

Sustainable low-cost housing in Sudan between Theory and Practice

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Abstract— The Sudanese housing policies encompass two main types of programs. The first one addresses the needs of all sectors of the population for the provision of plots through site and services schemes. The second type provides small built core units (Incremental housing) for the low- income groups. The aim of the paper is to review the provision of sustainable low-income housing in research and practice. The research selected some low-cost housing studies to represent research efforts and some low-cost housing constructed projects to represent the practice, these projects were constructed in different periods of time e.g. New Duim project _1949, El shabiya project_1963, Al Iskan Project _1975 and state fund projects _2001. The analysis focused on three parameters: the scope of the project, the design of the core unit and the construction including building materials and technologies, these parameters are discussed comparing research efforts and the practice. The research found that studies presented proposals for housing clusters provided good ventilation and simple design of the plots with direct access for cars and savings on sewage network. Old constructed projects had comprehensive approach including socio-economic surveys of the intended inhabitants, while new constructed projects put more emphasis on quantities of built units than on quality of housing. Research studies proposed cheap building materials and technologies which is more sustainable than the expensive imported materials used in new constructed projects. The research identified the introduction of mixed housing of different income levels in new constructed projects that guaranteed social sustainability.

Keywords— low-cost housing projects, sustainability, research studies, core-unit, building materials and technologies

INTRODUCTION

Sustainable Development is a comprehensive process of providing development within the umbrella of the four pillars of sustainability (UNDP 2002): cultural vibrancy, economic prosperity, environmental responsibility and social justice. In practicing sustainable community development, proposed actions and policies must be judged for their economic value as well as for their ecological and evolutionary effects, moreover following a model of sustainability requires integrating different human values with the multiple dynamics of natural systems (Flint, 2013). One of the main factors of achieving sustainability in a community is the sufficient range, diversity and affordability of housing within a balanced housing market (Egan 2014). Housing projects must be properly integrated into the social, cultural and economic local environments, it is important to connect housing to infrastructure networks and basic services (water supply, electricity, etc.).

Many of Africa's cities and towns population lives in informal sector housing. Squatter settlements represent 74% of urban areas In Zambia, 80% in Nigeria, 92.1% in Tanzania; 92.9%; in Madagascar and 99.4%. in Ethiopia. (Giddings, 2007). UN-Habitat (2012) prepared a policy framework for developing countries to guide provision of sustainable housing, in which cultural and economic impacts of housing contribute to make healthy residential neighborhoods. To achieve economic sustainability housing policies, design and construction should be connected to micro and macro -economic development, and employment of the area. Also, production of housing projects contributes to economic prosperity of the community, as stated by Davis (2015) construction of housing creates new opportunities for urban investments at the local level, it privileges the role of private developers and the housing industry and transfers responsibility for housing to smaller municipalities. Social sustainability is a serious issue in housing as it concerns with social equity in providing basic and social services and access to work. Another important factor in providing sustainable housing is the social mix of the inhabitant of different income-levels and different ethnic groups and distributing 20-50% of the residential floor to low-income families (UN Habitat 2014).

The Universal Declaration of Human Rights (Article 25.1) states very clearly that Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, The United Nations Housing Rights Programme (UNHRP) emphasizes the leading role of Governments in promoting, protecting and ensuring the full and progressive realization of the right to adequate housing" (paragraph 61). The UN-Habitat clearly stated that it is a priority for all governments to provide adequate and affordable housing taking into consideration residents lifestyle and livelihood strategies. Provision of adequate housing requires number of conditions such as: affordability, habitability, accessibility, location, availability of services, materials, facilities and infrastructures, cultural adequacy and security of tenure (UN 2014). Availability of different types of housing tenure such as freehold, leaseholds, condominiums, cooperatives, shared leaseholds and various forms of rental housing to suit various needs and preferences of different inhabitants provides security of tenure (UN Habitat 2015).

Provision of sustainable housing involves a complex network of components: stakeholders and matters e.g. land, building materials, finance, labor etc. Each component plays an important role that affects roles of other components e.g. government policies guide urban plans, land-use and other regulations related to housing. Scaling up sustainable housing is a crucial issue in developing countries, which require supportive institutional and regulatory environment, monitoring and evaluating mechanism and appropriate capacity development of the housing sector (UN Habitat 2012). The demand for new housing projects in developing countries is huge e.g. in Nigeria, the rate of provision of new housing stock has lagged severely behind the rate of population growth resulting in staggering housing deficit (Olotuah,2010). There are multiple alternatives of sustainable building materials such as, earth which is widely available, affordable and recyclable. It is well suited for passive solar heating and cooling, and offers a wide range of environmental benefits, including significant reductions in pollution and greenhouse gas emissions (Bayazitlioglu,2017), one example of a developed sustainable technology of earth is compressed and stabilized earth block (CSEB) which used as low-cost structural systems (Kumar et al,2018) table (1) shows properties of compressed stabilized earth blocks versus other walling materials . Also, wood as a sustainable building material is durable and its greatest attribute is that it is a renewable resource, it has low carbon impact and low embodied energy. (Falk,2009) one example of a developed sustainable technology of organic based construction materials is straw based material that used for walls (Goodhew,2012).

Table (1) Properties of compressed stabilized earth blocks versus other walling materials. Source pp7

Property	Compressed stabilised earth blocks	Fired clay bricks	Calcium silicate bricks	Dense concrete blocks	Aerated concrete blocks	Lightweight concrete blocks
Wet compressive strength (MN/m ²)	1 - 40	5 - 60	10 - 55	7 - 50	2 - 6	2 - 20
Moisture movement (%)	0.02 - 0.2	0.00-0.02	0.01-0.035	0.02-0.05	0.05-0.10	0.04-0.08
Density (kg/m ³)	1700-2200	1400-2400	1600-2100	1700-2200	400-950	600-1600
Thermal conductivity W/m°C	0.81-1.04	0.70-1.30	1.10-1.60	1.00-1.70	0.10-0.20	0.15-0.70
Durability against rain	Good t-very poor	Excellent - very poor	Good - moderate	Good t-poor	Good - moderate	Good - poor

HOUSING IN SUDAN

Sudan as a developing country experienced changing and urbanizing conditions, the population increased from 10.3 million in 1956 to 39.154 million in 2008. Population of Greater Khartoum-the capital- also increased rapidly from just over half a million in 1956 to 6.8 million in 2014 with estimated growth rate as 2.7% (Khartoum State (2015)). The population influx caused a severe housing problem and a massive housing demand in a country, 46.5% of its population are under the poverty line (Sudan census ,2008). That means half the population have inadequate income to afford living and housing. The review of the Sudanese housing policies shows that those policies encompass two main types of programs. The first one addresses the needs of all sectors of the population by providing plots through site and services schemes -an application of the enabling approach. The second type provides small built core units for low- income families. However, the recorded built core units in Greater Khartoum in the period 1961 -1996 by both public and private sectors are only around 2000 units which represents a few portions of the need for new housing at that time .After 1996 the state of Khartoum took serious actions to solve housing problem and established a new body: The State Fund for Housing and Development (The State Fund), which is created to address housing deficits through provision of more core units, The built core units constructed in the period (1996-2015) are more than one million in the three towns Khartoum, Khartoum North and Omdurman.

RESEARCH METHODOLOGY

The research was based on literature review and field survey, it had followed qualitative and quantitative methods which included: Plans and photos documentation, observation, interviews with senior officials at Ministry of Physical Planning and the State Fund, and some inhabitants of the selected housing projects. Three low-cost housing studies are selected to represent the research efforts. These studies are: Low- Cost Housing Study (1982), Low- Cost Housing Project (2006) and Al Rasheed Pilot Project 2008 – 2010. Four low-cost housing projects were selected as case studied to represent the practical efforts of the public sector. They are constructed in different periods of time: New Deims in 1949, El Shabyia in 1963-1985, Al Iskan in 1975 and Elthora hara 72 in 2003. The analysis was focused on comparison between the selected low-cost housing projects describing the scope of projects, the design of the core unit and the construction including building materials and technologies.

PRESENTATION OF CASE-STUDIED RESEARCH EFFORTS

Low- Cost Housing Study (1982): The French Agency Cooperation et Management and Building and Road Research Institute (BRRI) established a low-cost housing study in 1982. The output of the study was a construction project for Khartoum region. The size of the plots was varying (180 to 220m²). Plot type A (10x20) (see figure (1)) and plot type B (12x18) (see figure (2)). The basic core includes: -A block with a surface of 32.20 m² containing a sala and one adjustment room slightly set off. -A water block at the rear of the plot with toilet and shower (surface: 2m²). The proposed sanitation systems are Improved privy and Aqua privy. -A fence (2m high) with two accesses. -The design of the basic core makes it possible to build extensions as follows:

- I. Basic core + a kitchen (2.18 mx2.80 m) the total surface 40.3m².
- II. Basic core + a kitchen + two bedrooms (11.70 m²) the total surface is 52m².
- III. Basic core + a kitchen+ three bedrooms (11.70 m²) the total surface is 63.7m².

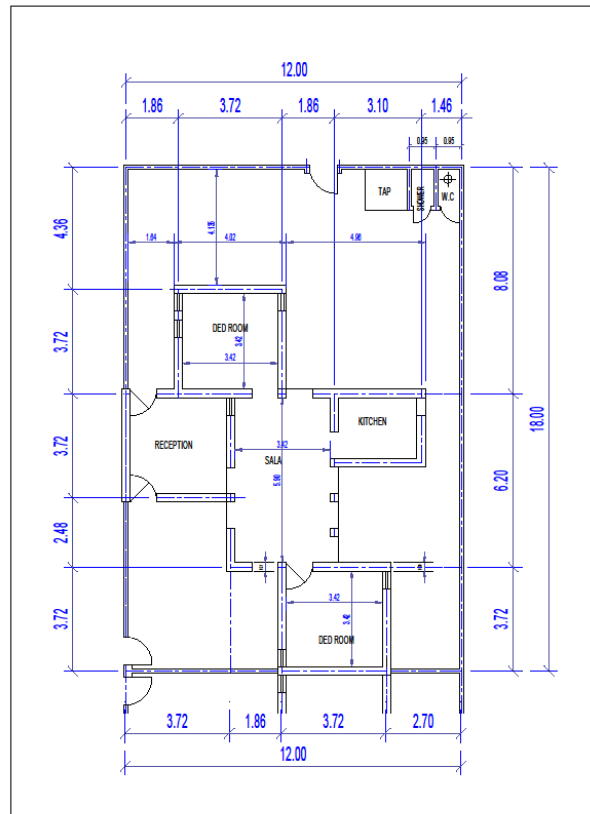
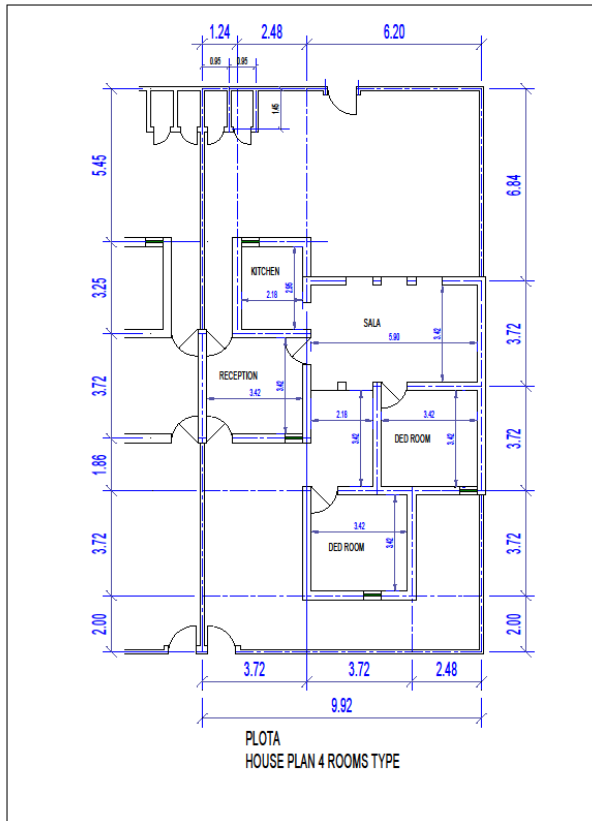


Figure (1) plan of the house type (A)

Source: Ministry of finance & economic planning 1984

Figure (2) plan of the house type (B)

Source: Ministry of finance & economic planning 1984

Low- Cost Housing Project (2006): The project was prepared by Building and Road Research Institute (BRRI) for Savings and Social Development Bank to be constructed in Khartoum. The proposed house is designed for the low- income employees of the bank. The size of the plots is the same (13.2x20) 264m² (see figure (3)). The core unit includes:

- A main block with a surface area 37.5m², consisting of a hall (4.8m x3.6m) and one adjacent room (4.5m x 4.5m) forming L shape.
- A kitchen at the rear corner of the plot with a surface area 8.7m².
- A water block (toilet + shower) at the front side of the plot with surface area 5.4m². The proposed sanitation system is improved aqua-privy. Each two houses share one soak-away pit outside of the plots.
- A fence 2.20m high with one access.

-The design of the basic core makes it possible to build other spaces for future extensions. Example:

- I. Basic core + one room (20.25m²). The total surface area is 71.9 m².
- II. Basic core + one room + a hall (20.5m²) and a veranda (8.7 m²). The total surface area is 102.2. m².
- III. Basic core + one room + a hall + a veranda + another room (14.4m²). The total surface area is 115.5m².

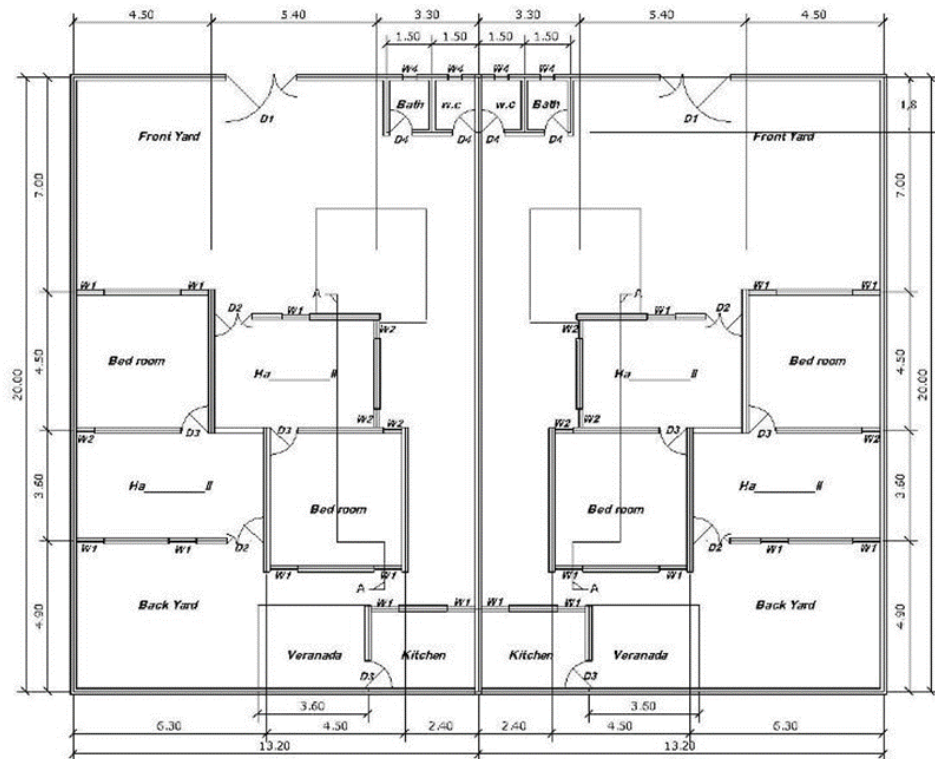


Figure (3) The design of the house

Source: Archive of Building and Road Research Institute 2007

AL RASHEED PILOT PROJECT: The project is one of many projects carried out by United Nations Human settlements Programme in Khartoum between 2008 and 2010 to formulate and implement pro-poor urban policy. The pilot project is constructed in Al Rasheed- Jebel Awlia- Khartoum town.

The size of the plots are (11.5x15.0) 172.5 m², (15.75 x15.00) 263.25 m², (10.75x15.00) 161.25 m². The core unit includes:

- A main block with a surface area 26.0m², consisting of one room (4.0m x 4.0m) and a veranda (4.0m x 2,5m)
- A kitchen at the rear corner of the plot with a surface area (4.0m x 3.0m) 12.0m².
- A toilet at the front side of the plot with surface area (1.5m x 1.5m) 2.25 m².

The design of the basic core makes it possible to build other spaces for future extensions. Example: -

- I. Basic core + one room (20.25m²) +veranda. (see figure (5)). The total surface area 71.9m²
- II. Basic core + one room + a veranda (8.7m²) + another room (14.4m²). (see figure (4)) The total surface area 102.2m².

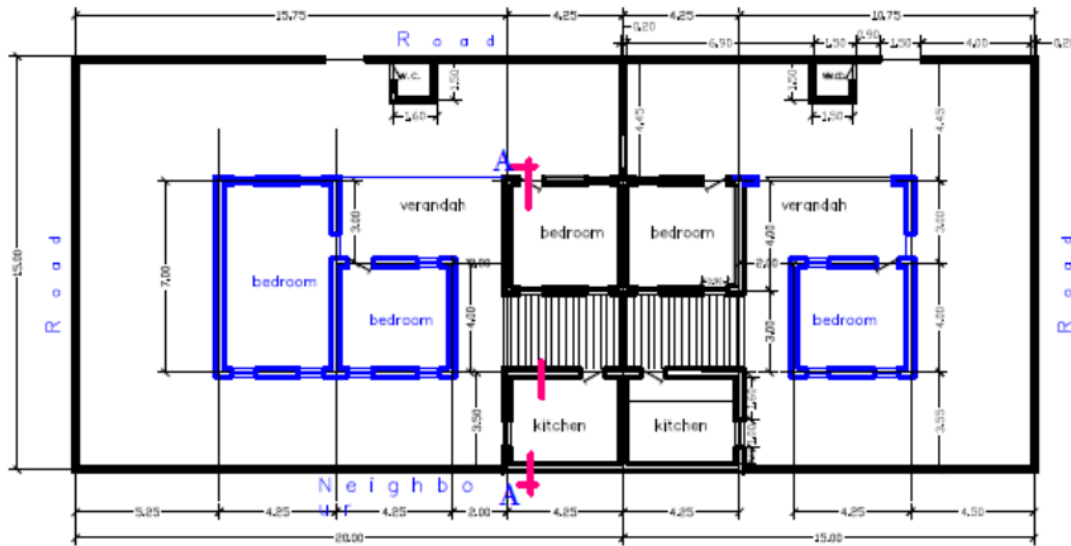


Figure (4) The design of the core unit+ Extension (2)
 Source: Archive of Institute of Technological Researches

Figure (5) The design of the core unit + Extension (1)
 Source: Archive of Institute of Technological Researches

LOW-COST HOUSING PROJECTS

New Deims Resettlement Project: New Deims is located in Khartoum town, it lies outside the Railway Ring, south of the light Industrial area. The resettlement project was carried out in 1949. New Deims comprises 1233 dwellings of 200 square meter. The core unit contains two bed-rooms, a veranda, a kitchen, a toilet and a shower (see figure (6)).

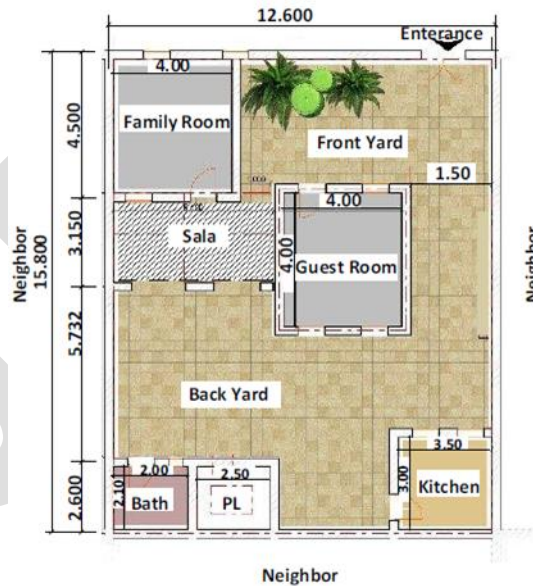


Figure (6) plan of the core unit - New Deims.
 Source: Ministry of Physical Planning archives

EL SHABYIA PROJECT: El shabyia is located in Khartoum –North. It was developed between 1963- 1985 to provide housing for the workers from Khartoum- North industrial area. Around 1048 houses were constructed. There were two types of houses: Small Dwelling in plots of 252, 261 or 290 sq. m and large Dwelling in plots of 300, 310 or 340 sq. m. The core unit contains three bed-rooms, two verandas, a kitchen, a toilet and a shower. (see figure (7)).

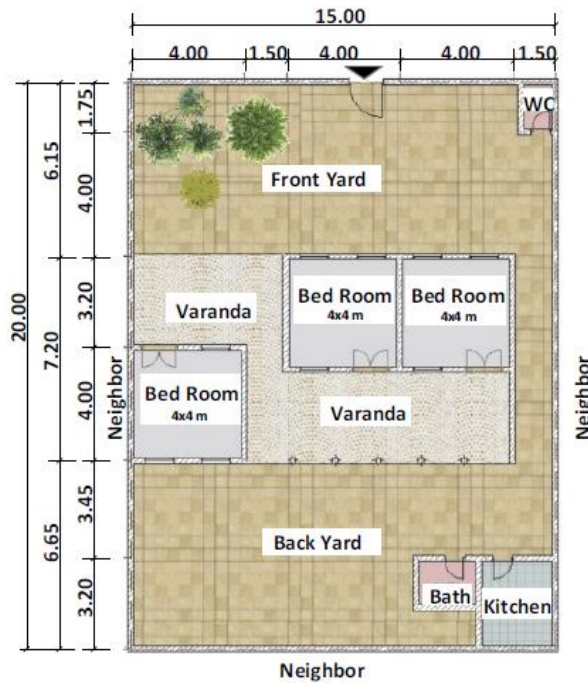


Figure (7) plan of the core unit -El shabyia.
 Source: Daiffalla (1998)

Al Iskan Project: The Project is located in West-South of Khartoum town-Jebra Block Three. The project started in 1975. It includes about 200 prototypes houses. Plots are 200 m². The core unit contains three bed-rooms, two verandas, a kitchen, a toilet and a shower (see figure (8)).



Figure (8) plan of the core unit - Al Iskan Project.
 Source: Ministry of Physical Planning archives

Elthora hara 72 Project: Elthora hara 72 is located North- West of Omdurman in Karari locality. The project is constructed by the State Fund, it was started in 2003 and contains 1818 houses. The project contains three types of dwellings:

- Low-cost housing (for low income families): A core unit consists of one bed room, a kitchen and a toilet (see figure (9)). This type of housing holds 58% of the project- 674 houses.
- Economic housing (for middle income families): A core unit consists of one bed room, a kitchen and a toilet. It holds 37% of the project - 410 houses.
- Investment housing (for high income families): A villa consists of two rooms, a kitchen, a bathroom and living area. The construction of the house permits vertical expansion. It holds 5% of the project -62 houses.

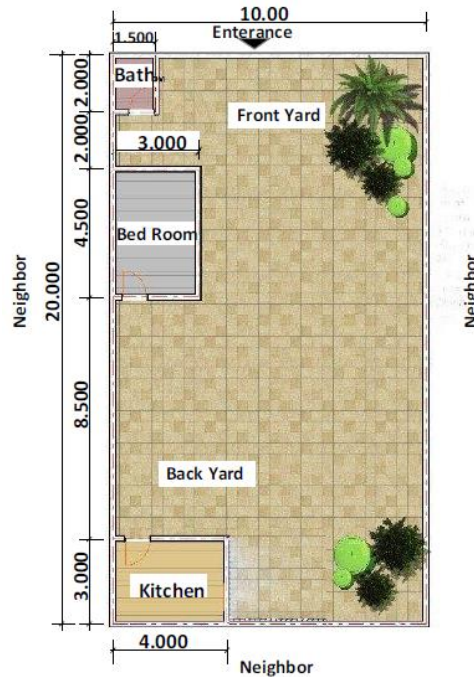


Figure (9) plan of the core unit - Elthora hara 72.

Source: The State Fund archives

DISCUSSION

The scope of projects : Low- Cost Housing Study (1984) was intended to provide housing for low -income families in Khartoum region without specifying a certain location , while the Low- Cost Housing Study (2007) was designed for the employees of Savings and Social Development Bank working in Khartoum and also without specifying a certain location. These researches presented proposals for housing clusters which can be reproduced to satisfy the number of intended inhabitants. The planning of the clusters provided good ventilation and simple design of the plots with direct access for cars and savings on sewage network.

Low- Cost Housing Study (1982) proposed a proto type of a cluster containing two types of houses type (A) and type (B) (see figure (10)).Each cluster contain fourteen plots that grouped around a semi-public interior space(20.0m x 20.0m) accessed by narrow pedestrian ways (3m large),while Low- Cost Housing Project (2007) increased the number of plots to reach 64 plots with two symmetrical semi-public open spaces (30.4m x 40.0m) (see figure (11)), and elaborated the planning proposal by specifying that every six clusters would be grouped around a larger public open space. The proposal provided hierarchy in open spaces and roads within the neighborhood.

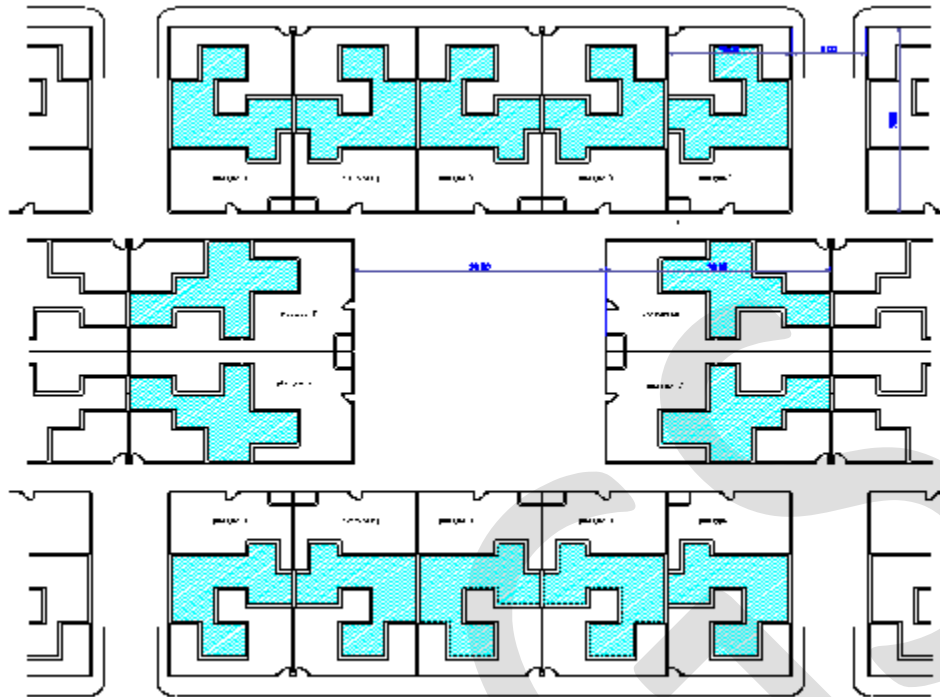


Figure (10) Housing Cluster -1984
Source: Ministry of finance & economic planning 1984

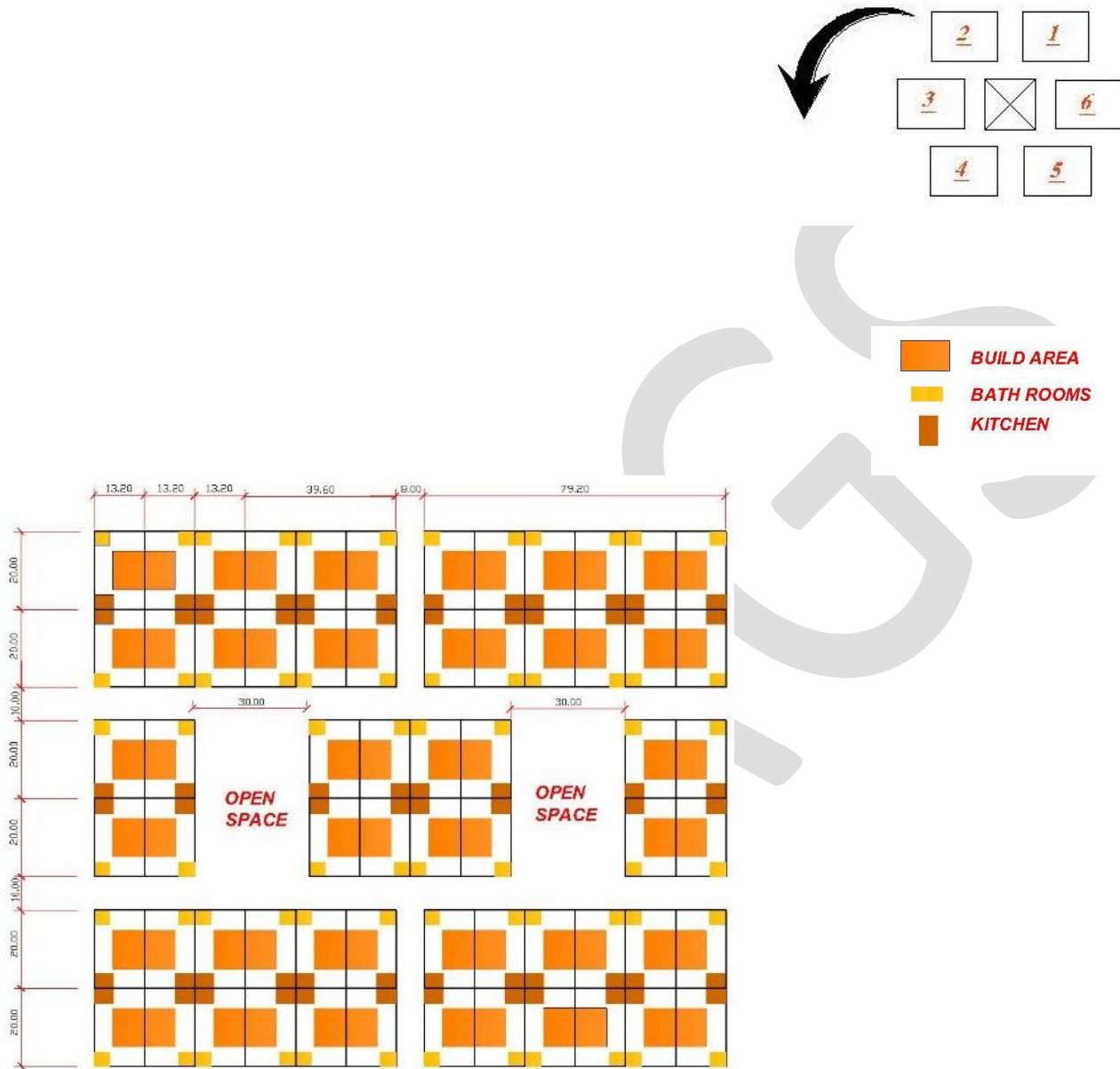


Figure (11) Housing Cluster-2007
 Source: Building and Road Research Institute 2007

The Low-cost housing projects implemented by the public sector started as resettlement projects in New Deims, which was a native lodging area built to accommodate the working people of Khartoum. At the time of Resettlement (1949) there were five thousand houses accommodating some seventeen thousand people, who lived in conditions of terrible over-crowding. There were two reasons for the resettlement, firstly, housing condition in the Old Deims were seriously inadequate for the minimum requirements of decent family living and secondly, Old Deims blocked the expansion southward of Khartoum. All resettled persons were left to build their new houses without financial assistance from the government except 29 families who had given some substantial assistance. In the sixties, the housing authorities-built houses for the poor workers families in El Shabyia -North Khartoum, the number of houses was large – 1048 units. In the seventies a Al Iskan experimental Project provided 200 houses for low-income groups. Regarding housing projects size, the big change in projects size occurred after the establishment of the State Fund, it had an expanded social housing programme providing more than one million units. The housing authorities became more organised and had reasonable budgets but at the same time the housing problem exaggerated and the demand for housing increased.

The increase in the projects size requires more vacant land which is available at the suburb of the capital so that new housing projects were located in remote areas, in which inhabitants are not well connected to jobs and to decent basic and social services Another important disadvantage in providing these large projects is the absence of demonstration projects, all housing projects were constructed without pilot projects to test sustainable practices and after completion there was no evaluation for the implemented projects to pick out advantages and avoid drawbacks.

Regarding social sustainability, in the first resettlement project- New Deims- housing authorities recognised the important role of the social sustainability; therefore, they conducted a comprehensive social survey. By doing so they emphasized the role of housing as a social structure that considers socio-economic interactions of the inhabitants and their social qualities. The housing authorities tried to conserve the community structure because on the social side, Old Deims comprised of well –integrated communities, sharing certain loyalties, and exchanging certain mutual obligation. The housing authorities distributed plots to the inhabitants of Old Deims, according to two fundamental criteria: permanent employment and ten years occupation. It was, however, recognized from the social survey that some families-29- were qualified for plots, but who could not build without substantial assistance, such families were given financial assistants and were left to their own devices. After that in the forthcoming projects, eligibility criteria for obtaining a house in El Shabyia project changed to focus on nationality -Sudanese, family size -five persons, employment -public sector and salary. The beneficiaries were required to deposit down payment, equal to 10% of the total cost of the house and the services provided. The balance was to be paid in instalments over a period of 20 years. In Al Iskan Project core housing units were allocated to all low-income families living in the capital without specifying working in the public sector. families were ranked according to certain social and economic criteria (the point system). The beneficiaries were required to pay the total official nominal price of the house without instalments.

The State Fund provided housing for mixed inhabitants in most projects, hence Elthora hara 72 project was intended for low, ,middle and high income levels but the majority were low-income families - 58% of the total number of the inhabitants .This new policy enables cohesion and interaction of different social classes in the same community, and most importantly all the inhabitants would have equitable access to basic and social services. Most probably the social mix will lead to social sustainability. Distribution of low-cost units were governed by rules- a point system- and a board to insure the merit of the applicant. The beneficiaries were required to deposit down payment, equal to 20% of the total cost of the house and the services provided. The balance was to be paid in instalments over a period of 12 years. Although the down payment was large but the instalments were affordable for the poor families.\

Later after sixty years of the first resettlement project - New Deims, United Nations Human Settlements Programme implemented Al Rasheed Pilot Project. Al Rasheed is a relocation area created in 2005 to house about 8000 families evicted from IDP camps and several squatter areas. The project was constructed in a remote area so that it is difficult to be linked with urban livelihood opportunities. The project applied findings of research to construct proto- type core units for 400 families which representing only 5% of the total families living in that area. Most inhabitants came from squatter areas However, the introduction of the housing construction project, has had a positive impact on the local economy and significantly improving living conditions. The project was constructed using self-help approach, classifying the inhabitants into different social groups:

A. vulnerable households were supplied with subsidies.

B. households without permanent employment applied “The three-block approach” which allows them to pay the cost of the lease of the stabilised soil blocks making machines and cement by providing blocks for the construction of public utilities. Every third block they make, they can sell it in the market as an income generation source.

C. households able to pay back in cash instalments. Credits provided in partnership with the Social Development Foundation (SDF). UN Habitat pilot projects integrated some common approaches, linking governmental and community efforts. These approaches involve empowering communities through training communities and public officials in the different project components.

The design of the core unit: Traditionally, the two basic types of dwellings are either houses or flats, in Khartoum the popular dwelling type is the single detached house. Although flats permit vertical expansion but they were not popular because of many reasons: the climate, the great desire for privacy, the large size of families, traditional tendencies and lack of supportive basic services especially sewerage. The choice of single detached house as a predominant dwelling type had led to many problems: horizontal expansion and urban sprawl of the city, low densities, and high cost of basic urban services. Most of low-cost studies and projects provided semi- detached houses, although the use of raw houses would have many advantages such as saving in areas and building materials.

The plot area increased from 180 - 220m² in the low-cost study (1984) to 264 m² in low-cost study (2007) and the built area also increased from 34.2 m² in the low-cost study (1984) to 51.6 m² in low-cost study (2007).The design of the core unit was compact in the low-cost study (1984) with two design options and semi-compact in low-cost study (2007).

Al Rasheed Pilot Project explored different prototypes of horizontal expansion and one prototype of vertical expansion -reinforced slabs and multi-storey buildings. In New Deims and El Shabyia project, the design of the built area is semi-compact. the built area was 64.5 m² in New Deims and it was enlarged to 91 m² in ElShabyia project. As a new housing experiment, the design of the core unit in Al Iskan Project changed to be compacted and the built area was reduced to 38.4 m². In Elthora hara 72 the design of the core unit was scattered and the built area was reduced again to 30.0 m². It is noticeable that in the housing projects , although the plot area of the house increased a little from 200 m² to 240 m², but the built area of the core units decreased from 91 m² to 30 m² and the percentage of

the built area also decreased from 32% to 15% (see table (2)). The reason behind this phenomenon is that the land in Sudan by constitution belongs to the government and its cost considered zero in the financial break down of the cost of the house, while the cost of the construction of the core-unit is considered high according to the financial ability of the public sector, so that the increased demand of housing units leads to provision of large quantities of core units with small built areas.

As the choices made for design and planning need to be derived from the specific context and climate of the community (UN-Habitat 2012), The design of the basic core unit proposed in the low-cost studies meets the climatic, cultural and economic requirements as follows:

- Transversal layout in relation to prevailing winds (North-South).
- A few or no openings on the East and West facades for protection against the sun.
- Direct access for visitors to the reception area and the toilet.
- Intimacy provided by the physical separation of the reception areas and the areas for family activities.
- Free space at the front of the plot for guest entertainments at early mornings and evenings. Free space at the rear side of the plot for family activities.
- Each two houses have shared walls of the built area.
- Water supply located at the front or the rear of the plot for the water block and extended to the kitchen.

Unfortunately, all designs of the core units in the four selected projects did not apply the proposed proto-types of the low-cost studies. However, they tried to their best to respect traditions and lifestyles of the inhabitants by separating the living area of the family and the guests and segregating males and females whenever the size of the built area permits. They also provided (by the location of the built area) possibilities for dividing the courtyard into two sections, front yard for males and back yard for females. Although The authorities provided proposals for future extensions - incremental development- of the core-unit but most inhabitants didn't follow these proposals and developed houses according to their needs and financial abilities.

Table (2) Relationship between the size of projects, the plot areas and the built areas. Source: (the researcher)

Project	Size of the project	Plot area (m ²)	Built Area	Percentage of built area%	House type	Design type
Low- Cost Study (1982)	-	180 to 220m ²	34.2	19-15.5	Row houses	compact
Low- Cost Study (2006)	-	264m ²	51.6	19.5	Semi-Detached	Semi-compact
Al Rasheed Pilot Project	400	225	40.25	17.8	Semi-Detached	Semi-compact
New Deims	1233	200	64.5	32	Semi-Detached	Semi-compact
El Shabyia	1048	252 - 290 300- 340	91	30	Semi-Detached	Semi-compact
Al Iskan Project	200	240	38.4	16	Semi-Detached	compact
Elthora hara 72	1818	200	30	15	Semi-Detached	Scattered

Sustainable building materials and construction techniques

Researches revealed that building materials were the most important factor in the process of providing housing. Generally, it is very difficult to construct permanent structure with affordable and sustainable building materials. Most local materials e.g. mud is cheap but not permeant. The challenge is to use affordable material that ensure the stability of construction.

UNESCO used compressed stabilized earth block technology to implement El Haj Yousif School in the Khartoum area, a practical way of demonstrating the potential of earth as a viable and desirable construction material. UNESCO published handbooks about

Compressed Stabilized Earth Block Manufacture and Roofing Systems (Adam 2001) to address small contractors, and government staff or government agencies concerned with low-cost housing schemes. The handbook includes information on the different soil types in Sudan and the materials used in the manufacture of compressed stabilized earth building blocks, the various production stages which include soil preparation prior to stabilization, block-making equipment for forming the blocks, and curing. Also, it describes properties of mortars as well as plastering and rendering techniques for block wall surfaces. Finally, it describes how to estimate the unit production cost and the socio-economic aspects. The usage of compressed stabilized earth blocks was found to be very cost effective by Sudanese standards. The total savings made, in cost per square meter, were approximately 40%. Reduction of the cost of blocks was approximately 70% and of the roofing sheets 48%. The research findings of El Haj Yousif prototype model school were used to launch a program to construct 800 houses using local building materials and building techniques developed while constructing the prototype.

-After twenty years the production and construction with Stabilized Soil Blocks (SSB) has been applied in UN Habitat projects which produced a significant community impact, mobilizing an enormous number of trainees, especially unemployed youth, for whom the work has the value of generating income and improving living conditions. -In first resettlement project- New Deims houses were built with sustainable traditional materials and applied indigenous knowledge and techniques in construction of houses which are affordable and environmentally friendly as walls were built with jaloos (i.e. rammed earth or cob) and houses were roofed with timber. The construction of houses was carried out by the inhabitants themselves helping each other's -public participation- without intervention of the housing authorities. The inhabitants were advised to collect all wood work, wooden beams and the like from their demolished houses, and to use them in their new houses, so that the building materials were recycled. Unfortunately, the houses were un-durable and couldn't resist climatic conditions e.g. rains and storms. In the following low-cost housing projects implemented by the public sector, design, construction and distribution of the houses were undertaken by the public authorities. In El Shabyia project, the authorities used more durable building materials so that houses were constructed with plain concrete foundations and cement block walls but roofed with asbestos corrugated sheets which was found to be unsafe for health (WHO 2011). More elaborated building materials and technologies were used in Al Iskan Project. The houses were constructed with grade beam of concrete in the foundation and load bearing walls with burned bricks. concrete slabs were used for roofs for the first time in housing projects. In spite of the fact that concrete slabs are more expensive than traditional local types of roofs (corrugated iron sheets or timber) but they are more durable and can resist climatic conditions, therefore increase the life span of the houses.

-The first construction technologies used in The State Fund projects were sustainable local traditional materials such as green bricks which has a small ecological impact, afterwards they used materials produced with imported technologies such as cement blocks. Therefore, in Elthora hara 72, the houses were constructed with strip foundations made of stone and cement block walls, roofed with concrete. The planning and design of the core units are prepared by Ministry of Physical Planning and The Fund handles construction and distribution of houses. It is noticeable that Mass production of house units by the fund contributed to the development of the building industry, by establishment and support of on-site factories for building materials manufacturing and provided employment opportunities for local workers from nearby areas .The important question is: In spite of the availability of multiple different sustainable construction materials which are used across the country with smaller ecological impacts than imported materials why the State Fund did not use them in construction of housing projects. One popular example is the stabilized soil blocks which enable zero consumption of firewood and structural timber, and 60%decrease in water usage. they are used in building houses for refugees in Darfur because they have many advantages such as :30% more affordable than fired brick and faster to build. It is chosen among ten good practices of sustainable construction materials world-wide (UN Habitat 2012).

Regarding sanitation systems, Traditional Pit Latrine is the cheapest and most commonly used sanitation systems in popular neighborhoods. It is generally, located as far as possible from the living areas at the corner of the plot and includes:

--A cesspool with a diameter of 1.50 m a depth of 10-30m.
--A 1.5-1.8 high walls without roof to provide privacy.

-After considering socio-economic aspects, soil constrains and economic constrains, the Low- Cost Study (1984) proposed three low-cost sanitation systems:

- Improved privy with a ventilated tank. It is similar to the traditional pit latrine adding a ventilation system for odour exhaust and catching insects, and a roof.

- privy with a set-off and ventilated tank. It is similar to the first option with two tanks set-off in relation to the seats. The first tank is used until it is full after one year then the other tank becomes in use.

- Agua privy with a direct fall. The effluent is channeled to an absorption field after settling and pre-treatment. It uses weather conditions instead of the purifying power of the soil. The Low- Cost Study (2007) proposed the improved aqua-privy with shared cesspool. Every two houses share one soak-away pit located outside of the plots (see figure () and figure ()).

-The UN Habitat project introduced a pilot low -cost sewage waste and water treatment system to serve a considerable number of the urban poor. Fortunately, the project provided training for masons and specialists in construction, guiding them on how to make slabs

for pit latrines that use less material, particularly cement and iron. The project succeeded to construct 500 public and private pit latrines,

Unlikely, all low-cost housing projects implemented by the public sector provided Traditional Pit Latrine without any improvements in building materials or technologies.

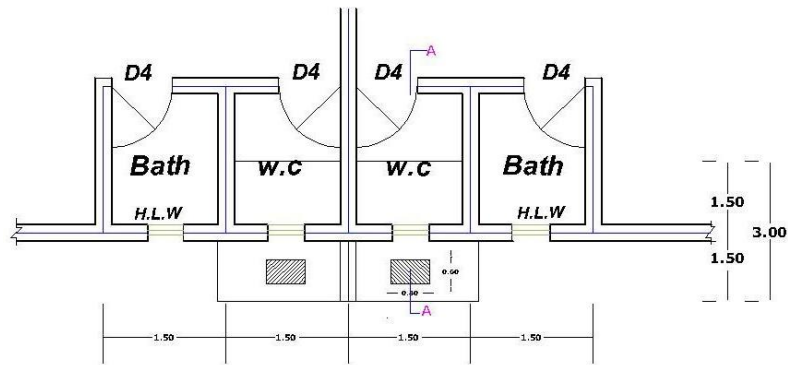


Figure (13) Plan of improved aqua-privy
Source: Building and Road Research Institute 2007

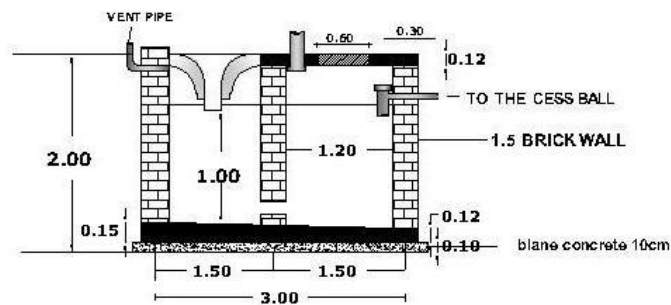


Figure (14) Section of improved aqua-privy
Source: Building and Road Research Institute 2007

CONCLUSION

A comprehensive housing approach should include not only economic, cultural, social and environmental but also institutional sustainability aspects. The challenge of creating a vibrant multicultural and diverse community require comprehensive plans to attain pre-defined goals. Moreover, the development of work places e.g. agricultural schemes near to new housing projects provides some job opportunities, creating local economic development, and linking these projects to their surrounding areas.

Research efforts on low-cost housing analyzed the housing problem in Sudan in a comprehensive approach. The analysis included institutional and financial context, design of pilot schemes, sanitation systems, roofing systems, earth construction techniques, production of building materials (burned bricks, Lime and plaster).

On the contrary, governmental housing policy for the poor people in Sudan has adopted a separate approach that dealing with housing problem isolated from other development issues, and ignoring the social, cultural, environmental and economic aspects of housing.

Although the first resettlement project- New Deims implemented after a comprehensive social survey was carried out. It covered cultural values, norms and traditions of the inhabitants as well as the life styles and behaviour, so that the proposed design of the core-unit was satisfactory for the occupants. The construction of the houses was made by the inhabitants themselves. Afterwards, in the following projects the inhabitants were excluded from the process of the design and the construction of the houses, their contribution started after settling in the neighbourhoods and their participation limited to provision of social services e.g. schools, mosques, health centres, etc. according to their needs.

Regarding the built area, as the size of housing projects enlarged (e.g. Elthora hara 72) the size of the built unit decreased, so as to serve a large amount of poor families. The reduction of the built unit makes it inefficient since most of poor families have large family size. Former projects (New Deims, Al Iskan Project and El Shabya) provided one or two proto-types of core-units for low-income

families only but new projects of The State Fund provides more options of affordable housing across different income levels to offer housing to families with varying needs and abilities. In general, the utilization of compressed stabilized earth blocks as sustainable building materials can provide a great number of advantages, especially to the Sudanese building industry. A maximum cost reduction could be obtained with optimum utilization of labor, materials and equipment as chief production factors. Standardization is an important principle in rationalization and requires that the dwelling unit should be built of standardized components. This can apply to dimensions, materials used, composition of materials, characteristics etc. This will make mass production of housing possible thus reducing cost per housing unit.

However, some socio-economic constraints may prevent or delay the wide adoption of compressed stabilised earth blocks as building material especially in low-cost housing programmes regarding Acceptance and Applications, as the small-scale production of compressed stabilised earth blocks is much more labour intensive than that of other similar building materials such as fired clay bricks or concrete blocks. It is important to find methods to modify the existing construction types and also to seek suitable alternatives for them at an acceptable cost.

The experience of Sudan in providing built houses for low-income families is not financially and technically appropriate. Still there is a need for more incentives for the private sector to invest in construction of low-cost housing under the supervision of the public authorities and within the framework of sustainable housing, and new affordable financial mechanisms to support the low level of construction by low interest loans. Moreover, there are possibilities of application of different sustainable technologies such as: ecological retrofitting, renewable energy and forms of saving water which are essential in providing sustainable housing.

If the public authority is sincerely interested to develop integrated approach for sustainable housing, its decision and actions would be flexible, adaptable and creative. Production of sustainable housing need to be addressed in three different levels: At policy/authority level to help local authorities to formulate housing policies to match sustainable development goals and objectives, at community level to enable community representative to participate in the project planning and decision making and at family level to enable the inhabitants to upgrade their housing according to their individual needs and capacity.

introduction paper adjustment

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