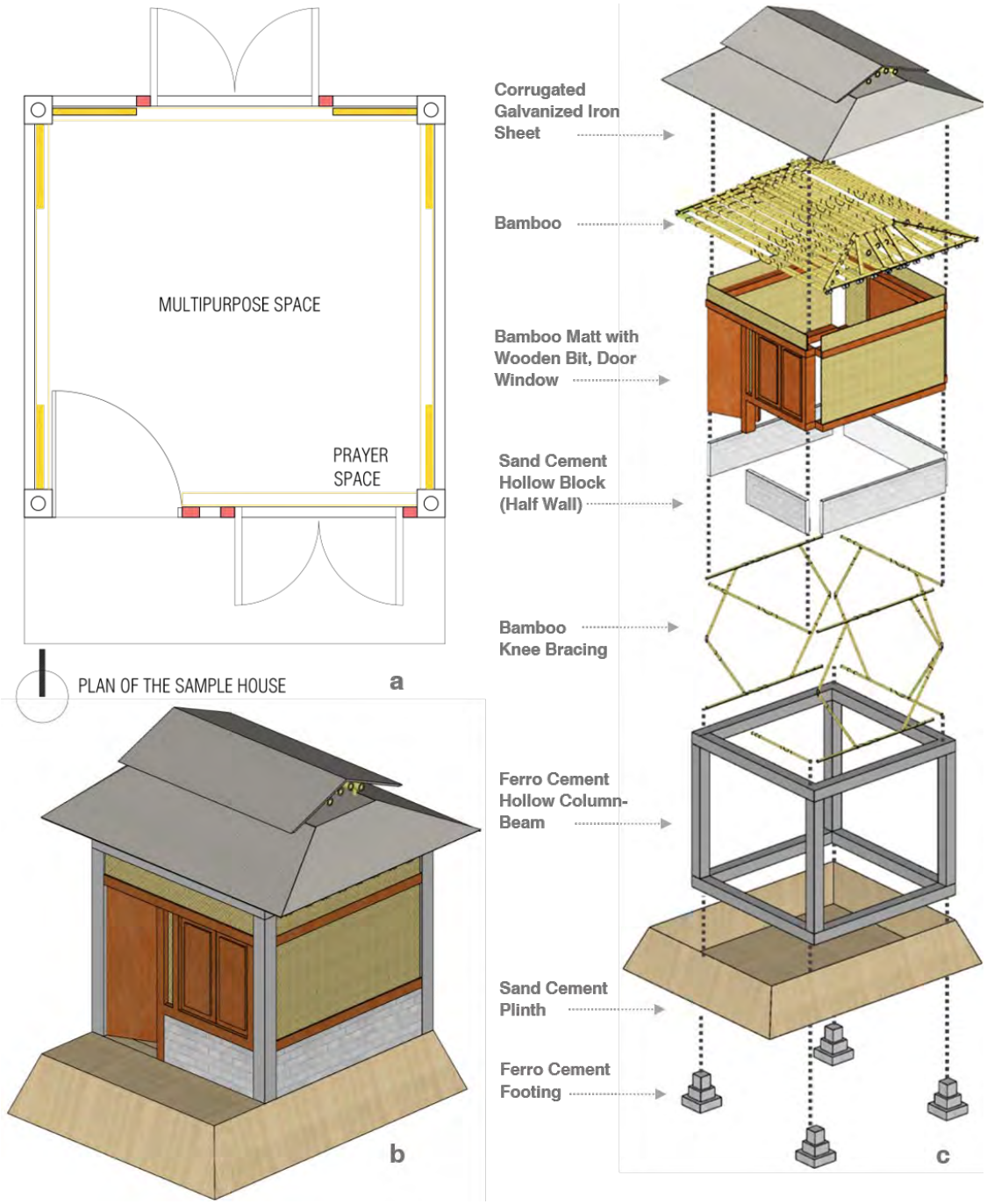

Figure 11: Proposed sample house a) Plan b) Perspective view c) Exploded Axonometric view to portray the implementation scopes of alternative materials prescribed by HBRI.

Considering economic and cultural sustainability, the construction method and elements are chosen in a manner that serves the following purposes – easy to adapt by the users through familiarity and low-cost techniques and materials and incorporation of smart features to derive maximum output environmentally from minimum input financially (Haque and Rahman, 2020).

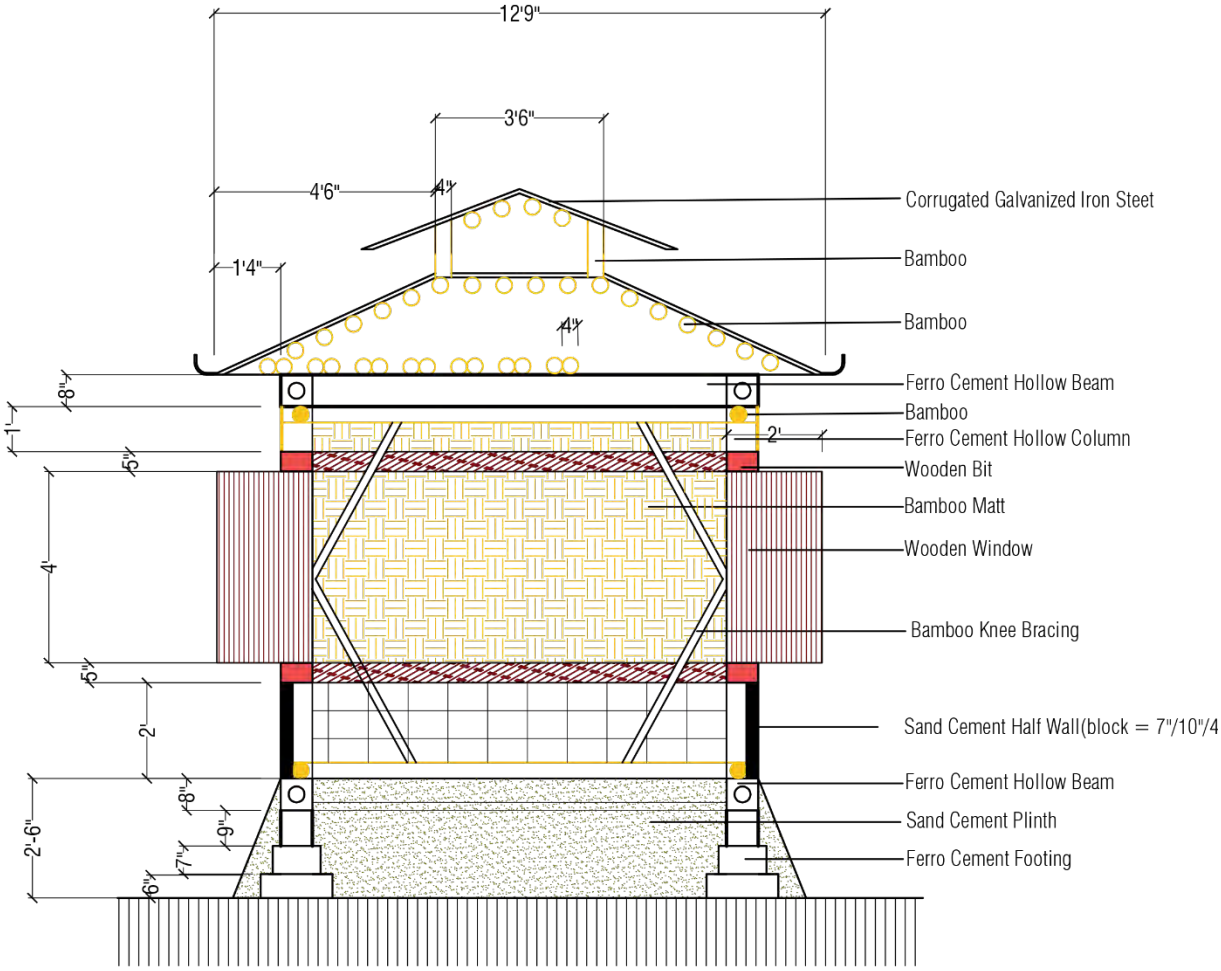

Figure 12: Detail section of the proposed sample house.

4.4 Cost Estimation

Presently, this community people use brick and bamboo matt, tin as wall material, CI sheet as roofing material and cement as flooring material along with wooden doors and windows. They use common kitchens and toilets. The construction system is so poor that, they need to repair their house frequently within a year, thus the costing gets higher than this. According to them, they spend around approx. 65,000/- taka only for a 100 sq. ft. house construction.

Cost Estimate of the proposed prototype is as follows:

Table 2: Cost estimate of prototype.

Sl. No.	Description	Item	Qtty	Unit	Unit price	Total (taka)
01	Foundation	F. C. Footing	4	Nos	300	1200
02	Plinth	Sand	400	kg	22	8800
		Cement	50	kg	420	420
03	Wall	Sand Cement Hollow Block	280	Nos	60	16800
		Bamboo	20	Nos	60	1200
		Bamboo Matt	25	Nos	20	500
		Door	01	Nos	4000	4000
		Window	02	Nos	3000	6000
		F. C. Beam	08	Nos	300	2400
		F. C. Column	04	Nos	300	1200
04	Roof	Bamboo	60	Nos	60	3600
		CGI Sheet	15	Nos	130	1950
05	Fittings	Nail	02	kg	90	180
		Wooden Batten	15	kg	50	750
		Chemical Powder	01	kg	300	300
		Water Proofing Admixture	01	liter	200	200
06	Labor	Skilled	02	Nos	600/per person	1200X4 day=4800
		Unskilled	02	Nos	300/per person	600X4 day=2400
07	Others					2000
		For 100 sq. ft. house			**Total**	**58,700/-**

5 Analysis

Through a thorough survey on materials conducted by the researchers to identify market price, popularity and properties, by talking to the local users, vendors and experts, the parameters were identified.

The survey conducted was both in-person and online. It garnered a cohesive understanding of the materials used and pointed towards how best to decide whether to replace, alter or keep using of said materials. The parameters and comparative analysis between a typical existing house and proposed prototype are as follows:

5.1 Parameters:

1. **Affordability:** This defines the cost of the material and whether or not it is affordable by the masses
2. **Durability:** This defines the self-life of the material.
3. **Availability:** This defines how easily the material is accessible by the users.
4. **Environmental Impact:** This defines the impact the material has on the environment during its production, transportation, and phase of use.
5. **Vulnerability to natural calamities:** This defines whether or not the material can resist the dangers of natural calamities and general weathering.

Table 3: Comparative analysis of affordability of materials.

	Existing dwellings		Proposed prototype	
	Material	**Affordability**	**Material**	**Affordability**
Plinth	Earth	Easily Affordable	Cement and sand+ F.C. Footing	Easily Affordable
Structural bracing	Bamboo/Timber	Easily Affordable	F. C. Beam + F.C. Column+ Bamboo Timber	Affordable
Walls	Brick + CI sheet	Easily Affordable	Sand Cement Hollow Blocks and Bamboo Matt	Affordable
Roofing	CI Sheet	Easily Affordable	Bamboo truss and CGI sheet	Easily Affordable
Doors and windows	Timber	Easily Affordable	Timber	Easily Affordable
Ceiling	Absent	-	Bamboo	Easily Affordable

Table 4: Comparative analysis of durability of materials.

	Existing dwellings		Proposed prototype	
	Material	**Durability**	**Material**	**Durability**
Plinth	Earth	5-6 years	Cement and sand+ F.C. Footing	7-8 years
Structural bracing	Bamboo/Timber	8-10 years	F. C. Beam+ F. C. Column+ Bamboo +Timber	10-15 years
Walls	Brick + CI sheet	10-12 years	Sand Cement Hollow Blocks and Bamboo Matt	12-15 years
Roofing	CI Sheet	6-8 years	Bamboo truss and CGI sheet	8-10 years
Doors and windows	Timber	5-6 years	Timber	5-6 years
Ceiling	Absent	-	Bamboo	8-10 years

Table 5: Comparative analysis of availability of materials.

	Existing dwellings		Proposed prototype	
	Material	**Availability**	**Material**	**Availability**
Plinth	Earth	Easily available	Cement and sand+ F.C. Footing	Easily available, only F.C. Footing available at HBRI
Structural bracing	Bamboo/Timber	Easily available	F. C. Beam+ F. C. Column+ Bamboo +Timber	Available at only HBRI
Walls	Brick + CI sheet	Easily available	Sand Cement Hollow Blocks and Bamboo Matt	Available at only HBRI
Roofing	CI Sheet	Easily available	Bamboo truss and CGI sheet	Easily available
Doors and windows	Timber	Easily available	Timber	Easily available
Ceiling	Absent	-	Bamboo	Easily available

Table 6: Comparative analysis of environmental impact of materials.

	Existing dwellings		Proposed prototype	
	Material	**Environmental impact**	**Material**	**Environmental impact**
Plinth	Earth	Positive, Low	Cement and sand+ F.C. Footing	Positive, Moderate
Structural bracing	Bamboo/Timber	Positive, Moderate	F. C. Beam+ F. C. Column+ Bamboo +Timber	Positive, Moderate
Walls	Brick + CI sheet	Negative, Moderate	Sand Cement Hollow Blocks and Bamboo Matt	Positive, Moderate
Roofing	CI Sheet	Negative, Moderate	Bamboo truss and CGI sheet	Positive, Moderate
Doors and windows	Timber	Positive, Moderate	Timber	Positive, Moderate
Ceiling	Absent	-	Bamboo	Positive, Moderate

Table 7: Comparative analysis of vulnerability to natural calamities of materials.

	Existing dwellings		Proposed prototype	
	Material	**Vulnerability**	**Material**	**Vulnerability**
Plinth	Earth	Highly vulnerable	Cement and sand+ F.C. Footing	Not vulnerable
Structural bracing	Bamboo/Timber	Moderately vulnerable	F. C. Beam+ F. C. Column+ Bamboo +Timber	Not vulnerable
Walls	Brick + CI sheet	Vulnerable	Sand Cement Hollow Blocks and Bamboo Matt	Moderately vulnerable
Roofing	CI Sheet	Vulnerable	Bamboo truss and CGI sheet	Moderately vulnerable
Doors and windows	Timber	Moderately vulnerable	Timber	Moderately vulnerable
Ceiling	Absent	-	Bamboo	Moderately vulnerable

6 Discussion

Based on the comparative analysis of the different parameters (Table 3,4,5,6, and 7) the parameters have been graded as high, low, and moderate.

Table 8: Grading of parameters.

Sl no	Parameter	Existing Models	Proposed prototype
1	**Affordability**	High	High
2	**Durability**	Low	High
3	**Availability**	High	Moderate
4	**Environmental Impact**	High	Low
5	**Vulnerability**	High	Low

This grading, in turn, highlights the areas which need to be worked upon to make alternate materials a reality in Bangladesh. In terms of affordability both the existing model and proposed prototype, score the same as both costs less than hundred thousand Taka and is, therefore, quite affordable even, in case, the funding is provided by the government or some other agency.

The durability of the existing model is low while that of the proposed prototype is high thus, rendering cost benefits in the long run. The availability of the existing model is high while that of the proposed prototype is easy to make and HBRI is willing to train the interested people for making these alternative materials locally. This suggests that in order to make the prototype an alternative to the existing model measures must be taken to make the materials easily available to the masses.

In terms of Environmental Impact, the existing model scores high as annually a lot of resources have to be added in order to maintain it while that of the prototype is low as it shall require minimal annual maintenance – a more sustainable solution.

Finally, the existing model is highly vulnerable to natural calamities and weathering while the prototype materials are sturdy and the construction method is protective enough. Therefore, it is expected that the proposed sample prototype would be a sustainable solution for rural housing in Bangladesh and other similar contexts.

7 Conclusion

Worldwide architectural problems do not have only one method of solution; rather the solutions must be tailored considering users' perspective, context, influences, and impacts (Haque and Rahman, 2020). The paper is primarily based on a literature review, government's guidelines, physical survey, and the solution can be applied to similar settlements, in which case the design module size, shape, functions may vary according to the needs. To make alternate materials a reality they need to be more affordable and readily available for which more production units must be set up in rural areas. The researched materials and construction method have a huge hidden potential in terms of cost-efficiency, low carbon emission, sustainability, and most importantly refraining immediate unsustainable construction in rural settlements.

From numerous studies, it's observed that there are thousands of architectural solutions regarding the needs of low-cost, sustainable housing settlements but the gap is these solutions are mostly futuristic and difficult to immediate settings as the poor people are unable to change their living pattern drastically with less time and unaffordability. So, this is the high time to research furthermore about using alternative affordable materials and construction methods to achieve sustainable goals, especially in rural housing design.

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MULTICULTURISM AND SOCIO-CULTURAL INTEGRATION IN BOTTOM-UP APPROACH TO RURAL HOUSING: A MULTI-CASE STUDY IN ASSAM, INDIA

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Abstract: *Over the recent decades rural development has been recognised as a part of holistic development of the country, however, in more recent years, the concept of smart villages has redefined the approach to rural development. As a component of rural development, the approach to housing and shelter has been demonstrated to be more effective with the inclusion of community-participation and contribution. Literature on bottom-up approaches and rural perspectives has led to the understanding that the multicultural identity of the community and the place shapes the perspective on housing and shelter. As such, this paper addresses the importance of the multiculturism of a community and the cultural adaptation and assimilation that occurs within a rural cultural ecology, to develop a bottom-up approach of rural housing for smart villages. Analysis of the house layouts and their supporting data of the select sample household cases from four ethnically diverse communities based on the degree of urban exposure demonstrated the levels of socio-cultural integration of the cases. Each sample case demonstrated their perspective of housing and shelter through the changes to the design and construction of the houses described by them. The causal analysis of these changes highlighted that the multiculturism and cultural adaptation and assimilation in the community play a major role in influencing the housing typology within a village. Therefore, addressing the levels of socio-cultural integration among the cases in the community aids to understand the perspective of housing and shelter and hence, facilitates the development of a user-oriented solution of housing.*

Keywords: *Multiculturism, Cultural Adaptation and Assimilation, Urban Exposure, Rural Housing, User-oriented Approach.*

1 Introduction

There have been many approaches to strategize a development plan for better quality of life. As such, most of the efforts were directed towards planning better cities however, over recent decades the interconnected relation between the urban and rural sectors indicated the need to support rural development along with urban development. This led to research and planning being directed towards rural infrastructure and development.

In the context of rural development, some of the current practices of providing housing and shelter have failed to deliver the expected outcomes from the community perspective. The community perspective is shaped by the different socio-cultural contexts and multiculturism experienced by the individuals and households of the community, which is a part of shaping the practice of housing and shelter. Focusing on four communities in Assam, India and based on the empirical evidence, this research aims to highlight the fact that the community perspective on housing and shelter is integral to successful housing practice.

The remainder of the paper will focus on the user-oriented perspective of housing and shelter to developing an effective bottom up approach to rural housing to ensure a successful rural development strategy. For this the dataset obtained through data collection among eighteen households from the four communities in Assam is categorised based on degree and type of urban exposure experienced by the respondents. Sample cases belonging to each category is spatial analysed based on the house layouts and supporting data to investigate the reasons and decision-making process for their self-devised housing solutions.

The results of the comparative spatial analysis conducted across the categories and sample cases is discussed to highlight the different levels of cultural adaptation and assimilation due to different socio-cultural contexts experienced by the respondents. The discussion leads to understanding of the degree of multiculturism of the communities as a result of the cultural adaptation and assimilation, therefore highlighting its importance to shape the rural perspective of housing and shelter. Therefore, this effectively demonstrates the relevance of integrating a component that incorporates the user-oriented perspective to develop an effective bottom up approach to rural housing.

2 Multiculturism in a user-oriented bottom-up approach to rural housing for smart villages

In recent years, the role of rural development has been recognised to be an equally important part of development along with urban-focused development. An example of this recognition is the introduction of the concept of smart villages as a counter-balancing venture along with smart cities to progress towards a holistic development of the country(Department of Urban Development, 2015; ZeeNews, 2016). This concept has been integral in reinventing the approach to rural development to ensure better housing, construction and infrastructure in the rural context (Cambridge, 2014; Doloi et al., 2019; IEEE, 2017; Shukla, 2016; smartvillages.org, 2014; Villages, 2014; Vswanadham, 2013).

Gkartzios and Scott (2009) demonstrated that housing is a fundamental part of rural development, which often treated in isolation affects the overall planning and development of rural areas. As such there have been efforts to develop socially acceptable bottom-up approaches to housing and development in the rural context (Donovan & Gkartzios, 2014;

Gao, 2016; Gkartzios & Scott, 2014). Within the context of smart villages defined by Doloi et al. (2019), housing has been determined as one of the key elements that requires research and understanding to enhance rural development, citing the need to develop a bottom-up approach. Gao (2016) defines a bottom up approach as one that incorporates the community participation in making decisions to strategize plans for effective implementation of rural development policies.

Gao (2016) argues the merits of a bottom up approach by discussing the correlation between the inclusion of the community's contribution in the decision-making process to better results in rural development. It demonstrated the difference in perception of traditional culture in houses between external stakeholders and the community. Foley and Scott (2014) demonstrated that the perspective of the users differ based on the degree of direct or indirect exposure to urban lifestyle through a focus group analysis. This resulted in the local rural group expressing disapproval of urbanising the surroundings while the recently relocated local group expressed the desire to see more development that resembled the urban counterparts.

This demonstrates the disparity of socially acceptable perspectives of housing and development among the participants based on whether they were local or not and the relevance to develop a bottom up approach to rural housing. This points to the multicultural identity of a community that helps shape the perspective on housing and shelter as demonstrated through the case study of sixteen Puerto Rican communities by Steward (1972, 1986).

Julian H. Steward (1972) proposed the concept of cultural ecology which is defined as the 'cultural adaptation to the environment', explains culture as a product of continuous evolution of interactions, environment and community. Steward (1986) explained that socio-cultural integration within a group determined the degree of cultural adaptation that takes place among communities in different levels, such as, the national level, community level, family level and individual level. As a result, each level of integration, introduced according to cultural ecology, determines the multicultural identity of the community and its people.

The literature suggests the inclusion of community participation and contribution into the approach to rural housing where the different perspectives of the households and individuals are taken into consideration. Due to their differing perspectives, the considerations need to be introduced based on whether they are locals or non-locals, and the degree of urban exposure experienced by the community. It emphasizes the significance of multiculturism and socio-cultural integration within the community that affects the perspective of housing and shelter, reaffirming the relevance of the community participation for successful implementation of bottom-up approaches to rural development.

3 Degree of urban exposure

To ensure a user-oriented bottom-up approach to rural housing, the factors that shape the perspective of what is regarded as the user expectation is discussed. Furthermore, in the rural context, urban exposure and urbanisation plays a role in fostering socio-cultural integration leading to cultural adaptation and assimilation in the community and thereby creating variations of multicultural identities within the communities. Therefore, based on

the degree of urban exposure experienced by a rural citizen the degree of socio-cultural integration will be analysed.

The perspective of housing and shelter is discussed based on the data collected the participants of selected households in the four ethnically diverse villages in Assam, anonymised as Kuki, Karbi, Dimasa and Labang. The data was collected through transect walks(Lorenzo & Motau, 2014), focus group discussions(Patton, 2002) and questionnaire/surveys in the village level, and an interview-based floorplan technique(Gaver et al., 1999; Zubin et al., 1965) in the household level. Using content analysis, cross-case analysis and analytic induction, the differences in the participants' views is discussed. The difference in perspective of socially acceptable housing has been attributed to the degree of urban exposure experienced by the participant of the data collection exercises and the analyses of its results.

Based on the analysis of the data collected through the questionnaire/survey of the household cases, the participants can be divided into four categories according to the type of urban exposure they have experienced: Local, Local relocator, Non-local rural relocator and Non-local urban relocator.

3.1 Local

Local participants are ones who have lived most of their life in the villages and occasionally visited towns and urban centres for selling their products in the market or healthcare. In this category, the participants would not have enough time or opportunity adapt to the lifestyle of the town or city. Even on occasions that they might have to stay over at a hotel or lodge, due to their meagre earnings, the accommodation would not be comfortable as compared to the comfort provided by their own home. However, in the case of the presence of a closely located urban centre, the urban centre becomes part of the surrounding context that directly influences the rural life and routine as is observed in KaH01 of Karbi. In contrast where the urban centre does not integrate into the immediate context of the village, the socio-cultural integration is experienced through a relative or a peer who is a regular visitor of the household or participants of the other categories as observed in LaH14 of Labang.

3.2 Local-relocator

Local-relocator participants are ones who were born in the village or moved to the village when they were children and had been exposed to urbanisation through education or employment. This condition would require them to live in the town or city for longer periods where the town or city becomes their adopted home, while visits to the village are occasional. The return to the village occurs during annual celebrations or designated breaks from academia or service which would lend a festive ambience to the visit which is different from the usual routine life in the village. This group of people would be ones who have experienced rural life but do not practice it and hence, is a memory than a day-to-day reality. Examples of this group are the participants of KuH02, KuH03, KuH11 and KuH19 of Kuki, KaH19 and KaH32 of Karbi, DiH01, DiH04 and DiH11 of Dimasa, and LaH01 of Labang, however only KuH03, KuH11 are discussed to demonstrate the analysis of the layouts.

3.3 Non-local rural relocator

Non-local rural relocator participants are those who were originally from a different village and had relocated to the case study village and built their life there. Having lived in different rural contexts the participant has knowledge and experience of two different kinds of cultural settings that is shaped by the people of the place. The perspective of the group will retain the rural perspective, however, due to the different socio-cultural norms in different places they may practice unique socio-cultural etiquette and therefore possess a different value system regarding people, place, and interaction. Examples of this group are the participants of KuH08 of Kuki.

3.4 Non-local urban relocator

Non-local urban relocator participants are ones who had been brought up in a town or city before relocating to the village. The movement of people from urbanised settlements to less-urban settlements and villages is called counter urbanisation. Having lived in an urbanised environment, the participants are used to the urbanised way of living which they bring to the village as part of their routine life in the village. Similar to the findings of Foley and Scott (2014) regarding the disparity of perspective of the rural landscape, the disparity in the perspective towards housing and shelter was observed in KaH26 of Karbi, DiH05 of Dimasa and LaH19 of Labang who are non-local urban relocator participants.

Based on this categorisation, the perspective of housing and shelter shaped by degree of urbanised influence on the community, household and individuals can be understood. However, aside from the exposure to urbanization, the different levels of socio-cultural integration from the local environment in the community level, household level and individual level also contribute to shaping this perspective. The relocators to the village are influenced by the locals and older relocators that help them adapt to the immediate rural environment while the locals are also influenced by the relocators who bring in foreign cultural practices, and thereby shaping a multicultural perspective of housing and shelter. As a result, there is a degree of multiculturism in the community due to the different households and individuals and their different levels of cultural adaptation and cultural assimilation.

4 Multiculturism through cultural adaptation and assimilation

The multiculturism in the community and their preceding cultural adaptation and assimilation is demonstrated through the analysis of the house layouts that were obtained through the interview-based floorplan projective technique and the transcript of the interview. The analyses the data as shared by the participants in the interview demonstrates the evolution of their perspective on housing and shelter that has been modified or maintained by the levels of socio-cultural integration.

4.1 Local cultural adaptation and assimilation

In the case of the local participants, the degree of cultural adaptation and assimilation is assumed to be the least since they are part of the existing environment. However, the analysis of the house layout of KaH01, KaH02 and LaH14, demonstrated the proximity to urban centres as a factor that influences socio-cultural integration.

KaH01 as seen in Figure 1 ,presents an example that integrates traditional elements within the house while the form resembles a contemporary house built in towns. The juxtaposition

of the rooms is according to the progression of space based on privacy and familiarity as followed in the traditional house. Similar to the traditional *Hong-Pharla* to receive guests, there is a fireplace in the left most room accessed through the corridor for the same purpose. The rooms like the *Tibung, Thenk-tor, Kut* and *Kam* are all present in the house, however, the spaces have been re-organised though the intended use of the rooms remain. The construction method and materials used for the house shows the continued vernacular practice of building with bamboo and wood, however the thatch roofs have been replaced with galvanised Iron sheets.

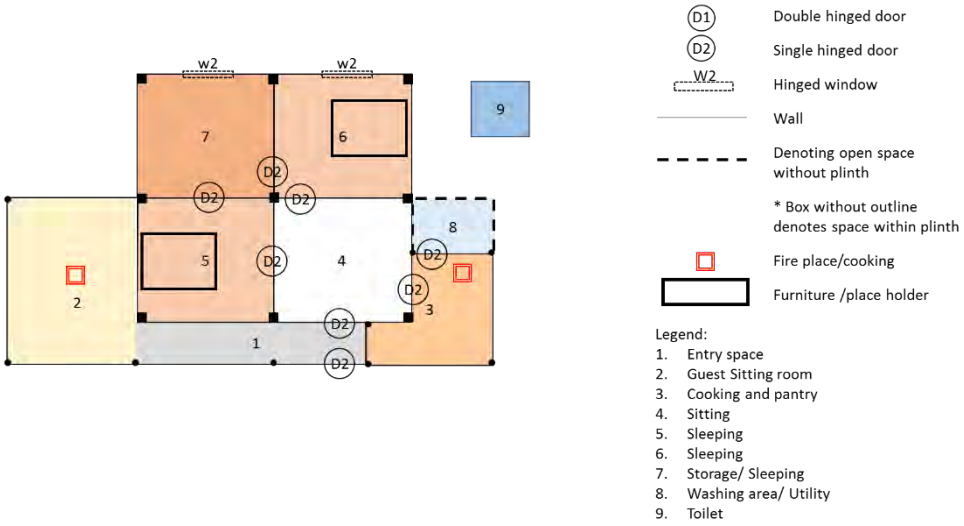

Figure 1: Present house layout, KaH01

In KaH02, as shown in Figure 2, the similar practice of maintaining the traditional elements while incorporating a simplified layout of the house is demonstrated. However, due to the single occupancy of the house and the socio-economic conditions of the household has consolidated the purpose of the shelter into a single room house that includes a cooking area, storage space and sleeping area within the small confines. The accommodation is minimal and indicates the individual level of influence that aids in decision making for housing and shelter.

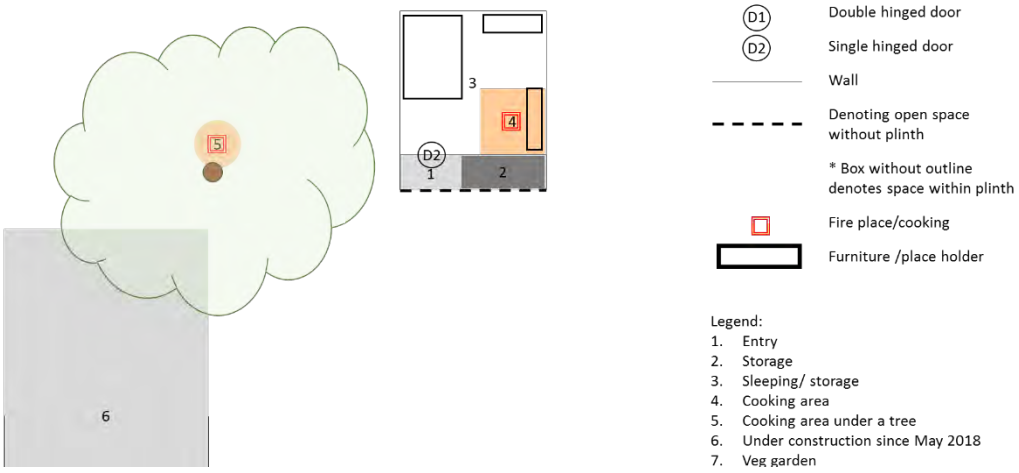

Figure 2: Present house layout, KaH02

In contrast, LaH14 as seen in Figure 3, demonstrates the evolution of housing and shelter as it retains the multiple unit huts within the same household built for each daughter that has come of age or as is the case here, for each generation. Of the four units that are still standing, the oldest belongs to the grandmother, the one built in 1985 is for the sons, the one built in 2013 is for the parents while the newest built in 2016 is for the daughter. According to traditional practice of letting the youngest daughter sleep in the inner room, which is also the main kitchen, has continued as the newest hut is also the cooking area and due to their socio-economic circumstances, it is built of bamboo. The 1985 unit was built for the mother of the household when she had come of age and newly married, the intention was to have a multiple rooms within the same house, however, the household returned to the practice of having multiple units per daughter/generation as shown below. As indicated, the grandmother of the household continues to live in her own traditionally built house.

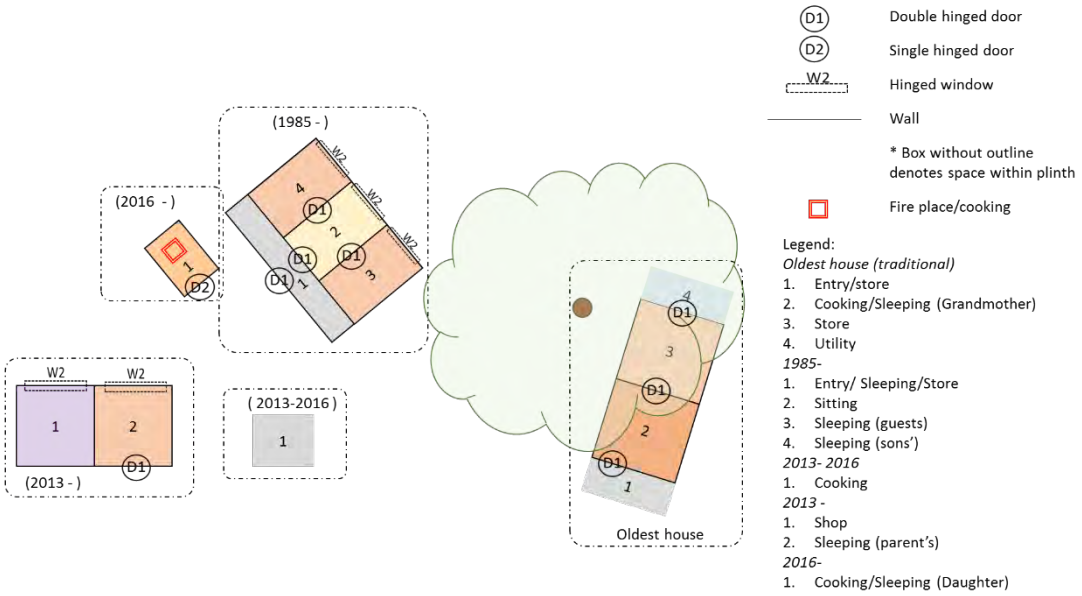

Figure 3: Present house layout, LaH14

Due to the difference in their accessibility and connectivity to other communities and urbanisation, where KaH01 is closer to an urban centre where as LaH14 is does not possess telecom connectivity, their immediate cultural context is different. In the KaH01, the layout is evolving to a generic layout while maintaining the progression of spaces through the house and the use of bamboo and wood for the walls and doors with a tinned roof indicates a community level influence. In KaH02, the simplification of spaces is translated into the house layout while the community level influence of maintaining traditional elements within the house is seen. In the LaH14, the change of materials used for building the 1985 unit and its layout in LaH14 demonstrates the desire to urbanise which is an individual and household level influence, however, the use of the units the separate units for each daughter/generation represents the retention of the traditional socio-cultural practice that indicates community level influence.

4.2 Local-relocator cultural adaptation and assimilation

In the case of the local-relocator participants, the degree of cultural adaptation and assimilation is observed in a higher degree than the local participants as they have been

exposed to different cultural contexts where they simultaneously practice both socio-cultural practices based on location. The disparity of the perspective was observed between the local-relocators KuH03 and KuH11 of Kuki as discussed below.

As seen in Figure 4, the participant of KuH03 returned to a house which had been built by his father which could accommodate his mother, himself, his wife, his two children under five years of age and his brother. The house had three rooms: one big room with a double bed at the centre from the entrance, a bedroom on the left that accommodated two double beds and a traditionally influenced kitchen on the right Since his older brother had recently moved to his own newly constructed home, it resulted in a much more spacious and comfortable accommodation, thereby forming an acceptable perspective of his accommodation in the village.

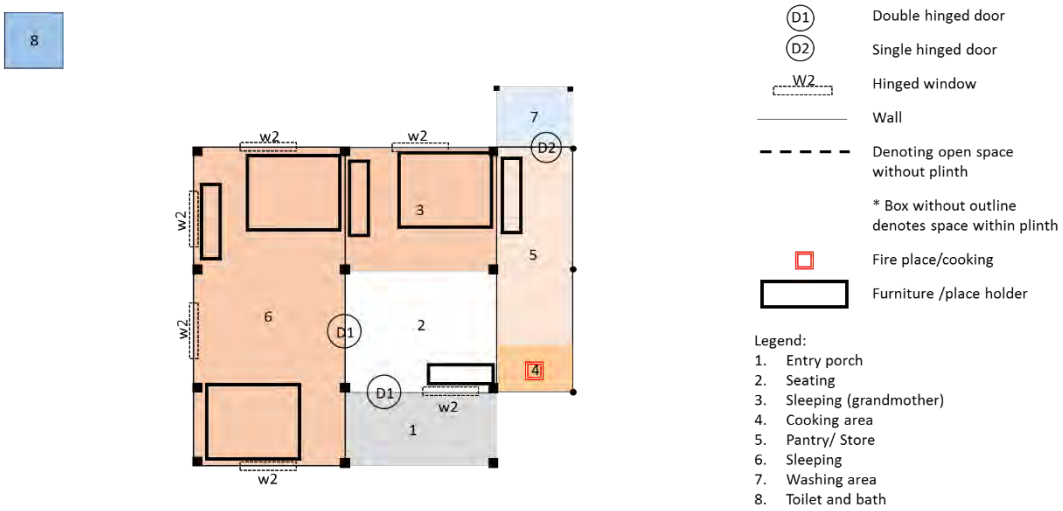

Figure 4: Current house layout, KuH03

In contrast, as seen in Figure 5, though the participant of KuH11 is of similar age as the participant of KuH03 with similar relocation and urban exposure history, he had returned from the city to a traditionally built house which was small for family of six, four adults and two children. The discomfort, as shared by the participant, of the cramped quarters encouraged the participant to build a house that had separate rooms for each adult/couple. The concept of privacy for the adults and couples was adapted into the new housing layouts.

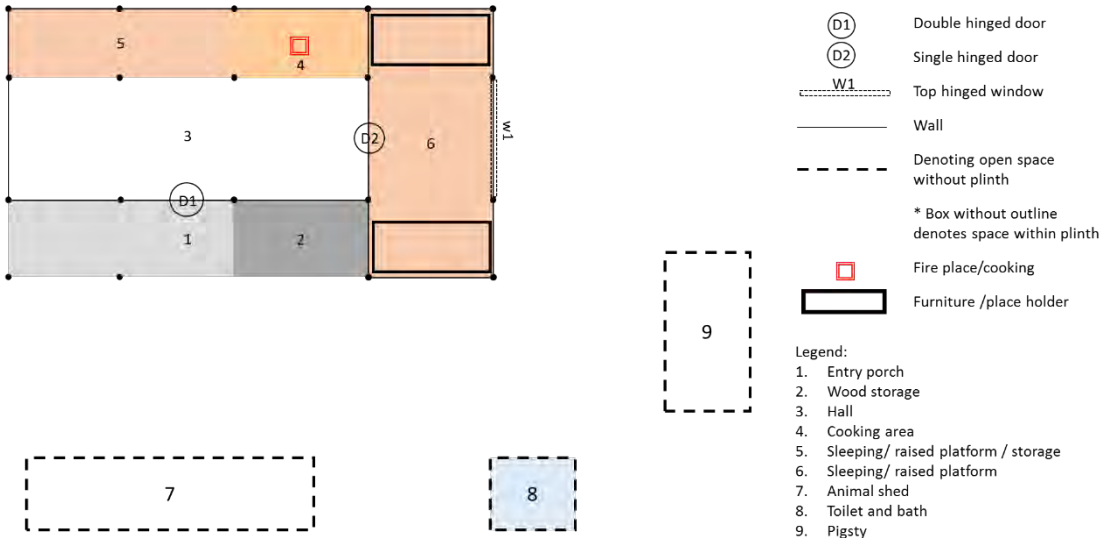

Figure 5: Past house layout, KuH11

As a result of their different experience of their rural accommodation, KuH03 and KuH11 demonstrate contrasting perspectives of housing and shelter in the village. As seen in Figure 6 the future house layout of KuH03 demonstrates the acceptance of the traditional architecture in the design of the kitchen while adopting an urbanised layout for the living room, bedrooms, storage and utility rooms. On the other hand, as seen in Figure 7, the present house layout of KuH11 demonstrates a rejection of the traditional layout by completely reorienting the layout away from the traditional style.

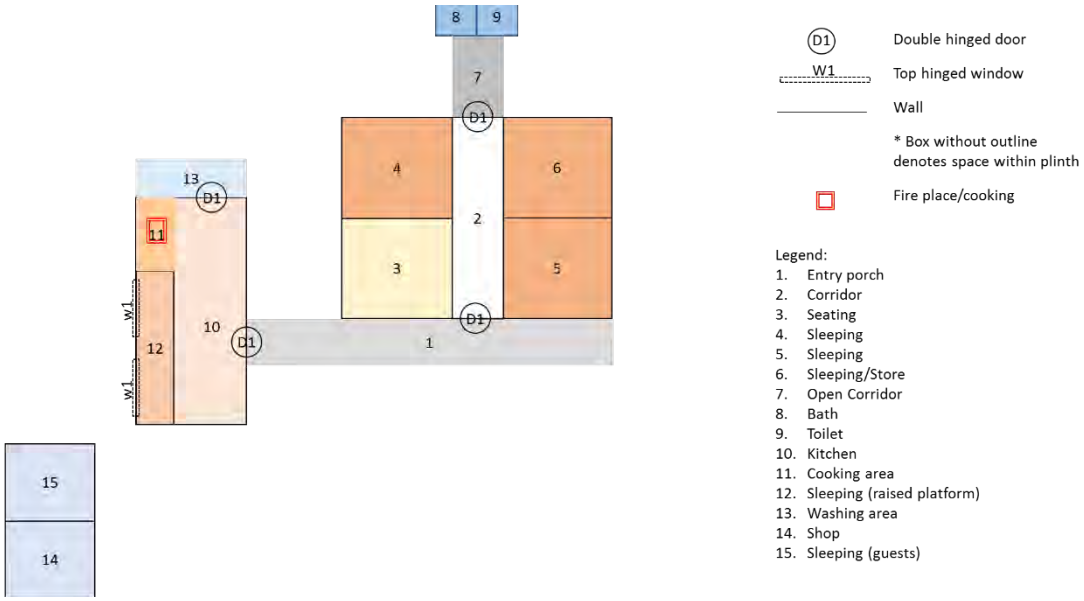

Figure 6: Future house layout, KuH03

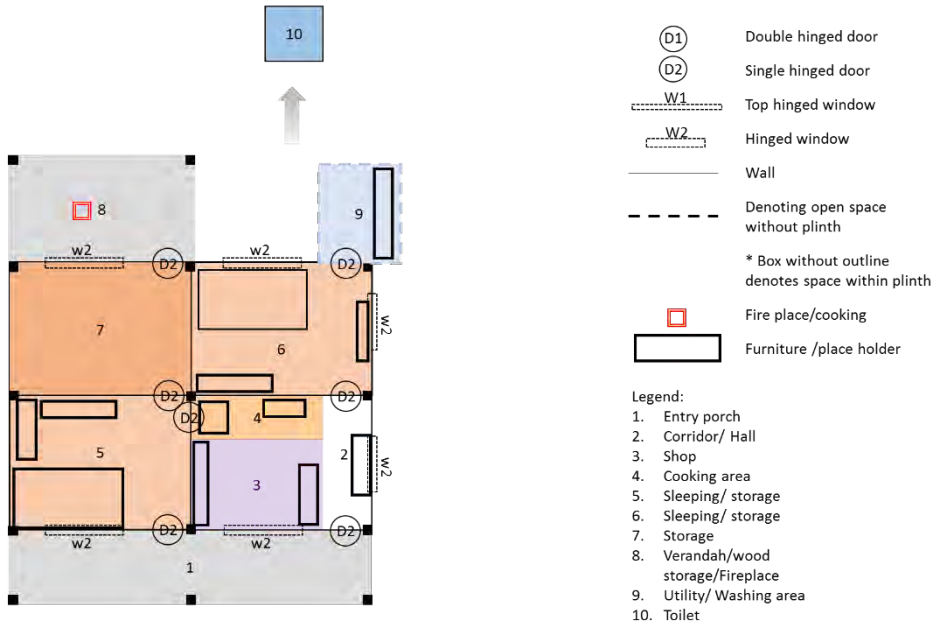

Figure 7: Current house layout, KuH11

Due to different levels of socio-cultural integration experienced by the participants, the evolution of the house layouts indicates the evolution of perspective among individuals and households within the same community. Further analysis into the layout and the architectural elements demonstrates that socio-cultural integration can take place in the community level, as seen in KuH11, the house built by the participant almost rejects the traditional architecture, however, the house maintained an accessible kitchen and had a wood-fire place with a suspended shelf similar to the elements of the traditional kitchen. In the household level, the example of KuH03 demonstrated that having moved back into a comfortable and spacious house, the occupants did not require modifications to the house, while over time, the socio-cultural practices of the household maintained by the local occupants was adopted by the local relocator occupant. The contrast of the two examples show the contrast in their perspectives to housing and shelter when the future layouts is discussed with each household case. While KuH11 is satisfied with the non-traditional architecture of his house, KuH03 described a traditionally built kitchen as part of the future house layout which would accommodate the traditional way of cooking and eating food in the house.

4.3 Non-local rural-relocator cultural adaptation and assimilation

In the case of the non-local rural relocator participants, the degree of cultural adaptation and assimilation is not demonstrated through the change in construction material, however, the spaces within the house are reorganised to suit the layout that was practiced in their previous accommodation. The analysis of the house layout of KuH08 is discussed below to demonstrate the socio-cultural influence on the household.

As seen in Figure 8, KuH08 describes a traditional house layout which has evolved by adding rooms on either side of the house and by adding walls around a section of the entrance area has created a room for the participant's son. Since the participant moved from a Kuki village in Manipur, the socio-cultural context is similar which explains why the

core original layout of the house is traditionally built. However, due to rushed construction of the house, as shared by the respondent, the location for building the house was selected too close to the village pathway. This, along with the direction of the wind and the slope of the ground, prompted the decision to place the cooking area along with the utility space away from the front door and towards the back of the house. This created a larger central space as is traditionally maintained with an accessible cooking area and a raised platform for sitting and sleeping.

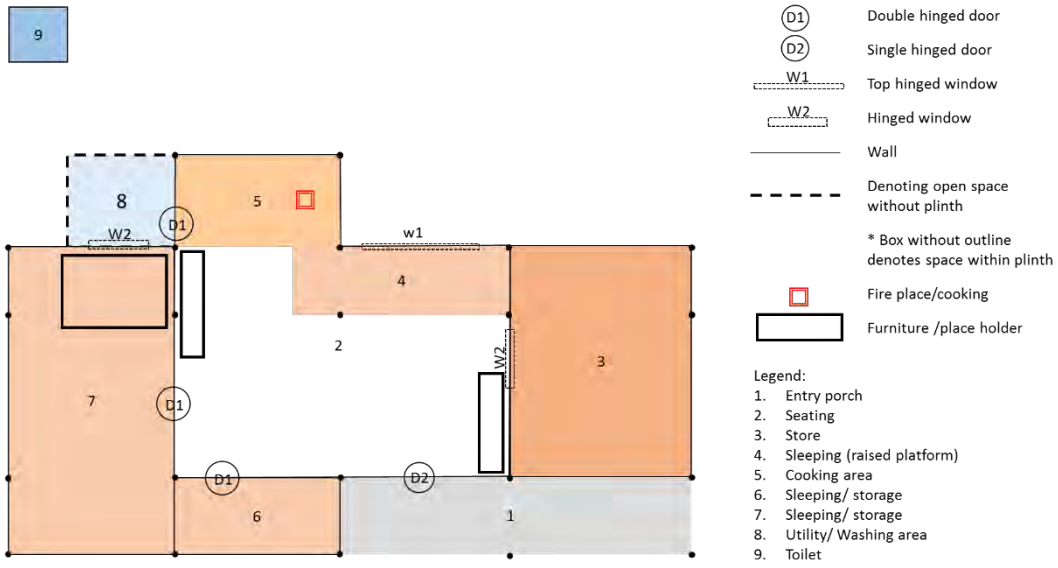

Figure 8: Present house layout, KuH08

However, due to the multicultural identity of the village where many of the community have been exposed to urban life through relocation or have relatives in urban areas who visit during festivals, the house has added rooms to accommodate the guests to the house. The house layout evolution and use of non-local materials in construction demonstrates community level and household level influence while the maintenance of the accessible cooking area near the central room and the raised platform demonstrates the individual level influence of socio-cultural integration.

4.4 Non-local urban-relocator cultural adaptation and assimilation

In the case of the non-local urban -relocator participants, the degree of cultural adaptation and assimilation is the highest as the disparity between the socio-cultural context is the most. The analysis of the house layout of LaH19 demonstrates community level influence of the rural context while the individual level influence is demonstrated in the internal layout of the house.

As seen in Figure 9, the present layout of LaH19 is a simple hut made of local materials that outwardly appears traditional which demonstrates a community level integration however, the internal layout resembled the layouts that she was accustomed to when she lived in the town demonstrating lower levels of household level integration. The individual level integration was observed to be low as her description of her future house as a double-storey house built of non-local materials that are common in towns and cities. This further

demonstrated the degree of cultural assimilation that had already taken place in the town and cities where she had been raised that the traditional way of living within the house in the village was not adopted by her.

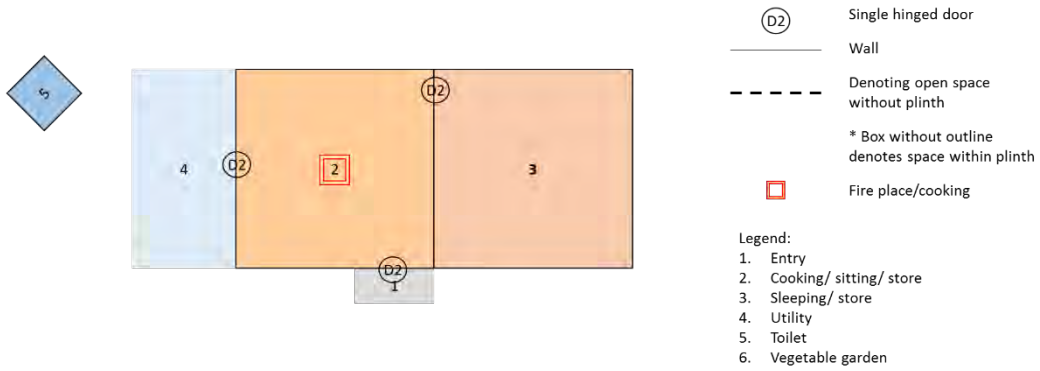

Figure 9: Present house layout, LaH19

4.5 Degree of Multiculturism and socio-cultural integration

As argued by Gkartzios and Scott (2010a, 2010b), the cases discussed in the preceding sections demonstrate that multicultural practices is imported to the rural areas through varying degrees of counterurbanisation. The different degrees of counterurbanisation was categorized under *-relocators* to include internal migration across villages. This shapes the multicultural perspective of housing and shelter that is influenced by urbanized way of living which is significant to produce user-oriented housing solutions as schematically represented in Figure 10.

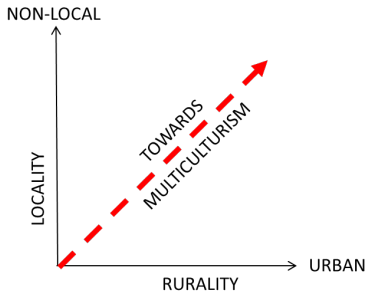

Figure 10: Rurality versus Locality

Figure 10 represents the degree of multiculturalism of a community is based on the disparity of the socio-cultural contexts that the user or occupant has experienced according to rurality versus localness, or local*ity.* Though the data sample was divided based on the degree of urban exposure experienced by the participants, the analysis of the socio-cultural integration led to the understanding the ancillary factors that aid in consolidating the perspective. For instance, there is a clear progression towards using materials that are both local and non -local, namely galvanised iron sheets for roofing, due to its lower cost and maintenance. The analysis of the house layout and the changes to the houses across the layouts indicated the progression from traditional to more generic forms of houses and thereby evolving towards a new housing typology that incorporates the multiculturism of the community.

Based on the responses provided by the participants, the ancillary reasons were instrumental in decision making for the when building their new house or describing their future house layouts as demonstrated in the disparity discussed between KuH03 and KuH11 who are local-relocators. The difficulty to adjust to the rural cultural context has contributed to the culture shock experienced by KuH11 which led to rejection of traditional way of living, while smooth transition of urban to rural lifestyle in KuH03 encouraged cultural adaptation and retention of traditional architecture and design. In the case of urban to rural relocation as done by LaH19, the different cultural contexts of the town she had lived in and the village she currently resides in is indicated through the non-traditional layout of the house.

Due to the different socio-cultural and socio-economic contexts of the respondents, their self-devised housing solutions that suit their needs and practices are unique to the user, or occupant. This signifies that implementation of rural housing schemes need to incorporate more than socio-economic and socio-cultural contexts of the village since the individuals in need of housing may have different expectations of housing and shelter based on their exposure to urban life. Thus, it is important to include a user-oriented approach to the bottom-up approach to rural housing.

5 Conclusion

To summarise, the paper introduced the relevance of multiculturism of people as the influencing factor contributing to the perspective of housing and shelter. This paper has presented different perspective on housing and shelter that have resulted in different house layouts across the village cases. The paper analysed the data from four ethnically diverse villages and the selected households within each village.

Based on the literature and the analysis conducted, the paper demonstrated the different levels of socio-cultural integration that need to be recognised to understand, firstly, the multiculturism of the community and secondly, the cultural adaptation and assimilation that takes place to shape the perspective of housing and shelter. The bottom-up approach is characterised by the incorporation of community participation and contribution of community opinions. However, the analysis of the paper introduced the diverse perspectives held among households and individuals thereby encouraging the integration of the user-oriented perspective to develop a bottom up approach to rural housing and development.

In conclusion, this paper has reaffirmed the importance of multiculturism, and cultural adaptation and assimilation form the perspective of housing and shelter in the rural context. Based on the analyses of the layouts of local and non-local relocators, it demonstrated that the evolution of the perspective is directly linked to socio-cultural and socio-economic contexts of the community. This established the importance of recognising the diversity within communities and incorporating the perspective into the approach to rural housing, hence, proving that the user-oriented perspective is relevant to develop a bottom up approach to implement rural housing schemes for holistic development.

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A SMART BI-PARAMETRIC APPROACH FOR HOMOGENEOUS DELINEATION OF RURAL ROADS

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Abstract: *In order to accord maintenance and rehabilitation strategies, it is important to segment pavements that possess similar performance characteristics through the process of homogeneous sectioning. Literature revealed that the existing delineating methods help segment the pavements using individual parameters such as International Roughness Index, rutting, deflection, and skid resistance. However, the resulting segments may have similar performance within the one parameter of interest, but may be different in the case of other parameters. Hence, there is a need to define a bi-parametric based sectioning process for pavements in order to arrive at a rational maintenance treatment. Thus, the objective of this study was to define a bi-parametric approach for delineation, in which the road roughness characteristics and rutting potential were considered for defining a dimensionless parameter called "spurn" for segmentation. The dataset comprising of 561 data points was collected from Andhra Pradesh Road Development Corporation (APRDC), India. Furthermore, quality control charts were established on the spurn values to delineate the pavements as homogeneous sections having similar spurn magnitudes. A pavement treatment classification scale was also defined based on spurn for suggesting maintenance treatment for the delineated segments. It was found that the spurn-based sectioning was quite efficient to suggest appropriate maintenance strategies to the homogeneous sections compared to the existing approaches in the literature. The rational sectioning method could be applied globally for sectioning as well as treatment selection for rural roads specifically where budget constraints are prevalent. Further, the suggested maintenance strategies would reduce wastage of material and emissions, hence conserve the natural of villages creating an ambience to establish smart villages within a larger community conglomerate.*

Keywords: *Homogeneous Sectioning, Roughness, Rutting, Pavement Asset Management System, Spurn, C-Charts*

1 Introduction

Of late, the development and maintenance of rural road infrastructure has become the focal point in the emerging economies, mainly to augment exchange of goods and services (World Highways 2020). Further, the economic growth is being matched with the number of rural road kilometers per capita of population. In general, road infrastructure deteriorates over time due to increased traffic loads as well as seasonal and climatic variations, which is characteristic of rural roads as well. Pavement asset management system (PAMS) is a tool used to aid in the pavement management decisions that helps reduce the deterioration rate while also enhancing the overall performance of roadway infrastructure. Based on the fundamental philosophy of PAMS, it is far less expensive to keep a pavement in good condition than to repair, if it has deteriorated. Therefore, PAMS focuses on suggesting optimum maintenance strategies to the pavement segments, especially with similar conditions (Haas et al. 2015). In the context of rural roads, scientific and innovative maintenance methods would improve the quality-of-life of smart cities and villages.

Nowadays, several agencies have started to use automated condition data collection vehicles (DCV) to map functional condition and pavement profiles as part of PAMS database creation. In the process, International Roughness Index (IRI), rutting, and texture are collected by the embedded sensors mounted within the DCVs, whereas the other distresses are retrieved from pavement videos (Bennett et al. 2006; Bogus et al. 2010; Haas et al. 2015; Ong et al. 2010; Peraka and Biligiri 2020). In order to suggest a maintenance strategy, pavement should be delineated having similar condition characteristics, called *homogeneous sections*.

In principle, segmenting the pavements into homogeneous sections is significantly affected by two factors: cost and time. As the data gets collected for long pavement stretches, a single type of treatment to the whole pavement section would result in high cost (Haas et al. 2015). Even though the agency is ready to bear the economic losses, it would not result in an efficient output. Consequentially, it will not improve the long-term performance of the pavement system (Thomas 2003, 2004). Therefore, the road section is segmented into homogeneous subsections, which will have consistent statistical properties and the information stored for each segment could be summarized without losing any significant information within each segment. The ability to delineate the general boundary locations of these segments in an effective manner is very important for maintenance and rehabilitation keeping the investment needs as top priority.

Several research studies pertinent to homogeneous sectioning of pavements have been performed having similar performance characteristic using cumulative difference approach (CDA), absolute difference approach (ADA), cumulative sum (CUSUM) method, classification and regression trees (CART) approach, and quality control charts (Cafiso and Di Graziano 2012; Donev and Hoffmann 2018; El Gendy, Amin, Shalaby 2008; Peraka and Biligiri 2020; Thomas 2003, 2004). Segmentation techniques have two main objects: (a) to identify change points where a structural modification is observed in the mean or variance of a dataset, and (b) to define indicators that characterize homogeneous sections in terms of mean and/or variance of data segments between the change points.

A detailed review of the segmentation methods is presented in Table 1. Importantly, homogeneous pavement sections have similar characteristics so a uniform maintenance strategy must be applied at an appropriate time. However, the existing methods / approaches delineate the pavement sections based on only one performance metric. Thus, there is a need to devise an approach to utilize more than one performance metric in the pavement delineation process in order to accord the best possible maintenance strategy, while also accounting for more than just one distress. Therefore, the objective of this study was to develop an approach to delineate pavement segments using multiple performance characteristics. It is envisioned that the novel delineation approach presented in this study will help segment the rural roadway sections in an optimal manner, and additionally suggest prioritized maintenance interventions, specifically for rural roads that are in dire need of repair and rehabilitation in several regions of the world.

Table 1: Existing methods used for pavement segmentation

Source	Method(s) used	Remarks
Thomas 2003	Bayesian approach (BA)	It is sensitive to closely spaced changes, also flexible enough to "react" to changes.
Thomas 2004	CDA	Non-substantial changes in trend are very frequent in these series and should be ignored (loss of data).
	ADA	Can be preferred for long distances, not preferable for short distances as the end portions (section borders) cannot be found. Smoothening is done to find and is expected to do more harm than good when sudden change has to be identified.
	BA	Measurement series containing excessive outliers might not be handled well. Missing values are not allowed.
Misra and Das 2003	CDA	Choice of minimum section length cannot be incorporated in CDA.
	CART	Has a better flexibility in terms of adjustments, possible to specify minimum section length and the number of delineated sections desired.
Tejeda et al. (2009)	CUSUM	This method produces the highest possible number of segments and the lowest sum of squared error.
Gendy and Shalaby (2008)	Quality control Charts (C-charts)	A profile can be segmented successfully without target range when there is no information about the referenced data was present.
Cafiso and Graziano (2012)	Minimization of sum of squared error (MINSSE)	Compared the SSE of CDA and ADA approaches. The method with lowest SSE would be considered for segmentation.
Syed and Sudhir (2015)	Falling weight deflectometer (FWD) data	Detection of local variations using CDA, T-test by making the process an iterative one (peak deflections and nearby deflections can be predicted and rehabilitated accordingly).

The scope of the work included analyzing the characteristics of the known parameters using control charts and find a dimensionless parameter called *spurn* comprising of characteristics of IRI and rutting parameters, both measured using the automated condition survey. This was accomplished by creating a grading scale based on metrics of

the known parameters, which resulted in optimum sectioning of pavement stretches using two parameters, i.e., based on bi-parametric sectioning approach. The chronology of the activities performed in this study is as follows (Figure 1):

- Review of the existing pavement delineation methods
- Sectioning of pavements using CDA and C-charts methods, and comparison of the results
- Establishment of a dimensionless quantity for the given dataset for two parameters, called spurn
- Use of C-charts method for sectioning of spurn values
- Comparison of the bi-parametric approach used in the study with the Indian Roads Congress (IRC) guidelines and check the defined scale compatibility, and
- Preparation of a new scale for the spurn value, which classifies a treatment utilizing both the parameters at individual levels.

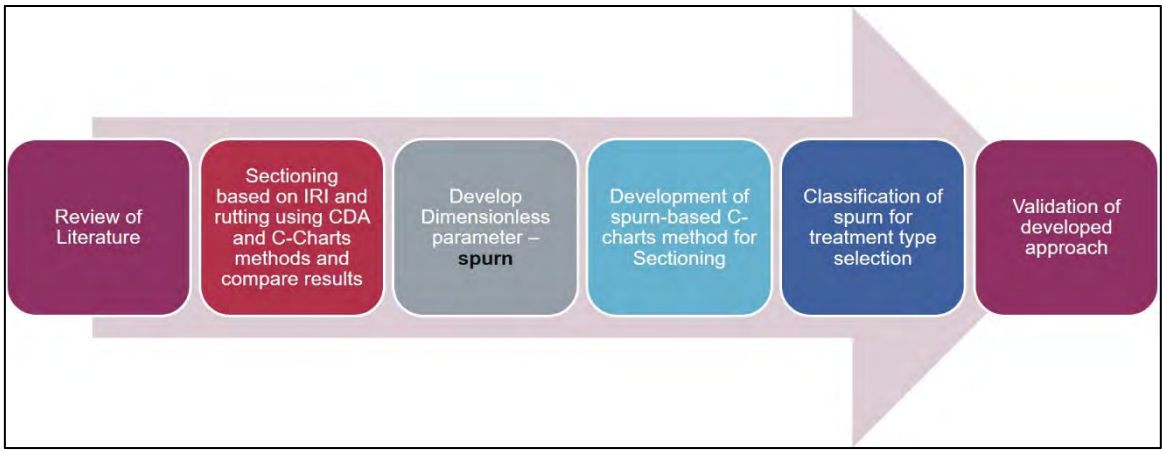

Figure 1: Study Methodology

2 Dataset and Comparison of Existing Methods

2.1 Dataset

The road maintenance division of Andhra Pradesh Road Development Corporation (APRDC), in the State of Andhra Pradesh, India collected condition data during 2015 and 2016, as part of annual maintenance activities. For this study, pavement condition data of fourteen road sections in the East Godavari district were used. These sections are major district roads (MDR) connecting the rural areas to the district headquarters and subsequently to the state highways. Poor maintenance of MDRs resulted in increased travel time and vehicle operating costs, thereby reducing the efficiency of the rural roadway infrastructure. Therefore, in this study, the maintenance of MDRs was given top priority and sectioning was performed to take appropriate decisions with respect to maintenance of rural roads and highways.

Amongst those, one road section data was used for development of the dimensionless metric spurn, and the others were used for testing the performance of the developed metric. The road section between Kakinada and Rajanagaram (56.09 km long) was used

for defining spurn. The road section was an undivided sealed bituminous pavement. Rutting and IRI magnitudes were collected at every 100 m interval, which resulted in 561 data points for performing the parametric studies.

2.2 Comparison of Existing Methods

In order to understand the gaps with the existing homogeneous pavement sectioning methods, delineation in this study was performed using CDA and C-chart approaches.

CDA Approach

The cumulative difference approach recommended by the American Association of State Highway and Transportation Officials ((AASHTO)-Guide (Thomas 2003)) deals with the cumulative difference of the z_i values, as given in Equations (1) and (2).

$$z_k = \sum_{i=1}^{k} x_i - k\bar{x}, \quad (1)$$

$$\text{Where} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{k} x_i \quad (2)$$

Where, z_k = cumulative difference of response to the mean, x_i = response, $\bar{x}$ = global mean of responses, and k = number of responses

The dataset was delineated based on the CDA method for both IRI and rutting individually. It was observed that a small change in response value resulted in a section border even though a significant change was not observed. The sectioning criteria in CDA were chosen according to the response values and a scaling was achieved, as given in Table 2 for IRI and Table 3 for rutting. A total of 24 homogeneous sections were observed when the segmentation was performed for IRI, whereas 11 sections were observed for rut depth. A schematic representation of homogeneous sectioning using CDA of chainage 20 to 40 km is given in Figure 2.

Table 2: Sectioning criteria considered for IRI – CDA method

Average IRI of each segment	Section No.	No. of segments in each section	Average IRI of each segment	Section No.	No. of segments in each section
2.0-2.2	H1	1	4.6-4.8	H14	3
2.2-2.4	H2	5	4.8-5.0	H15	5
2.4-2.6	H3	8	5.0-5.2	H16	2
2.6-2.8	H4	14	5.2-5.4	H17	4
2.8-3.0	H5	11	5.4-5.6	H18	1
3.0-3.2	H6	23	5.6-5.8	H19	1
3.2-3.4	H7	21	5.8-6.0	H20	1
3.4-3.6	H8	16	6.0-6.2	H21	2
3.6-3.8	H9	16	6.2-6.4	H22	3
3.8-4.0	H10	11	6.4-6.6	-	-
4.0-4.2	H11	9	6.6-6.8	H23	1
4.2-4.4	H12	9	8.2-8.4	H24	1
4.4-4.6	H13	3			

Table 3: Sectioning criteria considered for rut depth – CDA method

Average of Rut depth of each segment	Section No.	No. of segments in each section	Average of Rut depth of each segment	Section No.	No. of segments in each section
0.0-1.0	H1	1	6.0-7.0	H7	3
1.0-2.0	H2	10	7.0-8.0	H8	2
2.0-3.0	H3	54	8.0-9.0	H9	1
3.0-4.0	H4	42	9.0-10.0	H10	1
4.0-5.0	H5	22	10.0-11.0	H11	1
5.0-6.0	H6	12			

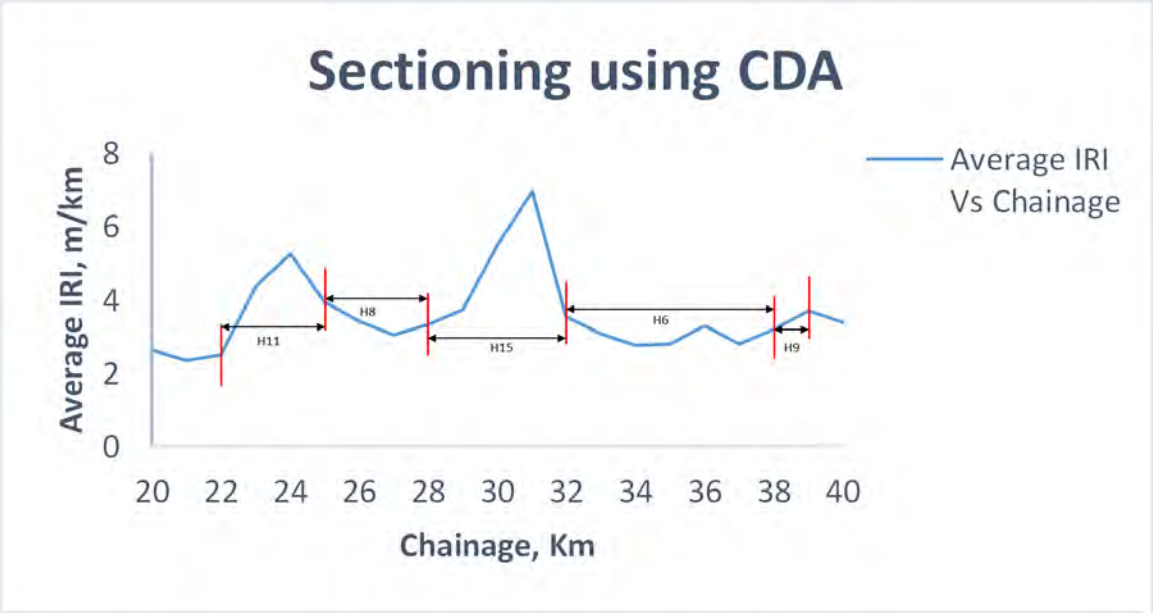

Figure 2: Homogeneous sectioning using CDA of chainage 20 to 40 km

C-Charts Method

C-charts method helps in treating the outlier data. The C-charts method was used to delineate the dataset for IRI and rutting individually. Variance, standard deviation, upper control limit (UCL), and lower control limit (LCL) are major parameters of the C-charts. The control limits were calculated for 95% confidence interval of over 560 data points. The control limits for IRI and rutting are given in Table 4. A total of 36 homogeneous sections were observed when the segmentation was performed for IRI, whereas 46 sections were observed for rut depth. Figures 3 through 5 show the outliers in IRI, rut depth, and a schematic representation of sectioning process, respectively.

Table 4: Control limits for IRI

Parameter	Variance (σ^2)	Standard Deviation (σ)	UCL ($\mu+2\sigma$)	LCL ($\mu-2\sigma$)
IRI	1.593	1.263	6.0	0.95
Rutting	4.418	2.102	7.596	0

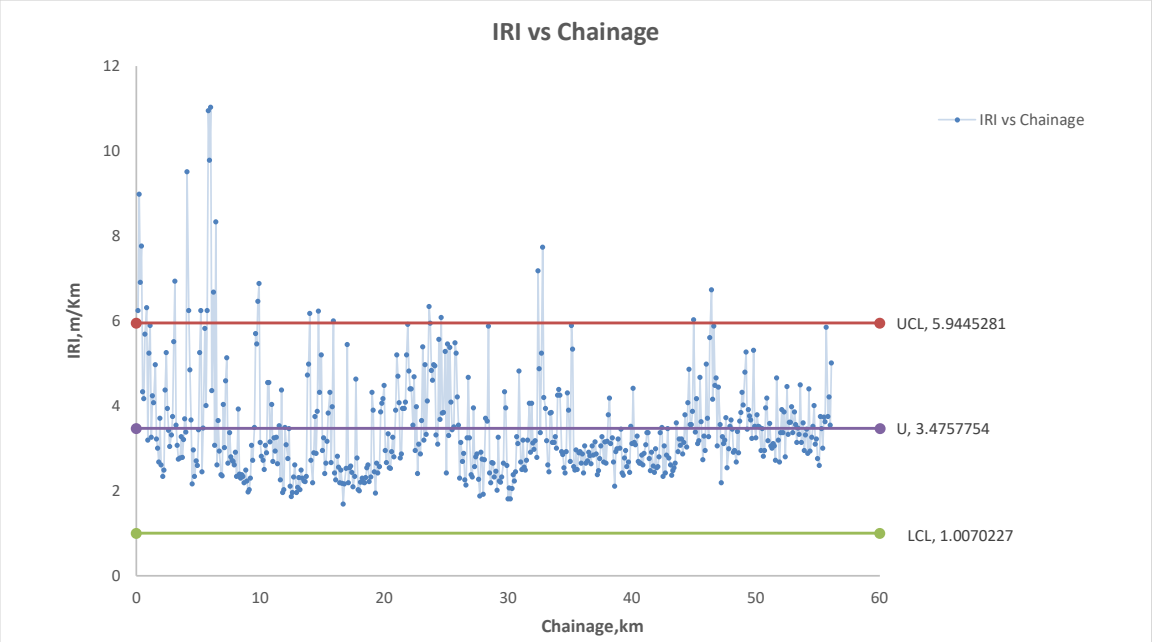

Figure 3: IRI vs Chainage using C-charts

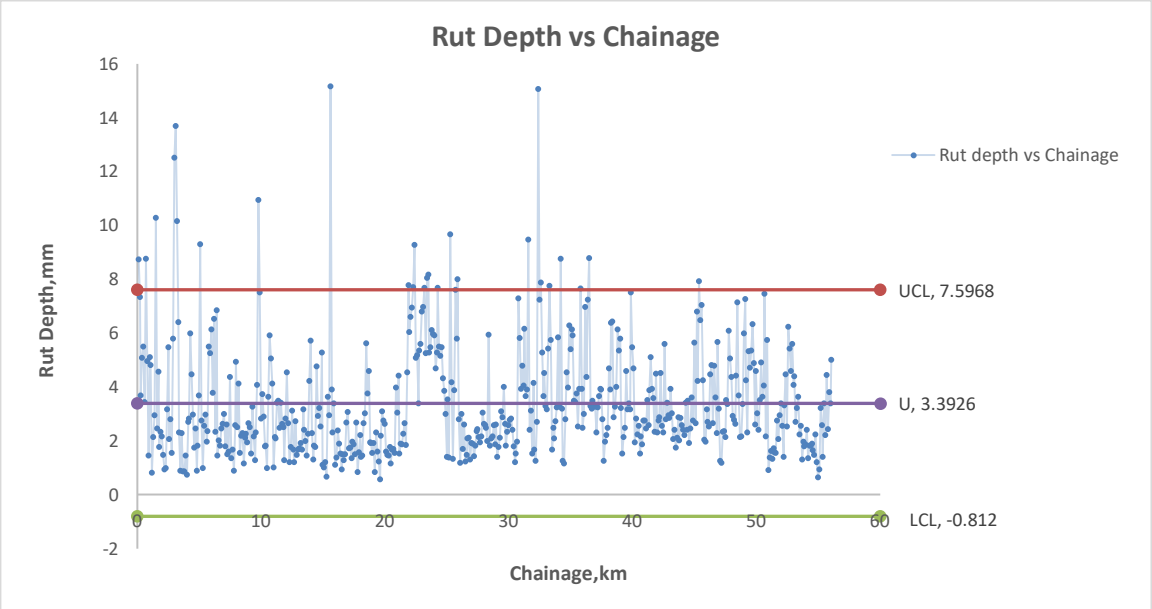

Figure 4: Rut depth vs chainage using C-charts method

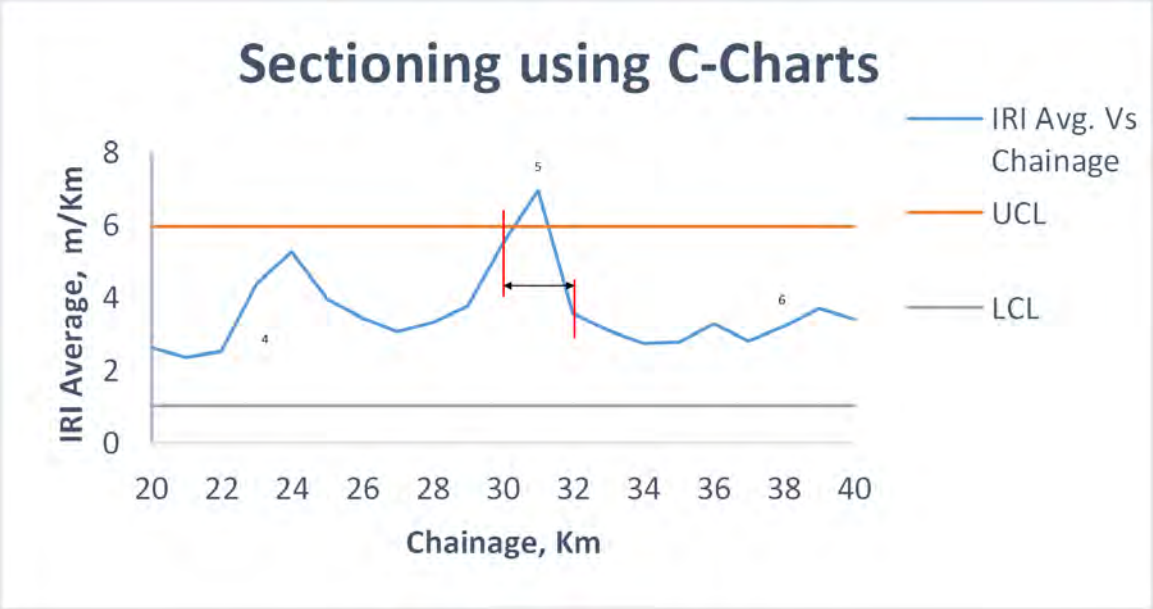

Figure 5: Homogeneous sectioning using C-Charts approach of chainage 20 to 40 km

The number of homogenous sections obtained in C-charts for IRI was greater than the CDA methods. This indicated that C-chart method identified sharp change in the readings, which resulted in a higher number of homogeneous sections. Similarly, C-chart method segmented higher homogenous sections for the rut depth criterion. As the chainage length was 100 m, it was essential to have higher number of homogeneous sections for rational treatment of the entire pavement stretch. Further, the C-charts method found the delineated sections with 95% confidence interval. Therefore, C-charts method was selected for the study for segmenting the other pavement sections in the dataset.

3 Spurn – A Dimensionless Parameter for Homogeneous Sectioning

3.1 Spurn

From the previous exercise, it was observed that both IRI and rutting did not have equal number of homogeneous sections, which indicated that the effect of individual parameters was different and sectioning based on either of the parameters would not provide optimum sectioning method. Therefore, in this study, a dimensionless quantity called spurn was defined, the term which explains that the data will get rejected if it was below the requirement (decline and lower than the threshold).

Mathematically, spurn is the summation of ratio of response to the average responses of the two metrics, IRI and rutting. The mathematical expression is given in Equation (3).

$$Spurn = \frac{x_{i(IRI)}}{\mu_{IRI}} + \frac{x_{i(rut)}}{\mu_{rut}}, \text{ where, i = 1, 2, 3, …k} \quad (3)$$

Where, Spurn = dimensionless metric, $x_{i(IRI)}$ = IRI response, μ_{IRI} = mean of IRI responses, $x_{i(rut)}$ = rutting response, μ_{rut} = mean of rutting responses, and k = number of datapoints in the measurement series.

Spurn was calculated for each data point, and sectioning was performed using C-charts method. The step-by-step procedure followed is as follows:

- Calculate the average of IRI and rutting,
- Compute the ratio of response to average response for each data record for IRI and rutting,
- Sum up the ratios and record it as Spurn Response (r),
- Square the responses (r^2),
- Calculate mean of the response,
- Compute standard deviation,
- Calculate UCL, and LCL for two standard deviations from the mean,
- Identify outliers, and
- Introduce section borders such that the outlier data falls in a different section.

The results of the analyses are given in Table 5 and Figure 6. In addition to these, sectioning was performed using the C-charts method for IRI and rutting individually in order to check reliability of the approach. Later, the mean of the responses in each homogeneous section obtained from spurn-based C-charts method was calculated. The control limits for the spurn computed from the dataset of over 560 datapoints of the Kakinada to Rajanagaram road section with 95% confidence interval were: variance = 0.7221, standard deviation = 0.849, UCL = 3.698, and LCL = 0.301. For these homogeneous sections, the average values of IRI responses and rutting responses were computed.

In order to select a maintenance strategy, a scale for spurn should be defined. For this purpose, the IRC guidelines for rutting, and APRDC guidelines for IRI were used. The details are given in Tables 6 and 7.

Table 5: Sample representation of first 10 response values of IRI and rut depth used for calculating spurn

S.No.	Chainage	IRI	Rut depth	X_i/μ (IRI)	X_i/μ (Rut depth)	Spurn (r)	r^2	Sectioning
1	0.1	6.25	8.73	1.79	2.57	4.372	19.119	1
2	0.2	8.98	7.32	2.58	2.15	4.743	22.501	
3	0.3	6.91	3.68	1.98	1.08	3.073	9.445	2
4	0.4	7.77	5.08	2.23	1.49	3.733	13.94	3
5	0.5	4.34	5.49	1.24	1.62	2.868	8.23	4
6	0.6	4.18	3.43	1.2	1.01	2.215	4.909	
7	0.7	5.69	8.77	1.63	2.58	4.222	17.825	5
8	0.8	6.31	4.95	1.81	1.46	3.275	10.731	6
9	0.9	3.2	1.46	0.92	0.43	1.352	1.828	
10	1.0	5.24	5.11	1.5	1.5	3.016	9.098	
		μ = 3.475	μ = 3.392	μ = 1	μ = 1			

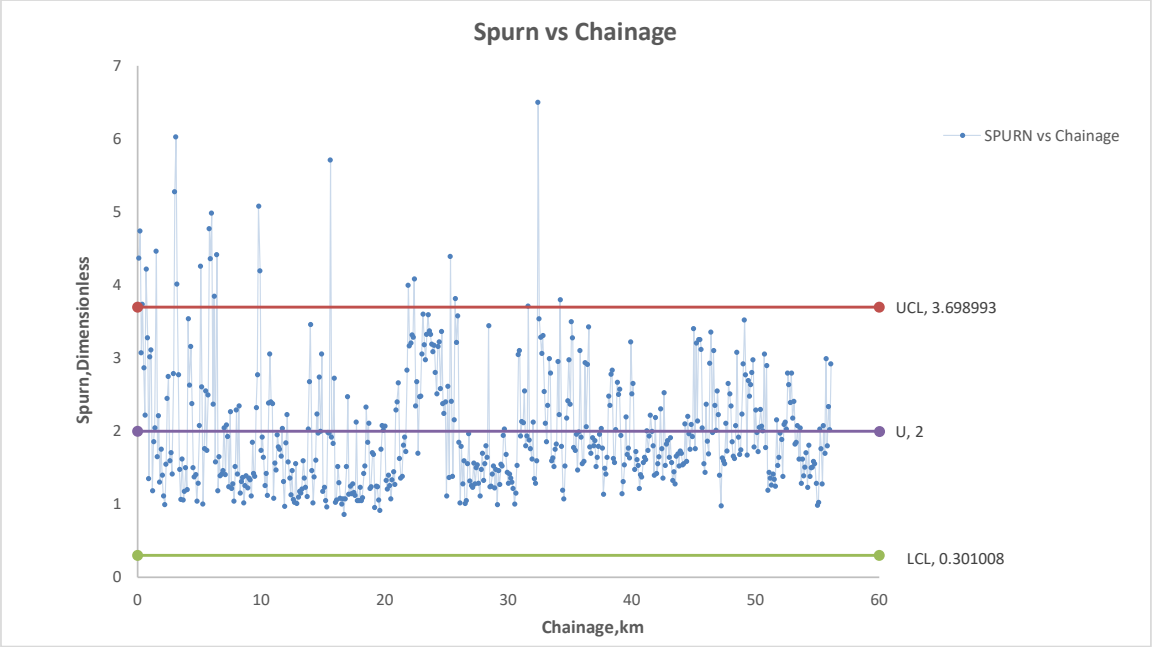

Figure 6: Spurn vs Chainage using C-charts method

Table 6: Classification pavement condition based on IRI

APRDC Guidelines			IRC Guidelines		
IRI (m/km)	Classification	Indication	IRI (m/km)	Classification	Indication
0-4.0	Good		0-2.0	GOOD	
4.0-6.0	Average		2.0-3.0	AVERAGE	
>6.0	Poor		>3.0	POOR	

Table 7: Classification pavement condition based on Rut depth – APRDC and IRC Guidelines

Rut Depth (mm)	Classification	Indication
0-5.0	Good	
5-10	Average	
>10	Poor	

3.2 Analysis

As the dataset of the pavement between Kakinada and Rajanagaram belonged to the State of Andhra Pradesh, local guidelines were considered for pavement classification as good, average, or poor based on the parameters (IRI and rutting). After sectioning was performed based on spurn value, the segment-wise average IRI and rutting were calculated to mark the condition of the pavement based on IRC and APRDC guidelines. Further, the total dataset was classified based on the condition criteria for IRI and rutting, as specified in Tables 6 and 7. Note that the APRDC guidelines for rutting are similar to the IRC guidelines. Sectioning for a sample of data points is shown in Figures 7 and 8.

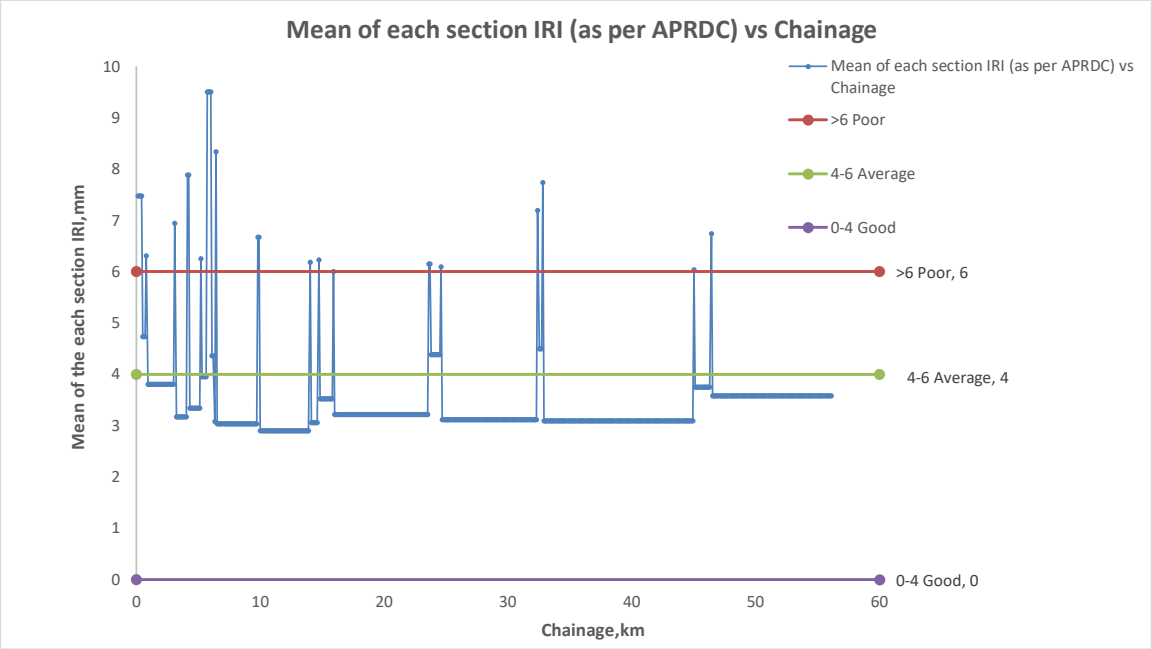

Figure 7: Mean of each section of IRI vs Chainage – APRDC guidelines

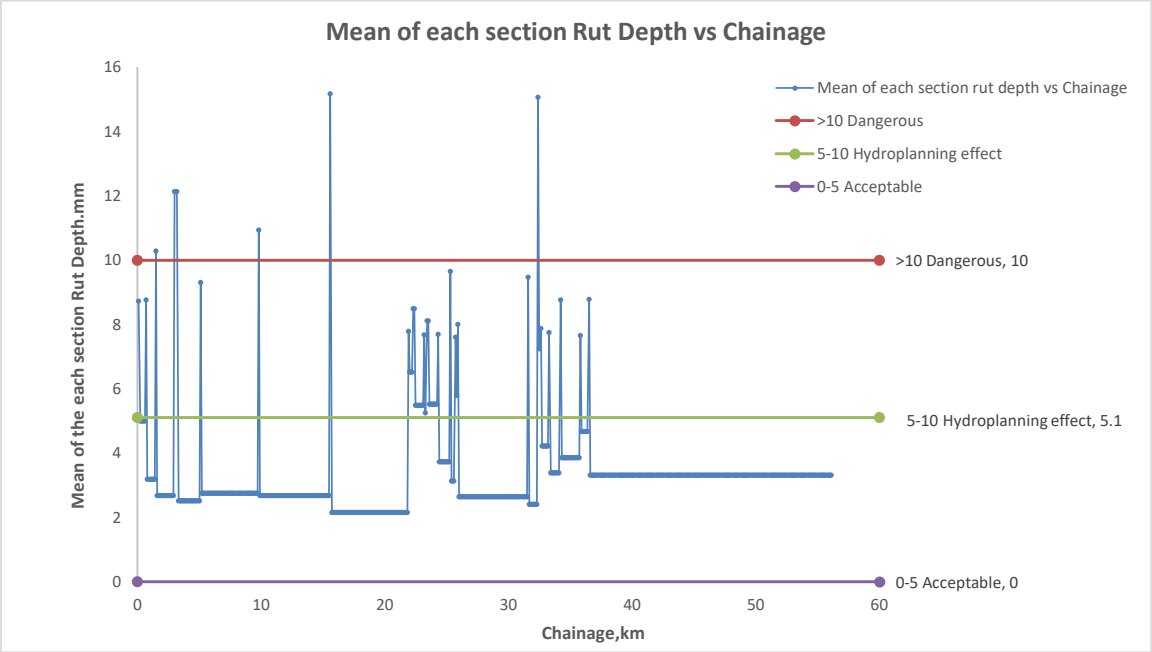

Figure 8: Mean of each section of rut depth vs chainage

In order to define a scaling for spurn for treatment type selection, the section-wise means of IRI and rutting were compared and contrasted with the section-wise mean of spurn. After thorough observation, the treatments were categorized into four major groups: preventive, corrective, major rehabilitation, and reconstruction. The section was

suggested with “preventive maintenance”, if both IRI and rutting were in acceptable limits, which reflected in a spurn value between 0 and 2. Similarly, the other scales were defined for treatments. The details of the spurn scaling for each treatment type is given in Table 8. Also, the graphical representation of section-wise treatments is given in Figure 9. Further, Table 9 shows comparison of the results of section-wise means of IRI, rutting, and spurn to check rationality of the defined classification.

Table 8: Classification pavement treatment types based on spurn

SPURN Value	Pavement Condition	Treatment type	Indication
0-2.0	Good	Preventive	
2.0-4.0	Moderate	Corrective	
4.0-6.0	Poor	Major Rehabilitation	
>6.0	Alarming	Reconstruction	

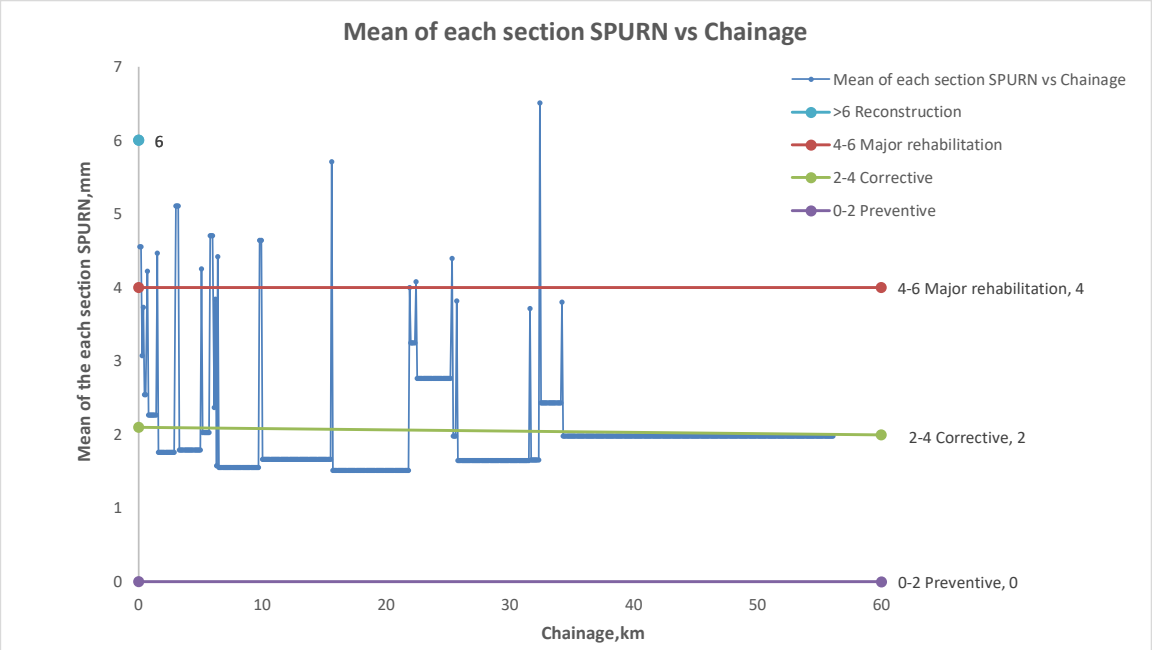

Figure 9: Pavement maintenance treatments based on spurn

As the C-charts method was used for sectioning different parameters, the length of each section varied amongst the parameters. When the spurn value indicates a specific treatment to a respective segment, the same treatment should be given to all the segments in the particular section. In Table 9, the spurn value for the segment 0.1 indicated a major rehabilitation to be performed. Therefore, the same treatment was suggested to all the segments of the section. The segments 0.2, 0.3, and 0.4 were also treated with the major rehabilitation treatment. By this classification, necessary treatments were given to the pavements efficiently.

After successful comparison and classification using APRDC data, an attempt was made to test the defined scale with the IRC classification for the dataset using the available guideline (IRC 82: 2015). It was concluded that based on IRC guidelines for IRI, most of the sections were classified as poor sections, whereas for rutting most of the sections were in good condition. The spurn-based classification has provided better classification,

which is economical and novel for rural roads, especially given the budget allocated for these types of roads. The comparison is also shown in Table 9. Note the APRDC guidelines for rutting are similar to IRC guidelines, as given in Table 7.

Table 9: Treatment type classes of IRI, Rutting, and Spurn

Chainage (km)	Mean of Each Section (IRI) – APRDC Guidelines (m/km)	Mean of Each Section (IRI) – IRC Guidelines (m/km)	Mean of Each Section (Rut Depth) (mm)	Mean of Each Section (spurn)
0.1	7.4775	7.4775	8.734	4.558
0.2	7.4775	7.4775	5.00	4.558
0.3	7.4775	7.4775	5.00	3.073
0.4	7.4775	7.4775	5.00	3.733
0.5	4.737	4.737	5.00	2.542
0.6	4.737	4.737	5.00	2.542
0.7	4.737	4.737	8.77	4.222
0.8	6.31	6.31	3.181	2.262
0.9	3.802	3.802	3.181	2.262
1	3.802	3.802	3.181	2.262

3.3 Validation of the Proposed Approach

In order to test the performance of the defined spurn-based pavement sectioning and classification, the data pertaining to thirteen road sections of the East Godavari district, Andhra Pradesh was used. Amongst them, the results of two road sections are presented below.

- 43 km long undivided sealed bituminous road section between Mandapeta and Jonnada, and
- 14 km long undivided sealed bituminous road section between Dwarapudi and Yanam.

Mandapeta to Jonnada Road

The road connecting Mandapeta and Jonnada of East Godavari district covering a stretch of 14 km is an undivided sealed bituminous pavement. The spurn-based C-charts method was used to delineate the pavement as homogenous sections. Further, the section-wise means of IRI, rut, and spurn were calculated. The sections were classified based on IRC and APRDC, and later spurn values were tabulated with suitable color coding (as given in Tables 6 through 8) in Table 10 for one km stretch of the road section. From IRC guidelines, all the road sections were in the poor condition, whereas, the sections were in good condition for rutting. The spurn-based classification analyzed this complex incidence, and corrective maintenance strategy was suggested as well.

Dwarapudi to Yanam Road

The road connecting Dwarapudi and Yanam of East Godavari district covers a stretch of 43 km and is an undivided sealed bituminous pavement. Similar procedure as described before was adopted, and the results of 1 km road section are shown in Table 11. For this pavement section, the mean of rutting was quite high, whereas the section IRI was acceptable. spurn developed suggested that the pavement should be reconstructed, as high rutting will lead to massive structural failure.

Table 10: Mandapeta to Jonnada road: Comparison of pavement condition or treatment classification as per IRC, APRDC, and spurn

Chainage (km)	Mean of each section (IRI) (as per APRDC) (m/km)	Mean of each section (IRI) (as per IRC) (m/km)	Mean of each section (rut depth) (mm)	Mean of each section (spurn)
0.1	4.489	4.489	3.492	2.048
0.2	4.489	4.489	9.068	3.563
0.3	4.489	4.489	4.736	2.164
0.4	4.489	4.489	4.736	2.164
0.5	4.489	4.489	4.736	2.164
0.6	4.489	4.489	4.736	2.164
0.7	4.489	4.489	4.736	2.164
0.8	4.489	4.489	4.736	2.164
0.9	4.489	4.489	4.736	2.164
1	4.489	4.489	4.736	2.164

Table 11: Dwarapudi to Yanam road: Comparison of pavement condition or treatment classification as per IRC, APRDC, and spurn

Chainage (km)	mean of each section (IRI) (as per APRDC) (m/km)	Mean of each section (IRI) (as per IRC) (m/km)	Mean of each section (rut depth) (m)	Mean of each section (spurn)
0.1	3.974	3.974	4.332	2.308
0.2	3.974	3.974	4.332	2.308
0.3	3.974	3.974	4.332	2.308
0.4	3.974	3.974	4.332	2.308
0.5	3.974	3.974	4.332	2.308
0.6	3.974	3.974	4.332	2.308
0.7	3.974	3.974	14.284	5.642
0.8	3.974	3.974	14.284	5.642
0.9	3.974	3.974	14.284	5.642
1	3.974	3.974	14.284	5.642

Conclusions and Recommendations

After referring to all the existing methods, it was concluded that the existing methods perform sectioning using one parameter as the input. The objective of this study was to provide optimum maintenance strategy to rural roads based on bi-parametric homogeneous sectioning using C-charts method. A dimensionless quantity called *spurn* was defined, which included IRI and rutting as the distress criteria. Scaling was defined for spurn in order to suggest four different types of treatments for the homogeneous sections. Fourteen road sections of the APRDC dataset retrieved from the state roadway agency in India were considered. All the 14 sections were made up of sealed bituminous pavement types. Amongst those, one was considered for defining spurn and the remaining sections were used for verification of the rationality of the defined approach. The scope of the study was confined to bituminous pavements only. However, similar approach could be adopted for cement concrete pavements.

It was found that the spurn-based sectioning was quite efficient in suggesting appropriate pavement maintenance strategies to the homogeneous sections compared to the existing approaches in the literature. The rational sectioning method could be applied globally for sectioning as well as treatment selection for rural roads, specifically where budget constraints are found to exist. The innovative spurn-based segmentation is anticipated to provide optimum maintenance interventions, thereby improving the efficiency of the roadway infrastructure. Further, the suggested maintenance strategies would reduce wastage of materials and emissions, hence conserving the natural resources in the vicinity of villages, in turn creating an ambience to establish smart villages within a larger community conglomerate. Most importantly, the study could be extended further by incorporating additional parameters to the *spurn* metric to obtain more reliable quantification of pavement condition as well as sectioning.

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LCA Framework for Utilization of Excavated Granulates in Pavement Systems

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Abstract: *Due to exponential increase in urbanization, there is a huge demand for aggregates in industry for construction of buildings and roadways. This in turn has accelerated quarrying from large rock formations, causing significant impacts on the ecosystem. Thus, there is a need to explore and develop alternative materials to meet the goals of sustainable infrastructure. Therefore, the major objective of this research was to formulate a lifecycle assessment (LCA) framework to investigate the environmental benefits of utilizing excavated granulates (EG) found within the soil deposits at the Indian Institute of Technology Tirupati during earthwork activities as replacement for virgin aggregates in the base layers of pavement systems. To accomplish the objective, a cradle-to-laid LCA approach was adopted as per ISO 14040 and ISO 14044. The LCA results showed that utilization of EG instead of virgin aggregates in pavement sub-base resulted in reduction of human health risk, global warming, and terrestrial eco-toxicity by 43.5%, 52%, and 68%, respectively. Sensitivity analysis showed that material production phase had the highest impact on environment for EG as well as virgin aggregates followed by material transportation and construction phases. The use of EG will not only alleviate the high environmental burdens associated with mining activities but also help conserve the depleting natural aggregate resources. Additionally, the use of EG in pavements will provide an alternative for disposal of these naturally occurring rock masses. It is envisioned that the outcomes obtained in this study will be used as a benchmark to initiate the process of utilizing EG in pavements. Furthermore, the systematic framework presented in this study will certainly help policymakers in the decision-making process and promote the development of similar LCA studies for site-specific conditions, specifically to create smart village ecosystems that call for utilization of local resources to create products that promote sustainable development.*

Keywords: *Lifecycle Assessment, Excavated Granulates, Sustainable Development, Global Warming, Resource Conservation.*

1 Introduction

The unprecedented urbanization witnessed by several countries across the globe demand for the development and construction of resilient and sustainable roadway infrastructures to cater to the mobility needs of mass population growth in the urban sector while maintaining environmental integrity. The construction of pavements requires a large proportion of virgin coarse aggregates in different layers. Natural aggregates account for 60-85% of the volume in asphalt and concrete pavement surface wearing courses (Asphalt Paving Design Guide 1995; Mehta and Monterio 2003). Additionally, bound and unbound base/sub-base layers of pavements also account for a large proportion of natural aggregates. It is reported that the demand for aggregates on a global scale is expected to hit the US $622 billion by the end of 2029, rising at the construction aggregate growth rate by more than 6% (Global Construction Aggregates Market 2020).

Aggregate mining brings together several environmental impacts such as (Langer and Arbogast 2002): (a) landscape change, (b) generation of noise, dirt, and vibrations during extraction, (c) depletion of groundwater and surface water, (d) energy consumption, and (e) dissipation of greenhouse gases into the atmosphere. Additionally, with depleting aggregate resources, there is a potential risk of increased costs that directly affect the national economy. Therefore, it becomes essential to focus on the utilization of recyclable and waste products for the construction of surface and underlying layers of pavements.

Researchers have suggested that utilization of construction and demolition wastes (C&DW) such as waste rock (WR), crushed bricks (CB), and recycled concrete aggregates (RCA) tend to have a deteriorating impact on the mechanical characteristics of pavement mixtures (Bennert at el. 2000; Sivakumar at el. 2004; Poon and Chan 2006; Nataatmadja and Tan 2001). Most of the studies have indicated that the optimum proportion of C&DW in conventional pavement surface wearing course mixtures generally varies between 15 and 30% (Sadati and Khayat 2016; Rizvi at el. 2010; Singh at el. 2017). On the other hand, some studies indicated that a higher proportion of virgin aggregates can be replaced with the addition of filler and mineral admixtures or with the use of high-quality aggregates (Disfani at el. 2014; Grubb at el. 2006; Leite at el. 2011; Mohammadinia at el. 2015; Herrador at el. 2012). Some other investigations recommended that C&DW could be effectively utilized in pavement base/sub-base layers as well. The California bearing ratio of the pavement sub-base layer comprising of recycled crushed concrete and fine crumb rubber was 7.14 higher as compared to sub-base layer consisting of crushed rock and fine crumb rubber (Li et al. 2018). Another study showed that WR, RCA, and CB (with lower target moisture contents of 70% of the OMC) were suitable materials for use in sub-base layers of pavements (Arulrajah et al. 2013).

According to a study conducted in the United Kingdom, around 307,335 tonnes of carbon dioxide emissions took place while transporting aggregates by road (Mankelow et al. 2010). Researchers have discussed the environmental benefits towards replacement of virgin aggregates with recycled aggregates produced from C&DW (Hossain at el. 2016; Marinković at el. 2010; Ram at el. 2020; Rosado at el. 2017). In China, the use of recycled C&DW aggregate in highway subgrade reduced the environmental loads by 79.5% (Zhang at el. 2020). Researchers showed that the use of recycled industrial by-products such as fly ash and recycled road materials such as RCA and recycled asphalt pavement for pavement applications resulted in a reduction of energy consumption, water usage, and carbon dioxide by 82, 97, and 85% respectively as compared to traditional pavements (Bloom et al. 2016). Chowdhary el at. (2010) reported that amongst the several industrial by-products such as coal fly ash, recycled concrete pavement (RCP), and coal bottom ash, RCP performed better in terms of cost and energy efficiency, global warming

potential, and toxicity potential provided the transportation distance ratio (RCP: natural aggregate) was greater than 1:4.

A few researchers suggested that C&DW can also be utilized in innovative pavement materials such as pervious concrete (a mixture of coarse aggregates and cement) provided their proportion is carefully controlled (Lu at el. 2019; Sata at el. 2013; Sriravindrarajah at el. 2012; Zaetang at el. 2016). An added advantage of using recycled or waste materials in pervious concrete pavements (PCP) could be a reduction in lifecycle cost. Research studies have shown that PCP is a sustainable pavement system that has high potential to minimize the environmental impacts of roadway infrastructure (Singh et al. 2020a; Singh et al. 2020b). Moreover, the environmental benefits associated with PC pavement systems (such as stormwater mitigation, reduction of flash floods, and groundwater recharge) can be further augmented by the utilization of alternative materials in pavement base/sub-base layers.

It is well understood that the utilization of natural aggregates in pavements has a detrimental impact on both resources and environment. Thus, it would be ideal if one can develop alternative strategies or policies that could promote systematic replacement of coarse aggregate content in the surface wearing and/or underlying base course layers in pavement systems.

Thus, the major objective of this research was to develop a generalized framework that could be utilized to quantify the various environmental benefits offered by the utilization of excavated granulates (EG) in base layers of pavement systems. Note that the EG utilized in this work were naturally occurring and locally available geological formations on the campus of Indian Institute of Technology Tirupati (IITT), State of Andhra Pradesh, India. Further, the environmental dividends generated from the use of EG were compared to those of virgin aggregates.

It is envisioned that the utilization of EG will not only help alleviate the high environmental impacts of construction activities but will also offer a suitable means for their disposal. Additionally, the findings presented in this study could also be used as a benchmark to understand the various sustainability aspects associated with the utilization of naturally occurring commodities for the design and construction of smart roads for sustainable development in villages. Moreover, the proposed framework has the potential to serve as a basic guideline for the development of similar lifecycle assessment (LCA) studies based on site-specific conditions, specifically, rural areas (example: villages) where high quality superior materials may not be required to carry low-volume traffic. However, sustainable and reusable materials such as EG would be best suited to create smarter villages keeping in mind the sustainable development goals of the United Nations.

2 Lifecycle Assessment Methodology

A cradle-to-laid methodology was used to assess the environmental impacts as per the guidelines presented in ISO 14040 and ISO 14044 standards, which define the principles and framework to capture the environmental impacts of a product or process lifecycle. The four major stages of LCA included: (1) goal and scope definition; (2) life cycle inventory analysis; (3) impact assessment, and (4) interpretation and analysis.

2.1 Goal and scope definition

The goal of LCA was to quantify and compare the environmental impacts and benefits of utilizing EG over virgin aggregates. The different stages involved in the LCA were quarrying (for natural aggregates) or excavation (for EG) for extraction of raw materials, processing (crushing of aggregates to different sizes), transportation of raw materials to the site, and placement.

The functional unit chosen for this study was a sub-base layer 2500 mm wide (IRC: 103-2012) and 1 km long of a PC sidewalk. The thickness of the base layer was 150 mm (Lancaster 2017). The system boundaries considered for the use of virgin aggregates and EG in PC pavement base layer are presented in Fig. 1 and Fig. 2, respectively. In this study, the IMPACT 2002+ assessment method was adopted because of its potential to combine the mid-point and end-point categories, and global applicability (Jolliet at el. 2003). Further, a consequential modeling approach was adopted conforming to ISO 14040. This approach was considered over attributional as it tends to include the direct and indirect effect due to the level of change in the product and its processing.

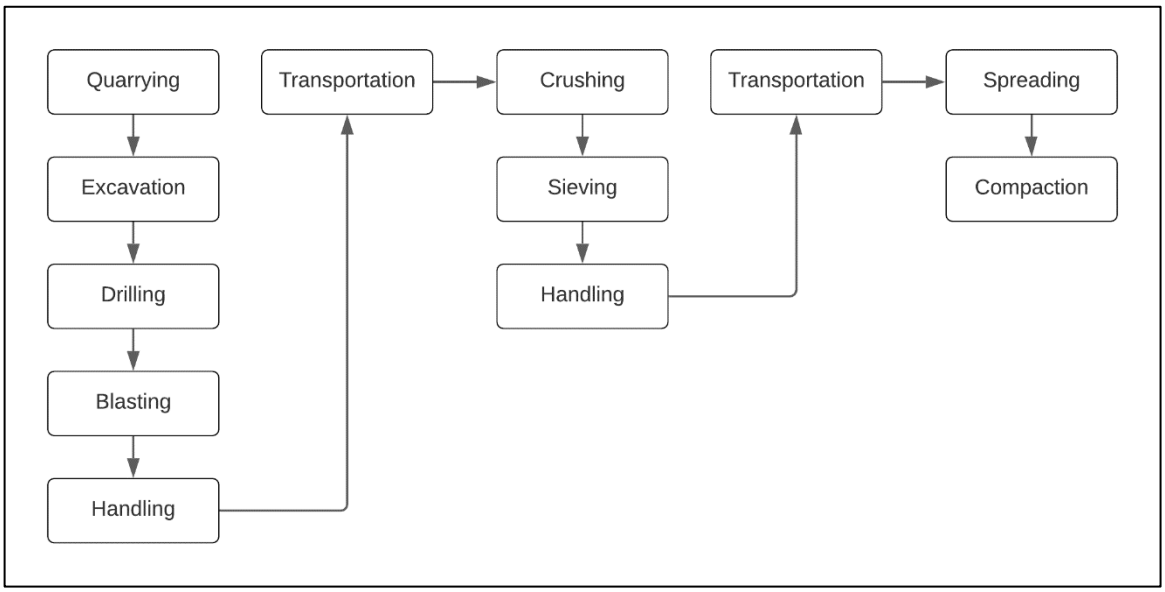


Figure 1: System boundary for production and placement of natural aggregates

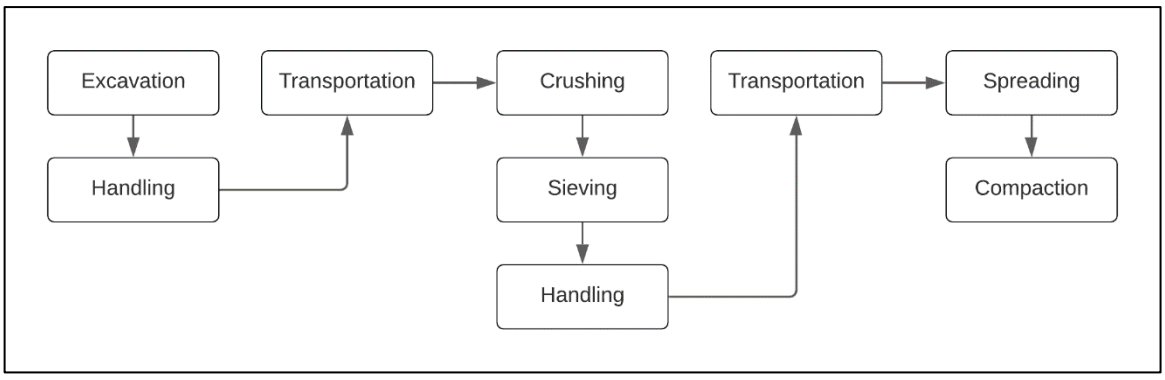


Figure 2: System boundary for production and placement of excavated granulates

2.2 Lifecycle inventory

The life cycle inventory analysis (LCIA) phase deals with the collection and assessment of different inputs and outputs to meet the specified goals of the study. This investigation primarily utilizes secondary data (except for transportation processes and activities associated with spreading and compaction of materials) gathered from existing literature and the Ecoinvent v3.5 database using SimaPro9®. Note that the major objective of this

study was to develop a framework that could be utilized in the future for most reliable prediction (using primary data for the majority of processes) of environmental impacts associated with the use of EG in base layer of pavements. The aggregate crushing and quarrying site considered in this study was located near Perur village, Chittoor, which was 32 km from the IITT transit campus. EG were recovered from the dumping site of IITT. Tables 1 and 2 represent the different input variables that were used to compute the overall quantities of estimated materials, and Table 3 presents the input variable that were utilize for computation of activities and processes for sub-base placement.

Table 1: Quantity involved in different activities and processes for virgin aggregate in sub-base

Activity	Sub-activity	Equipment / Infrastructure	Unit	Quantity	Remark
Sub-base material: virgin aggregates	Aggregate production	Mining, quarrying and crushing infrastructure	ton	850	Sub-base density: 2.25 t/m^3
	Loading aggregates into the truck	Skid steer loader	m^3	515	Loose bulk density: 1.65 t/m^3
	Transportation to site	Freight truck	t-km	27200	From Perur village to IIT campus

Table 2: Quantity involved in different activities and processes for excavated granulates in sub-base

Activity	Sub-activity	Equipment / Infrastructure	Unit	Quantity	Remark
Sub-base material: Granulates	Total material requirement	-	ton	795	Sub-base density: 2100 kg/m^3
	Excavation	Hydraulic digger	m^3	1325	Excavating of 1 m^3 soil results in 600 kg coarse granulates
	Loading material to freight truck	Skid steer loader	m^3	1560	Loose bulk density: 1.8 t/m^3; Soil density: 2.12 t/m^3
	Transportation to quarrying and crushing site	Freight truck	tkm	4214	Dumping site to crushing and quarrying site.
	Crushing and quarrying for granulates	Quarrying and crushing plant	ton	795	
	Loading granulates to truck	Skid steer loader	m^3	442	Loose bulk density: 1.8 t/m^3
	Transportation to site	Freight truck	tkm	1193	Quarrying and crushing site to construction site

Table 3: Quantity involved in different activities and processes for sub-base placement

Activity	Sub-activity	Equipment / Infrastructure	Unit	Quantity	Remark
Sub-base Placement	Spreading the material	Backhoe	hr	3.125	Operating speed: 60 m^3/hr; Using 2 backhoe simultaneously
	Compaction	Static wheel roller	hr	2.4	Rolling width: 1.81 m; Operating speed: 5 km/hr; Number of passes: 6

It must be noted that there exists an innate variation in the database adopted for this study. For example, the traffic delays due to congestion were ignored, and the vehicular speeds were based on experience. The emissions due to infrastructure for the equipment used for compaction were not considered. Water consumed during the cleaning of equipment and trucks was not accounted for. In future, a more precise database should be developed specifically for excavation and processing activities involved during production of granulates at IITT premises.

3 Results and discussions

3.1 Lifecycle impact assessment

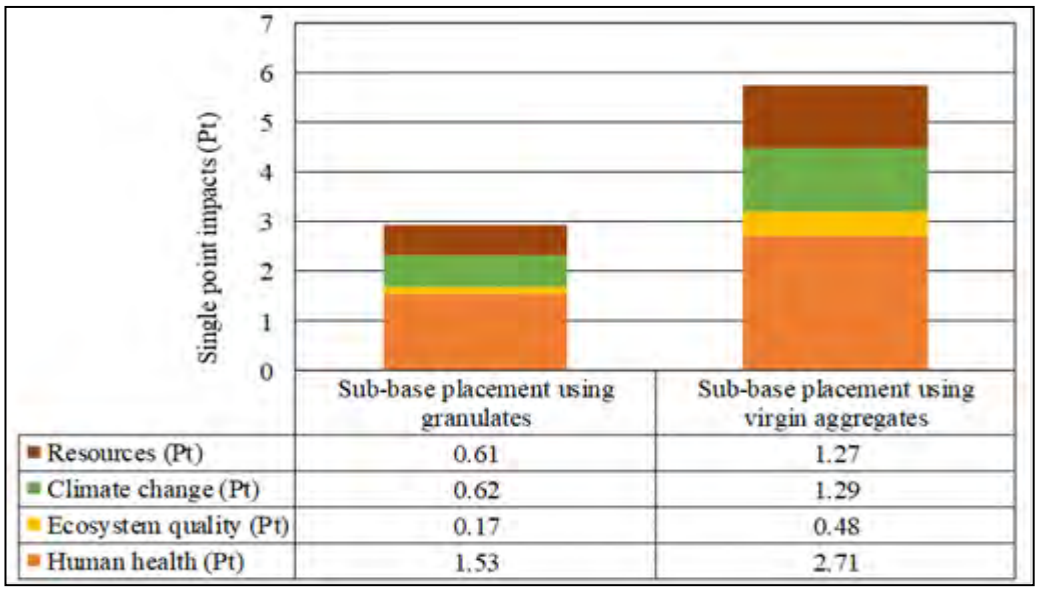
The results of characterization of the virgin aggregates and EG are presented in Table 4. Based on the characterization results, it was understood that the utilization of granulates in base layer has about 43.5% lower impact on human health as compared to virgin aggregates.

Table 4: Characterization impact for virgin aggregates and granulates in sub-base

Impact category	Unit	Using granulates	Using aggregates
Carcinogens	kg C_2H_3Cl eq.	67.91	170.64
Non-carcinogens	kg C_2H_3Cl eq.	105.59	300.21
Respiratory inorganics	kg PM2.5 eq.	14.78	25.54
Respiratory organics	kg C_2H_4 eq.	4.39	5.89
Terrestrial eco-toxicity	kg TEG soil	214457	671791.38
Terrestrial acidification/nitrification	kg SO_2 eq.	244.58	300.46
Global warming	kg CO_2 eq.	6164.88	12810.63
Non-renewable energy	MJ primary	92500.18	192641.26
Mineral extraction	MJ surplus	296.73	754.34

Amongst the various human health indicators, the contribution of respiratory organics was the lowest whereas non-carcinogens had the highest impact. Additionally, the global warming potential of sub-base prepared with EG was almost 52% lower than virgin aggregates. Moreover, the non-renewable energy usage and mineral extraction for production of granulates were lower than virgin aggregates by about 52 and 60.6%, respectively.

The end-point results generated in this study were further converted into a single score that was measured in the units of points (Pt). A 'Pt' represents the average annual share of environmental impacts per person. The single point impact (with endpoint effects) through excavated granulates as shown in Fig. 3 was 49% lower as compared to virgin aggregates. The positive impacts generated by the utilization of granulates were primarily attributed to the reduced burdens associated with mining and transportation activities during different phases of pavement construction. Amongst the four end-point indicators considered in this study, the highest damage occurs to human health, and ecosystem quality was the least affected indicator. The major advantage of utilizing single score is an easy interpretation of results, which further helps the policymakers in the decision making process. The assessment of single score results could further be used to justify the environmental benefits of using EG in pavements. Such an approach is expected to accelerate the initiative of IITT in utilizing naturally occurring EG in base/sub-base layers of pavements, and further minimizes the impacts associated with their disposal.



	Sub-base placement using granulates	Sub-base placement using virgin aggregates
Resources (Pt)	0.61	1.27
Climate change (Pt)	0.62	1.29
Ecosystem quality (Pt)	0.17	0.48
Human health (Pt)	1.53	2.71

Figure 3: Single point impact for virgin aggregates and granulates in sub-base

Some other studies have also recommended that the use of recycled and waste materials as aggregates in base/sub-base layers of pavements leads to a reduction in environmental impacts (Li et al. 2013; Marinković et al. 2013; Bloom et al. 2016; Rosado et al. 2017; Li et al. 2019). Researchers suggested that the utilization of mixed recycled aggregates as base/sub-base material was a sustainable alternative to natural aggregates provided the transportation distance exceeded 20 km (Marinković et al. 2013; Rosado et al. 2017). Another investigation showed that the use of recycled materials as replacement of virgin aggregates in base course had minor environmental benefits when compared to their utilization in surface layers, especially for hot-mixed asphalt pavements (Bloom et al.

2016). It was further suggested that production and transportation were the most energy-intensive processes. A study recommended that the most suitable conditions for utilizing solid waste materials in pavements were either on-spot or close-by recycling units (Li et al. 2019). This recommendation seems promising for utilizing EG in pavement systems at IITT due to the presence of an on-campus recycling facility. This will drastically scale down the energy consumption and generation of emissions involved in the transportation of EG from the recycling unit to the pavement construction site.

3.2 Interpretation - sensitivity analysis

In order to determine the reliability of this LCA study, a sensitivity analysis was performed to investigate the effect of various input parameters on the results. The sensitivity analysis was carried out for three major phases: a) material production; b) material transportation; and c) sub-base construction. Three scenarios were created where the inputs were increased by 30% with respect to the base scenario of 1 km long and 2.5 m wide sub-base layer of PCP sidewalk. Since the primary objective of this study was to investigate the impacts of EG when used as replacement of virgin aggregates, sensitivity analysis was conducted for sub-base layers comprising of EG and virgin aggregates.

From Fig. 4 and Fig. 5, it can be clearly observed that material production phase, which involved crushing, quarrying, and excavation had highest environmental impacts when compared to transportation and construction phases. The transportation phase had intermediate environmental impacts in both cases. However, environmental burdens were slightly higher for sub-base comprising of virgin aggregates as compared to that with excavated granulates primarily due to increase in transportation distance.

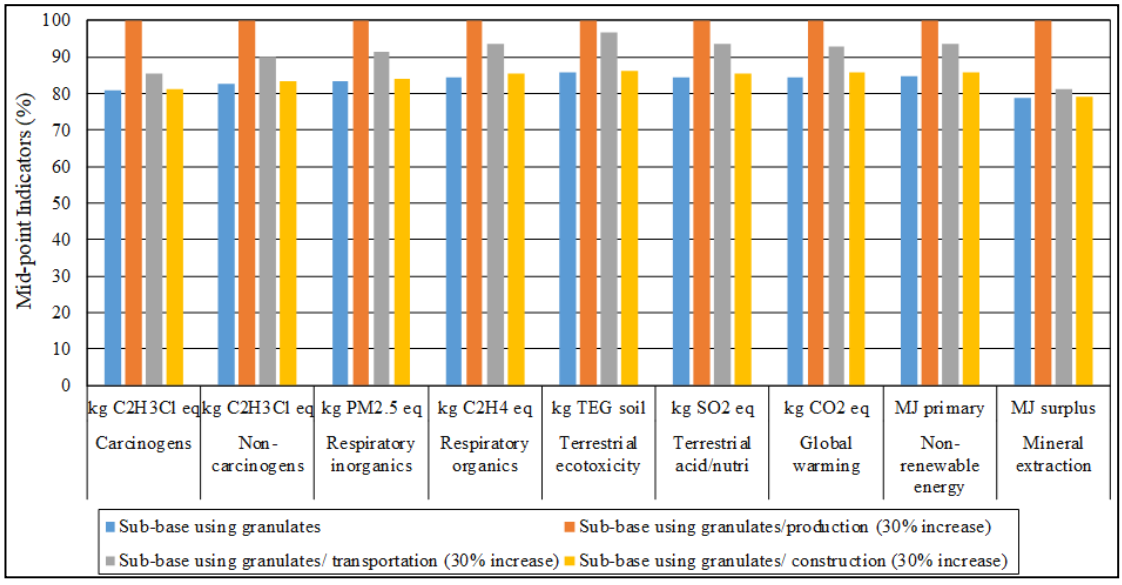


Figure 4: Characterization impacts for different phases of sub-base placement using granulates

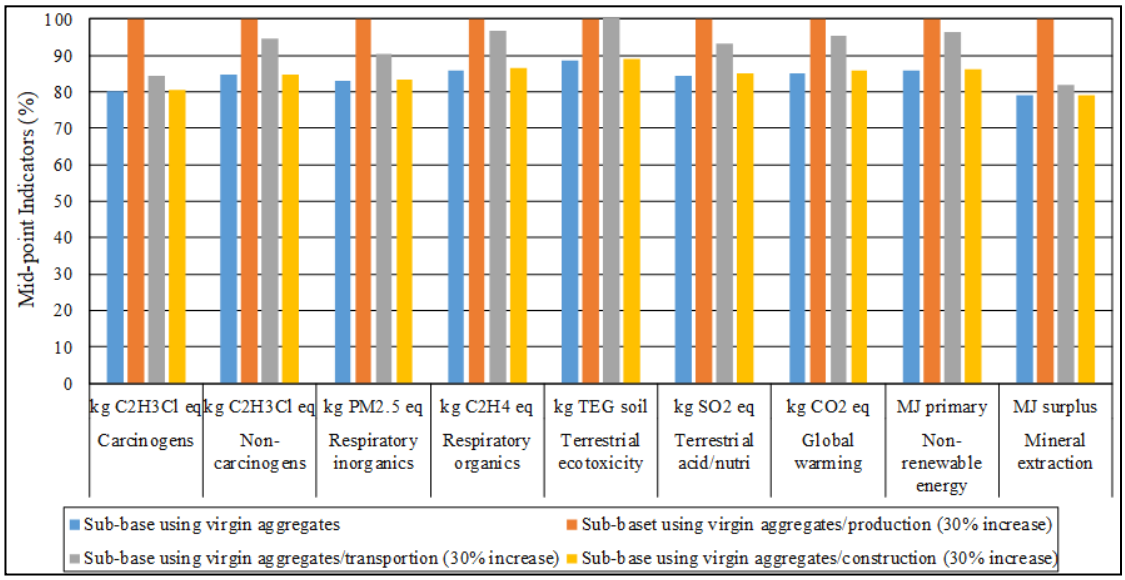
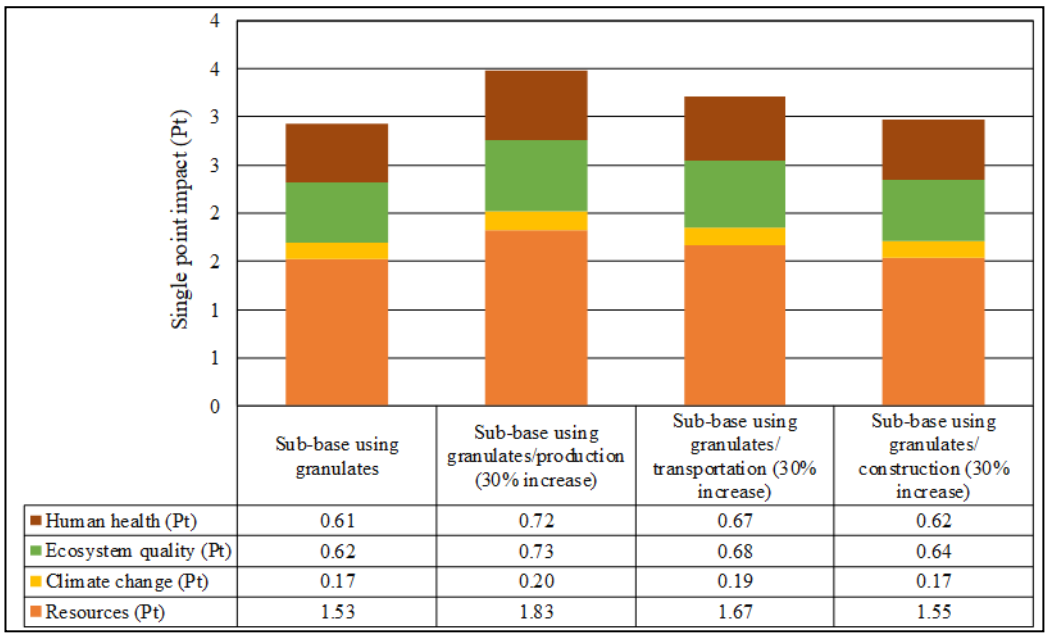


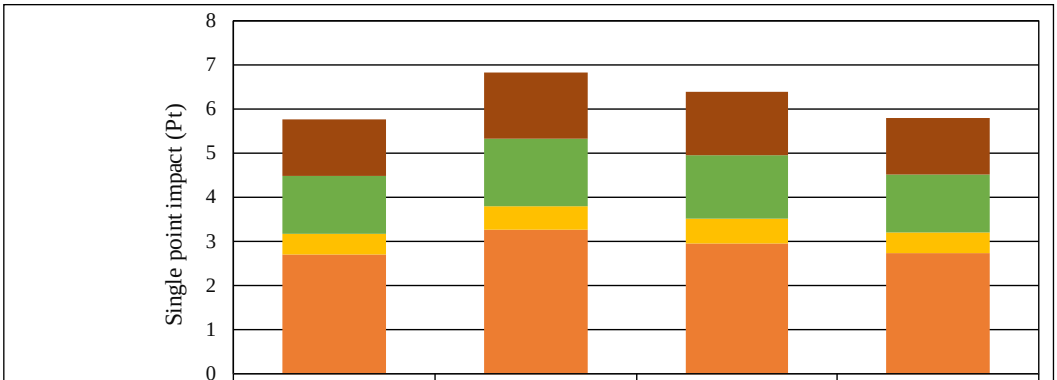
Figure 5: Characterization impacts for different phases of sub-base placement using virgin aggregate

Construction phase had lowest environmental impacts amongst the different phases considered in sensitivity analysis. From Fig. 6 and 7, the single point impacts were highest for the material production phase and lowest for the construction phase, with human health being at highest risk as compared to other end-point indicators.



	Sub-base using granulates	Sub-base using granulates/production (30% increase)	Sub-base using granulates/ transportation (30% increase)	Sub-base using granulates/ construction (30% increase)
Human health (Pt)	0.61	0.72	0.67	0.62
Ecosystem quality (Pt)	0.62	0.73	0.68	0.64
Climate change (Pt)	0.17	0.20	0.19	0.17
Resources (Pt)	1.53	1.83	1.67	1.55

Figure 6: Single point impacts for different phases of sub-base placement using granulates



	Sub-base using virgin aggregate	Sub-base using virgin aggregate/production (30% increase)	Sub-base usingvirgin aggregate/ transportation (30% increase)	Sub-base using virgin aggregate/ construction (30% increase)
Human health (Pt)	1.27	1.48	1.43	1.29
Ecosystem quality (Pt)	1.29	1.52	1.45	1.31
Climate change (Pt)	0.48	0.55	0.56	0.48
Resources (Pt)	2.71	3.26	2.96	2.73

Figure 7: Single point impacts for different phases of sub-base placement using virgin aggregate

4 Conclusions and recommendations

The major objective of this research was to develop a framework to quantify the environmental impacts of EG found within the soil deposits at IITT, India during earthwork activities as replacement of virgin aggregates in the pavement systems. Based on LCA results, it was understood that the use of EG had 43.5% less human health impact and 52% lower global warming as compared to virgin aggregates. The non-renewable energy usage and mineral extraction for production of granulates were lower than virgin aggregates by about 52 and 60.6%, respectively. Sensitivity analysis indicated that sub-base material production phase for EG and virgin aggregate had highest contribution towards environmental impacts followed by material transportation and construction phases

The results of this preliminary study are promising in the sense that the environmental burdens generated from the use of EG are substantially lower as compared to PC pavement systems comprising of virgin aggregates in base layers. However, additional research is mandatory to determine the optimum percentage of naturally occurring rock masses within the soil to partially or completely replace the virgin aggregates in different layers of pavement. Further, LCA must be performed by utilizing a majority of primary data that could be gathered in the future. Besides, more input and output parameters must be investigated, and the scope of LCA should be improved by incorporating additional impact categories.

The systematic framework proposed in this study is envisioned to assist the policy-makers in the determination of sustainability benefits that could be attained with the use of recycled/waste materials in the base and/or sub-base layer of pavement systems. Such an approach is expected to create avenues for the development of smart cities and sustainable village ecosystems that could potentially utilize locally available / marginal quality materials to build green and sustainable pavement systems.

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AN EVALUATION OF PERFORMANCE AND WELL-BEING OF USERS THROUGH BIOPHILIC INDICATORS- A REVIEW

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Abstract:
Cities were emerged due to industrialisation, forcing people to spend more time indoors. This has caused distancing from nature which is now affecting human health and well-being. Human evolution shows his connect with the natural landscape for the last 25,0000 years. This has created our inherent affiliation towards nature. The disconnect from the natural environment for the last 300 years is disturbing human's desire to be in nature. Scientific research indicates that nature impacts our physiological, psychological, and cognitive health. By applying biophilic design patterns in the built environment one can get connected with nature to overcome modernisation issues. The study explains briefly the importance of creating positive human-centric spaces for human well-being. The paper aims to find out the effects of biophilic indicators on occupants of workspaces and classrooms. Objectives are finding out different tools. A literature survey method was used for secondary data collection. Different case studies were discussed based on typologies as workspace and classrooms of educational institutes. For office spaces study examines literature for performance, creativity, and health of the employee and classrooms explore for attention capacity of students and their well-being. While concluding study identifies common tools for different health or performance metric.

Keywords: *Biophilic design, Indoor greenery, Daylight, Performance, Well-being*

1 Introduction

Industrialization & globalization has increased a shift from rural to the urban area reducing our access to nature. Human evolution, from 12,500 years of farming & other activities that transformed the natural landscape whereas since only the last 250 years modern cities were developed. Gradually we become urban dwellers with disconnection with nature. It is projected that by 2050, 70% of the world's population will live in cities (Browning, 2014). Modern building environments are becoming unsustainable in terms of energy, usages of resources, polluting air and water, creating unhealthy indoor environmental conditions. All this is resulting in alienation from nature creating "place lessness". As people are spending 90%of their time into deserted built environment in today's context, it is affecting human health- psychologically and physically to a great extent. Due to this stress is induced and stress has been called the "health epidemic of the 21st century" by the World Health Organization. The situation demands an increasing need for individuals to focus on their physical & mental health (Oliver H., 2018).

In today's hectic world employees of the office are facing huge work pressure because of long working hours, tight deadlines, and ever-increasing demands. Stress is getting generated because of fear of being jobless, pressure to perform to meet rising expectations, to work at optimum levels at all the time. Even students in high schools and universities often experience study-related stress due to high expectations from themselves and others, pressures from exams and classes, and lack of time, skills, money, sleep, or support (Hurst C.S., 2013). These and related stressors can have a negative impact on employees' and students' health, well-being, and academic achievement (Beiter R., 2015). The design of the built environment can play a vital role in dealing with the issues mentioned.

Creating positive human-centered spaces is a need of an hour. The premise that the office environment can influence people in ways that may reduce or improve their productivity is well established (Roelofsen P., 2002). The theoretical framework of Abdelaal (Abdelaal, 2019) proposes that including biophilic elements such as plants, natural landscapes, light, and water in learning spaces, such as classrooms, supports its learning function and can thereby generate a sustainable, inspiring, and innovating learning environment. Considering this shift in rural population to urban population biophilic design is a need and not a luxury. Biophilic design will connect people with nature & that will give health & well-being in the future (Browning, 2014). The study aims to analyse the effects of biophilic indicators on the performance of occupants through literature. While studying, indicators of the biophilic design were chosen. The first objective is to find out different tools used to measure the effects on occupants. The second objective is to examine the influence of indicators of biophilic design on employees and students in terms of physiological and psychological effects.

2 Biophilic design

People's physical and mental wellbeing remains highly contingent on contact with the natural environment, which is a necessity rather than a luxury for achieving the lives of fitness and satisfaction even in our modern urban society (Stephen K., 2008). There has been a great deal of scientific research on why the desire for a nature connection is so deeply embedded in our physical and mental states. This has led to the development of theories about how Biophilic Design can help fulfil that need and improve wellbeing. Biophilic design is not just an aesthetical consideration rather it has a profound effect on

people's well-being. Biophilic design is an emerging field that is trying to understand the parameters which can be applied in architectural terms. This is enabling the architects to grab the cognitive and psycho-physiological benefits which will enhance the health and well-being of human being. Old wisdom & new opportunities are getting enforced with emerging shreds of evidence which enabling the understanding between science, nature & built env (Catherine O. Ryan, 2014). Biophilic design can have tangible benefits in educational, workplace, hospitality, retail spaces. Biophilic design can give benefits in terms of health as well as finances for building occupants. For educational buildings by implementing the biophilic design, one can see the change in the speed of learning, attendance, academic performance & creativity (Oliver H., 2018)

Many architects have defined this term few are as follows. Biophilic design reconnects us with nature and is essential for providing people opportunities to live and work in healthy places and spaces with less stress and greater overall health and well-being. (Browning, W.D., el.al 2014). Biophilic design seeks to connect our inherent need to affiliate with nature in the modern built environment. (Kellert S. 2015). Building with Biophilic design will include natural elements indoors attributes encompassing views to nature, natural ventilation & daylight, access to green plants & water features, & the use of natural materials & biomorphic forms for indoor elements. (Yin, J. 2019).

Biophilic Design', has three categories & fourteen patterns. These patterns discuss in a general sense to address universal issues of human health and wellbeing (e.g., stress, visual acuity, hormone balance, creativity) within the built environment. While informing about all patterns in detail, it gives roots of the pattern, working with the pattern, Design consideration, relation with other patterns. (Browning, 2014).

Table 1: Three categories & fourteen patterns of biophilic design by Browning, 2014

Nature in the Space Patterns	Natural Analogues Patterns	Natural Analogues Patterns
1. Visual Connection with Nature 2. Non-Visual Connection with Nature 3. Non-Rhythmic Sensory Stimuli 4. Thermal & Airflow Variability 5. Presence of Water 6. Dynamic & Diffuse Light 7. Connection with Natural Systems	8. Biomorphic Forms & Patterns 9. Material Connection with Nature 10. Complexity & Order	11. Prospect 12. Refuge 13. Mystery 14. Risk/Peril

The challenge of biophilic design is to address the shortcomings of contemporary architecture in buildings, landscapes, and the interior, initiating a new framework for the beneficial experience of nature in the urban environment (Julia A. S., 2018).

2.1 Selection of study Parameters

Literature has reported many parameters of biophilic design such as attributes discussed by Stephen Kellart (6 categories, 24 attributes) (Stephen K., 2008), William Browning (3 categories,14 patterns) (Browning, 2014), Nikos Salingros (10 patterns) (Salingaros, 2019). The International WELL Building Institute is a public benefit corporation whose mission is to improve human health & well-being in buildings & communities across the world. These 14 patterns that prioritizing the most prominent nature-health relationships

in the built environment are supported by the WELL Building Standard rating system. WELL Building Standard is still decoding new patterns but this certification system has Greenery & daylight are the features included in their certification. Hence for this literature review-based paper, study is limited to these two parameters.

3 Indoor Greenery

Indoor greenery can be used in the form of potted living plants or green walls. Plants can function as figurative cues, wherein they remind building occupants of outdoor environments, and in doing so, people's thermal comfort range broadens, as if they were outside (Hellinga HI, 2010). Indoor nature can help increase the relative humidity, and reduce temperature, carbon dioxide concentration, and level of volatile organic compounds (Torpy F., 2018). Evidence for the effect of biophilic design, specifically plants, on human health, well-being and performance stems from research into cognitive, psychological, and physiological responses. These responses have been explored within the lab- and field-based studies, including schools, hospitals, and offices (Nieuwenhuis, 2014)

3.1 Workplaces:

As people often spend up to 90% of their time indoors, evidence shows investment into sustainable, healthy, and attractive workplaces can encourage enhancements in human health, well-being, and performance (Haghlesan, 2013). This investment not only increases financial gain but reduces costs significantly, by recovering profits lost through absenteeism and staff turnover (Clements-Croome D. K., 2019). There are many stressors such as excessive thermal factors, lighting aspects, moisture, noise and vibration, radiation, chemical compounds. It has been shown that exposure to these stressors can cause both short-term and long-term effects. This influences people's cognitive abilities, health, comfort, attitude & productivity (Julia A. S., 2018).

3.1.1 Performance

Nalise H. (Nalise H., 2020)experimented with office space where living plants were introduced on the individual desk and in break-out spaces for two weeks and after that those were removed. The questionnaires were distributed in the control condition, in experimental condition i.e. in presence of plants and once plants were removed from respective spaces. The questionnaires were based on industry-known occupant satisfaction surveys including the Building Use Studies (BUS) Occupant and Office Productivity Network (OPN) Survey. Introducing plants into individual offices and/or break-out spaces elicited a statistically significant change in perceived health and several performance metrics. Statistically significant perceived metrics were then tested using the Wilcoxon Signed Ranks test. Employees reported a 15% increase in creativity and productivity when plants were introduced into work environments. Jeonghwan K. (Jeonghwan K., 2018) has explored the underground space to analyse the effect of indoor plants and artificial window on the occupants. The study uses the Response Time task (RT) as an indicator of the work productivity of dwellers. RT was recorded by using the web-based test www.psytoolkit.org. A one-way ANOVA was conducted to examine the effects of indoor plants and artificial windows on each RT. Total RT shows that indoor plants make subjects more responsive toward a task, whereas artificial windows made them less (Jeonghwan K., 2018).

3.1.2 Creativity

Jie Yin examined the influence of biophilic elements such as indoor plants, natural view, natural light, natural materials, and biomorphic forms in office spaces through a virtual environment. Creativity related cognitive function was measured by Guilford's Alternative Uses Test. Biophilic interventions generally had positive effects on improving participants' creativity yet increasing their reaction time in an attention task (Jie Y., 2019).

3.1.3 Health

3.1.3.1 Physiological Health

Julia studies the effect of indoor greenery in the pilot study that measures heart rate, sympathetic activity, salivary amylase activity for objective evaluation. The study shows a positive correlation between the presence of greenery and satisfaction with the thermal environment (Julia A. S., 2018). In a virtual environmental study by Jie Yin, physiological indicators were measured. The results show consistently that biophilic intervention had positive effects on reducing stress levels (Jie Y., 2019). Tony (Tove F., 2000) has investigated with workspace and classroom for health and discomfort. For office space study applied 12 item questionnaires, a tool used when solving indoor climate problems. It was found that the mean score sum, a mean of 12 symptoms, was 23% lower during the period when the participants were exposed to plants in their offices compared to the period without plants. In the classroom study, the author has control classroom and biological classrooms where foliage plants were placed. The sum of symptoms or health complaints was 21% lower among pupils in biological classrooms compared to those in the control classrooms. Pupils using biological classrooms seemed satisfied with the intervention: 69% evaluated their well-being as better in a biological classroom, and 82% of the pupils hoped to use biological classrooms in the future. Mangone (Mangone G., 2014) has conducted quasi-experiment in an office building for four months, one month each season. The experiment was planned to evaluate the effect of the indoor plant on the thermal comfort of employees. Environmental measurements were recorded with dataloggers and the thermal comfort of participants was evaluated via online questionnaires. The questions recorded the participants' Thermal Comfort Vote, Thermal Preference Vote, Moisture Comfort Vote. Logistic regression analysis shows that plants had a significant positive effect on participants' thermal comfort. The results indicate that the presence of plants had a substantial positive effect on occupant thermal comfort in the winter, even though the average thermal comfort of the occupants was generally lower during the winter test period than during the test periods of the other warmer seasons.

3.1.3.2 Psychological Health

Julia (Julia A. S., 2018) uses Jikaku-sho shirabe questionnaire that consists of 25 fatigue symptoms items and NASA-TLX for the subjective workload. There is a significant correlation between the presence of greenery and daylight and the subjective feeling drowsiness. The workload sensation is significantly lower in the presence of daylight and greenery. The results conclude that there is a decrease in the stress levels with the presence of greenery. In Jeonghwan's (Jeonghwan K., 2018) study of the underground space, authors use Electrodermal Activity (EDA) as an indicator for tonic (continuous) arousal by measuring the Skin Conductance Level (SCL). Each SCL data-set was converted into a z- (standardized) scale to eliminate individual differences in EDA. The

result indicates that subjects were less aroused when they had both indoor plants and artificial windows than when they had only indoor plants.

3.2 Classroom

In classrooms, large numbers of people in a confined and limited space in combination with poor ventilation, electronic equipment, and many other factors can result in low humidity and rising temperatures, carbon dioxide concentrations, level of volatile organic compounds, and other biological agents (WHO, 2015). This is concerning because poor indoor climate may reduce feelings of comfort and has been associated with reduced attention, vigilance, study performance, and more health complaints such as fatigue, headaches, irritation of eyes, nose, and throat, and nausea in teachers and students (Kishi R., 2018). Recent studies examining students' exposure to nature found the amount of vegetation on and surrounding campus significantly predicted school-wide student performance (i.e., standardized test scores, graduate rates) (Wu, 2014). During their time in classrooms, students are required to focus, absorb information, and actively reflect on this information. These tasks call upon students' directed attention resources, which are susceptible to fatigue. This mental fatigue can lead to a reduced ability to solve problems, difficulties with inhibition, an increase in distractions, errors, irritable feelings, and susceptibility to stress (Boksem M.A., 2008). Specifically, epidemiological studies provided population-level evidence that greater exposure to greenness is associated with reduced absenteeism in schools; improved student academic performance; increased physical activity; improved mental health, brain development, and cognitive function; higher birth weights; and lower mortality rates (Dadvand P, 2018). Creating positive space emphasize on creating naturalised learning spaces for children. These spaces can: i) Enhance their cognitive abilities and increase the ability to focus, ii) Reduce symptoms of Attention Deficit Disorder (ADD), iii) Increase physical activity, nutrition, and creativity, iv) Reduce stress (Oliver H., 2018)

3.2.1 Attentional capacity

Jie Yin has virtually experimented with graduate students at Harvard school. Participants were tested in biophilic and non-biophilic virtual environments. The study measures attention capacity using a visual reaction time task as an indicator of attention, the Stroop test to measure attention and cognitive flexibility, and visual backward digit span task to measure the direct-attention performance. Students also reported their self- reported emotional changes in emotion before and after the experiment for environmental evaluation. In the visual reaction time task and Stroop task, although participants scored higher when in the biophilic environment, those improvements were not statistically significant at the 95% confidence level. Participants in the biophilic environment reported lower stress and frustration levels, higher engagement, and excitement level compare to their responses in the non-biophilic environment (Jin Y., 2018). The five public high schools of Illinois were studied for subjective and objective attention of students by Dongying Li and William S. Three classrooms were selected with no window, windows with built space view, and window with green space view. For subjective and objective attention, Visual Analogue Scale (VAS) questionnaire, and Digit Span Forward and Digit Span Backward test performed respectively. Students in the green window view condition demonstrated a 13.12 % increase in attentional functioning after the 10-minute break (Dongying L., 2016). Nicole has experimented in a university, secondary school classroom where potted plants and green walls were used as stimuli to understand its effect on

students' performance. Attention was measured by the Digit Symbol Substitution Test (DSST). Results show that students preferred classrooms with indoor nature to control the classroom. For student's self-reported attention this study demonstrates positive results (Nicole B., 2020).

3.2.2 Health & well-being

Jie Yin's virtual experiment Participants' physiological results showed more reductions in BP and SCL from baseline when in a biophilic environment compare to that in the non-biophilic environment. It is found that the changes in physiological measures are not significantly different in physical exposure versus virtual exposure to the same environment (Jin Y., 2018). Dongying's public school experiment, stress reduction in a green condition was higher than that of the barren condition. In the experiment conducted by Nicole, Well-being and Health complaints were measured with The Dutch Profile Mood States (POMS) and 12 item MM questionnaire respectively. Here authors mentioned that the physical health scale was unsuitable for this study and results may change if one changes the tool. This experiment has contradicting findings or no meaningful effects on well-being and health complaints were found (Nicole B., 2020). The experiment was carried out for 4 weeks and measurements were taken in the second week and third week after introducing the living plants in the classroom. The health or well- being of students depends upon many aspects and to show substantial results, the experiment should have longitudinal nature.

4 Daylight

Lighting design has long been used to set the mood for space, and different lighting conditions elicit differing psychological responses. The impact of daylight on performance, mood, and well-being has been studied for many years, in a variety of environments (Browning, 2014). Natural daylight triggers cells in the eye that signals the secretion or suppression of melatonin - the sleep-inducing hormone that regulates our Circadian Rhythms. However, artificial light can throw our Circadian Rhythms out of kilter and have physiological, cognitive, and overall health consequences. We can reset our Circadian Rhythm through increased exposure to sunlight. Designing spaces that offer occupants more opportunities for exposure to natural light will help them reset their Circadian Rhythms and improve wellbeing and performance (Oliver H., 2018).

4.1 Workplaces

In Julia's (Julia A. S., 2018) experimental study, it is shown that the use of daylight in the workplace could contribute to a perceived reduction in workload among the workforce. It is shown that the use of daylight in the office space does not contribute to an improvement in the work efficiency of simple work but may contribute to the performance of creative work. A pilot experiment by Boubekri et al. (Boubekri M, 2014) has studied the impact of daylight exposure on the health of workers from the perspective of subjective well-being and sleep quality as well. The study was conducted in two groups, employees with windows and abundant levels of daylight, another group with no direct contact with daylight at their workstations. The well-being of the office workers was measured by Short Form-36 (SF-36), while sleep quality was measured by the Pittsburgh Sleep Quality Index (PSQI). Performed t-tests to determine any statistical difference between the two groups in terms of office workers' health-related quality of life and sleep quality as measured on the SF-36 and PSQI. Results from the SF-36 show workplaces without windows have a

significantly negative impact on workers' role limitations due to physical problems (RP) and vitality (VT). this research study shows office workers in workplaces with windows may have more light exposure, better sleep quality, more physical activity, and higher quality of life ratings than office workers in workplaces without windows. Peiman (Peiman P., 2020) has conducted a simulation study of office-space. The purpose of the study is to develop a framework for the optimisation of office window design (position and area), which targets the minimisation of energy usage and the optimisation of daylight and visual performance. For daylight analysis authors have used indices like Annual Sunlight Exposure (ASE) and Daylight Autonomy (DA). Grasshopper plugins like Ladybug and Honeybee was used for simulation. Whereas visual performance or quality of view has four parameters like view access, view angle, view factor, view depth, and the python-based plugin is used for performance simulation. For optimisation Octopus, an evolutionary algorithm is used. The optimum solutions proved the efficiency of the optimisation framework in finding the best window system, for satisfying all studied objectives. It was revealed that it is possible to provide a satisfactory QV performance, for more than 80% of the reference room points, while minimising the energy usage, and maximising the daylight.

4.2 Classrooms

In the design guide by Oliver, it is mentioned that optimising exposure to daylight alone can: increase the speed of learning by 20-26%, improve attendance by an average of 3.5days/year and improve test scores by 5-14% of students (Oliver H., 2018). While contrasting findings of Dongying's (Dongying L., 2016) public school experiment arguing that exposure to daylight had no impact on stress recovery. The findings indicate that daylight is not a major factor underlying the relationship between window view and reduced stress and better attentional functioning. Thus, authors are suggesting to use caution while reviewing evidence on daylight and student performance or stress recovery because the presence of green window views could be driving the different outcomes between window lighting conditions and no window conditions. Parnian (Parnian B., 2020) has done a simulation study of the primary classroom that meets inhabitants' comfort needs and energy efficiency. The study has variables like Building orientation, Wall inclination angle, Window. Number, WWR, Glazing material. Grasshopper plugins were used for different parameters like i) Ladybug for Thermal comfort, Energy simulation, ASE simulation, ii) Honeybee for Daylight (DGP), Environmental analysis, Calculating received daylight illuminance, energy consumption, visual & thermal comfort, and iii) Octopus- to find an optimal design solution. The authors find that building orientation has the most effect on ASE and occupant thermal comfort. The number of windows is the least influential input variable. Also, the wall inclination angle plays a determining role in the value of DA.

5 Findings

There are many factors among others such as level of education, skills, age, gender, circadian cycle, emotional states, and response bias that should be considered when investigating the relationship between indoor architecture and human performance (Clements-Croome, 2006). Jie Yin's (Jin Y., 2018) study examines the results of physiological and cognitive results. It is observed that the findings of the physical and virtual biophilic environments are no significantly different. Participants in the biophilic environment had 14% better performance in short-term memory and improved emotions

compare to their performance in the non-biophilic environment. Biophilic design, as a health promotion approach, could help reduce stress and improve creativity in office settings. Students in the green window view condition scored significantly higher on tests of attentional functioning and recovered significantly faster from a stressful experience than their peers who were assigned to rooms without views to greenspaces. There was no evidence that stress-mediated the relation between view to green landscapes and attention restoration, suggesting these are two distinct pathways influencing students' psychological and cognitive functioning. (Dongying L., 2016).
While reviewing the literature it is observed that researchers have used different tools to measure blood pressure (BP), heart rate (HR), and skin conductance level (SCL) as physiological indicators of stress. These are discussed commonly in literature. Other than these heart rate variability (HRV), Salivary amylase activity, body temperature was also measured of employees and students.

Table 2 Tools used for different purpose of the study

Sr. no	Purpose	Tools used
1	Cognitive measure	Stroop test (Jie Y., 2019) (Jin Y., 2018)
2	Fatigue symptoms	Jikaku- sho Shirabe questionnaire (Julia A. S., 2018)
3	Task load index	NASA- TLX (Julia A. S., 2018)
4	Creativity evaluation	Guildford's Alternative Use test (Jin Y., 2018)
5	Objective attention	Digit Span Forward and backward test (Jin Y., 2018) (Dongying L., 2016)
6	Subjective attention	Visual analogue scale questionnaire (Dongying L., 2016)
7	Subjective stress	Visual analogue scale questionnaire (Dongying L., 2016)
8	Overall attention	Digit Symbol Substitution Test (DSST) (Nicole B., 2020)
9	Well-being	Dutch Profile Mood States (POMS) (Nicole B., 2020) Short-form 36 (SF-36) (Tove F., 2000)
10	Health complaints	12 item MM questionnaire (Nicole B., 2020) (Tove F., 2000)
11	Employee performance matric	Building Use Studies (BUS) Occupant and Office Productivity Network survey (Nalise H., 2020)

Out of these commonly used by researchers are for objective attention is Digit Span forward and backward test and for health, complaints are 12 item MM questionnaire.

6 Conclusion

In today's hectic world people are spending the majority of time indoors in a very deserted built environment. It is taking a toll on human physical and mental health. The paper discusses the literature on biophilic design and its importance in human health and well-being. The study presented here focuses on the influence of two indicators of biophilic design that are indoor greenery and daylight on employees and students. Paper suggests after reviewing literature that indoor greenery is proving beneficial for employees in maintaining health by reducing stress. It is found that there is an improvement in cognitive functions, creativity, short term memory, and attention capacity of occupants after introducing plants in the built environment. While optimal daylight in the environments suggests a decrease in perceived workload in employees and for classrooms, an increase in vitality and reduced physical problems are observed. Further research should address the duration, type, and location of the plant with respect to occupants. For daylight studies, it is needed to determine the duration of light exposure that is optimal for benefits to well-being.

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Smart Villages Design Posters

Deconstructing PMAY-G: ICT 4 Nation Building

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ABSTRACT

Pradhan Mantri Awaas Yojana - Gramin (Prime Minister's Housing program - Rural, PMAY-G), previously *Indira Awaas Yojana* (IAY), is a social welfare program, launched by the Ministry of Rural Development, Government of India, to upgrade or construct housing for the underserved rural population. The program ambitiously targets constructing 29.5 million houses by 2022 in two phases. The beneficiary family is provided with financial assistance, with caveats, for the construction of a house with essential basic amenities. The program has also played a key role in women empowerment along with providing a respectable living to millions of rural underserved families. However, it faces challenges in meeting the gaps between policy paper and the on-ground implementation.

The study is based on the cradle to grave As-Is process mapping of the program. We achieve this through a cross-stakeholder analysis approach and participatory rural appraisal (PRA). It shall help understand the detailed scheme structure, gaps across administrative tiers and its causalities. We further recommend an ICT based framework with Digital India Mission at its core to address the identified challenges, thus improving the scheme efficacy. It will aid the policymakers to achieve the doable over chasing the desirable.

The proposed ICT based review lays the foundation for driving future policy reforms ensuring that PMAY-G addresses:
a) **"First-Mile"** challenges: Remain fit for purpose and maximize impact, through improved visibility, accessibility, and transparency;
b) **"Last-Mile"** challenges: deliver governance and services on demand, and empowerment of citizens; and
c) **"Beyond-The-Last-Mile"** challenges: Inclusion of the rural underserved families excluded due to social menace, and policy paralysis.

Keywords: *PMAY-G, Digital India, ICT, Rural Development, Business Process Re-engineering*

INTRODUCTION TO PMAY-G

Launched on 1st January, 1996, *Indira Awaas Yojana* (IAY) aimed at addressing housing needs of the poor households in rural India. Later, on 1st April, 2016, the scheme was restructured into "*Pradhan Mantri Aawaas Yojana*" (PMAY-G) with the vision of "Housing for All" by 2022. The scheme provides financial assistance ranging from Rs. 70,000 to Rs. 1.30 lakh depending on area to construct or upgrade ones house.

Identification and selection of genuinely deprived beneficiaries, based on multi-layered prioritisation reflecting housing deficiency and other social deprivation parameters in SECC.2011 data

Verification by *Gram Sabha*

Construction using local materials, appropriate designs and trained masons along with development and provision of sustainable house design typologies

Convergence with other Govt. schemes for provision of basic amenities viz., toilet, drinking water, electricity, clean & efficient cooking fuel, treatment of waste etc

Payments, Direct Benefits Transfer (DBT), in installments after verifications at defined stages

STATUS

NO. OF BENEFICIARY FAMILIES
as on 30 June, 2020

PHASE I (2016 -19)		PHASE II (2019 - 22)
99,96,012	MORD Target	1,12,50,000
1,12,55,899	Registered	59,01,727
98,15,383	Sanctioned	57,11,275
89,06,659	Completed	18,43,636

Objective

Constructing the operational case for the Government's Digital India effort, in particular Vision Area II (Governance and Services on Demand) & III (Digital Empowerment of Citizens)

- Increase coverage by reaching out to greater number of eligible citizens
- Manage scheme delivery better
- Improve accessibility and service delivered to citizens
- Monitor benefits, by program and location, improving their visibility

Methodology

First, we analysed the program guidelines. Meanwhile, extensive field visits were conducted during study in various villages in Maharashtra state (Konkan region (Raigad and Palghar district), Solapur district, Nashik district).

Limitations

Citizen engagement for the scheme largely occurs at the *Gram Panchayat* (GP) level – i.e. across 2.5 lakh units in the country, which vary widely in delivery capacity and operating realities. This makes it impossible, within the scope of this study, to examine every individual delivery issue experienced on the ground.

Cross-stakeholder Workshop

Techniques And Execution

Identifie,selected, and invited 42 stakeholders, from 8 States: representing most of India's regions, responsible for delivering the Scheme across every administrative tier – GP (beneficiaries, *Gram Sarpanches* (Village heads)), Block (block development officers (BDO)), District (district development officers (DDO)), State, and Union.

It also brought non-governmental organisation representatives, and other experts.

The Workshop used an interactive issue-surfacing technique called Strategic Roadmapping, to help participants identify, prioritise, and articulate the target areas.

Each exercises followed the Chatham House Rule: while comments and input from the exercises can be quoted, they are not attributed to the individuals making them. This was in order to ensure confidentiality for, and therefore free and open discussion and comment from, the invited stakeholders.

STAGE 4 Followed with one-on-one interviews with delegates, to engage more detail within the areas identified.

STAGE 3 To-Be process prescriptions — Delegates in clusters, each group comprising at least one representative from every administrative tier, specified mechanisms and techniques to achieve those end-states.

STAGE 2 Gap Analysis — **Enhancement: Specifying Improvement -** What practices can we improve? What will these practices look like, after improvement, in concrete terms? This process identified interlocking clusters of delivery issues outlined the causal chains and revealed the factors that drive each of these clusters, to generate priority targets.

STAGE 1 As-is Mapping — **Baseline: Identifying good.** Where have we done well in the scheme so far: what specific delivery practices should we retain? Delegates specified factor(s) in their own or any other administrative tier that they wish to retain. This isolates factors that should not be affected – or that should be further extended – in reengineering.

ROADMAPPING WORKSHOP: Group Discussions

ACCOMPLISHMENTS

of As-Is Mapping technique

Unify process and problem analysis
Systematic, complete understanding of process issues – a 360-degree view of every operational problem in the field understood both at its own level and in the context of the larger implementation framework.

Grasped the specifics of information asymmetry
How particular communication gaps between stakeholders affect Scheme execution.

Comprehensively trace the causal chain interconnections between different process issues
'Ground-level' Scheme delivery issues in the field or operations management difficulties at Block or District inadvertently driven by deeper-rooted causes: State and Central procedures and guidelines that influence field delivery. These are interconnected, and inextricable from beneficial processes.

Identify and frame, prioritise major contributors to delivery issues
a. Issues affecting Scheme delivery across several administrative layers (across panchayat, district, State, and Centre); and
b. Issues significantly affecting delivery within a particular administrative layer (e.g. pressing issues faced by block development officers)

PROBLEMATICA

Gap Analysis Findings

Issues Identified

1 SECC-Based Enrolment Compliance

a. Precluding fake entries

- *Preserving entitlements of vulnerable demographics from interference*
  Women, widows, and tribal groups who were accurately placed on the Socio-Economic Caste Census (SECC) list excluded due to biases at the GP.
- *Support against extra-legal pressure*
  The fixed SECC list is difficult to modify and populated with well-designed processes. However, their actual compliance and execution in the field was less than reliable –being open to various influences (including local political pressures).

b. Dynamically-updated enrolment mechanisms

- Data is frequently found to be out of date, or inaccurate. It excludes immigrants and those who have fallen back into poverty; and includes emigrants, and those who have built their own 'pucca' houses since 2011.

c. Community-based beneficiary engagement and enrolment

- Deeper community engagement and community-centred enrolment needed.
  'Decentralising': exception verification processes among communities.

2 Field-level video-based advisory mechanisms

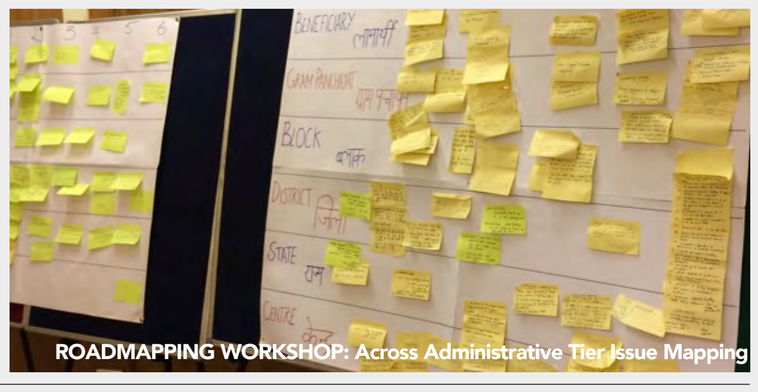
a. Medium of instruction concerning information dessimination related to scheme, registration, and processess there-after does not comply with local dialects.

Psychological barrier resulting from inhibitions prevents clear understnding of various aspects of the scheme.

b. Often localised unsustainanble building materials and designs used in practice.

3 Other recommended Actions

- Record keeping through registers and monthly progress reports involving manual entry.
- Absence of data validation and data safety mechanisms.
- No local administration level dash board maintenance for progress monitoring.
- Unestablished feedback mechanism.



ROADMAPPING WORKSHOP: Across Administrative Tier Issue Mapping

Proposed ICT based Solutions

- Generation of a fixed SECC-based list, which is prioritised rule-base.
- There is a need to introduce beneficiary enrolment processes on regular intervals. Verifying, including, and possibly excluding citizens whose circumstances changed or whose details had been recorded wrongly.
- Video/photograph based record updation from time to time.

- Need ICT based Awareness/Information dissemination (Audio/Video in nature) mediums to drive preliminary awareness and demand generation among citizens.
- Information of Sustainable building materials, constructions methods, and designs based of geographical conditions and resource available locally.

- Improving grievance redress mechanisms, by using simple helpline-based ticketing systems to raise, track, monitor, and resolve issues faced by the beneficiary.
- Use of SMS/Email for updates and notification.

CONCLUSION

ICT systems shall enable State-Led Agile Development Cycle initiative to re-engineer above discussed processes tasked with program delivery on the ground.

Pre- COVID-19 ICT as a development tool (quick fixes)
Post- COVID-19 ICT as a development platform (cradle-to-grave)

ICT lays the foundation for SDG pillars to improve the livelihoods and prospects of the bottom of the pyramid.

SDGs Addressed

Primary: 9 Industry, Innovation and Infrastructure; 10 Reduced Inequalities; 11 Sustainable Cities and Communities
Secondary: 5 Gender Equality; 12 Responsible Consumption and Production; 17 Partnerships for the Goals

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THE REVIVAL OF THE TRIBAL COMMUNITY BY THE CONCEPT OF S.M.A.R.T. VILLAGE: A CASE OF SABAR TRIBE OF JHARKHAND, INDIA

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ABSTRACT

Most of the tribes in India are in a vulnerable and dilapidated state. Some tribal communities have been categorized as primitive tribal groups based on their extremely backward socio-economic status and other sociological traits. Sabar is one of such ignored tribe mainly found in Jharkhand, Chhattisgarh, and West Bengal, India. The people still live according to their traditional life lacking necessities such as shelter, sanitation, water supply etc. and mainly depend on resources from forests. The Sabar people are skilled artisans and excelled in mainly brooms, baskets, ropes etc. Their products/ artifacts could not fetch a good price lacking variation in the product's designs which has brought the languishing craft on the verge of extinction. The upliftment of the tribal people is not only necessary to improve the living conditions of the people and to revive the lost art, but their upliftment will also contribute in increasing the country's GDP, thus improving the status of the nation globally. This paper looks at the adaptation to develop a self-sustaining community-based solution, with a holistic approach to improve the standard of living of the people by providing them the basic amenities at reasonable price and in a sustainable manner.

Keywords:
Tribal communities; Vulnerable and dilapidated; skilled artisans; primitive; self-sustaining community-based solution; Sabar Tribe.

1.2 OBJECTIVES

- To study the existing living and working conditions of the Sabar tribe.
- To study the conditions of their arts and crafts.
- To provide solutions to improve the infrastructure and basic requirements of the people such as housing, health, education etc.
- To provide solutions to improve and uplift the arts and crafts of the community.
- To study the various models and tools for the imple mentation of the suggested solutions.
- To explore the methods and applications of reusing treated grey water.

1. INTRODUCTION

India is a very diverse nation comprising of people from different ethnicity and cultural background. India is a house to several tribes or adivasis viz. Andh, Bhil, Gond, Chenchwar, Kammara to name a few, residing in several parts of the country.

There are few tribes listed as primitive tribes on the basis of their socio-economic conditions and other sociological traits living in remote locations without basic infrastructure and necessities. They live in dilapidated houses and still depend on forests for food which is uncertain. Most of these tribes are skilled artisans and craftsmen specializing in crafts such as wooden toys, statues, bamboo works, clay models and ornaments, paintings etc. Due to lack of good price for their crafts, they are moving out of their profession in order to work as daily wagers leading them on the verge of extinction and bringing the identity of these groups to jeopardy. Although several initiatives both by government and several NGOs have been taken to uplift and improve the conditions of these people still it has been not very effective.

1.1 AIM

To improve the living and working conditions of the people of the Sabar community, a primitive tribe, with a holistic approach by providing them the basic amenities at reasonable price and in a sustainable manner.

2. TRIBES & PRIMITIVE GROUPS IN INDIA

The scheduled tribe (ST) population is 104.2 million, which is 8.6 percent of the total population of India (Census of India, 2011). Madhya Pradesh, Maharashtra, Orissa, Gujarat, Rajasthan, Jharkhand, Chhattisgarh, Andhra Pradesh, West Bengal, and Karnataka having a large number of ST populations.

The ST population are scattered all over the country depicting heterogeneous culture and socio-economic status. There are about 700 tribes (with overlapping categories in some States/UTs) as per notified Schedule under Article 342 of the Constitution of India (Ministry of Tribal Affairs)2018.

3. DOCUMENTATION I JHARKHAND

These primitive tribe lives in extreme deprivation, according to their traditional primitive lifestyle and are deprived of basic amenities, hence, suffer from stark poverty, starvation (***with many surviving on not more than 30 grams of food per person per day***). Very low level of literacy (***For instance, only 1.73 percent of tribal literates in the state belong to PTGs, 88 percent of Sabars are illiterate and among other PTGs too literacy rate varies between 5 to 16%).***

The PTG is ecologically and biologically endangered tribe. They are struggling for their very existence by braving the challenges of malnutrition, disease and natural calamities. Their population is fast declining and some of the ***primitive tribes are reduced to even 100 in numbers.***

Living Condition: Housing - The Sabar houses are tiny hut made of twigs, leaves and sticks, not tall enough for someone to stand (Sahu, 2015). Some have been allotted houses under Birsa Awas Yojana.

There are no toilets in the houses and use the fields and waterfalls for bathing and toilet purpose.

Remote and Inaccessible Habitats - Located in interior and remote regions and one has to travel quite a bit to reach these villages.

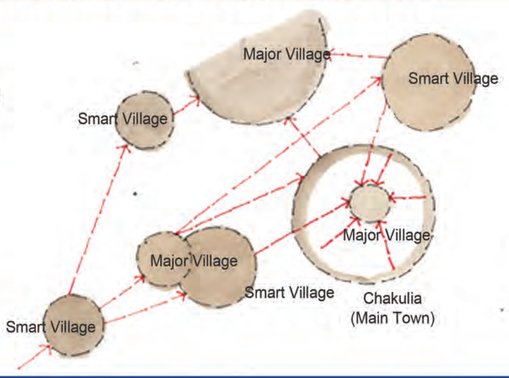
Electricity- Connection is almost nonexistent. Those having connections have no access to electricity.

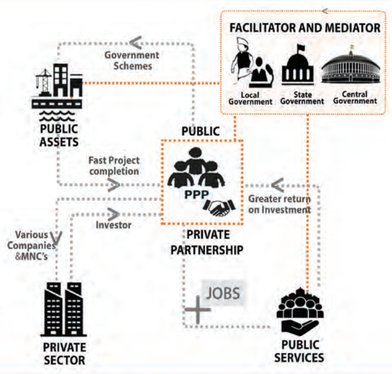
State of Economy-Once they were depended on their arts and craftsmanship. Now majorly work as labor and construction workers and some survive selling wood, hacked from forests.(Sahu, 2015), with an average monthly income between Rs. 500 to Rs. 1000.

Left Wing Extremism-Tribal villages are scattered and many of them are located in accessible areas where left wing extremism prevails.

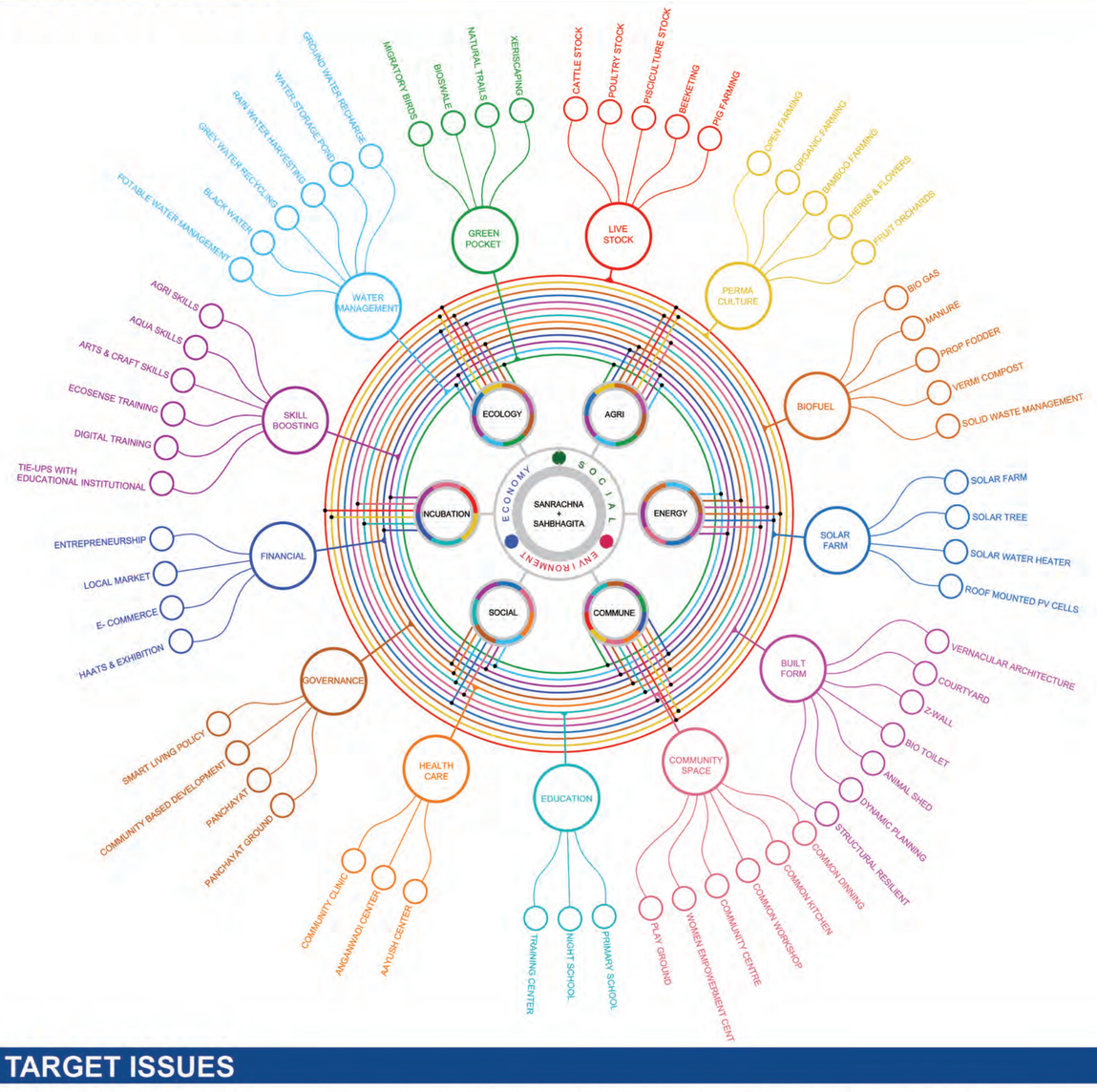
4. STRATEGY I MODELS AND TOOLS IMPLEMENTED

Village: Pather Chakri, Chakulia
District: East Singhbhum, JH
Nearest Town: Chakulia (15 Kms.)
Population: Males - 73
Females - 82
Children (0-6): 26
Nearby Village: Khayerbani
Connectivity: Roadways, Public Bus

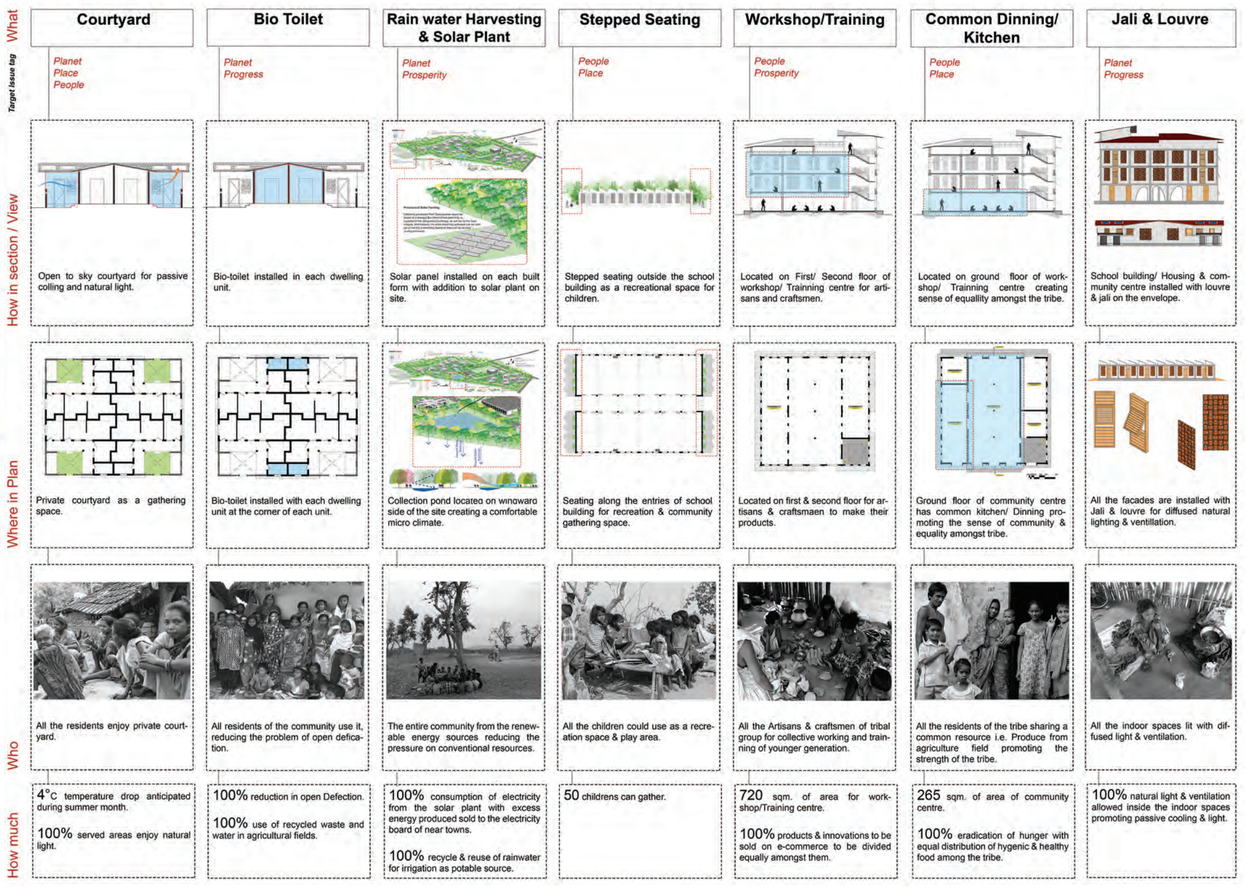




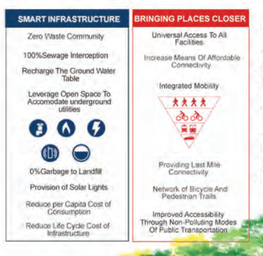
5. STRATEGY STELLATE



6. TARGET ISSUES



7. PROPOSAL



Provision of Farmland

Provision of small farmlands near houses to provide for their daily needs. Surplus produced can be sold in the market to gain extra profit

Provision of community ground

The ground could be used as an extension to the community hall as gathering for festivities, weekly market and celebration. It can also be used as an extension of school as playground. Thus, temporal in nature

Solar Streetlights

Solar Energy shall help power the lighting
Solar power along with the use of LED lighting shall reduce energy consumption significantly

CO Reduction

Native species require minimum maintenance for the plantation
The new plantation will be the source of tones of fresh oxygen every year

Accessibility

Access road for ease of connectivity to the nearby villages and town centers

Colorful Landscapes

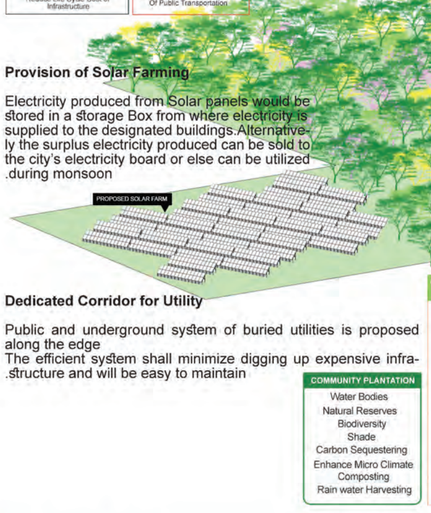
Colorful planting strategy to create excitement and vibrancy

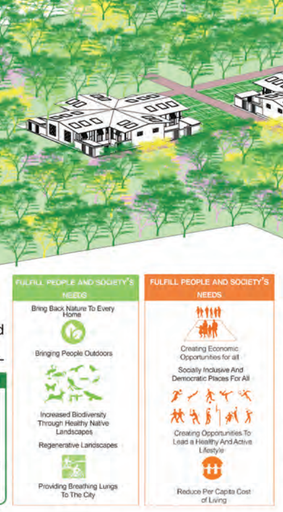
Provision of Solar Farming

Electricity produced from Solar panels would be stored in a storage Box from where electricity is supplied to the designated buildings.Alternatively the surplus electricity produced can be sold to the city's electricity board or else can be utilized .during monsoon

Dedicated Corridor for Utility

Public and underground system of buried utilities is proposed along the edge
The efficient system shall minimize digging up expensive infra-.structure and will be easy to maintain





Native Plant Species

Thrive Migratory Birds inhabit
Small Animals Maintain Ecosystem
Insects and Bees Help the Plantation Grow

Water Bodies

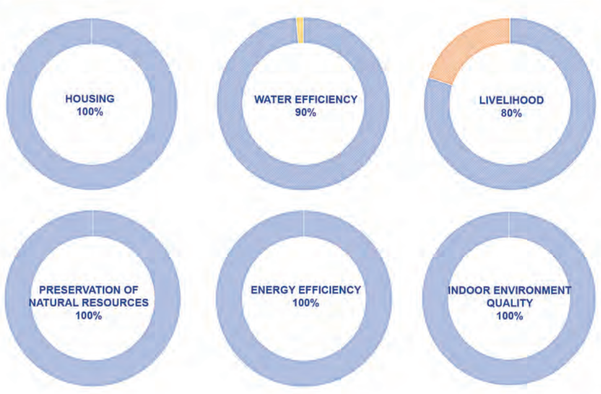
Water Bodies reduce local temperature through evaporative cooling
Water Bodies provide visual relief reduce stress

Wind Protection Against Extreme Weather

Green Corridor/Natural Trail

Trails shall be a series of walkways running through plantation areas

8. IMPACT



9. CONCLUSION AND CONTEXTUAL APPLICATION

The model village would help in rejuvenation and upliftment of the living standards of the Sabar tribal by spatial interventions and providing them with basic necessities. The interventions would also help in the revival of the dying arts and crafts, by introducing new designs and skillset, will make them socially and economically stable and would preserve and intact the identity of the tribe and provide them a national identity. With improved literacy and skillsets and contribution to the nation's economy would help in increasing the GDP of the country thus, improving the status of the nation globally.

This model village can be easily implemented, operated and managed in any part of the country. Providing shelter, food to those who do not have it is the prime target. Different investors from different areas could be persuaded to invest in this project, thus all the investment will not be burdened on the central or state government. This idea would create a model village which would act as a context and reference for similar developments in any part of the country. It will also help in uplifting and upgrading the dying arts and crafts of the country such as Chamba Rumal Painting, Himachal Pradesh, Madhubani Art, Bihar.

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FLOOD RESISTANT HOUSING IN ASSAM

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INTRODUCTION

Almost every monsoon, Assam is overwhelmed by the angry waves of the Brahmaputra, which sweep away thousands of village homes. The houses are not equipped enough structurally to resist the massive force due to floods. The Traditional Assamese rural houses are rooted to the ground. Apart from the general convention of building houses on the ground, it is also due to the belief of the people that living up on stilt houses all the time like the Mishing, would be uncomfortable and inconvenient. This distinct jump in character between these two ways of living, allowed us with space for exploration of an alternative way of meeting them in the middle, introducing ***Amphibious House****.*

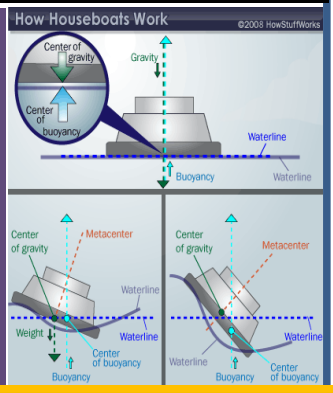
OBJECTIVE:

To develop an innovative and sustainable flood resilient house design which is environment friendly and can be built using locally available materials.

FLOATING HOUSES *: Floating house is a unique mechanism of living on a buoyant platform without the fear of sinking and get afloat with the rising ups and downs according to the water level. When flood occurs, the house also rises with the water level , therefore they keeps floating on water.*

WORKING PRINCIPLE OF FLOATING HOUSES

1.Buoyant force and centre of buoyancy
2. Metacentre and Meta-centric height
3. Twisting Moment



DESIGN PARAMETERS

1. *Floating Foundation*
2. *Structural Stability*
3. *Buffer Height*
4. *Structural Material*
5. *Horizontal Stability*

STRUCTURAL STABILITY OF THE HOUSE

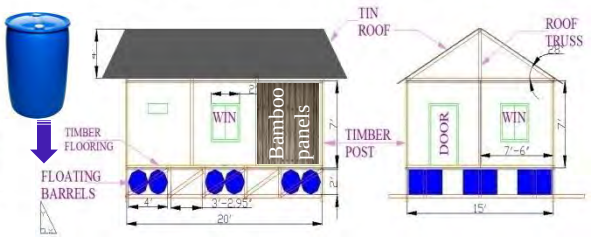
Factored Load= ***35.86 kN***
Buoyant Height , h=0.48 ft
Position of meta-centre is greater than the centre of gravity of the structure

Such houses are really helpful for the flood prone rural areas near the bank of Brahmaputra and its tributaries. As example we can take villages like Bechimari, Gahiya , Agdia in the district of Barpeta(Assam) where almost every year the floodwater shallow up the whole settlement almost upto its neck

METHODOLOGY

Bamboo has been used as a primary building material for the floating house. It is eco friendly and cost effective. It has abundant availability in Assam.

INTERIOR PLAN



PVC barrels *will be stacked in the frame which will help the whole structure in floating*

The frame of the house made of ***Bamboo*** *and Timber. Woven panels of Bamboo are being used in wall*

Estimated Cost of the House=₹36000

Water Supply through harvesting and recycling rainwater.

Electricity is obtained from one solar panel installed on the roof

The solid waste is directed into a floating barrel which will act as a septic tank

Conclusion

Floating or Amphibious houses are the need for tomorrow. Such Floating house concept can really help the poor class people of Assam. It is low cost house and is durable due to its flexibility.

Construction Process flowchart

Locally found materials Like Bamboo and Timber

PVC Barrels and Anchorage chain are supplied or imported from industries

Material inspection and testing

Access overall flood risk for the locality by FRH governing body under PMAY scheme

Approval

Construction materials

Analysis & Design by engineers or trained people

Construction of FRH by local workers under the supervision of trained people

FRH- Flood Resisting House
PMAY- Padhan Mantri Awas Yojna

Thank You

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End of the Proceedings