EXPLORING VERNACULAR BUILDING TECHNOLOGY AS A NEW MODEL FOR SUSTAINABLE FUTURE: MRU TRIBE'S BUILDING FORM AS CASE STUDY

M.S.R.Shovon*[1], M.R.Khan[2], P.S.Anik[3] and A.Rahman[4]

[1,3,4] *B.Arch. Student, Department of Architecture, KUET, Bangladesh, e-mail: anik1725031@stud.kuet.ac.bd*
[2] *Assistant Professor, Department of Architecture, KUET, Bangladesh, e-mail: raihankhan@arch.kuet.ac.bd*

***Corresponding Author**

ABSTRACT

The building construction industry alone produces much amount of building wastage materials all over the world. Rapid economic growth promotes the physical development of the cit y to the peripheral area. For this, the manufacturing of construction materials needs more natural resources that threaten the environment and human existence. The primary reasons for the production of these bulk construction wastes are the demolition of old buildings and the effects of natural disasters on the environment. Besides the economic loss, the process obstructed achieving a sustainable built environment, particularly for developing countries. Recent developments in the building and construction professions have emphasized the adoption of environmentally friendly construction technologies as well as a study into the reusability of old, deteriorated building detritus. Many local markets have developed informally that involved the trading of recycling materials. The parties, seller, and buyer are broadly dealing for economic benefits, although it reduces the consumption of natural resources. Lack of institutional involvement and systematic exploration of the field restrict the growth of this most potential marketplace. The purpose of the study is to spell out the potentiality of building debris as alternative construction materials and bring forth the challenges of the current marketplace, moreover elaborate practical cases of how these materials have been using for construction to finishing purposes. The empirical studies and papers will be reviewed for a critical understanding of the potentiality of old materials from a methodological standpoint. Discussion with stakeholders, detailed observation, and the illustration of practical examples will help further exploration. Every year excessive use of natural resources for building construction pushes the world into destruction, while the findings could minimize this consumption and promote the trading of old building materials. Moreover, the uniqueness of the issue will inspire professionals to work with the possibilities of old building resources. According to the study, recycling building materials are not only beneficial for the economy but reduce natural resource consumption and assure environmental sustainability.

Keywords: *Vernacular technology, sustainable future, Mru tribe, Building form.*

1. INTRODUCTION

During past decades vernacular technology has been a topic for professions like architecture, civil engineering, site planning, urban planning, etc. Even sociologists are now thinking about the vernacular system or vernacularism. Vernacular means tradition, context, locality, and the people who use locally available materials and indigenous construction techniques to make a built form (El-Shorbagy 2010). Human needs, climatic conditions, and contextual needs are some criteria that drive the generation of the vernacular form of development. According to Nguyen and Reiter, the form reflects the environmental, cultural, technological, and historical context of the specific region on which it was built (Muşkara, 2017). The present responses of climatic changes, reducing energy consumption, minimizing waste production, and environmental pollution influence many research

communities to explore the regional forms of development since 2007; the interest has been growing across the world.

Rapid urbanization poses several social, economic, and environmental issues, calling into question the current development pattern and its long-term viability. At present, physical development is guided by the mechanical system from material from production to construction process. This consumption and production impacted the environment with the industrialized system used to satisfy needs. Relying on advanced technology increases the range of affordability that seems critical for many developing countries. Unprecedented population growth requires high-rise development for accommodation, but this should align with the context. People of many regions now ignore the potentiality of local materials and import unfamiliar resources and techniques in the name of durability, which in the long run creates many impacts.

Nowadays, in Bangladesh, brick and concrete are the most used construction materials, which cause the development of brick burning furnace that requires a vast amount of topsoil of the alluvial plain. For this, nature and the environment are equally being damaged. The process not only emits a lot of carbon but also destroys natural woods for burning purposes. Moreover, the modern typology is being plotted everywhere without respecting the contextual settings regarding social, economic, and environmental. The use of brick, steel, and other modern building materials influences the production system, and the profit-centric market promotes growth without concerning the hazardous the system is generated. As a result, the most sustainable architectural form, which has been produced for 1000 years by inhabitants of each region using bioclimatic approaches, is now under threat (Nguyen, Truong et al. 2019).

To this end, the study focuses on vernacular architecture and analyzes its various aspects related to structural systems, materials, construction techniques, and processes. The Mru Tribe's Building form is taken to apprehend the details from a sustainable perspective. The findings will guide the development that is taking place in the unique topography and landscape of the hilly region. It will lead to achieving a sustainable built environment within the context of the delta.

2. METHODOLOGY

The paper is an outcome of theoretical analysis and a field case study conducted on building construction technology of the Mru tribe, located at the hill tracts of Bandarban of Chittagong. For their residence design and traditional societal practices, the Mru tribe's construction technology is viewed as a research area for framing the discourse to discover the vernacular building technology of Bangladesh. Data on the construction process with bamboo and wood was collected from discussions with professional experts. The experience of living on the houses regarding climatic and environmental comfort took from the residents. The average costs of making the houses and the elements are also collected. Lead informants are proceeded towards to gain enough ideas about convincingness of houses both from the environmental and economic viewpoint. Market analysis, discussion with community people, and masons were conducted for a detailed understanding of the housing process. Knowledge and other information were collected from the internet. Data attributes for the study have been inspected from an observational viewpoint and experience. Figure 1 depicts the overall workflow diagram of the study.

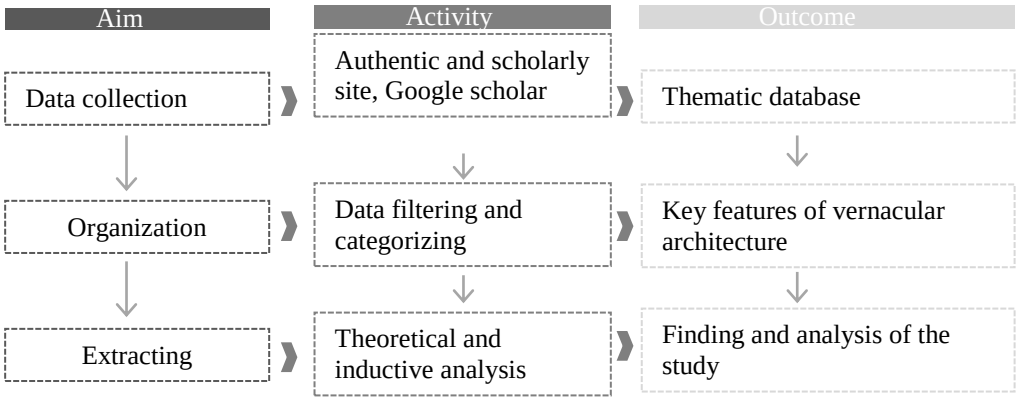

Figure 1: Work process diagram of the study (Nguyen, Truong et al. 2019).

3. VERNACULAR ARCHITECTURE IN GLOBAL CONTEXT

For thousands of years, every region across the world has had these people build homes based on their needs, in tune with the local climate. For this, they relied on things close at hand. People in every region have a bio-climatic method based on the weather and climate of the context. The variations of contextual factors shape the construction technology and building pattern due to material types and lifestyles. Over time, the environmental, cultural, technological, and historical context is reflected in the vernacular house form that develops as a cell of local climate (Nguyen, Truong et al. 2019). Sustainable development in this respect focuses on increasing the efficiency of local materials, energy, and topography, reducing the adverse effect on humans and the environment (Muşkara, 2017). To this end, knowledge of tradition is much more important in this age of advanced technological and large buildings (Nguyen, Truong et al. 2019).

Vernacular construction technology means a native and unique method to meet their needs for constructing dwellings without imported components and processes. The traditional technology of building construction has many benefits. Among many, affordability, self-made technology, and environment-friendly features are the core. According to Paul Oliver, traditional buildings are rich in cultural resources that have lightly complex elements and can express numerous meanings through structure and ornamentation. Vernacular buildings and construction technology reflect history, culture, tradition, climate, geography, topography, etc (Laz Banti 2021).

Moreover, the self-made technique is practiced in almost all countries based on different traditions. To ensure a sustainable future, vernacular architecture is essential. The need for vernacular building technology to achieve social, environmental, and economic conditions, a critical component of sustainable ability, is immense today. Sun-baked mud bricks, instead of bricks, can protect the environment from the black smoke from brickfields. The mud houses in earlier days were much more environmentally friendly. These were not only economical but also much more thermally comfortable. The house was cold on hot days, and the indoor environment was warm on winter days. Building a house made of wood is relatively easy and does not require much skill. But, today's unprecedented growth and climatic changes are questioned the process from a need-based perspective, which needs the adaptation of advanced technological support.

Many architects, planners, and geographers are now concerned about the traditional living for the environmental degradation and analyze the sustainable form of development with the help of modern technology. Conservative and interpretive attitudes are two popular approaches in working with vernacular architecture that has been introduced by the Egyptian Architect Hasan Fathy (6). The contemporary living and needs ignore the traditional processes due to its inconsistency with time and style and lack of compliance with the current requirements. But, the architect assembled tradition and

contemporary thinking and evolved a new form of development. A great example is the New Gourna Village, Egypt. The project features traditional techniques, materials, and vernacular styles and solutions with the benefit of contemporary ideas, that generate an economically sustainable building culture among the community. Fathy combined vernacular material and design methods to incorporate with the economic condition. Moreover, he trained the residents to develop their knowledge and skills regarding materials from locally available resources..

Figure 2: Examples of modern version of vernacular typology, New Gourna Village (left, Architecture for the poor: an experiment in rural Egypt by Hassan Fathy, 1969, Kapa training center, www.archdaily.com (right,)

Other one is Kapa training center, Costa Rica. The architects interacted with the local community to understand their needs and local design techniques. Moreover, the agreement between the parties has been operated by the community. Furthermore, the project's timber, planks, and frames were collected from the local area. Incorporating local methods into the design and building phases has a favorable impact on the ongoing possibility for community and environmental awareness. Working closely with the community helps the project to understand the struggling community and create a language fitting to their current pediment.

4. VERNACULAR ARCHITECTURE IN THE CONTEXT OF BANGLADESH

Vernacular architecture has been practiced in Bangladesh since ancient times. The unique landscape of the delta is the breeding place for diversified building materials. Due to the climate and various types of materials, and traditional construction of vernacular technology is observed differently in different regions. Most parts of the country except the contoured area of Chittagong, Sylhet, Cumilla are Flat Region. Generally, two types of vernacular housing are observed in Bangladesh. Most of these houses are made of mud houses, huts, tin-shed houses with bamboo-supported bars. On the other hand, about 90% of housing in the Hilly area is made of bamboo, and their building construction method differs from the flat area.

Most of the traditional houses in Bangladesh, are self-built by the residents for centuries. The geographical location, climate, tradition, and customs are the significant features to determine the characteristics of the construction system (Muşkara, 2017). This working process completes a communicative construction that allows workers and residents to interact with each other to create a social space. Despite being built without the assistance of any professional, it has been serving the majority of inhabitants in the country. There are still mud houses in the northern and southern parts of Bangladesh that have survived for years and are serving the people successfully.

Besides, mud houses can be seen in Satkhira, Khulna, Bagerhat, Bogra, Pabna, Dinajpur and Joypurhat. Of all the vernacular houses in our country, tin houses are the most common. Tin is readily available material. There are several flood-prone areas in Bangladesh. Such as Kurigram, Nilphamari,

Gaibandha. Many house forms need to be built in these areas as temporary housing or shelter house. However, most of the time, houses are made of bamboo can be seen in these areas because bamboo is a very fast-growing tree. There are two types of settlement patterns in our country. One is elongated-linear, and the other is amorphous. Both are established on elevated lands above the natural flood level. The amorphous type housing is clustered settlements, and the elongated-linear type is developed along natural levees of rivers by following the terrain. The roofs of most of the vernacular houses in Bangladesh are pitch roofs, gable roofs, hipped roofs, which are constructed with thatch.

In the name of modernity, the practice of vernacular architecture is slowly disappearing in the cities of our country. Moreover, the vernacular forms of hill tracks are replaced with concrete-made forms, which are a symbol of modern facilities. However, some eminent professionals are involved with exploring the potentiality of self-made technology and re-invent it through modern technology. These innovations would be a sustainable model for future development. Bellow illustrates some types of common vernacular house forms of Bangladesh developed .

4.1 Mud Walled House

Houses with mud walls are commonly known as mud houses in Bangladesh. This housing feature is mainly evident in the northwestern part of Bangladesh. Low rainfall, dry climate, and being flood level are the main reasons for mud housing development in this region. The roof is made of other commonly used materials like tin sheets and thatch to help keep it at medium temperature. Again in some other areas, sun-dried mud bricks are used for housing development.

Table 1: Comparison of various bamboo and the local price available in Bandarban (Author constucted based on field survey, October 2021).

Local Name	Scientific Name	Uses	Durability	Unit price (Tk)
Bailka Bash	Bambusa balcooa	Bamboo pillar, hard frame	10-12	300
Makla Bash	Bambusa tulda	Bamboo mat, Frame, wall enclosure	10	300
Muli Bash	Melocanna baccifera	Bamboo mat, bamboo fence	10-15	70

4.2 Thatch Houses

This type of hut is seen in all areas of Bangladesh. Materials such as reeds, long grass, paddy straw, and jute sticks use for walls and roofs. Reeds and long grasses are mainly selected because these are found in abundance on the river banks, and the price of these materials is comparatively low. The sides of thatch houses are covered with mud, and the roofs are made of bamboo and covered with different types of straw.

4.3 Bamboo Houses

Bamboo is the readily available building material in Bangladesh. In the eastern and northern parts of Bangladesh bamboo, is used in house construction. There are two types of bamboo, usually thick and thin. Thick bamboo is used for poles, roofs, and thin bash for walls. Thin bamboo is for making mats, wall partitions, and pannels. The Table 1 represents the various bamboos available in the Mru Tribe's context. The material is cheap and light in weight, and due to the addition of a hole, it helps in the necessary ventilation and conducts heat exchange.

4.4 Corrugated Iron (CI) / Tin Sheet Houses

Tin-roofed houses and wall-mounted materials are becoming more common in the rainforests where rainfall is relatively high because it provides advantages. The sheets are lightweight, durable, and effective in heavy rain. Over the past decade, natural construction materials have declined drastically,

and the country has undergone a lot of changes due to a lack of committees and planning. Conversely, locally available resources and techiques can be used to build eco-friendly build forms.

4.5 Examples of Modern Time

METI Handmade School is the finest example of modern times blended with traditional knowledge with modern technology. Architects Anna Heringer and Eike Roswag conceptualize the design based on geographical construction techniques and local materials. It also presents new methods for structural integrity. The school is designed with thick clay blocks and bamboo.

Figure 3: (Left) METI School, (Right) Pani Community centre, (www.archdaily.com)

The building is based on deep brick masonry to reduce the effect of moisture on the mud walls. The ground floor is surrounded by an earthen wall where the first floor has bamboo walls to help light and natural ventilation. Moreover, the assistance from local craftsmen makes the procedure easy to achieve a unique visual aesthetics. Another example is the Pani Community Center, an educational building designed by Schider Scholte, located in the north Bengal of Rajarhat (Figure 3). The plan contains two volumes shaded under a large bamboo roof construction. The cross-ventilation and planned vegetation maximize the cooling of indoor space. The design concentrates on regionally accessible materials and climatic conditions. The principal materials are mango tree wood, recycling steel, bamboo, hand-shaped brick, local grout, and wafer-thin recycled ridged panels. Furthermore, the chemicals used for bamboo and mud wall processing increased durability and strength.

5. FINDING AND ANALYSIS: MRU TRIBES BUILDING CONSTRUCTION TECHNOLOGY

5.1 Collection of Bamboo`

One of the few vernacular architectures in our country is the architecture of the Murang community living in the Chittagong hill track. They have been building houses with bamboo growing in the hills year after year. The Murang community in Bangladesh usually builds a house with bamboo. These grow in the surrounding environment and are collected from the shore. Table 2 illustrates the benifits of bamdoo from tenchinacl, economic and environmental dimensions. For constructing a house, one has to collect older bamboos 25 to 30 feet in height. Raw bamboos were used without any chemical processing, which may boost durability and make them stronger to withstand bad weather conditions. In total, 3-4 weeks are required for collection to processing for construction.

Table 2: Benifits of bamboo as construction materials from various dimensions.

Benefits of the Bamboo as construction material		
Technological Advantages	Durability	With proper treatment, bamboo provides a service life of up to 30 years
		Can be used as a complimentary/supportive material.
		Easy maintenance and replaceable
	Earthquake resistance	Due to its lightweight and elastic property, bamboo can resist earthquake pressure
Economic advantages	Affordability	Bamboo housing is low cost compared to wood and masonry
		It is available as raw building materials
	Employment generation	The manufacturing of low-cost bamboo houses provides employment to a large number of people
		It can generate extra employment like cultivation, harvesting, primary processing, transportation and marketing of bamboo
Environmental advantages	Environmental benefits	Bamboo is a energy efficient material that do not harm the health and environment
		Bamboo requires only 1/8 of the energy that concrete needs to create a building material of the same capacity.
		In comparison to steel bamboo needs only 1/50 the amount of energy for processing
	Control of deforestation	In the Costa Rican context 70 Ha of bamboo plantation is sufficient for 1000 houses where if it was made of timber it would 600 Ha of natural forest
		Bamboo can regenerate within 2-3 years
	Social acceptability	Bamboo has been in use for centuries and socially valued and accepted element of construction

5.2 Sorting

The settlements of the Mru community are mainly self-built or by local masons. The owner of the house or worker goes to the mountains to collect the bamboos, and the selection of perfect bamboo based on the thickness is vital, as well, it should be straight and narrow for making the wall frames and support. Certainly, bamboo is the main component of house construction, with different sizes and lengths required for various purposes. They collect husks from the crops grown for the roof structure, which must be dried for a few weeks.

5.3 Processing

The bamboos are first cut and assembled with sharp tools from the hill and remove the unnecessary elements from the surface. These bamboos are then cut into slices with an instrument in the middle, and then the pieces are sliced into several more layers and collect flexible fibers. Comparatively hard and thick bamboos as material for house poles/columns and structures but use a few more layers of work, which they use to cover the floor walls of the house and as porch overhang and window overhang. The whole process requires high skills for the contoured landscape, which challenges the system. The only step that has been used is to dry the slices in the sun to use as fiber.

5.4 Structural analysis

5.4.1 Foundation

The thick bamboos they first identify for use in the foundation are divided into five distinct sections. There are three relatively small bamboos and one long, which acts as a column. The core part of their house is lined with five columns. First, they bury the long bamboo used for the column. Then three

smaller bamboos are tied to the bamboo below the floor in the form of a three-legged stand with bamboo fibers (Figure 4). As a result, the long column receives standing support and resists small earthquakes. Long bamboos are used from ground to roof. It is usually best to use bamboo of 25 to 30 feet. The height of the floor from the ground is kept at a minimum of three feet, so they get a minimum clear height to cover the floor deck of the house and at the same time to protect it from wildlife and insects.

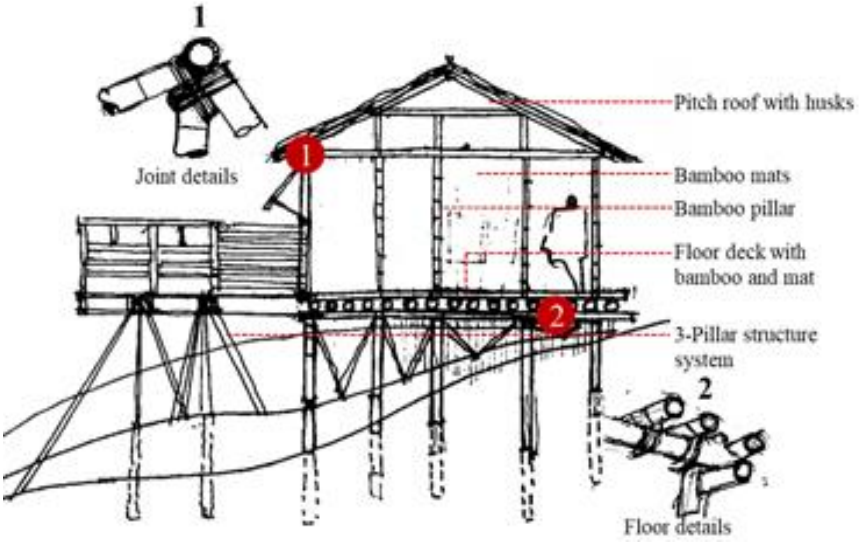

Figure 4: Mru Tribe's build form cross-section and details of joint (Drawn by author based on field survey, October 2021).

5.4.2 Floor construction

First, they arrange the bamboos horizontally and tie them with bamboo fibers to create a floor and an infrastructure in which the length of the bamboo depends on the floor size. They weave the fluted bamboos like mats and tie them with the floor with bamboo fibers. A traditional technique is used for joining different components of the structural system (Figure 5). The mat is used as the finish material of the floor deck.

Figure 5: Joint details of floor deck binding (Captured by author, October 2021).

5.4.3 Wall construction

The load-bearing columns are located on both sides of the core structure of the building. The mat is joined to the main structure to create a space enclosure, often known as a partition or an outside screen.

Figure 6: The mat used at outer façade and the thatch roof (Captured by author, October 2021).

5.4.4 Roof

The roofs of traditional houses maintain a pitch or slope for climatic or privacy purposes. Firstly, a pitch or slope structure has been designed with selected bamboo. The pores in the roof are then covered with tightly bonded leaves and husks (Figure 6), which prevent rainfall from infiltrating. The mat is then re-created from fused bamboo and is utilized in the ceiling.

5.4.5 Window

They usually make a frame in the middle of the wall when building a wall to give windows. The windows are made of mats, and a bamboo stick is used to open or close.

5.4.6 Overhang

The mat is used as an overhang for porch or windows.

5.5 Comparative cost analysis (Based on field case study and Paudel and Lobovikov 2003)

A Comparative analysis between bamboo house and 10 ft brick wall is given:

The Table 3 is made from the Survey Data and a paper. The cost of an 10 ft by 10 ft bamboo house is collected from the residents and the workers who build bamboo houses. On the other hand the cost of the brick wall is collected from a reference paper. We can see that a single brick wall costs 8820 tk . So a 10 ft by 10 ft brick house will cost minimum 40000-50000 Tk. Which is almost 3 times higher than a house made of bamboo.

6. CONCLUSION

Vernacular technology is a worthy example of architectural knowledge, coordinated with the environment, economy, and social aspects. It engrosses on the sustainable factors and human needs. But, the so-called faceless modernist growth has put this localized type of knowledge at risk. These not only destroy human roots from a cultural standpoint but also pose a threat to the environment due to climate change. The study aimed to explore the vernacular construction technology, local's observation of the environmental behaviour and economic factors of a unique landscape, where topography influences the living.

Already, many contextual forms of knowledge and skills are obsolete and replaced with the modern typology, and people rapidly adopt due to a lack of prudence and availability. Many local masons are switching to other professions or embracing modern technology for the demands. Many ethnic and traditional settlements are in danger. Mru tribes is one of the oldest and elegant ethnic communities living on the Chittagong hill tracts are residents of the Bandarban District. Bandarban is famous for its natural resources and contoured landscape. Last decade, the landscape experienced rapid changes in the number of tourists, which is increasing every year. Many recent prototypes using bricks and concrete have been imprinted from a utilitarian standpoint. These footprints adversely impacted the

unique landscape of the country. The vernacular construction of the Mru Tribe could be a future model for further development of the context.

Table 3: Comparision of 10'X10' house constraction costing based on two different materials.

Cost of Bamboo house (Constructed by author based on field case study)					
Item	Description	Quantity /area	Total Quantity	Unit Price [Tk]	Total Price [Tk]
Wall	Made of bamboo mat	10'X10'	4 nos	800	3200
Roof	Thatch roof	-	20 nos (thatch bundle)	150	3000
Floor	bamboos and bamboo mat	10'X10'	8 nos (bamboo)	300	3200
Labour cost	It requires 3-4 days to build and the payment is considered daily or contract	-	4-5 nos	500-700	2500-3000
Bamboo Pillar	Made of hard bamboo	-	2 nos (bailka bash)	300	600
Door window	Wooden door/window [Shirish kath]	3'X4'	One door and one window	1000	2000
				Total Cost	14500-15000

10 ft Brick wall construction cost (Paudel and Lobovikov 2003)					
Item	Description	Quantity/Area	Total Quantity	Unit price (Tk)	Total Price (Tk)
Along Width(brick)	Let, A 5" wall, Height = 9.5'	95 sft.	480 nos.	8	3840
Along width(brick)	Cement	95 sft.	2.5 bag	480	1200
For wall	Sand	95 sft.	11 cft.	20	220
Plaster Work	Cement	190 sft.	2 bag	480	960
For wall	Sand	190 sft.	10 cft.	20	200
Head mason		2 nos		600	1200
Helper		3 nos		400	1200
				Total cost	8820

At present, the professionals are more sensitive towards nature and respect the topographic factors before conceptualizing physical development. To some extent, this modernized vernacular pattern turns out to be expensive, such as Sairu Resort in Bandarban. From this perspective, Mru Tribe's technology would be a model that requires a little professional's intervention for increasing durability and making it visually appealing. The Mru Tribe's typology is the outcome of unique topography and the most energy-efficient and environment-friendly prototype that needs further exploration from lifestyle and economic dimensions in detail.

The paper reveals the benefits of vernacular building technology. This form of expertise is a sustainable model in consortium with the local environmental knowledge and local observation on

economy, environment, and socialization, which has high value. So, it is highly suggested this understanding should instantly be practiced before it fades away.

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