Revolutionizing Industry: Unveiling Engineered Bamboo Mass Production for Sustainable Economic Growth in Bangladesh

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Abstract

Bamboo has gained prominence in the research community as a sustainable material due to its eco-friendly nature, affordability, and rapid growth. Over time, researchers have aimed to enhance bamboo's suitability for construction, potentially replacing conventional materials like timber and steel. The solution comes through engineered bamboo, a processed form that addresses the challenges of raw bamboo. This innovative approach has sparked interest globally, leading to large-scale manufacturing in various countries. The South Asia is the main exporter of engineered bamboo, where countries like Bangladesh is far behind. Bangladesh, blessed with a tropical climate, holds immense potential to harness the economic and sustainability benefits of mass-producing engineered bamboo. This research studies the feasibility of producing engineered bamboo in large scale in place of timber. A comprehensive cost-benefit analysis unveils a promising prospect: through this initiative, Bangladesh could contribute a substantial 51.5 million USD annually to its economy, with potential for growth up to 71 million USD through full production optimization. Moreover, this industrialization initiative could markedly reduce 14.8% of the total carbon footprint of Bangladesh.

Keywords

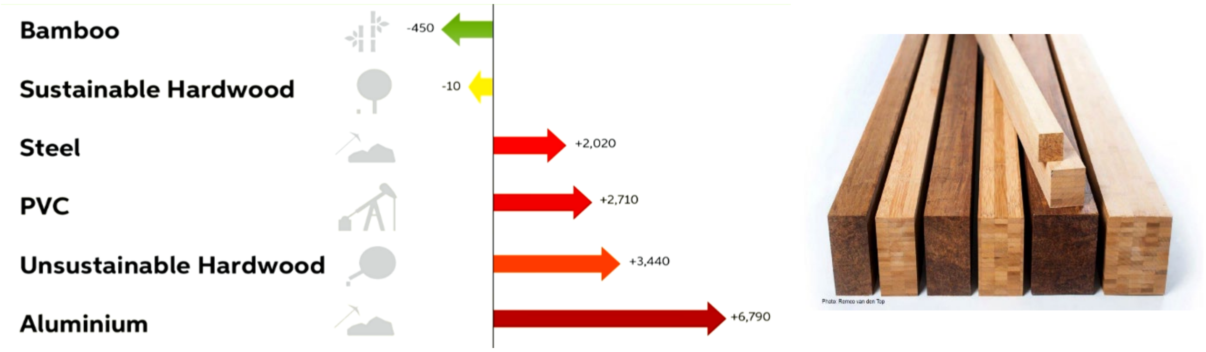
Bamboo Products, Engineered Bamboo, Sustainable Construction Material, Mass Production, Industrial Revolution

Introduction

The anticipated growth and urbanization of the global population in the coming years will lead to a significant need for building new homes, buildings, and accompanying infrastructure. Yet, this surge in construction comes at a cost – the production of nonrenewable materials like cement and steel produces huge amounts of greenhouse gases (Chowdhury et al. 2016; Doan et al. 2017). In the search for sustainable construction materials, researchers have identified bamboo as a promising alternative where Bamboo and bamboo-derived panels emerge as the optimal choice to meet the construction sector's wood demand. To surmount some of the obstacles of raw bamboo, researchers have undertaken a transformative approach by refining bamboo into engineered bamboo, thereby enhancing its structural properties and rendering it more amenable to construction applications.

Not just in construction materials engineered bamboo has gained significant attention within the realm of architecture, particularly for its suitability in applications such as flooring, roofing, walls, decorative elements furniture and components of green building (Sharma et al. 2015; Sharma and Vegte 2020). Its emergence is attributed to its rapid growth (matured in 3-5 years), lightweight quality, affordability, visual attractiveness, and environmentally friendly attributes compared to steel and other materials (Joseph and Tretsiakova-McNally 2010; Lugt et al. 2006; Tazowar et al. 2023). More than 60% of all building components' embodied energy is used by steel, concrete, and cement, whereas, bio-based materials such as; wood and bamboo are considered as renewable and sustainable material for many positive characteristics, including low embodied energy, low carbon impact and a good service life (Kibert 2016; Li et al. 2016; Su and Zhang 2016).

Bamboo has an excellent tensile strength to weight ratio compared to timber and steel. Being an anisotropic material with property variation in the longitudinal, radial and circumferential directions, it can the take the ultimate compression of (70.5-199.3) MPa and tensile strength up to 365 MPa (Huang et al. 2019; Li 2004). Compared to engineered bamboo, which absorbs 1 ton of CO2 during its growth, where production of steel and cement emits nearly 50 times more CO2 into the atmosphere (Sharma et al. 2015; Xiao et al. 2013). As shown in Figure 1 bamboo has significant negative carbon footprint compared to sustainable hardwood and steel which are the mostly used material over the world.



(a) (b)

Figure 1. (a) CO^2 emission (ton) in producing of different raw materials per ton (van der Lugt 2017) (b) Engineered bamboo laminates (van der Lugt 2017)

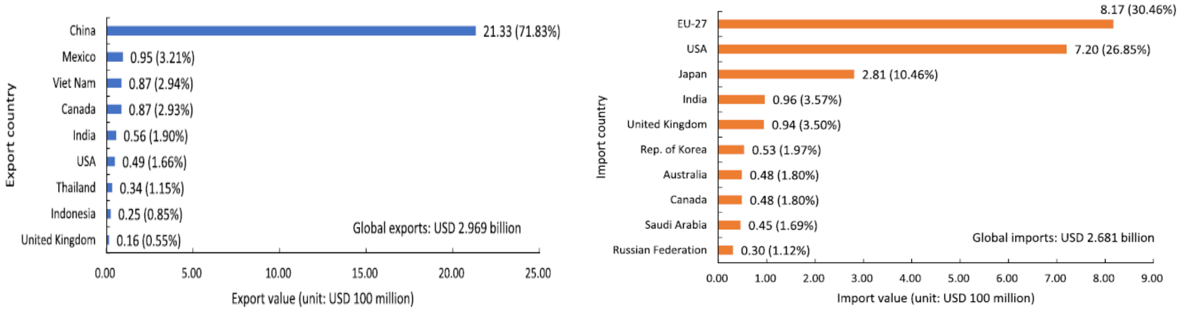
Leveraging engineered bamboo presents a valuable solution for swift construction, especially in situations requiring temporary structures, in contrast to the lengthier process of casting and curing in traditional reinforced concrete buildings. Nations like China, the USA, and the Netherlands have initiated the use of engineered bamboo across diverse applications such as flooring, roofing, interior design, and walls (van der Lugt 2017). Notably, these countries are engaged in large-scale production of the material, yielding time and cost efficiencies while championing sustainability for the future (see Figure 2).

The utilization of engineered bamboo also extends its influence on socio-economic dimensions, fostering local engagement and employment prospects. The initiation of engineered bamboo production within a country would stimulate the growth of bamboo forests, yielding substantial environmental benefits through reduced Carbon footprint (Dam et al. 2018). Moreover, eco-conscious industries like engineered bamboo production would yield employment opportunities for the local populace. The diminished reliance on foreign imports of materials such as cement, stone, steel, and wood products would profoundly impact a nation's GDP and overall economy. Furthermore, the extensive production of engineered bamboo holds the potential to contribute to foreign currency earnings through exports and by attracting Foreign Direct Investment (FDI) (“Trade Overview 2020” n.d.).

Firstly, learning, adapting and knowledge sharing is a must for Bangladesh from different countries that manufacture engineered bamboo products, specifically focusing on laminated bamboo and bamboo scrimber (Bala and Gupta 2023). These products are known for their unique qualities and are made using different techniques. China leads in producing these items and conducting related research (“Trade Overview 2021” n.d.). Even though Asia is a major bamboo importer, Bangladesh has not tapped into this market yet, despite having enormous potential for bamboo production.

Looking at the global scenario, North America and Europe are the primary importers of engineered bamboo goods due to their limited bamboo resources and industrialization ("Trade Overview 2020" n.d.). Bangladesh, being a tropical country, has an excellent opportunity to invest in bamboo production. This would not only cater to local needs but also allow entry into the global market, impacting both research and the economy positively.

This study aims to explore the feasibility of large-scale engineered bamboo production using local resources. A detailed analysis of costs and benefits has been conducted to determine its viability. Moreover, this study investigated the possibility of transforming existing plywood industries into engineered bamboo production facilities.



(a) (b)

Figure 2. (a) Main exporters of bamboo commodities (Trade Overview 2020) (b) Main importers of bamboo commodities (Trade Overview 2020)

Data Collection

Within the contours of Bangladesh, an assemblage of 33 bamboo species, encompassing nine genera and 18 naturally occurring species, have been documented across the nation (Rana et al. 2010). This verdant array of bamboos extends its reach across both forested and non-forested domains, converging into two expansive classifications—forest bamboos and village bamboos—comprising a mosaic of species. In the plains of Bangladesh, approximately 15 bamboo species have been cultivated, with Bambusa balcooa, Bambusa vulgaris, and Bambusa nutans emerging as prevalent contenders. Notably, a significant 76% of Bangladeshi farmers have woven bamboo into the fabric of their lives, integrating it into household constructions and protective barriers (Rana et al. 2010). Figure 3 elucidates the intricate production process of laminated and scrimber engineered bamboo, integral components for applications such as flooring, plywood, and construction panels. Remarkably, raw bamboo's utility encompasses a comprehensive 77%, distributed across diverse products as highlighted in Figure 4.

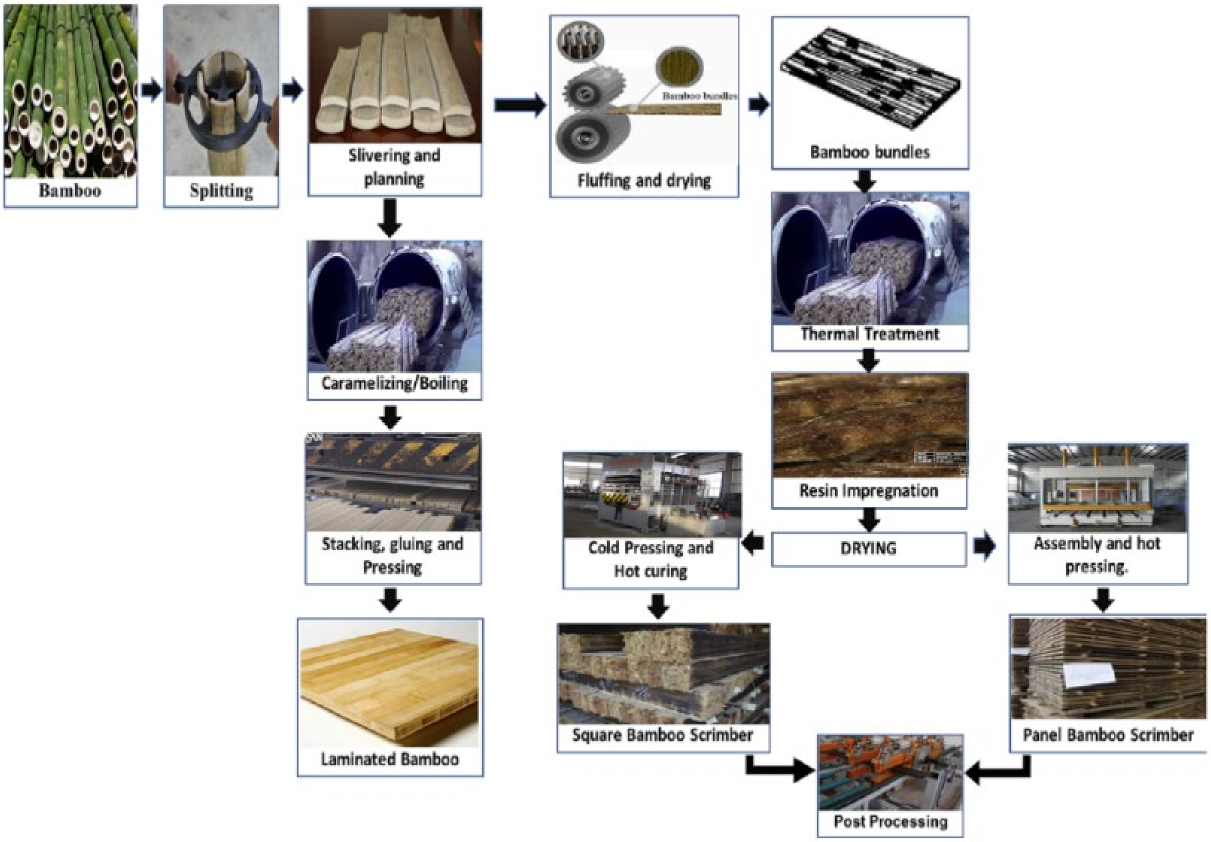


Figure 3. (a) Manufacturing process of Laminated Bamboo and Bamboo Scrimber (Kumar et al. 2016)

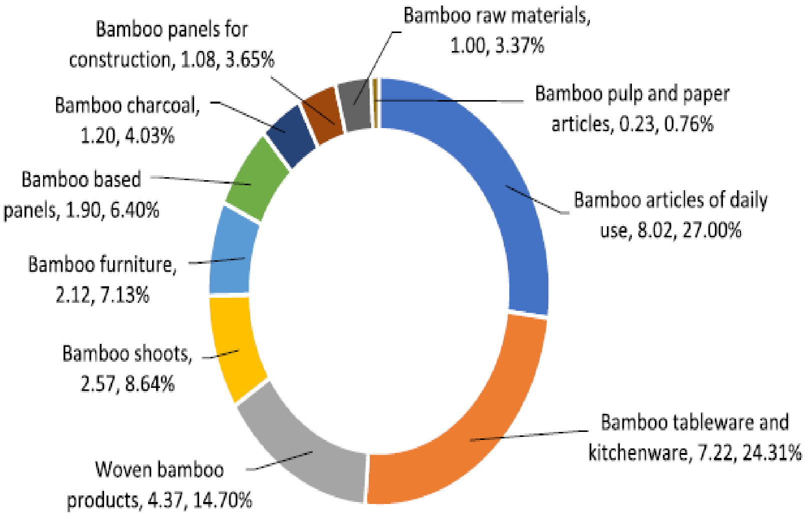


Figure 4. Proportion of the global main bamboo commodities (unit: USD 100 million; %) (Trade Overview 2021)

The cost for cultivation of bamboo per acre of land considering a number of 250 plantations with an inter-plantation space of 4 by 4 m for the first year is $2450 with a continuous expense of $1131 from the 2nd year onwards.

Typically, bamboo production averages about 16 tons per acre. However, a systematic approach to engineered bamboo manufacturing generates a usable yield of 8000 kg or 10 units (each unit weighing 800 kg) (Scurlock et al. 2000). This implies that around 50% of the bamboo remains unutilized, offering possibilities for alternative applications. The expenses entailed in crafting a cubic meter of Engineered Bamboo, factoring in an 18mm thickness, are detailed in Table 1.

Table 1**.** Cost of engineered bamboo (flooring, plywood, panels for construction) per unit

Item	Cost ($)/unit
Bamboo materials	362
Chemicals	139
Water and Power	39
Wages	78
Manufacturing costs	45
Other materials	28
Total	**691**

Results And Discussion

For getting a clear picture of understanding the comparison between engineered bamboo and timber, a comprehensive cost-benefit analysis was essential. This approach allows for a thorough examination of the financial implications and long-term returns associated with each material. By weighing costs against benefits, this analysis provided crucial insights into economic viability and sustainability, guiding informed decision-making. It considered production, utilization, and market trends, aiding in material selection while aligning with strategic goals.

So, an analysis contrasting the attributes of engineered bamboo and timber over a 30-year timeline (reflecting a single timber harvesting period) is presented in the provided Table 2. This study encapsulates the net-profit figures per acre for both materials. By considering a timber yield of 87,000 kg per acre for taking as clearcut of forest (Rahman 2012), which equates to 133.85 units (each unit weighing 650 kg) (Rahman 2012), a comparative evaluation of profitability emerges. The study juxtaposes the returns from dedicating an acre of land to Engineered Bamboo production against the returns from an acre allocated for timber production. Notably, bamboo harvesting is accounted for within a 4-year timeframe (Huang et al. 2019), while the comparative framework adopts the industry-standard timber harvest duration of 30 years (Rahman 2012).

On an equivalent annual basis, a noteworthy profit of 3,672 USD can be realized, surpassing the corresponding figure of 1606 USD attributed to timber. If the intent is to cultivate bamboo for Engineered Bamboo production earmarked for export, the existing bamboo forest in Sylhet spanning 14,063 acres serves as a pivotal foundation (Bangladesh Bureau of Statistics 2023). In this pursuit, the establishment of facilities for generating 720 cubic meters of engineered bamboo per year (factoring in an 18mm thickness for the panels produced) necessitates a setup expenditure amounting to 3,66,560 USD supplementing the aforementioned manufacturing costs (QiSheng and Bin 2020).

Table 2. Cost-benefit analysis of engineered bamboo products and timber.

	Engineered Bamboo for [Flooring, Plywood, Panels for Construction]			**Timber**	
Harvest Time	4 years			30 years	
Per Acre Production (kg)	For 4 years		For 30 years	For 30 years	
	8,000		60,000	87,000	
Production Cost ($)	Per unit (kg/m^3)	Per Acre	Per Acre	Per unit (kg/m^3)	Per Acre
	691	6,910	51,825	90	12,047
Export Price ($)	Per kg		Per Acre	Per Unit (kg/m^3)	Per Acre
	2.7*		1,62,000	450	60,233
Total Export Profit Per Acre ($ Per 30 Years)	1,10,175			48,186	
	Annual Profit ($)				
	Engineered Bamboo			Timber	
	3,672			1,606	

Footnote: *(INBAR Annual Highlights 2021)

In a vast expanse spanning 14,063 acres, a close examination underscores the need for (14063x(10/4))/720 = 49 facilities, demanding an initial investment of roughly 18 million USD, to initiate operations. As time unfurls, a promising annual gain of (14063*3672.5) = 51,646,367 USD or approximately 51.5 million USD materializes from this enterprise. Significantly, close to half of the harvested bamboo can be harnessed for productive purposes, while the remaining portion can be ingeniously repurposed into a range of bamboo-based goods.

Expanding the horizon further, the canvas of Bangladesh unfurls with a staggering 8,000,000 hectares (equivalent to about 19.7 million acres) of arable land. By tapping into merely a fraction of this vast expanse, envision about 0.5 million acres, the potential annual revenue becomes a compelling prospect, edging close to a significant 1.8 billion USD—a captivating portrayal of the considerable economic vistas that Engineered Bamboo production could usher in.

Building upon the worldwide data indicating the utilization of up to 63.5 percent of the entire raw bamboo yield per acre, this study also investigates the supplementary economic advantages attainable by harnessing the remaining 27 percent of engineered bamboo waste (“Trade Overview 2021” n.d.). Hence, a calculation for (8000*0.27) = 2160 kg/per Acre of raw bamboo employed in various international goods is presented in Table 3.

With a comprehensive outlook encompassing net profits from both engineered bamboo and various other bamboo-derived commodities per acre, a foresight emerges that hints at a minimum annual profit of 5,042 USD that can be garnered from every acre of land. Considering the expanse of 14,063 acres, the anticipated profit amounts to approximately 71 million USD.

Table 3. Net-profit analysis of other bamboo products (waste of engineered bamboo)

Other Bamboo Products	**Tentative Percentage of Each Product* (%)**	**Production (Kg)/Acre**	**Production Cost ($)/Acre**	**Export Value ($)/Kg**	**Total Export Value ($)/Acre**
Small bamboo sticks	0.096	207.36	312	5.02	1041
Bamboo furniture	0.0713	154.008	156	3.38	521
Bamboo articles for daily use	0.011	23.76	20	2.79	66
bamboo chopsticks	0.026	56.16	37	2.18	122
Bamboo Chopping boards	0.0174	37.584	29	2.61	98
bamboo basketwork	0.124	267.84	362	4.5	1205
bamboo mats/screens	0.0321	69.336	68	3.26	226
charcoal	0.0403	87.048	65	2.47	215
Bamboo seats	0.012	25.92	30	3.81	99
semi-finished bamboo plaits	0.0209	45.144	38	2.84	128
Raw	0.033	71.28	15	0.69	49
shoots	0.096	207.36	101	1.62	336
bamboo paper-based articles	0.27	583.2	1025	5.86	3418
bamboo pulp	0.15	324	91	0.94	305
Total	**1**	**2160**	**2349**	**-**	**7829**
Net Profit ($)/Acre per year			**1370**		

Every metric ton of processed engineered bamboo has the potential to offset approximately 450 metric tons of carbon dioxide from the environment (Figure 1(a)). Therefore, an annual output of 28,126 tons of engineered bamboo translates to a reduction of approximately 12,657 kilotons of carbon emissions, constituting a substantial 14.8% decrease in Bangladesh's overall carbon footprint.

Conclusion

From this study it is visible that engineered bamboo has a huge opportunity in countries like Bangladesh. This study tried to encapsulate the cost-benefit analysis with a view to establishing the feasibility of the production of Engineered Bamboo on a large scale in such area. The world market of bamboo is dominated by China and the market of engineered bamboo has an immense potential for the likes of countries with available arable land like Bangladesh. This study points towards the establishment of large scale engineered bamboo production to facilitate overall economic growth as well as a green approach towards sustainable development. It is also notable that engineered bamboo can potentially replace timber and also other construction materials in the structural usage due to its extraordinary structural properties given its ease of availability. The engineered bamboo industry leaves a negative carbon footprint which is an incredibly positive scenario for the global environment along with the country's atmosphere. In conclusion it can be sensibly claimed that the advent of the engineered bamboo industry would provide tremendous benefits to Bangladesh and will have its green shadow cast on the environment as well.

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Biographies

Manshib Tazowar is a civil engineering graduate from Bangladesh University and Engineering and Technology (BUET). Right after graduation, he started working in Bureau of Research, Testing and Consultation (BRTC-BUET) as a research assistant. Manshib is an ardent researcher who has a passion for research and development in the field of civil engineering and materials science. During his undergraduate studies, he conducted research on enhancing the bond of bamboo-reinforced concrete through corrugation methods, resulting in a recent publication in a reputable journal. His interest lies in enhancement and optimization of existing material designs and exploration of novel, bio-inspired materials, renewable resources for sustainability and green future. Manshib aspires to further his research and development journey by pursuing post-graduate studies at a renowned institution. Adaptability defines him as seamless integration into diverse settings as he is primed to forge ahead by his quick learning capability and versatility.

Abu Fatin Md Muhtasimul Islam is a diligent industrial and production engineering graduate from Bangladesh University of Engineering and Technology (BUET). With a solid academic background and a keen interest in innovation, his research work is concerned with enhancing unmanned aerial vehicles' performance and autonomy through advanced control and modeling techniques. His research interests also encompass optimizing manufacturing processes using predictive maintenance methods and exploring Supply Chain Engineering and Circular Supply Chain concepts. Muhtasimul actively contributed to innovative projects, including the design of a Construction Rod Cutting and Bending Machine and the development of an IoT-based Smart Jar for efficient supply tracking. With an experience of a quarter of a year as the Management Officer of Fournetsha Bangladesh Limited, he promises proficiency in problem-solving, people management and collaborative teamwork. Aside from academics, he showed his skill as a golf player, having represented Bangladesh in international tournaments. His dedication to continuous learning and enthusiasm for research renders him a potential professional in his field.