Proceedings of The 4th International Conference on Smart Villages and Rural Development COSVARD 2021

13-14 December 2021
Webinar

Conference Chairs:

A/Prof Hemanta Doloi (Chair)
Prof Atul Bora (Co-Chair)

Editor:

A/Prof Hemanta Doloi

The University of Melbourne
Victoria 3010, Australia

Smart Villages Lab
Culture • Construction • Capacity • Community

4th International Conference on Smart Villages and Rural Development (COSVARD 2021) 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 2021 conference.

Having had the success in past three COSVARD conferences, the unpreceded COVID-19 pandemic has forced us again to host our COSVARD 2021 as a Webinar. While a little relaxation of the COVID-19 restrictions in India allowed our local organising partner to host at least the inaugural session at Assam Engineering College (AEC) in a face-to-face mode, due to ongoing restrictions in international travel coupled with the general acceptance of the online as a norm for such events, bulk of the proceedings were conducted as Webinar. Nonetheless, COSVARD 2021 was proven to be a great success once again with over 950 enthusiastic attendees participated from over nine countries.

Once again, COSVARD2021 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 four 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 years, the scope of COSVARD 2021 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 2021 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 2021 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 12 final papers and one design poster 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 Nayan Sharma, Indian Institute of Technology Roorkee (IIT Roorkee), Prof VK Vijay, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) Indian Institute of Technology Delhi (IIT Delhi), Prof KN Satyanarayan Director of Indian Institute of Tirupati (IIT Tirupati), Prof Mark Burry, Director Smart Cities Research Institute from Swinburne University of Technology, 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, Brand Ambassador, International Academy of Science, Engineering & Technology, New Delhi, India Guwahati, Assam and Mr Tushar Joshi from TVASTAGroup Chennai India,

Last but not least, I sincerely appreciate the support, dedication and commitment of every single member of the scientific committee, distinguished reviewers and colleagues who have been instrumental for taking the COSVARD to entirely a new height. Without their selfless support and good wishes, COSVARD 201 would not have been possible.

With warm regards

Associate Professor Hemanta Doloi
Convenor and Chair (COSVARD 2021)
Director (Smart Villages Lab)

Committees and Partners

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Swinburne University of Technology, Australia

COSVARD 2021 – The 4th International Conference on Smart Villages and Rural Development

Online Webinar
Date: 13 - 14 December 2021

Topic: **COSVARD 2021**
When: **Dec 13, 2021 02:30 PM Canberra, Melbourne, Sydney**
9:00am (Indian Standard Time, IST)
Please register via the link below:
https://unimelb.zoom.us/webinar/register/WN_cGrhPt5aQ5qDOuehG7LGPQ

After registering, you will receive a confirmation email containing information about joining the webinar.

Webinar ID: 83222179841
Password: cosvard21

Conference Schedule (Final, 12 Dec 2021)

Smart Villages Lab
Faculty of Architecture, Building and Planning

Agenda for Opening Ceremony and Inauguration (TBA)
Day 1 - Monday 13th December 2021
2:30pm (AEDT#) – 3:30pm (AEDT)
9:00am (IST*) – 10:00am (IST)

#Australian Eastern Daylight Saving Time (AEDT), *Indian Standard Time (IST)

Anchored by: Mr Kaustavpallav Baruah (Ex Student, Assam Engineering College)	
2:30pm (AEDT) 9:00am (IST)	**Inviting Guests to Dias, Lighting of Lamp and Felicitation of Guests**
2.40pm (AEDT) 9:10am (IST)	Welcome and Introduction **A/Prof Hemanta Doloi (Chair)**
2.50pm (AEDT) 9:20am (IST)	Opening Remarks **[Prof Atul Bora (Co-Chair**) (Principal, Assam Engineering College)
3:00 pm (AEDT) 9:30am (IST)	**[Prof Mark Burry, AO, Swinburne University of Technology, Victoria, Australia]**
3:10 pm (AEDT) 9:40am(IST)	**[Prof Nayan Sharma, IIT Roorkee, India]**
3:20 pm (AEDT) 9:50am(IST)	**[Dr Samir Baruah, Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, NE]**
3:30m (AEDT) 10:00am (IST)	**[Prof Robert Crawford, The University of Melbourne]**
3:40pm (AEDT) 10:10am (IST)	**[Dr Hannah Robertson, The University of Melbourne]**
3:45 pm (AEDT 10:15am (IST)	Remarks by **[Sri P. Saikia, IAS, Special Commissioner, Govt of Assam]**
3:50 pm (AEDT 10:20am (IST)	Remarks by **[Sri Dilip kumar Bora, IAS, Secretary to the Govt of Assam, Finance Department]**
3:50 pm (AEDT 10:30am (IST)	Inauguration and Address, COSVARD 2021 **[Sri Kuladhar Saikia, IPS, President *Asom Sahitya Sabha***
	Vote of Thanks **[Dr Purabi Patowary]**
Technical Session starts at 4:00pm (AEDT) 10:30am (IST)	

Technical Session

Time	Day 1 - Monday 13th December 2021	
4:00pm (AEDT) 10:30am (IST)	**Keynote 1: Prof Nayan Sharma, IIT Roorkee, India** Topic: Technology Upgrade in Vital Sectors to Usher in Economic Revolution in Assam **Chair: A/Prof Hemanta Doloi**	
5:00pm 11:30am (IST)	**Session 1: Housing - Resilience**	
	Chair: Prof Robert Crawford	**Authors**
Paper 3	Community centric assessment on sustainability of affordable housing in Sri Lanka	Tharaki Sathyavi Hettiarachchi[1] and Hemanta Doloi[2] *[1]University of Vocational Technology, Sri Lanka* *[2]The University of Melbourne, Australia*
Paper 2	Study of Traditional Tribal Houses of Assam	Saurav Jyoti Dutta and Nayanmoni Chetia *Jorhat Engineering College, Assam, India*
Paper 1	Efficiency of Banana Stem-Juice for Treatment of Wastewater	Y. Bidyalaxmi Devi, Prajnan Parthasarathi, Partha Pratim Boruah, Debotush Mukharjee and Mebalamki Langstang *North Eastern Regional Institute of Science and Technology (NERIST), India*
6.00pm (AEDT) 12:30pm (IST)	**Break**	
6.30pm (AEDT) 1:00pm (IST)	**Session 2: Waste Management**	
	Chair: Dr Sally Donovan	**Authors**
Paper 9	Design of Portable Waste Sorting Device for Segregation of Waste for Smart Waste Management in Village	Menonjyoti Kalita and Pradip Baishya *Assam Engineering College, Assam, India*
Paper 4	Rural infrastructure for smart villages – sanitation case study	Hemanta Doloi *The University of Melbourne, Australia*
Paper 13	Possible techniques to minimize the household waste management problems in rural Chittagong	Ahim Mohammad Chowdhury and MD Obidul Haque *Premier University, Chittagong*
7:30 pm (AEDT) 2:00pm (IST)	**Break**	
7.45pm (AEDT) 2:15pm (IST)	**Keynote 2: Prof V.K. Vijay, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) (IIT Delhi)** Topic: Unnat Bharat Abhiyan - a program of ministry of education, government of India for development of villages through higher educational institutes **Chair: A/Prof Hemanta Doloi**	

8.45pm (AEDT) 3:15pm (IST)	**Session 3: Infrastructure**	
	Chair: Dr Gao Shang (The University of Melbourne)	**Authors**
Paper 16	Compulsory land acquisition process for rural connectivity: A case study of Mangaldoi district in Assam	Ishaan Borthakur *Gujarat National Law University*
Paper 17	Study of rural infrastructure for smart villages	Nabankur Sarma[1] and Hemanta Doloi[2] [1]*Golaghat Engineering College, Assam* [2]*The University of Melbourne, Australia*
Paper 19	Wellbeing-centred behavioural change towards domestic energy saving in Iran	Dorsa Fatourehchi, Masa Noguchi and Hemanta Doloi *The University of Melbourne, Australia*
Paper 5	Thermal Performance and occupants' perception of prefabricated timber-frame house in coastal region, Bangladesh	Rezuana Islam[1] and Sajal Chowdhury[2] [1]*Chittagong University of Engineering & Technology* [2]*The University of Melbourne*
9.45pm (AEDT) 4:15pm (IST)	**End of Day 1**	

	Day 2 - Tuesday 14th December 2021	
2:30pm (AEDT) 9:00am (IST)	**Keynote 3: Prof KN Satyanarayana, Director (IIT Tirupati)** Topic: New National Education Policy in India and its implications - NEP 2020 (TBC) **Chair: Dr Sally Donovan**	
3.30pm (AEDT) 10:00am (IST)	**Session 4: Infrastructure**	
	Chair: Mr Geoff Kimm (Swinburne University of Technology)	**Authors**
Paper 18	Role of rural infrastructure and smart villages in development	Ashraful Huda[1] and Hemanta Doloi[2] [1]*Golaghat Engineering College, Assam* [2]*The University of Melbourne, Australia*
Paper 8	Manufacturing of paver blocks for rural areas by using plastic waste and its performance analysis	Pradip Baishya, Ripunjoy Kalita, Rajesh Das, Bikash Das and Shashank Laskar *Assam Engineering College, Assam, India*

Paper 10 (Poster)	Community farming in rural context	Prachurjya Das[1] and Prajnan Parthasarathi[2] [1]*NORTH-EASTERN HILL UNIVERSITY, Shillong, Meghalaya, India* [2]*National Institute of Construction Management and Research, Pune, India*
4.30pm (AEDT) 11:00am (IST)	**Break**	
	Chair: Mr Bhaskar Phukan, Director Technical, NRL	
4.45pm(AEDT) 11:15am (IST)	**Keynote 4: Prof Mark Burry, AO, Director (Smart Cities Research Institute) Swinburne University of Technology, Victoria, Australia** Topic: Artificial intelligence (AI) and the Smart Village: a Challenge or an Opportunity?	
5:30pm(AEDT) 12:00pm (IST)	**Keynote 5: Prof Atul Bora, Principal (AEC) and Director (Technical Education)** Topic: Creating a roadmap for implementation of new national education policy - 2020 of India	
6:15pm(AEDT) 12:45pm (IST)	**Break**	
	Chair: Prof Shyamanta M. Hazarika, IIT Guwahati	
6:30pm(AEDT) 1:00pm (IST)	**Keynote 6: Dr Arvind Phukan, USA** Topic: Flood solutions in Majuli – some reflections *[Dr Arvind Phukan, Past Rotary District Governor Arvind Phukan 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)*	
7.15pm(AEDT) 1:45pm (IST)	**Keynote 7: Dr Pranjal Kumar Phukan** *[Brand Ambassador, International Academy of Science, Engineering & Technology, New Delhi, India]* Topic: Design based approach for sustainable rural-based enterprises	
8.00pm(AEDT) 2:30pm (IST)	**Keynote 8: Prof Koshy Varghese (IIT Madras), Adithya VS and Tushar Joshi (Tvasta)** Topic: Affordable Housing Through 3D Printing	
8.45pm (AEDT) 3:15pm (IST)	**Awards announcements** **A/Prof Hemanta Doloi**	
9.00pm (AEDT) 3:30pm (IST)	*Closing remarks* **A/Prof Hemanta Doloi and Prof Atul Bora**	
- End of Conference -		

Keynotes Speakers and topics

1. Prof Nayan Sharma, Indian Institute of Technology Roorkee (IIT Roorkee), India
    - *Technology Upgrade in Vital Sectors to Usher in Economic Revolution in Assam*

2. Prof V.K. Vijay, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) (IIT Delhi)
    - *Unnat Bharat Abhiyan - a program of ministry of education, government of India for development of villages through higher educational institutes*

3. Prof KN Satyanarayan Director of Indian Institute of Tirupati (IIT Tirupati)
    - *New National Education Policy in India and its implications - NEP 2020*

4. Prof Mark Burry, Director Smart Cities Research Institute from Swinburne University of Technology
    - *Artificial intelligence (AI) and the Smart Village: a Challenge or an Opportunity?*

5. Prof Atul Bora, Principal Assam Engineering College, Assam
    - *Creating a roadmap for implementation of new national education policy -2020 of India*

6. Dr Arvind Phukan, President of the Core Professional Group for the Brahmaputra (CPGB), USA
    - *Flood solutions in Majuli – some reflections*

7. Dr Pranjal Phukan from Guwahati, Assam
    - *Design based approach for sustainable rural-based enterprises*

8. Mr Tushar Joshi from TVASTAGroup Chennai India
    - *Affordable Housing Through 3D Printing*

Prizes

Research Papers

1st Prize

SAURAV JYOTI DUTTA and NAYANMONI CHETIA "STUDY OF TRADITIONAL TRIBAL HOUSES OF ASSAM", Jorhat Engineering College, Assam, India

2nd Prize 1

FAHIM MOHAMMAD CHOWDHURY and MD OBIDUL HAQUE, "Possible techniques to minimize the household waste management problems in rural Chittagong", Premier University Chittagong, Bangladesh.

2nd Prize 2

THARAKI TATHYAVI HETTIARACHCHI[1] and HEMANTA DOLOI[2], "COMMUNITY CENTRIC ASSESSMENT ON SUSTAINABILITY OF AFFORDABLE HOUSING PROJECTS IN SRI LANKA", [1]University College of Kuliyapitiya, Sri Lanka, [2]Smart Villages Lab (SVL), The University of Melbourne, Australia.

3rd Prize

REZUANA ISLAM[1] and SAJAL CHOWDHURY[2], "THERMAL PERFORMANCE AND OCCUPANTS' PERCEPTION OF PREFABRICATED TIMBER-FRAME HOUSE IN COASTAL REGION, BANGLADESH", [1]Chittagong University of Engineering and Technology, Bangladesh, [2]The University of Melbourne, Australia.

Design Posters

1st Prize

PRACHURJYA DAS[1] and PRAJNAN PARTHASARATHI[2], "COMMUNITY FARMING IN RURAL CONTEXT", [1]North-Eastern Hill University, Shillong, Meghalaya, [2]National Institute of Construction Management and Research, Pune.

Research Papers

EFFICIENCY OF BANANA STEM-JUICE FOR TREATMENT OF WASTEWATER

Y. Bidyalaxmi Devi[1], Prajnan Parthasarathi[2], Partha P. Boruah[3], Debotush Mukharjee[4], Mebalamki Langstang[5]

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Abstract: *Approximately two-thirds of our planet is water, but most of it is occurs in forms in which it cannot be used for human activities; this combined with increasing population, rapid industrial developments and urbanisation is creating an ever increasing demand for clean, usable water. Thus, the need for techniques for effective and economical treatment of water for reuse and safe disposal has been realized. Throughout the world researchers are trying to come up with newer and better procedures for treatment of wastewater so that it may be reused or disposed safely into water bodies or groundwater. Industries are one of the major contributors of wastewater. The water after being used on these industries get contaminated by various impurities like grease, organic and inorganic salts, oil, etc.. The treatment of waste water is an expensive process and though the big companies and factories can easily afford it, it becomes very difficult for some smaller factories to afford these expensive procedures which call for the need for cheaper methods for treatment of water. This paper aims to analyse the efficiency of banana stem juice as a cheap, natural alternative for treatment of polluted water from two different sources. Six different parameters, viz. turbidity, electrical conductivity, total dissolved solids, suspended solids, total solids and dissolved oxygen were taken and the change in these parameters after adding banana stem juice to it were measured. It was found that adding banana stem juice significantly decreases the turbidity and suspended solids in the samples and increases the dissolved oxygen. But, it also causes an undesirable increase in the total dissolved solids, which results in an increase in the total solids and conductivity of the samples. It was also observed that banana stem juice is more effective for highly turbid water as compared to low or moderately turbid water.*

Keywords: *Wastewater Treatment, Natural Coagulant, Banana Stem-juice, Industrial Wastewater Treatment, Turbidity.*

1 Introduction

In many developing countries, the waste water is usually discharged directly into water bodies or ground water without proper treatment. This not only possesses a major health hazard for people but is also very harmful to the flora and fauna of the water bodies (Kristianto, 2018). If not treated properly before disposal, wastewater may find its way into drinking water reservoirs and cause contamination. Contamination of drinking water sources represent a major health hazard in many parts of the developing world. Removal of turbidity is a very important part of treatment of contaminated water as suspended particles represent transport vehicles for undesirable organic and inorganic contaminants, taste, odour and colour-causing compounds as well as pathogenic organisms (Giwa, 2016). Coagulation is the process of removing turbidity of water by adding certain metal salts, synthetic organic/ inorganic polymers, etc., called coagulants, which destabilizes the colloidal materials and cause the small particles to agglomerate into larger settleable flocs. The most commonly used primary coagulants are aluminium and iron (III) salts which have been linked with increasing cases of Alzheimer's disease, Neurotoxicity, Cancer, etc. They also produce large volumes of sludge (Sundaresan, 2016). Ashydrated aluminium potassium sulfate [$KAl(SO_4).12H_2O$] or commonly known as alumas, used as a clarification and finishing agent is also regarded as an important poisoning factor in dialysis encephalopathy. Other chemical coagulants like synthetic organic polymers, like acrylamide have been found to have neurotoxic and strong carcinogenic effects too. Chemical coagulants and alum salts are also inappropriate for use in developing countries due to their high costs and low availability (Giwa, 2016). Alum can also react with the natural alkalinity present in water leading to decrease in pH and lower efficiency in treatment of cold water (Anju, 2016). Thus, there is a need for better, natural, cheap, easily available, non-toxic coagulants for treatment of wastewater in developing countries.

This need can be fulfilled by natural coagulants. Natural coagulants manufactured from plant seeds, leaves, and roots have been used for more than 2000 years in countries like India, Africa, and China (Asrafuzzaman, 2011). In recent years, few researchers have explored the use of plant based coagulants as substitutes for harmful metal salts. The results so far has been very promising due to their abundance, low price and biodegradability (Giwa, 2016). When compared to chemical coagulants, plant based coagulants are safer, more eco-friendly and are generally toxic-free. Also, natural coagulants usually produce lower volumes of sludge of higher nutritional values, thus making the handling, treatment and disposal of sludge easier and cheaper. Natural coagulants are also non-corrosive and thus do not cause pipe erosions. Further, they do not consume alkalinity, so pH adjustments can be omitted. This provides extra cost-savings (Pricilla, 2019:66).

1.1 Banana Stem Juice as a Natural Coagulant

In this study, we have used banana stem juice as a plant based coagulant for treatment of waste water from two different sources, one from a very polluted water tank where waste water from the laboratories of Department of Mechanical Engineering, NERIST gets collected, and the other from a local brewery.

Banana is an herbaceous plant of the genus *Musa spp.* of the family *Musacae* and is one of the most widely grown tropical fruits because of its high food value. Once a banana tree bears fruit, the stem needs to be cut off as it cannot grow fruit again. In some cultures, the pith of the banana stem is also consumed as a delicacy, but in most cases they are just left abundantly in the plantation field where it rots and is used as a manure (Alwi, 2013). Sometimes the abundant stems gets infected with a fungal disease called Sigatoka (Black

Leaf Streak) which destroys the leaves and reduces crop yield by around 40% (Agunwamba, 2016).
Waste banana pith was found to be an effective absorbent for removal of Rhodamine B from textile wastewater (Namasivayam, 1993). It was also found to effectively remove direct red and acid brilliant blue from aqueous solutions through adsorption (Namasivayam, 1998). Banana stem juice is also a useful biosorbent in preliminary removal of cuprum from electroplating wastes (Alwi, 2013). Banana stem juice contains polysaccharide compounds inulin, which is a natural polymer for bridging and entrapping the microfloc to form larger floc. This helps in fast settlement of flocs for coagulation of wastewater (Gopika, 2016). Many other researchers have also studied the efficiency of banana stem juice as a natural, plant based coagulant for treatment of waste water, but most of them have not included the effect in the levels of total dissolved solids when it is added to a solution. As the total dissolved solids strongly affect aquatic life of a water body we have included the measurement of change in total dissolved solids of each sample when banana stem juice is added in our study. Also, the dissolved solids in a solution directly effects the total solids and electrical conductivity of the solution.

2 Methodology

For each sample, first the optimal coagulant dosage and the retention time were measured. Then the six parameters, viz. Turbidity, Dissolved Oxygen, Electrical Conductivity, Total Dissolved Solids, Total Suspended Solids and Total Solids were measured before and after the coagulant was added. The change in the parameters were then observed and studied to analyse the efficiency of banana stem juice as a plant based natural coagulant.

2.1 Sample Collection

For our experiment we have collected wastewater samples from two sources, one was from a water tank where the water used in the workshops and laboratories of Mechanical Engineering Department of NERIST for washing and cleaning machineries and equipment gets collected. The water in the tank was highly contaminated and was of very high turbidity (208NTU). The wastewater contained mostly dirt, grease and oils, and also some organic matter from leaves and branches from nearby vegetation that falls on it. As natural coagulants are not effective in removing the oil and grease floating in water samples, we manually removed the oil and grease from the surface of the sample manually by using sponges to soak out the floating oil.
The second sample was from a local brewery located in Lekhi Village in Papum Pare district of Arunachal Pradesh, India. This particular industry was chosen as breweries consume large quantities of water and also produces a lot of wastewater. The primary characteristics of the brewery wastewater are high organic matter content, no toxicity, low content of heavy metals, and are easily biodegraded. However, if not treated properly prior to consumption or disposal, it can possess a serious risk to human health and environment (Choi, 2016).

2.2 Extraction of Banana Stem Juice

Matured plants that have beared fruits in the past were collected and cleaned. The stems were then cut into small pieces as shown in Fig. 1. Then the pith was separated from the foliage. The pith was further cut into smaller pieces for ease in grinding (Fig. 2). A little water was also mixed to facilitate the grinding. The paste that was formed after grinding was then strained with a cotton cloth and the filtrate was used for experiments. The juice

was stored in a refrigerator to maintain its freshness. Also, the sample collection, stem juice extraction and the experiments were conducted within 3 days for each sample to avoid fermentation and biodegradation. So, the banana stem juice was required to be prepared separately for both the samples as the tests on both samples were not done at the same time.

Figure 1: Banana Stem cut into small pieces

Figure 2: The pith cut into smaller pieces

2.3 Measurement of Turbidity

The turbidity was measured using the ITS 1000 Turbidity meter by Iso-Tech Systems (Fig. 3).

Figure 3: ITS 1000 Turbidity Meter

2.4 Jar Test Experiment

The optimal coagulant dose was found using the Jar test apparatus (Fig. 4). One litre of the sample was taken in separate beakers (4 for sample1 and 6 for sample2) and the coagulant was added to it in different dosage. The samples were first stirred at 100-120 rpm for 1-2 minutes, during this stage the coagulant got distributed in the entire sample thoroughly. The samples were then stirred at a reduced speed of 20-30 rpm for 20-30 minutes to allow thorough mixing of the coagulant with the sample. Then the samples were stirred at a much slower speed of 1-2 rpm for another 20-30 minutes. This facilitated the formation of flocs. Then the samples were allowed to settle for a period of 30 minutes without any disturbances. The turbidity of the sample after the resting period and the coagulant dosage were plotted and the optimal coagulant dosage was found using this graph (Fig. 6 &7).

Figure 4: Jar Test Apparatus

2.5 Measurement of Retention Time

The optimal dose of the coagulant was added to 1 litre of the samples and its turbidity was measured at various time intervals. The optimal retention time was found by comparing the turbidity removed at various intervals.

2.6 Measurement of DO, EC, TDS, TSS, and TS

The dissolved oxygen, electrical conductivity and total dissolved solids were measured by using the ITS 601 Water Analysis Kit by Iso-Tech Systems (Fig. 5).

Figure 5: ITS 601 Water Analysis Kit

For measurement of total suspended solids, the sample was filtered through a 2-micron Whatman filter paper. The total suspended solids was obtained by measuring the difference of the weights of the dry paper and its weight after filtration. The total solids was obtained by adding the suspended solids with dissolved solids.

3 Results

3.1 Optimal Coagulant Dose

3.1.1 For Sample 1

Original turbidity of the sample from the wastewater tank of Mechanical Engineering Department of NERIST was found to be 208NTU. The turbidity at various doses of the coagulant has been tabulated in Table 1 and represented in a graphical form in Fig. 6.

Table 1: Turbidity of Sample 1 at different Coagulant Dose

Coagulant Dose (mL per 1L of Sample)	Turbidity (in NTU)
10	61
15	57.67
20	54.33
25	57.67

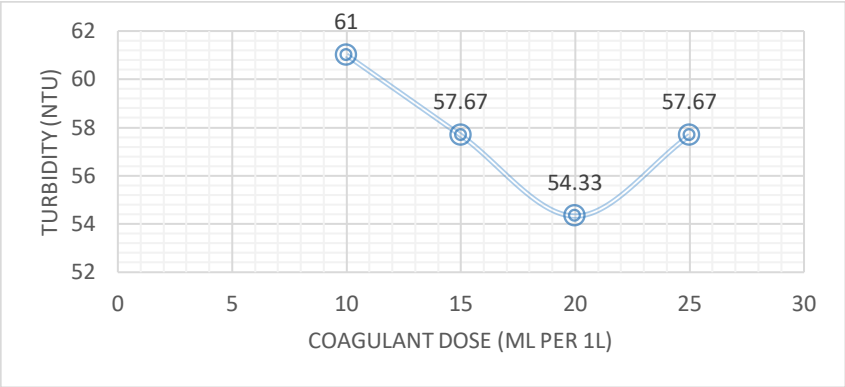

Figure 6: Turbidity of Sample 1 at different coagulant dosage

From Fig. 6, the optimal coagulant dosage for Sample 1 was taken to be 20mL of banana stem juice per 1L of the Sample.

3.1.2 For Sample 2

Original turbidity of the sample from the brewery was found to be 72NTU. The turbidity at various doses of the coagulant has been tabulated in Table 2 and represented in a graphical form in Fig. 7.

Table 2: Turbidity of Sample 2 at different Coagulant Dose

Coagulant Dose (mL per 1L of Sample)	Turbidity (in NTU)
10	64
15	62
20	61
25	63
30	70
35	71

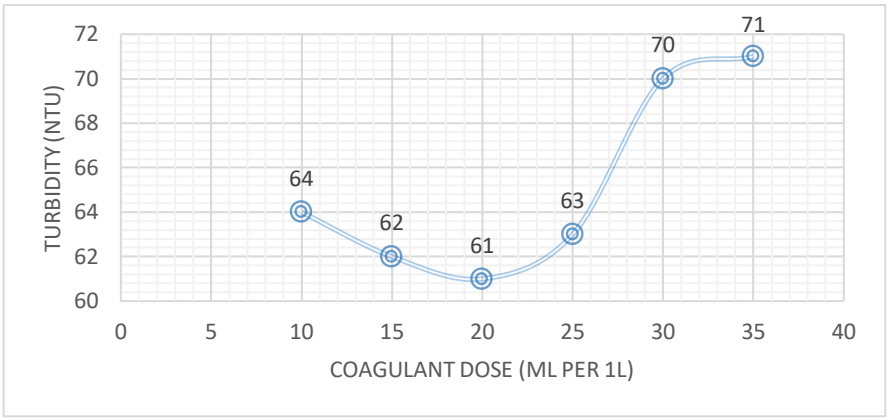

Figure 7: Turbidity of Sample 2 at different coagulant dosage

From Fig. 7, the optimal coagulant dosage for Sample 2 was taken to be 20mL of banana stem juice per 1L of the Sample.

3.2 Retention Time

3.2.1 For Sample 1

The original turbidity of Sample 1 was found to be 208 NTU. The turbidity of the sample, when coagulant is added at optimal dosage, at different time were measured and tabulated in Table 3 and represented in graphical form in Fig. 8.

Table 3: Turbidity of Sample 1 at various Retention Time (Optimal Dosage, no agitation)

Retention Time	Turbidity (in NTU)
30 min.	100.33
1 hr.	92.67
2 hr.	70.67
3 hr.	63
5 hr.	64
10 hr.	68.33

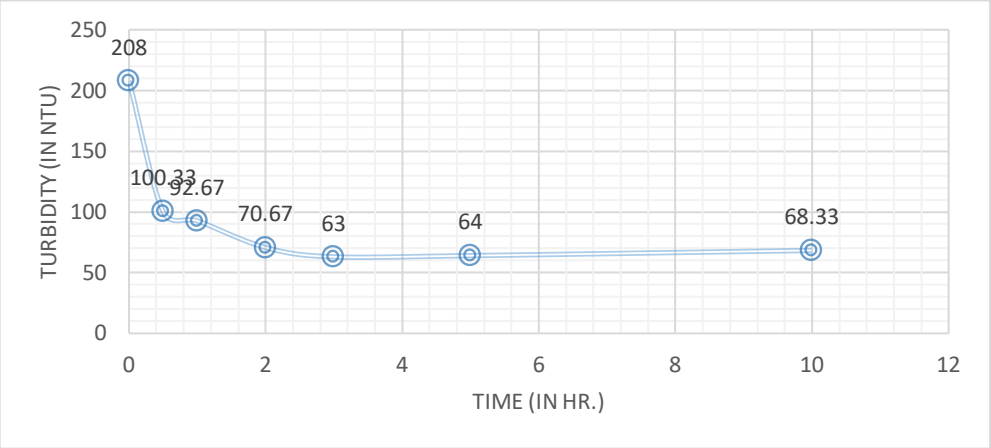

Figure 8: Turbidity of Sample 1 at different retention time

From Fig. 8, the optimal retention time was found to be 3 hours.

3.2.2 For Sample 2

The original turbidity of Sample 2 was found to be 72 NTU. The turbidity of the sample, when coagulant is added at optimal dosage, at different time were measured and tabulated in Table 4 and represented in graphical form in Fig. 9.

Table 4: Turbidity of Sample 2 at various Retention Time (Optimal Dosage, no agitation)

Retention Time	Turbidity (in NTU)
30 min.	59.75
1 hr.	56
2 hr.	53
3 hr.	53
5 hr.	58
10 hr.	57.5
12 hr.	56
15 hr.	56

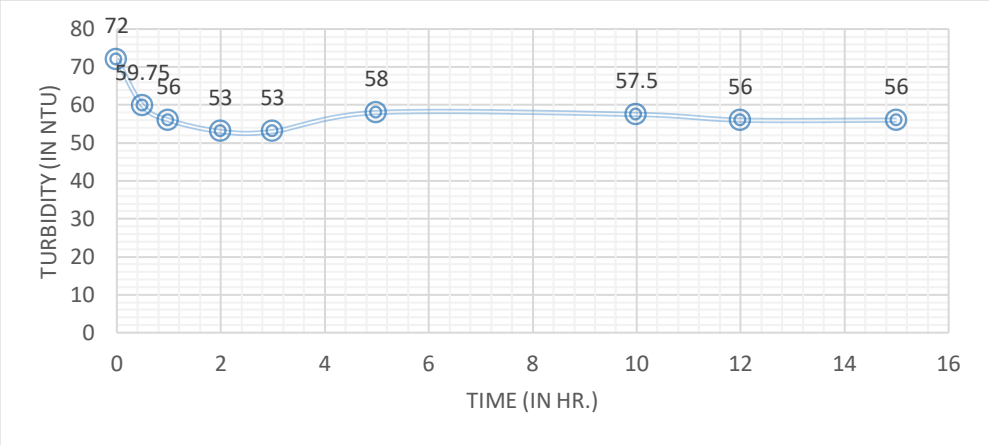

Figure 9: Turbidity of Sample 2 at different retention time

From Fig. 9, the optimal retention time was found to be 2 hours.

3.3 Effect of adding Banana Stem juice

3.3.1 For Sample 1

The measures of each parameter and their percentage changes before and after the coagulant was added for Sample 1 are tabulated in Table 5 below.

Table 5: Percentage change in the selected Parameters for Sample 1

Parameter	Values		Change in Values	Percentage Change
	Initial	Final		
Turbidity	208 NTU	63 NTU	-145 NTU	-69.71%
EC	0.131 mS	0.248 mS	0.117 mS	89.31%
TDS	89.9 ppm	218.67 ppm	128.77 ppm	143.24%
DO	7.8 mg/L	8.33 mg/L	0.53 mg/L	6.79%
TS	1700 ppm	2650 ppm	950 ppm	55.88%
SS	1610.1 ppm	1243.7 ppm	-366.4 ppm	-22.76%

3.3.2 For Sample 2

The measures of each parameter and their percentage changes before and after the coagulant was added for Sample 2 are tabulated in Table 6 below.

Table 6: Percentage change in the selected Parameters for Sample 2

Parameter	Values		Change in Values	Percentage Change
	Initial	Final		
Turbidity	72 NTU	53 NTU	-19 NTU	-26.39%
EC	1.32 mS	1.885 mS	0.565 mS	42.8%
TDS	880 ppm	1215 ppm	335 ppm	27.57%
DO	12.3 mg/L	13.9 mg/L	1.6 mg/L	13%
TS	1333 ppm	1609 ppm	276 ppm	20.71%
SS	453 ppm	394 ppm	-59 ppm	-13.02%

The percentage change in each parameter (when coagulant is added at optimal dose and is allowed to settle for optimal retention time) is represented in graphical form in Fig. 10.

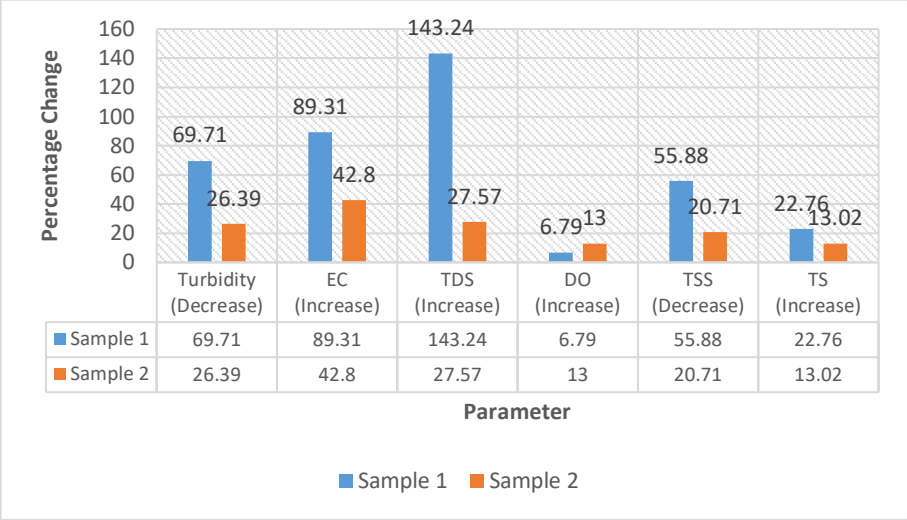

Figure 10: Percentage change in various parameters of different samples on addition of optimal dose of banana stem juice and retaining for the optimal retention time

From Fig. 10 we can see that the turbidity of the samples has decreased by 69.71% and 26.39% respectively. These are very high reductions which clearly shows the potential of banana stem juice as a coagulant. This reduction in turbidity is also reflected by the significant reduction in suspended solids of the samples (55.88% and 20.71% respectively). It was observed that the reduction in sample 1 (145 NTU) was far greater than that of the second sample (19 NTU), this shows that banana stem juice is far more effective in removing turbidity from highly turbid water (initial turbidity of sample 1 was much greater than that of sample 2). Further, an increase in dissolved oxygen levels of the samples also has been observed (6.79% and 13% respectively).

But the addition of banana stem juice to the samples has also caused an undesirable change in the samples. It was observed that the total dissolved solids have increased greatly for both the samples (143.24% and 27.57% respectively). This was mainly due to high dissolved solid content of the banana stem juice. The percentage increase for the first sample was observed to be 143.24% which is very high as compared to that of the second sample (27.57%), but when we compare the actual change in the values, they are very similar (128.77 ppm and 335 ppm). The high difference in the percentage change was observed due to the very high difference in the initial values of TDS in the samples (89.9 ppm and 880 ppm respectively). The initial dissolved solids in sample 1 was low so a smaller change has resulted in a higher percentage change. The increase in TDS has also caused an increase in the total solids and the electrical conductivity of the samples. The increase in the TS was 22.76% for sample 1 and 13.02% for sample 2. The electrical conductivity of the samples increased by 89.31% and 42.8% respectively.

4 Discussion

Banana is widely grown in almost all the tropical regions of the world. In rural areas and even most urban areas of Assam banana plants can be found in almost every home in abundance. These plants bear fruit just once and then never bears fruit again. The pith of banana plant is widely consumed as a delicacy, still there are more banana plants than there's demand for the pith. So, most people just let the plants which bore fruit once to rot in the fields and become manure. This is not only a very wasteful method but can also cause fungal diseases in the newer plants as discussed above. If we can extract the juice from the plants instead of letting them rot and utilize the juice as an alternative of chemical

and synthetic coagulants for treatment of wastewater it will not only be economic but also very environment friendly.

The various small to medium industries can buy the banana stem from rural communities and extract the juice to use for treatment of their wastewater. This way they can save a lot of money on chemical coagulants and reduce the impact on nature and health caused by chemical and synthetic coagulants. Alternatively, new organisations can be formed which buys the stems in bulk from cultivators and extract the juice and sell it to industries. This can generate some employment and would be much more convenient for the industries as they can obtain the natural coagulant directly. Also, the people growing banana plants would especially benefit from this as after getting the crop and taking out whatever quantity of pith they need as food, they can earn a profit from the remaining plants by selling them to be used as natural coagulants.

But, as we have seen that the addition of banana stem juice to a sample can also cause an increase in the total dissolved solids of the sample, which causes an increase in the total solids and the electrical conductivity of the sample, it is not safe to directly discharge the water treated with banana stem juice into water bodies. Thus, banana stem juice should be used only as a primary treatment for wastewater, and not as the only treatment. The wastewater should be further treated to make it safe for disposal.

5 Conclusion

It was observed that banana stem juice is very effective at removing turbidity from wastewater. It was found to be especially good for treatment of highly turbid water. It also effectively reduces the suspended solids in the water. Addition of banana stem juice also increases the dissolved oxygen levels. This increase was observed to be more when the wastewater was of organic nature. This shows that the quality of the wastewater has improved due to the addition of banana stem juice. Also, the increase in the dissolved oxygen levels indicated that the biological oxygen demand (BOD) of the samples decreased, thus separate experiments for measurement of BOD were omitted from this study. But, addition of banana stem juice to the samples also caused a great increase in the total dissolved solids. This also caused an increase in the total solids levels and the electrical conductivity of the samples. The increase in electrical conductivity proves that there is an increase in ions in the samples. Increase of dissolved solids is not a good sign for aquatic life as it hinders their senses and causes problems in their respiratory organs. Banana stem juice is a very effective coagulant and can be used as a primary treatment for industrial wastewater. But it is advisable to further treat the wastewater before disposing it to water bodies or ground water.

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STUDY OF TRADITIONAL TRIBAL HOUSES OF ASSAM

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Abstract: *The aim of this study is to analyze existing traditional tribal houses of Assam for earthquake forces. A type of stilt house raised either on bamboo or timber stilts are locally known as chang ghar very commonly seen among the Mishing, Deori and some other tribal communities as they are the preferred mode of inhibition in river side areas. The north east region is rich in forest products like timber, bamboo, thatch, ikra etc and these have been considered as building materials by inhabitants since ages making the structures more economical, lightweight and sustainable in nature. Information regarding different types, shapes and materials used in traditional tribal houses were collected through a field study. Three chang ghar models were modelled in SAP 2000 concept gathered from field study. One of these models is completely made up of indigenous materials (Traditional Chang ghar), the other is RCC framed chang ghar (common in today's context) and last one is RCC framed chang ghar with RCC slab (RCC chang ghar). Base shear and deflection for three models have been compared. Base shear in the traditional Chang Ghar was nominal as compared to the RCC framed structures, inevitably due to the smaller mass associated whereas maximum joint displacement for bamboo traditional chang ghar was found to be as more compared to RCC chang ghar models.*

Keywords: *Traditional tribal houses, Stilt house, Chang ghar, Assam, Bamboo house*

1 Introduction

Assam is in the eastern most projection of the Indian Plate where the plate is thrusting underneath the Eurasian Plate, Which leads the entire state being prone to earthquake of moderate to High Intensity. There are numbers of indigenous tribal and non tribal people from Mongolian, Indo- Burmese, Indo- Iranian and Aryan origin living in the region with solidarity. Total 23 numbers of scheduled tribes resides in Assam; according to census of India, 2001[1]. Major tribes are mainly Boro, Mishing, Rabha, Kachari, Lalung, Dimasa, Deori etc. and have their own unique art of living which includes houses, colourful tradition, food, dresses and languages contributing to form the greater Assamese community.

A traditional structure is a representation of the characteristics of the people living in that particular area, materials available and workmanship practiced and the condition of the climate. North Eastern states including Assam consist of tropical rainforests, deciduous forests, grasslands, bamboo orchards and numerous wetland ecosystems. According to Environment & Forest department, Govt. of Assam recorded forest area of Assam is 26,832 sq km accounting for 34.21% of its geographical area. There are estimated 3513 beels and hoars, 1,85,623 ponds and tanks in Assam. Bamboos are called the poor man's timber. From the data of India State of Forest Report 2017[2], Assam has 8,955 sq km area covered by bamboos. Commonly cultivated species are Bambusa balcooa (Bhaluka bamboo), *Bambusa tulda* (Jati bamboo), *Malocanna bacciferra* (Muli bamboo), *Dendrocalamus hamiltonii* (Koko bamboo) and *Dendrocalamus giganteus* (Mokalm bamboo). The climate of Assam is categorized as Tropical Monsoon Rainfall type and it experiences heavy rainfall and humidity during monsoon. The annual average rainfall in the state is about 200 cm (in some district it goes up to 320 cm) per year make it rich in timber and bamboo productions. Forest products like bamboo, timber, thatch, Ikra etc. are considered as building materials by indigenous people since ages. The structures constructed using these locally and easily available materials are found to be economical, comfortable and lightweight in nature.

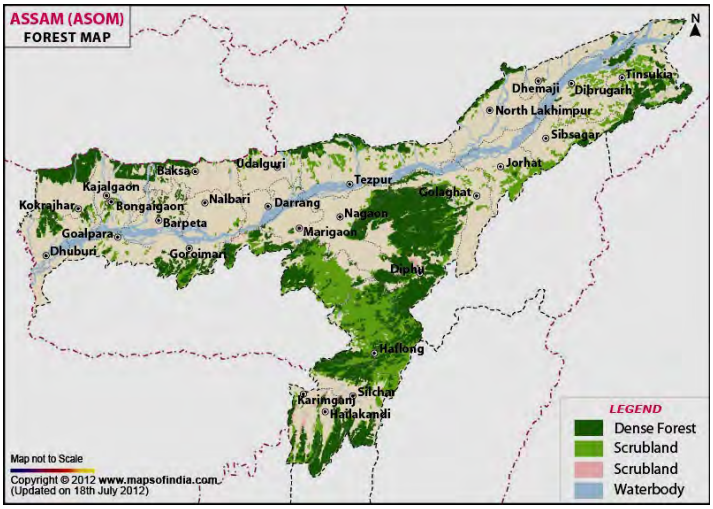

Fig 1.1- forest map of Assam [source: www.mapsofindis.com]

Every year the Brahmaputra and the Barak River and their tributaries cause flood in its nearby plains to about 39.58 % of the total land area of Assam (Data from water

resources, govt. of Assam).Also Assam is situated in the zone-V of earthquake prone area. This region has history of experiencing two major earthquakes in recent centuries accordingly, 1897 Great Assam Earthquake of magnitude 8.7 and the 1950 Assam Earthquake which of magnitude 8.4 [3].

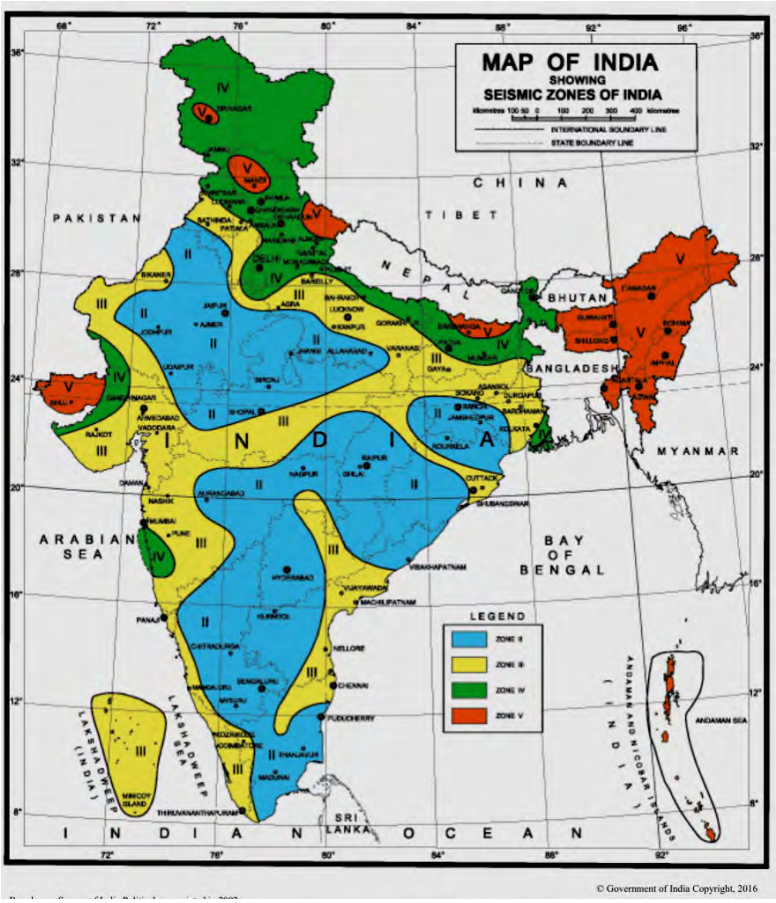

Fig 1.2- Seismic map of India [source: IS 1893 (Part 1): 2016]

To deal with the rainy and humid environment and taking due consideration to seismic vulnerability, the indigenous people of Assam had started developing disaster resilient structures. Some common traditional houses found in this region are Chang ghar, Assam type house, Bamboo house etc. A type of stilt house raised either on bamboo or timber stilts, locally known as chang ghar. Chang ghar is commonly seen among the Mishing, Deori and other communities who live in riverine areas. The houses on raised stilts are the age old structures originated in the Himalayan range. It was mainly seen amongst the Mongoloid tribes. Houses on stilts are predominantly found in India, China, Tibet, Thailand, Cambodia and in pockets of Bangladesh [4]. On the other hand Assam type houses became popular during British era, they promoted these houses being inspired by common indigenous people of that time and named those as Assam type house[5] which

were proved to be both weather friendly and pocket friendly, in addition earthquake resilient to a great extent.
This paper mainly focuses on study of the traditional houses of Mishing and Deori communities (Chang Ghar). For this, a case study has been carried out. Three models of such houses inspired from case studies have been modelled in software.

Fig 1.3- Traditional stilt house (Location- District: Jorhat, Assam)

2 Case Studies

2.1 Area of Study

Some villages were visited in the month of February 2021 to study the indigenous housing system and their recent development within Mishing and Deori tribal people, situated in west block (tehsil) of Jorhat district, 17 kilometres away from the Jorhat town located very near to the river Brahmaputra and is highly flood prone area. According to the villagers the last major flood they had experienced in 1998 of flood height 1.70 meters from ground level.

2.2 *General Descriptions*

The chang ghars are made in such a way that the spaces under the chang (floor) can be used for various other purposes, such as cattle farming, handloom weaving, vehicle parking etc. The chang or bamboo floors of these houses are made of three layers of bamboo. From the lower side, first layer is made of whole bamboo laid in transverse direction of the house. Second layer is made by spliting the bamboo into two parts and laid in longitudinal direction. Third layer which is the top layer locally called Gadhari bera or tarja, is made by splitting green bamboo culms, removing the diaphragms, then opening and flattening them.

Fig 2.2.1- Traditional chang or bamboo floors

The walls of these houses are made of bamboo mats. Mats are made by weaving thin strips of bamboo. It has been observed that RCC chang ghar with all RCC beam column and brick wall component are becoming common day by day. Each house under the study is listed with abbreviation as presented in the following table 1. The photographs of these five models under study are presented in figure 2.2.1 to fig 2.2.5.

Table 1-list of houses

Abbreviations	Descriptions			
	Sl No	Stilts	Chang (floor slab)	Roof cover
H1CBG	House 1	Concrete	bamboo chang	Galvanized sheet roof cover.
H2CBG	House 2	Concrete	bamboo chang	Galvanized sheet roof cover.
H3CBG	House 3	Concrete	bamboo chang	Galvanized sheet roof cover.
H4BBG	House 4	Bamboo	bamboo chang	Galvanized sheet roof cover.
H5CRG	House 5	Concrete	RCC slab	Galvanized sheet roof cover

Three chang ghar which have been studied were considered for further study modelled in the modelling software SAP 2000.

Fig 2.2.1- View of House 1, H1CBG

Fig 2.2.1- View of House 2, H2CBG

Fig 2.2.3- View of House 3, H3CB

Fig 2.2.4- View of House 4, H4BBG

Fig 2.2.5- View of House 5, H5CRG

3 Description of the Models

Three simple model of chang ghar was modelled in SAP 2000. Both the houses have double sloping roof on either side. Stilts are extended as columns in both the house. Joints are considered as fixed joints restraints in all translations and rotational degrees of freedom. Details for the models are given in tabular form below-

Table 2-Details of Models

SL no.	Dimensions	No of stilts	Spacing in X direction	Spacing in Y direction	Height of chang/floor from the GL	Chang/floor made of	similar to
Model 1	20 X 12 feet	15	6 feet	5 feet	3 feet	Bamboo mat	H4BBG
Model 2	20 X 12 feet	15	6 feet	5 feet	3 feet	Bamboo mat	H3CBG
Model 3	20 X 12 feet	15	6 feet	5 feet	3 feet	RCC slab	H5CRG

3.1 Material & Section Properties for Model 1

For modelling the bamboo stilt house, bamboo is used as the primary construction material. There are more than 1000 species of bamboo in total, broken into two groups: herbaceous and woody. Woody bamboo diameters vary from 10mm to 200mm, wall thickness is <10% of the external diameter and can be used for construction purpose [6]. Sixteen species of bamboos are recommended for structural usage in round form and their physical and mechanical properties are given in both for air-dry conditions and green conditions[7]. In Assam it is seen that *Bambusa balcooa* (Bhaluka bamboo) and *Bambusa tulda* (Jati bamboo) are majorly used in construction.

For modelling, *Bambusa tulda* species was selected, which is widely distributed throughout all the parts of North East India and used for building [8]. According to Table 1, Part 6 NBC 2016, it has a density of 722 kg/m^3 in air dry conditions. Modulus of elasticity (E) is considered as 10.07 X10^3 N/mm^2. Poisson ratio was taken as 0.3 [8]. Section designer was used to design bamboo sections. The Bamboo section was designed in pipe shape of which outer diameter was 10 cm and wall thickness was 2 cm. The support conditions were assumed to be fixed. The floor of the house is made of bamboo of which load is considered as 1 kN/m^2. Also assumed Live load as 2 kN/m^2

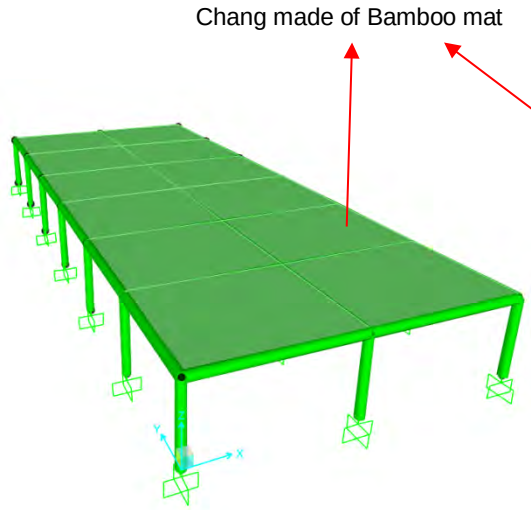

Fig 3.1.1- Model 1 upto chang (plinth)

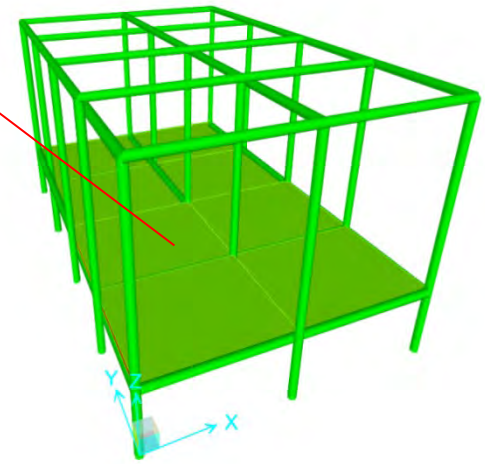

Fig 3.1.2- Model 1 upto beam

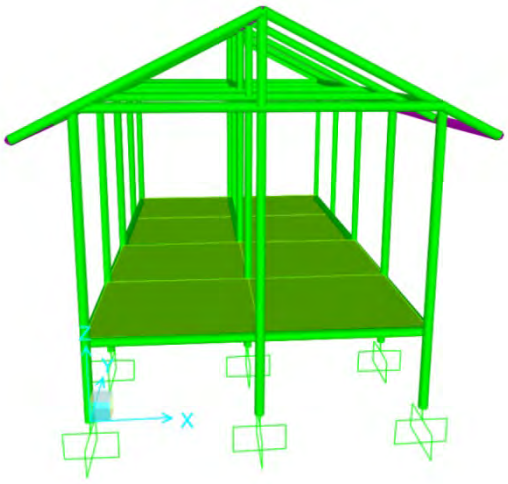

Fig 3.1.3- complete Model 1(Extrude view)

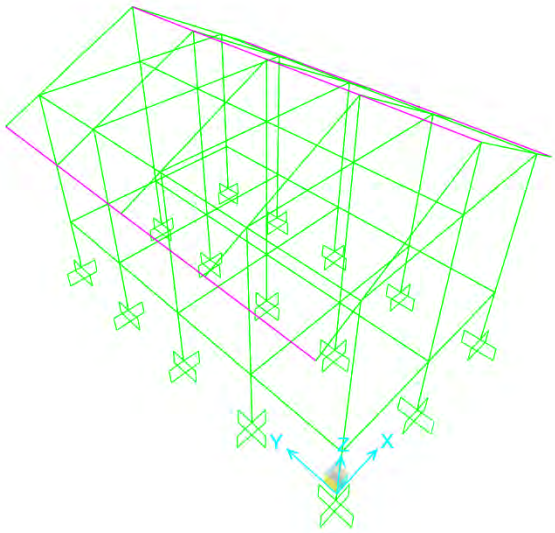

Fig 3.1.4- complete Model 1 (Standard view)

3.2 Material & Section Properties for model 2

In this model it has been considered that the stilts, columns, plinth beams and the roof truss are completely made of RCC. Chang (floor slab) was considered same as previous bamboo model (Model 1). Beam was considered as 0.250 X 0.200 meter and column was considered as 0.300 X 0.300 meter in size. The floor of the house was made of bamboo of which load was considered as 1 kN/m^2 and thickness of chang or floor is 10 cm. Live load was assumed as 2 kN/m^2. M25 grade of concrete and HYSD 415 grade of steel was assumed.

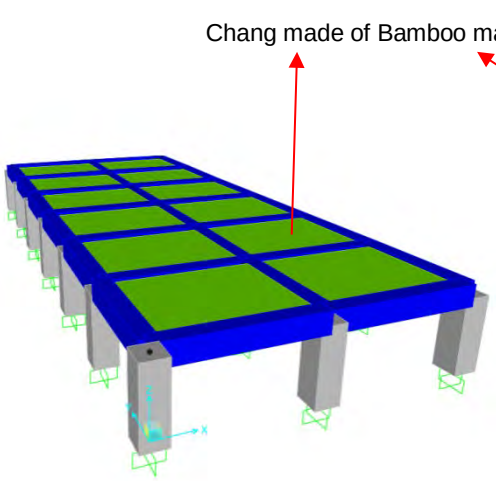

Fig 3.2.1- Model 2 upto chang (plinth level)

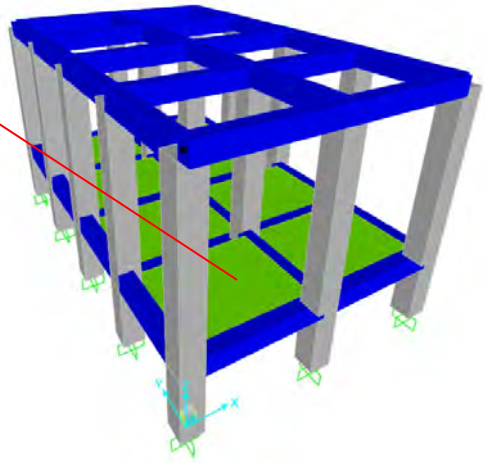

Fig 3.2.2- Model 2 upto beam

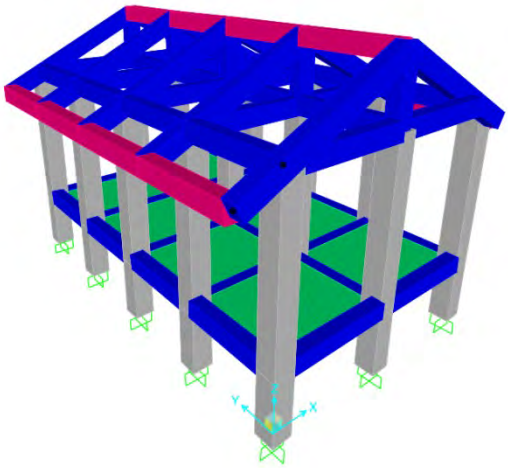

Fig 3.2.3- complete Model 2 (Extrude view)

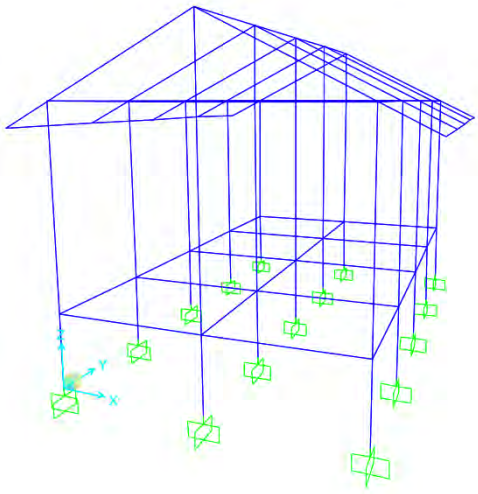

Fig 3.2.4- Complete Model 2 (Standard view)

3.3 Material & Section Properties for model 3

The same procedure of modelling as Model 2 has been adopted for Model 3 also with a difference that the bamboo chang has been replaced by an RCC slab of M25 grade. This makes it similar to H5CRG of the field. Other material and section properties of model 3 were kept same as that of model 2.

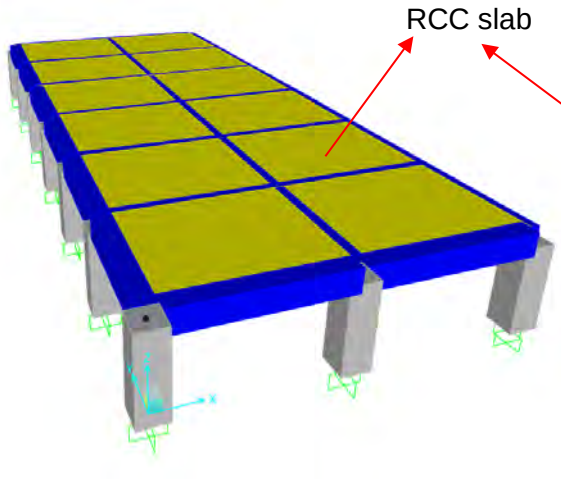

Fig 3.3.1- Model 3 upto chang (plinth level)

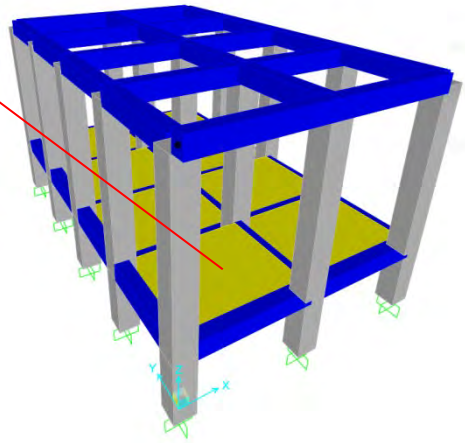

Fig 3.3.2- Model 3 upto beam

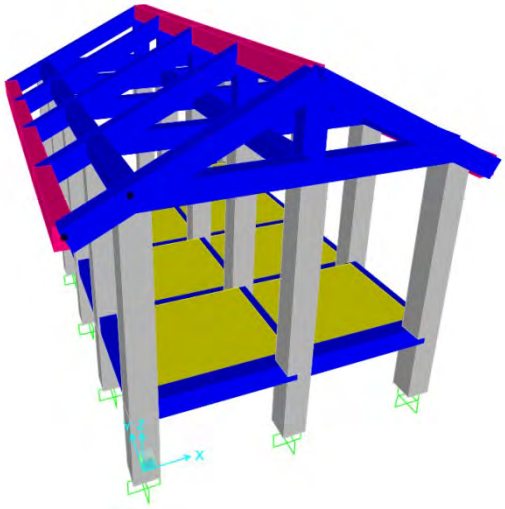

Fig 3.3.3- complete Model 3 (Extrude view)

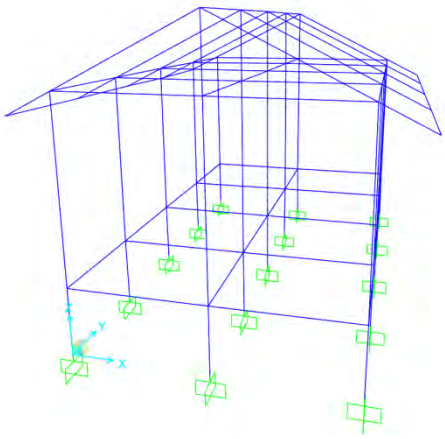

Fig 3.3.4- Complete Model 3 (Standard view)

4 Comparison of Results

A comparison of self weight, base reaction and maximum joint displacement of three models under earthquake load was done and the relative results are presented in table below-

Table 1- comparison of different results

Model	Self Weight (kN)	Maximum Base Shear (kN)
Model 1	6.179	4.078
Model 2	267.171	25.667
Model 3	406.484	36.199

Table 2- comparison of maximum joint displacement in meter

	Upto plinth level		Upto beam level		For complete model	
Model	U1	U2	U1	U2	U1	U2
Model 1	0.656112	0.262467	1.884174	1.54404	2.016037	2.762149
Model 2	0.475509	0.508739	0.400249	0.33314	1.190428	0.990969
Model 3	0.314557	0.339997	0.400386	0.24023	0.815704	0.989812

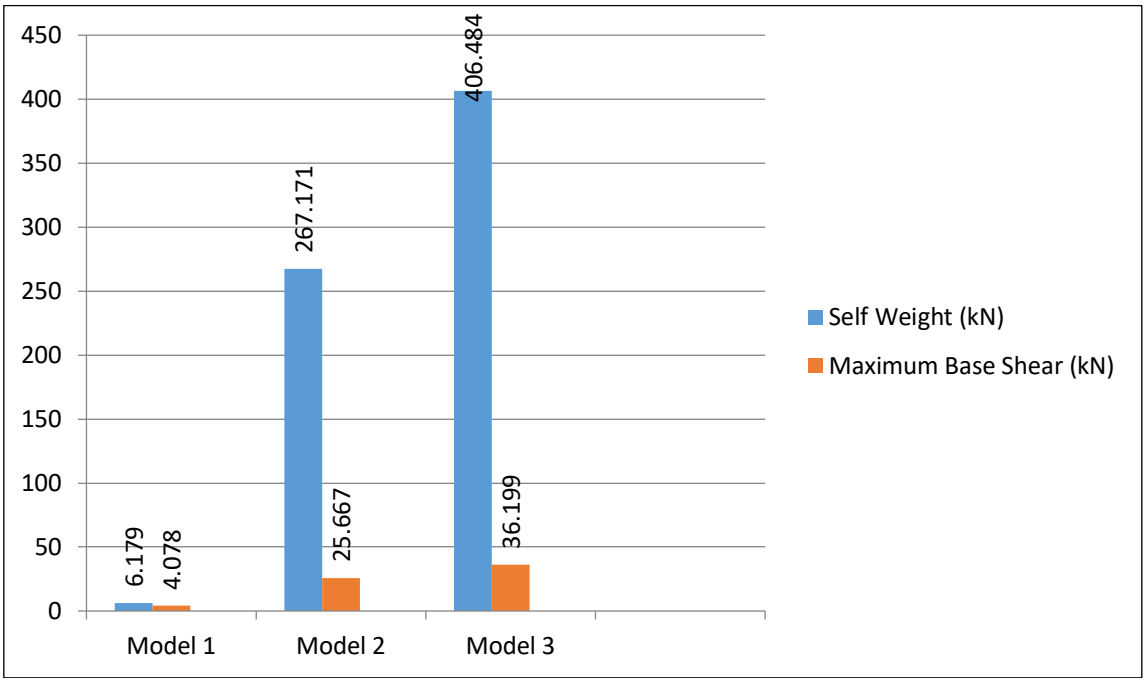

Fig 4.1- bar chart comparison of Self Weight & Maximum Base Shear

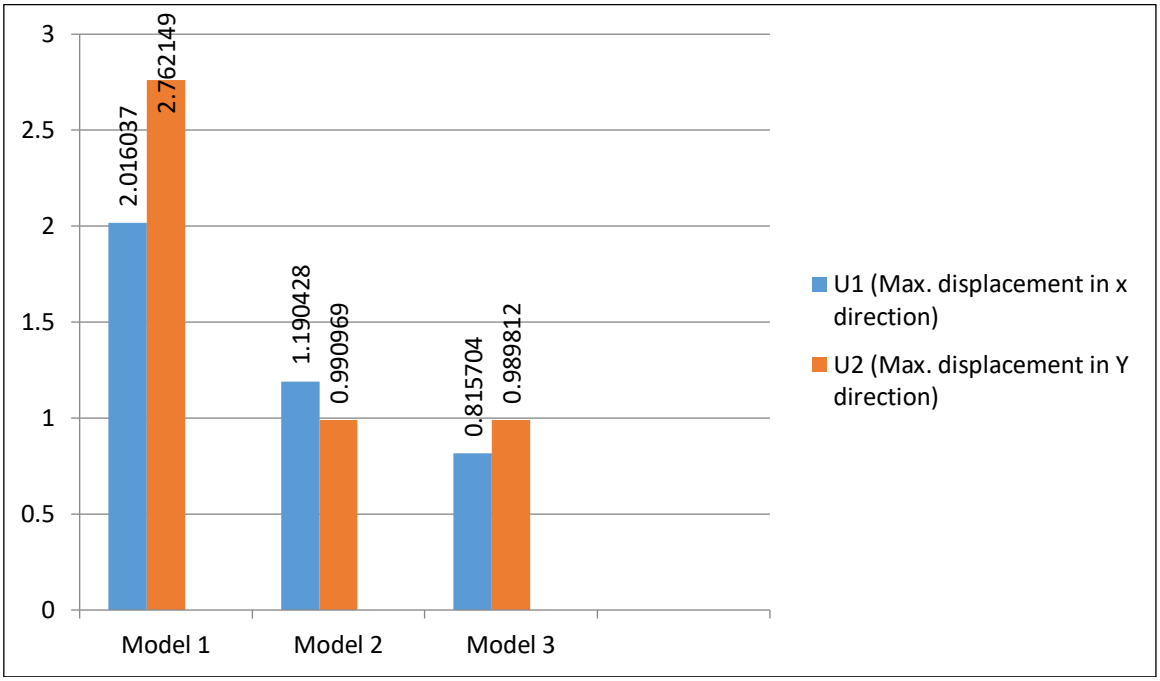

Fig 4.2- comparison of maximum joint displacement in meter for complete model

5 Discussions

The findings of this study are going to provide an insight about the response of stilt houses commonly available in the field. Self weight, maximum base shear & maximum joint displacement of these models in SAP 2000 software were obtained which can be used when necessary. An RCC framed chang ghars or stilt house (Model 2 & Model 3) specially in earthquake prone area is not suggested due to its large value of maximum base shear. The RCC framed chang ghars will also have the soft storey effect where no infill wall is present. Due to some favourable indigenous properties of concrete such as durability, mouldability, workmanship etc RCC structure are becoming popular; yet the people should be concerned that traditional chang ghar is far better option due to its maximum compatibility towards disaster like earthquakes (Details explained in clause 4).

By eliminating the drawbacks of bamboo by treatment of bamboos and following standard joint techniques over traditional joints bamboo chang ghar can be used very effectively. Standard joints of bamboo are suggested in National Building code of India, 2016 in Part 6, clause 7.2 (example- lapped joint, spliced joints, bearing joints, nut bolt joints etc.) The excessive deflection in these structures can be eliminated by providing some efficient bracing systems to a great extent which was already studied by Lala et al (2017)[8].

Since these houses are mainly constructed in riverine areas, they experiences flood in every year. There is an option of “wave load” in load pattern section in SAP2000. These basic models can be also used analysis against flood load. Another important implication of this study is the information like weight, base shear, deflection can be useful for disaster management point of view.

As compared to Model 1(chang ghar made of complete bamboo), Model 2 a chang ghar with RCC beams and columns, bamboo walls and floors (hybrid mode, similar to H3CBG) is a good option over Model 3 (RCC chang ghar). Model 2 eliminates the problems of decaying of bamboos which remains in direct contact with soil surface and flood water and thus increase its durability. Also Model 2 has less self weight as compared to complete RCC chang ghar which reduces the base shear making it more effective in earthquakes. Risk associated with RCC beam Column joint at roof level will also be eliminated if roof truss is constructed with bamboo or timbers. Another advantage of this type of chang ghar is that they have more stiffness as compared to a chang ghar made of complete bamboos which ultimately reduces the joint deflections.

6 Conclusions

From the comparison of results, following observations are listed below-

a) Self weight of bamboo chang ghar model(Model 1) is very less as compared to RCC framed chang ghar model (Model 2) & RCC chang ghar (Model 3).

b) Base reaction for bamboo chang ghar model (Model 1) was also very less compared to concrete framed chang ghar model (Model 2) and RCC chang ghar (Model 3). Bamboo is very light in weight in nature as compared to concrete which makes the structure lightweight and ultimately reducing the base reaction for the bamboo chang ghar model (Model 2).

c) For maximum joint displacement, bamboo chang ghar model shows more displacement as compared to concrete chang ghar model. This is because bamboo is very flexible as compared to concrete. Bamboo section has negligible stiffness value as compared to concrete section. In stilt house (Chang ghar) bottom storey is similar to a soft storey where no infill wall is present. This is considerable for model 2 & Model 3.

Chang ghar made of bamboos, which is an age old traditional practice, despite having some drawbacks like durability issues due to moisture contact, fungal and insect attacks, weak joint techniques, found to be advantageous over RCC framed chang ghar(hybrid mode) & complete RCC chang ghar(having RCC slab) in this study. More emphasis should be given to develop a smart and sustainable form of this traditional model in the villages of Assam and other states of north east India for best performance which optimizes the strength, resources and minimizes the risk in earthquake prone riverine areas.

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COMMUNITY CENTRIC ASSESSMENT ON SUSTAINABILITY OF AFFORDABLE HOUSING PROJECTS IN SRI LANKA

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Abstract: *Sri Lanka as a developing country has been experiencing a considerable housing shortage out of the population during last few decades. Although the country has adopted numerous approaches in establishing sustainable affordable housings, they are found being only short-term solutions. Therefore, the need of sustainable affordable housings has not effectively fulfilled yet specially within the urban high-density areas. The present study examines end-user's perspectives of sustainability in the government funded high-rise affordable houses in urban high-density areas. The study has adopted a qualitative research methodology while referring the sample to high-rise affordable housing projects of low and middle- income households at urban high-density areas in Sri Lanka. The primary data collection was subjected to the evaluation of case studies at Ratmalana, Kottawa, Pannipitiya, Wellawatta and Maradana in Colombo and interviewing low and middle-income households, experts of authorities, construction professionals and other related personals. The scope of the secondary data was ranged over the publications of authorities, books, journals, regulatory publications, newspapers and related other sources. The means of 'sustainability' is measured in terms of environmental and social parameters while analysis of the data is achieved by a content analysis. The findings of the research have revealed a gap in between adoption of sustainable principles during pre-construction phase and achieving the proposed sustainable performance by the end users. Hence, the study stresses the necessity of addressing changes in environment, population, economy, social formations and desires of end-users during the pre-construction phase.*

Keywords: *Affordable Housing, Sustainability, Post Construction, Sri Lanka.*

1 Introduction

Housing is an essential, basic human need as it displays the standards, ambitions, desires and socio-cultural attributes of households as a whole (Hamdi, 1990). Thus, developing countries are generally challenged on the future of its settlements, against the backdrop of addressing issues of inadequate housing, rapid urbanization and lack of infrastructures (du Plessis, 2002:1). Inadequate housing has been a major issue in third world countries and subsequently, Sri Lanka faces numerous socio-cultural and economic issues in unplanned urbanization, poverty and rapid growth of urban population (Samaratunga, T., 2013). This concept was further stressed by Nair (2005) who mentions that developing countries suffer the most among other nations to acquire proper housing conditions. Although this problem is associated with numerous causes, the Central Bank report in 2006 revealed that the housing shortage is mostly influenced by slums, shanties and informal settlements, which encroach on crown lands in the city. The application of sustainable construction models for affordable housing strains identification of major means. The interpretation by Nallathiga, R (2010) best defines 'affordable housing' as the houses that are accessible at a cost that can be achieved by a modest household with an average annual income; statistically, to median price that can be afforded by median household; and symbolically, to right housing options to right income groups. Similarly, the term 'sustainability' is defined as the use of natural resources in such an equilibrium condition that they do not reach decay, depletion, non-renewable point and handing down the next generations by developing them (Yılmaz and Bakış, 2015), while 'affordable housing' refers to any type of housing (market or non-market provided) that is rented or purchased at a cost that is not beyond the financial capacity of a household (Wiesel, I., et al., 2012). In relation to the major means of considerations, this research becomes significant in integrating sustainability and affordability during post construction phase of government funded high-rise affordable houses in Sri Lanka. While sustainability is traditionally measured through Economic, Environmental and Social performance of projects, often how these parameters perform from users' experiences in the post project phases is not quite clear. In this research, an attempt has been made to gather the evidence from the end users of a few selected communities who reside in government funded affordable housing premises to understand how the sustainability is experienced or sustainable considerations are providing the end-results at the post construction phases of projects.

2 Background of The Study

The development of affordable housing models has been a longstanding discourse among researchers all over the world. 'Housing affordability has become a frequent terminology on the nature of the housing struggle in many nations' (Hulchanski, 1995). While numerous studies have stressed the impact of not owning liveable housing by some of the population, Musterd, 2010 emphasized that lack of sufficient habitable housing has become a global problem. This is further stressed by Samaratunga (2013) who emphasizes on the similar circumstances of having inadequate housing, in the Sri Lankan context. Although the country has adopted various strategies to enhance affordable housing, Niriella (2010) stressed the matter of not having long term significant solutions to any of these attempts except temporary fixes. Consequently, the report published by the Censes and Population Department of Sri Lanka (2007) revealed a considerable housing shortage among population. Hence, the existing housing shortage exposes unsolved issues of affordable housing in Sri Lanka. The report published by Bruntland (1987) defined 'sustainability' as

'meeting the needs of the present without compromising the ability of future generations to meet their own needs' in order to achieve providing necessities to the people while protecting the ability for the future generations to meet similar needs. While this concept has been adopted by numerous nations to provide housing for communities, 'The National Housing Policy' (2014) indicated its ultimate goal as 'to ensure the right to live in an adequate, stable, qualitative, affordable, sustainable, environment friendly and secure house with services for creating a high living standard on the timely needs of the people'. Thus, Fernando (2002) emphasized that most urban under-served settlers have suffered severe deterioration due to the poor maintenance and management of the building structures and their infrastructure. The same author has further discovered the causes for being unable to manage their houses as poor awareness, social status, level of education, lack of willingness, incorrect attitudes and bad habits of the communities. The defined findings as well as similar studies have revealed solid waste management, drinking water supply system, lighting systems, community centers and parking lots as the areas that required much needful attention in Sri Lanka. Hence, the government as well as private stakeholders have considered high-rises as the most sustainable solutions for urban high-density areas. Consequently, sustainable housing has been designed mainly based on social, economic and environmental aspects.

In examining if sustainable principles impact affordability in the Sri Lankan context, several projects undertaken by the government reveal that general sustainable criteria are insufficient in improving the degree of affordability. The 68 story Altair building in Colombo city and the 'Sahaspura' high-rise low-income housing project that comprised 671 housing units over 14 floors are some of the greater projects where the sustainable principles have been applied in housing projects. Thus, these projects have caused several controversies in the country in achieving the goals of the 'affordable housing' category, under the adopted sustainability measures. Hence, it is significant to adhere to the three conditions of social acceptability, economic viability and being environmentally friendly, while serving the purpose of affordable housing. Therefore, the present study has focused on verifying if adoption of sustainable principles in housing is affordable to the target groups of communities. The measures of sustainability may comprise evaluation of culture, heritage and other values of the households.

In assessing the scholarly views on 'affordable housing' in Sri Lanka, though Udawattha and Halwatura (2017) defined it as the ability to purchase a particular item; the practical implementations exhibit a vast range of complications in achieving this interpretation. The study conducted by Niriella in 2010 stated a tendency of Sri Lankan affordable housing projects to be beneficial for wealthy households except the aimed population. Similar misapplications have been found during the last few decades in leading the country's affordable housing projects being affected by political influences and poverty rather than considering community development. The overall combination of factors such as existing housing shortage, unsolved issues of affordable housing, insufficient interpretations on affordable housing and poverty further stresses the need of defining 'affordability' in the Sri Lankan setting, in contrary to the traditional framework to enable providing solutions for the defined associated complications. Therefore, the present study engages in identifying interpretations and defining a baseline for housing affordability in Sri Lanka. Accordingly, this study aims at evaluating the gaps of adopting affordable housing in urban high-density areas while achieving sustainable necessities to proceed with model

development, as it benefits in resulting defining policy frameworks in the Sri Lankan context.

3 Problem Statement and Objectives of The Research

Sri Lanka, in being an under developing nation faces inadequate housing problems in relation to the growth of population. Although numerous approaches were undertaken to overcome housing problems in urban high-density areas by the government and private sector of the country, the overall factors tend not sustaining the future needs due to lack of holistic planning. The present study examines way forward by reviewing and evaluating the possible sustainable solutions while interpreting affordability and sustainability on affordable housing in Sri Lanka.

The key objectives of the research include the following:

I. To demonstrate the degree of living standards of affordable housings in urban high- density areas in Sri Lanka.
II. To examine application of sustainable principles for affordable housings in urban high- density areas in Sri Lanka.
III. To define Sri Lankan affordable housings in urban high-density areas in terms of sustainable solutions.

4 Research Methodology and Data Collection

The research methodology contains the research design that was adopted to realize the targets, objectives and questions of the study. “Research in modest expressions denotes pursuit for knowledge and a scientific and systematic exploration for evidence on a specific theme or subject, research methodology is a systematic approach that a research adopts to accomplish the research aims” (Creswell, 2009). The present study has adopted a qualitative approach to evaluate the aim and objectives of the research. The population of this study refers the affordable housing projects in Sri Lanka while the sample the is limited to high-rise affordable housing projects of low and middle-income households at urban high-density areas in Sri Lanka. The research has gathered primary data by evaluating 80 number of respondents at Ratmalana, Kottawa, Pannipitiya, Wellawatta, Maradana, in Colombo while interviewing middle-income households, experts of authorities, construction professionals and other related personals. These interviewees were sampled based on purposive sampling method. The purposive sampling technique which is known as judgment sampling, is the deliberate choice of a participant due to the qualities the participant possesses (Etikan,I., Musa, S.A and Alkassim,R.S.,2016). The secondary data was obtained via publications of authorities, books, journals, regulatory publications, newspapers and related other sources. The analysis of the data is designed to achieved by a content analysis with the use of attained results while focusing on cultural, heritage values and preservations that limit the housing sector in better planning for the community.

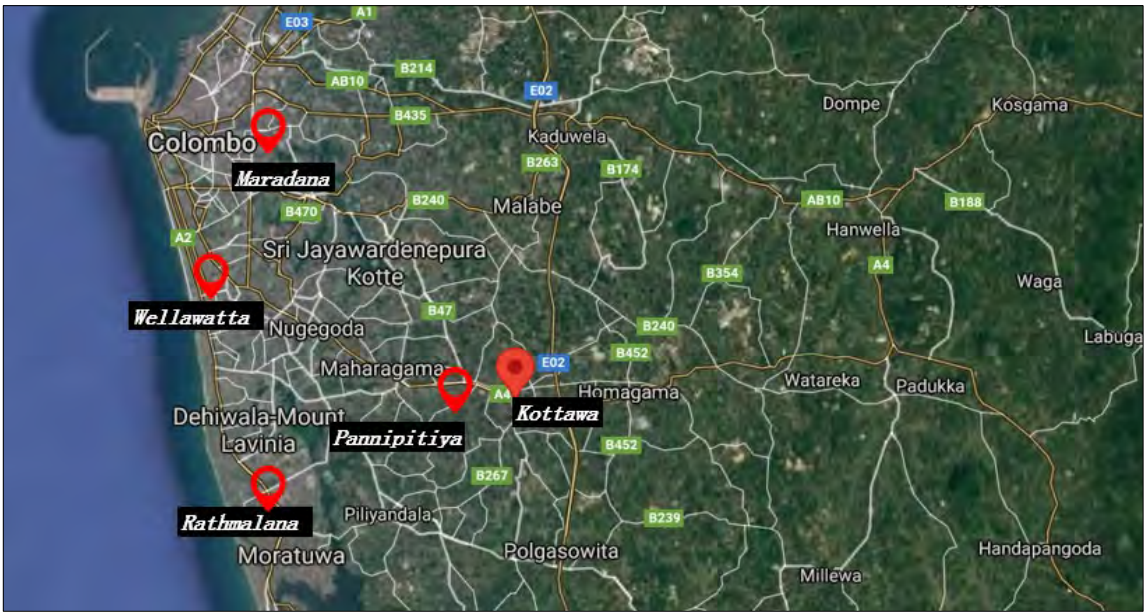

Figure 01: Location of the case study
Source: Google Map (Accessed on 29/07/2021)

The present study has evaluated the degree of sustainability of government funded high-rise affordable houses in Colombo by the means of environmental and social perspectives. According to the discoveries of Doloi, H (2018), addressing perspectives of communities is the core in infrastructure planning as social values denote the success or failure of such projects. In relation to the present study, the parameters of examining these aspects were concerned based on the environmental and social sustainability measures of GreenSL rating system issued by the Green Building Council, Sri Lanka. Consequently, the respondents were evaluated based on the following criteria.

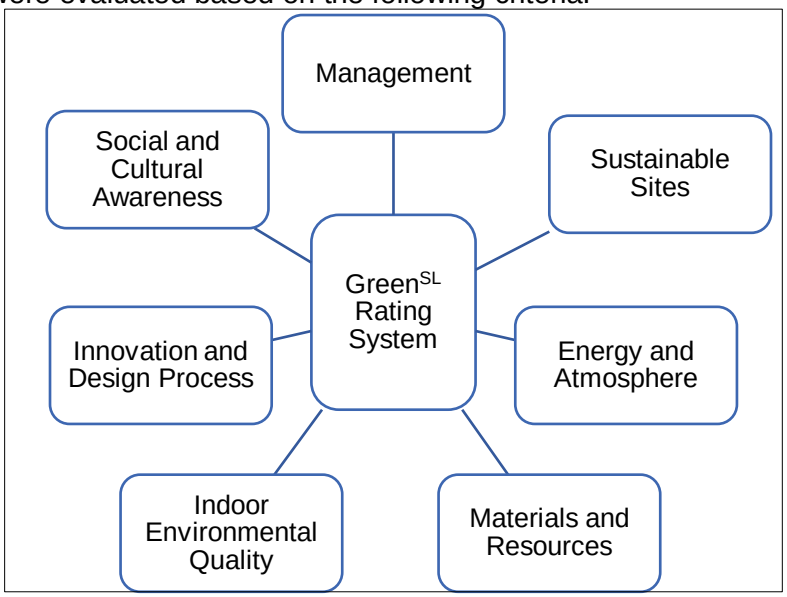

Figure 02 GreenSL Rating System,
Source: Green Building Council, Sri Lanka.

5 STUDY FINDINGS

I. Environmental Sustainability of Affordable Housings in Urban High-Density Areas in Sri Lanka

Sri Lanka is divided into 9 provinces and each province is subdivided into several districts based on the geographical formation. Colombo in being one of districts in the Western province, ranges over 699 square kilometers. The department of census and statics (2020), Sri Lanka has estimated 77.6% of urban population in Colombo city. It has become Sri Lanka's most economic city since many years back. The analysis of both primary and secondary data has revealed the degree of application of sustainable principles in affordable high-rise housings in urban high-density areas in Sri Lanka. In assessing the impact of environment on living standards of building occupants, greater issues were found in increment of heat, obtaining fresh air, noise pollution, sanitary facilitations and green spaces.

Green Spaces and Green Materials

In examining the degree of heat experienced by the defined building users, 69.84% of them have experienced a greater heat during the day time and night time as well. The geographical formation of these residuals is evident that these residents are impacting by high-density population, global warming, lack of green spaces and design errors in major. One of response received by an interviewee emphasized that 2 × 2 ft2 sized windows and lack of green spaces caused indoor heat gain during both day and night time. Colombo is the main commercial metropolitan city in Sri Lanka, with having the highest population and building density, making the city an ideal place to form Urban Heat Islands. (Dissanayake, at al 2020). The study findings of Census of Population and Housing (2012) have revealed that the highest number of household units have been recorded from the Western Province while Colombo containing residential population of 558755, making it the densest city in Sri Lanka. Apart from common impacts such as global warming and Sri Lanka being located near by the equator, these housings are having insufficient green spaces. Although most of these occupants were privileged by a common garden or an adjoining park in Colombo, the existing amounts of trees and plants are inadequate to overcome heat gain especially in high-rise buildings. In addition, the housing projects which were located close by Sri Lankan coastal line are experiencing a less heat as they get sufficient wind. Thus, the degree of existing green spaces is similar to the other building units. Additionally, the houses have initiated construction materials such as asbestos sheet for roofing, and excessive concrete structures while not adequately adopting sustainable building materials or energy efficiency sources.

Living Spaces

The proportion of population living in households is a factor of sustainability (Klopp, J.M. and Petretta, D.L., 2017). The present study has assessed end-user's perspectives on 'Design Factor' to demonstrate the degree of application of sustainable measures in government funded affordable high-rise projects, Colombo. Consequently, average dimensions and design principles of some of the case studies were identified as follows.

Average Values (Approximate)	Housing Projects in *Ratmalana,*	Housing Projects in *Kottawa*	Housing Projects in *Pannipitiya*	Housing Projects in *Wellawatta*	Housing Projects in *Maradana*
Number of bed rooms	02	02	02	02	02
Dimensions of room	130 ft^2	440 ft^2	693 ft^2	551 ft^2	622 ft^2
Dimension of kitchen	24 ft^2	36 ft^2	96 ft^2	36 ft^2	36 ft^2
Dimension of washroom	6ft^2	6 ft^2	8 ft^2	9.5 ft^2	8.5 ft^2
Number of members in a family	5	6	5	6	6
Dimensions of Living room and verandah	Majority had no living room or a verandah.	Majority had no living room or a verandah.	Living room: 924.9 ft^2 Majority had no personal verandah.	Living room: 355 ft^2 Majority had no personal verandah.	Living room: 412ft^2 Majority had no personal verandah.

Table 01: Average values of living space dimensions

In global context, floor area per person is highly variable among countries, hence the median reported floor area per person is 14,4 sqm, with a global range from 2 to 69 sqm (Kozhenova, S., 2010). Thus, evaluation of the defined housing projects revealed that existing spaces are inadequate in relation to population growth. Limited living spaces also challenge achieving Green^{SL} criteria of indoor environmental quality.

Air Quality

The present study has exposed building users experiencing inadequate fresh air due to common factors such as excessive power generation, higher use of fossil fuels, emissions of motor vehicles, etc. In accordance with the According to the World Health Organization's guidelines (2020), the recommended maximum level of the annual mean concentration of PM2.5 is 10 µg/m3 and however, Sri Lanka has exceeded this as the most recent data reveals that the country's annual mean concentration of PM2.5 is 11 µg/m3. Additionally, the research has noted indoor air pollution within these affordable housings in Sri Lankan urban high-density areas. Consequently, the respondents are found consuming gas stoves, firewood, burning of waste, mosquito coils and cigarettes. Altogether both outdoor and indoor air pollution highly tends negatively impacting on good health of these building users in long term by causing diseases such as asthma, allergies, cancer, depression, heart strokes, etc. The World Health Organization has estimated number of deaths caused by indoor and outdoor air poluution in Sri Lanka to be around 4200 and 1000 deaths respectively. (Nandasena, S., Wickremasinghe, A.R. and Sathiakumar, N., 2012).

Noise Pollution

The World Health Organization (WHO) defines noise above 65 decibels (dB) as noise pollution. The housing projects being located in the most urbanized city in Sri Lanka has resulted its residents experience excessive noises throughout the day by traffic noise, night life, animals such as dog barks and even by the louder noises of televisions, radios of neighbors. The matter has also emphasized by Nagodawithana N.S.,et al (2016). The residents at *Rathmalana* are even impacted by air traffic noise.

Sanitation

The affordable housing projects in Sri Lankan urban high-density areas have facilitated sanitary needs either attached to the residual units or as separate units. Although the residents who are accessible to attached washrooms are satisfied with existing sanitary facilities, the ones who consume common washrooms are found unsatisfied. According to them, school children are severely impacted as it takes more time to be in a que until they get the opportunity. Similarly, young women have undergone several infections such as UTI (Urinary Tract Infection) in consuming common washrooms. Thereby, secureness of environment sustainability becomes significant for affordable houses in Sri Lanka.

In overall, the defined housing projects are found not adequately fulfilling the sustainable criteria in preserving environmental perspectives during the pre-construction phase. The fishbone diagram stated below (figure no: 03) further illustrates potential causes and relative effect respectively. Accordingly, the state of environmental sustainability of the case study is revealed inadequate due to lack of green spaces and green materials, insufficient living spaces, poor indoor air quality, noise pollution and insufficient sanitations.

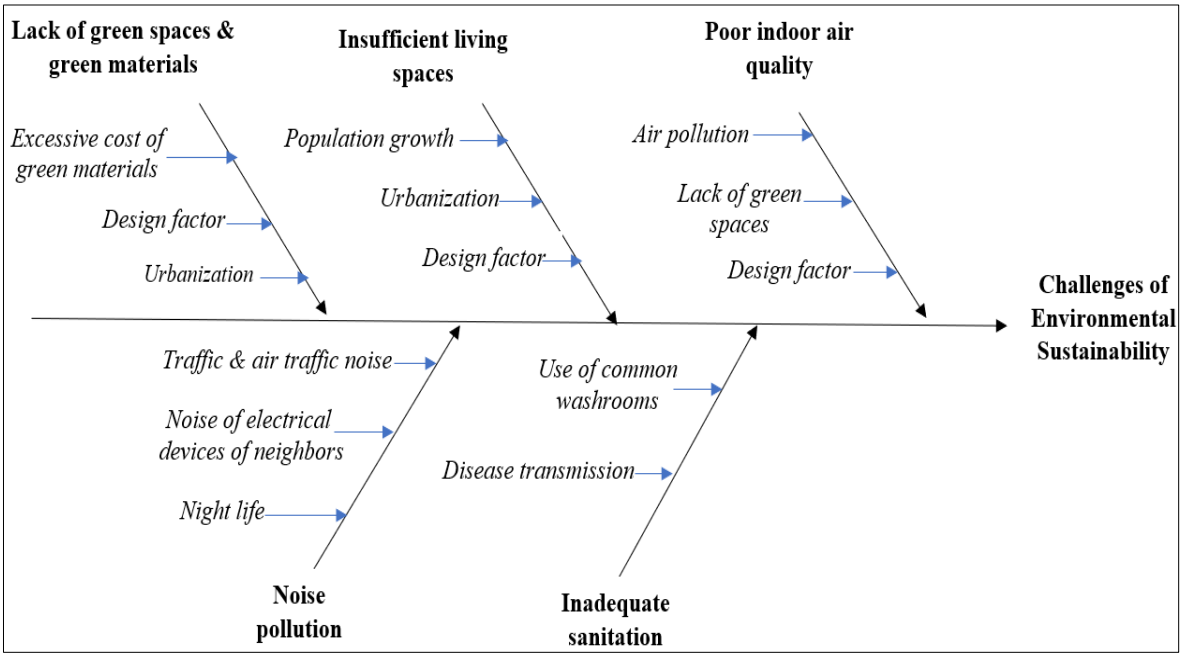

Figure 03: Fishbone diagram for challenges of environment sustainability

II. Social Sustainability of Affordable Housings in Urban High-Density Areas in Sri Lanka

The 'New' Culture and Social Formation

The social formation of majority of the residents at most of the affordable housings in Colombo urban high-density areas were belonging to a specific social class. A huge population of Sahaspura belong to the lower or working class while majority of the Millennium City and Mattegoda are middle class (Niriella, N.C.,2012). As per the research discoveries, defined communities are found comprising of various types of residents at their schemes. Thus, the study has also revealed an emergence of a change in the existing culture due to the impacts of globalization, drug addiction, poverty, prostitution, depression, isolation, inequity and lack of education.

> "*When we were at slums, we had a unique way of living. But, the new community is a 'Fruit-Salad'. We have residents form various professions and versions. New houses are environmentally better than earlier ones but socially we are unsecure. And we work hard to protect our children from negativities"*

The residents' point of view on their social formation referred to a 'fruit-salad'. Similarly, together with other respondents' reviews, the study has exposed a change in the existing social formation within these housing units. This study becomes more significant as a majority of these changes were found influenced by similar communities lived in similar other housing units in Colombo. The cultural changes are also emerged creating a 'new culture' and accelerating social formation into an extent which contains inadequate sustainable attributes such as cultural dominance, lack of community engagement, inequity, social illness, etc.

Social Wellness

In assessing social wellness, the research has identified an increment in prostitution and consumption of drugs. Since most of the parents were engaged in prostitution, their children tended addicting into drugs. These have consequently accelerated smuggling and organized crimes in order to fulfill financial needs in reaching into drugs and prostitution. Similarly, the obtained data has disclosed most of the housing communities being dominated by an existing set of residents. These groups are found influencing on common opinions, decision makings and even the culture of the communities. Following responses are evident that they have undergone a change in their social formation during the past years.

> *"There is a set of residents living here originated by 'Thara-waththa' and they domain here. Their children have the opportunity to attend reputed schools but they do a lot of party with loud noises. It's difficult to concentrate on studies by then". (*watta referes to a cluster of slums).*

Moreover, the respondents revealed difficulties in attaining a sufficient income in relation to the amount of basic expenses they bear.

Equity

Although initiation of these projects aimed at attaining new employment, education and social opportunities to the end users, practical implementation exhibits limited moments. Niriella (2012) exposed circumstances where poor community being treated minimum as the middle and the higher middle-income groups were benefited by various housing policies and housing programs. In relation to the discoveries of 'changes of social formation' by the present study, the existing low and low-middle income communities are found being influenced by such privileged middle and the higher middle-income sets in all above stated ways. A majority of the respondents aged between 11-29 years old exposed that they experience minimum opportunities at schools and interviewing for white-collar jobs as they have been labeled as inferiors. Although the ones who were originated from slums and socialized at new locations while undergoing several socio-cultural and economic transitions during past years, they still used to be treated based on their origin by the society. In addition, media is found highly impacting on their social formation. One of respondents at Sahasrapura housing revealed that some of their residents are always subjected to be a part of drug dealing or murdering cases as it was emphasized by the media, although they are not guilty. Afterall, residents being isolated due to any reason limits community involvements and social sustainability as a result.

Isolation

The nature of new culture exhibits poor sustainable attributes while containing dangers. Accordingly, another portion of this community exhibit resisting these cultural changes to achieve secureness for their families. As a result, they are found being isolated purposively or sometimes even with no hesitation. While most of the families purposely separate themselves from being a part of new culture, the domaining culture isolates the rest unintentionally. For an example, parents attempt separating their children from others to protect from negativities such as drug addictions, prostitution, mental illnesses, etc. The resulted state of social affairs also challenges the community being socially sustained.
Apart of being isolated by their own community, the research has discovered an extent where they have been indirectly isolated by the society in general. Most of the youngers and mid agers exposed being unequally treated in achieving education and employment opportunities. Some have stressed the matter of iconizing them based on the fact of being orient from Watta.

In addition to the isolation caused by cultural matters, the residents are also revealed being proceeding through self-separation due to the design factors of houses as design factors have not adequately addressed the need of privacy for the end-users. Most of the responses received by interviewees emphasized that higher noises (Ex: noise of the television, talking loudly, etc) distracts their neighbors. Similarly, some of the washrooms were designed as they disclose to front direction of the house hence their residents revealed the necessity of adequate privacy. Accordingly, the present study has revealed poor living conditions due to the proposed design during the pre-construction phase.

In overall, an inadequate status of social sustainability is discovered among the low- and middle-income residents at affordable housings in Colombo urban high-density areas due to an isolation undergone either by themselves, society or design factors while facing its relative circumstances.

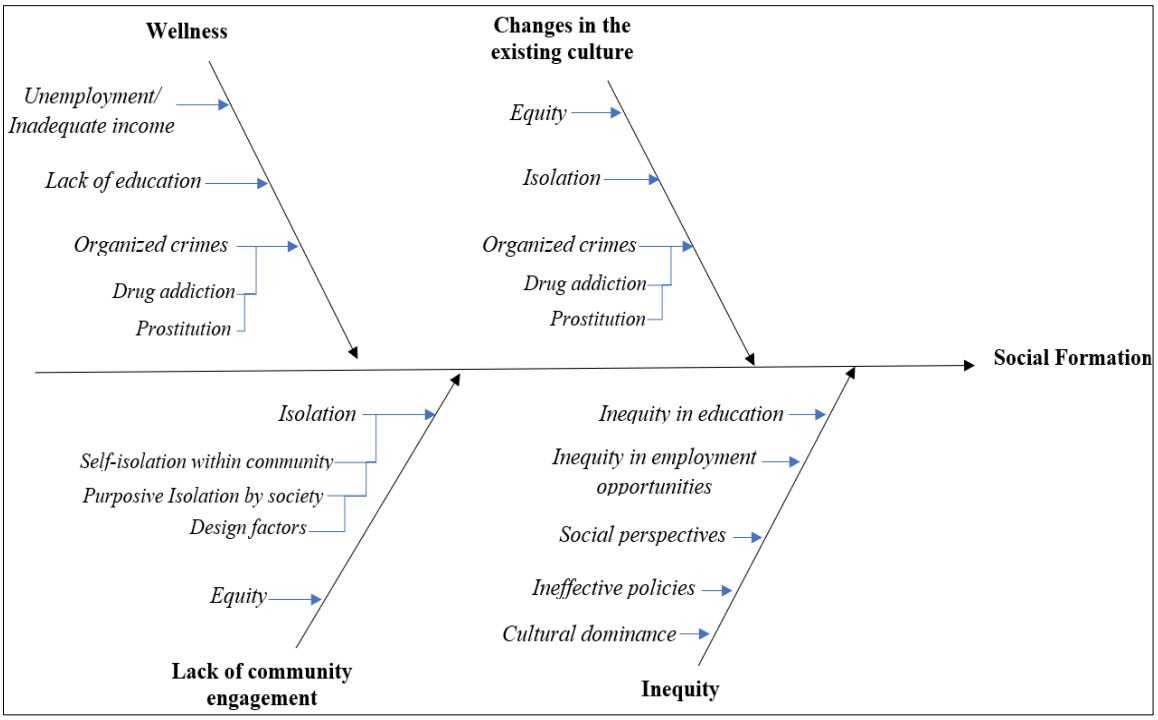

Figure 04: Fishbone diagram of social formation resulted by 'new culture'

6 Conclusion

The study has examined the status of environmental and social sustainability of high-rise affordable housings in urban high-density areas in Sri Lanka through the perspectives of end-users. Consequently, they have exposed an inadequate degree of sustaining environmental and social perspectives. In accordance with environmental sustainability, design factor is found being one of a major cause for the existing issues in indoor heat exposure, indoor air quality, sound insulation, sanitary facilitations, living spaces and green spaces. Hence, the study has revealed that achieving post-construction environmental sustainability performance is challengeable in compared to the degree of sustainable principles integration during pre-construction phase.

The assessment of social sustainability enclosed emergence of a change in the existing social formation due to major two causes. First, the community has undergone a change once they were established at government funded houses due to the impact of mixed-culture at the same housing scheme and other housing schemes as well. Although these residents had a unique way of living before transforming into the present residents, the new culture initiated getting influenced by globalization, drug addiction, poverty, prostitution and depression. Second, the defined community is discovered isolating either by their own or by society. Self-isolation has empowered as a majority of individuals intended protecting their relatives from addicting into drugs, smuggling, prostitution, depression, etc; while 'design factor' of these residents played a dominant role as well. The community has also isolated by the society for being originally from slums and iconized as people with low qualities. The present study has discovered emergence of a 'new culture' empowered by above stated causes. The attributes of new culture are revealed not adequately sustainable as it challenges equity, living conditions, health and

safety, wellness, community engagement and existing culture. Therefore, expected social sustainability is found not adequately experienced by the residents of these houses.

Overall, the study has revealed a gap between adopting sustainable principles during pre-construction phase and achieving the proposed sustainable performance by the end users. Hence, the study stresses the necessity of addressing changes in environment, population, economy, social formations and desires of end-users during the pre-construction phase. Integration of this fact in decision making and policy planning may enable the nation to reach sustainable goals effectively.

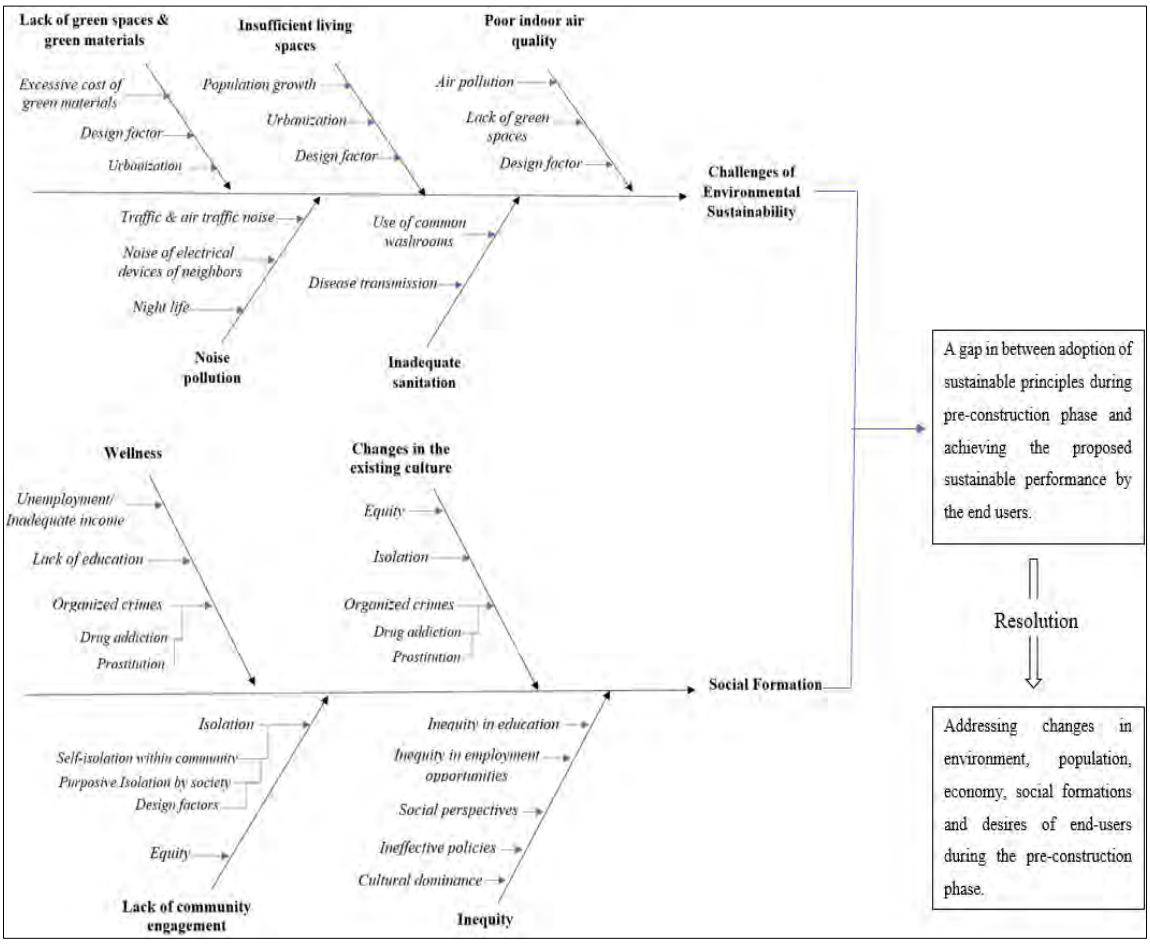

Figure 05: Research Findings and Resolution

7 Recommendations

The present study has examined reliability of achieving pre-construction sustainable needs in the perspective of end-users. The findings denoted a gap in between pre-construction aspirations of sustainable goals and degree of sustainable performance during the post-construction phase. As the gap was emerged due to the changes of environment, population, economy, social formations and desires of end-users; the study suggests addressing those changes in pre-construction phase. In there, empowering employee's knowledge and awareness on such variances is also similarly important for effective decision making.

Additionally, adoption of sustainable criteria and standards during pre-construction phases and enhancement of sustainable awareness among construction professionals is significant. In reference to the defined case study, the matter of adequate living spaces can be overcome by initiating a new infrastructure while expanding the existing house spaces by combining adjoining areas into it. In assessing the degree of social sustainability, the findings suggested addressing the defined change in existing social formation in order to mitigate the emergence of forecasted culture and its negative circumstances. Therefore, updating the investment strategies with aiming at long-term benefits, establishment of rules, policies and monitoring systems to equally treat the poor, middle- and higher-income holders, addressing socio-economic and cultural needs during the initial phases on construction, expansion of legal compliances and programs to overcome social issues of poverty, living conditions, wellbeing, health and safety, community engagement, etc., are suggested to be implemented in the future. More importantly, a specific change on social mindsets can be performed to create an equally treated society.

8 Limitations & Further Study Directions

The research has evaluated sustainable approaches of high-rise affordable housing projects for low and middle-income households in urban high-density areas in Sri Lanka. The collection of data was limited to the areas of Ratmalana, Kottawa-Pannipitiya, Wellawatta and Maradana in Colombo. Hence, it is proposed to undertake further studies into a wider range over the specified areas in Sri Lanka. Since the present study has focused on high-rise affordable houses, the scope can be expanded into individual residential units as well. Moreover, a separate study can be undertaken to evaluate the status of economic sustainability as the present research has assessed 'sustainability' in terms of social and environmental perspectives.

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RURAL INFRASTRUCTURE FOR SMART VILLAGES – SANITATION CASE STUDY

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Abstract: *Infrastructure is the backbone of the rural economy. Without reasonable and functional infrastructure systems, rural community can not thrive. In the Smart Villages model, reliable infrastructure system is highly crucial for the communities to function effectively. As the smart villages concept implies, the core principle of smartness lies with the community being self-sufficient and able to explore the potential for developing in every aspect of life without relying on others. In order for communities to be self-functioning, grassroots level infrastructure support must be provided. The term infrastructure in the context of rural community may refer a raft of basic but functional facilities such as roads, agriculture, sanitation, health and well-being, education, water, power etc. While the adequacy of all these infrastructure is important, there is no any set priority for any particular type to prevail over another. Focusing on sanitary infrastructure, this paper investigates the current state, needs and requirement of the Mishing community in Assam, India. Many Mishing villages in Assam reside in flood plains along the valley of the river Brhamaputra where need of a custom built sanitation provision is need of the hour. Based on the field study and the research conducted at the Smart Villages Lab, this research proposes a new design of a compost toilet system potentially to be useful for the communities residing in the flood prone areas, especially for the Mishing community residing in houses known as "Change Ghar" which are built on stilts. Practical implementation and efficacy in the compost toilet will have a greater positive impact among the rural communities in flood prone areas in Assam.*

Keywords: *Smart Village, infrastructure systems, sanitary infrastructure, flood-prone community*

1 Introduction

Infrastructure is one the key enablers of economic wellbeing of the community. While the term 'infrastructure' could have differing meaning across range of different settings, the meaning of the term in the context of Smart Villages is very clear. With over 40% of the world's population now living in rural areas, functional infrastructure required for rural community is quite different from what is generally considered important in urban settings. While the rural communities' needs and requirements are usually confined in local jurisdictions, under the smart villages model, local infrastructure needs to go a step further for supporting adequate connectivity between local and regional communities. Integrated development of rural community encompassing the boundaries beyond the local jurisdictions in important for harnessing the added potentials for economic and social exchanges leading to range of direct and indirect benefits such as income earning, job prospect, cultural cooperation etc. In a state like Assam located in the North-Eastern part of India, over 86% of the 35 million population still lives in very rural areas. The need for infrastructure interventions in the rural areas is even greater for supporting current trend of rapid upgradation of the rural community across the country. In the context of rural infrastructure, research undertaken in the Smart Villages Lab (SVL) at the Faculty of Architecture, Building and Planning of the University of Melbourne provided some useful insights on new modalities for supporting the communities with cost-effective planning, development and operation of localised infrastructure solutions. Focusing on the sanitary infrastructure, this research introduces as new compost toilet concept for supporting communities living in flood-prone areas. A field study undertaken in Assam focuses the opportunities and challenges for compost toilet solutions in relation to the Mishing community and their way of living mostly in the houses on stilts. The reminder of the paper discusses the needs of sanitary-based infrastructure interventions in the context of smart villages (Doloi *et al.* 2019a)

2 Why Smart Villages

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. Referring to the infrastructure requirements in the Smart Villages context, in this paper, the author aims to look at the sanitary system as one of the key enablers for promoting health and wellbeing of the rural community especially focusing in the flood prone areas in the State of Assam.

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 health, hygiene and safety, 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.

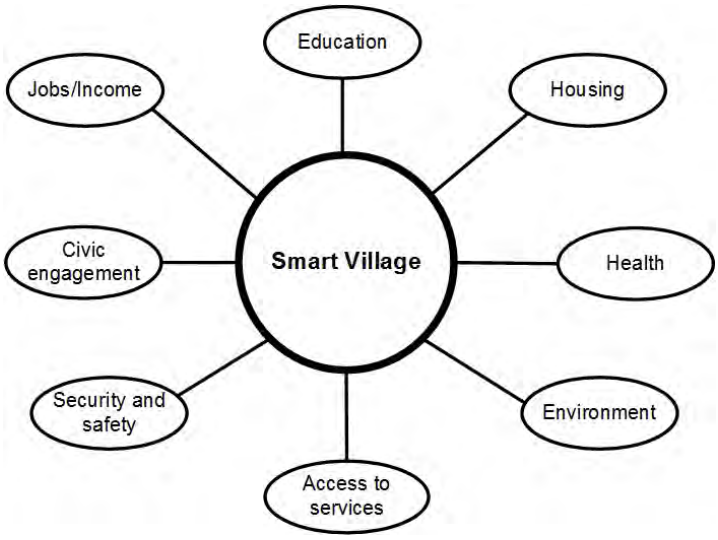
3 Broad areas of focus in Smart Villages design

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 health and hygiene is a concern, any sort of localised solutions for providing a functional system for promoting good health and hygiene 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.



(*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 (Doloi 2020).

4 Community centric sanitary infrastructure intervention – example from Assam

4.1 Background

Hygiene conditions is one of the key perquisites for wellbeing of any community. When it comes to Smart Villages in the rural settings, the combined effect of adequate provision for Water, Sanitation, Health and Wellbeing becomes pivotal for supporting development, growth and thieving the community in their modernisation journey. Referring to the sanitary and waste management provisions, as the rural areas are far from the urban centres, provisions for centralized sewerage networks and wastewater treatment plants at remote or decentralized areas is almost an impossible idea. The challenges become greater due to unconducive hydrological, climatic limitations (e.g. topography and water scarcity), and demographic habits (Nasri *et al*. 2019, Hill and Baldwin 2012). These areas generally suffer from lack of standard urban infrastructures, such as sewerage, electricity, water supply and road access. Without these basic services providing suitable sanitation systems becomes expensive, offensive and intensive but is vital to prevent environmental contamination, occupational hazards, disease transmission and to meet legal necessities (Hill and Baldwin 2012). Sanitation systems, which hygienically separate human excreta from human contact, are generally divided into two categories, including basic and improved. According to the World Health Organization (WHO, 2006), the difference between basic and improved sanitation facilities is only that improved sanitation is not used by more than one household.

Approximately 2.4 billion people worldwide have inadequate sanitation facilities and 70% of them live in rural areas (UNICEF & WHO, 2015). A situation which has detrimental

consequences for the environment and public health. The response to these challenges is ecological sanitation, which is an umbrella term for a variety of sanitation systems that include treatment, confinement and safe reuse of human excreta (Dickin 2018). The technical idea behind ecological sanitation is to keep the urine and faeces separated so that the faeces dry quickly with the minimum smell and the urine can be used directly on crops as fertilizer (Dellstrom- 2005)[6]. By comprising the faeces for about 8 – 12 months depending on climate, in addition to contributing to their dehydration and decomposition, the faeces are then sanitized and fit to be used as soil conditioner [7]. Several studies have revealed that dry methods diverting urine and faeces kill pathogens more effectively than other commonly used strategies [8, 9].

According to World Health Organisation (WHO) [10], improved sanitation can lead to up to US$9 in social and economic benefits for every US$1 investment as it increases productivity, reduces illness, disability, early death and healthcare costs. On-site sanitation (OSS) systems such as pour-flush toilets and pit latrines are often recognized as the most suitable and cheapest form of sanitation at remote or decentralized areas with low population and income (Paterson *et al*. 2007, Strande *et al*. 2016). For both toilets, the pit is designed that should be emptied regularly. Nonetheless, it has previously been observed that as emptying the pit is usually expensive and unhygienic, it can lead to dangerous practices of overfilling and /or flooding the pit out which adversely impact the public health and environment (Marion *et al.* 2015).

Additionally, due to the increasing use of both pit latrines and groundwater resources at remote or decentralized areas, there is a concern that pit latrines may cause ecological and human consequences associated with chemical and microbiological contamination of groundwater (Graham and Polizzotto 2013). While there have been several investigations into the impact of pit latrines on water quality, the quality of experimental techniques and chosen indicator contaminants varied greatly that leads to varies outcomes (Graham and Polizzotto 2013). Additionally, only a little information is available on possible effects of pit latrines on climate [15]. According to Graham and Polizzotto (2013), over 1.7 billion people around the world use pit latrines and this number are expcted to increase in the next few years, therefore, methane emissions could be substantial. It is estimated the annual methane emissions from the anaerobic process in pit latrine is approximately 1 Kg per person, corresponding to around 2% of methane emissions from an average person (Reid 2014).

In 2011, the Bill & Melinda Gates Foundation (BMGF) challenged research institutions to find innovative sanitation solutions for that capture and process human waste without sewer, piped water or electrical connection, and transform waste into useful resources, including water and energy, at an affordable price (Bill and Melinda Gates Foundation 2019). The blue diversion toilet (BDT), which is essentially urine diverting dry toilet (UDDT) as suggested by Katukiza (Katukiza 2010). Katukiza (2010) showed that UDDT has several advantages, including small land requirement, using local material to construct and repair, no need for constant water to be used, long life since it can be emptied for reuse, suitability for flood-prone areas due to non-mixing of waste, and odour control that is achieved through proper usage.

A study examined the BDT system at early stages in the target area (i.e. urban slums) using only one working model that limited the number of people who could test it (Tobias 2017). The outcomes of this study showed: (1) Separating urine and feces is feasible and

was accepted by participants; (2) Separating urine and water turned out to be technically challenging because of mud in the water; (3) The collection service and feces component were not well received by the population due to using a relatively small container. Nonetheless, while it is well documented that the acceptance of UDDT rises especially when people realize the advantages of this system, traditional UDDTs have larger and more distant feces compartments that makes it easier to ignore the fact that feces are stored (Dellstrom 2005). The BDT system must also be improved to enhance its usability for elderly and disabled people as well as children (Tobias 2017). While this system is using a relatively small container, it still has a massive size that makes it challenging to find a place to set it up inside the building or under a shelter.

Long-term usage of sanitation systems after their implementation has been a challenge in many contexts, therefore, there is a growing emphasis being placed on ensuring the sustainability of these facilities (Godfrey 2014). Dellström (2005) argue that the major challenge concerning sustainable sanitation is an insufficient number of available sanitation options. Furthermore, while a limited number of concepts for safe, affordable and sustainable sanitation systems exist, their acceptance and feasibility must be explored at the early stage of development. However, it is challenging due to the high costs of building real models, and therefore, there are very few studies about sustainable sanitation concepts. Additionally, to the best knowledge of the authors, no previous study has investigated stilt house compost toilet. The following section moves on to describe in greater detail the different types of sanitation technologies.

4.2 Sanitation system types

Sanitation systems can be divided into water-based or composting-based categories. The following sections describe each of these systems.

4.2.1 Water-based sanitation systems

The water-based sanitation technology, which avoids the disposal of human waste on streets in densely populated urban areas, was first introduced in the 18th Century (Czemiel and Hyvonen 2002). Currently, different sources of water, including potable water, rainwater or greywater are generally used for flushing in the water-based sanitation systems (Anand and Apul, 2014). There are also different human waste treatment methods used in these systems, such as conventional wastewater treatment, septic tanks, constructed wetlands or living machines (eco-machines) (McCray 2005, Kadlec 2009, Kumar 2011). Conventional wastewater management usually evolves to include large and centralized wastewater treatment plants fed by networks of sewer pipes that connect to individual wastewater generators (McCray 2005). Nonetheless, this practice can be neither sustainable nor cost-effective in remote or decentralized areas due to various factors, such as sparsely population, lack of terrain or limited energy and water supplies (Siegrist 2001). Septic tanks, which are the most popular on-site wastewater treatment systems, are used to collect waste from toilets and removes most settleable solids and functions as an anaerobic bioreactor that promotes partial digestion of organic matter (Nasr and Mikhaeil 2013). However, due to the short hydraulic retention and lacking post-treatment by drainage trenches or leaching fields, effluents of these septic tanks are still highly polluted (Eriksson 2002, Rodgers *et al.* 2011). Constructed wetlands, which has proven to be very convenient and efficient for decentralized areas, constitute a nature-based system resembling the decontamination processes occurring in natural wetlands (Alvarez 2017). One of the main constraints for this practice is the lack of expertise at the

local scale and the adaptation of the technology to the local conditions (e.g. locally available materials, vegetation, climate, water quality, etc.) (Alvarez 2017). Overall, Anand and Apul (2014) argue that while all of the water-based sanitation systems provide the same function of treating human waste, portable water-based systems with conventional wastewater treatment or with septic tanks are mainly the ones used in developed countries.

4.2.2 Composting-based sanitation systems

Composting-based sanitation, which is primarily used in rural areas and areas with water shortage, is known as dry toilets, composting toilets, biological toilets, waterless toilets or bio-toilets (Kaczala 2006, Del Porto and Steinfeld 1998). These systems require little or no use of water for the conveyance of wastes and therefore can be disconnected from both water supply and wastewater infrastructures. The solids obtained from composting toilets can be used as fertilizer (Anand and Apul 2014). As noted by Anand and Apul (2014) composting toilets can be a sustainable solution to water and wastewater infrastructure challenges in decentralized areas due to their little to no water requirement and producing a value product (fertilizer). Furthermore, the operation of composting toilets is well aligned with the ecological sanitation design principles, such as considering the human dimension, learning from nature (e.g. limited energy input to the system, system design specific to location and scale, decentralization, etc.) and integrating nature (Apul 2010). Overall, as explained before, the focus of this study is on rural areas in Assam, India. These areas are generally decentralized with no or limited infrastructures. Therefore, this research proposes a sustainable composting toilets solution that meets the ecological design principles. This project provides a significant opportunity to explore the functionality of the proposed system.

Despite several advantages of using composting toilets, there is still limited studies about these systems that lead to diminishing their acceptance and implantation (Anand and Apul 2014). The structure and types of existing composting toilets will be explained in the following sections.

4.3 Case study – Mishing Gaon in Majuli Island

Assam being a catchment state of the monsoon rain located in the valley of Himalayan Mountain ranges, it receives an average rainfall of 2800 each year. While the river Brahmaputra acts as one of main channels running across 670 km East West of Assam for draining out the rain water through to the Bay of Bengal, it inundates a large part of the habitable land on both banks of the river. Due to the fertile nature of the land and also due to the geographic spread of the habitable areas of the state, over 30% of the 35 million population in the state reside by the bank of Brahmaputra river. Figure 2 shows the alignment of the Brahmaputra river over the course of 640 km flowing through Assam.

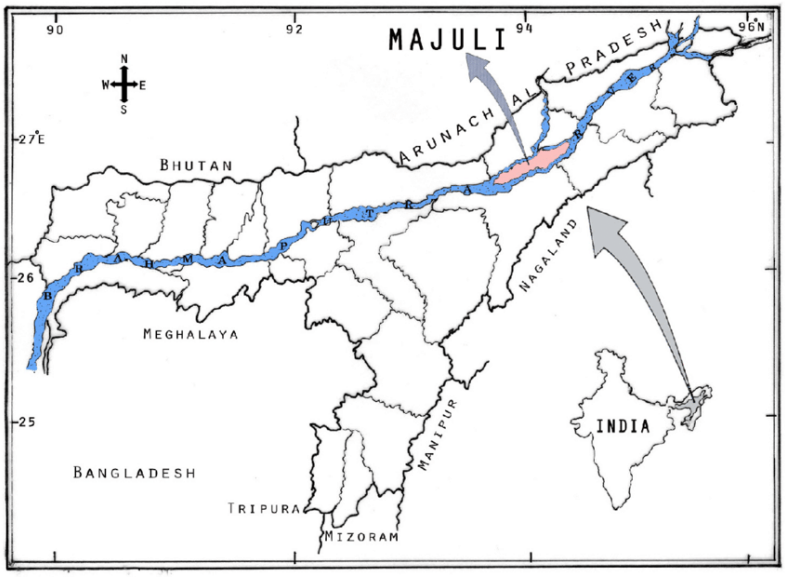


Figure 2: Brahmaputra River in Assam (Sarma and Sarma, 2014)

The world's largest river island Majuli in the Brahmaputra river is the residence of over 168,000 population across 246 villages and 32500 households. Due to large part of Majuli being flood-prone, many of the villagers especially the Mishing community live in a particular kind of houses known as "Chang Ghar" which are typically built on bamboo or concrete stilts. These Chang Ghars with raise floor levels serve multiple purposes. During flood season, while it protects the people and assets from inundation, in the dry seasons, the sub-floor area provides ample storage including the room for domestic animals such as cattle, pigs, ducks and chicken. Figure 3 shows a few such houses on stilt foundations located in the Mishing Gaon in Majuli. Figure 4 shows a typical low cost brick and mortar toilet with an in-ground septic tank. Such toilets are usually built under the Swachh Bharat Mission – Gramin of the Central Government of Indian and common among the village communities in rural areas.

Figure 3: Chang Ghar among the Mishing community in Majuli

Figure 4: Low cost brick mortar toilet with a septic tank in Assam (*Source: The Indian Express, May 27, 2016*)

4.4 Issue of sanitation and waste management during flood

As depicted in Figure 5, the situation of these villages during flood season is grim. Water-logging is a common problem where villager struggle across multiple fronts. When the vast areas get inundated, there is no any demarcations between the fresh water and waste water. Clearly, living by the contaminated water become the way of life for the flood-affected community as long as the flood continues. When the flood recedes in the upstream areas over time, flood problem persists for a longer period of time in the downstream areas. In regards to the contamination, the downstream areas are even much worse than the upstream due to high BOD and other living pathogens and bacteria in the water.

One of the key factors of flood water being contaminated is the poor design of traditional septic tanks. The problem is further exacerbated with the open defecation by a vast majority of the population in rural settings. During the high flood when water flows with a reasonable current, the contaminated water flows out from the highlands and get dry quickly. But for the low lying areas with stagnant water, acute mosquito borne disease even after receding the flood becomes prevalent among the wider population.

In this research, a solution to minimise the waste water contamination during flood season is put forward by proposing a unique and purpose-built design of a compost toilet especially usable in the houses on stilt. The remainder of the paper will focus on design and implementation of the compost toilet.

Figure 5: Flood affected houses in Majuli (*Source: The Indian Express, August 28, 2021*)

4.5 Compost Toilet – an innovative idea

Acceptance of composting toilets over the original pit latrines have been quite widespread [35]. A composting toilet has two primary components, such as the toilet and the composting tank. The other parts of composting-based sanitation are often a fan and

vent pipe to remove the odour, as well as a drain to remove excess leachate and access doors to empty compost. Key feature of the compost toilets includes the design of the composting system by separating solid waste from the liquid. In the composting process, solid waste is collected into the composting tank which composts aerobically. While solid excreta decomposes over time naturally, bulking agents such as dry leaves, food waste, sawdust etc. can be added to help for a number of reasons including co-manage different types of waste, adjust carbon to nitrogen ratio, increase the porosity of the compost [22]. Kitsui [36] points out that the most popular amendment is sawdust as it creates an environment for bacteria to thrive with high porosity, high water and air retention and high drainage properties. The end product from composting toilets contains stable, high molecular weight dissolved organic matter that can be recycled as solid fertilizer [37].

Figure 6 shows a purpose-built design of a compost toilet for the Chang Ghar used by the Mishing community in Assam. In designing a compost toilet, a number of key factors are important to consider. These include:

- Cost effective solution
- Easy to design and accessibility to the materials used
- Ease and practicality in installation and use
- Ease of cleaning and maintenance
- Meeting the purpose of being water-proof and resilient

There are currently various designs of composting toilets available. According to Anand and Apul [22], composting toilets can be central or self-contained, be operable manually or electrically, have multiple or single chamber tanks, be waterless or water-based, be installed in a single or multi-story building, and collect urine and feces through one pipe or separately collect urine.

However, the challenge in simple one-chamber design is that the decomposed end-product at the bottom of the pile might be continuously contaminated by fresh materials and pathogen (disease-causing organisms) deposited on the top of the pile. Additionally, sometimes the pile does not actually move down the slop of container and can become compacted and very difficult to remove [35].

As seen in the Figure, keeping in mind the above challenges, for the sake of simplicity, the current design contains a single container to build as a prototype and examine the efficacy in practice. The main container in this case is a water proof PVC water tank which is readily available in Assam. The common brand of the PVC water tank is Syntex which is not very expansive and it comes in various sizes from 200 litres to 1000 litres or more.

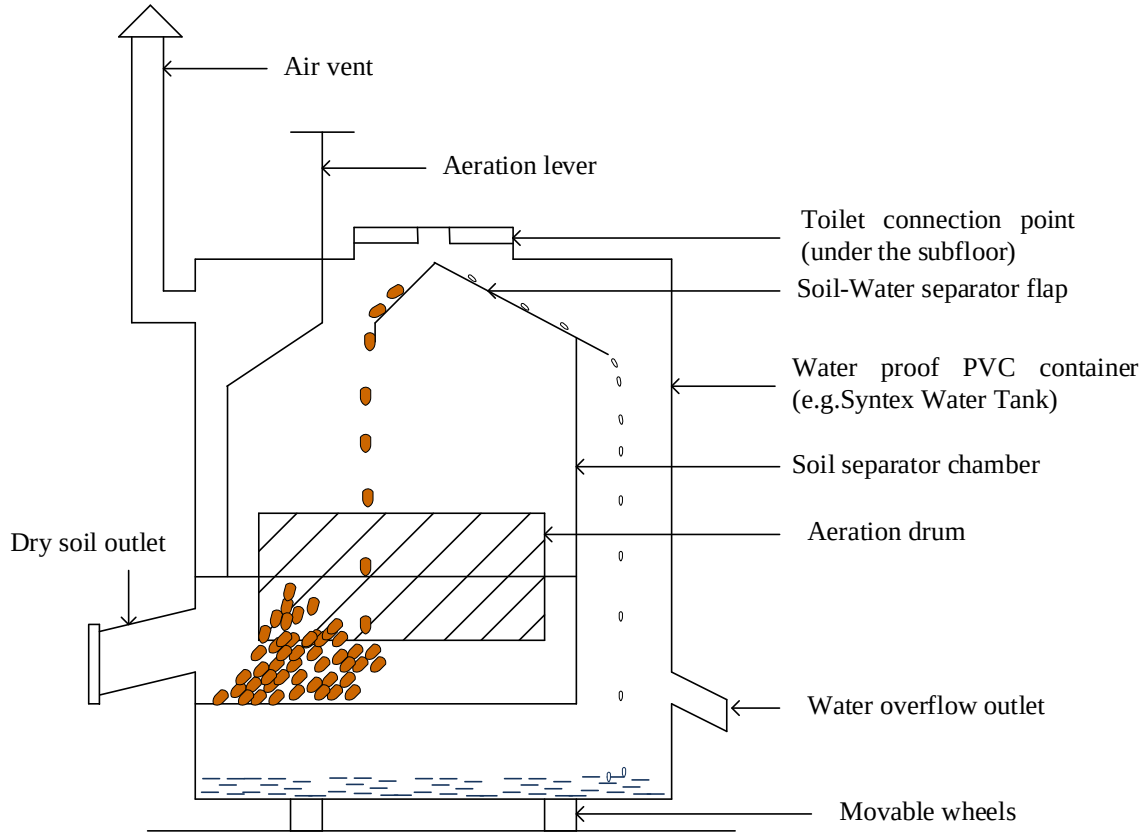


Figure 6: New design concept of a Compost Toilet system

4.6 Key design elements and the functions

In order for functioning the compost toilet properly, a few elements are important from both design and operations perspective. Some of the key elements and their functions are discussed below:

Main container – The main container in the design is made of plastic materials of a popular brand of traditionally water storage tank known as Syntex which comes in various sizes. Due to its light weight, low cost and durability in tropical weather conditions, this is one of the most suitable solutions for this initial design.

Soil separator chamber – The soil separator chamber is nested inside the main chamber anchored in the side walls. The materials for chamber could be either plastic or galvanised steel sheets. The main purpose of this chamber is to store the faeces (e.g. soil) separated from the liquid (e.g. urine) and keeping in dry conditions for natural decomposition. The main tank will host the liquid underneath the separator chamber which will naturally dry out or spill through the overflow outlet into the ground. The outlet point can be directed to the farming area by underground or exposed pipes.

Toilet connection point and toilet bowl – Toilet connection point including the design of the toilet bowl is a critical consideration in the entire design and installation process. Toilet connect assembly will need to be positioned inside the house in such a way that it allows

the separation of the soil and liquid at the closest point of the user, so that there is no or minimal chance of mixing the two.

Aeration vent – Aeration vent could be either a PVC, Plastic or even steel pipe connected to the top of the main tank for allows in oxygen and exhausting the odour from both the separation chamber and the main tank. Adequate oxygen supply is important in the biological decomposition process. A fan exhaust fan can be also be installed at the top end of the aeration vent for allow better circulation of airflow if necessary in the case of a larger tank with high number of users.

Aeration drum and lever – Aeration drum and the lever is a critical component flow allowing regular shaking of the soil to settle properly and excel the air circulation in the soil for easy decomposition process. The Aeration drum and lever assembly could of made of steel or iron and the drum is anchored on the side walls as shown in Figure 6.

Soil-Water separator flap – *S*oil water separator flap assist in separating the soil from liquid which needs to be placed for guiding the flow from the toilet bowl. This flap should be of still with smoother surface and sharp angles so that soil does not get deposited on the surface.

Dry soil outlet – Dry soil outlet allows the decomposed soil to be removed from the tank during the dry season. The dry decomposed soil then can be used as fertiliser in the farmland.

Movable wheels – Rubber or plastic wheels with a steel shaft should be installed at the bottom of the tanks for easy manoeuvrability of the toilet. Depending on the size of the tank, two to four wheels may be installed. As far as possible, the base plate should be made of concrete slab which will then allow appropriate anchoring of the tank stemming the movements during flood or other forces.

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. The process of transformation starts with a smaller first step focusing on the grassroots level issues and moving upwards. Taking into consideration of the chronic flooding in Assam and particularly the large Mishing community who traditionally live in the Chang Ghars in the flood prone areas, this research put forward a simple and sustainable solution of am purpose-built toilet design. The design is based on the assumptions that the houses will be on stilt and then there will be adequate space for housing the toilet chamber under the subfloor. Then from inside the house, the inlet on the top of the chamber will need to be connected with a custom-built toilet bowl and seat mechanism so that the soil-water separator installed in the chamber is functional and effective in the soil-water separation process at the source.

As the Monsoon period last over 3 months in Assam and so as the flooding issue, the capacity of the toilet chamber needs to assessed based on the family size and household requirements. The idea is that the chamber is sufficient for holding the waste for entire Monsoon season and cleaning is then done in the dry season only. For efficient

composting, the aeration lever needs to be used for shaking the soil in a regular basis. If successful in the prototyping, the scalability of the toilet fabrication and rolling out will be not an issue. Initially the program will be support based on voluntary basis and financial support will be secured from the philanthropic sources.

The efficacy of the compost toilet will be evident through the containment of the waste from the fresh flood water and stemming the contamination being flown into the downstream areas during the food season. The solution will not only increase the health and well-being of the community at large but also support the local farming with the organic compost fertiliser. Once the success in achieved in the field, the roll out could potentially be mandated in Smart Villages initiative through the state government of Assam.

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THERMAL PERFORMANCE AND OCCUPANTS' PERCEPTION OF PREFABRICATED TIMBER-FRAME HOUSE IN COASTAL REGION, BANGLADESH

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Abstract:*People need comfortable thermal environment as indoor thermal environment impacts occupants' comfort and safety.Global warming due to climate change affects indoor thermal environment. Today, people are more concerned about sustainability for quality life and environment-responsive construction has been given importance. People who lives close proximity of nature give key concern to the climatic factors while building their houses. But due to development in building sector and technology traditional houses have gone through modification of structure, materials and construction technology. Local pre-fabricated timber-frame houses of Bangladesh are one of such examples. Traditionally, timber is used as wall envelope material which isreplaced by manufactured plain-sheet material and known as 'timber-frame plain-sheet' or simply 'timber house'. These houses are gaining popularity among rural people because of its quick installation and low construction cost. These resulted in different types of region-specific local houses having particular characteristics reflecting environmental concern.This study, aiming towards evaluation of indoor thermal environment, has conducted in-situ thermal parameter monitoring with HOBO U-30 data logger and occupants' perception. The findings may help design-concerns towards early-stage design consideration regarding sustainable materials selection for effective integration of sustainability of built environment.*

Keywords: Indoor Thermal Environment, Prefabricated Timber-frame House, Occupants' Perception, Coastal Region, Tropics.

1. Introduction

Local tropical houses have specific environmental physical appearance that evolved considering local material constraints, construction technology and microclimate(Islam 2021). To deliver occupants with the essential comfort perception, these naturally ventilated houses assumednumerous passive design approaches. Furthermore, occupants have unique living patterns which may have contributed towards achieving indoor thermal comfort (Islam 2021, Chowdhury 2019). People who live close association of nature for years develop their own knowledge of construction techniques resulting in the precise character of regional architecture coupled with culturally defined values and norms of a particular region (Salman 2018). The

wisdom of these traditional construction techniques is achieved through trial and error and handed down through the generations that have been ignored in a deeper understanding of human existence (Salman 2018). However, technical data regarding these issues is still marginaled. Consequently, considering traditional timber houses of Bangladesh as sample cases, this study aims to examinethe existing connection between indoor thermal environment and occupant's perceptions within these tropical houses(Islam 2021).

Barisal is one of the biggest river ports in Bangladesh. Barisal is fast growing city of the country stands on the Kirtankhola River.The city is called the "Venice of the East" or the "Venice of Bengal" and the "Paradise of Bengal". "Barisal guns" is a natural phenomenon named after Barisal; it is kind of a booming sound heard near lakes and rivers which is due to seismic activity under water, first heard in this region by the British in the 19th century (Daily Star 2006, GoB 2015).Swarupkathi (selected study area) is an upazila of Pirojpur District in the Division of Barisal, Bangladesh (Parvez 2012).Swarupkathi is known for its business centre specially for its floating timber market. It is possibly the largest timber market in the south of the country (Ahmed 2018). The single-storey and two-storey houses with different types of wooden frames can be seen in this region. These houses have an interrelationship with the way of life of the people here and around these houses they conduct their various ceremonies, features of life. In particular, these community-based homes are built using local construction techniques and materials (Fig. 1 and 2). But now, these houses are in a dilapidated condition due to a lack of proper maintenance and upkeep. If the construction techniques and living environment of the houses can be more closely linked to the flow of life of the common people then on the one hand the quality of life of the people will improve and on the other hand it is hoped that these houses will get back to their heritage.

Figure 1: Locally available timber frame houses in Swarupkathi, Barisal (Photo: Authors)

Figure 2: Selected timber frame houses for case study in Swarupkathi, Barisal (Photo: Authors)

These traditional houses cope with the adverse environmental situation. It's a significant and investigated prototype that has existed from generation to generation. But the speedy progress of science and technological enlargement has hardly left any space for these traditional knowledge (Islam 2021). As a result, an environmental study is required to carry out to uncover this housing technology ofthis region.

2. Problem Statement

The traditional houses of Barisal are adaptive in nature and developed with balancing relations between natural elements and cultural traits. Local people use locally available rural resources (plain sheet, mud, timber, straw, etc.) as raw materials for their housing (Pal 2016). At present pre-fabricated houses can be seen in the rural areas or villages of Bangladesh. These houses are made of CI (corrugated iron) or plain sheets, including timber framing. These houses are usually from one to two-storied. In many cases, these are on-site construction and such installations are more common because lower-middle-class families are within the purchasing power. The structure of such houses is currently being modernized. It is possible to build these houses in a short time. Although such places are familiar in the villages, there is not much research on how the internal environment can affect the inhabitants while living here. Further research is needed to understand how its internal temperature changes at different times of the day.

Therefore, serious lack of ethnographic data regarding eco-adaptive issues has been found on traditional housing technology in this region. Since the skill of construction workers, the technology of housing construction and the knowledge about local construction materials and indoor environmental data are not recorded properly, it is imperious to urgently document this hidden transcript of knowledge before it dissolves. Many local housing technologies have been established by the inhabitants that retain them least-affected but there is a serious shortage to conserve proper documentation of eco-adaptive, environmentally sound and self-sustaining traditional housing technology in this region. The main purpose of this study is to evaluate the traditional and environmental performances of typical timber framing plain sheet house with respect to local climatic considerations. Another aim of this research is to develop an outline of an indoor environmental database of a local house in the context of humid-tropics. This study focuses on issues that could play an essential role in further research and rural development.

3. Scope and Limitation

The research work presented in this study concentrates on indoor environmental performance evaluation of a plain sheet timber house in the Barisal region, Bangladesh. Characteristics of local building materials such as timber and plain sheet combination and their sectional layout have been studied to determine their thermal performance. Some degree of uncertainty has been presented in the data collections during field investigations due to leakage of airflow between the roof and the envelope. However, given the limited time and scope of the study, this research has been concentrated on the indoor thermal issues and occupants' perception only. The performance of dwellers and their productivity regarding active and passive ventilation systems, heating, cooling, lighting issues, acoustics, insulation, safety, and security are beyond the scope of this research.

4. Climatic Context

The climate of Bangladesh can be defined as a warm-humid climate, based on the widely used climate classification of tropical climate (Koenigsberger 1973). Four pre-dominant seasons: hot and dry pre-monsoon (March to May), hot and wet monsoon (June to September), post-monsoon (October to November) and dry winter (December to February) (Ahmed 1995; Mridha 2002; Ahsan 2009) with moderately noticeable seasonal variation all year round is noticed. Winter is cool and dry but other seasons are hot and humid (Ahmed 1995) that have high temperature combined with high humidity and heavy rainfall. But patterns of climatic factors among various parts of the country vary from region to region considering locations (Mallick 1996). Traditional timber houses are mostly found near the Southern part of Bangladesh and because of proximity of the Bay of Bengal, climatic condition of this region is different from rest of the country. Pre-monsoon periods are the warmest month of Bangladesh because of clear sky, dry climate, greater sunlight angles, greater solar intensity, longer sunshine duration (Roy 2010).

Table 1: Monthly temperature (ºC) data of Barisal during the period 1981-2010

Month/Variables		Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Season		Hot-dry			Hot-humid						Cool-dry		
		Pre-monsoon			Monsoon				Post-monsoon		Winter		
Temp.	Max.	32.4	33.5	33.4	32.0	31.2	31.4	31.7	31.7	29.8	26.8	25.5	28.5
	Min.	20.5	23.8	24.9	25.8	25.7	25.8	25.4	23.7	18.9	13.6	12.0	15.4
	Dry bulb temp.	25.9	28.3	28.9	28.7	28.2	28.4	28.2	27.2	23.6	19.2	17.9	21.5
Relative Humidity		76	80	83	88	90	89	89	87	84	83	81	78

(Source: Bangladesh Meteorological Department)

Temperature data of Bangladesh Meteorological Department shows that maximum temperatures Barisal are recorded in pre-monsoon period (March-May) and high temperature remains for most of the days compared to other months. Table 1 illustrates the monthly temperature data of Barisal for 30 years period (1981-2010). From the table it is observed that at Barisal, temperature is higher in April with a normal maximum value of 33.5ºC (Khatun, Rashid et al. 2016). During hot-humid period mean maximum temperature fluctuates between 31ºC-32ºC at Barisal.

January is the coldest month with an average high-temperature of 25.5°C and an average low-temperature of 12°C.

5. Research Methodology

Field observations, environmental data monitoring, and literature reviews have been conducted in this specific study. Data loggers (HOBO ware Pro. U30) with smart sensors and thermal monitoring tools (Thermal Imaging Cameraand Laser Non-Contact Thermometer) were used at the midpoint of the selected house floor level to measure day-long environmental data of temperature, (°C) (dry bulb), humidity, RH (%) and solar radiation(W/m^2) to study the indoor environmental condition of the house of Barisal region, Bangladesh. Climate data was collected with the help of Data Loggers (HOBO ware Pro. U30) and sensors for a day (24 Hours) (Cunha 2015). Data was collected at two different heights (first floor and second floor) (Fig. 3), firstly at 750mm above (from the ground) which is the minimum height of working plane generally used in residential space in living area and secondly at 3050 mm above which is the minimum ceiling height of a production space.

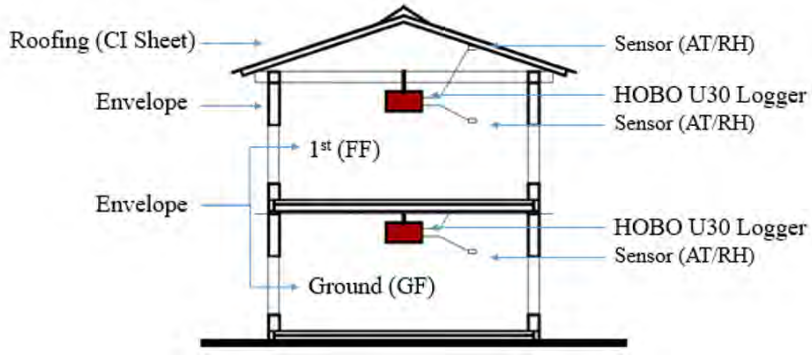


Figure 3: Environmental data monitoring system of Mud house (Here, FF/UF=First floor/Upper floor)

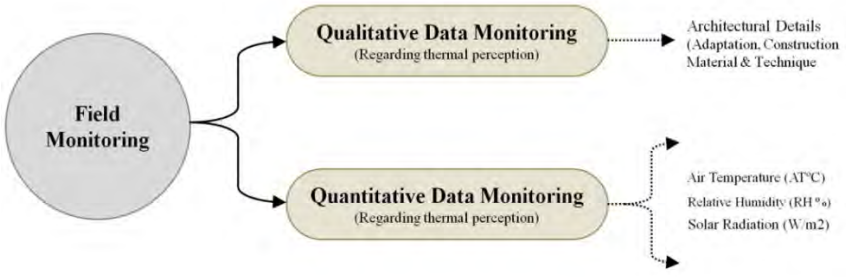


Figure 4: Overall research structure

Observations on environmental factors made during the fieldwork have been categorized into groups. Some factors relate directly to thermal behavior, such as 'Indoor Air Temperature', 'Globe Temperature' and 'Surface Temperature'. These factors are directly influenced by the house envelope. Finally, the qualitative approach allows a better understanding of the occupants'

experiences of the indoor environmental quality in dwelling that can be used in producing local housing design guidelines for the tropics. Fig. 4 demonstrated overall research methodology.

6. Settlement Pattern

This particular house is usually filled with sand at the bottom and brick soiling on top. CC (cement concrete) flooring is done on top of brick soiling. Above this flooring is placed the infrastructure of the installation. However, care must be taken to ensure a slight gap between the vertical walls and the floor. Usually, in this installation, the gap is made within 35-50 millimeters. This gap is usually kept so that there is no direct wooden connection to the floor. This can cause damp problems. However, this gap is filled up by the sealer. This installation uses a vertical timber frame. A plain sheet wall envelope has been used with this timber frame. Plain sheets are typically 4'X8' in size and are formatted according to design. The windows are fitted with MS (mild steel) grills with wooden frames around them. Roofing uses insulation with timber frame CI sheet to control indoor temperature. The upper part of the house has timber framing and wooden flooring inside. The upper part has wooden rafters, wooden batten, a false wooden ceiling and an unvented roof attic. They are finally covered with CI sheet. Locally made metal-designed carvings are placed around the roof for ornamentation.

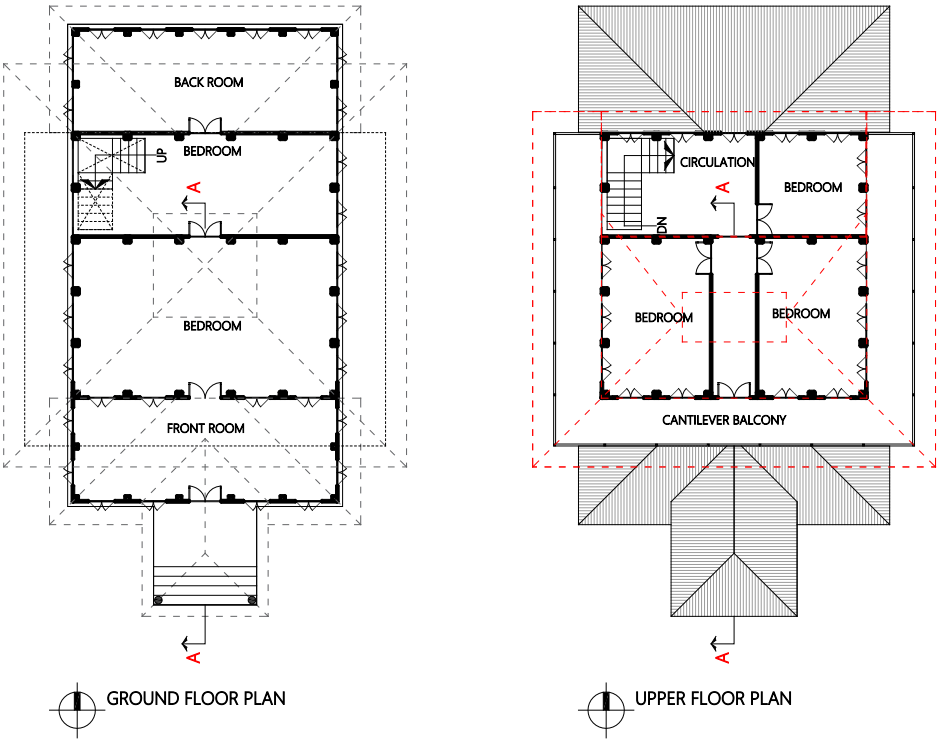


Figure 5: House plan

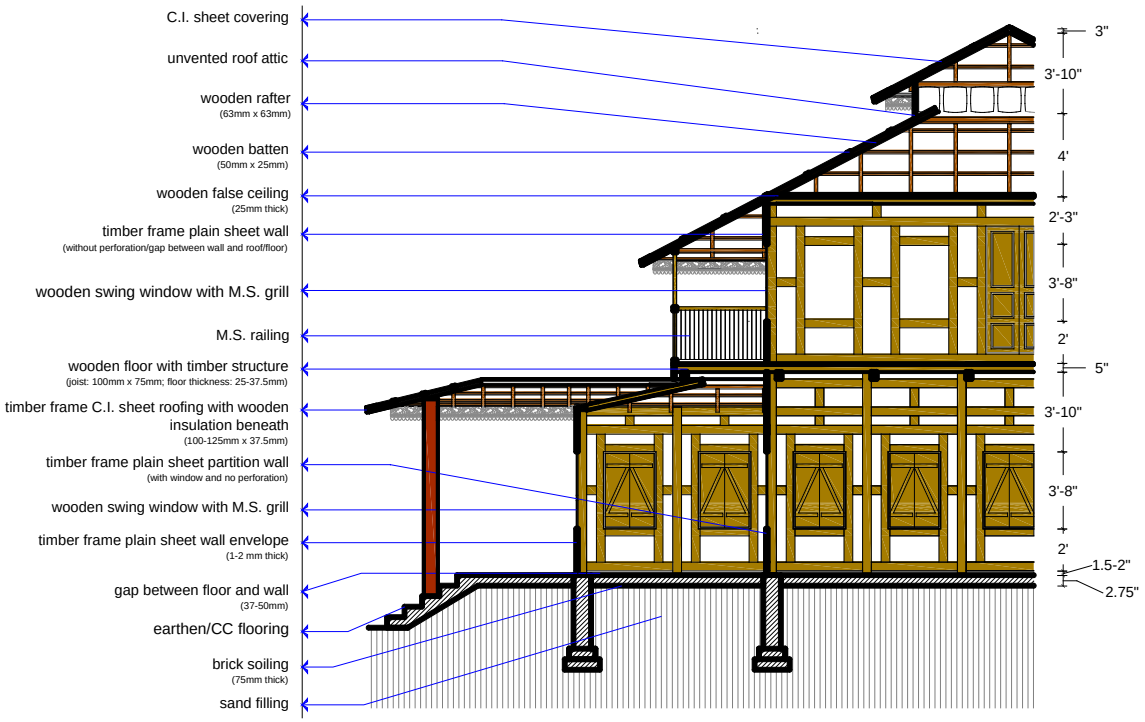
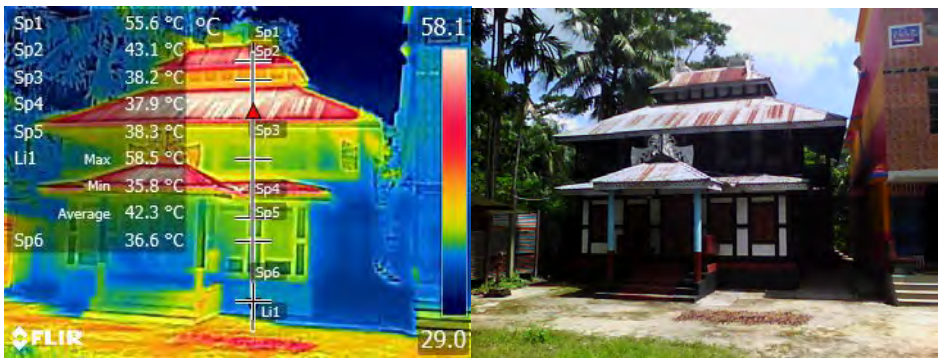


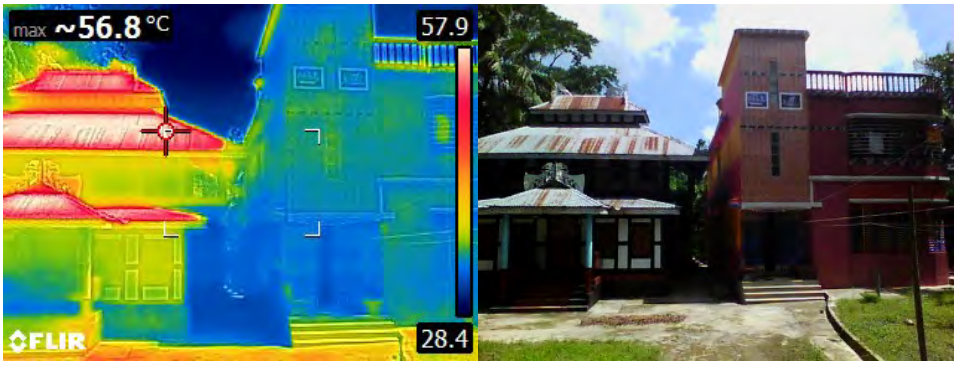
Figure 6: Detailed house section

The whole house has been gradually raised to the top in a step-by-step manner and the roof has been tilted so as not to trap rainwater.The houses of elongated-linear types are mainly found near the coastal belt and plain area near the dam and built on a high plinth above the flood level. Generally in these types of settlements, each and every house has the front space used as courtyard and backspace as the backyard. Backyard serves as the private space for the women of the community. The toilet is placed in one corner of the backyard. The front yard has functional utility for husking and drying of paddy, drying of clothes, etc. But the use of this space is gradually being decreased under the pressure of population growth and technological advancement. As a result, many post-harvest works are being performed. in the mills or even on the nearer roads. Here, Fig. 5 and 6 have been demonstrated of detailed house plan and section.

7. Indoor EnvironmentalProfile

A thermal imaging camera has been used to identify thermal profiles of the various materials and internal thermal conditions of the house at different times of the day. The pictures (Fig. 7) showed that the roof was the most heated part of the house, where the maximum temperature was 55 to 58°C. Having another installation next to the house casts a shadow on the place where the temperature is less high. The temperature of the part relative to the soil is slightly lower than that of the other part above. In addition, if the two houses are compared, it can be seen that the walls of the houses made of bricks during the day reflect the relatively low temperature from the houses made of plain sheets.


Sp1 55.6 °C
Sp2 43.1 °C
Sp3 38.2 °C
Sp4 37.9 °C
Sp5 38.3 °C
Li1 Max 58.5 °C
Min 35.8 °C
Average 42.3 °C
Sp6 36.6 °C
58.1
29.0
FLIR


max ~56.8 °C
57.9
28.4
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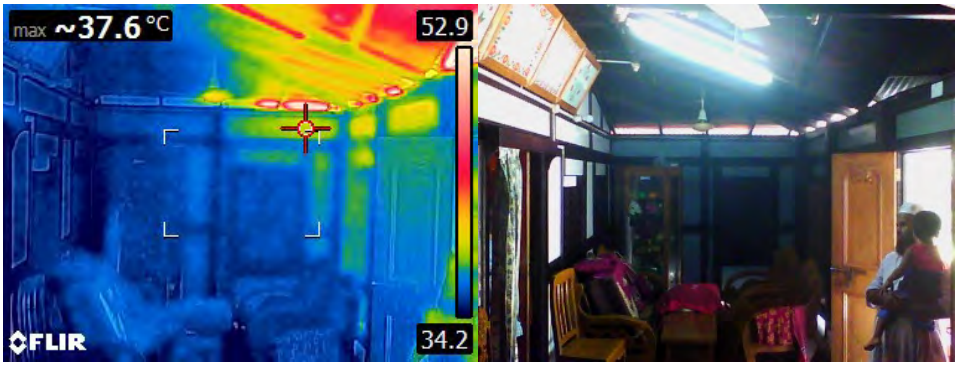
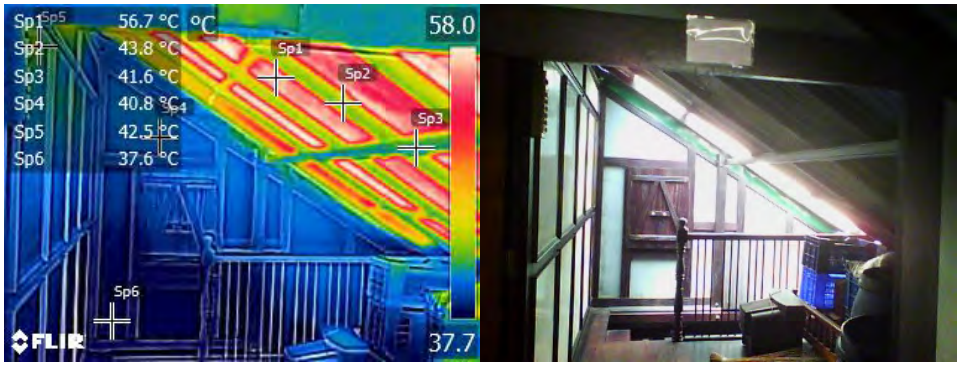

max ~37.6 °C
52.9
34.2
FLIR


Sp1 56.7 °C
Sp2 43.8 °C
Sp3 41.6 °C
Sp4 40.8 °C
Sp5 42.5 °C
Sp6 37.6 °C
58.0
37.7
FLIR

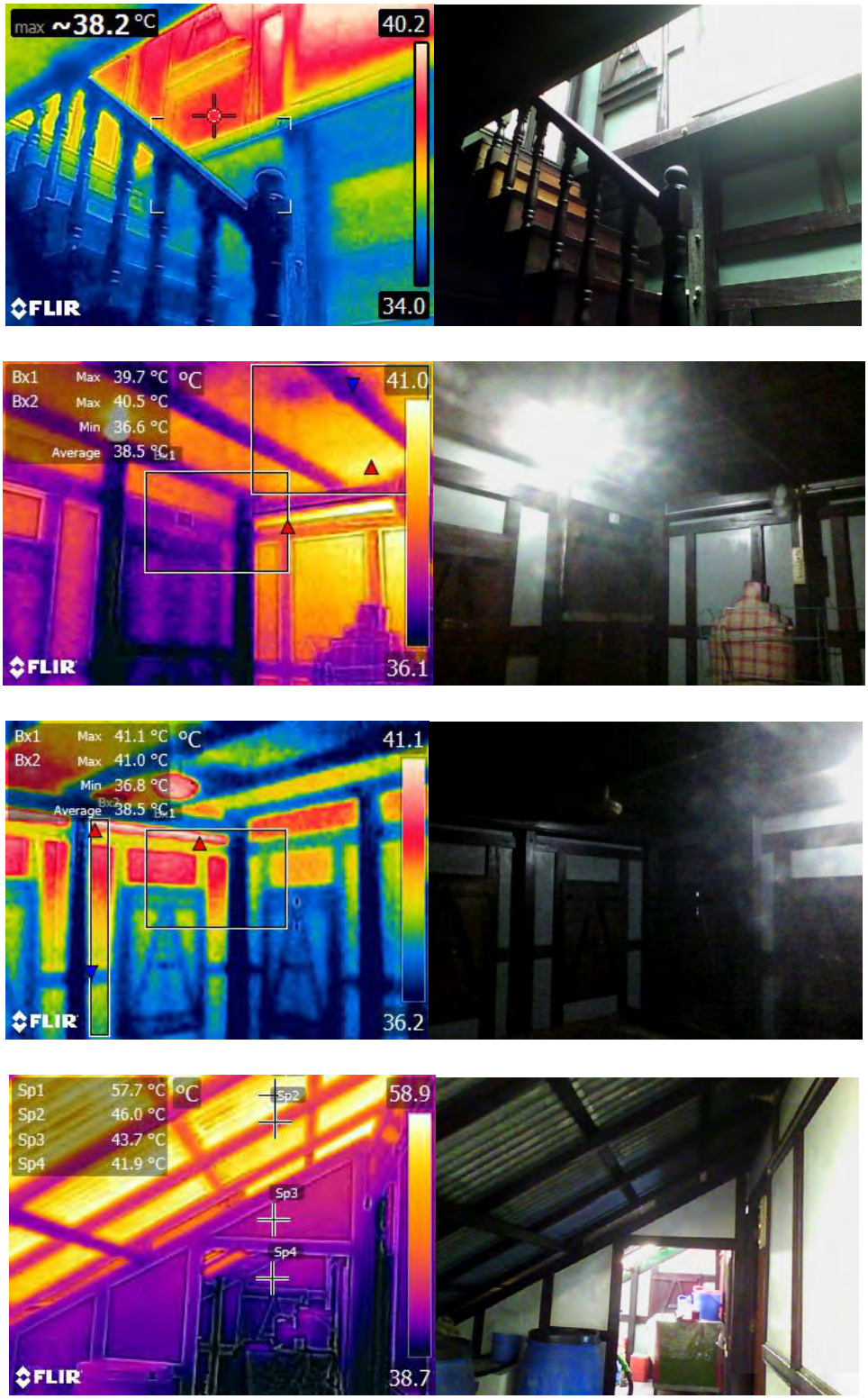


Figure 7: Indoor thermal profile of house envelope

Even the following picture shows the internal thermal profile of the house where it has been seen that in the part of the house where direct sunlight falls, the temperature is much higher than in

other places. Even indoor ceiling fans increase the internal temperature through heat radiation. Moreover, the part of the roof close to the slope dwellers' occupants feels hotter. However, lower temperatures are observed on the wooden floor in all cases. Since the stair in the middle of the house is made of wood, the materials do not feel too hot even during the day. However, excessive heat is observed in the adjacent plain sheet when climbing stairs and supposition is created if adequate ventilation is not provided. Even the electric light used in the house raises the internal temperature observed in the pictures. However, in areas where insulation has been used between the false ceiling and the outer roof has been left somewhat empty, this management acts as a heat insulator to bring the internal temperature under control. Observations show that the upper rooms feel warmer than the lower rooms and the living conditions are disturbed due to the daytime indoor temperature.

As mentioned above, HOBO ware Pro. U30 data logger with smart sensors was used at the midpoint of the selected house floor level to measure day-long environmental data to study the indoor environmental condition. In this case, observing the profile of outdoor solar radiation throughout the house (Fig. 8), it is seen that the radiation of the house's envelope gradually increases after 4:30 pm and the rate of radiation is highest from 12:00 pm to 2:00 pm (about 40 W/m^2). The solar radiation phase continues until 5 am in morning. The variation of this radiation causes changes in the internal temperature and the relative humidity value which are shown below.

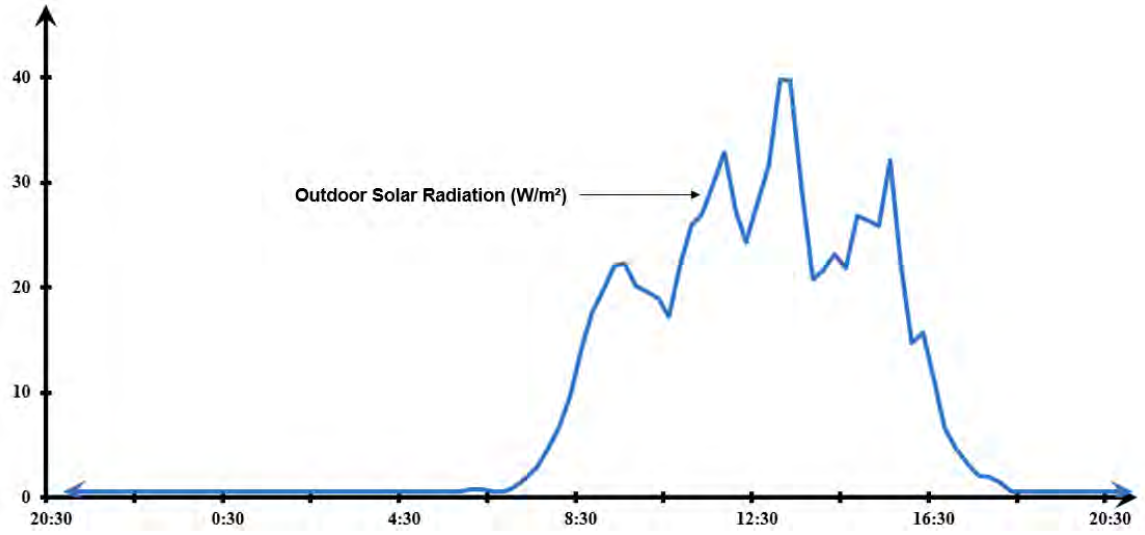


Figure 8: Day long solar radiation of outdoor environment

Data monitoring shows that the room temperature on the second floor is higher than the room temperature on the lower floor (Fig. 9). When the maximum temperature of the upper room is 33°C, then the lower room's maximum temperature is around 30°C. In both cases, the temperature gradually decreases from morning to 4 pm but increases from 4 pm to midnight. The maximum and minimum temperature changes in the houses vary depending on the temperature in the outdoor environment. From 3 pm to 7 pm, the temperature difference between the upper and lower rooms is minimal. Temperature variations are most noticeable from 12 midnight to 4:30 am.

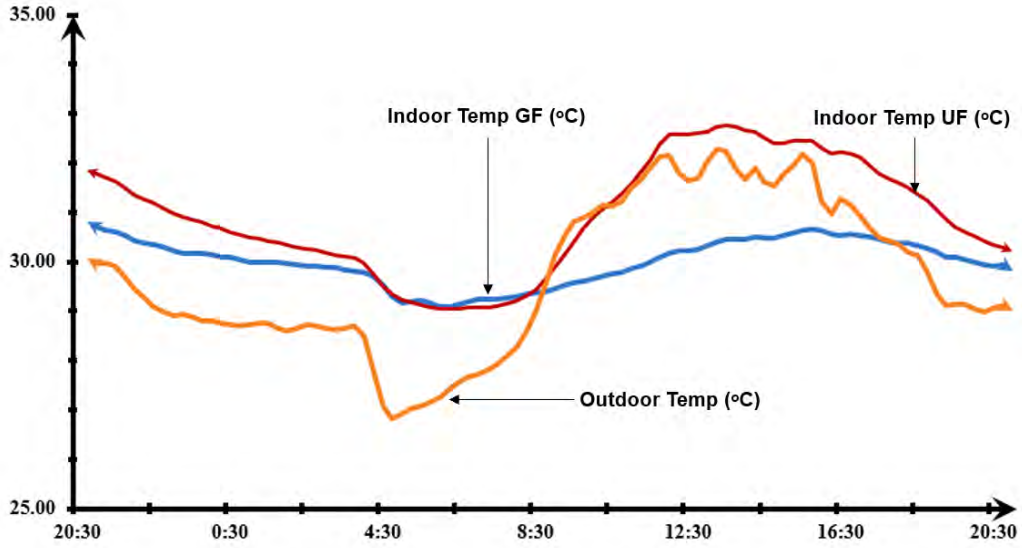


Figure 9: Day long thermal profile of indoor environment

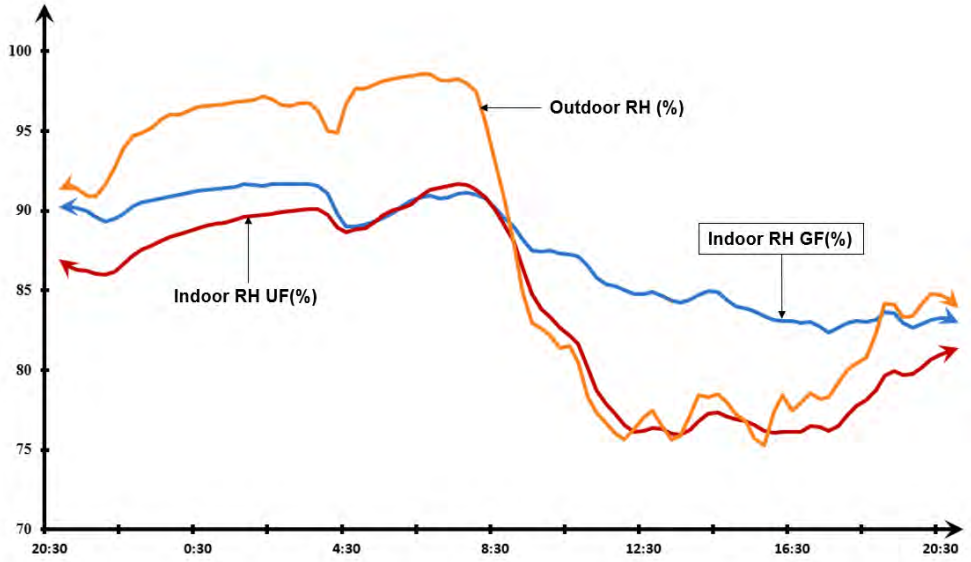


Figure 10: Day long relative humidity of indoor environment

Observations in the case of relative humidity (RH) show that the value of RH (%) in the upper floor is relatively lower than that of RH (%) in the ground floor (Fig. 10). However, from 8 am to 8 pm in both cases, the difference is more negligible. But after 8 pm, observations show that the humidity in the upper and lower rooms is much higher. In that case, the humidity of the upper room is 75%, while the humidity of the lower room is about 85%. As the internal temperature changes, the moisture gradually changes and the humidity in both the rooms remains almost the same from 4:30 pm to 8:30 pm.

8. Occupants' Perceptions and Discussion

Field-level observations and conversations with occupants provide insights into their living conditions and thermal perceptions. They even provide a narrative on how they adapt to the current living environment and what kind of future management will create a comfortable living environment for this house type that will guide further research. Below are their statements regarding indoor thermal living environment:

> *"…In this house, we live about seven people. The rooms downstairs are mostly occupied during the day because it is a bit cold downstairs. Upstairs we usually go to bed at night. However, if there is no electricity on a hot day and the ceiling fan does not work, it gets very hot..."*
>
> *"… Many times in summer we can't wear heavy clothes. Especially half sleeves are to be worn. Wear very thin clothes…"*
>
> *"…It gets colder again in winter. Especially if it touches the hand or body on the plain sheet wall, it feels very cold. This cold weather affects the health of children..."*
>
> *"…If the roof of this house is better insulated with wooden/bamboo knitted false ceiling, it will feel a little colder and more comfortable in the summer. If you could think a little more about the interior color and use a lighter shade or coating, maybe the room would feel even more relaxed in the summer..."*
>
> *"…Another problem with this house is that the tin has rusted in some places, subject to later fix costs. If the design of the houses can be changed and modernized a little, it will be a little easier to see and place the furniture.Many times rainwater seeps in, which causes a lot of suffering..."*
>
> *"…Since the house does not have proper lighting all the time. So many times, the electric lamp is kept on. Although the number of windows is very high, it is not possible to keep the furniture in the room properly due to the many windows. Some windows have to be closed due to the placement of furniture. This is to light the electric lamp inside the house and increase the monthly electricity cost. On the other hand, the windows should always be kept open as they get hot. This often leads to theft through the window due to a lack of adequate protection..."*
>
> *"…There is a balcony at the top. A lot of time can be spent there. And because the balcony is big, boys and girls can play there as well. That's a good thing..."*

Data monitoring findings identified that indoor air temperature (AT°C) fluctuates readily with that outdoors without a timelag resulting in daytime overheating. The occupant's daytime thermal perception is mostly slightly warm to hot. Semi-open and outdoor shaded spaces i.e., balcony

become a way to cope with the daytime overheating period. Occupants frequently use indoor spaces during the night when thermal sensation ranges between neutral to slightly cool.From the above discussion, most occupants are worried about their living environment during the hot season. In that case, they are talking about using envelope materials and highlighted that though using wood as wall envelope is more effective regarding thermal comfort butthis is too costly for them. As an alternative they are interested about usingplain sheets in these houses with adequate insulation especially on the roof and using a particular type of paint or coating to keep the indoor environment cool. Being pre-fabricated, installing these houses in less time and at a relatively lower cost as possible. It is essential to think about the position of the windows, especially in case of natural lighting and ventilation. In addition, the balcony act as a buffer zone, simultaneously controlling the entertainment and the indoor temperature (Fig. 11).

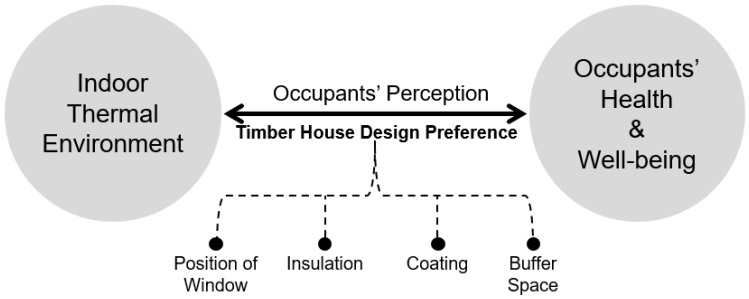


Figure 11: Timber house design preferences by occupants

9. Conclusion

Bangladesh's local pre-fabricated timber-frame houses are gaining popularity among rural communities because of their quick installation and low construction cost. Traditionally timber is used as wall envelope material, replaced by synthetic plain-sheet material and known as 'timber-frame plain sheet or simply 'timber house'. The infrastructural features of these houses vary from region to region and the local environment of Bangladesh which is associated with the occupants' way of living.This study evaluates the indoor thermal environment and occupants' perception of timber house in Bangladesh. Another aim of this research is to develop an outline of an indoor environmental database of a local timber house in the context of humid-tropics. From this study, it has been identified that there is a knowledge gap between the architectural design consideration and occupants' indoor thermal perceptions of pre-fabricated timber house in Bangladesh. Without clearly understanding occupants' thermal perceptions and comfortable feelings, developing this house type further would be challenging (Chowdhury 2020). The findings may help architectural design concerns towards early-stage decision-making regarding local materials selection for effective integration of sustainability of the rural environment. They could also play an essential role in further research development.

Acknowledgment

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MANUFACTURING OF PAVER BLOCKS FOR RURAL AREAS USING PLASTIC WASTE AND ITS PERFORMANCE ANALYSIS

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Abstract: *The management of solid waste has been evolving as a major challenge, both in the urban and rural areas, with its effect being more prominent in developing countries like India. One type of solid waste that is of global concern is plastic wastes. The degradation rate of plastic waste is very slow and many forms of plastic is even non-biodegradable. This project is mainly focused on exploring the prospect of using the non-recyclable plastic waste as a potential binding material for paver blocks production, which can be used for construction of pavements and roads in the rural areas. This can prove to be an effective waste disposal technique in the villages where there is lack of proper waste management system, besides being a cheap alternative to concrete paver blocks. The project aims at studying the volume and composition of waste generated in the rural areas. The waste collected will be segregated into recyclable and non-recyclable waste, from which the useful plastic waste will be extracted for subsequent treatment and construction of paver blocks. A number of samples will be prepared with varying proportion of the constituents and the samples will be subjected to further testing for determining their compressive and flexural strength.*

Keywords: *Non-recyclable plastic waste, paver blocks, waste composition, compressive strength, flexural strength*

1 Introduction

Solid waste management refers to the collection, treatment and disposal of solid material that has been discarded and is no longer of human use. It is a very important aspect of urban development. Municipal Solid Waste (MSW) is primarily generated from households, markets, hotels, hospitals, shopping malls, industries, etc. These wastes can lead to significant health problems and a very unpleasant living environment if not disposed properly. It can serve as breeding grounds for insect-vectors, pests, etc. that increase the likelihood of disease transmission and at the same time, it may pollute the water sources. Thus, the management of solid waste has proved as a global challenge that must be carefully tackled in order to create a sustainable environment. This challenge of solid waste management is further amplified in developing countries like India, due to unavailability of suitable waste management and disposal system. Moreover, rapid urbanization and exponential growth in population has contributed to increasing rate of waste generation in the recent times. (Kumar et al. 2019)

A major chunk of solid waste generated comprises of plastic waste. According to the annual plastic waste management report of Central Pollution Control Board (CPCB) for the year 2018-19, the total generation of plastic waste in India was 33,60,043 tonnes (CPCB Annual Report 2020:14). Such a huge amount of plastic waste creates problem in its proper disposal and puts tremendous load on the limited number of landfill sites available. Again, plastic, being a non-biodegradable material, pollutes the surrounding environment and affects human beings and animals in direct or indirect ways. Hence, there is an urgent need to utilize the generated plastic waste in a more judicious way that is both technically feasible and economically viable. One such area where plastic waste could be of great importance is in the manufacturing of paver blocks, used for construction of roadside pavements, parks, schools and office premises, etc.

Paver blocks are very versatile, aesthetically attractive, cost effective, durable and requires minimal maintenance. Presently, paver blocks are mostly manufactured using concrete, having some limitations like occasional failure due to excessive surface wear and variability in the strength of the block. But, with gradually depleting natural resources and the generated wastes from industries and residential areas increasing substantially, the current situation demands the use of some non-conventional and innovative materials in order to compensate for the depleting resources and thereby maintain sustainable development. Hence, the use of plastic wastes in lieu of cement in paver blocks may provide potential environmental as well as economic benefits.

From the perspective of rural areas, a lot of wastes are being generated in the villages nowadays. However, the waste management techniques applied in the rural areas are still old and traditional. The plastic waste management practices adopted by the households in the villages are mainly open burning, disposal in the backyard or in the pit, burying the plastics, reuse, and selling the plastic wastes to the recyclers. Among those activities, open burning is the key activity of disposal of the wastes in the rural areas. But, burning the plastics in unsafe ways will results release in toxic gases that effects the environment as well as causes various diseases such as reproductive abnormalities, cancer etc. On the other hand, if the waste was not burnt then, it was disposed in the backyard waste pits which is also not recommended. So, conversion of these waste materials into paver blocks can prove to be an effective measure for its proper disposal, which at the same time can be used for making rural roads and for other household purposes.

The primary objective of the present research is to utilize the non-recyclable plastic waste for making paver blocks as a means for reducing the environmental impact of plastics. In order to achieve this goal, the following sub-objectives are outlined:

1. Determine the viability of plastic paver blocks by finding out its compressive strength, flexural strength and water retention capacity, and comparing the corresponding results obtained with concrete paver blocks.

2. Find the optimum mix ratio of plastic, coarse aggregates and quarry dust for which the paver blocks exhibit the best results in terms of compressive strength, flexural strength and water retention test.

2 Literature Review

For this project, literature reviews are made to find out the environment impact of plastic wastes and its long term consequences. In the recent years, there has been several research efforts towards investigating the viability of employing plastic as a binding materials in paver blocks due to its superior characteristics like better elasticity, less brittleness, poor heat conductivity and more importantly, its environmental and economic impact in the long run.

Some of the literature reviews made for this paper are mentioned below:
Mahadevi et al. (2018) used PVC plastic in powder form to partially replace sand and made paver blocks, carrying out compression tests and water absorption tests. In this way, they addressed the major issue of plastic waste pollution in India. Since plastics take a long to degrade naturally, its use to make paver blocks helps in disposal of plastic wastes in an environmentally conscious way. (Mahadevi et al. 2018)

Lairenlakpam Billygraham Singh et al. (2017) made bricks and blocks from sand and plastic waste. The plastic waste used was derived from old CDs and discarded water bottles. The bricks thus produced had a waxy surface, and compared to traditional bricks, has lower water absorption, lower porosity and a high compressive strength. (Singh et al. 2017)

B. Shanmugavalli et al. (2017) replaced cement with plastic to make paver blocks and hence to reduce the cost of manufacturing the blocks. Plastic wastes in different proportions were mixed with quarry dust and coarse aggregate to form the blocks, which were then tested. (Shanmugavalli et al. 2017)

High density polyethylene (HDPE) and Polyethylene (PE) plastic wastes can also be used, as demonstrated by Dinesh.A, Kirubakaran. K et al. (2016). These are cleaned and added along with aggregate and sand at various proportions and made into paver blocks. These blocks possess thermal and sound insulation properties, as well as having high strength. This use of plastics solved the problem of accumulating plastic wastes to reduce pollution and to reduce cost of construction. Cost was reduced because plastic is abundantly available from wastes, and it also has the added advantage of less usage of sand and aggregates which often have to be dredged out of river beds or mined, thus further preventing pollution. (Dinesh et al. 2016)

Adding plastic to concrete has the added benefit of strengthening it, as was investigated by Manhal A. Jibrael, Farah Peter (2016). The compressive, splitting tensile and flexural strength tests were carried out in a time interval of 7 to 28 days. Waste plastic was added in proportions of 1%, 3% and 5% of the fine aggregate mix. It was found that when waste plastic was increased from 0% to 5%, the compressive and tensile strengths decreased while the flexural strength increased. The concrete strength decreased too as the concentration of plastic wastes was decreased. (Jibrael et al. 2016)

Ganesh Tapkire, Satish Parihar et al. (2014) studied how industrial wastes such as plastic pallets, carry bags, bottles containing Polypropylene (PP) and polyethylene Terephthalate (PET) could be used as substitute for conventional aggregate of concrete. The question was whether plastic wastes could be mixed with concrete in any form, without affecting much the properties or strength of the concrete. This subject was explored extensively in the research paper. Three proportions of plastic were used as a substitute for aggregate - 10%, 20% and 30% by weight of aggregate. (Tapkire et al. 2014)

Apart from plastic wastes, a few research papers also explored the addition of different waste materials in conjunction with concrete/cement to decrease costs and reduce pollution by using waste materials. S. Revathi et al. (2015) used groundnut husk ash as a replacement for fine aggregate in proportions of 0, 10%, 20%, 30%, 40%, 50% and 60%. Paver blocks were prepared using M40 mix with coarse aggregates, portland cement and fine aggregates (some of which was substituted by groundnut husk ash). Some tests were carried out like compressive strength test, water absorption and density test. (Revathi et al. 2015)

Another novel research paper by Koli Nishikant, Aiwale Nachiket, et al. (2016) explored using waste glass as partial replacement for fine aggregate. The waste glass was mixed in proportions of 15%, 30% and 45% to substitute fine aggregate, and then the properties of the concrete were investigated. The investigation showed that the inclusion of waste glass increased the compressive strength of the concrete product, and that waste glass can be used as a fine aggregate substitute without change in strength. (Nishikant et al. 2016)

Based on the above literature reviews, it can be concluded that plastic has the potential to offer many advantages such as:

- Plastic waste can be used as a substitute for fine aggregates (FA) in paver blocks, without compromising much on strength (compressive or flexural) and improving upon water absorption capacity.
- Plastic blocks can reduce the cost of manufacturing, weight of the blocks, as well as providing an effective way to dispose of waste plastic that would otherwise pollute the environment.
- Adding plastic as a binding material along with concrete in paver blocks has added benefits of strengthening of the block.

3 Experimental: materials and setup

The different materials used for the manufacturing of paver blocks are discussed below:

3.1 Waste Plastics

The Plastics are made up of different types of synthetic and semi-synthetic organic compounds. They can be moulded into different shapes because of their malleability properties. The plastics are strong and they are durable also. Hence, they can impart higher strength and they are light weight as well. These plastic polymers have longer chain of atoms bonded with each other. They are the polymers which are having higher molecular mass and containing other substance. Hence, these plastics can be used as a replacement of binding materials. (Mane et al. 2019)

3.2 Stone Dust

The Stone dust is the materials which are produced during the crushing of stones. The stone dusts are very fine in nature, and they can impart higher strength to the paver blocks. The stones dust can also provide good binding characteristics in between the materials during the manufacturing of paver blocks. Hence, they can be used as the replacement material of sand (fine aggregate). (Dhoke et al. 2020)

3.3 Coarse Aggregates

These Coarse Aggregates are the granular materials which are produced from crushed rocks having size greater than or equal to 5 mm. Normally, the size of the coarse aggregates is in between 4 mm to 10 mm. They are generally used in making concrete and construction work as well. The shapes and the grading of these aggregates are very important as they will give an impact on the

workability of the blocks. If the aggregates are in bad shape and poorly graded then, the blocks will have low packing density as compared to the good shaped and good graded aggregates. Because of the low packing density, more paste volume of plastics is required to fill up the voids in between the aggregates. The poor graded aggregates will increase inter particle friction; as a result, the workability will be reduced. The mixture having poor shaped and poor graded aggregates, they will require more materials in order to have the same workability like the good shaped and higher grade aggregates. Hence, right selection of the coarse aggregates can minimize the increase the amount of materials and ensure the adequate workability. (Chavan et al. 2019)

3.4 Manufacturing of the blocks

I. Preparation of the melting barrel

A waste oil drum is used in the construction of the melting barrel. Top plate of the drum is cut so that materials can be put inside easily. An aluminium cooking pot is also used in some cases for better handling and melting of the mixture.

II. Preparation of the mould

The mould used for preparation of the paver blocks for compressive strength is of Zig-zag Unipaver shaped, while the mould used for preparation of the blocks for flexural strength has a rectangular shape having dimensions of (100*100*500) mm^3.

III. Required proportion of plastic, aggregates and stone dust

Strength of the paver block mainly depends upon the mixing of its various constituents. Different proportions of the mixture are tried in this experiment and tried to evaluate the best mixture among them. Usually it contains more sand than plastic, because plastic acts as a binding agent to held the sand together. The following table (Table 1) shows the different proportions of the constituents used for making the samples.

Table 1: Composition of the paver block samples

Sl. No. of the sample	Batch Designation	Plastic waste (in kg)		Coarse Aggregates (in kg)	Quarry Dust (in kg)	Mix Ratio by mass
		MLP	Carry bags			
1	PB1	0.800	0.400	0.700	1.700	1 : 0.6 : 1.4
2	PB2	0.600	0.400	0.750	0.750	1 : 0.75 : 0.75
3	PB3	0.600	0.900	NA	3.000	1 : 2

IV. Selection of the required type of plastic

It is very important to select the correct type of plastic. This is due to the fact that different types of plastic melt and burn at different temperatures and have different physical properties. In this experiment we will be dealing with LDPE and MLP. Water bags, non-woven plastic shopping bags and plastic film are usually made of LDPE. While biscuits wrappers, chips packets are generally

made up of MLPs. Before using it we have to make sure that plastic waste is clean. All other plastics which are not LDPE and MLP should be omitted.

V. Heating of the materials

After lighting a small fire, the metal drum is pre-heated and then multi-layered plastics are added to it at an approximate temperature of 423 Kelvin. As a result of which, MLPs start to melt. During this process we have to make sure that the fire does not get too hot. MLP are then added in small amounts until all the required amount of it is melted. When MLP are in the condition of semi black coloured liquid type, low density polythene is added to it in the definite proportions. Stone dust and coarse aggregates are also added afterwards as required and well mixed. For better binding and fluidity of the raw materials, waste engine oil is also added.

VI. Mixing process

The constituents are thoroughly mixed until all the plastic has melted and there is a consistent black liquid (Fig. 1). Sometimes, LDPE lumps can remain even at very high temperatures. Hence, stirring and heating is continued until all the lumps are removed and a homogenous paste is obtained, since these lumps affect the strength of the blocks.

Figure 1: Molten mixture for filling in mould

Figure 2: Demoulded plastic paver block

VII. Filling material in the mould

The molten mixture is then transferred into the metal mould which had been cleaned before by using dry clothes. As the mixture is too hot, gloves are preferable during the transferring of materials. The mixture is transferred with the help of an iron rod.

VIII. Setting of the block

The metal mould along with mixture is then kept in the 15 tons baling press machine and pressed for around 30 minutes. After few hours, the paver block is removed from mould and allowed to dry for 24 hours so that it hardens (Fig. 2). The block will be ready to perform different tests on it once it gets hardened. The same process is repeated for different proportions of the mixture.

4 Laboratory testing

In order to determine the quality of the plastic paver blocks, compressive strength, flexural strength and water retention tests were performed on the blocks. The results obtained from these tests were compared with a standard concrete paver block, which would give an idea about the feasibility of the plastic paver blocks.

4.1 Compressive Strength Test

For each of the compositions, three specimens of blocks are taken to laboratory for testing and tested one by one. In this test, a paver block specimen is put under the Compression Testing Machine (CTM) and load is applied till the block fails under the loading. The ultimate load at which the block is crushed is taken into account. All the three paver block specimens are tested one by one and the average result is taken as the paver block's compressive strength for that composition. Similarly, three specimens of the remaining two mix ratios are also subjected to compressive testing and the average compressive strengths are determined. (BIS Precast Concrete Blocks-Specification 2011:12)

Figure 3: Setting of the block under CTM

Figure 4: Crushed sample after CTM testing

4.2 Flexural Strength Test

Tests are carried out on beam specimens of size 100 mm × 100 mm × 150 mm. The flexural strength test was performed according to IS: 516 - 1959 using two-point load method. The beam is placed horizontally such that the support system of Flexural Testing Machine (FTM) is spaced 5 mm from both ends of the beam. Load is applied centrally with the help of load gauge which is attached to the analog load meter. The load is transferred to the beam in the form of two-point load, which is generated with the help of a steel plate and two reinforcement bar placed beneath the plate in a continuous uniform manner without shock at a uniform rate of loading. The applied rate of loading should be continuous until the specimens fails under the applied load. The maximum recorded load will give the flexural strength of that particular sample. (BIS Methods of Tests for Strength of Concrete 2006:16-18)

Figure 5: Placing the beam under FTM

Figure 6: Plastic beam after flexural testing

4.3 Water Absorption Test

In this test, the paver blocks are first weighed in dry condition and then immersed in fresh water for 24 hours. After 24 hours of immersion, the blocks are taken out from water and the visible water on the specimens are removed with a damp cloth. Then the paver blocks are again weighed in wetted condition. The difference between the weights of wetted block and dry block is the required amount of water absorbed by the paver block. The percentage of water absorption is then calculated. The lesser the amount of water absorbed by the paver block, the better will be its quality. Good quality paver block does not absorb more than 5 percent of its own weight. As per IS 15658:2006, the average water absorption percentage of the blocks should be limited to 6 percent by mass and in individual samples, the water absorption should be restricted to 7 percent. (BIS Precast Concrete Blocks-Specification 2011:11)

Figure 7: Plastic and concrete paver blocks immersed in water for 24 hours

5 Results and Discussion

5.1 Compressive Strength

The results obtained from compressive testing of the plastic and concrete paver block samples are listed below (Table 2):

Table 2: Compressive strength results for the paver block samples

Sl. No.	Batch Designation	Sample	Compressive Strength (in N/mm^2)	Average Compressive Strength (in N/mm^2)	Compressive Strength of concrete sample (in N/mm^2)
1	PB1	1	5.321	5.101	37.689
		2	4.681		
		3	5.301		
2	PB2	1	7.716	7.472	37.284
		2	6.748		
		3	7.952		
3	PB3	1	7.586	7.343	38.500
		2	7.052		
		3	7.392		
Average				6.639	37.824

The key points worth noting from the test results are as follows:

- The compressive strength of the plastic paver blocks is lower than that of concrete paver blocks.
- The batch designated as PB2, having mix ratio of plastic, coarse aggregates and quarry dust as 1:0.75:0.75, provides the highest average compressive strength of 7.472 N/mm^2, among all three compositions considered for experimentation.

5.2 Flexural Strength

The results obtained from flexural testing of the beam specimens are shown in the following table (Table 3):

Table 3: Flexural strength results for the plastic and concrete beam specimens

Sl. No.	Batch Designation	Flexural Strength for plastic beams (in N/mm^2)	Flexural Strength for concrete beams (in N/mm^2)
1	PB1	0.8163	2.70
2	PB2	1.1574	3.20
3	PB3	1.1834	2.90
Average		1.0524	2.933

The key points notable from the flexural testing of the specimens are summarised below:

- The plastic beam specimens have slightly lower flexural strength as compared to concrete beams of the same size.

- Among all the three compositions of plastic beams, the batch designated as PB3 having mix ratio of plastic and quarry dust as 1:2, provides the best flexural strength result of 1.1834 N/mm^2.

5.3 Water Absorption Capacity

The water absorption shown by the paver block samples are as shown in the following table (Table 4):

Table 4: Percentage of water absorbed by the plastic and concrete paver block specimens

Sl. No.	Batch Designation	Percentage of water absorption by plastic paver blocks	Percentage of water absorption by concrete paver blocks
1	PB1	4.615	4.878
2	PB2	3.030	5.542
3	PB3	2.295	5.185
Average		3.313	5.202

The following points are worth notable from the water absorption test results as shown above:

- The plastic paver block samples provide better results with regard to water absorption test, as compared to concrete paver blocks.
- As per IS 15658:2006, the average water absorption percentage of the blocks should be limited to 6 % by mass, which is very well satisfied by the plastic paver blocks where the average water absorption is 3.313 %.
- The batch PB3, having mix ratio of plastic and quarry dust as 1:2, provides the best results in water absorption test of 2.295 %, among all three compositions considered for experimentation.

6 Long-term challenges and possible remedies

Burning of plastic waste has been a big challenge as it produces harmful gases, which may cause serious health hazards. Burning inorganic wastes in the open with uncontrolled fire is very dangerous. It may release many toxic gases, resulting in air pollution. Particularly, plastic waste may contain styrene and PVC, which may cause dangerous emissions such as styrene gas and highly toxic chemicals. The styrene gas can be absorbed by the skin and lungs. Toxic gases emitted by plastic waste burning can also cause cancer, asthma, and other diseases. Hence, there is some serious need to address this issue. In this regard, a few recommendations have been listed below:

1. Use of chimneys: Chimneys having customized filters that can trap the toxic gases produced by burning of plastic wastes can be used. A series of effectively designed filters can be used for better entrapment of the gases.

2. Use of eco-friendly plastic waste burner: The apparatus uses low-cost natural fuel such as coconut shell/fiber and sawdust for burning plastic, without the use of any other chemicals. The trick lies in pyrolysis of sawdust, which produces a large amount of heat, as high as 300 degrees Celsius. For treating the hazardous gases being produced when plastic burns, it is necessary to treat them with water, which will dissolve the harmful gases. (Somasundaran 2019)

7 Conclusion

Plastic is a very innovative material which acts as a binding agent when mixed with coarse aggregate and sand dust in its molten state. This property of plastic has been used in this project for manufacturing paver blocks. Although, plastic paver blocks have lesser compressive strength than concrete blocks, yet it can be effectively used in low traffic roads, footpaths, bus-stands and for domestic purposes. These blocks provide good heat resistance, better water absorption capacity, ductility, etc. Since waste plastic is used, it is cost effective when compared to concrete paver blocks. It also requires less time for manufacturing.

Apart from this, waste plastic has been posing a big threat to land as well as marine pollution since long time. Hence, if this process of utilization of plastic is done on a large scale, then it will definitely reduce these pollutions significantly. At the same time, it will restore the beauty and cleanliness of the environment. On a bigger picture, the viability of plastic wastes in paver blocks can open the doors for setting up of many small and medium scale industries in a small state like Assam, thus providing a boost towards solving the current unemployment scenario in the state.

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DESIGN OF PORTABLE WASTE SORTING DEVICE FOR SEGREGATION OF SOLID WASTE

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Abstract: *Smart Village concept is adopted by India to develop the villages. Solid Waste management has become a practical necessity in villages also. One of important requirement of smart villages is management of solid waste. Efforts have been made by villagers to convert biodegradable waste to compost. But from the survey and data collected it was found that the difficulty was faced during segregation of waste. In the paper a portable design was developed using CATIA V5 software. Different types of sorting machines are already available in the market. The proposed design can be fabricated in low cost and it will occupy very less space. The proposed design is for segregation of biodegradable and non-biodegradable waste. The biodegradable waste can be converted to vermicomposting and non-biodegradable waste is to be sorted and send to different buyers for recycling and reused. The main aim of the research is to make ecofriendly environment of the rural areas by managing the waste.*

Keywords: *Smart Village, Solid Waste, CATIA V5, Segregation*

I. Introduction:

A. Smart Villages: In India the as of 2019, there are around total of 664,369 villages, the development of India not only depends only on developing the cities but the villages must also be developed. Smart Village is a concept adopted by national, state and local governments of India, as an initiative focused on holistic rural development, derived from Mahatma Gandhi's vision of Adarsh Gram (Ideal Village) (Sinha et al 2016) (Garg et al,2015) and Swaraj (Self Reliance)(Gandhi 2010) . Sansad Adarsh Gram Yojana (SAGY) or SAANJHI) was launched on 2 October 2014, Gandhi's birthday Prime Minister Narendra Modi, in addition to Smart Cities and Digital India, as a development programme for India (digitalindia.gov.in, 2016).

In smart villages the improvement in education, health, agriculture, well-built connective of roads are given importance, also there is provision of creating a clean, healthy and sustainable environment. For creating a clean and healthy environment a proper waste management is needed. Effective waste management is a major challenge in areas with high population density. Despite the developments in waste management India is not able to manage the waste. A proper waste management system is to be developed to solve the current problem. The waste generated is not being properly sorted out and are being dumped in landfills.

B. Waste management techniques*:* Some of the common waste management techniques are-

Biological Reprocessing: In this process waste disposal is applicable to those of organic nature like plants, food scraps and paper products. Organic matter which goes through the biological decomposition process forms compost, which later can be used for agricultural purpose (MWMT, 2018). In villages this process is practised. Different types of compost are develop and use in agriculture in villages.

Dumping the waste: Waste is used for landfilling the sites. Waste is dumped in the landfilled sites. It is the most common way found in the developing countries.

Waste to Energy: Waste to energy conversion is a very efficient way. Heat or electricity can be generated from waste materials. The non-recyclable waste items can be converted into heat, fuel or electricity. Now a day's biofuels are obtained from wastes which are also sources of energy.

Bioremediation: It is an eco-friendly and cost-effective way to make the environment free of pollution using environmental friendly microbe. Toxic and hazardous wastes can be converted to non-toxic products using this natural degradation process. The limitation of this technique is that it takes a long time, and controlling the natural process of degradation can be hard.

Thermal Treatment Incineration: In this process waste material is converted into gas, ash and heat. Waste mass is reduced by 95 to 96% when processed through incineration plants. This process is suitable where there is a shortage of land. Particular weather condition is not necessary in this process. The energy produced can be used for many other useful purposes. In this process since there is no decay, occurrence of bad smell and the heat produced also destroys the harmful germs and chemicals.

Plasma Gasification: This process of waste management utilises highly ionised or electrically charged gases called plasma within a vessel to convert carbon-based materials into fuel. Treatment of hazardous waste by converting incinerator ash or chemicals into non-hazardous slag is done in this technique. The high temperature and lack of oxygen prevent the formation of toxin compounds like dioxins, NOX, furans or sulphur dioxide. This way of processing of waste is ecologically clean, converting solid or liquid wastes into a syngas (MWMT, 2018).

C. Sorting of waste*:* The main difficulty face in waste management is the sorting of waste where they are separated into different elements. Different techniques and devices are built for sorting of waste.

An attempt has been made Singh to develop a waste sorting machine, which is conceptualized to sort wastes into light materials, ferrous metals and other heavy materials. The machine is designed with the major components being the fan, the belt conveyor and the magnet. Tests carried out on the machine successfully classified wastes into light materials and heavy materials with inability to sort ferrous metals.

Segregation of waste is very important because if all the waste materials mixed up and the waste is used for landfilling then it will contaminate the land and water. Moreover if all the waste materials are done thermal treatment without sorting then poisonous gases may be released in the atmosphere. Therefore it is very much essential to sort the waste. Sorting the waste makes its useful otherwise the different process used for waste management become useless.

There are various methods of sorting the waste.
Manual sorting: It is the simplest sorting technique which is found in household and here materials can be sorted manually into several categories. Although manual sorting may be the easiest but its productivity is low (Yuan et al, 2015) and it may not be economical (Sadat et al, 2011). Therefore, it does not seem to be a suitable method in waste management.

Screen sorting: Different types of screens and sieves can perform waste sorting. Screening is certainly the most general and oldest sorting method based on physical size. In spite of the long history, it is not thoroughly understood. The efficiency and kinetics of screening based on different factors which have been studied. (Chen et al, 2010)

Magnetic sorting: In this method metal contaminants and the magnetic parts are removed from the other materials by a magnet. The method is based on the presumption that the magnetic force is greater than the gravitational force of the handled components.

Gravity-based sorting: The particles can be sorted according to their density differences. The most common ways for gravity sorting are centrifugal (cyclones), sink-float, and pneumatic sorting (Lupo et al, 2016).

Centrifugal sorting Centrifugal sorting is also known as cyclone sorting, due to the apparatus of sorting. It is used extensively in mineral processing and in the recovery of metals from vehicle recycling. The operation of the cyclone is based on centrifugal forces. When the particles are fed into the cyclone, large and dense particles are

forced against the wall and migrate downwards, while fine or low-density particles move upward to the overflow (Pita and Castilho, 2016).

Sink-float sorting: The sink-float sorting method sorts materials depending on their different densities in the process medium. The method is quite simple, but it may also be challenging if the densities of the materials are almost similar to each other. The intermediate density of the process medium must be between that of the sorted particles. For example, plain water is a suitable medium for sorting if the densities of the sorted materials are higher and lower than 1 g/cm3. If the densities are something else, innovative solutions for the process medium need to be applied (Serranti et al 2015)

Air-gravity based sorting In addition to centrifugal and sink-float sorting, there are sorting methods based on a combination of air and gravity. Examples of these are pneumatic sorting and an air table utilizing air as power in the sorting.

Flotation: Flotation was originally developed for ore sorting, and the principle behind it is based on the surface tension and hydrophobic properties of surfaces that have a contact with bubbles. The gaseous bubbles come to a contact with the hydrophobic particles and the particles are carried on the top of the flotation apparatus, from where it can be removed (Shent et al, 1999)

Electric conductivity-based sorting Electrostatic devices are used for sorting metal from plastics. (Richard et al 2017). There are a few typical separation techniques, which are based on electric conductivity, such as eddy current, turboelectric, and corona electrostatic sorting. It has been stated that electrostatic sorting may be economically problematic if the throughput is high (Bakker et al 2009).

Eddy current sorting Eddy current sorters (ECS) are some of the most significant developments in the recycling industry, the operability of which is based on the use of rare earth permanent magnets. It is a widely used sorting system for the recycling of non-ferrous metals from solid wastes, and it has been an effective sorting technology in recycling light metals from end-of-life vehicles (Amir et al (2016).

Triboelectrostatic sorting: In this method sorting is a method that sorts particles based on charging mechanisms, more exactly tribo series of materials through an electric field.

Corona electrostatic sorting Corona electrostatic sorting (CES) uses corona charging to sort materials based on the differences in the density and electric conductivity of the materials. An excellent case for corona electrostatic sorting is separation between metals and non-metal materials. The sorting efficiency is based on the electrode system, rotor speed, moisture content, and particle size (Huang et al 2009)

It is designed on the basis of manual sorting of this domestic waste or garbage into the various components.. It will be a very cost-effective, efficient and reliable, simple machine which can be manufactured and maintained by local artisans. It will only require a simple prime mover as a two-stroke engine to power its mechanisms which will perform some motions of a few degrees of freedom and vibration.

D. Aim of the Work: This works aims at developing solid waste sorting machines that could be useful in solving the waste management crisis in India. The waste sorting machine can be used for domestic purpose and in small hotels and restaurants. The sorting machine is portable and light in weight.

II. Preliminary Design of Waste Sorting Machine:

A waste sorting machine is designed for sorting the waste. The waste sorting machine is designed in CATIA V5.

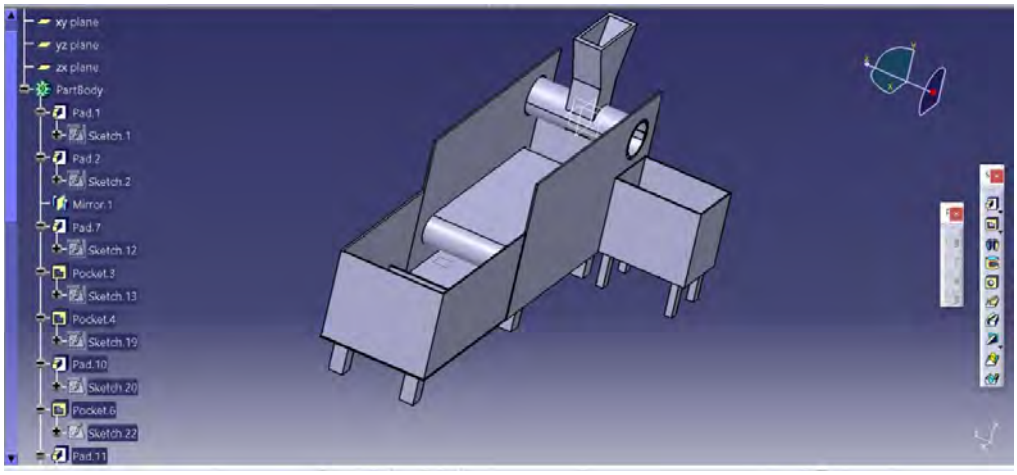

Figure 1: View of sorting machine designed in CATIA V5

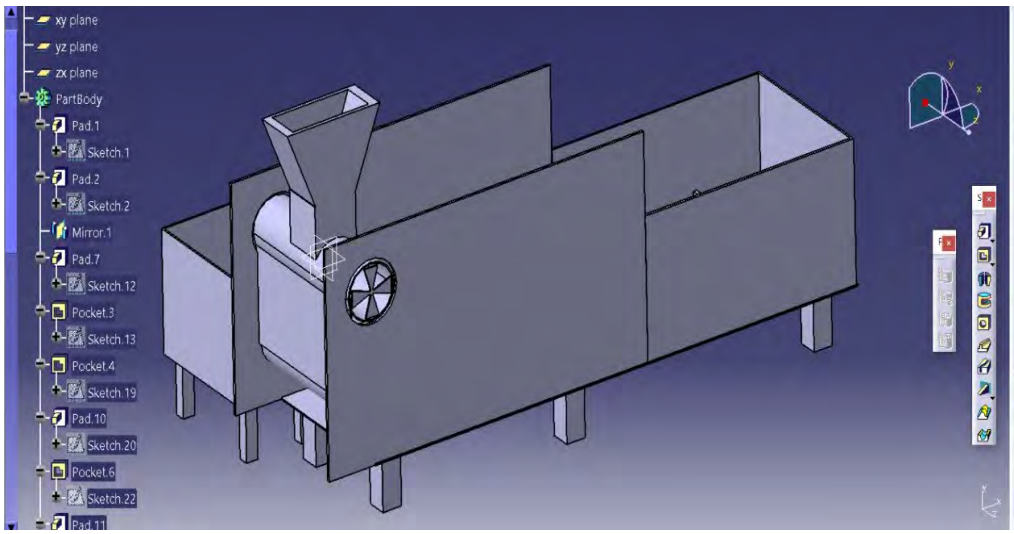

Figure 2: View of sorting machine designed in CATIA V5

III. System requirements

For Waste Sorting Machine

- Conveyor belt: Conveyor belt is the carrying medium of a belt conveyor system. A belt conveyor system consists of two or more pulleys, with an endless loop of carrying medium-the conveyor belt- that rotates about them.
- Pulley: Pulley is a wheel on a shaft that is designed to support movement and change of direction of belt or transfer of power between the shaft and the belt.
- Axle: An axle is a central shaft for rotating wheel or gear.
- Ball bearings: The purpose of ball bearing is to reduce the friction and support radial and axial loads.
- AC motor: An AC motor is an electric motor driven by an alternating current.
- Blower: A blower is used to blowing out the unwanted light weight particles.
- DC motor: DC motor is a class of rotary electrical machines that converts direct current electrical energy to mechanical energy.
- Magnet: A magnet is used to attract the ferrous materials in the waste matrix.

IV. Design and Basic Framework Calculation

A. Design of belt conveyor

Design of a belt conveyor is especially for the flat idler type. The cross sectional area of load on the belt or load stream area, is estimated using

Area, $A = 0.16B^2C \tan \Phi$ (Singh, 2000)

Where B= width of the belt which is selected to have.

C= a constant with a value between 0.85 and 1.00. A value of 1.00 is selected.

Φ= 0.35× static angle of repose of load

A value of 45° is selected to maintain the flow ability

The capacity of the conveyor is estimated using

$Q = 3600A\gamma\upsilon$ (Singh, 2000)

Where υ= conveying speed

γ= specific weight of the load in kN/m³

$= \rho g$

ρ = density in kg/m³

g= acceleration due to gravity = 9.81 m/sec²

The nominal volume capacity is estimated using (Singh 2000):

V = 3600× load stream area(A) ×belt speed(υ)

= Q/γ

B. Design of conveyor pulley and shafts

Design for conveyor pulleys and shafts for the belt width selected, the diameter of conveyor pulley drum, D. The rotational speed of the pulley, hence the speed of the shaft, which bring about the selected translational speed of the conveyor belt is evaluated as-

$$N=60v/\pi D$$

The torque produced around this force around the pulley of diameter 90mm is

$$T=P\times 60/2\Pi N$$

The power to be delivered to the conveyor belt through the pulley is

$$P=F_{all}\times \upsilon$$

C. Design for fan/air flow

Air is forced through a rectangular channel by a fan to separate light weight materials from the waste. The weight of the material is thus

$$W= (mA)g$$

The force of the air required to be delivered by the fan should be,

$$F=m\Delta\upsilon$$

$$=\rho A v\upsilon^2$$

Where, υ is the required velocity of the air stream.

To evaluate the minimum required velocity of the air flow,

$$\upsilon= [F/\rho_a A]^{1/2}$$

The volumetric flow rate, = Aυ

= (0.010×0.012×3.12) m³/s

= 0.000372 m³/s

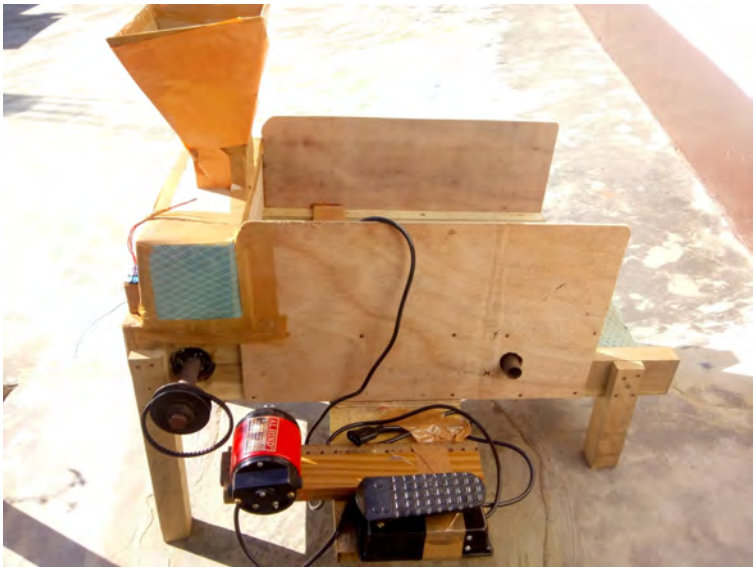

Figure 3: Side view of Prototype Model of Sorting machine

Figure 4: Top view of Prototype Model of Sorting machine

V. Results and Discussion:

A sample composed of household materials like paper, plastics, metal pieces, wood, dry leaves and vegetables was used to test the machine. The mass of the sample was measured using mass balance.

The waste used to test the machine was a sample obtained from a household waste. It consists of spoilable materials leaves and peels of vegetables, paper, plastics, sponge, and metal pieces. Waste sample with masses of 1kg and 2kg waste were used during the test. The masses of the materials that were sorted at each level were obtained and

the ratios of those masses to the initial masses of the mixed waste were evaluated. The average of these ratios was then calculated to know the relative composition of two types of waste in the waste stream. This was done for three replicates.

When the conveyor was operated, the fan was able to separate light materials from the waste stream. Metal pieces could separate by the magnet. Hence the waste stream was classified into light materials and heavy materials based on the sorting capability of the machine.

The results obtained from testing the mass of 3 kg.

Table 1: Table of results obtained from testing of materials for a mass of 3 kg

Test	Total Mass(in Kg)	Mass of light materials(in Kg)	Mass of heavy materials(in Kg)
1	3	1.11	1.89
2	3	1.15	1.85
3	3	1.12	1.88
4	3	1.17	1.83

The results obtained from testing the mass of 5 kg.

Table 2: Table of results obtained from testing of materials for a mass of 5 kg

Test	Total Mass(in Kg)	Mass of light materials(in Kg)	Mass of heavy materials(in Kg)
1	5	1.575	3.425
2	5	1.567	3.433
3	5	1.570	3.440
4	5	1.571	3.429

From the results obtained it was observed that the percentage of light materials found in the waste with total 3 kg was about of 37.5 % but was observed to be 31.5% when the total mass of the waste was increased 5 kg. The test conducted implied that the variation of the composition of the different samples was not very significant.

An average time of 3 min 25 sec was required to sort 5 kg of waste which contains 31.5% of light materials and time take to separate 3 kg of waste is 2 min 45 sec. Although the time recorded for separation for each sample was close, the relationship of the time of with the mass of waste component segregation shows an increasing time relationship. This may be due to light materials requiring more separation time when quantity increased.This can be improved to reduce the time needed to have the separation done more efficiently.

VI. Conclusion

A waste sorting machine has been developed which have been able to sort wastes from the household waste. The machine needs modifications of the magnetic end to efficiently separate ferrous metals from other metals. The machine can be manufactured at a well-equipped at a very low cost. Automation sorting machine for Smart Waste Management System is an excellent example of proper waste management. This portable machine can be used to install in household to sort the waste. It will ensure an effective recycling system. Since the machine is portable it will also take very less amount of space and can be installed in a very small floor space area. In household the amount of waste generated in daily basis is in low quantity. So this machine will be helpful to households.

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POSSIBLE TECHNIQUES TO MINIMIZE THE HOUSEHOLD-WASTE-MANAGEMENT PROBLEMS IN RURAL CHATTOGRAM

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Abstract:

Problem Statement- *This paper addresses the existing waste management gaps in remote areas and depicts possible opportunities and techniques in the management of different kinds of waste generated from a rural house of Chattogram.*

Methodology- *The study is based on literature synthesis which helped in the judgment of the drawbacks of the existing practice regarding household waste management. Primarily, the concepts of household waste management led to three techniques. These are on-site, curb-site, and off-site household waste management. The study was approached through a sustainable technique i.e. vermicomposting in the view to obtain a greater natural solution to the household wastes which would benefit the habitats in several ways in order to lead a healthy life.*

Findings: *The management of waste is a serious concern in rural regions especially owing due to a scarcity of adequate infrastructure and services for waste management in emerging and developing nations. Wild dumps are encountered owing to a lack of garbage and sanitation services in rural Chattogram. Uncontrolled dumping sites are frequently found in close proximity to homes and bodies of water. The dumps pollute the environment to a great extent (bio-diversity, atmosphere, moisture, and earth) that puts people's health at risk. Floating trash infiltrates marine and ocean ecosystems through polluting tributaries and rivers, lakes, and coastal regions. According to recent research, 1.9 billion people in rural regions have no garbage collection services available, and the remote population coverage rate in 105 nations is less than 50%.*

Originality/contribution- *Numerous research studies have focused on variety of techniques regarding household waste management. However, this study focuses on sustainable food production considering the benefits of proper household waste management of rural Chattogram.*

Limitations- *The study was executed solely on literature review and synthesis. The pilot investigation is necessary to analyse the socio-cultural impact and overall feasibility.*

Keywords: *waste management, rural sustainability, household waste, sustainable food production*

1 Introduction

Household waste is described as waste created by everyday activities in the dwelling. Rapid urbanization and demographic change have led to a tremendous rise in the quantity of rubbish produced around the world. In urban and rural communities alike, changing consumption patterns and lifestyles, including the increased use of goods made from non-biodegradable materials, have added to the problem (Mustafa et al., 2009). Moreover, improper waste disposal is one of the prominent issues in the rural Chattogram, which has an impact on the occupants' existing way of living (Flores et al., 2017). This is due to the rapid growth of the population. This paper is purposed to identify the present waste management needs in remote areas in rural Chattogram and depicts possible opportunities and techniques in the management of different kinds of waste generated from a rural house.

Waste is an unused or unavoidable product of human activity (Gajalakshmi et al., 2020). Bangladesh's 1995 Environment Conservation Act defined waste as “any radioactive material, solid, liquid, or gaseous whose emission or disposal may cause detrimental environmental impacts”. The word “waste” has attracted many definitions and description in research and application. Many researchers believe that wastes are garbage, undesirable, useless, broken, sludge, and abandoned materials resulting from man’s actions which include activities in industries, homes, commercial centres, institutions, construction and demolition sites (Azodo et al., 2016; Ozor et al., 2013; Leton and Omotosho, 2004; Anurigwo, 2000; Tchobangolus and Peavy, 1983; Avinash and Ruchi, 2007).

Waste management, on the contrary, has turned into one of the severe problems, especially in developing countries. Management of waste includes the gathering, conveyance, treatment as well as dispersal of discarded materials and substances (Unnisa & Rav, 2012). It is a major concern that Bangladesh's waste generation per individual by 2025 would be 0.75 kilograms daily, and the overall quantity of garbage produced would've been roughly 21 metric tons (average yield) (Ashikuzzaman. Md and Howlader. Md., 2019). However, Bangladesh is a country with a high population growth with 162.7 million people living in a territory of 1,47,570 square kilometres (1,115.62 people/sq.km) (BBS, 2018; Kormoker et al., 2017). With 23.3 % of urban people and 76.7 % of rustic inhabitants, the country's demographic increase is 1.37 percent (BBC Monitoring, 2019). As a result, consequences become critical when considering rural populations. This research aims to solve this problem by combining current practices with technical expertise to provide a greater nature-based solution such as. vermicomposting-which can be accepted and easily applied by the rural populations regarding waste management.

1.1 Aim and Objectives

The goal of this research would be to promote knowledge about the positive effects of inherent nature trash control through a disciplined technique in rural Chattogram so that people can live a long and healthy life and find new productive opportunities like sustainable food production. The study's objectives are to look at home trash management techniques in rural areas, to depict possible solutions in the management of rural waste, to point out a feasible solution regarding rural waste management for rural Chattogram,

and to align the findings regarding rural waste management which are being depicted through literature review, analysis, and discussion.

1.2 Organization of the study

There are three sections to this study. To begin will be doing a background investigation using a literature synthesis to determine the present issue and the best way to address it. This includes an analysis of relevant research in order to identify any gaps in existing practice regarding the population of rural Chattogram and efforts to depict possible techniques to solve them in the following part. To tackle the problem, the researchers include what they've learned from past investigations as well as their own ideas. The approach presented was developed by combining natural phenomena that are simply applied and understood by locals in order to tackle waste management issues. Finally, the discussion and conclusion help to bring the research to completion.

2 Literature Review

2.1 Literature Review

Hazardous garbage poisons significant regions of our globe and impacts the health of millions of people. Many people live in locations surrounded by rubbish and landfills, particularly in rural and remote areas where waste management is more difficult compared to urban areas. The three fundamental types of residential the waste management techniques outlined in the literature are curb-side, on-site, and off-site. Moreover, dwelling trashes vary depending on economic situations, seasons, in addition to the demographic landscape and geographic location of the regions (Birhanu et al., 2015). Higher-income areas, for example, produce more inorganic garbage, whereas low-income areas produce more organic waste (Viljoen et al., 2021).

However, waste volumes are affected by population density, socio-cultural characteristics, and seasonal considerations (e.g., changes in garden waste). Off-site, on-site, and curbside waste disposal are the waste/recyclables disposal strategies available to households, according to Ferrara (2008)'s conceptual framework (Ferrara. I., 2008). Figure 1 depicts these three methods of household trash management.

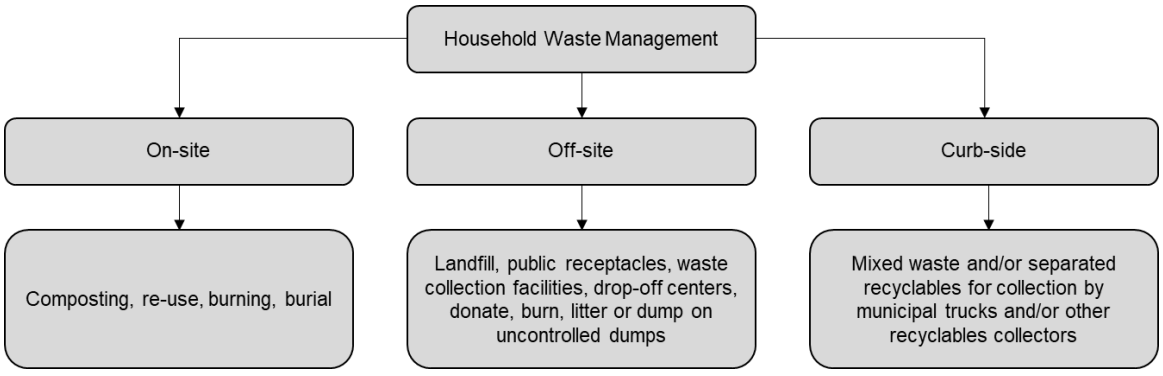

Figure 1: The trash maintenance options accessible to individuals and families (Serret and Ferrara., 2008).

Composting, recycling, repurposing, as well as burying or burning trash on one's own yards are all examples of residential trash management on-site (Moqbel et al., 2010).

Garbage collection and disposal at a distance (off-site) includes things like donations and transportation of sorted recyclables drop-off sites rather than dumping in a landfill or in public trash cans (Arena et al., 2003). Moreover, off-site trash/recyclables disposal also covers 'traditional' environmentally unfavourable waste disposal procedures including open-burning and refuse to dump in uncontrolled situations (for example, on roadways, in vacant lots, and beside riverbanks) (Ferronato et al., 2019). Further behaviours harm the environment, represent a health threat to the population, and need costly clean-ups by the local authorities (Hamilton, J. T., 1995). Curbside household waste management entails the collection of mixed rubbish and separated/sorted recyclables from households by the municipal government and/or other recyclers (Abdelkader Radi, 2018). The rubbish is turned over after pickup to the municipality or collector, who has the option of recycling, landfilling, or composting it (Talyan et al., 2008).

2.2 Techniques of household waste management

2.2.1 Techniques of household waste management

Residential sanitation works effectively in developing nations, however municipal composting has a high failure rate (Birhanu, 2015). High operating, managerial, and transportation expenses, inadequate quality of goods supplied because of inefficient sorting of garbage, and a lack of working knowledge of the composting process are all cited as reasons for municipal failures (Birhanu, 2015). Composting waste, on the other hand, as a waste management strategy, has a lot of potentials because municipal solid trash is largely organic stuff (Sharholy et al., 2007). Composting organic waste may be done at home, in the community, and in the city.

Furthermore, in most undeveloped countries, waste processing is rare or non-existent, making recycling and composting impossible (Ziraba et al., 2016). Hidalgo also discovered that rural populations' practices of using biodegradable debris as animal feed hamper centralized composting. In isolated rural areas, composting at the home and community level works best (Hidalgo et al., 2017). Use of natural materials as fertilizer (plant nutrients) at home can be helpful. Garbage must first be cleaned before being reused in its original condition for a similar or different function (for example, containers, clothes, and publications) (Birhanu, 2015).

In rural areas, particularly in lower-middle and middle nations, manure, agricultural wastes, timber, dust, newsprint, and carton are all recycled as power or warming sources. Animal feed is made from food leftovers such as meat and bones. Reusing recyclables is preferred to compost and recycling because it lowers pollution, conserves natural resources, and reduces the energy costs associated with creating new goods from recycled materials (Birhanu, 2015). Reusing, redistributing, and/or remanufacturing solutions are promoted in a circular economy since they are fewer expensive overall, as repairing a long-lasting commodity is always lesser expensive than producing it from the beginning (Milios, 2017).

2.2.2 Household waste management (off-site)

Preceding research has found that the gap between homes and garbage collection utilities has a major detrimental impact on household garbage disposal in China's rural areas (Wang et al., 2018). Furthermore, better access to drop-off recycling centres encourages households to recycle more (Serret and Ferrara, 2008). However, this does not apply to

all forms of recyclables in the U.S.A (Jenkins et al., 2003). The success of ecologically friendly off-site residential trash management is influenced by a number of additional factors. To ensure proper waste disposal, for example, emphasize the significance of several collection stations near houses (Wang et al., 2018). In addition, the authors discovered that inadequate garbage gathering systems in rural, distant, and underdeveloped locations will enhance the likelihood of emptying in open places, as well as a lack of knowledge (Niyobuhungiro and Schenck, 2020). (Abel, 2014). The possibility of dumping and littering increases when individuals are unaware of the precise position of the nearby trash collection services. There were demonstrations of either drop-off facility (off-site rubbish treatment) or curbside collection schemes to minimize recycling time and storage expenses (curb-side waste management). Curbside recycling initiatives, on the other hand, improve recycling rates higher as they reduce household expenses on transportation (Fischer et al., 2013).

In rural areas, door-to-door recycling gathering has indeed been reported to yield the best outcomes (Hidalgo, Martn-Marroqun, and Corona, 2017). Environmentally hazardous domestic garbage management activities such as cremation, open waste, and defacing pose problems for municipal governments across regions, cultures, and languages, according to research in advanced countries such as Japan (Sasao, 2015) and Australia (Comerford et al., 2018) and emerging countries like China (Wang et al., 2018), South Africa (Momoh et al., 2010). Agricultural and household garbage are frequently disposed of in poor nations by open burning and dumping (Mihai, 2017). As a result, there is more littering, unlawful discarding, concealing, smoking, stockpiling, and unregulated abandonment of such wastes as well as underutilized commodities (Hidalgo et al., 2017).

2.2.3 Household waste management (curb-side)

Leaving mixed household garbage/recyclables for pickup by the municipality/recycling business is one form of curbside waste management used by households. If waste is placed for curbside collection but is not collected, it is more likely to be burned or dumped (Mihai, 2017). Furthermore, littering develops dramatically in locations where cleaning is not done on a regular basis (Dur and Vollaard, 2014). In terms of access to trash services and service levels, there are significant disparities between geographic areas and municipalities (StatsSA, 2019). Households can help the recycling process by separating their recyclables from other trash and placing them on the curb for recyclables collectors, who recycle or sell them to recycling firms. Replacing is the method of transforming recyclables into various useful products.

It is classified into two categories: primary recycling and secondary recycling. Primary recycling happens whenever the initial recyclables are incorporated into a very identical type of substance, such as when the newspaper gets produced using reusable newsprint. The term "secondary recycling" focuses on the creation of goods that are not identical to the initial recyclable item. Newsprint made from recyclable cardboard is a kind of secondary recycling (Birhanu et al., 2015). Before new items can be manufactured, the recyclables must be recycled. However, recycling is profitable since the expenditures and ecological and social consequences of using recycled rather than new products are generally cheaper (Matete, 2009). Curbside recycling initiatives encourage homes to participate in the recycling process (Jenkins et al., 2003).

Although curbside recycling service is the most expensive, it is also the most convenient for homeowners (Matete, 2009). Mostly in lack of a curbside recycling process, waste segregation at the household scale would be relatively low for villagers who generally lacks professional abilities and the motivation to generate potentially tradeable things from their trash, which is crucial given the great distances to large recycling facilities (Volschenk et al., 2021). (Liebenberg, 2007).

Furthermore, it was shown that the regularity with which trash is collected had a beneficial impact on home environmental attitudes. Households will engage in garbage separation and classification if the pickup site for recyclables is handy and regular, as well as simple and quick (Serret and Ferrara, 2008). Households that charge for non-separated garbage pickup depending on the mass of the trash, the capacity of the trash container, or the regularity of gathering instead of the house's value or size of the real estate have better waste management practices (Hidalgo et al., 2017, Fischer et al., 2013).

Reuse and trash separation for recycling can help prevent improper garbage disposal, save power, conserve resources, lower waste collection, and disposal expenses, and preserve the environment (Mihai, 2017). In order to work towards better sustainable waste management systems and for a municipality that aspires to manage resources effectiveness, cycling, and re-use of commodities, it is indeed crucial to know the current garbage disposal procedures of both the town's households, as well as the issues they confront.

3 Composting Technique

Composting is a microbial mechanism that recycles nutrients and energy through the use of decomposers (Lazcano et al., 2011). Three of the foremost prominent forms of compositing used for the management of waste and natural biofertilizers are Composting methods include standard recycling as well as vermicomposting. The biological breakdown of biodegradable trash is known as composting that uses microbes (pathogens, fungi, as well as actinomycetes), wherein the biomass is transformed to Carbon dioxide, water vapor, ammonia, inorganic compounds, and a durable product (compost) (Senesi, 1989). Composting is probably among the more preferred waste management techniques, owing to a large number of active elements in most waste streams (Mohee and Soobhany, 2014).

Under regulated circumstances (temp, moisture, and acidity), the conventional bacterial breakdown of organic trash generates a treatment system that may be used in beautification, farming, and horticulture. When composting is done under controlled settings, it doesn't emit any smells and isn't attracted to insects or other animals. It contributes to the recycling of nutrients by restoring them to the soil. The higher the quality of the compost produced, the lesser the number of inorganic components that enter the process. Condensation and degradation may reduce the mass of organic materials by approximately half due to the significant relative humidity (Singh et al., 2011). Composting also helps to reduce pollutants and extend the life of landfills. If it can be done at a minimal cost, it is culturally desirable removing as much organic debris as feasible from dumpsters for recycling.

4 Vermicomposting technique and significance?

Vermicomposting is a sustainable technology (vermitechnology) that turns biodegradable materials into nutrient-rich biofertilizers that may be used by plants. It is a composting process that involves utilizing worms to transform biodegradable materials into higher compost largely consisting of worm cast and degraded organic matter (Devi and Prakash, 2015, Piya et al., 2018). It has been discovered to lower the content of heavy metals in contaminated feeding ingredients (Piya et al., 2018). Vermicomposting also assists in the conversion of biological pollutants (agricultural garbage, livestock waste, and domestic waste) into rich nutrient supplements for plants and ground (Gajalakshmi and Abassi, 2004). Vermicomposting technology, on the other hand, is a modern notion of using earthworms to manage an ecosystem for such efficient exploitation of organic waste (Ismail, 2004). On the contrary, it is indeed a cost-effective, quick, and ecologically beneficial waste disposal method. In the vermicompost process, urban garbage is successfully digested by earthworms, resulting in pathogen-free fertilize. By transforming organic waste into fertilizer through the vermicomposting process, waste material can be made more valuable. Although the nutrients in the fertilizer do not change significantly, the C/N ratio (carbon-to-nitrogen ratio) drops dramatically, allowing plants to absorb the chemical more easily.

Vermicompost also helps enhance soil quality and enhances soil structure for organic cultivation, and it plays an important role in environmental preservation since it uses waste as its basic ingredient. It is in line with the notion of a healthy environment because its values resource conservation and sustainable practices as a technique for handling organic residue, which is an alternative way to waste management that is not dumped or burnt but recycled (Aalok et al., 2008). The C/N factor is an important metric in the composting process that indicates the rate of decomposition, and vermicomposting has also been shown to dramatically lower the C/N proportion (Suparno et al., 2017). Vermicompost can help vegetables and fruits grow faster and produce more.

Furthermore, the grade of the mineral delivered influences the effect of vermicompost on plants. It also serves to control the growth of other components like plant growth hormones, as well as to improve soil quality by promoting microbial activity (Arancon and Edwards, 2006). Many advantages of using vermicompost include efficient conversion of organic waste, stabilizing soil conditions, assisting in the reduction of microbial pathogens and heavy metal toxicity, being a relatively simple and inexpensive economical technology, and serving as the most environmentally safe nutritional supplement for organic crop production (Suparno et al., 2017).

Earthworms, alternatively, are creepy, soil-dwelling critters. They are important in vermicomposting because they act as an adaptable nature's biomaterials, efficiently harnessing beneficial bacteria microbial activity and destroying ground bacteria while converting biodegradable waste into high - value products such as biomaterials, biocontrol agents, micronutrients, enzymatic, medications, and undisturbed parasite biomaterials. Worm composting is the process of transforming organic waste in to the manure under the activity of epigeic organisms (Singh et al.,2003). The material must first be partially broken down for the worms to consume it. Vermicompost refers to the deposition of epigeic organisms which have been grown on biowaste (Hemalatha, n.d.). A framework related to vermicompost depicts the overall process regarding vermicomposting (Figure 2).

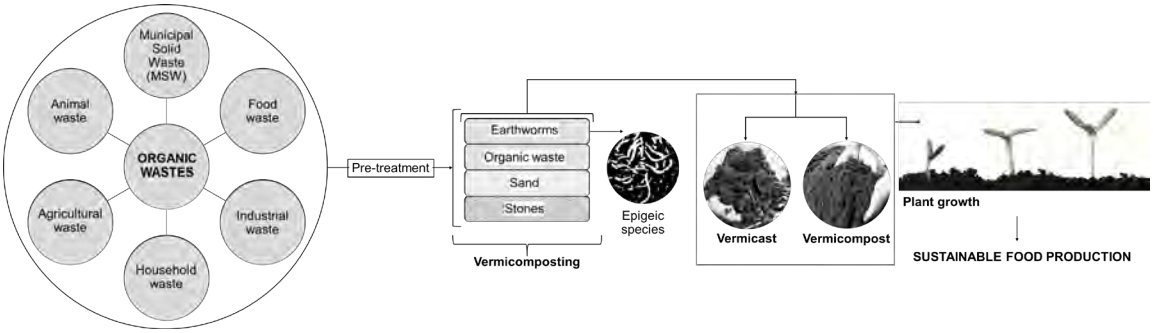

Figure 2: Steps required in converting organic wastes to vermicompost in general (Kiyasudeen et al., 2020).

The vermicomposting method is preferred because in vermicomposting technique, vermicompost has a better nutritional content than other conventional methods (Olle, 2019). This is owing to the presence of earthworms, which has enhanced the pace of mineralization and the degree of humification. Moreover, vermicompost also offers a lot of porosity, circulation, drainage, and moisture capacity. It is a necessity for plant growth due to the presence of microbes, particularly fungus, bacteria, and yeasts. Vermicompost also contains organic forms of nutrients including phosphorus and nitrogen, as well as phosphates, transferable calcium, and solvent potassium.

Agrochemicals as well as other microorganism-produced plant growth-influencing chemicals are also found. Earthworms have been shown to generate cytokinin's and auxins from inorganic waste. Earthworms emit a variety of by-products into the soil, including multivitamins and related chemicals. The castings have higher levels of potassium, calcium, phosphorus, and magnesium, which were not present in other processes. Trash handling, on the other hand, is regarded as a necessary component of a harmonious society, demanding the redirection of compostable waste from landfills and towards innovative planning techniques like vermicomposting (Joshi et al., 2014). However, it can boost crop output while also protecting them from pests without damaging the environment (Adhikary, 2012). As a result, the technology would serve as a cost-effective and environmentally beneficial solution for Chattogram's rural residents.

4.1 Benefits of vermicomposting technique

Vermicomposting using worms consist of several advantages such as 1) There is no pollution, and there are no odour or leachate issues. 2) Worms convert organic wastes to vermicompost more quickly than any other composting method. 3) It is a cost-effective and pollution-reduction technique in the industrial sector. 4) There is no need to utilize or manufacture polluting chemicals. 5) There are fewer risks to one's health. 6) National economy saves on subsidies (Hemalatha, n.d.). Vermicompost, like regular compost, benefits agricultural soil by increasing moisture retention, improving nutrient storage capability, improving the structure of the soil, and increasing the activity of microbes. Furthermore, compared to standard composting, vermicomposting produces a higher-quality product based on nutrient availability. Vermiculture technique provides a number of benefits, including being odourless, end up costing, and waste-free, as well as producing a valuable finished product (Singh et al., 2011). Vermicomposting might be a helpful technique for increasing phosphorus intake from a range of biological wastes (Ghosh et al. 1999).

Compost has more ammonium, while vermicompost contains more nitrate, which would be the most organic source of fertilizer (Broz, Verma, and Appel, 2016). Vermicomposting enhanced the method of raising a variety of minerals when compared to traditional composting (Hammermeister et al., 2004). Despite their variations, both processes are critical for nutrient recycling and soil health maintenance (Shak et al., 2013). Recycling centres and as well as researchers have also employed the combination of composting and vermicomposting to degrade various organic wastes, improve disease control, and produce excrement more quickly than any of the separate processes.

4.2 Benefits of vermicomposting technique

Table 1: Basic difference between composting and vermicomposting. (Lim et al., 2016)

No.	Criteria	Composting	Vermicomposting or Home composting
1	Definition	Microorganisms' biological oxidation and stabilization of organic matter degradation.	Vermicomposting is the biological degradation and stabilization of organic waste by earthworms and microorganisms
2	Active agent	Microorganisms	Earthworms and microorganisms
3	Type of process	Thermophilic (40-70℃) and Mesophilic	Mesophilic (25-40℃)
4	Major phases	1. Mesophilic phase 2. Thermophilic phase (45-65℃). 3. Cooling phase 4. Curing	1. Acclimatization 2. Hydrolytic 3. Curing
5	Characteristics	Microorganisms- major drivers of broken down organic matter	Earthworms- crucial drivers as aerators, grinders, and conditioners, finally increasing microbial activity
6	End product	1. Compost 2. Stable, humus-rich, complex mixture	1. Vermicompost and earthworm biomass 2. Stable, homogenous, humus-rich, and peat-like material 3. Disinfected and high nutrient content
7	Advantages	Sorting of waste and pre-composting not required, applicable on large-scale waste decomposition	Fast, economical, ecofriendly, zero-waste technology

4.3 Methods of vermicomposting

Rub worms are being used to convert biodegradable materials into nutrition compost, which itself is dark brown in appearance, which is a useful source of plant manure. Worms can also break down certain contaminants and may facilitate the establishment of beneficial microbial communities. The following are three commonly used vermicomposting methods:

- Bin composting: Bin composting is the most prevalent method for small-scale composting. The bin could be made of a variety of materials, including wooden/plastic/recycled bathtubs and barrels. The dimensions of a vermicompost bin can vary in size and shape, but the common measurements are 45 x 30 x 45 cm. Aeration and drainage can be achieved by drilling 10 holes in the bottom, sides, and cap of the bin using 1–1.5 cm diameter holes (Kaur, 2020).
- Pit composting: Pits 2.5m x 1m x 0.3m under covered sheds with edges left open are recommended for large-scale composting. A wooden mallet should be used to harden the bottom and sides of the pit (Kaur, 2020).
- Pile composting: In large-scale vermicomposting, the piling technique is preferable over the bin method. When vermicomposting a big amount of trash, is the preferred method, heaps are a cost-effective solution. In warm areas, the piles could be built in a porch, such as a greenhouse, or on a floor with drainage facilities. Although the pile size may vary much in breadth and length, it cannot be too high, and it is preferable to use the height of bin technique (Rostami, 2011).

5 Discussion

Waste management is a global issue that is growing increasingly complicated as a consequence of rapid population growth, industrialization, and changes in our lifestyles. The majority of rubbish is now disposed of in open dumps in emerging cities such as Chattogram or landfills in developed cities. The paper is depicted for rural Chattogram since residents in rural areas would gradually adapt to the new technique and contribute to the process on a regular basis (by family members). In contrast, in metropolitan Chattogram, the majority of households have a dedicated waste collection system (such as. house-to-house garbage service) which could lead to an inappropriate application and management of the proposed technique.

However, landfilling and open dumping both take up a lot of space and can cause a number of environmental issues. Because it is high in organic content and contains a substantial portion of recoverable fertilizers, household waste is excellent for land application. Field utilization is forbidden before treatment due to the existence of toxic substances and other harmful chemicals. Because the sludge formed at the end of the composting process is beneficial to plant nourishment and free of dangerous organisms, vermicomposting of rubbish prior to land application may be an effective waste management solution. By decreasing the need for mineral fertilizers and eliminating the problem of soil degradation, the use of compost generated from household waste in agriculture can help a country's economy flourish. Vermicomposting home waste can be useful since it recycles essential plant nutrients. This paper is primarily based on a research study, and the solution may be applied to a variety of contexts, with the application procedure varying depending on the demands. However, the research is restricted to literature study and present implementation in rural Chattogram.

6 Conclusion

Household trash disposal is a major issue all around the world. Landfilling is a time-consuming and costly operation that necessitates a large amount of land. Landfilling poses a threat to the ecosystem and people's health. Waste to energy is not an environmentally or ecologically feasible option since rubbish from developing cities (such as Chattogram)

has a high-water content and energy content. Although household garbage is abundant in organic compounds and contains a significant quantity of reusable organic fertilizers, it cannot be used without treatment because of the existence of poisonous substances and other dangerous substances.

Recycling these trashes is a possible option, but the resulting compost is poor in nutrients and requires time. Composting steady biowaste from both urban and industrial sources could be a viable option for waste management. The finished product is a microbe, odourless, and high in nutrient elements when compared to traditional compost. Composting will assist in the recovery of nutrient elements into the soil while also reducing soil deterioration in agriculture. Vermicompost application in farming will help with economics by reducing the need for mineral fertilizers and enhancing plant productivity. Using vermicompost as an organic component will also help ensure the ecosystem's long-term viability. There are limited study activities on worm composting of household rubbish and perhaps other green matter in underdeveloped countries like Bangladesh, Malaysia, Burma, Korea, and Indonesia. F

or entrepreneurs, this technology offers a lot of possibilities. Vermicomposting such pollutants will help to solve the problem of waste management while also regenerating the nutrients for plant growth and turning the debris into a usable commodity. Consequently, this paper on vermicomposting techniques would prompt architects, engineers, researchers, stakeholders, and policymakers to build a healthy environment through the implementation of sustainable waste management techniques in such regions worldwide.

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COMPULSORY LAND ACQUISITION PROCESS: CASE STUDY OF MANGALDOI HIGHWAY BYPASS

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Abstract: *The National highway number 15 transverses through Mangaldoi town under Darrang district of Assam, which is the part of a critical network of highways that connect the north-eastern part of India to the mainland. In the past few years, there has been an exponential growth of population in Mangaldoi town as well as in the rural hinterland, resulting in higher traffic volume and severe traffic congestion. Therefore a highway bypass was conceptualised by the Public Works Department, Government of Assam through a detailed engineering survey for identification of a feasible alignment and the submission of an economic road construction proposal to the Government of India. The accepted alignment is purposed to avoid the town and cut its way through the rural farmlands. The paper therefore discusses and highlights the measures taken by the government and its officials to compulsorily acquire various tracts of agricultural lands in order to make the highway bypass a reality. Emphasis is given on the administrative and legal processes including the grievances raised by the effected agricultural landowners. Finally the paper attempts to put forward policy suggestions in order to strike a balance between the need for rural connectivity and the personal hardships faced by landowners whose land has been compulsorily acquired..*

Keywords: *Land Acquisition, Mangaldoi Bypass, Compensation, Rehabilitation.*

1 Introduction

In the Indian rural economy, land is a vital asset and it is of great significance to the livelihood of farmers and agricultural workers as most often rural poverty is caused by unequal distribution of land (Mearns, 1999). Hence this study assesses land acquisition with its implication on rural sustainability. Quite notably, India has a population of 1.2 billion which leads to the fact that habitable lands in the country are densely populated even in rural areas and any compulsory land acquisition is likely to result in a substantial number of people being displaced (Morris & Pandey, 2007). Moreover, because underdeveloped land markets have tiny average holdings and poorly kept ownership records, every land transfer is a time-consuming procedure, which is exacerbated by the fact that land typically serves as a safety net in scarcity of industrial jobs or social security (Mearns, 1999). If future economic development is essential for poverty reduction, the growth will depend on the transformation of densely populated agricultural land even though there is a great risk that rural industrialisation might fail to reduce poverty. Nevertheless, the key lies in just and seamless process of land acquisition guided by sustainable planning of rural settlements.

Mangaldoi is the district headquarter of Darrang district in Assam. The National Highway No. 15 transverses through this busy town of Mangaldoi. A crucial stretch of the highway passes through an irregular cluster of rural areas interrupted by this small town that is designated as the district headquarter.

In the last few years, there has been an exponential growth of population in Mangaldoi District, resulting in higher traffic volume and severe traffic congestion. Therefore a highway bypass was conceptualised by the Public Works Department, Govt of Assam through a detailed engineering survey for identification of a feasible alignment and submission of an economic road construction proposal to the Government of India.

The final accepted alignment of the proposed bypass starts at km 26.40 and ends at km 41.505 on the southern side of the existing National Highway Number-15 as illustrated in Figure 1 (Email Communication dated 11.08.2020, Assam Public Works Department National Highways Division)

It passes through the following seven revenue villages, namely- 1)Boniyaojapara 2)SaruThekerabari 3)Chengeliapara 4)Barkumarpara 5)Kamarpara 6)Gerimari 7)Mowamari 8)Baghpari 9)Bandiagaon 10)Gelaidingi 11)Ondalajhar (Notification Dated 13.03.2020 under Section 3A of National Highway Act 1956) Total length of the proposed bypass is 15.10 km. (Email Communication dated 11.08.2020, Assam Public Works

Department National Highways Division)

FIGURE 1: Proposed Alignment of the Highway Bypass

2 Approach

The study in this paper is essentially doctrinal in nature as it takes place from a legal perspective. The objective of this paper is to highlight the statutory measures taken in order to commence the process of compulsory land acquisition. Having understood the significance of land acquisition for public projects and the underlying issues, this study aims to examine the land acquisition practice from a case study perspective. Due to ease of access and author's particular interest, the focus of the study is in Mangaldoi Town located in the North Eastern state of Assam in India. The most prominent sources of this paper are the statutory notifications released by the Central Government to make this project a reality. References are also made to the key legislations and significant court rulings that provide us with an explanatory framework of the compulsory land acquisition process as well as the subsequent compensation and rehabilitation measures. Finally a brief email correspondence dated 11.08.2020, with the Public Works Department, National Highways Division, Government of Assam gave me the necessary insights and inputs as wells as the crucial suggestion to pick Mangaldoi Bypass Project as the case study.

3 Hypothesis

Efficient land acquisition process can contribute to rural sustainability.

4 Effect of The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013

Despite several modifications over decades to the Land Acquisition Act of 1894, there was an unfulfilled need for a comprehensive national legislation that would provide for fair compensation when private land is compulsorily acquired by the Government for public use. The Central Government then resolved to introduce the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, as an all-encompassing legislation which would provide the mandate for compulsory rehabilitation and resettlement while simultaneously allowing the government to swiftly conclude the acquisition process of land for public purposes and thereby avoid escalating costs due to inordinate delays.

In addition to compensation, the 2013 Act also prescribes rehabilitation and relocation assistance to affected landowners. The compensation to be awarded to landowners is based on a multiple of market value and other considerations. The Act seeks to regulate acquisition if it involves multi-crop irrigated area. It also altered the rules for acquisition of land by private corporations or public-private partnerships by incorporating a clause for compulsory approval of 80% of the landowners. Other changes include a compulsory social-impact study that needs to be conducted before an acquisition is commenced. (Cernea, M. (2013)

5 Decoding the land acquisition process

Land Acquisition is undoubtedly the most critical, challenging and controversial first step for commencement of public infrastructure projects in India, which begins once the alignment and acquisition plan for a specific project is approved. The process starts with the appointment of a revenue functionary of the State Government as the Competent Authority for Land Acquisition (CALA) for each national highway project after which it commences to physical possession of the land by the implementing authority and finally the disbursal of compensation to each affected landowner.

The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (RFCTLARR), 2013 read along National Highways Act, 1956 are the principle legislations that deal with the process of land acquisition for highway construction in the entire country. The enactments seek to implement a more transparent and fair process for land acquisition keeping in mind the need for industrialization, development of essential infrastructural facilities along with improved connectivity in rural areas.

In a recent milestone, the Ministry of Road Transport and Highways, Government of India has unveiled "Bhoomi Rashi" as a single point online platform for online processing of land acquisition notifications to accelerate highway infrastructure development projects in India.

Bhoomi Rashi is aimed to fast-track the process of land acquisition and result in greater benefits for all stakeholders from the transparency introduced by the online portal in the land acquisition process.

Accordingly in this project, a 3(A) notification under National Highways Act 1956 for appointment of competent authority for land acquisition (CALA) along with a brief

description of the land was processed through the Bhoomi Rashi Portal of Government of India and subsequently notified in the official gazette of Government of India and Government of Assam on 13th March 2020. The said notification declared the intention of the Government of India for acquisition of land required for the bypass with a detailed description of the plot numbers, the type of land, the nature of land and the area required. This was also subsequently published in two local newspapers, one of which had to be in the vernacular language.

Several public objections were received by CALA under section 3C (Hearing and Objections) of the National Highways Act 1956 and the objections are currently being scrutinised for disposal.

A joint survey was conducted by revenue, water supply and power supply officials for identification and collection of details of landowners such as their names, addresses, phone numbers, identification numbers etc., which were then recorded against the land plots proposed to be acquired. Figure 2 and Figure 3 illustrate how the field level officials demarcate the patches of land that has been compulsorily acquired to form a part of the bypass road project.

FIGURE 2: Field officers demarcating the patches of land

FIGURE 3: Typical tools used for demarcation

Before issuing a final notification under section 3(D) under the National Highways Act 1956, an indicative assessment of the total cost of land acquisition based on prevailing market rates was submitted to the National Highways Ministry for scrutiny. If the indicative cost of Land Acquisition was found to be prohibitively high, appropriate changes in the project alignment/features was to be considered to bring down the cost of acquisition to an acceptable level which may include exploring alternate routes for the project or terminating the project altogether.

The competent authority for land acquisition then submits a report to the Central Government after disposing the complaints as per procedure and thereafter the Government of India declares the finalization of acquisition through 3D notification under the National Highways Act 1956.

After publication of 3(D) notification in the Gazette of India, the land vests with the Government of India (The Central Government) free from all encumbrances.

6 Grievances of the affected land owners

Complete details of the effected persons in this project were released by the Central Government vide notification dated 14th October 2020 under section 3D of the National Highways Act, 1956. In pursuance of any compulsory land acquisition process, these details are always released in a Section 3D notification through a table displaying the names of the effected landowners, extent of the land and the type of land (whether agricultural or not).

A bare perusal of the notification clearly indicated the usual trend in the profile of landowners and proved that most of the lands which have been compulsorily acquired are agricultural patches of different kinds with the owners mostly being farmers or closely connected to farming activities. This is an expected trend considering the fact that most highway bypasses traverse through rural hinterlands.

Various public petitions were submitted by some of the affected landowners. A petition dated 8th July 2020 submitted by one affected person highlighted his problem of having to lose his tract of land that holds his water and sanitation facilities of the house. In his petition he requested the government to consider an alternate route running through his own crop lands in which he emphasised that the difficulty would be minimal. (Public Objection No. 13 Dated 10.09.2020 received by Assam Public Works Department National Highways Division)

Another petition dated 8th July 2020 submitted on behalf of many other effected persons brought to notice the fact that the proposed bypass and the acquired land goes through a burial ground and according to them they won't have any alternate site to conduct burials in the future. (Public Objection No. 13 Dated 10.09.2020 received by Assam Public Works Department National Highways Division)

7 Compensation and Rehabilitation measures

The cost of compensation under Section 3(G) of the National Highways Act 1956 will be finalized by the CALA taking into account the following considerations:-

a) The market value of the land on the date of publication of the notification under section 3(A)
b) The damage, if any, sustained by the landowners at the time of taking possession of the land, by reason of the severing of such land form other land.

c) The damage, if any, sustained by the landowners at the time of taking possession of the land, by reason of the acquisition injuriously affecting his other immovable property in any manner, or their earnings.
d) If, in consequences of the acquisition of the land, the landowner is compelled to change his residence of place of business, the reasonable expense, if any incidental to such change.

Relief and rehabilitation measures as prescribed by the RFCTLARR ACT 2013 will also have to be considered while proceeding with the land acquisition exercise.
Measures to determine the value of compensation under this project is currently under process. The process is being executed by the District Collector's Office and other revenue functionaries in the district.

Figures 4 and 5 illustrate how the field level officers assess the quantum of compensation and rehabilitation package to be awarded to the affected landowners. Efforts are made to arrive at a commensurate amount by measuring the extent of land and structures therein, determining the market value as well as making a rough estimate of the hardships caused.

FIGURE 4: Assessment measures undertaken by field officers

FIGURE 5: Assessment measures undertaken by field officers

8 Evolution of land acquisition policy in India

Some landmark court rulings such as Golden Iron and Steel Forging v. Union of India (CWP No. 11461, Punjab & Haryana High Court) and T Chakrapani v. Union of India (WP No. 15699, Madras High Court) had held that the effected persons were held entitled to additional solatium, interest and additional market value for delay in compensation and rehabilitation, bringing if not complete but great respite to the effected persons. This was subsequently incorporated by the executive government in NHAI handbook. The competent authority in this project is also preparing to provide the same.

Another noteworthy development is the adoption of the one-stop online platform for all land acquisition processes named as 'Bhumirashi' under the aegis of the Ministry of Road Transport and Highways, Govt. of India. This is expected to improve transparency in land acquisition and it has been used extensively in this particular bypass project as well.

In a recent policy overhaul, a large number of highway construction projects are now done as public-private partnerships (PPPs) that involve the join collaboration of the government and private corporations in building highways and maintaining them. However, in those cases quite expectedly, the costs of land acquisition will increase owing to the procedural complexities of land acquisition associated with PPPs particularly due to the requirement for additional regulatory approvals such as social impact assessment.

It is widely agreed that if the country is to reach its full growth potential and if the rural population's poor economic position is to be alleviated, the trend of urbanisation must be hastened. For the benefit of sustainable rural development and in order to avoid disorderly urbanisation, spatial planning must be implemented, and spontaneous urban sprawls must be avoided. Urban sprawls are known to cause low-density urbanisation and have a proclivity to consume vast sections of cropland and industrial areas.

Even if the urbanisation strategy is improved, the increased demand for land would undoubtedly put immense strain on agriculture. A total of 31.1 million hectares of additional land for targeted urbanization in the country cannot be obtained without encroaching on agricultural lands. If farmland is used to meet the full demand, the net planted area will be reduced by 22%. Assuming that farmland will provide at least half of the demand, cropland will account for 11% of the net planted area (Ellis and Roberts, 2016). The protections in the LARR Act of 2013 against the purchase of agricultural property are quite important. Even though, it may be eventually impossible to prevent farmland loss due to urbanisation in the next decades. It should be noted, however, that greater productivity as well as multiple cropping may be able to compensate for the loss of agricultural production. Although there is room for modest irrigation development, the outlook has been harmed by the threat of climate change. Climate adaptation will need the use of micro-irrigation (drip and sprinkler irrigation) to preserve water while increasing agricultural productivity to compensate for the loss of farmland.

The land acquisition rules that India inherited from colonial times were clearly highly weighed in favour of landowners and other persons who rely on property for a living. By contrast, the Land Acquisition, Rehabilitation, and Resettlement (LARR) Act of 2013 considerably increased the size of compensation available to landowners, as well as providing for their rehabilitation and resettlement (R&R) in the case of displacement. Compensation payments and rehabilitation rights have been made available to sharecroppers and others who rely on land for their livelihood. The openness of the land acquisition process has been greatly improved thanks to social impact assessments and, in some circumstances, prior agreement from landowners and other impacted parties. They are not only compensated more, but they also have a voice in whether land acquisition should be done at all if it involves private players. There are also safeguards in place to prevent large-scale agricultural land acquisitions that might reduce food production and jeopardise food security. The above-mentioned developments have definitely resulted in a balance of government authority as the protector of public interest and private landowner rights. While landowners and other impacted parties have benefited

significantly, some of the rules might prove to be stumbling obstacles in the development process. Most people are reconciled to the increase in compensation and to the additional cost of rehabilitation as these are construed to be provisions justified from the point of view of fairness and equity, even though there could still be a fall-out on the process of development due to the increase in the cost of infrastructure, for instance. There is also considerable worry about the impact that the newly implemented social impact assessment and prior approval processes would have on infrastructure development, industrialization, and urbanisation. To address these issues, the central government had submitted an amendment bill in 2015 that sought to alter the land purchase legislation in a number of ways. The most significant changes sought were to relax the requirements of prior consent, social impact assessments, and restrictions on the use of agricultural land for five types of projects in the areas of national security, rural infrastructure, affordable housing, industrial corridors and infrastructure, and social infrastructure. The bill is still in the stage of deliberations.

9 Conclusion

The proposed bypass is eagerly awaited by the people of Mangaldoi Town as well as the adjoining areas. The construction of this project is all set to commence from April 2022 with the acquisition process in its final stage. Its estimated completion date is March 2025. Once completed, it is anticipated to bring sweeping development to the region by ensuring better connectivity to entire North-Eastern Region of India and therefore it has earned its place as a high priority project for the National Highways Authority of India (NHAI). However, just like every other key infrastructure projects involving acquisition of land, this one has also led to a certain extent of hardship for some affected sections of people. Even though the process of compensation and rehabilitation is underway, it remains a long and tedious task. It is evident that the concerned district functionaries are over-burdened with many other routine tasks which very often hinder the process of timely compensation and rehabilitation of the affected sections.

While addressing the question of how efficient land acquisition process can contribute to rural sustainability, the core problem lies in the absence of information regarding property valuations. As previously stated, the Land Acquistion Act 2013 requires compensation to be equivalent to the asset's market price with additional solatium. The process of determining market value, on the other hand, is extremely complicated and prone to mistakes. As a result, the compensation that is formally awarded eventually faces litigation.
Some studies have offered strategies to overcome the problem that arises from a lack of knowledge on property assessments (Gangopadhyay 2011). The proposed schemes call for the state to decide on the type and amount of compensation by considering differences in quality, location, and other factors concerning the type of land surrendered by the owners in the execution of rehabilitation and relief packages. All things said it is henceforth concluded that striking a perfect balance between the need for rural development and rights of the rural landowners is difficult but certainly achievable and this would contribute immensely to rural sustainability.

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STUDY OF RURAL INFRASTRUCTURE FOR SMART VILLAGES

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Abstract: *Good infrastructure contributes to economic development by increasing productivity and services in the area which enhances the quality of life. Focusing in the Northeastern region of India where a large section of the population live in rural settings. Assam being one of the most populated states in the region, with over 86% rural communities of a total population of 35 million, where Housing and infrastructure are two critical aspects that need heed in this overall development of villages. The idea for creating smart villages is highly significant for promoting sustainable growth and overall development of the entire region. For smart villages, development is needed in both rural and urban areas for improved livelihood. In rural areas, it is necessary to provide access to basic infrastructures like road networks, drinking water networks, sewage and waste, and good education and health facilities. Assam being an agrarian economy, Road networks and irrigation infrastructure is very essential. By developing infrastructures like road networks in rural areas and implementation of irrigation will increase the productivity of the agricultural sector which will result in the economic growth of the entire country. In this paper, the significance of infrastructure is highlighted in the context of Smart Villages. A case study focusing on Assam revealed that poor quality of infrastructure not only hinders growth but also impacts negatively on the lives of people.*

Keywords: *Rural Infrastructure, Smart Village, Agriculture, Economy of villages, Sustainable Development .*

Introduction: Assam is located in the Northeastern region of India. Guwahati is the capital of Assam which is known as the Gateway of North-east. Assam has a population of 3.12 cores as per the 2011 census. The growth rate during the decade was 17.07%. The rapid growth of the population has resulted in demands for housing and infrastructure(Doloi et al,2017). Infrastructure plays a vital role in the development of the country. Over 65% of the people of India live in rural areas and 35% live in urban areas. Therefore the development of rural Infrastructure like road networks, housing, water network, irrigation systems will play an important role in the development of the country. Rural areas of Assam lack sufficient roads that would increase access to agricultural input and markets. Poor infrastructure hinders communication, resulting in social isolation among the rural people (Hussain et al,2020). Agriculture is the main livelihood in the villages of the country. Over 50% of the population in India depends on Agriculture. Consequently, Agriculture is very important to the Indian economy. Which is directly proportional to the development of the rural Infrastructure. The development of the irrigation system in rural areas of the country will impact the agricultural sector. In 2013-14 only about 36.7% of total agricultural land in India was irrigated (The World Bank,2013) and the remaining 2/3 cultivated land in India depends on the monsoon. There is a clear need to provide basic infrastructure in rural areas, such a development will vastly improve the lives of the population from rural areas.

1 Rural Infrastructure: Infrastructure is the backbone of the country. It plays a major role in developing the economic growth of the country. Rural Infrastructure in the country encompasses rural road networks, irrigation and drainage systems, rural water suppliers, and electrical networks. A brief overview is provided to highlight how different sections of rural Infrastructure play their role in improving the rural economy as well as the life of the people.

1.1 Road Networks: Roads are arteries of the nation and provide the much-needed infrastructural push for social and economic growth. The absence of all-weather road connectivity is a serious problem in the country, particularly in rural areas. Poor road infrastructure affects economic growth, agricultural productivity and employment in rural areas, and has a strong link to poverty. Rural road Infrastructure provides connectivity to people living in rural areas. It also provides a much needed boost to the agricultural sector by making available water, seeds and other raw materials used for the agricultural sector. Developed rural roads also enhance employment opportunities for people from rural areas in the non-agricultural sector(Mazumder,2020). Rural roads ensure that the rural areas are served with all the benefits offered by the State Government. Roads can provide better access to educational and health care services to rural people. Rural road connectivity is a key ingredient in ensuring sustainable poverty reduction in the rural areas of Assam. In India, “Pradhan Mantri Gram Sadak Yojana (PMGSY)” is Improving rural connectivity, by providing all-weather roads to connect eligible habitations in rural areas. The share of various types of roads of India is shown in Figure 1. (National Rural Infrastructure development Agency,2011)

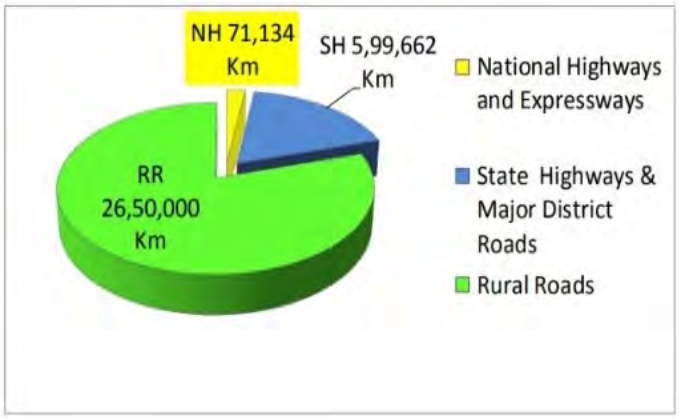

Figure 1: Share of different categories of roads
(source : Ministry of Rural Development, Rural roads,2011)

1.2 Rural Housing: Rural housing infrastructure has the potential to improve the standard of living of the people. In India, "Pradhan Mantri Awas Yojana (PMAY- Gramin)" is Providing Housing for All by 2022, PMAY-G aims to provide pucca (permanent) houses and other basic amenities such as piped drinking water, power supply and Liquefied Petroleum Gas (LPG) connection in convergence. (Business today,2015)

1.3 Water supply systems: Rural Water Supply Projects for providing drinking water supply facilities in Rural Areas of the state. It can lead to sustainability of systems and sources to tackle the problem of water quality, thereby increasing the good health of people. In India," Jal Jeevan Mission (JJM)" Providing Functional Household Tap Connection (FHTC) to every rural household by 2024 (Ministry of Jal Shakti).

1.4 Irrigation: Irrigation is the artificial or mechanical process of application of controlled amounts of water to land for better production of crops. Irrigation helps to grow crops in dry areas and even during the period of less rainfall. In India " Pradhan Mantri Krishi Sinchai Yojana (PMKSY)" is Providing access to some means of protective irrigation to all agricultural farms in the country - to produce 'per drop more crop'. Thus bringing much desired rural prosperity (NABARD).

1.5 Energy or power network: Electricity is an essential requirement for all facets of our life. It has been recognized as a basic human need. It is a critical infrastructure on which the socio-economic development of the country depends. It is fulfilling the requirements of agriculture and other activities including irrigation pump sets, small and medium industries, village industries, healthcare and education. The Government of India has launched the scheme "Deendayal Upadhyaya Gram Jyoti Yojana" for rural electrification. As of April 1, 2015; there were 18,452 villages that still remained then un-electrified (Ministry of power).

1.6 Internet and telecommunication: The Indian telecommunication sector has grown rapidly in the last few years. India has the second-largest telecommunication network in the world. Teledensity in rural areas is 56.87 percent whereas 173.72 percent in urban areas. The Government of India's "Digital India " initiative acts as a catalyst in India's

development in the internet and telecommunication sector (*Electronicsforu,*2021). This initiative encompasses offering the internet to all by promoting digital literacy, building robust infrastructure, delivering Innovative content and services from web and mobile platforms.

2. Smart Villages: Smart Villages refers to a concept developed in rural areas that provides solutions to problems occurring and improves the quality of life in rural areas (Doloi at el,2019). Smart Villages is a relatively new concept for developing rural communities. It will boost the economy of the entire country. The main aim is to smarten the Villages by offering basic facilities, good infrastructure, better healthcare and educational systems. The concept of Smart Villages is adopted by the Government of India, as an initiative focused on holistic rural development, which is derived from Mahatma Gandhi's vision of "Adarsh Gram" and "Swaraj" which means Ideal villages and Self-reliance respectively (Raut et al,2015). On 2 October 2014, The Prime Minister of India launched a program called "Sansad Adarsh Gram Yojana " which is a program focused on the overall development of villages. India's first Smart village is “Bari” which is in Rajasthan. The village is situated 30 km away from the Dholpur district and 248 km from Jaipur. The population of the village is about 2,000. Figure 2 gives the overall concept of a smart village framework.

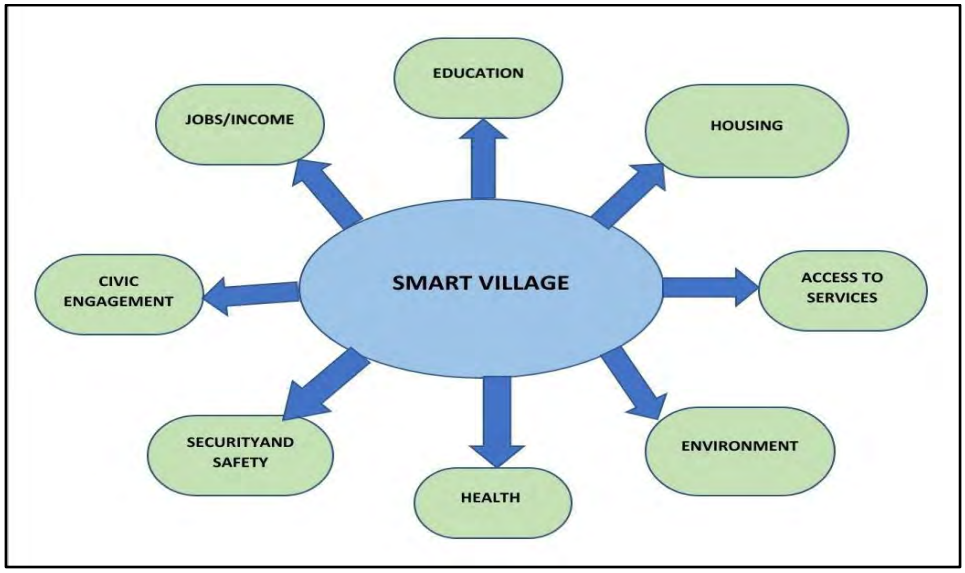

Figure 2: Ideal smart village framework.
(Source: Doloi et at 2019a: Planning, Housing and Infrastructure for Smart Villages, Routledge, UK)

3. Objective: The key objective is to study various rural Infrastructures and development of Smart Villages. The main scope of the study is to highlight the current situation of the various infrastructures of the village and the various works done by the Government to improve the livelihood of villagers.

4. Approach: The approach of the study includes the review of papers on existing approaches of Smart Villages and Rural Infrastructure. This study also includes a case study in Assam for understanding the current state of the infrastructure provisions and highlighting the underlying gaps and priorities from a community perspective. The study

also includes the basic concept of Smart Villages in India and various types of rural infrastructure.

5. Case studies:

Bamuni village, Nagaon, Assam: The study of Bamuni village is taken to understand how the existing situation of this village can be modified with the help of modern technological intervention for the holistic development of the village. Bamuni is a medium size village located in Nagaon district, Assam with a total of 302 families residing. The Bamuni village has a population of 1387 as per population census 2011. Agriculture is the predominant economic activity of the people of the state of Assam. The economy of the Bamuni village is agricultural based, with most of the people engaged in it. Bamuni has two tea estates, one is the Kondoli tea estate and the other one is the Dhontula tea estate. It is one of the backward and underdeveloped villages of Nagaon. Economic stagnation, poor standard of living, lack of basic Infrastructure and environmental disasters are some of the reasons for this underdeveloped village.

Figure 3 : Map of Bamuni village (Source: Google Map)

5.1 Infrastructure of the village: Infrastructure plays a crucial role in not just the country's economic growth but also its progress in human development. The infrastructure of Bamuni village is very poor and lacks basic infrastructures like All-weather roads, Pucca housing, drinking water network and irrigation facilities.

Road networks: Nagaon is well connected by road links. The National Highway No. 36 and No. 37 provide easy access to important places in the Nagaon District. Road Distance from Guwahati to Nagaon Town is 123 Kilometres. Road networks provide 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. In Bamuni the condition of the road is very poor. The Road which connects the village to National Highway no 37 is not well maintained by the authorities. There is a lack of all-weather roads Which makes the economic situation of the village weaker. The Roads in the village are maintained by the Gram panchayat. There are two tea gardens in the Bamuni village and one tea factory for manufacturing. But due to poor road conditions it is

not easy to export the tea to other parts of the state. The current condition of the village road is shown in Figure 4.

Figure 4: Road which connects the village to NH 37

Housing : Housing is a basic necessity which provides shelter, safety, security and comfort. The Government schemes for housing i.e., Pradhan Mantri Awas Yojana (Gramin) have not completely reached the village. There are only a few people living in pucca houses. The housing conditions in the village have not improved much. Most of the houses are with thatched roofs. These houses are not safe for living, highly vulnerable to rainfall, wind blow, fire and many other accidents. Many improvements need to be done to provide better housing facilities to the Bamuni village. There is a clear need of development in the housing sector of the village for better livelihood of the rural people. Figure 5 shows the bam

Figure 5: Houses which are not under Pradhan Mantri Awas Yojana (Gramin)

Irrigation infrastructure: Irrigation plays a vital role in development of rural economy. It determines the agricultural productivity of a region. Almost 90% of the people of Bamuni are engaged with agriculture, most of them dependent on the monsoon. Proper irrigation is essential for rural development. The availability of assured and timely water supply is an important condition of modernization of agriculture. There are some deep tube well powered by solar energy which are provided by the irrigation department of the

Government of Assam. But there is a clear need to increase the number of tube wells for irrigating overall cultivable land in the village so that all the farmers of the village can cultivate during both seasons and get more profit. This will increase the productivity of the village and economic growth.

Figure 6: Irrigation infrastructure of the village Bamuni

Power and Energy: Energy infrastructure is very important to bring electrical power to a particular area. Power and energy sector in the village is rapidly growing in recent times. The village has a 15 Megawatts solar power plant. Which is helping the other nearby villages with solar energy. Solar energy is naturally more sustainable than fossil fuel energy sources and environmentally more sustainable. The 15 MW solar power plant is shown in the Figure 7 below.

Figure 7: 15 MW solar power plant of Bamuni village

5.2 Benefits of developed rural infrastructure: Infrastructure plays very important role in a country's economic growth and its progress in human development. There is a clear need to provide basic infrastructure in rural areas. such a development will vastly improve the lives of the Indian population living in rural areas. Economic development of the state depends on the production of the state. The government had been making continuous efforts to develop the already existing agriculture based economy and to improve the other sectors of the economy in the state of Assam. Tea is considered as one of the main agricultural produce in the state and is reputed all over the world for its aromatic quality. Developed Road Infrastructure helps in the economic growth of the entire country. Road networks provide a much needed boost to the agricultural sector by making available raw

materials and seeds. Rural roads ensure better public services offered by the Government. Irrigation infrastructure ends the uncertainty of water from rainfall and providing water in all seasons will improve production level and agricultural productivity. Therefore good Infra is necessary for economic growth of the country and better livelihood of rural people.

5.3 Following points are as per the conversation with some villagers :

• The infrastructure sector in the village (Bamuni) is rapidly growing within a short period of time.

• Due to the developed Irrigation sector in the village the villagers can now cultivate their land in both seasons i.e., Kharif and Rabi. Nowadays villagers don't need to depend on rainfall. They can manage the required water from the tube wells provided by the Government. Figure 8 shows the current condition of agriculture of Bamuni village using irrigation systems provided by the Government.

Figure 8: Agriculture of the Bamuni with irrigation

• Villagers are getting employment in the New industries which have been installed in the village recently. Some industries which are in the village are - Stone crushing machine, Tea manufacturing factory, Pipe factory. Due to growing industries in the village, the livelihood of villagers is changing as people are getting jobs in the new industries. But due to the pandemic, the village people who are working in different parts of the country had to return due to a lockdown. So unemployment has been increasing recently.

• One of the villagers said the energy and power is one the best as compared to other Villages nearby. The 15 MW solar plant is helping the village with less Load Shedding/tripping.

• Housing infrastructure is the sector where the development is not up to the mark as compared to other infrastructure of the village. The government Schemes i.e., Pradhan Mantri Awas Yojana (Gramin) is not provided by the authorities to the needy people. There is corruption during the allotment of houses to villagers by the panchayat.

• According to a villager,a shortage of village doctors was identified as one of the main barriers. The health Infrastructure in the village is not good. There is one Government dispensary in the village but the current situation of the dispensary is very poor. There is no doctor available at the centre due to poor infrastructure conditions. There is a clear need for development in the health sector.

• The education infrastructure is good. There are three government schools and one college near to the village. The children are getting free education from the Government schools. The infrastructure of schools is decent enough with solar panels installed on the roof for electricity generation and one school has a rainwater harvesting(RWS) system installed In their school building.

5.4 Need of villagers: Villages in India are in desperate need of better infrastructure for boosting the economy and helping to improve the quality of livelihood in Villages. While many cities made progress in recent times, generally most villages of India continue to lag behind. Basic infrastructures are an essential foundation for a decent living and it enhances economic growth and livelihood of rural people. The basic infrastructure includes all-weather road networks, developed houses, energy and power infrastructure, irrigation infrastructure, drinking water supply, educational and health Infrastructure etc. At present time the villagers of Bamuni are getting facilities like good Road networks, irrigation and water supply. But the housing Infrastructure of the village is not as good as other sectors. People of Bamuni village are still living in mud houses or bamboo houses. They are not getting houses under Pradhan Mantri Awas Yojana (Gramin). Secondly, most of the people of Bamuni depend on the agricultural sector. By providing good irrigation in the entire village will drastically improve the economic situation of the village.

Work done by Government in the village:
• Rural Infrastructure development fund to promote the balanced and integrated economic development of rural areas of Assam by constructing roads and bridges in a phased manner.

• Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for providing wage employment. With the help of this scheme, the people of Bamuni village can earn money by doing the development of their village.

• National Rural Livelihoods Mission (NRLM) for self-employment and skill development,

• Pradhan Mantri Awas Yojana - Gramin (PMAY-G) for providing housing to BPL households. Villagers are getting good houses to live in under this scheme.

• Pradhan Mantri Gram Sadak Yojana (PMGSY) for construction of quality roads. All the roads covering the village are constructed under this scheme.
•Atal Amrit Abhiyan is a new health insurance scheme announced by the State Government of Assam. Under the scheme, the government is providing insurance coverage of up to Rs. 2 lakh per year to each family of the state.

•Orunodoi' scheme is Providing Financial Assistance of Rs. 1000 per month through Direct Benefit Transfer (DBT) scheme to around 17 Lakh Families in the state.

Government schemes: Government schemes help rural communities by providing financial aid and various other facilities. These schemes are aimed at benefiting poor, Economically backward rural people. Schemes address the social and economic welfare of the citizens of India. The different ministries of the Government of India have different schemes or Yojana.

Various benefits of such Yojana (schemes) are

•Provide social security measures such as pensions, insurance, maternity benefits, housing etc.

•To improve the quality of the life of the people.

•Upliftment of the poor.

•Development of rural and backward areas.

•Reducing the economic inequality between different sections of society.

•Empower women for their better participation in society.

•To provide employment opportunities.

•To provide education and training to the weaker sections of society.

•To provide financial security to the vulnerable sections of society.

•To provide financial assistance to women, small businesses and weaker sections of society.

6. Steps for rural development :

6.1 Utilization of local resources: Proper utilization of locally available resources will have a direct impact on the economy of the country. For example, if a village has water resources like rivers and tanks then proper arrangements must be made to use the water by constructing new reservoirs, canals and simultaneously improving existing ones. So that water can be used for both drinking and irrigation purposes. Similarly, in areas where there is a tea garden, there should be factories to manufacture and export the tea to the other parts of the country.

6.2 Establishment of rural industries: Establishing industries in rural areas will help unemployment in the area. It will improve the livelihood of the people of rural areas. Since people of rural areas depend upon the agricultural sector. Agro industries such as oil

processing from oilseeds, fruit juice makers, pickle makers etc. will help the economic condition of the area. In hilly regions as there are many natural resources, forest-based industries such as wood and bamboo products makers, plates makers from leaves will provide employment to the villagers.

7. Some limitations for rural development:

Land availability: There is a continuous tussle for land for agriculture, agro-based industries, and housing in the rural areas, which is a severe constraint to meet the housing demands of all populations.

Inadequate financing: Inadequate access to formal sources of finance for the rural population has been an issue in the rural housing sector. Lack of proper documentation/ steady source of income for the rural population has been a hindrance in securing formal finance.

Poor condition of the rural road network: India has one of the largest and densest rural road networks around the world. However, 2.7 million kilometers of the rural road network is in poor condition. At present, most of the rural roads are not all-weather roads and lack connectivity to rural areas.

Lack of funds for improving rural infrastructure in India: Improving the quality of life and services to the urban population has been given a higher priority over improving the provision and coverage of basic civic services in the rural areas (*National Infrastructure Pipeline*, 2020)

8. Initiatives taken by the Government of India: The Government of India's Vision for 2025 is for 100 percent of the rural population to have access to pucca houses with basic civic amenities such as piped drinking water, power supply and LPG connections. For there to be the provision of urban facilities in rural areas under the Rurban Mission. There should be good quality and well-maintained rural roads facilitating improved connectivity, safer and efficient access to livelihood and socio-economic opportunities for rural communities. Under Jal Jeevan Mission, 100 percent of rural households will have functional household tap connections by 2024 and 100 percent of the rural habitations to have full access to safe drinking water. All rural households have access to toilets (Individual Household Latrines) and for 100% of villages to be Open Defecation Free (ODF).

8.1 Boosting rural affordable houses to ensure "Housing for all by 2022": However, for the affordable housing initiative to succeed there needs to be efficient land usage and easy access to finance and innovative financing mechanisms. For that, the government is setting up an affordable housing fund in the National Housing Bank (NHB) that can be funded from the priority sector lending shortfall.

8.2 Improving condition of roads under PMGSY: All roads to be covered by five-year maintenance contracts, to be entered into along with the construction contract with the same contractor in accordance with standard bidding document (SBD). Policy Framework

for road maintenance by National Rural Infrastructure Development Agency in collaboration with the International Labour Organization (ILO) to be implemented on a state level. Ensuring greater fund availability, acknowledging feedback from the Meri Sadak App and Improving last-mile connectivity in rural areas.

8.3 Improving coverage of basic civic amenities: By increasing accountability of GPs by decentralizing service delivery model, improving the capacity of local government to undertake and implement quality infrastructure projects in the rural areas. And Creating awareness among the rural population regarding user charges/ fees for quality services/ amenities.

8.4 Improving supply of drinking water: By bringing structural changes in the regulatory environment, a shift is needed in the institutional framework of the Central Water Commission (CWC) and the Central Groundwater Board (CGWB) to make water management more holistic and multidisciplinary. Restructuring and unifying the CWC and CGWB to form a new National Water Commission (NWC). A model law on water resource regulatory mechanisms can also be drafted and implemented on the state level.

9. Recommendations: The study recommends that the government should give more consideration to rural areas for developing rural Infrastructures. Good infrastructure can bring various benefits to villages like Bamuni. Governments should assign substantial budgets for developing the rural areas. There should be irrigation networks in agricultural land of villages within the preferred distance for better production. The energy and power sector must reach every village for better livelihood. In very backward places Solar energy can be used for electrical purposes. Government should take various initiatives to install drinking water supply networks in the villages.

10 Conclusion : The findings of the study indicate that the rural areas of Assam are underdeveloped. It is necessary to provide access to basic infrastructure like road networks, drinking water networks, sewage and waste and good education and health facilities. Good infrastructure can bring various benefits to villages like Bamuni and improve the productivity and the economy of the village. There are many Government schemes designed for developing the rural areas but the selection of beneficiaries should be done effectively to ensure that the needy people are able to get those benefits. Study also highlighted the current state of Infrastructure and underlying gaps and priorities from a community perspective. Based on the above study it is clear that the Government should take various more initiatives for development of rural areas of the state. Smart Villages are the need of the hour as development is needed in rural areas for better livelihood of villagers and sustainable development. Developed infrastructure can change the economic situation of the village which will result in overall development of the country.

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ROLE OF RURAL INFRASTRUCTURE AND SMART VILLAGES IN DEVELOPMENT

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Abstract: *Due to its climatic condition, the state of Assam which is one of the North-eastern states in India is prone to natural calamities and flooding every year which results in the huge loss of life, livestock's, agricultural products and hinders the growth and development of the state. Among the affected infrastructure types, houses and roads are the most affected sectors due to chronic flooding during the long Monsoon season across the state. As most rural roads in the flood affected areas submerge in flood, rapid deterioration of these roads make accessibility as one of the major issues hindering quality and well-being of the community. As the state has 98.4% rural area, development and modernization of rural Infrastructure is of vital importance to improve the quality of life and overall development of the state and the country as a whole. Smart villages is an initiative focused on integrated rural development by providing basic infrastructure facilities, rural road network, rural water supply, canal works for irrigation, rural electrification , rural telecommunications, sanitation, tree plantations, water conservation system. Focusing on the smart villages concept, this study aims to evaluate a rural village as a case study. The purpose of the case study is to understand the current conditions, impact of various government schemes being implemented including the gap in meeting the needs and potential for development. This study highlights the insignificance of interconnectedness of rural infrastructure and underlying functionalities for supporting the community's growth and development.*

Keywords: *Rural infrastructure, Rural development, Road connectivity, Housing facilities, rural economy.*

INTRODUCTION

Among the eight states in North East India, Assam is the largest state with a geographical area of 78,438 km² (State profile of Assam).The majority of the population (86%) in Assam lives in rural areas, which constitute 98.4% of the total area. The state has abundant fertile land and ample water resources; additionally the solar energy potential is also higher compared to other states in this region. Agricultural production being the main activity is the largest contributor to the domestic sectors, accounting for more than a third of Assam's income and employing 69% of the workforce. (Mazumder 2020)

During the rainy season, floods wreak havoc on the state, destroying crops, cattle, land, and property, among other things. Every year, the destructive flood causes bank erosion and drainage congestion, destroying the state's economy.

Infrastructure plays a critical part in a country's development. Roads alone contribute for 7% of the rise in aggregate output in India's rural districts. Agriculture accounts for 18 percent of the country's GDP, while agriculture employs around 64 percent of the overall population, which is dependent on rural infrastructure. (Mazumder 2020) Even though 65 percent of India's population lives in rural areas, some fundamental services such as road connectivity, housing, running water, power, playgrounds, libraries, banking, and medical aid are not readily available. Low agricultural production is obviously linked to rural isolation, which is linked to a lack of market access, fertilizer shortages and the use of improved agricultural technologies. It's also linked to bad health and a lack of school attendance. As many rural communities lack even basic services and economic prospects, large-scale rural-to-urban migration is occurring, resulting in rapid urbanization (Munoth & Jain 2020). The lack of the conveniences in the village is also a reason for lack of opportunity for income generation and interdependencies among the community (Doloi 2020). As a result, the requirement for rural infrastructure development is now more important than ever.

The Indian government has initiated a number of programs and policies with the goal of improving rural infrastructure but due its poor quality and inefficiency in project implementation, rural development is not quite addressing the needs of the community. Rural infrastructure development will reduce poverty, raise rural population living standards, improve health, create jobs, and strengthen the economy, all of which will contribute towards the country's overall growth and well-being.

2. STUDY AREA

Upper Doomdoomia village is located in Nagaon district in the state of Assam and is considered for the study. According to data obtained from the Panchayat office, the village has a population of 3578 people which consist of 746 families. There is a primary school and an upper primary school in the community and a local college for higher education is 6 kilometres distant. A primary health care centre is located in the village. The majority of the village's areas are connected by roads, but they are maintained in bad condition. Agriculture is the primary source of income. The village is electrified; however there are still concerns related to electricity persist. Approximately 70% of the population lives in permanent housing. It is one of the district's underdeveloped villages. Poor infrastructure quality and maintenance, political instability and environmental calamities, as well as the government's failure to properly implement policies, have all contributed to the village's poor standard of living and limited rural infrastructure development.

2. OBJECTIVE

The main objective of the study is to comprehend the role of rural infrastructure and Smart villages in the county's growth, taking a real village as a case study, furthermore building up connections between rural infrastructure types. It likewise attempts to comprehend the prevailing ground situations, implementation of policies, schemes and their progress. It also seeks to find a means to enhance the current situation by identifying gaps in Government initiatives and filling them with practicable approaches in rural infrastructure in order to achieve growth and sustainable development.

3. APPROACH

The methodology incorporates investigation of different formative projects, plans and drives attempted by the public authority to elevate provincial framework. Based on field visits, the study examines a number of public schemes for supporting infrastructure in relation to the issues and challenges being faced by the residents. The aim is to understand how the public infrastructure systems are meeting the needs and assisting in the development of the community generally.

4. HOUSING FACILITIES

4.1 Overview

Housing is a basic requirement for human survival and has a direct impact on the population's health and well-being. There has been a significant shortage of suitable housing facilities that needs to be tackled; as a result of this shortage, people are without protection from wind, rain, and other natural calamities, as well as basic sanitation and clean drinking water facilities, resulting in people living in unsanitary conditions and being exposed to insects, rodents, and other pests. Housing is extremely crucial in Assam

because every year, due to devastating floods, a large amount of money is spent on the maintenance of temporary houses, or even the rebuilding of houses. Livestock and belongings are also lost, putting a huge burden on the poor rural population who must bear the cost, further trapping them in poverty. The percentage of people living in Pucca houses (permanent or durable houses) in the country has increased over time, from 55 per cent in 2011 to 71 per cent in 2015-16; however, the proportion in the north-eastern part of the country, where Assam is located, falls less .As defined by the Census, a Pucca home (permanent house) is a dwelling with roofs and walls built of upgraded materials such as galvanized iron (GI), stone with cement or bricks or concrete, asbestos, sheets, and so on.

4.2 Types of houses

The Assam type home is the most prevalent style of house in Assam, and it is made of bamboo and timber with stone or brick masonry up to 1m above the plinth level, the walls are made of bamboo works where strips of bamboo are interwoven, and then plastering is done with cement, mud, and lime. The trusses are built of wood, and the roof is covered with tin. Because precipitation in this region of the country is higher than the rest of the country, the roofing is done in an inclined posture to drain rainwater.

Mud houses, which use bamboo as a structural element, are another style of dwelling seen here. The walls are formed of bamboo strips that are interwoven together and plastered with mud. The roof is usually built of rice straw or dry vegetation, both of which are common in this region.

Figure 1 shows a permanent housing facility received under a government scheme. As it can be seen the house was built in poor condition. The plinth level is too low and finishing is very poor. Such substandard constructions of houses are not meeting the housing standards seen in urban areas. These houses are quite widespread in the Upper Doomdoomia village.

Fig 1 - Housing Facility received under Govt. scheme

Among the population surveyed 70 % of them in Upper Doomdoomia Village live in permanent houses, however there are mud houses which are vulnerable to harsh weather conditions such as rain, storms etc. due to which it needs maintenance and lead to economic loss.

4.3 Government Schemes To Provide Housing Facilities

Pradhan Mantri Awas Yojana (PMAY - Gramin) scheme aims to provide housing for all by 2022.This scheme was launched on 20th November, 2016 and the target was set to construct 2.65 Cr. houses in different phases, in the first phase i.e. from 2016-17 to 2018-19 the target was to construct 1 Cr. houses. Under this scheme, financial assistance amounting to Rs-1.20 lakh is provided to the beneficiaries living in plain region and financial assistance of Rs-1.30 lakh is provided to the beneficiaries living the hilly areas, the eligible beneficiaries are the ones living in Kutcha (mud) house or not having house at all. This scheme covers other Government schemes as well to provide basic facilities such as toilets, clean drinking water, LPG gas connection and electricity connections. The beneficiaries are also entitled to get 90-95 days of unskilled labour pay for looking after and work on one's own house under Mahatma Gandhi National Rural employment Guarantee Scheme (MGNREGA), also the beneficiaries can avail loan of up to Rs- 70000 where interest subsidy is 3%.

In the FY 20-21 the overall release of funds amounting to Rs- 39269 Cr. was made which is the highest since the launch of the scheme.(Press release : Ministry of Rural Development)

In Assam, during the financial year 2020-2021, as of 31 March 2021, 131282 housing facilities have been completed under this scheme. In the entire country the number of houses completed is above 35 lakhs during the same period.

4.4 Present Scenario

Although the rural housing situation has improved, there is still a big gap because the government's initiatives to offer rural housing amenities for everybody have restricted reach. Around 30% of the inhabitants of Upper Doomdoomia village do not have a permanent home, forcing them to live in mud homes that are susceptible to weather conditions and lack basic amenities such as sanitation. Furthermore, it has been seen that the speed of construction has slowed, despite the fact that COVID is a contributing element. Other reasons for this include postponing construction owing to beneficiaries' unwillingness, not obtaining timely grant of funds, and a variety of other circumstances.

5. CONDITION OF RURAL ROADS

5.1 Overview

The rural road network is a critical piece of rural infrastructure. Road connectivity and good quality roads are essential for an area's economic growth and development, providing access to basic products and facilitating service delivery. Poverty is more widespread in places that are not connected, according to many research conducted in the past. The focus has switched to rural connection, which has improved the conditions over time.

5.2 Present Scenario

In Upper Doomdoomia village roads are mainly of two types which are made of flexible pavements and rigid pavements. Some parts of the village are not connected by roads. The flexible pavements are used to connect the neighbouring villages and town, while the rigid pavements are now-a-days commonly used and cover the majority of village area. As it can be seen in figure 2 the road network in Upper Doomdoomia village including the main route that connects the town, is maintained in poor condition, with several potholes. The difficulties that the residents face occur during the rainy season, when the road in the low-lying area becomes blocked by water, making it difficult to transport goods and commodities produced. Furthermore, trade activities are harmed, and products such as eggs, agricultural produce, fish, milk, and other dairy products are unable to be transported efficiently to other markets in order to obtain a fair price.

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Fig 2 - Condition of rural road

In addition to that, poor road network affects the mobility of the inhabitants and the vehicle's maintenance cost gets high. For the socio-economic activity to sustain, road connectivity as well as maintenance of roads is of utmost importance. Therefore proper road connectivity is a necessary element for the socio-economic activity to sustain in the village. Poor roads in Upper Doomdoomia village often result in injuries and accidents, and poor maintenance has a negative influence on people and vehicles' health. Because some parts of the village are not accessible by roads, the entire area is cut off from services such as health care or if available the cost of goods and services is higher.

5.3 Government Initiatives

The government has made efforts to improve connection by providing all-weather roads that are permanent. The Pradhan Mantri Gram Sadak Yojana (PMGSY) plan was initiated in the year 2000 with the goal of providing all-weather road access and appropriate drainage infrastructure to disconnected habitations as part of a poverty-reduction strategy that will be completed in phases. Phase I seeks to connect 178,000 habitations with a population of more than 500 in plains areas and more than 250 in hilly areas with all-weather roads. The goal of Phase II was to upgrade 50000 kilometres' of existing rural roads. It was envisaged in phase III to build 1, 25,000 km of road in the states, which would connect Gramin Agricultural Markets (GrAMs), higher secondary institutions, and hospitals. The cost is projected to be Rs 80,250 crores. Between 2004 and 2014; the average speed of rural road development under the PMGSY was 98.5 kilometres per day, increasing to 130 kilometres per day by 2014-17.

Figure 3 shows the target length and completed length of roads with respect to Assam under the scheme PMGSY, which aims to provide all weather road connectivity. The target length of road construction for the year 2021-2022 for Assam is 2200 km. Also, it can be seen in the figure that the completed length of road has always been less as compared to the target. Only for once the target has been met.

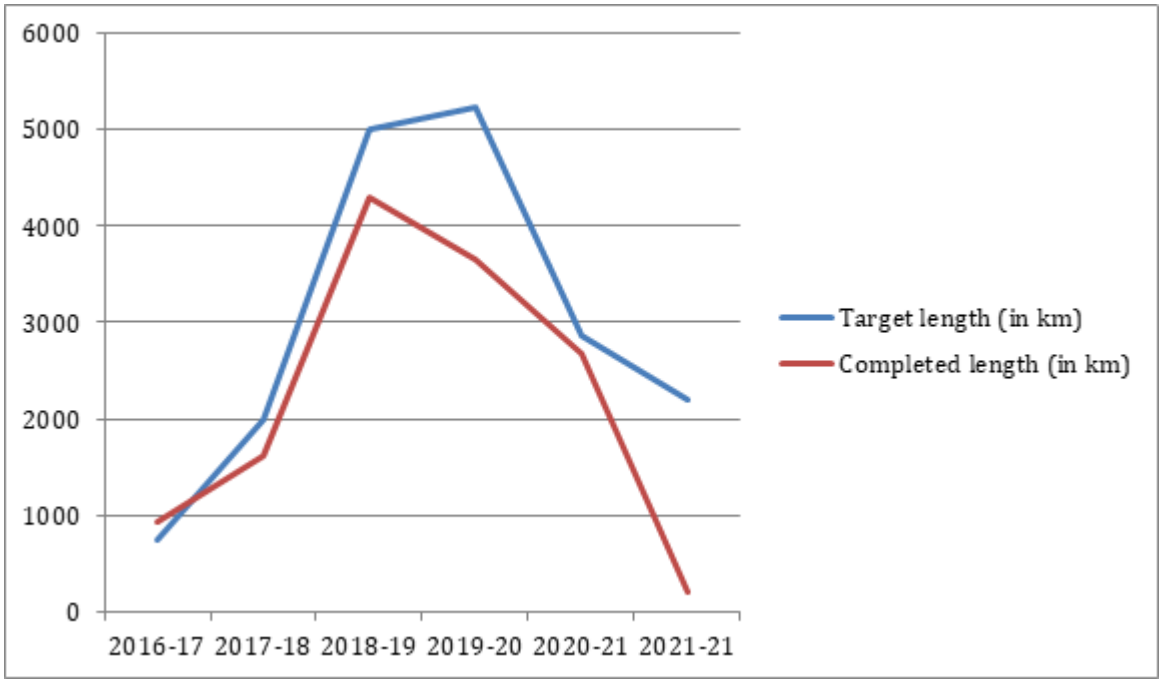

Fig 3- Target length vs completed length of roads in Assam

(Data taken from National Rural infrastructure development agency www.omms.nic.in)

The major reason behind this lack is due to floods, which are an annual phenomenon in Assam. The incessant rainfall during monsoon hinders construction activities in the state

and that leads to less working season. Moreover, lack of labour and availability of materials, restrictions imposed due to COVID-19 are contributing factors for not being able to reach the target length of the road to be constructed under the scheme (PMGSY)

6. WATER SUPPLY AND SANITATION FACILITIES.

6.1 Overview

Water is a basic human necessity for living, and it is necessary in villages for human consumption, animal feeding, irrigating agricultural fields, and other residential uses, among other things. According to Census 2011 data, just 30% of rural areas have access to tapped water. Hand pumps, tube wells, and open wells are the principal sources of water in the remaining rural areas. People walk miles to fetch water from rivers in various parts of the country. According to UNICEF, the economic burden of estimated USD 600 million a year in India is due to waterborne diseases. The state of Sanitation facilities has been equally poor, as per Census 2011 report, 69.3 % of rural household's still practice open defecation.

In Assam, people mainly depend on groundwater source, rain water, water from streams and lakes to carry out water related activities and also for drinking. Safe drinking water facilities as well as sanitation facilities have been poor as compared to the rest of the country.

6.2 Rural water supply

The majority of residents in this community, Upper Doomdoomia, rely on groundwater to supply their water needs. In addition, water from adjacent rivers is used, as well as rainwater collected in ponds is used. However, the usage of this source has resulted in a slew of problems: groundwater is depleting, and the water from these sources has been linked to a variety of ailments. Furthermore, water contamination occurs in rural regions as a result of the use of chemicals in agriculture, pesticides, and inappropriate waste disposal. Because of many factors such as inability to purchase filtered water, mismanagement of water sources, lack of effective planning, absence of water conservation system, lack of technology and understanding, etc., the majority of rural areas lack safe and purified drinking water services. The water supply line has been laid in Upper Doomdoomia Village; however there is no water supply yet.

6.2.1 Government schemes

To provide safe drinking water Jal Jeevan Mission (JJM) was launched which aims to provide Functional Household Tap Connection (FHTC) to every rural household by 2024.The main goal of JJM is to provide functional tap connection to every household to provide safe, clean and prescribed quality water with delivery at the rate of 55 litres per capita per day (lcpd).In this scheme, in-village water supply infrastructure for tap water

connection is be made as well as reliable drinking water source /augmentation of existing sources, water resource management, treatment of water, treatment plants is required which will contribute to the generation of employment opportunities moreover access to safe drinking water will improve the quality of life of rural household .The total estimated cost of Jal Jeevan Mission (JJM) is Rs. 3.60 Lakh Cr. over 2019-24.

6.3 Sanitation Facilities

Sanitation infrastructure is just as critical as water delivery infrastructure. Maintaining a healthy lifestyle necessitates sanitation. Inadequate sanitation services make the area unsanitary, and bad odours irritate people. Sanitation facilities are critical for the protection of water sources and bodies, as well as aquatic life. When there is no proper treatment of wastewater and solid waste generated by the human faecal matter and these are directly disposed of in the rivers, the water resources get degraded and it affects the ecosystem, untreated wastewater may cause Algal bloom which results in the death of aquatic life.

Safe disposal of human excreta and waste treatment is required to sustain human health; it is critical for human life since it can decrease our exposure to disease-causing pathogens. Diarrhoea is a known cause of death in children under the age of five, although it can be prevented if safe drinking water and sanitation facilities are available (UNICEF). Many people have died as a result of a lack of cleanliness, along with economic losses such as treatment costs and lost production.

Investment in this sector can create job opportunities; have a positive impact on the economy by increasing productivity and in several other ways. Moreover, water waste can be thought of as a resource and proper management and planning can lead to massive economic benefits.

6.3.1 Government Initiatives

With this aim to make each and every village of India clean and open defecation free, Swachh Bharat Mission-Gramin (Clean India Mission) was launched. Since its launch i.e. since 2nd October 2014, 1071.05 lakh toilets have been built.711 Districts and 6, 03,004 villages have been open defecation free (ODF) as per latest data available at the official site. Under this mission 134000 Cr. will be allocated for construction of about 11 core 11 lakh toilets, the amount granted to individuals for construction of toilets is 12,000. Central Government share will be Rs. 10800 and the share of northern states is Rs. 1200.Apart from infrastructure, which needs to be done when it comes to make a village open defecation free, the behavioural aspect of the communities, needs to be changed. Even when there is a functioning toilet, people do not use it.

Figure 4 shows a toilet which has been received under a government scheme. The toilet is built of poor construction quality and is not well maintained. The most common problem faced by the villagers is the small size of the toilet and the foul smell that comes out due

to less circulation of air, among other reasons. It is also vulnerable to weather conditions, due to which most of the time it is left abandoned or not in working condition.

Fig 4- Toilet received under Govt. scheme

To understand the reasons behind open defecation a survey has been conducted to understand why people go for open defecation despite having toilet among the random 300 individuals from different parts of the Upper Doomdoomia village belonging different families or within same families, most of them had more than one reasons, however these were not the actual individuals who practice open defecation. The data is shown in figure 5 –

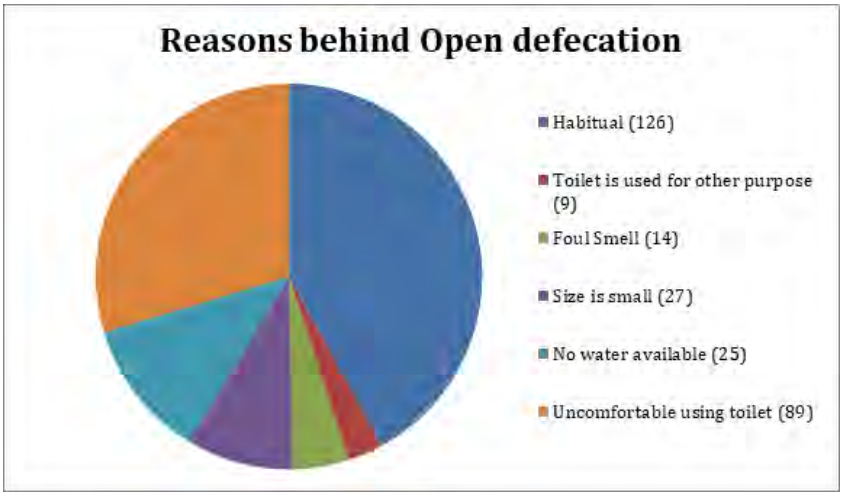

Fig 5 – Reasons behind open defecation

Source: Field survey (2021)

As per survey conducted by National Statistical office (NSO) between July and December 2018, close to 93.7 % households have toilets within their premises, only 2.2% didn't have access to toilets.

6.4 Irrigation Facilities

The majority of the Upper Doomdoomia village's rural residents employ pumps to irrigate their lands, which are irrigated by groundwater or neighbouring ponds. Rainwater is also used by farmers to irrigate their lands. Irrigation facilities are critical for agricultural purposes, and suitable irrigation channels and provisions must be installed, as well as the area under irrigation needs to be increased, to boost agricultural production. By improving crop intensity and raising crop yield in the community, there is a significant potential for agricultural expansion and production. Even though efforts have been made to lessen the load of electricity bills caused by the use of pumps by installing solar powered pumps, the service is still not available to the vast majority of the people.

Figure 6 shows irrigation from ponds using pumps. Majority of the farmers in this village use this method to irrigate their fields. However, in some cases solar powered pump received under government scheme is being used by a small proportion of farmers.

Fig 6- Irrigation from nearby pond

In comparison to demand, the state's current irrigation facilities and capacity are extremely limited. Because paddy is commonly grown in the state, as well as in this village, facilities must be expanded during the paddy and Rabi crop seasons. The State Agricultural Department has given emphasis to establishing irrigation facilities, including pump sets, which are believed to be an efficient way of utilizing Waters for agricultural growth. However, these facilities are not available in every area of the village.

6.4.1 Government Initiatives

With the goal of expanding irrigation coverage, increasing water efficiency, and reducing water waste, On July 1, 2015, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was inaugurated with the motto "Har Khet Ko Paani," which means "water to every field." It involves the formation, distribution, and management of sources, as well as the micro-harvesting of rainfall. PMKSY's major goal is to create water resources through minor irrigation, which includes both groundwater and surface water. One of the numerous goals is to increase the use of accurate irrigation systems and water-saving technologies (More crop per drop).

Thousands of farmers benefited from the Assam State Action Plan of PMKSY, which covered 19116 hectares and 19664 hectares in two phases during the 2018-19 fiscal year. The Solar Pumping System, which was established by the State's Irrigation Department, is an innovative move that can address the challenges of power outages. The state's irrigation potential was estimated to be 11.27 lakh hectares, or 40% of net cultivated land. As of March 31, 2015, 7.33 lakh hectares, or 26 per cent of the net cultivated area, were under utilizable assured irrigation.

Under Rural Infrastructure development fund (RIDF) STW Scheme the Government of Assam Sanction installation of 1 Lakh Shallow Tube Wells and 10000 Solar PV powered STW which started from 2016-17.

Figure 7 - shows a solar powered pump installed in Upper Doomdoomia Village under a government scheme. These pumps are granted to a group of individuals who look after the operation and responsible for maintenance and protection. The number of pumps received has been very low, more such pumps can be installed for the benefit of farmers.

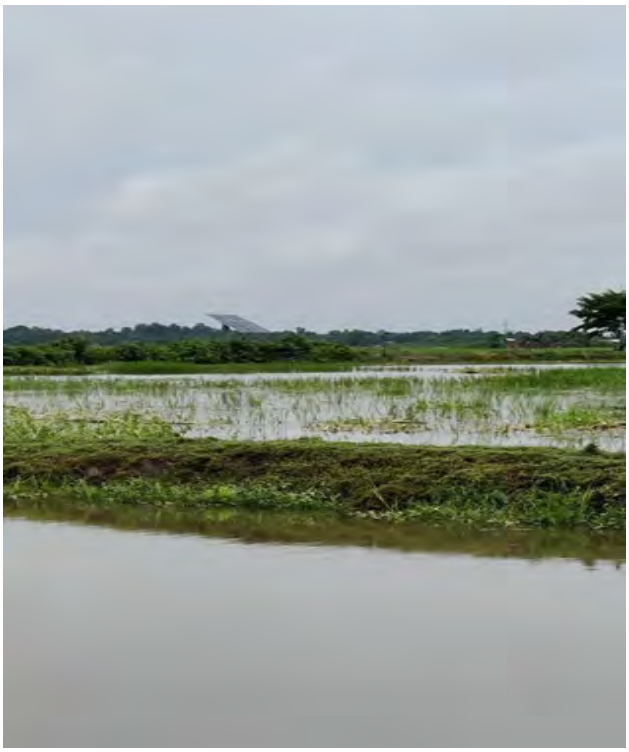

Fig 7– Solar powered pump

6.4.2 Use of Solar powered pump

Solar Photovoltaic Technology in Irrigation is an innovative approach toward sustainable development that will have an impact on a state's economy and growth. Farmers can save money on power by using this technique as the cost per unit for operating a pump is higher than for home usage. It is common knowledge that agriculture is not profitable these days since a significant amount of money is spent on the purchase of power. After the initial high cost of using a solar PV-powered pump is recovered, it provides electricity basically. Furthermore, the power capacity can be expanded as needed to cover a larger area.

7. RURAL ELECTRIFICATION

One of the most important aspects of rural development is rural electricity. It's needed for lighting and studying, among other purposes. Electrification can boost agricultural production because it is required for irrigation. It can also improve health care facilities, educational facilities, and business hours, resulting in more income. It can also improve non-farm productivity and contribute to economic growth. Upper Doomdoomia village residents engage in a variety of agriculture operations, including egg production, poultry farming, and fish farming, all of which require power to operate.

One of the most prevalent practices in the village is to grow chickens for eggs, which are subsequently hatched using an egg incubator, which comes in a variety of sizes and can also be produced locally.Figure-8 shows farm activities that require electricity as input. The most crucial aspect is that these incubators require continuous power to work. The hatchability of eggs reduces as a result of frequent power outages, resulting in financial loss.

Fig 8 – Farm activities that requires electricity

Even if the villagers have access to energy, they experience frequent power outages owing to load shedding, and there are times when there is no electricity for days due to severe weather.

7.1 Government Initiatives

In 2005 Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched with this mission to electrify all Indian households across every corner of the country. Later, it was renamed as Deendayal Upadhayaya Gram Jyoti Yojana (DDUGJY) in 2014 which aims towards achieving “24x7 Power For All” in rural areas. In 2018, the Central rural development ministry found in its survey that 14,700 were yet to be electrified. As per Ministry of Power by 2019, 99.99 per cent of the households were electrified. An amount of Rs. 44896.30 Cr. has been sanctioned (including DDG Projects) grant involving Rs

28158.93 Cr.; against which Rs 30942.9 Cr. including grant of Rs 22365.69 Cr. has been released till date.

8. DISCUSSIONS AND FINDINGS

Housing facilities – It has been found that 70% of the population of Upper Doomdoomia village lacks housing facilities. Also, the pace of construction of houses (granted under government schemes) has slowed due to various reasons. Unwillingness of beneficiaries and delaying of construction has been reported. Moreover, the government scheme has limited scope for coverage. Non-availability of land and documents required to avail the government schemes are the reasons that are contributing to restricted reach of the schemes.

Road connectivity- It has been found that roads are in poor condition and also every part of the village is not accessible by roads. Even the main road connecting to the town gets blocked by water which creates difficulty in the mobility of villagers and also leads to economic loss. All weather road connectivity is a prerequisite for the development of the village which would improve trade and communication, agricultural production and reduce the transportation cost. Better roads can lead to proper distribution of products such as eggs, agricultural produce, fish, milk, etc. produced in the village thereby increasing the farmer's income. The roads must be maintained in good condition for expansion of the economy of the village which would lead to proper distribution of products and services and improve the living conditions of the village.

Water supply and sanitation facilities- In Upper Doomdoomia village the water supply line for clean drinking has been laid but there is no water supply yet, also it is seen that open defecation practice still exists, while the sanitation facilities are there, still it is not able to meet community demands. In most situations, villagers do not use toilets (received under government schemes) because of their tiny size and lack of air circulation; nevertheless, there are other reasons for toilets not being in functioning order. Proper sanitation facilities can reduce disease transmission and economic burden, as well as malnutrition in children's caused by diseases due to a lack of access to safe drinking water and sanitation. Furthermore, it will boost the village's productivity, resulting in socioeconomic improvement.

Irrigation facilities- - Groundwater is the main source of irrigation in Upper Doomdoomia village, and though solar-powered pumps are available through government programmes, only a small percentage of farmers have been able to employ them. There is a large potential for agricultural expansion and production, which requires additional cultivable land to be brought under irrigation.

Electrification – Even though the village is electrified, complications related to electricity supply exist. Frequent power outages, no supply due to bad weather conditions affects

both farm and non-farm activities of the inhabitants. Apart from providing interrupted power supply through grids, use of solar panels can be done to tackle these issues as in this case electricity can be generated in a decentralized manner. Proper planning and investment is required which can further lead to sustainable development and improve the economy of the village.

9. RECOMMENDATIONS

The study suggests that the government should correctly implement the schemes and policies that have been launched, existing infrastructure facilities be maintained, and that current programs be monitored and evaluated on a regular basis. Government should prioritize the provision of safe, clean drinking water and sanitation. Public agencies should investigate the quality of infrastructure offered as well as inefficiencies in project delivery. The government will need to make more investments in order to give services to every corner of the village. More policies be framed engaging the community for addressing their needs and contributing their ideas of development, subsidies be provided to improve the quality of infrastructure and uplift the rural economy. The village's overall development would be enhanced by proper planning, monitoring, and implementation of policies.

10. CONCLUSION

Since India's rural population comprises the majority of the country's population, rural infrastructure development is critical to the economy's and country's overall growth. Integrated rural development with basic infrastructure facilities, roads, rural housing, irrigation facilities, clean drinking water and sanitation facilities, health care facilities, rural electrification, and telecommunication will alleviate poverty in the country, improve individual health and well-being, raise living standards, and create job opportunities, all of which will boost the economy and play a critical role in the country's development. Furthermore, it has been observed that all components of rural infrastructure, including road networks, housing, sanitation, and electrification, are interconnected and reliant on one another for development, therefore each aspect must be given equal weightage. For overall development, it necessitates a holistic approach.

Some basic services, such as road connectivity, housing, running water, and power, are not readily available in the village under investigation. The village's low standard of life and restricted rural infrastructure development are due to inadequate infrastructure quality and management, as well as the government's failure to properly implement policies. Although the situation in rural infrastructure has improved, there is still a significant gap since the government's initiatives to give rural infrastructure facilities to all have restricted coverage. More investments, as well as proper implementation without delay and maintenance of facilities as well as and the effective use of services and the benefits associated with it should be promoted. Also, monitoring and assessment of policies from the perspective of the community are required.

The expansion of the rural economy is directly tied to proper rural connection. Durable roads, combined with adequate planning, can help residents earn money, improve product and service distribution, and provide better living conditions. Apart from grid-connected electrification, solar panels may be a reasonable alternative for generating power as electricity can be generated at a remote location and installed capacity can be increased.

To mitigate the consequences of climate change and regulate pollution, sustainable construction processes and eco-friendly materials can be used. Water, energy, and resource conservation are also necessary for long-term development. Solar power plants, water treatment plants, and water conservation systems in communities should be prioritized, and these areas should receive significant funding. Apart from government infrastructure programs and initiatives, residents' views toward those services, living patterns, individual attitudes, and community requirements all play a role in growth. It is crucial to provide education on personal health and hygiene, as well as the advantages of using the services provided. Government, organizations, communities, and individuals working together will assure the village's growth and development, as well as the country's advancement and well-being.

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Review of the existing energy policies and challenges of energy consumption to achieve a sustainable behavioural change among Iranian households

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Abstract: *The growing number of household subscribers have resulted in high energy demands leading to wrong energy consumption patterns in Iran. As a result, power supply has failed to fully meet energy demands in housing sector, causing unplanned recurring blackouts. Although government has endeavoured to propose supply-side initiatives for energy conservation, achieving energy efficiency required further investigations in terms of demand-side to include households' energy consumption behaviour. Various interventions and energy use models were proposed to analyse demand-side approaches to change households' energy related behaviour, however, the incidental nature of behaviour has caused unsustainable change over a longer period of time. This issue necessitates more value-based strategies aiming to reduce peak load time's electricity consumption to achieve a more sustainable behaviour change. This entails new perspective in intervention strategies rather than punishments or monetary or environment-related motivations. The notion of changing lifestyles may impact wrong energy consumption patterns, which can be related to daily habitual life routines. Therefore, consumption may not solely address households' basic needs, but includes perceived values. This research will emphasise the need to develop strategies based on households' values and beliefs in terms of their well-being to be nudged towards more energy saving activities. It aims to focus on the important role of households' values on choosing their daily life activities to be used as an effective reward for a more energy efficient consumption pattern. This research suggests well-being related activities to sustain the change in households' energy consumption habits as well as achieving energy efficiency as a reward.*

Keywords: *Consumption Pattern, Energy Efficiency, Health and Well-being, Lifestyle, Self-care Activities.*

1 Introduction

The intensive growth of urbanisation worldwide, especially in developing countries has significantly affected environment in a local and global scales (Riazi and Hosseyni 189). The increase of energy demand is one of the drivers of such effects, which has been exacerbated by the lack of energy efficiency in existing buildings. This has led to an increase in all sectors of energy consumption in Iran, particularly housing as a major factor of energy use increment (Kazemi and Hosseinzadeh 231; Raeiszadeh and Monjazeb 92). As a result, the energy intensity in Iran has become one of the highest in the world, representing a high level of inefficiency in energy consumption (Moshiri et al. 122). Many researchers have attributed the ever increasing energy demand to the allocation of energy subsidies in oil-rich countries including Iran (Solaymani "Energy Subsidy Reform Evaluation Research – Reviews in Iran" 520; Groot and Oostveen 1926; Araghi and Barkhordari 399). This policy, which was deemed to be a solution for accessibility of electricity and other energy sources for low-income households, brought about serious problems. It has not only imposed significant burden on government budgets (Moshiri "Consumer Responses to Gasoline Price and Non-Price Policies" 10), but has caused overconsumption, energy inefficiency and eventually, climate change (Li, Shi and Su 51; Groot and Oostveen 1927; Araghi and Barkhordari 400; Moshiri "Consumer Responses to Gasoline Price and Non-Price Policies" 111078). Along with the inevitable increase of demand, the use of fossil fuel as a major energy resource in Iran has also resulted in additional pressure on the environment and public health due to greenhouse gas (GHG) emissions (Wang et al. 284; Vafa-Arani et al. 24; Torbatian et al. 434).

The issues of energy subsidy are not limited to the above-mentioned problems. These heavily subsidized prices have also caused difficulties for country's power supply network in terms of managing and planning for the electricity supply and demand (Bazzazan, Ghashami and Mousavi 16). In a study conducted by (Veloza and Santamaria 45), the review of the main causes of major blackouts showed that high load level was the main cause of the most occurred blackouts in Iran. In this regard, (Dehghan, Amin-Naseri and Nahavandi 12) demonstrated that with the current trend of energy consumption in Iran, power supply will fail to fully meet energy demands. Due to this failure, Iran is recently experiencing recurring blackouts in healthcare, domestic and industrial buildings, which is mainly attributed to peak loads during specific times of hot summers and cold winters (ISNA).

In accordance with the national plan of Iran, the government and researchers started to suggest different solutions for the existing energy-related problems. To reduce energy consumption, the government enacted the "Targeted Subsidies Law" for price rationalisation in the year 2010 which was an increase up to 90% of the border prices in five years (Moshiri "The Effects of the Energy Price Reform on Households Consumption in Iran" 179). However, according to UNRISD, the implementation of the policy has faced several difficulties, since subsidy reform entails long-run political commitment (Lindebjerg, Peng and Yeboah 14). In spite of the positive impacts of the reform in terms of controlling energy consumption, its achievements were short-lived (Demirkol et al. 14194). Accordingly, a study revealed that the removal of subsidies has temporarily affected households' energy use pattern (Ojand and Nazari 147). Therefore, energy efficiency gained researchers' attention to achieve a sustainable change in energy use patterns, instead of a total removal of energy subsidy (Sovacool 156; Barkhordar, Fakouriyan and Sheykhha 542). In this regard, researchers started to accompany government policies by

demand-side incentives or supply-side initiatives for the purpose of energy conservation (Gelan 187; Ghadaksaz and Saboohi 2). In terms of supply-side solutions, the development of renewable energy technologies was mainly focused in research studies (Oryani et al. 971; Soltani et al. 11). Unfortunately, due to the fact that renewable energy technologies do not play an adequate role in the energy supply of Iran (Solaymani "A Review on Energy and Renewable Energy Policies in Iran" 7328), the solution of reduction in demand-side gradually began to be in the spotlight in Iran (Rahmani et al. 4). In this regard, (Soltani et al. 11) demonstrated that reducing energy consumption requires crucial countermeasures to be implemented by not only government, but people. Therefore, households' demographic information, behaviour, lifestyles and energy consumption pattern became the main focus in studies regarding demand-side solutions (Soltani et al. 12; Ojand and Nazari 131).
Although studies exist regarding achieving energy efficiency through households' behaviour change and energy use models (Jackson 30; Sepehr et al. 481; Chatzigeorgiou and Andreou; Crowley et al. 2209), the existing interventions and models seem to have issues in terms of sustainable behavioural change to achieve energy conservation. This may be due to the fact that most of the existing solutions focus on environmental and monetary aspects. This has resulted in ineffective behavioural change solutions for Iranian households. This research aims to demonstrate the necessity of paying more attention to reduction of energy consumption in housing sector by highlighting the importance of behaviour change towards a more energy efficient lifestyle to resolve unplanned recurring blackouts in Iran. For this purpose, this study will focus on values of households to achieve sustainable behavioural change rather than solely focusing on environmental or monetary aspects. To achieve this goal, first, different interventions and policies will be studied to analyse demand-side approaches to achieve a behaviour change regarding energy consumption. Second, wellbeing is proposed as a motivation to change wrong energy consumption pattern in Iranian households' lifestyle to achieve a more sustainable behaviour change. In other words, the study will introduce a new area of study in energy efficiency researches by highlighting the importance of wellbeing-centred activities of households and energy consumption. This study also endeavours to introduce a possibility of well-being related awards to sustain the change in households' energy consumption habits.

2 Energy related challenges in Iran

The concept of sustainability has significantly increased concerns in terms of energy related issues in Iran (Mohammadi et al. 261) as the world's eighth largest emitter of GHG in 2015 (CarbonBrief). According to a report by Energy Information Administration, energy use in building sector is predicted to have a rise by 42% by the year 2040 worldwide (EIA 104). Among different Iranian building sectors, housing sector accounts for one of the largest sectoral energy consumer after the industry sector (Abbasizade et al. 4218). Therefore, housing sector contributors to sustainability challenges of GHG emissions in Iran (Kazemi and Hosseinzadeh 231). Most of the energy use in buildings is supplied by natural gas and electricity, which is equivalent for 23.3% of total CO_2 emissions in the year 2017 (Energy-Ministry 82). In recent years, nearly 30% of CO_2 emissions in this country are attributed to households' energy consumption (Delavar and Sahebi 1).
As a result of the arising issues related to energy consumption, energy efficiency in buildings has recently gained increasing attention among Iranian researchers due to inefficient performance, especially in housing sector (Sepehr et al. 481; Belussi et al. 1). A variety of factors (number of households, floor area and etc.) can affect energy consumption and thus

energy supply and demand on a global or local scale (Shittu 11). However, the most influential factor in daily energy related activities is indicated to be lifestyle which dictates the residential energy consumption pattern (Fong et al. 395). In addition to this, oil-rich countries are facing another major issue of energy subsidy which has significantly contributed to a further increase in energy demand of households (Tofigh and Abedian 1304; Mohammadnejad et al. 4654). The goal of energy subsidy is to make electricity and other energy resources accessible by reducing energy prices for low-income households (OECD 46). However, this has not only led to a significant burden on government budgets in Iran, but has caused over consumption, energy inefficiency and environmental degradation (Moshiri "Consumer Responses to Gasoline Price and Non-Price Policies" 1; Li, Shi and Su 51; Sovacool 154; Araghi and Barkhordari 399). Energy subsidies have also discouraged investments on renewable energy technologies to benefit from cleaner energy resources (O. IEA 26; Charles, Moerenhout and Bridle iv; Stiglitz et al. 12). Therefore, although subsidies have been considered as a poverty relief solution for low-income households, higher income group may benefit even more than other income groups (Groot and Oostveen 1927). This is due to the fact that higher income households account for a larger share of energy consumption when compared to lower income groups (Solaymani "Impacts of Energy Subsidy Reform on Poverty and Income Inequality in Malaysia" 2708). A study by (Del Granado, Coady and Gillingham 2234) demonstrated that nearly 65% of subsidy benefits belong to higher income groups. To resolve such problems, different policies, namely increasing gasoline prices, energy price reform through removal of subsidy have been adopted (Moshiri "Consumer Responses to Gasoline Price and Non-Price Policies" 1). Although the reform policy was considered to be a real step toward sustainable development (Craig and Feng 786), it has faced challenges and setbacks in Iran, which resulted in unclear outcomes. (Solaymani "Energy Subsidy Reform Evaluation Research – Reviews in Iran" 520) showed an evidence that the removal of energy subsidies in Iran was solely effective in reducing energy consumption in the first 2 years of policy implementation. Moreover, it is worth mentioning that Iranian household welfare, especially low-income groups will decrease if a 400% or 500% rise in energy prices occurs (Araghi and Barkhordari 398). As a result, researchers concluded that this reform should be accompanied by both demand-side and supply-side measures to better encourage energy conservation (Gelan 186).

In previous years, the increasing gap between energy supply and demand had led to peak loads which in turn had caused issues in terms of unplanned blackouts in Iran (Veloza and Santamaria 45). However, in recent years this gap has been widened in such a way that resulted in recurring blackouts, raising concerns regarding future energy supply security in Iran. According to a study by (Dehghan, Amin-Naseri and Nahavandi 12), with the current pricing policy in Iran, supply will fail to meet the electricity demand and country budget will not be sufficient to increase the supply in order to meet demand, leading to more serious blackouts in 2025, 2028 and 2024 in base, low and high demand scenarios, respectively. Iran is recently experiencing recurring power outages, impacting all building sectors of housing, commercial and health care centres. This is mainly attributed to peak loads during specific times of days when the energy consumption of households reaches to the highest amount. Power outages seem to be inevitable due to existing gap between demand and supply. Many researches have been conducted in terms of power outages to estimate the value of constant electricity supply for households by their willingness to pay (Cohen et al. 139; Ozbafli and Jenkins 443; Amador, González and Ramos-Real 953; Praktiknjo, Hähnel and Erdmann 7828). A study conducted by (Morrissey, Plater and Dean 141) revealed that

households were willing to pay to avoid lengthy blackouts for the ones which were mostly occurred during peak times. This can demonstrate the important role of blackouts on objective and subjective costs in households' life (Fig.1). Other attributes which affected households' willingness to pay are duration of the blackout, peak or off-peak times, day of the week, planned or unplanned and winter or summer season.

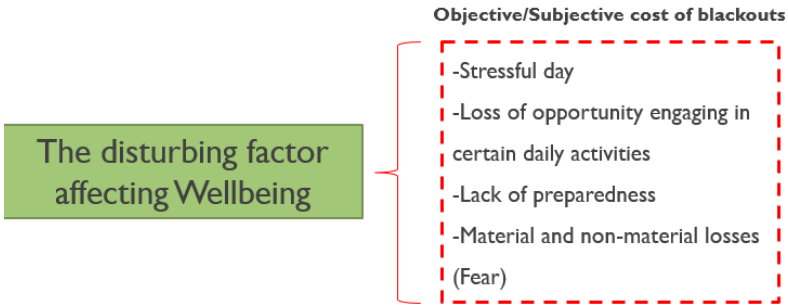

Figure 1: Costs of blackout for Iranian households

According to reports by Iran's Energy ministry, blackouts are mostly attributed to the increase in power peaks, which in turn increases the gap between energy demand and supply. One of the most disturbing blackouts is unplanned one, which can not only be stressful, but it can bring life into a grinding halt, leading to a loss of opportunity to engage in certain daily activities. This loss of opportunity can have significant impact on the quality of life, causing damages from lack of preparedness. According to (Praktiknjo, Hähnel and Erdmann 7825), the damages differs based on households' personal needs, their existing assets and individual preferences. Therefore, constant electricity supply is considered as a fundamental requirement for well-functioning modern societies. In addition to the negative impacts of sudden blackouts on home appliances, spoiled food, it can cause non-material losses, such as inconvenience or fear, which in turn could affect households' health and wellbeing (Morrissey, Plater and Dean 142). The non-material cost of blackouts can be more devastating in future if energy consumption pattern of Iranian households continues with the current trend. Such costs are indicated to be quality of life, economical costs, environment, health and lifestyle. It has been indicated that (Praktiknjo, Hähnel and Erdmann 7826) electricity corresponds to many basic needs of human beings as indicated in Maslow's Hierarchy of Needs (physiological, safety and health, belonging, esteem, self-actualisation). As a result, when supply fails to satisfy households' needs, loss of welfare will be unavoidable. Among non-material blackout costs, home activities or non-working time are classified as power outage costs which indirectly affects quality of life, unless they were substituted with other activities. This means that several domestic activities are only partially possible during blackouts (Praktiknjo, Hähnel and Erdmann 7829). The problem caused by blackouts is not limited to housework. Due to digitalisation, all kinds of home activities will become dependent on electricity in near future, thus discomfort perceptions will increase among Iranian households.

Overall, the issue of unplanned blackouts in Iran necessitates crucial measures to be employed regarding supply and demand-side solutions. In the studies concerning energy supply issues, shifting to more renewable energy technologies was a suggested solution by studies implemented in Iran (Tavana et al. 1194; Oryani et al. 971; Ahmadi, Mirghaed and Roshandel 265). However, barriers such as high initial capital cost, lack of awareness and knowledge as well as sanctions have significantly slowed Iran's transition to a cleaner energy system (Wilkins 68). Another solution suggested for energy supply problems was to

increase power plant capacity to address winter and summer blackouts caused by limited natural gas and electricity supply, respectively (Vedadi Kalantar, SEFODDIN and Hajinezhad 276). However, (Basiri, Sobhani and Sadjadi 1) demonstrated that natural gas availability can be achieved by both a sufficient supply and efficient energy use by occupants. According to several reports in Iran, although production capacity may lessen the existing gap during peak loads, the wrong consumption pattern has always been faster than the growth of power plants' capacity (IRNA). Therefore, government, policymakers and researchers have started to pay more attention to demand-side of energy including households' characteristics, behaviour and habits of consumption as a more feasible solution to achieve energy efficiency in the near future in Iran (Mohammadi et al. 263; Oryani et al. 974; Soltani et al. 1; Sepehr et al. 481). In this regard, both government and researchers have proposed several interventions to achieve energy efficiency in household's energy consumption.

3 Policies and strategies proposed by the government and researchers

In terms of energy policies, government and researchers have proposed several policies and strategies to reduce households' energy consumption. One of the policies focused on peak and off-peak energy costs to lower peak load times in energy consumption. In a study by (Ojand and Nazari 131), suitable electricity prices for the peak load and off-peak times were suggested to contribute to the decrease of energy use during peak load times, while keeping social welfare in a high level. This policy included discounts for off-peak times and overpayments during peak load time consumption. However, it should be noted that social and economic challenges for low-income households, such as household welfare, unemployment and higher inflation have hindered the applicability of this policy (Moshiri "The Effects of the Energy Price Reform on Households Consumption in Iran" 178). Moreover, the rise in the tariffs did not significantly affect the consumption pattern of high income households. In another policy named "Omid electricity", government aimed to institutionalize the culture of optimal electricity consumption in housing sector by using incentives (e.g. discounts) for households with lower electricity consumption. In this plan, subscribers were divided into three categories (low, good and high consumption) in accordance to the acceptable energy consumption pattern in their local area. Those with low consumption would enjoy incentive benefits in proportion to their amount of consumption, including discounts of up to 100% on electricity tariffs. In this project, households with 100% discount could also be eligible for solar panel installation for their homes. Although this policy was successful in 2020, but government faced major problems, since Iranian households already pay 50 % of the energy price, which has caused a shortfall in the annual budgets of the power plants. Also, due to low energy prices in Iran, higher consumption households receive 10 times more subsidies from the Ministry of Energy than lower consumption subscribers (Fig.2). Therefore, there is a recent debate to revise the plan through increase the electricity cost for high-consumption subscribers, who are mostly high income households, and to lower energy cost based on the same amount for lower consumption subscribers. This means higher amount of consumption during peak loads will result in higher electricity price without subsidy.

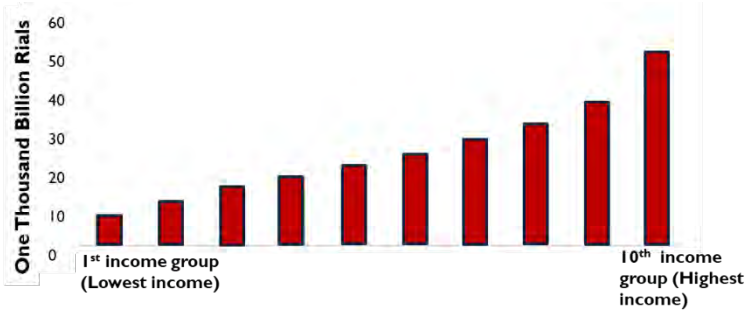

Figure 2: Subsidy distribution for different income groups in 2018.

It can be concluded that neither the elimination of subsidies nor other policies proved to be successful in resolving the gap between energy demand and supply. Therefore, researchers started to consider human aspects as the most effective factor in households' energy demand. Various researchers have studied the effects of human behaviour on household energy consumption (Ucal 775; Park and Kwon 494). In their studies, different solutions were proposed based on households' attitudes on the energy-related issues such as home appliances or electrical energy use. In this regard, researchers proposed energy behaviour models to predict energy consumption of households (Sepehr et al. 481; Larsen and Nesbakken 179; Zhang et al. 110; Kim and Cho 72; Mora, Carpino and De Simone 125; Paatero and Lund 273; Swan and Ugursal 1819; Richardson et al. 1878), however, studies have showed that difficulties in prediction have occurred during specific times of a day. After modelling the energy consumption profile for houses in Iran, (Sepehr et al. 487) noticed that although the predicted model was well matched to the measured consumption profile in most hours of a day, the error has occurred in the time intervals like hours 12–16 and 21–23. They concluded that the residential subscribers' peak usually occurs during these times of the day, leading to difficulties in the model's predictions.

Other studies proposed a set of actions undertaken to bring about changes in behaviours related to energy consumption called intervention. Each proposed intervention was based on different strategies to be effective for households' energy related behaviour (Abrahamse et al. 273). Different approaches of energy saving programmes were mostly categorized into education (Estabrooks et al. 25; Kaufman and Rousseeuw 4; Carrico and Riemer 1; Wensing, Bosch and Grol 85; McMakin, Malone and Lundgren 848); persuasion (Grier and Bryant 319; Philip Kotler and Lee 10; Peattie and Peattie 260; Gonzales, Aronson and Costanzo 1049; Emeakaroha, Ang and Yan 290), law and public policy (Gillingham, Newell and Palmer 597; Hedlund 82; Houston and Richardson Jr 2063), feedback use (Gölz 1453); home retrofits (Elsharkawy, Rutherford and Buildings 295) and technological interventions (Karatas, Stoiko and Menassa 539). Although the aforementioned interventions were successful at the beginning of their adoption, but such policy tools were ineffective in reducing household energy consumption over longer period of time (Drews, Exadaktylos and van den Bergh 1; Dietz et al. 18452). Furthermore, these programs could not address different characteristics of households and their different activities, which played a key role to induce energy-change patterns, since households reacted in different ways to intervention strategies.

Another problem was their high emphasis on environmental issues raised from high energy consumption (e.g. pro-environmental behaviour and energy efficiency) and their less attention to other aspects and values of households. Study of different policies and interventions revealed that most of them based their strategies on restriction, motivation, persuasion, education to elicit intentions of households to save energy. Most of the

suggested programs were either short term or less effective. For example, campaigns often emphasise both the environmental and economic benefits of energy saving behaviour, although studies indicated that this may not be the most persuasive method (van den Broek, Walker and Klöckner 811). Other interventions used motivational approach, to pledge households to save more energy in the future (Bull et al. 1998). However, research on the effectiveness of interventions that involved pledges or goal-setting reported mixed findings (McCalley and Midden 590). Other campaigns have focused on social norms to persuade householders to reduce their energy use (Allcott 1082). However, besides the success of the program, only 2.3–2.4% reductions in energy use were observed. (Schwartz et al. 15244) concluded that behavioural changes of energy use interventions have accounted for 2.7% reductions in energy use in their study, which indicates the ineffectiveness of such interventions in sustaining energy-related behaviour changes. This may be due to the fact that households' may pay more attention to value-based solutions rather than economic solutions. Since, energy consumption can indirectly affect households' wellbeing (Fig.3). This means consumer behaviour can be extremely complex which rarely follows the rational decision-making theories of economics.

Figure 3: Electricity as a possible criterion for measuring the level of wellbeing.

Overall, the significant effects of households' activities, characteristics and their incidental behaviour on prediction errors, necessitates more value-based strategies aiming to reduce peak load time's electricity consumption among households. As a result, with regard to the proposed interventions and policies regarding energy efficiency, it can be concluded that blackouts can be resolved through a more effective solution which includes peak load duration reduction in houses to further take the burden of inadequate energy supply and blackouts in specific times of days.

Investigation of various policy and strategies proposed by government and researchers indicates that the approach of their solutions are based on restrictions with punishments or motivations with environmental awareness or monetary rewards. Nonetheless, literature revealed that problems still exist regarding feasibility and sustainability of such programs. Therefore, a research gap exists in terms of strategies which are mostly based on households' perceived value of reducing energy consumption during peak and off-peak times and their wellbeing which may help to resolve problems regarding applicability and sustainability of the existing programs.
The burden of an electricity outage may vary among different user profiles. For instance, larger households experience higher objective and subjective costs since more people experience this problem. Therefore, understanding the households' demographic information and its relation with energy consumption pattern can be crucial to reveal contributing factors of inefficiency in energy use and blackouts. This can also lead to a development of a more feasible incentives and motivations for energy conservation attitudes.

4 Household lifestyle and energy consumption (Demographic Information)

As indicated previously, the damages of blackouts differ based on households' needs and preferences. Therefore, understanding households' demographic characteristics and energy consumption pattern can be a crucial step to recognise the reason behind their tendency towards inefficient energy use.

Various researchers highlighted different variables affecting households' daily energy demand. The inefficient use of energy is mostly attributed to increasing growth in population, number of households, floor area, changes in lifestyle and climate change (Aryanpur et al. 60; Papadis and Tsatsaronis 2; Yetano Roche, Paetz and Dienst 12; Tofigh and Abedian 1302; Mohammadnejad et al. 4652; IEA). For instance, (Ojand and Nazari 139) concluded that family income, size of house and number of households were amongst the primary factors of electricity demand in Iran. In another study, (Soltani et al. 1) demonstrated that demographic feature of household age, gender, size and awareness level impacted households' energy conservation. They have concluded that women are more involved in housing activities (e.g. cooking), therefore, consuming more energy. In terms of age, researchers have shown young adult-headed households were more likely to have high electricity use. Also, in this study, they pointed out that the increase in income did not displayed more energy-saving actions at home. In terms of household size, it has been revealed that with the increasing number of households, the incidental behaviour has increased, which has resulted in unpredictable peak loads (Sepehr et al. 487). (Sarmast and Poor Hassan 1) as well as (Tabli and Khajavi 66) highlighted income and their residential district (location) have caused differences between energy consumption patterns of Iranian households. In another research, (Akbari, Talebi and Jalaei 1) revealed that space area, the number of home appliances and space layout have affected energy consumption among Iranian households. According to above-mentioned researches, an increase in space area from 100 m^2 to 140 m^2 has accompanied by a rise in appliance ownership and energy consumption in Iran.

Although energy consumption can be effected by various indicators of income, climate, age, household size etc., incidental behaviour of households seems to be underestimated as an effective driver for unpredictability of peak loads, leading to unplanned blackouts in Iran. Nowadays, the Iranian households' lifestyle has been pursued to a higher living standard, resulting in an excessive amount of energy use (Rahmani et al. 2). A report by the Statistical Centre of Iran (SCI 51) shows that with the increase of Iranian's per capita disposal income, the direct energy consumption has also increased. In this regard, previous studies have demonstrated that daily energy related activities were mostly dependent on households' lifestyle, which dictated the residential energy consumption pattern (Fong et al. 395; Lotfalipour, Mahdavi Adeli and Rezaei 54-56). Moreover, (Soltani et al. 12) concluded that the amount of energy consumption in households was surprisingly not concerning climatic conditions, but mostly based on a habitual life routine. Thus, increasing energy consumption (heating or cooling) was mainly regarded as a routine procedure in different climates. This points out the notion of "consumption routine" which is referred to a repeated consumption learned by groups of consumers in response to their living context. Based on this notion, a shift in households' routine lifestyle seems to be an effective approach to affect their daily energy demands. Various theories exist regarding lifestyle and consumption pattern of households. According to Veblen (Gao et al. 515) lifestyle is an integrated system of attitudes, values, opinions and interests of households, which can affect consumption pattern of households. Therefore, consumption pattern can be altered when considering households' values and interests in their life routine activities.

Unfortunately, little number of researches and energy efficient campaigns have focused on the notion of changing lifestyles to impact wrong energy consumption patterns so as to achieve a more sustainable energy related behaviour change. For instance, previous campaigns and researches have proposed programs and incentives to change households' energy related behaviour by proposing various energy saving strategies, emphasising environmental and monetary benefits of energy efficient activities. However, studies have shown that consumption does not specifically address living and basic needs, but it includes signs, symbols, ideas and values. This highlights the important role of households' experience and values on choosing their daily life activities, which can be used as an effective reward for a more energy efficient consumption pattern rather than environmental or monetary outcomes of their activity.

5 Interventions towards household's interests

As indicated previously, interventions were proposed to change energy consumption behaviour of households in global scale. Each proposed intervention was based on different strategies of education, persuasion, feedback and home retrofits. The most prevalent techniques that have been implemented by researchers were goal setting behaviour, problem solving, feedback on behaviour, social support and education. Among these interventions, energy consumption and resource efficiency were the mostly focused goal.
Studies have revealed that there are some limitations, contributing to their limited success and maintenance of the desired behaviour over longer periods of time. The first limitation is that such single policy tools were ineffective in reducing household energy consumption (Dietz et al.). Although informational programmes appeal and they can change attitudes while increasing knowledge, they usually have failed to achieve sustainable behaviour change (Karatas, Stoiko and Menassa 539). To address this issue, various studies integrated education with other intervention approaches (e.g. persuasion, penalties etc.), for those households with extreme energy-use patterns (Azar and Menassa 211). However, not all households react in the same way to multi-level intervention strategies. Therefore, interventions may need to consider different characteristics of occupants and their daily activities, to develop a more feasible strategy for a sustainable behaviour change.
Another limitation is that technological interventions have highly uncertain energy-reduction benefits (Chidiac et al. 620; Entrop, Brouwers and Reinders 628; Schneider and Rode); relatively high initial costs (Nemry et al. 976; Yudelson 108); reluctant stakeholder commitment, especially while taxes and energy prices are still low (Menassa 3577); and lack of information about the existing building systems and the challenges of integrating new technologies. In terms of retrofit solutions, (Galvin 398) did not find significant relationship between behaviour change and retrofitted built environment and stated that households in retrofitted homes often consume more energy than expected. This is due to the fact that retrofitting homes can solely reduce energy consumption to a certain extent (Elsharkawy and Rutherford 32).
The limitation of existing intervention programs showed that for the creation of a lasting behaviour change, a value-based approach can be a better solution to encourage households to a more desired behaviour, which is also beneficial for their wellbeing containing energy efficiency as an additional reward. This can also become a motivating factor for households to maintain their wellbeing, while reducing energy consumption and preventing unplanned blackouts. Accordingly, blackouts have caused difficulties in implementing activities which are valued by households in certain times of a day. This can be considered as a main reason that unplanned blackouts could affect households'

wellbeing, since households may implement different activities during certain times. Therefore, exploring daily life activities and households' life routines can be a contributing approach to identify the value of domestic activities and its substitution with other activities which can be valued by households to be integrated in the life routines to maintain wellbeing while achieving energy efficiency.

Areas of life which can be related to energy use differs based on households' daily domestic activities. In Iran, domestic consumption of lights, household appliances, and air conditioning is the main sources of the electric power demand (Bazzazan, Ghashami and Mousavi 9). However, daily life activities are not solely limited to such energy-related activities. In a recent report of Statistical Centre of Iran (SCI), households have spent most of their time in leisure as well as self-care activities. Iranian households spent approximately half of their day, in self-care activities (including sleeping, eating and drinking, health care - medical, trips related to care and self-care activities, etc.). According to this report, the average of time spent per day was 11 hours and 42 minutes, which was the highest percentage of daily activities in 2019. The second highest percentage allocated to different leisure activities (exercise, entertainment, studying, watching TV etc.) with 4 hours and 13 minutes on average. Housework of cooking and cleaning, which were in the third place, were spent about 2 hours and 51 minutes on average by Iranian households.

According to the above-mentioned report, it can be concluded that wellbeing related activities are as important as other energy related activities in Iranian households' lifestyle. This demonstrates that a reduction in energy demand may not necessarily effect their life routine in a negative way, if substituted by self-care activities. In this regard, lifestyle changes can be introduced to reduce energy demand while improving levels of personal health and wellbeing.

6 Conclusions and Recommendations

This research endeavoured to explore the neglected impact of lifestyle on household's energy consumption pattern and introduced a new area of study in energy efficiency researches by highlighting the forgotten hidden link of wellbeing related activities of households and energy consumption pattern. This study introduced a possibility of well-being related awards to sustain the change in households' energy consumption habits.

Given the above issues regarding blackouts and the limitation of the existing interventions to achieve a sustainable behaviour change, it can be concluded that the main goal of energy interventions need to be shifted from monetary values to more user-centred values. The unsustainability of behaviour changes over time has demonstrated that most of the daily activities seem to be unintentional. This necessitates further considerations of households' lifestyle and the way in which changing of behaviour can be sustaining by a more user value-based intervention approaches. A routinized type of behaviour can be achieved by emphasising wellbeing of households in the first place. Since researchers showed that many households are not motivated to reduce the energy use for the sake of minimising GHG emissions or reducing energy bills. Therefore, the nature of motivation should be more focused on wellbeing benefits of energy efficient actions rather than emphasising pro-environmental behaviour. This can be achieved by identifying the value of their daily life activities (including bodily activities and mental activities) and afterwards identify a way to substitute wrong energy consumption patterns with more well-being related activities valued by households, which will lead to a reduction in energy loads during peak and off peak times. Therefore, blackouts can be addressed in terms of energy use patterns and substituting them with more value-based activities to decrease the energy demand side.

This research highlighted that value-based activities such as self-care can play a crucial role in motivating households towards a more sustainable behaviour change. This needs further exploration regarding motivational knowledge and states of emotion of households when implementing domestic energy related activities.
Based on this review, the future study will focus on bridging the gap between human behaviour and existing Iranian energy policy and will endeavour to propose a predictive model based on Iranian households' energy consumption behaviour (Fig.4).

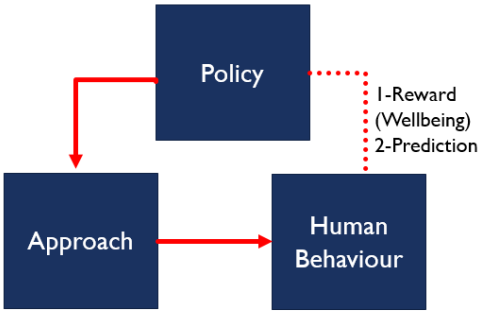

Figure 4: Vision of the future study

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COMMUNITY FARMING IN RURAL CONTEXT

ABSTRACT

AGRICULTURE IS ONE OF THE LARGEST EMPLOYERS AND GDP CONTRIBUTORS OF THE WORLD. IN INDIA THE NUMBER OF PEOPLE EMPLOYED IN AGRICULTURAL SECTOR HAS BEEN INCREASING OVER THE YEARS BUT ITS GDP CONTRIBUTION IS DECREASING. ALSO, THE SATISFACTION AMONG FARMERS IS DECREASING. OUR MODEL OF COMMUNITY FARMING INVOLVES POOLING OF RESOURCES AND EFFORTS OF ALL FARMERS IN A COMMUNITY OR VILLAGE. THIS WAY WE CAN ACHIEVE HIGHER YIELDS, GENERATE MORE EMPLOYMENT, IMPROVE SATISFACTION AND OVERALL SOCIO-ECONOMIC STATUS OF FARMERS. IT CAN ALSO IMPROVE THE INFRASTRUCTURE AND SPEEDUP THE DEVELOPMENT OF RURAL AREAS.

INTRODUCTION

AGRICULTURE IS ONE OF THE MOST IMPORTANT INDUSTRIES WORLDWIDE AND CONTRIBUTES TO ABOUT 6.4% OF THE GLOBAL GROSS DOMESTIC PRODUCT (GDP). IN INDIA, WHICH IS THE SECOND LARGEST CONTRIBUTOR IN THE AGRICULTURAL SECTOR, ABOUT 15.4% OF THE COUNTRY'S GDP IS FROM AGRICULTURAL SECTOR (DATA FOR THE YEAR 2016-17. SOURCE: WWW.STATISTICSTIMES.COM) IS ALSO ONE OF THE LATRGEST EMPLOYING INDUSTRIES OF THE

YEAR	TOTAL NO. OF PEOPLE INVOLVED IN AGRICULTURE (IN MILLIONS)	NO. OF CULTIVATORS (IN MILLIONS)	AGRICULTURAL LABOURERS (IN MILLIONS)
1951	97.2	69.9 (71.9%)	27.3 (28.1%)
1961	131.1	99.6 (76%)	31.5 (24%)
1971	125.7	78.2 (62.2%)	47.5 (37.8%)
1981	148.0	92.5 (62.5%)	55.5 (37.5%)
1991	185.3	110.7 (59.7%)	74.6 (40.3%)
2001	234.1	127.3 (54.4%)	106.8 (45.6%)

TABLE 1: NUMBER OF PEOPLE EMPLOYED IN AGRICULTURAL SECTOR (SOURCE: WWW.CSISINDIA.NET)

FROM TABLE 1, WE CAN SEE THAT THE NUMBER OF PEOPLE EMPLOYED IN AGRICULTURE HAS INCREASED FROM 97.2 MILLION IN 1951 TO 234.1 MILLION IN 2001. ALSO, IT HAS BEEN OBSERVED THAT THE NUMBER OF AGRICULTURAL LABOURERS IS INCREASING AT A MUCH FASTER RATE THAN THE INCREASE IN NUMBER OF CULTIVATORS. THIS IS DUE TO THE INCREASING POPULATION OF THE COUNTRY AND THE INCREASING LAND SCARCITY.

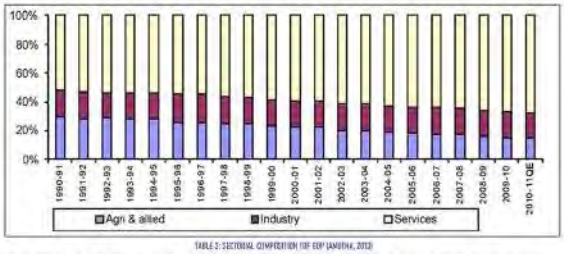
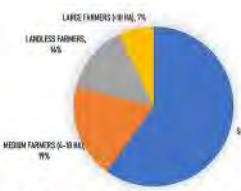


TABLE 2: SECTORAL COMPOSITION (OF GDP (ANANTHA, 2012)

FROM TABLE 2 WE CAN SEE THAT THE THOUGH THE NUMBER OF PEOPLE ENGAGED IN AGRICULTURAL ACTIVITIES HAS INCREASED OVER THE YEARS, THE GDP CONTRIBUTION OF THE SECTOR HAS DECREASED. THIS IS MAINLY BECAUSE OF TWO REASONS. FIRST, DEVELOPMENT OF OTHER SECTORS. SECOND, NO SIGNIFICANT DEVELOPMENT IN AGRICULTURAL SECTOR.

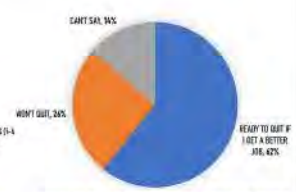
STATUS OF FARMERS IN INDIA

FARM SIZE/ FARM OWNERSHIP



GRAPH 1: DISTRIBUTION OF FARMERS OF INDIA BASED ON LAND SIZE (SOURCE: SHRIVAR, 2019)

WANT TO QUIT FARMING



GRAPH 2: REPLY OF FARMERS OF INDIA WHEN ASKED IF THEY WANT TO QUIT FARMING (SOURCE: SHRIVAR, 2019)

STATUS OF FARMERS IN ASSAM

70% OF THE TOTAL POPULATION OF ASSAM ARE DIRECTLY OR INDIRECTLY DEPENDENT ON THE AGRICULTURAL SECTOR. BUT MOST OF THE FARMERS ARE EITHER SMALL OR MEDIUM FARMERS. ALSO, MOST PEOPLE INVOLVED IN AGRICULTURE BELONG TO WEAKER ECONOMIC SECTIONS (SOURCE: DEPARTMENT OF AGRICULTURE AND COOPERATION, MINISTRY OF AGRICULTURE, 2012).

THUS, WE CAN SEE THAT AGRICULTURE IS ONE OF THE BIGGEST SECTORS OF OUR COUNTRY AND PROVIDES EMPLOYMENT TO A LARGE POPULATION, BUT ITS CONTRIBUTION TOWARDS THE GDP IS GRADUALLY DECREASING. ALSO, MOST OF THE PEOPLE INVOLVED IN AGRICULTURE ARE GENERALLY POOR AND NOT SATISFIED.

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6. HTTPS://WWW.CSISINDIA.NET
7. HTTPS://WWW.STATISTICSTIMES.COM

OBJECTIVE

OUR OBJECTIVE IS TO DESIGN A COMMUNITY FARMING MODEL, WHICH IS A SYSTEM OF AGRICULTURE WHERE AN ENTIRE COMMUNITY OR VILLAGE POOLS ITS RESOURCES AND MANPOWER TO ACHIEVE MORE YIELD, MINIMISE THE ECONOMIC GAPS IN SOCIETY AND GENERATE MORE EMPLOYMENT. THE BASIC PRINCIPAL BEHIND OUR MODEL IS THAT AN ENTIRE VILLAGE OR COMMUNITY FARMS TOGETHER IN A SINGLE LARGE FARM INSTEAD OF MULTIPLE INDIVIDUAL SMALLER FARMS. THIS WAY BY POOLING TOGETHER THE RESOURCES OF MULTIPLE FARMERS BETTER FARM TECHNOLOGY, ENHANCED SEED STRAINS, MORE SCIENTIFIC METHODS OF FARMING ETC. CAN BE PROCURED.

OUR MODEL

OUR BASIC MODEL CONSISTS OF A COMMUNITY FARMING VILLAGE CONSISTS OF THE HOUSING FACILITIES, LARGE AGRICULTURAL FIELDS, LARGE FISHERIES, COMMON PASTURE LANDS, STORAGE FACILITIES, COMMUNITY BUILDINGS LIKE SCHOOLS, NAAMGHORS, DISPENSARIES, AND A VILLAGE MARKET WHERE THE FARMERS CAN ALSO SELL THEIR PRODUCE LOCALLY. THE VILLAGERS MAY REAR ANIMALS EITHER AS A COMMUNITY OR INDIVIDUALLY OR BOTH. THE PROFITS CAN BE DIVIDED BASED ON THE RESOURCES AND MANPOWER CONTRIBUTION OF EACH FARMER. AN ELECTED OR NOMINATED OFFICE MAY ALSO BE SET UP TO RESOLVE CONFLICTS AND ENSURE SMOOTH OPERATION. THIS OFFICE CAN EITHER BE RUN BY GOVERNMENT OR THE VILLAGERS MAY CONTRIBUTE A CERTAIN PERCENT FROM THEIR INCOME AS TAX. THIS OFFICE MAY ALSO MAINTAIN A FUND FROM WHICH THE RESIDENTS CAN TAKE LOANS IF REQUIRED. LARGER VILLAGES AND COMMUNITIES CAN ALSO BE DIVIDED INTO MORE THAN ONE MULTIPLE COMMUNITY FARMING GROUPS.

A SIMILAR SUCH MODEL WAS USED FOR COMMUNITY FISH CULTURE IN LAKHIMPUR. THEY HAVE SEEN AN INCREASE IN THEIR YIELD PER HECTARE FROM 520 KG IN 1991-92 TO 1,389 KG IN 1997-98. DURING THIS PERIOD THEIR INCOME HAS INCREASED FOUR-FOLD FROM ₹15,591.00 TO ₹62,500.00. A COMMITTEE, LAKHIMPUR MIN UNNAYAN SAMITI RESPONSIBLE FOR DEVELOPMENT ACTIVITIES WAS ALSO SETUP. A SCHOOL AND LIBRARY AND AN HERBAL MEDICINE GARDEN WAS CONSTRUCTED BY THE COMMITTEE. THEY ALSO ORGANIZE SEMINARS AND WORKSHOPS TO CREATE AWARENESS ABOUT FISH CULTURE AND TO DEVELOP HUMAN RESOURCE AND ORGANISE VARIOUS FESTIVALS TO INCREASE SOLIDARITY AND UNITY AMONG VILLAGERS (GOSWAMI, 2000).

THIS MODEL CAN SIGNIFICANTLY IMPROVE THE AGRICULTURAL OUTPUT OF A VILLAGE AS EVERY VILLAGER WILL POOL TOGETHER THEIR RESOURCES AND EFFORT INTO PRODUCTION. AS THE ENTIRE VILLAGE IS WORKING AT THE SAME FIELD, THE EFFORT OF ANY INDIVIDUAL FARMER WOULD ALSO REDUCE, THUS THE FARMERS WILL HAVE MORE FREE TIME WHICH THEY CAN SPEND ON THEMSELVES OR TO GENERATE SIDE INCOMES FROM ALTERNATE ACTIVITIES. WITH MORE TIME IN HAND AND MORE MONEY, THE QUALITY OF LIFE OF THE VILLAGE WILL SIGNIFICANTLY IMPROVE. THE MODEL ALSO CREATES NEW AND MORE EMPLOYMENT WHICH CAN SOLVE THE PROBLEMS OF UNEMPLOYMENT. REDUCTION OF UNEMPLOYMENT WILL LEAD TO DECREASE IN ANTISOCIAL ACTIVITIES LIKE THEFT, LOITERING, ETC. A SURPLUS OF MONEY EACH YEAR CAN BE ACCUMULATED AND USED FOR COMMUNITY BUILDING ACTIVITIES LIKE HEALTH CAMPS, AWARENESS ACTIVITIES, ETC. ALSO, SINCE THE ENTIRE VILLAGE WILL BE WORKING TOGETHER, A SENSE OF HARMONY AND BELONGINGNESS SHALL FORM BETWEEN PEOPLE. THIS SENSE OF TOGETHERNESS CAN BE FURTHER STRENGTHENED BY COLLECTIVELY ORGANIZING LOCAL FESTIVALS IN THE COMMON PASTURE GROUNDS.

CONCLUSION

THIS MODEL OF COMMUNITY FARMING WILL HELP BOOST AGRICULTURE, GENERATE MORE YIELD AND EMPLOYMENT, CREATE A SENSE OF BELONGING IN EVERY COMMUNITY AND IMPROVE THE OVERALL SOCIO-ECONOMIC STATUS OF THE FARMERS. IT WILL ALSO BRING MORE DEVELOPMENT TO VILLAGES AND INCREASE THE SATISFACTION OF THE RURAL POPULATION. ALSO, THE RISKS OF CROP FAILURE CAN BE REDUCED BY UTILIZING BETTER FARM TECHNIQUES AND IRRIGATION WHICH INDIVIDUAL FARMERS MAY NOT BE ABLE TO AFFORD BUT WHEN THEIR RESOURCES ARE POOLED AS A COMMUNITY THEY CAN AFFORD IT.

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End of the Proceedings