Adoption of appropriate technology for building construction in the tropics; a case of Nigeria

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Abstract. Construction technology from the West has played a vital role in building construction in the Tropics. Due to the level of organization, capital and personnel, some cities within Africa can absorb the latest technology faster and better than other cities; thus, their construction development projects using the western borrowed and learned technology has been verbatim and most times, excessively done. This trend, which cuts across many regions of tropical Nigeria leads to the neglect of folk wisdom. Local construction wisdom is usually substituted for new technology without the geography of the area being considered. In 1996, the economic crisis caused the construction business to come to a halt. The cost of oversea technology significantly increased due to the baht flotation policy. Several manufacturers and contractors went bankrupt at that time, including owners of small property in remote parts. While it seems that construction problems from the past are being alleviated, some signs of financial crisis are still evident in recent times. To prevent such future reoccurrence, the study focuses on appropriate construction technology to create social resilience and promote sustainable development. Utilizing literature review research methodology, the concept of appropriate technology is examined, highlighting the appropriate construction technology for the industry in Nigeria’s tropical environment. Photographs of existing building of historic and contemporary architecture were collected and used as a basis for analysis of building construction technology. Benefits and hindrance of appropriate technology are discussed and the research concludes that the only way to achieve economic, social and environmental justice and sustainability is by the adoption of this appropriate technology.

Keywords; appropriate technology, tropical environment, sustainability, construction, Nigeria

1. Introduction

Access to affordable and decent housing accommodation is fast becoming a global issue for all income groups due to the rise in urban population. Even with the available supply of housing, one of the critical problems facing the Nigerian cities has been that of deteriorating living conditions leading to increased death rates and diseases caused by pollution and poor sanitation [1]. In the developing economies, it continues to resonate as an obdurate issue due to low incomes, lack of access to housing finance facilities and supply bottlenecks from centralized institutions resulting to an irreversible strain on the building construction industry. Building construction industry here refers to the people and activities involved in producing the built environment from raw materials. The building construction industry, since the
Paleolithic era, has seen transformation across the world due to technological advancement and industrial revolution particularly, played a significant role in the transformation.

In Nigeria the advent of colonialism and globalization led to the replacement of traditional building practices, which largely employed appropriate technology, for imported technologies and materials from Europe and America. The Nigerian construction industry is being categorized as the most dynamic, with ever changing material choices flocking from various part of the globe [2]. The sad part of this importation is that production of those foreign building materials are under special environmental and economic conditions that differs from the Nigerian situation, thus leading to disregard of Nigerian-homemade materials and resulting in structures that seem to be out of place in the local context. According to [3] buildings, their materials, shape, texture and space represent culture in its most persuasive physical form, but the contemporary buildings in Nigeria have been largely associated with building materials like glass, PVC, steel etc, rather than the traditional building materials like earth and thatch. The quest for sustainability and use of appropriate technologies should be paramount as the nation faces complex socio-economic and environmental challenges ranging from climate change to urban poverty. Therefore, this paper aims to emphasize the significance of adoption of appropriate technology in the Nigerian building construction industry with the following objectives;

- To understand the concept of Appropriate Technology (AT)
- To reveal the change in architecture of building in tropical Nigeria.
- Highlight the benefits and hindrance of appropriate technology adoption in Nigeria

2. Literature review

Butenhuis et al [4] and Pearce [5] have opined that appropriate technology is applicable to a wide range of field, including: commerce, agriculture, water, medicine, transport, energy, construction etc. However, in the building construction industry, Hazeltine and Bull [6] reported that the terminology of appropriate technology has over the years developed, starting with the works of Dr Schumacher [7] through his book “Small is beautiful” where he discusses what is commonly referred to as Intermediate Technology. Other well-known figures cited by the same authors in relation to this technology include Julius Nyerere of Tanzania, Mao Zedong of China and Mahatma Gandhi of India. According to Willoughby [8], a synthesis of Schumacher’s ideas gives a definition of appropriate technology as “a technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period”. Although this definition is general to cater for ideas that founders of appropriate technology had in mind, it again ends up too wide to the extent any technology could easily be characterized as “appropriate”, even what appropriate technology’s founders and proponents would consider not to be.

Auroville Building Centre [9] (one of the proponents of appropriate technology) defines appropriate technology as “building processes and tools that are appropriate to the climate, socio-economic conditions and natural resources of an area, and which contribute to sustainable development”. Hazeltine & Bull, [6] went further to give the characteristics appropriate technology (AT) for ease of identification as follows: energy-efficient, decentralized, locally controlled, small-scale, capital saving, environmentally sound, people-centered and labor-intensive. A technology that produces materials while meeting most or the features listed would therefore be deemed “appropriate”. It is also instructive that appropriate technology stands in contrast to the high technology of mass production which is more mechanized and less labour intensive.

Willoughby [8] gives two approaches to defining “Appropriate Technology” that are worthy noting, these being the general-principles approach and the specific-characteristics approach. The former implies that {the technology} is specially fitting, suitable, proper or applicable for or to some special purpose or use; it places emphasis on technology as a means to certain ends and on the importance of articulating the ends in each case. The general-principles approach creates many loopholes to the extent of one author using it to
brand a nuclear reactor system as Appropriate Technology. The latter approach assigns specific and tangible operational criteria to the definition thus eliminating ambiguity.

Going by the specific-characteristics approach, the definition seems to be all-encompassing: “An appropriate technology is relatively inexpensive and simple to build, maintain and operate; uses renewable resources rather than fossil fuels, and does not require high energy concentrations; relies primarily on people's skills, not on automated machinery; encourages human scale operations, small businesses and community cohesion; is protective of human health, and is ecologically sound.”

2.1 Concept of appropriate construction technology

From review of published literature, Appropriate Technology (AT) can be seen as materials and methods that are amenable to the environmental, ethical, cultural, social, political, and economic facets of the community it is intended for, that require fewer resources, are easier to maintain, and have less of a social or environmental impact. In other words, it is the simplest level of technology (method) that can be used effectively to achieve the (desired) intended purpose in a particular location. It shows that technology can be divided by the level of tools usage and knowledge transmission. From the selection of suitable technological method comes the appropriate technology (AT) and the interaction of AT with the site and surrounding environment of proposed development birth Appropriate construction technology (ACT). This relationship is exemplified in figure 1 below

![Figure 1. Concept Appropriate Construction Technology](source; Teartisup, [10].)

Appropriate construction technology is not a one-size-fits-all design solution however it adapts to suit best the environment in which it is being built. It fits best with the community it represents, since people developed it to fulfill a need. The environment and culture is therefore put at the center of decision making and to generate technologies that is preeminent for their interests in the long term. The concept of Appropriate Construction Technology (ACT) as summarized by Teartisup, [10] is shown below.

1. Technology is the implementation of science for human benefit both physically and mentally. It has two major components: Concrete components (hardware and peopleware) and Abstract components (software and managementware).
2. Level of technology regarding tools and learning: Low or Traditional Technology, Intermediate Technology, High Technology and future technology
3. Criteria for appropriate technology selection:
   - Technology must conform to geography and climate of the particular area.
   - It can be manipulated by human focusing mainly on creating job opportunities for local people.
   - Must be simple technology that can be studied easily and can be trained in the area.
   - Must be low investment risk and technology that can be possessed by a majority in the community.
   - Must be a technology that uses local materials and low energy production.
   - Must be environmental, user friendly technology, durable, long lasting and occasionally be recyclable
4. Appropriate Technology is the accurate use of technology according to situations and the environment such as location, local resources, users’ skill, tools, transportation, social state, culture and economic for desired purpose.
(5) Appropriate construction technology comes from two components which are construction material production’s technology and construction technology using the materials. Influential factors depend on location, local resources users’ skill, tools, transportation, social environment, culture and economy.

2.2 Concept level of construction technology
Construction technology in tropics can be classified into two, mainly construction material manufacturing technology and construction technology from those materials called construction technique [10]. Both technological combinations will form a building. Among these two sub-division, there are traditional or low, intermediate, high and future materials and technologies as illustrated in figure 2.

![Figure 2. The concept level of construction technology.](image)

3. Research methodology
The study utilized research methods, tools and instruments that is relevant to give insight about appropriate technology for building construction in the tropic. It is a qualitative research and employed both primary and secondary sources of data. The primary data were derived from anecdotal evidences and used techniques of direct observation/photographs with author’s previous research works on sustainable development in the 21st century to provide a holistic representation relating to the situation analysis of the materials and construction technology in tropical environment. The secondary data were obtained from the review of published literature identified in various sources including, journals, workshop and conference papers. Papers reviewed were identified via searchers on online databases such as Google scholar, and Science Direct among others. The findings of the study are examined in the light of what was obtained through literature and is in line with the available studied literature. It points to low patronage of appropriate material and construction technology, based on these results, recommendations are made for the promotion of appropriate construction technology and not abandonment. The research contributes to the body of knowledge concerning the object of study and opens up the subject for further studies.

4. Findings; problems of building in the tropics and the use of appropriate technology
The effects of the intense heat on the comfort of building occupants has continually risen and has reached a critical point for designers to be concerned, especially in the advent of today’s Green Architecture and
much talk about energy efficient buildings that climax at Net Zero Energy Buildings (NZEB). For architects and builder, designing for the Tropics is a constructive confrontation with extreme climatic conditions. Solar radiation, precipitation, high humidity levels in conjunction with the constant heat represents a major problem for materials and construction in the tropics. These elements of weather affect surface finishes, metal sheeting, plastic panels, wood surfaces etc. The great temperature differences, with daytime temperatures of 45°C in the summer and cold winter nights with temperatures below freezing point, impose considerable strain on construction and materials in the form of expansion and contraction. Sand-bearing winds have a damaging effect on exterior surface and deface façades. Roof failure is now considered as an emerging epidemic as all concrete-decked and flat roofs are being re-roof to hip and cover with aluminum sheets.

The attainment of any level of comfort within a building in the tropics is directly proportional to the quantity of solar radiation excluded from the interior space and rate of air flow. The use of external shading devices has proven to be the most efficient appropriate technology for direct solar control in buildings, but presently, the use of exposed glazed façade as found in curtain walls and large window panes seems to be the norm in Nigeria. This was largely not the case with buildings designed between the ‘50s and the ‘70s in Nigeria of the tropical-modernist period when adequate consideration was given to material selection, the geographical setting and effect of climate on the occupants of a building. This implies that technology focus is shifting from protecting the building envelope from the intense solar radiation to aesthetic facades. The need for designers to embrace the use of appropriate technology that addresses the prevailing climatic conditions in Nigeria cannot be overemphasized. With regard to the present international style, Ogunsote [11] referred to them as not respecting local conditions of weather and that the resulting buildings often depend mainly on artificial technology (active strategies) to achieve comfort. The figures below explain the shift in architectural design technology. It shows a brief comparison of tropical building of Nigeria in the past and the present day.

![Figure A](image1.jpg) ![Figure B](image2.jpg) ![Figure C](image3.jpg)

**Figure A** is the museum is also known as the “Old Residency National Museum”. This elegant colonial building is one of Nigeria's finest examples of colonial architecture in Calabar.

**Figure B** Kenneth Dike Library, University of Ibadan The building which exists as one of the oldest tropical modernist style was designed by Maxwell Fry, Drew and Associates in the early 50s (1953-1954)

**Figure C** Hood Awning made of fabric protruding over a window opening, characteristics of most precolonial buildings found in Enugu.

These “archifacts” pictures in an enormous sense the use of external shading devices in the then Nigerian setting when there was growing interest in designing to suit the context of the tropical climate. It was at this point that there was the emergence of a patterned guide of sunscreens – taking a cue from Le Corbusier’s “Brise-Soleil” (French word for sun breaker) was invented.
These buildings embodied the use of glass glazing on facades, characterized by no roof overhang or canopy, no external shading, no fenestration all heating or cooling strategies are active system which does not encourage sustainability. It can be concluded that buildings of the past utilized appropriate technology to protect the building exterior but this is not the case with the contemporary architecture.

5. Discussions

It is important to note that building materials are the motivation behind the drive for adoption of appropriate technologies. For different building elements, material composition is in a range of given classification as put forward by [10], from low material technology to future technology materials; some are classified as foreign while others are said to be traditional. These traditional "pool" of materials is what is commonly referred to as Architecture for the poor. It includes mud walling, fired bricks, unstabilized earth blocks, bamboo, timber, raffia, compressed stabilized earth blocks (CSEB), thatch, adobe, wattle and rammed earth but just to mention a few. The materials have long ago been deemed outdated and thus not suitable for the modernized communities. Therefore, it is this traditional material the research advocates for its appropriate use. This is not to say we are critics of advanced or what we refer to as modern technology rather our recommendation below centers on a switch to intermediate technology material to balance against high construction technology to create structures of high stability. The concinnity of intermediate technology material and the high construction technology gives a blend of building and structures that are environmentally responsive. An example is the Makoko floating school, as reiterated by Okeke etal., [12] its design and construction is much more diversified, humane, viable and sustainable because local employees were hired with the idea that they could then go out and build their own homes with the techniques learnt while the school was being erected. Everyone in the community understands its value, not least because all of the materials used are ones they live with each day [12].

From the result in figures E and F, the extensive use of glazing and mass concrete is not a construction technology peculiar to tropical environment and is it not environmentally friendly. The building materials are not sourced locally and they have the tendency to emit large amount of heat and greenhouse gases to the atmosphere resulting to the global warming epidemic. Also the buildings having such exterior façade and windowless requires more energy for heating, ventilating and air conditioning as compared to the buildings in figure A and B without protective canopy or roof from weather conditions. The importance of appropriate technology cannot be overemphasis although its adoption in the tropical environment is hindered by some factors that will be discussed below.
5.1 Importance of adoption of appropriate construction technology

‘The impact that appropriate technology can have on people has the potential to make the difference between prosperity and poverty, even between survival and death,’ Wicklein and Katchmar, in Wicklein [13]. This buttress the point that using appropriate technology sustains the environment and the inhabitant because nothing alien has been introduced into the system. However, the benefits of AT include:

- The gap in supply of housing in the tropics can be reduced by the adoption of appropriate technologies. It is obvious that the housing deficit in West Africa and Nigeria in particular is huge. However, every household can utilize the available and cheap appropriate material and construction technology to build shelter for themselves without government intervention, this will help alleviate the plight of inadequate housing been experienced. Minke [14] indicates that presently the number of people housed using earth technologies is more than one third of the world population and in Lowly Developed Countries (LDCs), the proportion is more than half. This boils down to the fact that using locally available material and self-build techniques is a solution to housing in developing countries.

- Adopting AT, materials energy and the carbon footprint in the construction industry will be reduced. These Materials are completely natural, non-toxic, synthetic chemical-free, and do not give out-gas. Other characteristics include sound resistance, thermal insulation, insect resistance and strengths. If practically implemented, use of appropriate technology has the potential to revolutionize the construction industry by addressing all environmental concerns of sustainability while delivering added benefits.

- Construction costs would also be reduced by choosing to adopt appropriate technology. Since appropriate technology encourages the use of locally available materials, on-site materials can be harvested and used, thereby reducing the waiting time required to obtain goods. This cuts down overhead costs, minimizes material shipping costs and increases efficiency.

5.2 Hindrance to the adoption of appropriate construction technology

There are several challenges encountered in the adoption of appropriate technologies which include;

- **Adverse government policy:** The Nigerian National Building Code [15], Section 10 on Building materials and components requirements, No. 1, paragraph 2 states that ‘locally available building materials SHOULD be integrated for their additional advantages of availability, identity, job creation and affordability. This statement in no doubt did not disprove the enormous benefits of the local building materials, however it is passive about the adoption of these building material. It leaves room for choice of other foreign materials and can also be interpreted as outlawing their use. Furthermore, Medador [16] assert that the government support for the sandcrete blocks (a foreign building materials) as material for construction of public projects led to the rapid eclipse of fired-clay blocks. This is because, given the socio-economic situation in Nigeria, Government patronage is regarded by the public as a confirmation of the good quality of the material concerned.

- **Loss of folk wisdom and technology of production:** when the indigenous building materials where first discovered and in constant use in the Nigeria’s building construction industry, it requires certain specialized skills that the artisan and craftsmen in those era possess. But with the passage of time and introduction of foreign building materials, the direction changed totally to embrace the high-tech material and these craftsmen of local building material were gradual phased out of construction business and active service without handing over the skill and techniques of local materials construction and technology to the younger generation. Therefore, anyone found still possessing this knowledge and skill has a high scale of fee for any service rendered and this leads to low patronage and adoption.

- **Investment requirements:** this is regarded as the greatest barrier to the small scale commercial production of local building materials as the challenge is difficulty in getting startup capital. For loan facilities, the interest rate from financial institution is usually very high and this significantly affects
prices of the finished products. In most cases, for local entrepreneur to break-even the quality of craftsmanship is usually sacrificed for quantity leading to poor output of the finished product

- Quality of output: the quality of output of indigenous building materials is usually considered low and therefore discourage it utilization. For this particular reason, this research has suggested a cross match of intermediate and high construction technology to achieve both sustainability and aesthetic finish. The submission agrees with the opinion of Egenti etal [17] who demonstrate that the ordinary compressed stabilized earth blocks (CSEB) one of the intermediate materials may need large overhangs to protect against rain thus resulting in higher overall cost than for cement/ sand blocks. In the discourse, he proposes a modification to Composite Compressed Earth Blocks (CCEB) as a possible future alternative. I.e. The blend of traditional material with high technology.

- Demand rate for indigenous products: following the laws of demand and supply we can relate and probably understand why the hike in price for this indigenous materials and technology. The materials are considered not ‘invoke’ and thus leads to a decrease in supply with and unchanged demand that results to a higher equilibrium price and lower quantity. But an increase in supply will result to lower equilibrium price and higher quantity. Also, as material use becomes more common, the technology spreads and their hidden potentials will continually be rediscovered.

6. Conclusion and Recommendation

Appropriate technology is generally recognized as encompassing small-scale, decentralized, labor-intensive, energy-efficient, environmentally sound, and locally controlled technological choice and application. Its adoption is a key in this age where demand for infrastructure in tropical Africa is increasing, in the shadow of a growing awareness of the earth’s finite resources. Appropriate technology has been discussed most frequently in its relation to economic development and as an alternative to capital-intensive technology transfer from industrialized nations to developing countries. However, the study highlights the fact that in low-income cities of Nigeria, the application of local building materials and appropriate technology perceived as more satisfying, convenient and prestigious is on the decline.

It is recommended from this study that a cross match of intermediate material technology and high construction technology be adopted and utilized for building construction in the tropics, with the re-introduction of appropriate external shading in buildings. Also, incorporating the aspect of biology to architecture is advocated as Humans could also address environmental problems by using biomimicry — examining nature’s solutions and applying them to building design, [18]. It is expedient that architects and designers should take a practical cue from the innovation of history. The history here, refers to the period in which solving a local problem rather than just customizing a foreign architectural idea was the drive. This goal can be reached through continual education and training. As in the submissions of Okeke etal, [19] there is no better time other than now for Nigeria to pursue green designs and technologies to combat present and future challenges of which appropriate technology encompasses.

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