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Review article

Assessing the policy issues relating to the use of bamboo in the construction industry in Nigeria

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ABSTRACT

The Nigerian government has promoted industrial development based on the area of policy implementation. The development of policy and the use of bamboo in the construction company is very significant because of the role of bamboo cultivation in reducing environmental pollution. Bamboo, in its existence, applies to the environment in absorbing carbon dioxide of about 35% and releases to the environment a high amount of oxygen. This carbon dioxide absorbs by bamboo reduces the ozone layer depletion in the aspect of climate change. Another significance of bamboo is that it creates an environment that reduces the light intensity to protect against ultraviolet emissions. The use of Bamboo is considerable in the construction industry and also as useful reinforcement material. This research discusses the effects of policy issues relating to the use of bamboo in the construction industry in Nigeria. And also, study the significance of bamboo implementation in terms of bamboo used for biomass as a source for bio-energy, furniture, and building development. Also, how bamboo cultivation will affect economic growth in Nigeria. This study also discusses the three policy dimensions as it pertains to implementing bamboo policy in Nigeria and suggested ways of developing bamboo policy for proper regulations.

1. Introduction

Bamboo is a gigantic woody grass that grows in tropical and subtropical areas all over the globe. Bamboo is a fast-growing plant with a rate of four to six years of planting, and it can propagate up to four feet in a day. Flynn et al. [1] explained that bamboo stalk could be short down, leaving the roots intact on the ground to cultivate. Bamboo plants have a lifespan of over 75 years, and bamboo reaches its harvesting maturity in three to six years. Farmers can develop them in a land unsuitable for crops. Markets for bamboo are exploding as many countries have insufficient capacity for wood production, and bamboo is a multipurpose and real substitute for wood [2, 3, 4].

Transformation and implementation of bamboo as a multi-used material for products, like charcoal, roofing, flooring, paper, and cloth-making, are significant to the economic development of a nation [5]. The competition between wood species and bamboo species is now on the increasing side towards the bamboo forestry role as a carbon sink. Several researchers have proven that bamboo capacity as carbon sequestration is satisfactory in both processes as a material or as a carbon sink [6]. Implementing bamboo has helped to cement the relationship and the transformation of rural areas to urban areas. The manner of how this transformation process is built and maintained gives valuable insight into product transformation in rural areas for sustainable development. Furthermore, this gives an understanding of the localized development of sustainable nurtured products and potential fragility [7, 8].

Ogunwusi et al. [9] carried out an inventory of bamboo accessibility and exploitation in Nigeria. The authors used partial essential survey and field inventory visits. The results show that the act of bamboo farming and production is more concentrated in the middle belt region and the southern part of Nigeria. The bamboo dominates with about 10% of the natural vegetation in these twelve states in Nigeria, which are Adamawa, Gombe, Bauchi, Borno, Kano, Katsina, Kaduna, Kebbi, Sokoto, Jigawa, Yobe, and Zamfara states. The availability of a bamboo plant in Taraba, Abuja, Niger, and Plateau State is small when compared to the middle belt and southern region with 3–5.9%. Atanda [10] carried out a study on sustainable material as a substitute for construction materials by examining the significance of bamboo and its properties. The findings show that bamboo is fit as a substitute for wood and steel for the construction industry. Because bamboo has excellent mechanical properties, such as lightweight to strength ratio, high durability, and cognitive flexibility

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when used as a construction material. The study also shows that Nigeria has much bamboo in over twenty different states. Figure 1 in this research shows the original design of the authors to illustrate the states in Nigeria with abundance of bamboo.

Oberholzer et al. [11] used bamboo to develop a bicycle for sustainable suppliers. Transforming bamboo into a bike involves molding, forming, milling, and shaping process. This study developed an optimization chain method for improving the primary manufacturing procedure. According to Ibrahim and Ogunwusi [12], the Nigerian fabric and cloth industry is experiencing deterioration in fabrication because of dependence on cotton as its primary raw material. Cotton manufacturing companies have decreased noticeably in Nigeria, thus hiring serious tinges on the capacity application in the sector. Hence, to boost the utilization of bamboo, there should be ways to approve the implementation of bamboo as a substitute or complementary materials for fabric and cloth production. The authors discovered that cellulose of 99%, wax of 0.24%, and ash of 0.25% are present in bamboo plants. The vital material needed in the fabric and cloth industry is cellulose. China, Europe, United States, and India have completed the utilization of bamboo in the fabric and clothes. Bamboo propagation is in 23 States of Nigeria, and the manufacturing procedure is simple and entails primarily of cooking the bamboo plants. The lenient inner from a stiff bamboo stem in a sodium hydroxide solvent of 15–20% at 20–25 °C temperature for 1–3 h to produce alkali cellulose. The next step is to grind the produce alkali cellulose and dry it for 24 h before applying carbon disulphide to form a solution of viscose. Moreover, through spinneret spouts into a diluted sulphuric acid media, and the renovated coupled with the regenerated bamboo fabric. Since farmers cultivate bamboo in Nigeria, implementing bamboo as fabric material will save Nigeria from an equivalent 500 billion nairas in terms of foreign exchange annually for exporting raw materials of cotton.

However, from literature, many researchers have confirmed the significance of bamboo to the economy of this nation [13]. If the Government gives bamboo more attention, as stated in this study. The issues remain the fact that bamboo cultivation in Nigeria does not have a regulating policy or a distribution policy as regards its product. Hence, this research focuses on the policy issues of bamboo implementation in the construction industry in Nigeria. However, suggested techniques that will further enhance the government to speed the policy development of bamboo implementations in this nation for sustainable economic stability.

2. Significance of bamboo

One major importance of bamboo is the ability to undergo a pre-treatment process. Such as Mechanical Pre-treatment, Thermal Pre-treatment, Steam Pre-treatment/Steam Explosion, Liquid Hot Water, Chemical Pre-treatment, Acid Pre-treatment, Alkaline Pre-treatment. Also, the thermal Pre-treatment/Alkaline Pre-treatment, Oxidation Pre-treatment, and Ammonia Pre-treatment. All these pre-treatment processes lead to different end products. Currently, in Nigeria, bamboo has two specific species which are Bambusa vulgaris and oxystenanthera abyssynica. Therefore, there are enormous needs to develop policies that will help to regulate the production of bamboo products and its implementation in the construction company.

Bamboo, as a multi-facets substance, is widely used in several aspects in the world, and Figure 2 shows some areas of application of bamboo [14, 15].

3. Review of sustainability of bamboo as a composite materials for furniture development, building structure, and bioenergy

3.1. Bamboo used as furniture

Using bamboo as materials to develop furniture cannot be overemphasized. Bamboo strips, when treated, the manufacturers used it to produce bamboo lumber. To boil, to dry, and to join, the manufacturers can mill this lumber to create more shapes and components that can make hardwood for furniture making [16]. The furniture industry uses bamboo lumber to manufacture different furniture, as presented in Figure 3. The hardness of bamboo lumber over some wood species varies, because of the difference in their density. For vertical and horizontal positions, they have a density of 750 kg/m^3, while when used in the form of strand woven, its density becomes 1200 kg/m^3. The engineer carries

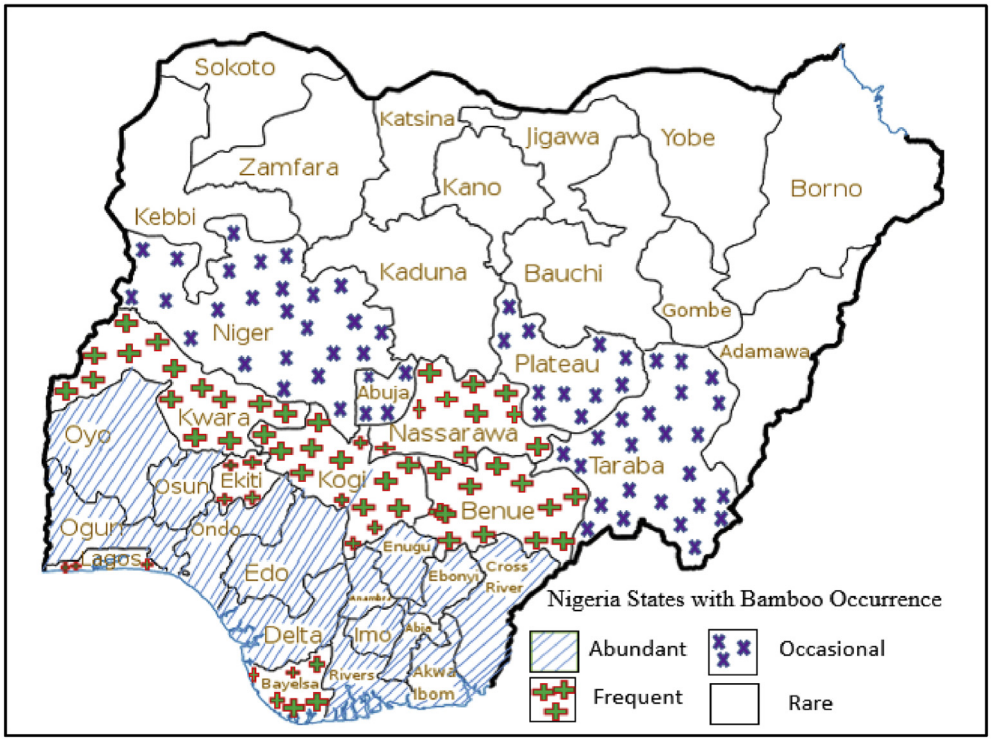

Figure 1. The Nigeria map, showing the rate of bamboo abundance in nature.

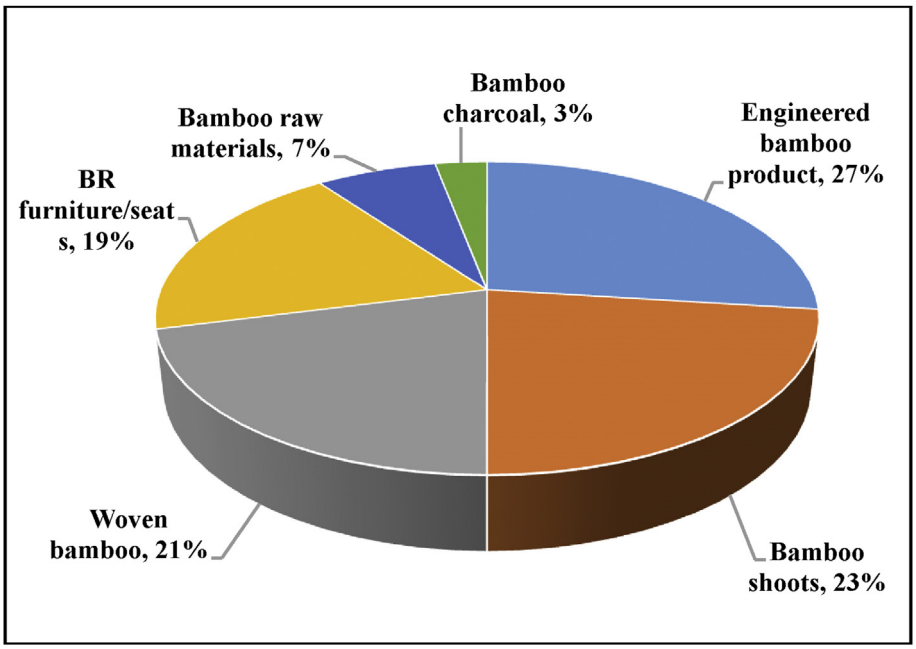

Figure 2. Some selected areas were industries have applied bamboo.

out the extrusion process of bamboo with low volatile organic compounds (VOC) resin. That is 100% renewable resources for bamboo to withstand high temperature and pressure. This process makes the product from bamboo more substantial [17]. The bamboo and its beauty, flexibility, sustainability, high strength, and versatility have caused great awareness and its significance. These excellent characteristics enable the choice of selection of bamboo and its use across the world in the construction companies and for furniture making [18].

3.2. Bamboo used as biomass source for bioenergy

The increasing cost of fuel, coupled with the pressure on fossil fuel reservations, is a severe issue that needs urgent attention. Bamboo is a good biofuel material, and it has a high rate of growth. This high rate of growth gives significant reasons Nigerians need bamboo as a sustainable replacement for fossil fuel [19]. The chemical industry uses bamboo for developing methane and ethanol gas for commercial quantity for industry applications [20]. However, the study of pre-treatment is highly significant to determine the calorific values of bamboo during the production of methane and ethanol from bamboo.

Bamboo is a sustainable resource, very easy to maintain with a good cultivation process, and its recovery rate is between 2 to 3 years when compared to other trees. Constituents majorly of hemicellulose, lignin, and cellulose, this makes it well suited for bio-energy generation [21]. However, bamboo into pellets is a superior alternative as it offers enhanced mechanical and thermal properties while reducing unwanted materials and is easier to store and transport [22]. Akinlabi et al. [23] carried out a study on producing charcoal from the bamboo plant and explained the operations of bamboo charcoal generation, which involves three significant steps, such as.

Figure 3. Bamboo as furniture (a) bamboo lumber (b) bamboo chair (c) bamboo step (d) bamboo flooring and cabinet.

- Milling of the bamboo culm into smaller particles,
- Carbonizing the bamboo particles in a kiln with a controlled temperature environment and
- Packaging process of the bamboo charcoal for quality control check and implementation.

The process of kilning bamboo particles into bamboo charcoal is one of the most critical operations. Due to charcoal production from bamboo undergoes different temperature range during the carbonization period. To get the optimal output of the product, as shown in Figure 4a. The temperature ranges from 60 to 100 °C for different stages of burning the bamboo:

- burning of the bamboo with a temperature of about 60–100 °C,
- drying at the temperature between 100 to 150 °C,
- applying a temperature of 150–300 °C for pre-carbonization,
- then carbonizing the charcoal process with a temperature between 300-450 °C, and
- finally, the manufacturers obtained the refined process within a temperature of 450–1000 °C.

Fu and Chen [24] carried out a study on bamboo charcoal. The authors discovered that the calorific value of bamboo charcoal is 33,400 j/g. The research also shows that the calorific values of bamboo vary with the different species of bamboo.

Bamboo has a potential material for energy generation in different forms, including bamboo as pellets, briquettes, and charcoal for cooking and the electricity generating process. Figures 4a and 4b present the bamboo charcoal and pellets. The campaign to decrease the emission of greenhouse fumes from fossil fuel has led towards researching into non-food plants as a replacement and manufacturing biofuel [25, 26, 27]. To get the goals above, Kim and Dale [28]; Gray et al. [29] identified that lignocelluloses are the only potential feedstock proficient in replacing fossil fuels. Sadiku et al. [30] reported that Bambusa vulgaris chemical composition contains a range of 4–7%. Extractives for the extracted process, with 39–46% of lignin and cellulose of 61–78% as cited in Chin et al. [31].

Engler et al. [32] worked on the assessment of Bambusa emeiensis and Phyllostachys pubescent's bamboo species. The authors confirmed that Bambusa emeiensis and Phyllostachys pubescent are potential materials suitable for biomass fuel in combustion plants. The authors also concluded that Bambusa emeiensis would be perfect for biomass fuel when harvested after five years. At this stage, the fatty values are very high, while the ash and chloride values are negligible. For P. pubescent, the best time to harvest in terms of energy production is between 2 and 3 years. From the study, the assured calorific value for P. pubescent and B. emeiensis is 19.44 MJ/kg, and 18.32 MJ/kg, respectively. Chin et al. [33]; Sadiku et al. [30] also study the potential of bamboo calorific and petroleum index value applied for the production of renewable biomass energy. The result shows that the bamboo total calorific value ranges between 1810.90 cal/kg to 4160.60 cal/kg. With an average of 3157.80, for the Bambusa vulgaris bamboo species between 2 to 4 years. The analysis of the chemical characterisation of the bamboo material has proven that bamboo is a potential material for a sustainable generation of energy.

3.3. The bamboo used for building structures

Akinlabi et al. [34] carried out a study aimed at verifying the microstructural and mechanical strength of bamboo when dipped in water media, acid, and brine. This study proves that bamboo withstands these media. Therefore, the authors concluded and recommended in their study that bamboo is one of the most suitable materials for building development and construction of bridges. However, most communities build houses on the shore and also construct bridges in the areas that contain much water. Which the water can be salty or freshwater, because of the speedy industrialization in many developing nations.

Akinlabi et al. [35] also studied bamboo as a replacement for reinforcement materials for a concrete structure. This study shows that vegetable fibres have high potentials when applied as reinforcement to several matrices, which include cement composite, metal, and soil. The result also shows the significance of bamboo microstructure as a useful ramp material for building applications.

4. Effects of bamboo farming, processing, and its end-product on the economic growth in Nigeria

The manufacturing and construction industry that produces and supplies the raw materials from the bamboo plant are the exploiters of natural resources, in terms of physical, chemical, and biological processing. This industry has a high rate of influence in both the sustainability and unsustainability development route of the global economy.

The economy of Nigeria is being dominated by crude oil funds, which need urgent expansion for the economy to be stable [36, 37, 38, 39]. Using bamboo as an excellent alternative for the cultivation and production process can lead up to 100 different products [40]. The native bamboo plant processing is a profitable business that will give a steady return on investment (ROI) to the nation [41, 42, 43, 44]. The government or the stakeholders need to put in place the right technology and great advertisement to draw the attention of the professional body to use bamboo as a multi-fact material. Nigerians used bamboo for scaffolding and fencing of buildings, which has limited its applied to a volume fraction from bamboo processing and when compared to the country who used bamboo as raw materials for other products [45, 46]. Currently, bamboo processing is uncoordinated with unexploited potentials. Nigerian timber wood forest resources are facing the inability to supply the nation's need in terms of wood supply to the consumers and the construction industry. There are no sustainable alternatives that can act as a replacement, which has generated serious discussion on the future of the supply of wood to the Nigerian economy sector. In 1996, the forest estates of wood were 10% of land areas, which is now 6% [47]. This lack of supply of timber wood has shown that bamboo needs to be

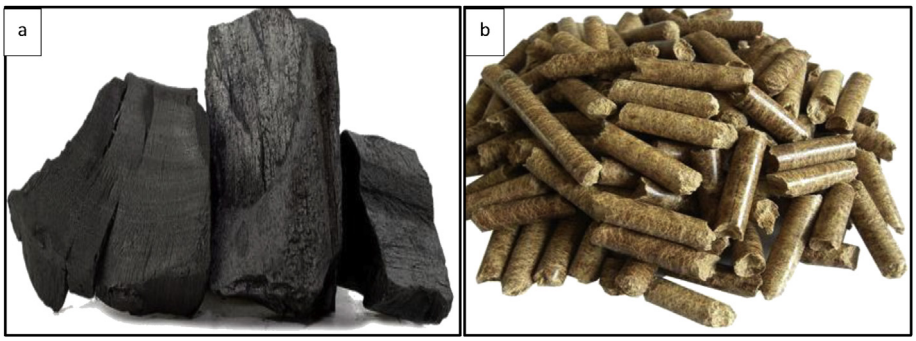

Figure 4. Bamboo used for (a) charcoal and (b) pellets production.

well-coordinated and exploit all its potentials for a replacement for timber wood.

5. Bamboo potential in cultivation and future prospects in Nigeria

Bamboo is a biodegradable plant with great renewable and sustainability potentials to produce a different end product [48, 49, 50, 51]. Nigeria has high possibilities in bamboo cultivation since the nation has a reasonable landscape with a total land area of 923,763 km^2. From literature, it is worthy of knowing that Nigeria's climate condition is suitable for bamboo cultivation. However, there is no policy for the commercialization of the harvested bamboo [52, 53, 54]. For successful bamboo cultivation, the nation needs to put in place enough available land for the bamboo farming process, superior technology, and create a suitable marketing medium. Since bamboo products are locally and internationally used [55].

According to Abdulkadir Hassan, "the bamboo industry can earn Nigeria economic over $22bn annually" if the Nigerian government gives quality attention to bamboo cultivation in Nigeria. From the study done on bamboo transformation into multiple products has proven that bamboo cultivation in Nigeria can generate a lot more to the national economy [56]. However, since bamboo has a high potential for transforming into different products, it is considered as an excellent source of income. Both for the micro-enterprise and livelihood for the rural community because bamboo has excellent market potential for both domestic and export markets [57, 58, 59]. This development of the bamboo industry will assist in poverty elimination from the rural community areas where this bamboo is mostly available.

6. The need and alternative ways to develop a strong policy on bamboo implementations in construction industry in Nigeria

The open policy decision-making encompasses a sequence of activities that promote a policy verdict and its implementation. The policy has three major types, including regulatory, distributive, and redistributive policy. These policies will help in developing the bamboo implementation policy. Implementing bamboo as an end product used in the construction industry needs to cut across these three aspects of the policy. This policy implementation will involve a lot of conscious effort from the government and stakeholders of the nation. It will also help in the bamboo's sustainability implementation policy and the organisation of the product used in the construction industry [60, 61, 62, 63].

Figure 5 displays the Schematic diagram from the authors to explain the several roles; the stakeholders need to play for bamboo development in Nigeria. The key role of the stakeholders includes, National Space Research and Development Agency (NSRDA), Federal Ministry of Environment (FME), Raw Materials Research and Development Council (RMRDC), Federal Ministry of Agriculture and Rural Development (FMARD) in line with the State Government Ministry of Forestry Departments in Nigeria.

6.1. Regulatory open policy on bamboo implementation in the construction industry

The main goal of the open regulatory policy of bamboo application in the construction industry is to maintain order and prevent behaviours that will jeopardize humanity. Bamboo from several investigations has proved as excellent material. However, implementing bamboo for the construction industry needs accurate regulation because bamboo is deficient in resisting attacks from termites, beetles, and fungus. Therefore, there is a need to heat-treat bamboo before used in critical structural systems [64].

The Government will achieve this goal by confining citizens, groups, or industrial organization engaging in an improper use of bamboo in structural applications that will affect the social and political order. Another unique goal for the developing bamboo regulatory policy is to protect the economic activities of the nation. However, prohibiting manufacturing companies from carrying out improper harvesting of bamboo plants that will be detrimental to the development of the economy in the country is highly needed. This regulating policy will also help to safeguard the working environment.

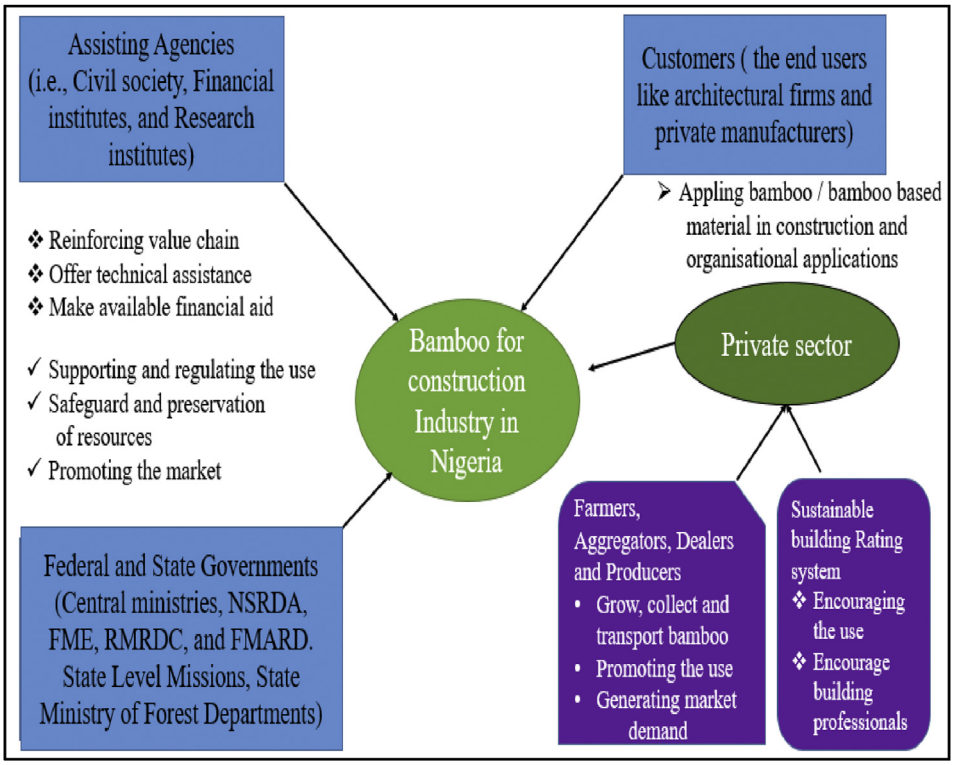

Figure 5. The role of the stakeholders in bamboo-segment in Nigeria.

6.2. Distributive open policy on bamboo implementation in the construction industry

Distributive policy as it pertains to the use of bamboo in the construction industry is very significant; the citizens need to be part of the benefits of bamboo revenue generation. This distributive policy will promote a lot of substantial investment, such as bamboo used for building houses, bridges, and construction of roads. The issue behind the poor improvement of bamboo utilization in the construction industry is because of policy formulations. This lack of awareness within the decision-makers and its application is hindering the bamboo-based construction industry from taking shape.

6.3. Redistributive open policy on bamboo implementation in the construction industry

The aspect of equalization of policy on bamboo implementation in the construction industry will encourage citizens to go into large-scale bamboo farming and bamboo transformation into different end products. To increase their revenue generation of the local government or state government, which in return will cause tremendous growth in economic development. Individual, private, and public companies will see the opportunity to invest in bamboo cultivation and processing since they know that bamboo can be their source of revenue [65].

6.4. Benchmarking and multi-criterial decision analysis techniques as ways for developing policy on bamboo utilization in the construction industry

The Nigerian government needs to apply some techniques to study the process of bamboo farming (planting, nurturing, and harvesting) to determine the percentage of this product at different stages. The authors recommend the benchmarking method and the multi-criteria analysis method in developing a firm policy for bamboo implementation in the construction industry.

Bamboo Benchmarking is the method of equating the performance of a bamboo plant with timber plant or bamboo performance at the previous state [66, 67, 68]. It is a vital tool to help determine potential economic savings. Benchmarking study is one significant method in setting policies, regulations, and goals [69, 70]. The bamboo benchmarking method is suitable in highlighting where the bamboo developments should have proper attention. Moreover, in some situations, temporal benchmarking can identify the need for policymaking in the process of bamboo production to its state using the finished product in construction [71, 72]. The government can carry out the benchmarking process in two different ways, the top-down techniques, and bottom-up techniques. The top-down method is a simple process of studying the annual report on the bamboo used as a finished product and the production data of the bamboo from the farm or using the bottom-up techniques which the evaluation of the bamboo processing stage audit and the production data.

These two processes are very significant techniques that need much commitment from the decision-makers, bamboo plant operational workforce, and end-users (the construction industry).

However, the benchmarking process consists majorly of five steps, i.e., the planning, data analysis, integration of the result, implementation of the finding, evaluation or assessment of the performance of the benchmarking process, mark and develop a policy for the executions of bamboo in the construction industry in Nigeria, as illustrated in Figure 6.

These five steps are briefly explained to guild the stakeholder's/the decision-makers on the process of developing the bamboo policy for construction industrials using benchmarking policy process as follows:

6.4.1. Step one

The planning process should consist of a committee made of five or seven, which will have sub-committee; this committee is to map out:

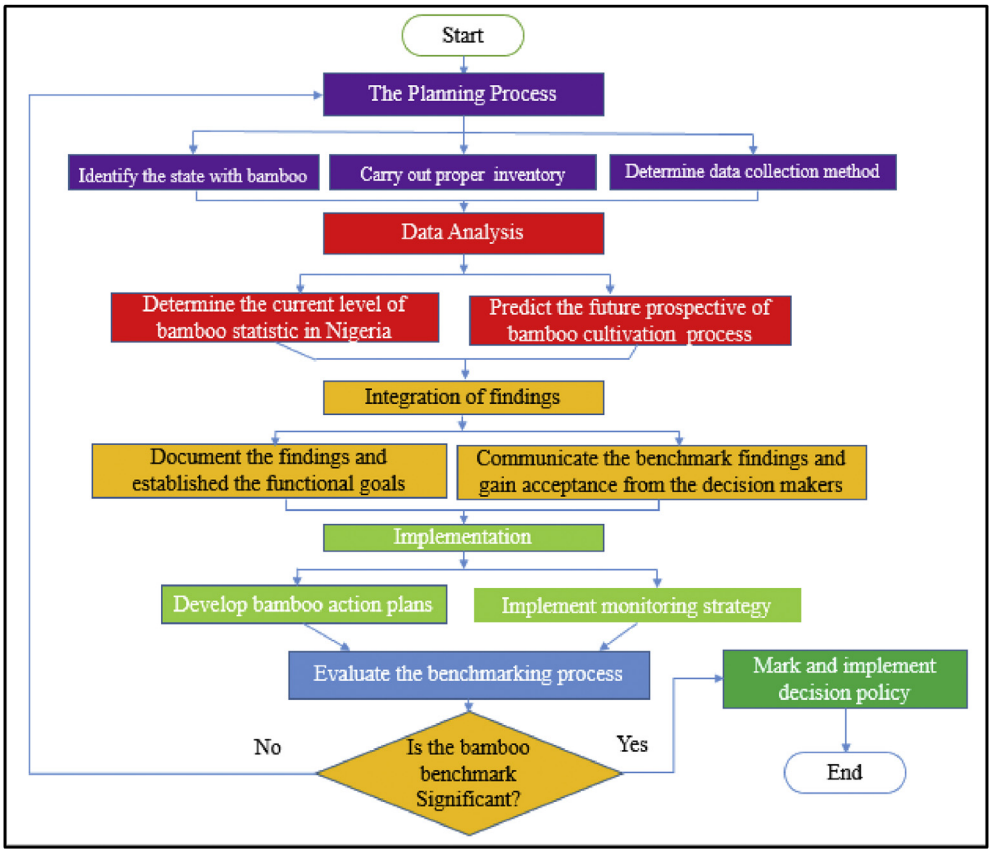

Figure 6. The benchmarking policy process for bamboo implementation for the construction industry.

- The locations in Nigeria were bamboo is highly in abundance
- Use their workforce to carry an excellent inventory on this located stated
- Device standard method to collect this data from each state as design.

This process should take a maximum of three months for the committee to have a good database of the most abundant state with bamboo. Also, the committee should obtain the following ideas:

- The types of species of bamboo in this located state,
- how close this bamboo farm to the community?
- the set of people farming the bamboo,
- when harvested, who are the kind of people that buys it from them, and
- the cost to cultivate the bamboo processes, and how much do they sell it?

Therefore, it is the responsibility of the committee to develop a dynamic way of collecting this data to enable proper data analysis.

6.4.2. Step two

After a successful collection of the data, the data analyst will carry out a study to determine the current statistic state of the bamboo in Nigeria. It is the responsibility of the data analyst to determine which method will be favourable and secure to obtain an excellent result.

At this stage, there are also needs to carry out some laboratory tests to determine the exact types of bamboo species in Nigeria. The data analyst will design a model to predict the future life span of bamboo in Nigeria. This predictive model will assist the nation in understanding the practical analysis of planting, harvesting, and the implementing process. This data analysis process is vital in the benchmark process of achieving a good policy of bamboo implementations in the construction industry in Nigeria. The committee should ensure a proper data are collected because it will have a significant effect on the integration of the finds of the bamboo systems in Nigeria.

6.4.3. Step three

This section has two significant levels, which are:

- Giving proper documentation of all the state having bamboo in Nigeria and establish functional goals
- The committee must communicate the benchmarking finds, operational objectives, and gain acceptance from the decision-makers.

This point in time, the committee, stakeholders's/decision-makers need to integrate their thinking, vision, and goals for excellent and reasonable ways of the implementations of the findings.

6.4.4. Step four

The implementation stage is a crucial state, where there is a real need to develop a bamboo action plan and also come out with an implementing monitoring strategy on the developed action plan.

This action plan should consist of the step by step ways of the cultivation of bamboo, which will give a breakdown structure of how the system put in place will be able to achieve the specific aim. Furthermore, if possible, this is the time the committee set in place should be able to come up with a particular position were the bamboo manufacturing or process industry should be located. To enable proper processing of bamboo into a finished product to be implemented in the construction industry. Also, in a situation where the bamboo raw product needs to be heat-treated, the end-user will be able to assess the sector to carry out the proper heat-treatment process for the company or individual operators.

6.4.5. Step five

The committee, stakeholders's/decision-makers need to put in place a proper system to evaluate the process. However, the result of the evaluation will influence the decision from the benchmarking of the bamboo process. This stage is a critical state, were the decision-makers of this nation need to know how significant the bamboo cultivation is to the country. Moreover, when this committee communicates this knowledge to the decision-makers, the law-makers and the stakeholders will be able to make and implement an excellent policy that will help Nigeria to operate and regulate the bamboo planting, processing, harvesting, and conversion into the different finish product.

An alternative method is the multi-criterial decision analysis (MCDA) is another unique method, and the government should adopt it, to solve the policy issues of bamboo used in the construction industry. This method will help to understand the economic concept of bamboo to this country and to enable the decision-makers to carry out a useful study of bamboo. That is bamboo in several areas of implementations and provides a suitable location site for the bamboo industry. Therefore, applying this method to study the significance of bamboo to economic growth and to develop the policy formulation will be of great help to the Nation. However, several fields of study have used this MCDA to solve many selections and chain distribution problems. Also, it has proven very efficient in the decision-making process [73, 74, 75, 76]. Using MCDA, the policy should consider these three aspects below during implementation:

- Proper regulation of farming of bamboo plant: in terms of percentage of bamboo that farmers must plant annually
- The percentage rate of bamboo that the manufacturers should harvest for product transformation
- The implementation process of bamboo in the construction industry, this will state the process that the bamboo end-users should follow in some critical application.
- The stakeholders should use the MCDA with laboratory tests to prove if bamboo has just two types of species in Nigeria.

Hence, the bamboo cultivation and implementation in the construction industry will run smoothly to contribute significantly to the national economy.

7. Conclusion

The issues of policy implementation or development of bamboo policy regulation lie in the knowledge of the policymakers, on the universal understanding of the industrial perspective of bamboo. Notwithstanding, even with the multi-facts ability of bamboo resources and species available in Nigeria. The stakeholders in Nigeria have not accepted the fact that bamboo cultivation, processing, and transformation into multiple products can serve as immense revenue to the nation. Furthermore, its ability to boost the economy of the country. This study has proven that there is a profound need to plan a firm policy on the regulations of bamboo implementations in the construction industry. Also, provide useful evidence for the stakeholders to realize their role in the policy development and implementation in bamboo operation in Nigeria.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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