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Exploring Prefabricated Construction Principles for Smart and Fast Housing Delivery in Abuja, Nigeria

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***Abstract*— The middle- and low-income earning groups in Nigeria have a high demand for housing development which is caused by the limited supply of housing units and the increase in population. The deployment of traditional construction methods for housing delivery has not been effective in catching up with the high demand for housing by an increasing population. This is because of the risks, time and labour-intensive characteristics related to the traditional process of construction. This study aims to examine how the low-income and middle-income groups can use prefabricated construction principles for smart and fast housing delivery to offset the high demand for housing. In order to achieve this, the study looked at existing literature and case studies that made use of prefabricated construction as an alternative method of construction; which moves a majority of the work done on the construction site to a manufacturing facility. This fosters improvement in predictability, productivity and efficiency with regards to time, cost and quality. Cost savings opportunities are also generated because of compressed construction schedules and less material waste.**

Keywords*— *Prefabricated construction; housing delivery; Abuja.

I. INTRODUCTION

A house is a structure that is developed for the core purpose of satisfying one of man's basic needs which is shelter. A house is important for the survival of man; it is also an indicator of a man's standing in society and his standard of living. Housing came to exist due to man seeking shelter from the elements. Housing shortages in countries in Africa, Latin America and Asia have come as a result of an increase in their populations. These deficits are more noticeable in cities [1]. Housing provision contributes to the physical welfare of a country and the stimulation of social stability. This will effectively reduce the rate at which slums emerge, provide comfort, reduce congestion and the high densities that are currently being experienced by urban areas.

In 1991, the seat of governance was officially moved by the Federal Government of Nigeria from Lagos to Abuja. The rapid development of Abuja was caused by this movement, which also included a massive migration of people from all over the country along with a substantial increase in construction. This massive influx caused a high growth rate for the city of Abuja. In 1979, the International Planning Associates (IPA) developed the principles that were used to guide the development of Abuja's masterplan. The regional development plan of the Federal Capital Territory (FCT) was prepared by Doxiadis in 1981 [2]. The city of Abuja is currently being developed in four phases over a 250 square kilometers area. For planning and development purposes, each phase is composed of districts, and each district is further divided into neighborhoods. The City was originally planned to accommodate about three million people when the master plan was fully developed.

The constraints to housing development in Nigeria are numerous, they include but are not limited to: ineffective planning and institutional frameworks, government programs and housing policies that are not fully implemented due to lack of funds and inadequate research. Due to the challenges of housing development that the government is facing, there is a shortage in the supply of houses. Because of the time-intensive characteristics associated with traditional method of construction (on-site brick and mortar), using traditional construction methods for housing delivery makes it difficult for the government to catch up with the high demand for housing by an increasing population. The traditional construction method has practices that are labor-intensive, and these practices are significantly impacted by risks related to weather conditions, market and site. Prefabricated construction moves the majority of the work done on the construction site to a manufacturing facility. This move allows for improvement in predictability, productivity, and the reduction of risks associated with the traditional construction method. Cost savings opportunities are also generated because of compressed construction schedules. There are also efficiency improvements with regards to time, cost and quality. This study aims to explore prefabricated construction principles for (smart and fast) housing delivery in order to find ways to offset the high demand for housing in Abuja, Nigeria. The objectives of this study are to identify prefabricated construction principles and to examine the approaches on achieving smart and fast housing delivery using prefabricated construction principles. This is particularly useful for middle and low-income earning groups in Nigeria who have a high demand for housing development, due to the limited supply of housing units and the increase in population. The scope of this research covers the investigation of prefabricated construction principles.

II. RESEARCH METHODOLOGY

The paper made use of a systematic literature review. The data was mainly gathered from internet sources (secondary sources) using document analysis. The internet source used is an academic search engine which is google scholar due to its broad content. Data was gathered from google scholar using

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prefabricated construction principles, and housing delivery in Abuja as separate keywords for the search. The search produced 34500 and 9480 results respectively. The search was sorted by relevance which rearranged the results. Only the first 30 pages were searched in order to further narrowed down the research articles. Articles relevant to our scope were then selected. Analysis of the data was primarily done using content analysis which made use of themes to group the result. The result was presented using descriptive approach with the aid of diagrams for better understanding.

III. HOUSING

Depending on their height or story, housing types are classified into three main categories namely: the low-rise housing which typically range from 1-4 story; medium-rise housing which are is generally between 5-11 stories high and high-rise housing which starts from 11 stories and above [3, 4]. There are many housing types by different names in different regions of the world, but the ones that are generally known and are common with similar characteristics in nearly all regions are bungalow, cottage, detached, flat, semi-detached, terrace, duplex house, triplex, quadplex, condominium, shop-house, apartment building (loft apartment, studio apartment, penthouse apartment), mixed-use building, mansion, maisonette.

A. *Brief History of Housing*

The two prominent events where the world witnessed a rapid growth in urbanization were the first and second World War and the industrial revolution [2]. The start of the industrial revolution was in Western Europe around the latter half of the eighteenth century and was later centered in the United Kingdom. Technological advancement increased significantly during this period, and this led to new and efficient ways of producing goods, new systems and the development of machines. After the First World War (1914 – 18) the demand for housing was critically high. It was caused by people migrating in search of safe shelter which was not damaged by the enemy attacks. [5] The Second World War (1939-1945) also defined affordable housing provision. During this period housing construction came to a halt because resources were being diverted for military use. Also, the construction of new houses ceased for six years in Britain. The war destroyed over half a million homes [5].

B. *Functions, Spaces and Relationships*

The history of spatial functions and relationships in a house has differed from culture to culture. The sizes of houses vary because their design is heavily influenced by the plot size, size of the owner's family, taste and income. Due to the activities that take place in domestic houses, spaces have been categorized into three zones which are: the public, work and private zones [6].

- **The public zone:** This zone consists of spaces that are generally open to non-family members. It is the area where visitors are mostly received. Such spaces include the foyer, living room, dining room, ante-room, *etc*. Depending on the lifestyle of the household the kitchen can also be included as part of the public zone. The public zone can also be determined by the proportion and arrangement of rooms in the floor plan/layout [7].
- **The work zone:** This zone consists of areas where the work activities of the household take place. This zone is dependent on the lifestyle of the household. It consists mainly of the kitchen and where members of the family change their clothes. A home office or library could also be viewed as part of the work zone [7].
- **The private zone:** This zone consists mainly of rooms used primarily by the household members for private activities. It is comprised of the bathrooms and bedrooms. If a family room is being utilized mainly by the household, it can also be included as a part of the private zone [7].

IV. HOUSING ISSUES

A. *Government Role in Housing Provision*

In Nigeria, government intervention in housing provision since independence has been mainly achieved through the provision of prototype public housing schemes in many communities. These schemes have undergone various transformations and, in some cases, been abandoned [8].

The position of Abuja as the Federal Capital Territory (FCT) of Nigeria has resulted in the daily influx of people. This is prominent among other factors that cause housing shortages and soaring rents. Despite the government's effort towards providing affordable housing through the provision of land, loans and housing schemes, the cost of accommodation has unfortunately been on the increase as the demand for housing is ahead of the supply.

B. *Challenges of Housing Delivery in Abuja*

A lot of challenges have developed despite the good intention of the Mass Housing Program (MHP). These challenges have a serious impact on the effective delivery of affordable housing in the F.C.T. Inadequate supervision as well as inadequate planning were one of the foremost challenges that were faced. A lot of provisions in the master plan were violated. The Neighborhood Concept was used when developing the master plan. A population of about 5,000 people was meant to be held in each neighborhood. A neighborhood center was provided to service this population. The neighborhood center provides facilities that include the recreational park(s), clinic, fire station, shopping center, police post, school, public library, public hall, post office, and others [9]. Reference [10] identified factors that bring about challenges to housing delivery. They include inadequate building technology, high cost of building materials, inadequate access to land, inadequate infrastructure and inadequate access to finance.

1) *Inadequate Access to Land*

Inadequate access to land is one of the major constraints to the provision of affordable housing in Nigeria. In Nigeria, the availability of land for affordable housing has been met with different problems such as ownership, use and accessibility. The difficulties in accessing land have resulted in land

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speculation by prospective developers, which ends up increasing land costs [11].

Access to formal land ownership is only available to the influential and the wealthy which are a minor set of the people due to the land constraints in Nigeria. The informal lands are usually left to the lower income earners. This leads to a low supply of affordable housing developments and the growth of an informal land market because of the challenges experienced in getting land legally.

2) Inadequate Access to Finance

Reference [11] stated that *"the most critical constraint of affordable housing delivery after land is finance. This is because housing provision is capital intensive hence the need to develop a sustainable supply of finance to fund housing investments is an important part of any policy which aims at improving housing affordability."*

The National Housing Fund (NHF) was established primarily to create long-term housing finance that is cheap. This would ensure that the finance for corporate developers and individuals participating in the scheme would be readily available. Mortgage banking services are expected to be more accessible as a result of this change.

Reference [11] also stated that *"some of the problems connected with mortgage finance in Nigeria include: the macroeconomic environment i.e. high inflation rate, the non-vibrancy of some Primary Mortgage Institutions, cumbersome legal regulatory framework for land acquisition and the structure of bank deposit liabilities."* This emphasizes the difficulty of getting land by the lower class due to their low income and position.

3) High Cost of Building Materials

In Nigeria, the cost of building materials takes up about 60% of the entire cost of a building. Despite the encouragement by the government in its policies to the use of local materials in a building, most housing developments still depend on materials that are imported. This dependence makes the final product unaffordable to the majority of Nigerians. Local materials such as bricks and cement stabilized blocks will reduce the overall cost of the building which will make it affordable [11].

4) Inadequate Infrastructure

In Nigeria, electricity, roads and other basic infrastructure are inadequately provided. Affordable housing delivery faces compounding challenges as a result of the lack of basic infrastructure. The absence of databases in a majority of African cities means that planning for cities is done with outdated/incomplete data. This approach to planning has resulted in limited service delivery. It has also affected the mobilization of municipal revenue either on property taxes or the basis of tenement rates. Effective strategies and progress are difficult to implement and measure in the absence of a database [10].

V. PREFABRICATED CONSTRUCTION

The Modular Building Institute defines prefabrication as *"the process of manufacturing and assembling the major building components at remote factory, transport to construction site, then installation."* Prefabrication incorporates the construction of all building components that are a part of a larger final assembly [12]. It is an offsite manufacturing process.

Prefabrication was introduced as a method for improving performance and sustainability in the construction industry and also as a substitute for on-site construction. Prefabrication has several terms that are associated with it which are off-site construction, industrialized construction, assembly, modular construction and mass production. The common activities linking these terms together is that they deal with producing prefabricated elements at a factory, the delivery of prefabricated components to the site, and the assembling of prefabricated components on the site to erect structures [13].

Prefabrication is an alternative method to traditional construction that offers benefits, such as reduction in environmental pollution, health and safety risks, time, waste, labor and cost. Traditional on-site construction unlike prefabrication, has been heavily criticized due to drawbacks associated with it, such as poor safety, environmental pollution, long construction time, waste of resources, external weather constraints, low productivity [13].

A. History of Prefabrication

The use of prefabrication techniques to manufacture homes started over a hundred years ago. It was in the early twentieth century that this method of construction started gaining recognition. Cities and towns with developing industrial sectors was where prefabricated homes were constructed. This allowed homes to be owned by middle-class families. Prefabricated homes were initially used as a source of low-cost housing at the beginning of their production. In the last few decades, innovation and technological advancements have allowed prefabricated housing to compete with the on-site method of construction in terms of time, quality, cost savings, and value. This method of home building has been developed over time to be environmentally conscious, while appealing to the upscale market [14].

1) Brief History of Prefabrication in Britain

It was through the global colonization effort of Britain that led to the beginning of prefabrication. Rapid building initiatives were required in settlements located in the U.S, India, New Zealand, Africa, Canada, Australia, and the Middle East. This occurred because the British were not familiar with the materials in these countries. In 1624, houses were manufactured in England and then shipped to Cape Anne, Massachusetts. This was the earliest recorded case of prefabricated housing. The structure for the shelters made use of timber frame, while timber panel infill was used for the walls, roof and floors [15].

The Manning cottage for emigrants consisted of triangulated trusses, floor plates and grooved posts with a focus on prefabricated infill and timber frame system. The panels of the cottage were standard sizes and interchangeable and could fit between the grooved posts. The system was mobile and easily shipped which aided the British to further their colonial agenda. Herbert (1978) stated that *"the Manning cottage was an improvement of the earlier frame and infill systems because of the ease of erection. The system was simply bolted together with a standard wrench, appealing to the*

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abilities and availability of tools to the emigrants. The Manning system foreshadowed the essential concepts of prefabrication, the concepts of dimensional coordination and standardization." [15].

Early in the 1800s, innovation was ushered in housing through the use of corrugated iron. In the 19th century when panel and spanning materials were underdeveloped, the technique of making prefabricated frames was developed fairly well. Wood planking and traditional canvas were used as a means of roofing in the Manning cottage. They also made use of prefabricated cast-iron trusses. Corrugated iron was a useful material that provided the benefit of being structurally efficient for roofs and walls, being affordable and could be quickly constructed. Many companies started galvanizing metals in 1837 in order to prevent rusting. Using corrugated sheets in prefabricated housing had the added advantage of being able to transport multiple layers which were cut into panels. This ensured the panels could be handled with ease and fastened into place at the site [16, 17].

2) Brief History of Prefabrication in Scandinavia

The development of prefabricated construction in Scandinavia has been centered around 3 main events which are the war, the post-war housing crisis and the industrial revolution. Housing construction in Sweden, Finland and Norway primarily made use of wood.

A housing shortage in 1917 led to an increase in the need for prefabrication as a substitute method for traditional on-site construction for housing delivery. The interest in making use of wood prefabricated housing spread to the design world and all facets of the society [18]. Prefabrication as a concept was generally understood by the construction industry and society at large in the late 1940s and early 50s. This led to the development of several new methods of production, experiments and prototypes which integrated plumbing and electrical systems with partition wall prefabrication. Prefabrication modules were built in larger partitions using wood and was adopted in standard building practice at the commercial building scale. The reason for the success of prefabrication in Scandinavia is based on two main factors according to [18]. The first was the development of detailing that had machine fabricated joinery and standardized connections. Secondly, prefabrication as a method of construction has become accustomed to in Scandinavia. The use of prefabricated construction resulted in lower initial cost [18].

In Scandinavia prefabricated housing as a substitute method to on-site construction continues to grow in Finland, Sweden and Norway. This is due to sustainable harvesting policies and the availability of forestland which maintain its growth. Buildings of varying sizes can be produced using glue-laminated members. Scandinavia's government supports timber prefabrication and precast concrete construction, its architects and peoples see prefabrication as a substitute method of construction which provides affordable public buildings and housing. By using wood as a medium Scandinavia has translated buildings crafted traditionally into buildings that can be mass produced [16].

3) Brief History of Prefabrication in Japan

One of the first pre-industrial advances in the principles of prefabrication in Japan was the post and beam which used the vernacular method of construction. The use of standardization in Japan's tradition made most of their historic structures beautiful and durable. They utilized structural grids (Ken), which is a 1:2 proportion, the sizes of timber used and standardized joints. These standards have been adopted in housing, public and governmental buildings. This tradition extended into prefabrication during the industrial age, which modernized the craft of Japanese vernacular architecture. Until the post-war era in Japan, the use of mechanized factories to produce prefabricated homes was not fully realized [16].

Out of approximately 49.5 million, only 2.2 million homes are of pre-war construction in Japan. 33 years is the life span for half of the wood-framed homes. Japanese consumers are buying existing homes, levelling them and building new homes because of the increasing need for efficient and durable homes. Many consumers have been driven to explore prefabricated construction as an option due to frustrations with poor scheduling and construction using the traditional method. Most prefabricators use the skeleton infill approach or the modular method [16].

The principles of prefabrication have been used to create functional and aesthetic works of architecture by Japanese architects. Examples of Japanese architects who have used the principles of prefabrication are: Waro Kishi, Osamu Ishiyama and Shigeru Ban [16].

B. Classifications of Prefabrication

Prefabrication is classified according to the degree of precast construction that occurs in the development of a project. The classes of prefabrication are: small prefabrication; medium prefabrication; large prefabrication; cast-in-site prefabrication; off-site (factory) prefabrication; open system of prefabrication; closed system of prefabrication; partial prefabrication and total prefabrication.

The method of construction used for a project is dependent on the equipment available for erection and transport, structural scheme used, connections between prefabricated elements and the special equipment used [19].

C. Systems in Prefabrication

There are various prefabricated systems used in the industry. Some of which are:

- **Pre-cut system:** The is one of the oldest systems of prefabrication. The materials (timber, steel, laminated wood, etc.) are processed to the required lengths and pieces at the factory, marked and then transported to be assembled at the construction site. The processed materials can be easily transported because the pieces can be delivered to the building site in units. Compared to the traditional method of construction this system is more accurate in its measurement and has less material waste [14]
- **Modular panel system:** Components of the building are produced in the factory using uniform sizes and a unit of measurement such as the module (M) as shown in Fig. 1 [14].

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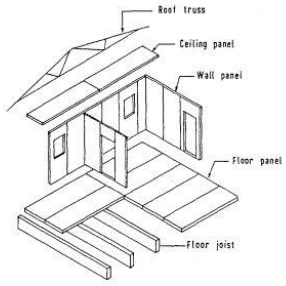

Fig. 1. Modular Panel System [14].

- **Large-size panel system:** When constructing a large project or large housing unit(s) at once, this system is suited for the task. The large-size panel system as shown in Fig. 2 increases the cost of transport and handling [14].

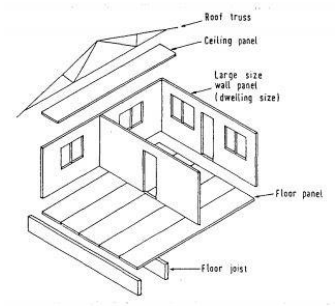

Fig. 2. Large-size Panel System [14].

- **Volume element system:** This system as illustrated in Fig. 3 makes use of units or modules of a building that are finished at the factory and then transported by trailers to the site. Cranes are required to assemble the units/modules into place. This system is faster than the others when dealing with site erection [20].

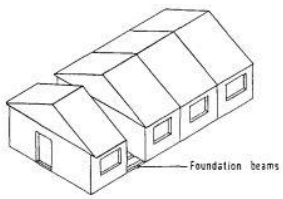

Fig. 3. Volume Element System [14].

Other prefabrication systems are:

- The facades of buildings mostly make use of a curtain wall system. It is used particularly with facades that have glass components. Structural insulated panels are also used for fire and sound insulation. Frame systems are commonly used for tower constructions. Complicated structures make use of the steel frame system because it provides the chance for obstacles to be predicted in the project before the commencement of construction. In small projects, wood frame systems are mostly used. This is because timber and wood are easily accessible which enables the fast execution of projects [21].

- The cell system is mainly used in countries that have extreme climatic conditions. Since producing components in extreme climatic condition is difficult, this system provides an allowance for producing the components in factories under favorable conditions.

1) Elements in Prefabrication

The elements of prefabrication in a building are: flooring / roofing system; precast beams; precast columns; precast wall panels and precast slabs

2) Components of Prefabrication

Reference [22] categorized the components of prefabrication into four types which are:

- **Processed materials:** It refers to materials (structural or cladding) that undergo a manufacturing process in order to be custom fabricated.
- **Prefabricated components:** It refers to any assembly that was fabricated. Examples are tunnel form construction, building envelope/façade systems, tunnel form construction composite panels, precast cladding, pre-cast structural elements, Light Steel Frame Building Systems (LSF) and insulating concrete formwork (ICF).
- **Panelized structures:** They refer to prefabricated components that are assembled that do not enclose usable space themselves. A large part of the final building envelope is constituted of panelized structures.
- **Modular structures:** They are prefabricated components that form an enclosed usable space. Modules are structurally independent and typically have finished interior and exterior surfaces. They are usually volumetric and fabricated offsite.

D. Process of Prefabricated Construction

Many prefabricated manufacturers vary in their construction technique and process flow. However, the generic manufacturing steps are followed in a majority of prefabrication facilities. These steps are shown in Fig. 4 [14].

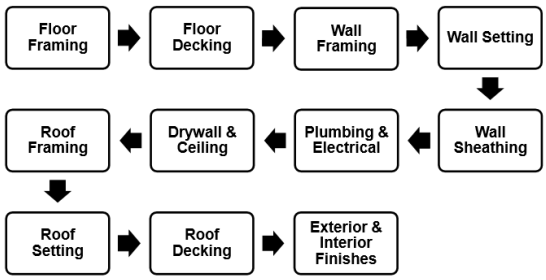

Fig. 4. Process of Prefabricated Construction [14].

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The installation of the load bearing joist system is involved in the floor assembly, which is followed by attaching the floor decking material. The components of the wall are first framed, set, and then covered with a sheathing material. The wall assembly also includes the doors, windows, plumbing and electrical fixtures. Vapor and insulation barriers are also installed during the wall assembly phase. Setting is a process where the walls are properly aligned and measured to ensure that they properly fit into adjacent subcomponents. The roof is erected in a manner that is similar to the sections of the wall and floor. A rafter or truss system is then manufactured and set in order to ensure alignment is achieved between the wall and the adjoining wall components. The insulation or vapor barriers and the decking material are then installed after [14].

1) Facility Flow Pattern

The two basic flow patterns that prefabricated (prefab) manufacturers use are the side-saddle flow pattern or shotgun flow pattern. The side-saddle flow pattern as shown in Fig. 5 consist of several subcomponent lines that operate simultaneously from start to finish on separate aspects of the building. While in the shotgun-flow illustrated in Fig. 6 subcomponent lines are arranged end-to-end and consist of multiple lines of production. These basic flow patterns have their production process advancing linearly through the facility [14].

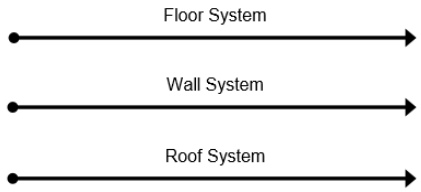

Fig. 5. Side-Saddle Flow [14].

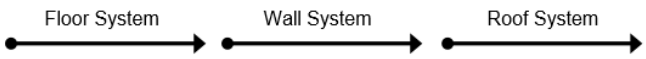

Fig. 6. Shotgun-Flow [14].

E. Benefits and Constraints in Prefabricated Construction

Due to the unique nature of prefabricated construction, it offers a wide range of benefits over the traditional method of in-situ construction along with some challenges.

1) Benefits of Prefabrication

There are several benefits of precast construction methods over the conventional construction method as found in the literature some of which are:

- **Faster Schedule and Cost Savings:** The ability of prefab construction to perform building construction and site work concurrently, shortens construction schedule which provides a means for cost savings in a project, due to the structural work on the site being confined to constructing the foundations and the erection of prefabricated components. This reduces the time that hoists and cranes are required on a site which helps to reduce overall cost. Manufacturers can buy material in bulk which aids in avoiding fluctuation on the cost of procuring materials. Due to the organization in the factory, the controlled climate and optimized repetition of tasks that occur within a factory setting work are done faster than work on-site. Also, a large part of the work can be completed with a smaller crew [19, 23].
- **Less Exposure to Weather:** Monitoring and control are easily achieved in a factory setting where prefabrication is used. This allows ventilation and air quality within the factory to be controlled, which reduces the possibility of building materials to have high levels of moisture. [19, 23].
- **Worker's Safety:** Safety risks are much higher in the field than in a factory setting. Conventional construction workers do not always work in ideal conditions, such as working in an environment with sun exposure, temperature extremes, wind and precipitation. While in prefab construction, workstations and materials are located adjacent to each other in an assembly line [23].
- **Less Materials Waste:** Construction material purchases are optimized, there is minimal on-site waste, and less exposure to the environmental conditions of a job site. The amount of materials that are required is significantly reduced, as formwork and scaffolding are mainly eliminated [19, 23].
- **Less Environmental Disturbance:** Site control is possible to achieve because the building modules are fabricated off-site. The impact on the surrounding site environment is reduced. The mess and noise produced by construction are reduced because a significant aspect of the work was done at a factory. This is an advantage for projects that are controversial or have difficult neighbors [23].
- **Consistency in Structural Quality Control:** Workers can be closely monitored using quality control as a consistent and methodical process in order to ensure the appropriate work quality. It is performed at each assembly station. This check significantly reduces error and the need to carry out quality control checks at the end of the production process. The use of machines and the working environment in the factory also contributes to the quality of a project [19, 23].
- **Economical:** It is economical for a large-scale project which has a high degree of repetition [23].

2) Constraints in Prefabrication

The constraints that affect prefabrication construction include regional manufacturing, architectural design and delivery, permitting and inspection, market demand, costs, labor and unions, logistics, codes and transportation [24].

The major challenge facing prefabricated construction are the transportation costs and shipping constraints. The transport cost depends on permit allocation, distance and the amount of

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trucks required to carry the prefabricated components. Shipping constraints include the size, load, and federal/regional road restrictions. The physical limits of the truck and the road restrict the dimensions and load of prefabricated components. Shipping of prefabricated components requires careful handling [14].

Other challenges that are faced in prefab construction are:

- Joints and prefabricated sections have to be strong and corrosion-resistant to avoid failure.
- Leakage can occur at joints in prefabricated components.
- Large prefabricated structures require the use of precision measurement, heavy-duty cranes and careful handling when placing prefabricated components.
- There is a tendency to look drab and monotonous especially if a large group of buildings are using identical prefabricated elements.
- It is a specialized construction which require specialized skill labors. Therefore, jobs normally awarded to locals or unskilled labors are lost.

3) Design and Delivery Constraints in the Prefabricated Method of Construction

According to reference [24], a high level of collaboration and planning is necessary at the early stage of the design process of prefabricated buildings. The issues that should be considered in the design are the shipping methods, the inflexibility of modules, interior opening, mechanical, electrical and plumbing (MEP) systems. Integrated delivery methods are beneficial for modular construction. There are a number of constraints when it comes to the design and delivery of prefabricated method of construction, which are:

- The design is limited by the physical constraints of transport, which is why it should be considered while designing. The width, length, height and load are subject to transportation constraints. The design also has to take into consideration the method of shipping to be used for transporting the prefabricated components from the factory to the site.
- The inflexibility of the modular unit is also to be considered. The shape of modules and panels are defined by a standard size and shape; they can also be combined create larger spaces.
- The use of modules tends to create structural redundancy.
- There is a large amount of planning and coordination required in the design process, especially if the architect, manufacturers, and the contractor are not accustomed to the constraints.

There is a need for a high degree of coordination required in the project between the architect, manufacturer and general contractor.

VI. CONCLUSION AND RECOMMENDATIONS

The study set out to explore prefabricated construction principles for (smart and fast) housing delivery in order to find ways to offset the high demand for housing in Abuja, Nigeria. Relevant findings from literature are categorized into the following sub-heads: a brief history on housing; types of housing; the function spaces and relationships in housing; housing issues such as the government's role in housing provision and inadequate access to finance and land; the cost of building materials and inadequate infrastructure. Additionally, the review also looked at a brief history of prefabricated construction; the classification, systems, and process of construction; the benefits and constraints in prefabricated construction and the design and delivery constraints of prefabrication. It is observed that the use of prefabricated construction offers several benefits over the conventional construction methods such as providing a faster schedule; cost savings for large-scale projects which have a high degree of repetition; less exposure to weather and increased worker's safety. Other benefits include: less materials waste and environmental disturbance and consistency in structural quality control. Although prefabricated construction offers a large number of benefits, there are also significant constraints such as transportation constraints, structural redundancy depending on the type of prefabrication used, inflexibility of modular units and a large amount of planning and coordination required in the design process. Other challenges are: leakage issues at joints in prefabricated component; the use of precision measurement, heavy-duty cranes and careful handling when placing large prefabricated components and the reduced number of jobs. For prefabricated construction principles to be implemented in the provision of smart and fast housing delivery in Abuja, it is recommended that some elements of the building that will not cause transportation issues can be prefabricated and assembled on site while elements of the building that are too large to be prefabricated off-site should be constructed on site. This takes advantage of the fast schedule and cost saving benefit of the prefabricated method of construction and the flexibility of conventional construction. In conclusion this study provided relevant information for developers, and the architects who design for housing developments. This will enable them to adopt prefabricated construction principles that increase the speed at which houses are constructed, thereby enabling developers to reduce the demand of housing. This study will also help to provide relevant literature for those who will carry out further studies on prefabricated housing. The authors recognize that the sources and the scope used for the paper are a limitation to the study. Hence, further studies could explore the use of more internet search engines to gather data. In addition, suggested areas for further research include: comparative analysis of the planning and coordination required in the design process between prefabricated construction and the conventional method of construction and to carry out similar studies using primary sources to collect data.

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