

**EVALUATION OF ALTERNATIVE CONSTRUCTION  
TECHNOLOGIES IN THE DELIVERY OF AFFORDABLE  
HOUSING -  
A CASE STUDY OF NAIROBI COUNTY**

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**Evaluation of Alternative Construction Technologies in the Delivery of  
Affordable Housing - A Case Study of Nairobi County**

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**A thesis submitted in partial fulfillment for the award of the degree of Master of  
Construction Project Management in Jomo Kenyatta University of Agriculture  
and Technology**

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## DECLARATION

This study is my original work and has not been presented for a degree or any other award in any other university.

Signature..... Date.....

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This thesis has been submitted for examination with our approval as the university supervisors.

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## **DEDICATION**

This thesis is dedicated to first and foremost The Almighty God, who sustained me through it all. In addition it is dedicated to my family especially my wife Mary and children as a challenge that learning is a continuous process. Its success is a result of their unwavering support, both logistical and emotional.

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## **LIST OF ABBREVIATIONS**

<b>ABMT</b>	-	Appropriate Building Materials and Technologies
<b>AAK</b>	-	Architectural Association of Kenya
<b>ACTs</b>	-	Alternative Construction Technologies
<b>BNG</b>	-	Breaking New Ground
<b>CBR</b>	-	Construction Business Review
<b>CIA</b>	-	Central Intelligence Agency
<b>EPS</b>	-	Expanded Polystyrene
<b>EHG</b>	-	Economic Housing Group
<b>FHWA</b>	-	Federal Highway Administration
<b>GIFA</b>	-	Gross Internal Floor Area
<b>GoK</b>	-	Government of Kenya
<b>GTZ</b>	-	German Technical Cooperation ( <i>Gesellschaft für Technische Zusammenarbeit (GTZ)</i> ),
<b>GDP</b>	-	Gross Domestic Product
<b>HABRI</b>	-	Housing and Building Research Institute
<b>HCC</b>	-	Hybrid Concrete Construction
<b>ICESCR</b>	-	International Covenant on Economic, Social and Cultural Rights
<b>ICF</b>	-	Insulating Concrete Formwork

<b>ISSBs</b>	-	Interlocking Stabilized Soil Blocks
<b>JIT</b>	-	Just In Time
<b>KBS</b>	-	Kenya Building Society
<b>LSF</b>	-	Light Steel Frame Building Systems
<b>MMC</b>	-	Modern Methods of Construction
<b>MSE</b>	-	Mechanically Stabilized Earth
<b>NACOSTI</b>	-	National Commission of Science, Technology and Innovation
<b>NHC</b>	-	National Housing Corporation
<b>PMC</b>	-	Permanent Modular Construction
<b>PMI</b>	-	Project Management Institute
<b>PRMC</b>	-	Pumping Ready Mix Concrete
<b>RSJs</b>	-	Rolled Steel Joist
<b>SIP's</b>	-	Structurally Insulated Panels
<b>SPSS</b>	-	Statistical Package for Social Sciences
<b>TQM</b>	-	Total Quality Management
<b>UK</b>	-	United Kingdom
<b>UN</b>	-	United Nation
<b>USAID</b>	-	United States Agency for International Development
<b>USA</b>	-	United States of America
<b>UN-HABITAT-</b>		United Nations Human Settlements Programme

## DEFINITION OF OPERATIONAL TERMS

<b>Affordable housing</b>	Low cost / cheap housing
<b>Alternative Construction Technologies</b>	Non-conventional, modified or manufactured building materials / products - not necessarily environmental friendly
<b>Appropriate Building Materials and Technologies</b>	Suitable, natural or modified or manufactured construction materials / products - environmental friendly
<b>Building owner</b>	Individual who owns the building
<b>Building users</b>	Individuals who occupy or utilizes buildings
<b>Consultants</b>	Professionals who oversaw the implementation of the buildings
<b>Contractors</b>	Firms which did the actual erections of the buildings
<b>Developers</b>	The entity that provided land and funds to construct the buildings
<b>Experience with ACTs</b>	Period of working with and using ACTs
<b>Evaluation</b>	Assessing and appraising weaknesses and strengths of ACTs
<b>Knowledge</b>	Awareness of ACTs as building materials
<b>Modern Methods</b>	New methods of construction which are non convectional stone and mortar
<b>Performance</b>	Quality and physical characteristics
<b>Post occupancy</b>	When buildings have been occupied and in use



## **ABSTRACT**

This study set out to evaluate the performance of houses built using alternative construction technologies (ACTs) in Kenya. ACTs have in the past been promoted as an approach to reduction of construction cost leading to affordable housing. The study objectives were to: assess the characteristics, quality and performance of building elements built with ACTs; establish the social and economic impacts of the ACTs; and gauge the adoption rate of ACTs by developers, consultants and contractors. The research design was cross - sectional case study of five projects and buildings erected using ACTs within Nairobi County. The study employed post occupancy evaluation approach and relied on both quantitative and qualitative research methods. Both primary and secondary data were collected from developers, consultants and contractors through checklists, questionnaires, interviews and visual observations. Descriptive statistics was used to analyze the data. They described functional performance, lessons learned, adoption rate, social and economic impacts of ACTs. The results showed that the costs of the raw materials as high and make the adoption rate of the ACTs in Kenya low. Additionally, the advantages of ACTs included savings on speed of construction, waste reduction, labour reduction, efficiency and quality production. These impacts are however not aggressively propagated or articulated to the general public. This lack of effective dissemination has led to constrained knowledge on the social and economical benefits of ACTs curtailing satisfactory solutions to affordable housing. Thus, the researcher recommends that the Sensitizing the public through open forums, printed pamphlets, show houses, physical demonstrations of construction speeds, active public participation and other promotion methods; of the many advantages of ACTs. These findings of the study should be applied in future projects as a way to promote adoption of the ACTs.

**Keywords:** Alternative, Construction, Economics, Performance, Technologies

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background to the Problem**

Worldwide, towns and cities have grown at a rapid rate and the dramatic problems linked to this include huge shelter needs; emergence of squatter settlements and slums; and deficient infrastructure in many low-income settlements (UN-Habitat, 2004). In the Kenyan context, population increase has been tremendous over the years. According to the National Council for Population and Development; Sessional Paper No. 3, Kenya's population was enumerated at 38.6 million in 2009 (Republic of Kenya, 2012). It also showed that the population was increasing by about one million people per year between 1999 and 2009 as reflected by the recorded increase from 28.7 million in 1999 to 38.6 million in 2009 (ibid). At the growth rate of 2.9 per cent per annum, the population is expected to double to about 77 million in 2030 (ibid). This leads to high demand for the low, middle and high income housing in most urban centres in the country.

The building and construction industry occupies a central place in the economy of Kenya because of its importance as a producer of capital goods and employment. By 2007, both the government and the private sector in Kenya produced an average of 35,000 housing units per year (Republic of Kenya, 2007). As per the National Development Plan (NDP), this was far below the yearly requirement of 150,000 units.

Ministry of Housing Strategic Plan of 2008 to 2013 decried the low level of investment in the housing sector. This was attributed to the lack of an enabling environment. According to the UN-Habitat report on the Africa's affordable housing, the major reason why housing is unaffordable for the urban poor majority in Africa is due to the high costs of both land and building materials (UN-Habitat, 2012). The later typically constitute the single largest input into the construction of housing, and can account for up to 80 per cent of the total value of a simple domestic house (ibid).

The building costs and rate at which the construction industry is able to provide housing are important key factors. Other contributing factors to low-income housing delivery include resources, delivery techniques, manpower, regulations, policy framework and negative stereotype. In Africa, due to the high construction costs of housing, approximately 75 per cent of low-income and middle-income earners have no access to adequate housing of reasonable standard of sanitation (Elias & Omojola, 2015). As a result, 60 percent of urban residents live in slums and unplanned settlements (UN-Habitat, 2012).

Over time, alternative methods of construction and new technologies have evolved. Nevertheless, despite the need to maintain business relevance in the long term, innovation is not sufficiently adopted as a strategic goal by most construction organizations (Dulaimi et al., 2002). The practice is to launch new building materials and innovations in a public fair; to market the alternative technology and use in real building, but no formal evaluation after use is ever done thereafter.

The lack of data on post occupancy evaluation brings in the uncertainty as to whether the alternative construction technologies (ACTs) actually address the problem of delivering affordable housing. The ACTs objectivity in choice is therefore not tangible. Hence lessons learnt in past housing projects lack in future projects. Toole et al, (2013) proposed a “maturity model” that allows construction organizations to evaluate and improve the innovation capabilities but there is no documentation of its application.

The use of appropriate building materials in the provision of affordable housing in Kenya was initiated in the 70s, but little has changed in the actual practice of the construction sector (Syagga, 1993). Kenyans have been slow to adopt ACTs and have a strong bias towards traditional materials and techniques, specifically stone and cement (Noppen, 2012). This could be attributed to the alternative technologies not really being appropriate or simple ignorance. The alternative technologies costs could also have contributed to the low uptake and adoption pace.

The uptake of alternative methods of construction has also been hampered by lack of awareness of the different methods available in the market. Efforts to revise the Kenyan Building Code to include these alternative methods emerged in the 1990s but have not been fully acknowledged (Okumu, 2014). According to the Architectural Association of Kenya (AAK) October, 2015 newsletter, the new Kenyan Building Code incorporating alternative technologies has now been redrafted and is set to be launched soon (AAK, 2015).

The City planning department of Nairobi County has recorded a few instances where different types of alternative building materials and methods, such as expanded polystyrene (EPS) panels and waffle precast slabs; have been relied on in delivery of housing. These includes residential houses in Balozi estate along Thika road, Nairobi and Ongata Rongai, Kajiado County (2010); Silver springs hotel extension in Nairobi (2007); partitioning and remodeling of Chinese Restaurant at Adams Arcade; Ngong road; Nairobi (2011) and Ruai police housing scheme (2013) among others.

The ultimate goal and relevance of ACTs is delivery of affordable housing. This should be through increased speed of construction, reduced material wastage, reduced materials costs and reduced labour costs. The economic advantages and sensitization of the ACTs has not been used to enhance adoption and acceptability. This has resulted in the low uptake of ACTs yet the acute shortage of affordable housing still persists. The stereotype mind set-up that conventionally built stone and mortar buildings as the only way to get decent buildings should be eradicated. To achieve this, the ideal position would be to carry out post occupancy evaluation on all buildings where the ACTs have been used. The achieved knowledge and findings should then be injected into future projects.

## **1.2 Statement of the Problem**

The adoption and uptake of ACTs in the construction industry in Kenya is quite low. The challenges and performance of these technologies remain vague and are not clearly understood. The standard procedure and requirement at the completion of building construction projects is to provide as built drawings and final costs of the

developments. There are few and scanty documentary records to proof that post occupancy evaluations has been carried out on buildings built using ACTs. The consequences of this state of affair are that mistakes are repeated, savings are not realized and a persistence of low rate of housing delivery. The experiences and lessons learnt are never utilized in other projects. The lack of post occupancy performance evaluations has also resulted in lack of important data that is necessary in improving the rate of adoption and improvement of these alternative technologies.

Samuelson and Zeckhauser, (1988), in their paper on status quo alternative argued that, when clients are faced with new alternatives, the decision maker often continues with the current or previous decision made. However, ways to encourage use of alternative techniques and overcome this fear has not been discussed or addressed. This gap needs to be addressed to enhance usage of alternatives.

There have been many attempts to classify different types of innovations. For instance Henderson and Clark (1990) classified innovation as incremental, modular, architectural and radical depending on the degree of product/architectural knowledge required to implement. The most significant model for innovation-development process was proposed by Rogers (1995) comprising six phases, starting with the emergence of need, research, development, commercialization, adoption and diffusion and lastly consequence of acceptance or rejection. These models however did not provide performance evaluation guidelines of the innovations hence little or no feedback is obtained.

Contrary to common practice in building, innovations are both initiated and developed by the supply side, rather than being the contractors' solution to a specific project requirement. This set-up slows down adoption and acceptability of alternatives and innovations. The users, contractors and clients would rarely use a product unless it is providing a solution or savings. Hartmann *et al*, (2008) in a study of the innovation adoption process and behaviour of public clients in The Netherlands, encouraged further research addressing the complex decision environment of construction clients.

An ideal position would be that a post occupancy evaluation is carried out on each development project where ACTs have been adopted. This evaluation would show the economic benefits resulting from the use of these technologies. It would establish affordability and housing delivery aspects. According to Toole et al. (2013), innovation should cause individuals to view things differently, and results in competitive advantage, increased value for the client and benefit to stakeholders. These improvements are often seen in terms of the value they create for a wide range of stakeholders, including clients, users, manufacturers, regulators, and providers (Blayse & Manley, 2004).

The purpose of the study was to assess post occupancy performance of ACTs in housing provision. Establish the physical and structural soundness of buildings erected using ACTs; establish economic benefits achieved; and finally establish impacts and challenges encountered. The data obtained will be utilized to improve ACTs uptake and enhance housing delivery.

### **1.3 Aim and Objectives**

The aim of this study is to evaluate the performance of ACTs in Nairobi County, Kenya. The specific objectives are to:

1. Assess the characteristics, quality and performance of buildings elements erected with ACTs.
2. Evaluate the economic impacts of ACTs in housing provision.
3. Establish the adoption rate of ACTs by developers, consultants and contractors.

### **1.3 Research Questions**

1. How have facilities constructed using ACTs performed in terms of weathering, defects, durability and aesthetics?
2. What is the user's satisfaction level on the alternative technologies?

3. Are there lessons learnt by consultants from buildings built using the alternative technologies?
4. What are the economic benefits of using ACTs by developers and contractors?
5. How can the ACTs uptakes be improved?

### **1.5 Justification of the Study**

The UN Agenda 21; on environment and development, advocates and promotes sustainable settlement developments. The Constitution of Kenya, 2010 propagates attainment of adequate, affordable housing and reasonable standard of sanitation as a fundamental right to the Kenyan citizens. The high population growth witnessed in Kenya in recent time's calls for the government institutions mandated with facilitation of housing provision to be more proactive in the realization of affordable housing. Attempts in meeting housing demand by citizens both in the urban and rural areas have witnessed enormous use of conventional building materials. This mode of construction not only takes long periods but also depletes the scarce natural resources. Alternative construction materials and new technologies have over the recent years been introduced in the Kenyan market to try and mitigate this phenomenon.

This study evaluated the performance of the ACTs in use. It appraised the physical characteristics to determine the weaknesses and strengths of the ACTs. The study assessed the users' knowledge and satisfaction level on ACTs. It also assessed the economic benefits realized by the developers. It interrogated the uptake of buildings erected using alternative materials. The study evaluated the ACTs as agents of delivering affordable housing. It also evaluated the ACTs usage agility and wastage factor during construction.

The study evaluated the delivery speeds of the houses and the resultant benefits. The labour outputs were also assessed and accrued cost savings articulated. The study

noted the constraints and lessons learnt by the projects teams. It also examined the general public perceptions on use of ACTs.

### **1.6 Significance of Study**

The observed findings will address the current unsubstantiated failure fears and other structural incompetence's towards ACTs. The findings of the evaluation will also be injected into future projects and offer ways to promote and propagate the use of the ACTs for housing provision.

The obtained evaluation data on economic benefits will be used to lower housing construction costs hence making housing provision affordable. Data on labour output will also be used to determine the end cost of future housing projects. Utilizing the delivery speeds data as an advantage will result in more housing unit production by the developers. This will reduce housing deficit. Finally the study data will assist in proposing guidelines on process improvement of ACTs with the aim of achieving affordable housing delivery.

### **1.7 Scope of the Study**

The study was carried out within Nairobi County in Kenya. The region was selected for the study because it has the highest need of affordable housing; which is a resultant of rural urban migration. The region also has also the largest number of buildings where alternative building materials and technologies had been used. The study was modeled on the post occupancy evaluation of housing projects and buildings erected using ACTs. The scope was restricted to residential housing buildings only.

The information sought related mainly to functionality performance of the completed buildings, attained economical benefits and lessons learned by the projects teams. The study also sought information related to acceptability of ACTs as a means of providing affordable housing.

The study used cross sectional design to collect the data. The data collection process



was by way of structured questionnaires, checklists, face to face interviews, discussions, documentary search and secondary data.

Participants were the building owners and users, building caretakers, construction workers; consultants; contractors; county government representatives and key informants; and personal visual observations. These were the policy makers and implementers on the one hand and the project implementation beneficiaries on the other hand. Apart from discussions, data collection involved visiting manufacturing firms specializing in production of alternative building materials with bias on three dimension (3D) wall and floor panels'.

The region was appropriate for the study since it had adequate sample. The study was aimed at exposing facts and information related to ACTs competence and reliability in providing affordable housing. The study also explored the ACTs to determine their social and economic benefits stakeholders. The available data will help un-housed population come up with critical conclusions on ACTs uptake and acceptability.

### **1.8 Limitation of the Study**

A major limitation of the study was the lack of up dated records by the building users and maintenance crews where various ACTs had been used. This was mitigated by carrying out physical inspections and noting down in defects checklists. Lack of access to information was mainly due to the current wave of terrorism as any inquiries are often considered with suspicion. This was mitigated through oral interviews and agreement with interviewee to integrity non disclosures of discrete information and not taking photographs by the researcher.

Another key limitation to this study was the building owner's refusal to disclose all their financial obligations and savings achieved during construction. This was mitigated through the use of percentage relationships and ratios. The actual amounts of cost savings; in figures, were not used.

There are only a few recent buildings where ACTs have been fully utilized. This limited the study to the few available cases. Many of the ACTs in the country have

not been tested locally for long hence less exposure in their use. The study used secondary data where the ACTs have been used extensively to fill in the gaps.

The other limitation was that the time required to carry out the study was limited to the academic calendar period and restrictions. This was mitigated by putting in more hours towards the study and getting research assistants to collect data questionnaires from the various respondents.

### **1.9 Study Organization**

The study comprise of five chapters and the preliminary pages. The latter includes acknowledgements, dedication, figures, abbreviations, tables and many more.

Chapter one includes introduction to the study, background of the study, statement of the problem, aim and objectives of the study with study questions, justification of the study, scope and limitations of the study, and the study organization.

Chapter two incorporates literature review of past studies related to the alternative building methods and materials. It includes highlights of key concepts of alternative construction methods, building materials and technologies in Kenya as well as the conceptual framework.

Chapter three discusses the methodology of carrying out the study and data collection. It comprised an introduction of the study, study design and description of the study area. It further incorporated the types of data, the data collection design, population size, sampling frame, sample size, data collection methods and tools, as well as ways of data analysis and presentation.

Chapter four comprises of data analysis, presentation and discussion. It also has an in- depth grasp of the outcome of the study.

Chapter five comprises of the conclusions and recommendations of the study. This chapter in addition provides suggestions on areas for further research for policy makers and / or implementers and the academia.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Chapter one discussed the lack of post occupancy evaluation data and low uptake of alternative construction technologies. This chapter presents the related literature reviewed and uncovers the knowledge gap in the literature. The chapter is organized around eight major topics namely; construction technologies and adoption rates, construction innovation, modern methods of construction, variety of alternative construction materials in Kenya, prefabrication, modular construction methods and three dimension (3D) panel systems. Eventually, it will be shown that no records of prior evaluation data of alternative construction technologies were found in the literature reviewed.

##### **2.1.1 Construction Technologies and Adoption rates**

Around the world, governments are demanding that timber not be used in building construction, materials that create pollutants be curtailed and that buildings adhere to new requirements to save energy. In mitigation, alternative construction methods have been acknowledged and accepted in the developed world as a means of providing housing (UN-Habitat, 2004). Around the globe, the world is now ready to adopt and utilize alternative building systems and methods to reduce the deficit of housing demanded by the rising population (UN-Habitat, 2011). The urge is more critical in Africa where the demand for shelter is extremely high. This has been demonstrated in Lagos, Nigeria and Johannesburg, South Africa where expanded polystyrene “space frame technology” is widely used to provide housing in settlement schemes in a World Bank-supported Lagos Slum Upgrading Programme dubbed “provision of one million housing units for low income households in Lagos” which was instituted in 1999 and South Africa’s new national housing policy dubbed "Breaking New Ground" (BNG) used to accelerate the delivery of quality housing (UN-Habitat, 2010).

According to Edge (2002), home buyers in the United Kingdom (U.K) are not resistant to new forms of offsite construction techniques, but are partially resistant to new building materials. He also asserts that there is a strong niche market for innovative forms of housing which are potentially affordable, sustainable and flexible. Using alternative construction methods result in potential cost savings due to shortened project schedules, less on-site work, improved labour productivity, and more efficient equipment utilization (Neale, 1993; Gibb, 2000).

A global initiative to promote sustainability in building construction has resulted in a myriad of choices in construction products and technologies for homebuilders and homeowners. However, limited information is available to enable decision-making for optimal integration of these technologies based on building performance requirements and individual priorities (Nahmens et al, (2013). While many contractors, architects, and homeowners today are concerned about the environment and interested in sustainable construction technologies, the perceived higher initial cost of innovative construction products and methods, and a lack of life cycle cost and benefit data present significant barriers in the implementation of such techniques (ibid).

Seeking to include all the benefits of the alternative technologies may enhance the performance of the many different building systems. Using a prioritization scheme, one can begin this sizeable effort by focusing on the building components that have the most impact on cost and time consumption. Nahmens (2013) asserts that such an approach would entail focusing on the large construction elements that constitute a building for instance the walling system. In addition, the implementation of innovative technologies poses greater risks and potential negative impacts for the contractors in terms of technological uncertainty, construction costs and schedule delays. Therefore, there is a great need to nurture “innovator” and “early adopter” homebuilders through the learning curves and decision-making process during the trial stages of the adoption process (Nahmens et al, 2013). This would improve, stimulate and shorten the adoption curve by the contractors and the building owners.

In Kenya, according to Sessional Paper No.3, (2004), the annual demand for housing in urban areas is 150,000 units while 300,000 units need to be improved in the rural areas (Republic of Kenya, 2004). The use of alternative methods of construction, materials and technologies is promising in Kenya to help to reduce this deficit. The major barrier is adaptability and market acceptance (Ivory, 2005). Most building deliveries tend to stick to stones and cement, and there is not a wide spread use of alternative building materials. A case study on the role of the client in innovation, Ivory, (2005) demonstrated that a strong client focus could even be harmful for innovating companies if clients' demands are limiting.

## **2.2 Construction Innovations**

In a paper on construction innovation covering key factors driving or hindering innovation in construction, Blayse and Manley (2004), identified the key role of clients in promoting innovation as one of the most prominent themes in construction innovation. Innovation incompetent clients are, for example, those clients who are risk averse and constrain innovation activity (Manley, 2006). He further argued that the innovation competence of clients is a major determinant of supplier-led innovation, such as the process innovation of prefabrication as exemplified by Ivory, (2005). This therefore, acknowledges challenges by clients' precognition, beliefs and existing cognitive rules-of-thumb and, thus, provides opportunities for identifying barriers to overcoming inertia in client decision making.

Managing a construction project typically needs a balance between the competing project constraints including, however, not limited to: scope, quality, schedule, budget, resources, and risk (PMI, 2008). In real estate development, developers always work to tighter schedules. Whether they can sell their products on time and repay loans before deadline depends on the project being completed on time and within the constraints. Project success relies heavily on the timely transfer of information between owners, project managers, general contractors, trade contractors, city authorities, inspectors, designers, and lawyers (Rojas & Songer, 1999). Therefore the time aspects in projects should be evaluated and a cost

component attached to it. These costs would act as a guide and assist in advocacy on the alternative materials usage.

McCoy, (2009) argued that US construction industry is often characterized as traditional and resistant to adoption of innovative construction products and techniques. Several studies in the literature and practice identified major impediments to homebuilding technology adoption into the housing market such as cyclical nature of construction, dominance of small firms, housing system compatibility issues, heavy reliance on subcontractors, inadequacy of labour skill set, poor communication between homebuilders and manufactures, diverse building codes, and lack of access to information about new products and practices (NAHB, 2002); (Toole, 1998); (Koebel, 2008); (Dawkins and Koebel, 2010).

In Kenya, the construction industry is no different, middle level residential housing output consists of single family and multi dwelling structures that are traditionally made of stone and mortar. Toole, (1998) found a relationship between the amount and access to sources of information about new products and the successful adoption of technology innovations wanting. Most builders, including large production builders, have limited opportunities to test innovative products or processes (Koebel, 2008). Therefore, efforts like the one described in this study are imperative to the goal of accelerating adoption of best building technologies and practices.

### **2.3 Modern Methods of Construction**

Due to longstanding criticism about the construction industry's poor performance, Modern Methods of Construction (MMC) are receiving increasing attention worldwide in regards to costs, adoption and effectiveness. The operation definition term MMC collects terms such as alternative construction technologies, offsite production, offsite manufacturing, prefabrication, and industrialized building. Various writers have written regarding the performances of MMC constructions worldwide, for instant in the European Union, Nadim and Goulding, (2011), in the United Kingdom Gibb and Isack, (2003); Goodier and Gibb, (2007); Nadim and Goulding, (2010) and in Australia Blismas and Wakefield, (2009). They all are

generally in agreement that MMC are efficient in terms of increase in construction speeds, lessened project schedules, reduced site wastage, improved labour productivity, and ultimately allow for better site management and equipment utilization.

The writers adequately addressed the many economic benefits of MMCs achieved during the construction period. However, post occupancy evaluations on the performance of the structures built using the MMCs have not been done. This post occupancy evaluation of the MMCs would assist revealing their real qualities and characteristics.

Considering that building materials account for about 60 per cent of the total construction costs, Appropriate Building Materials and Technologies (ABMT) and alternative construction technologies with the many varieties could be instrumental in lowering construction costs in Kenya, owing to the fact that these new technologies can reduce materials cost by up to 50 per cent.

Firstly, there are the prefabricated components that are simple building blocks that usually involve a single building trade. Examples includes timber frame panels; precast panels; steel frame panels; Structurally Insulated Panels (SIP's); building envelope/façade systems; composite panels; precast cladding; Light Steel Frame Building Systems (LSF); pre-cast structural elements; Insulating Concrete Formwork (ICF); and tunnel form construction (Hartley and Blagden, 2007).

Secondly are the steel prefabricated structures that are viewed as being modern. It is used in flooring, walling and roofing materials which are easily prefabricated in workshops and off sites then transported to construction sites. These materials are easily assembled and installed on site. The main handicap with these prefabrication methods of construction is transportation due to long spans and poor road infrastructures (SKAT, 2012).

Thirdly the concrete industry embraces innovation and Modern Methods of Construction (MMC) by offering concrete solutions which can be used to reduce

construction time and promote sustainable development, as well as offering cost savings. Precast concrete industry has adopted and used various products in promoting and providing housing. These alternative products include concrete roofing tiles, waffle slabs, pre-stressed floor slabs, precast concrete wall panels and many more.

Fourthly an emerging construction technology that is receiving global acclamation is the Pumping Ready Mix Concrete or PRMC. The Mix is computer controlled, weighing, setting the proportions and mixing precisely to the specific requirements. Thorough concrete examination is carried out before the ready mixed concrete is transported to the site. It also eliminates waste at the site. The PRMC technique takes less time and the fact that it is much easier to move around the site, makes it much cheaper and significantly reduces project finish time by up to 25 percent (Al- Araidia et al, 2012).

Syverson, (2007) claimed that in the first world, over ninety percent of the construction projects apply the Ready Mix Concrete. Expanse high rises to neighborhood sidewalks are constructed using Ready Mix Concrete. This approach offers proper amount of cement mixing with other necessary materials. The process protects the developer or a contractor from being over charged by aggregate and sand suppliers. Fifthly are the manufactured materials that offer another avenue of alternative construction methods. Such materials include Three Dimension Expanded Polystyrene panels (EPS) integrated with galvanized steel trusses; steel mesh clipped or welded to the protruding points of the trusses and then finished with coat of cement plaster. This technology implements the 3D- Panel Systems and is a relatively new innovative approach in Kenya and in many parts of Africa. According to Journal of Material Science, (2006) this technique is favoured as the most suitable approach for mass housing construction worldwide because of its versatility. Building panels can be delivered to the site and erected utilizing unskilled labor alone. This is a technique that is ideal for unsuitable soil conditions; physically, the joined panels create structures which are monolithic in nature providing superior strength to the walls, which prevents cracking. Plastering with a 14 mpa cement



plaster leaves the wall four times stronger than the conventional stone wall. This material exhibits excellent thermal insulating properties, its water proof and bulletproof (NHC, 2011).



**Figure 2.1: Foundation and substructure works**

Source: The Star Monday, December 9, 2013



**Figure 1.2: NHC workers construct a house with EPS panels**

Source: The Star Monday, December 9, 2013

## **2.4 Variety of alternative construction materials in Kenya**

Some of the popular alternative building materials include precast concrete panels, hybrid concrete, interlocking stabilized blocks, rammed earth, steel and timber.

### **2.4.1 Pre-Cast Concrete**

Pre-cast panel building process was invented and pioneered in Liverpool, England, in 1905 by John Alexander Brodie a city engineer (Jain, 2014). It was later adopted all over the world, particularly in Eastern Europe and the Scandinavia. There are many different types of precast concrete forming systems for architectural applications. These are different in size, function and cost (Qadir, 2014).

Precast concrete building components and site amenities are used architecturally as fireplace mantels, cladding, trim products, accessories, and curtain walls. Structural applications of precast concrete include foundations, beams, floors, walls, and other structural components. It is essential that each structural component be designed and tested to withstand both the tensile and compressive loads that the member will be subjected to over its lifespan (Poon, 2003). Precast concrete provides the manufacturers with the ability to produce a wide range of engineered earth retaining systems.

Precast architectural panels are also used to clad all or part of a building facade, free-standing walls, general retaining walls, soundproofing and security walls. Some of these walls can be of Pre-stressed concrete structural elements. Precast concrete products can withstand the most extreme weather conditions and will hold up for many decades of constant usage (Poon, 2003). Pre-stressed concrete panels can either be used horizontally and placed either inside the webbing of Rolled Steel Joist (RSJs) I-beam or in front of them. Alternatively panels can be cast into a concrete foundation and used as a cantilever retaining wall (Poon, 2003).

Precast concrete technology significantly reduces the need for formwork carpentry as re-useable metal forms can be specially made for use in the prefabrication yard. The

use of formwork, reinforcement and concrete is better controlled and wastage reduced. Close monitoring and better quality assurance of raw materials, together with the use of steel forms; produce finished products that are of a superior quality. The components and their detailing can also be standardized to reap economies of large-scale production (Low & Chan, 1996).

In summary, prefabrication technology therefore brings with it a host of benefits: improved quality with better quality controls, reduction in wastage, less labour-intensive operations, faster production of building components and economies of large-scale production (Low & Chan, 1996). However, data on the performance of these structures built using the pre-casts materials lacks. Post occupancy evaluations would be relevant in bringing to the fore the physical, social and economic benefits after the buildings are constructed and in use



**Figure 2.3: Precast concrete**

Source: The Little Green Book of Concrete (2008)



**Figure 2.4: Concrete House Construction in lightweight precast concrete wall panels.**

Source <http://www.litecretesystems.co.nz/concrete-house-in-one-day-you-better-believe-it.htm>

#### **2.4.2 Precast concrete and Hybrid concrete**

Hybrid concrete construction (HCC) comprises highly innovative combinations of *in situ* and precast concrete elements (Goodchild, 1995, 2001; Glass & Baiche, 2001; Barrett, 2003). HCC has been under-utilized and is a relatively new technological innovation for many firms (Arditi *et al*, 2000; Glass and Baiche, 2001; Goodchild, 2001). HCC aims to offer the benefits of using each individual element, hence compensating for individual component weaknesses. Goodchild, (1995) argues that *in situ* reinforced concrete frames are often regarded as the least expensive solution, whereas precast concrete solutions promote speed and high quality. Combined solutions therefore have the potential to provide greater speed, quality and overall economy.

HCC provides a high quality finished product, in terms of both aesthetics and function, as demonstrated by buildings using precast components (Freedman, 2001; Goodchild, 2001). It offers a wider range of benefits beyond traditional time, cost

and quality considerations. Essentially, best value buildings overall are more likely to enhance client satisfaction. The use of HCC was perceived as being unlikely to minimize cost (Arditi *et al*, 2000; Goodchild, 2001), hence the “minimizing construction cost” criterion is unlikely to influence its adoption. Gibb, (1999) argued that the use of prefabricated components, whilst reducing overall cost due to reductions in project time, will incur extra costs due to, for example, transportation, crane-age and factory overheads. He further suggested that the main cause of these extra costs was the failure to assess all the costs involved in traditional construction.

## **2.5 Management Techniques and Impacts**

### **2.5.1 Just in Time (JIT)**

In the JIT philosophy, raw materials are not stocked up. Instead, they are delivered in the right quantities, in the right condition, to the right place, and at the right time for production. JIT has proven to work well in the manufacturing sector (Lim and Low, 1992; Low & Chan, 1997).

Essential features of lean construction include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design of product and process, and the application of production control throughout the life of the product from design to delivery (Howell, 1999). In essence, lean construction emerges from the application of a new form of production management to construction. Nevertheless, the concept of lean production consists of a complex cocktail of ideas including continuous improvement, flattened organization structures, teamwork, the elimination of waste, efficient use of resources and co-operating supply chain management.

### **2.5.2 Total Quality Management (TQM)**

Green (1999) skeptically attributed the Japanese success to an imprecise mixture of Total Quality Management (TQM), JIT, team working and supply chain management. He went on to posit that the main argument in support of TQM is that it encourages employees to identify themselves as parts of a supply chain, which

comprises a sequence of relationships between suppliers and customers, and that this provides employees with a sense of self-esteem from serving the next person in the chain rather than having to derive satisfaction from the task itself (ibid).

In addition, lean production is continually advocated by universities and business schools that are increasingly dependent upon the business sector for funding (Green, 1999). Despite Green's (1999) reservations, examples could be shown to support the application of JIT in the construction industry. Tommelein and Li (1999), for example, argued that ready-mix concrete is a prototypical example of a just-in-time construction process. This is because ready-mix concrete is a perishable commodity, batched to specifications upon customer demand which makes just-in-time delivery necessary (ibid). In view of the significant variability in the cycle time for a truck, the batching plant will be idle at times when waiting for trucks to return for additional batching.

Tommelein and Li's (1999) findings suggest that a typical order lead time is three to four days before the day of the placement so that the plant has time to procure materials, reserve batching capacity, and mobilize drivers and trucks. The sooner the batching plant knows about an order, the more likely that, that order can be scheduled for delivery as requested.

The delivery of precast concrete components is very similar to the deliveries of ready-mix concrete from the batching plant to the site (ibid). The same batching and queues would happen if precast concrete components are not delivered to site just-in-time for installation. The writers only concentrate on the economic benefits of alternative materials procurement and placement during construction. The performance of the materials after application when the buildings are in use is left hanging. The aesthetics, defects, weathering and physical impacts are not addressed.

## **2.6 Innovative Material Technologies**

### **2.6.1 Interlocking Stabilized Soil Blocks**

According to UN Habitat, (2009), earthen construction has witnessed a renaissance in recent years due largely to economic & environmental concerns. Availability, low cost & eco-friendly nature of soil as a building material makes it an attractive alternative to conventional building methods. Stabilized soil blocks are uniform in texture. They need less mortar and can be dry-stacked. Uniformity speeds up the laying/building process and results in straighter walls.

While making compressed soil blocks is labour intensive, they can significantly reduce the costs involved in building a house, outbuildings, fences and garden walls (UN Habitat, 2009). The only cost involved in producing compressed soil blocks is the block press and the time invested by the builder. However if the soil at the building site consists of clay, caliches and silt, admixtures can be omitted. This process have not only been successfully adapted, but this technology has also expanded products and services to include special community re-development projects, incorporating environmental management with effective social and community sustainable modeling (ibid).



**Figure 2.5: Interlocking stabilized soil blocks and construction of low cost houses using blocks**

Source: <https://www.google.com/search?q=interlocking+stabilised+soil+blocks&biw>

The uptake of interlocking stabilized soil blocks however has been low. This can be attributed to negative stereotype that soil blocks produce poor quality housing (UN Habitat, 2009). The satisfaction level of users for such facilities is never carried out. The physical features such as weathering, defects and durability evaluation lacks. Hence this negativity is never addressed. This could ideally be addressed through post occupancy evaluation of buildings built using the soil blocks.

### **2.6.2 Rammed Earth**

Earth structures buildings are well known for their construction quality and significant environmental benefits. Rammed earth construction involves the compaction of earth between formwork to form monolithic walls. The massive monoliths that are earth structures walls offer beautiful living environments while providing buildings with valuable thermal mass. According to Earth Structures Property Magazine (2013), the walls contain a fraction of the embodied energy of manufactured wall products such as fired bricks and building blocks. No other walling can provide architects with such natural elegance combined with such low environmental impacts (Wayne, 1976). A well designed earth structures building can



be managed without air conditioning in hot weather and with reduced heating input in cold weather (ibid).

The resurgence of interest in rammed earth in Australia may be partially due to its potential as a commercial construction system (Owen, Treloar, & Fay, 1999). Rammed earth can be used as a simple constructional system, but a high technology approach similar to standard construction technologies can also be applied (Houben & Guillaud, 1994). Pressures of economic viability, stringent building regulations, and public expectations of performance have led to technological advancements in construction methods to meet consumer, regulatory and industry demands. Consequently rammed earth construction has generally become more mechanized in its processes. Traditional earth construction methods are high in labour content and relatively low in capital requirements. However, mechanization results in a reduction in labour requirements and an increase in the use of plant, machinery, fuel and capital (North, 1994b).

Furthermore, raw materials are frequently sourced locally and are often stabilized using cement to increase durability, strength and water resistance. Use of earth as a construction material represents a large embodied energy saving over conventional materials such as clay bricks (Lawson, 1996). The use of cement as a stabilizer for rammed earth improves its compressive strength and durability. Stabilization modifies the properties of a soil to increase strength, decrease porosity and reduce dry shrinkage and swell (Easton, 1996). Proportions of cement vary depending on such factors as the soil composition, climate and design, but are generally around 8 per cent (Carter, 1999; (Owen, Treloar, & Fay, 1999).).



**Figure 2.6: Rammed earth construction in progress**

Source: <http://www.permies.com/t/33925/cob/Cheaper-easier-rammed-earth-technique>

The rammed earth construction is well received and adopted in upcountry housing but rarely in urban set-ups. The building regulatory framework locally does not recognize rammed earth construction as permanent form of construction. This bias aspect plays a big role in reducing the adoption rate of this mode of housing delivery. The incorporation of alternative technologies in the new Kenyan Building Code according to the AAKs October,2015 newsletter would be very instrumental in the use and adoption of rammed earth construction. It also help reduce the negative mind set that mud or earth housing are inferior quality despite the long historical usage.

## **2.7 Innovative Construction Methods**

### **2.7.1 Steel Building Systems.**

Historically, steel buildings first gained popularity in the early 20th century. Their use became more widespread during World War II and significantly expanded after the war when steel became more available. Steel buildings have been widely accepted, in part due to cost efficiency and the wide range of applications. Steel also

provides several advantages over other building materials and is a "green" product. It is energy efficient and any excess material is 100% recyclable. Steel is easy to modify and offers design flexibility.



**Figure 2.7: Steel construction**

Source: <http://room-decorating-ideas.com/built-with-lightweight-steel-frames/>

### **2.7.2 Timber Construction**

Timber frame construction method is not very popular with the environmental conservation activists and green belt movements. It requires wood in construction of the walls, floors and roof structures, a demand which puts more pressure on the already depleted forests (Maathai, 1991). However, because of the need to conserve natural forests, interest in the potential of cardboard and even paper use in the construction sector has increased. Notwithstanding, use of timber frame actively helps in reduction of the effects of global warming and has excellent insulation properties.

Mahapatra and Gustavson, (2008) suggested that, in comparison to on-site building, the Swedish industrialized production of timber-framed building systems have relative advantages such as cost savings and improvements in quality through increased prefabrication, improved logistics and improved building processes. The focused industrialized building; industrialized building of multi-storey, timber-framed buildings (hereafter referred to only as “industrialized building”) was started by small contractors who identified the opportunity to meet the quality and cost demands of professional clients (Tykka *et el*, 2010). These small firms developed the off-site factory production of timber-framed volumetric modules or flat elements (Tykka *et el*, 2010).

Timber construction is not an eco-friendly solution to housing and is not very popular with the environmental conservation activists and green technology movements. Its demand is high and puts more pressure on the already depleted forests (Habitat, 1996). This ecological fact far outweighs timber as an ACT. It can however be supplemented by other alternative construction materials such as factory manufactured building products.



**Figure 2.8: Timber construction**

Source: <http://www.heavytimber.net>

### 2.7.3 Prefabrication

Prefabrication encompasses the construction of all building components that are a part of a larger final assembly (Gibb, 1999). Prefabrication is an offsite manufacturing process that takes place at a specialized facility in which various materials and building systems are joined to form a component or part of a larger final installation (Haas et al. 2000). Work is done at a remote location for increased construction speed and quality. The types of prefabricated components vary based on size and complexity and based on the amount of labour required for onsite assembly.



**Figure 2.9: Low cost Prefabrication panels homes**

**Source:** <http://blog.karmod.eu/low-cost-prefab-homes/>

A study conducted at the Graduate School of the University of Clemson by Lu Na in 2007 revealed that there are several perceived benefits and limitations to using prefabricated components (Lu Na, 2007; Haas et al. 2000). The survey received responses from a mixture of 138 practicing architects, engineers, and general contractors in the United States. The advantages of prefab houses, the manufacturers

include shorter construction periods that save on labour costs and environment conservation by avoiding digging up the ground and wastage of construction material on the site (ibid).

Some manufacturers for instance Economic Housing Group (EHG) say prefabricated timber houses can allow for up to 60 per cent saving on the total cost of the house (Daily Nation August 26, 2010). The company specializes in wood products and also claims they can put together a two-bedroom house, complete with furniture, in eight hours. Off-site manufacture of building components saves both time and costs.

The benefits associated with prefabrication in the study by Lu Na, (2007) and Haas et al. (2000), revealed are; the reduced overall construction time and efficient scheduling due to parallel production activities; increased building quality and better craftsmanship; increased labour productivity; increased labour safety; reduced construction schedule; disruptions due to the use of a weather protected work environment and the minimal environmental impact of the construction process on the site.

The constraints to using prefabricated components identified, included the effects of transportation restrictions on designs (Lu, 2007). Also the inability for changes to be made during the construction process, increased design costs and engineering work required upfront are also typically referred to as barriers to prefabrication (Haas et al. 2000).

#### **2.7.4 Pre-fabricated wall systems**

Panelized wall systems consist of prefabricated or factory-manufactured panels that form a structural envelope (Reichel, 2013). Typically, the panels are brought to the site as prefabricated wall, floor, and ceiling components that workers erect and join (ibid). Similar to conventional homebuilding, all electrical, plumbing and code inspections are completed on site. Published benefits include reduced on-site construction time and reduced labour costs, increased product consistency, improved energy efficiency, increased soundproofing, resistance to natural disasters, moisture,

and rodent/insect infestation, and decreased noise pollution (ibid). Potential drawbacks include higher initial costs, which can vary based on the panel type; amount of customization needed, site proximity to a manufacturing plant, code acceptance, and increased design and engineering costs (ibid).



**Figure 2.10: Pre-fabricated wall system**

Source: Energy Efficient and Green Technology Building Template Guide for the State of Maryland, 2007.

SIPS are a type of high performance building panels used in construction of houses as floors, walls, and roofs components. The panels are typically made by sandwiching a core of rigid foam plastic insulation between two structural skins of oriented strand board or other materials. This technology has existed for over 50 years, but has experienced rapid growth in the past five years; due mainly to utilization in Europe. In the USA, however, SIPS made up only 0.5 percent of the building market in 2005 (Mullens & Arif, 2006).

Driving forces that encourage the use of SIPS technology include increasing global skilled labour shortages, recent research dedicated to hurricane resistant materials, and the movement towards sustainability. However, high uncertainties in costs, schedule, labour productivity, quality, safety, possible benefits, and waste involved

in the implementation of SIPS are believed to have discouraged its growth rate (Mullens & Arif, 2006).

### **2.7.5 Modular Construction Method**

According to the Modular Building Institute, an industry trade group, modular construction is the process of building a structure off site, under controlled conditions, using the same materials, codes and standards as conventionally built facilities, in about half the time (Hardiman, 2014). Buildings are produced in modules that, when put together on site, reflect the design intent and specifications of the most sophisticated traditionally built facility (ibid).

Modular consists of the use of large, three dimensional modules to construct homes. Modules are fabricated and assembled in a manufacturing plant and shipped virtually complete with exterior and interior finish, plumbing, wiring, and mechanical systems (Carlson, 1991). After transport to the construction site, modules are set on a permanent foundation using a construction crane and finished by the contractor. Completed modular homes must comply with the same building codes as conventional, stone built homes.

Published benefits include reduced building time, built in a controlled environment, improved energy efficiency up to 30 percent savings in cooling energy use (Chandra *et al*, 1998; Mcilvaine *et al*, 2006), reduced material waste, and constant skilled workforce. Some of the drawbacks of the wide implementation of this type of building system are perceived negative stereotype, limited transportation, design variety, and regulatory requirements (Mullens, (2011).

When building under controlled conditions, quality goes way up (Quirk, 2014). The off-site setting is a safer, more comfortable work environment that tends to attract the best workers. It also can provide quality assurance opportunities that may not be available at the site. For example, work crews can monitor connections on a factory-built building facade to make sure joints are tight and waterproof, making it less likely the joints will fail in the field (Quirk, 2014).



The application of modular construction is most economic in the repetitive production of a large number of similar, often room-sized units where the economy of scale can be realized. Critical portions and service installations are made 'off the critical path' and where quality can be assured. This is especially important for repetitive parts of the design, like patient rooms and bathrooms. If a design calls for 200 rooms, "you can build 200 rights," particularly if you aren't working with several different framing, plumbing and drywall crews. "The more variables you have, the harder it is to have a consistent product," (Taylor, 2014).

Third party vendors can provide expertise on specialized components. Purchased components can provide high-quality engineering and aesthetics, with a number of different finishes and other available design options (Palmer, 2014). Both speed of construction and improved quality create business-related benefits to the client by early return on capital invested, or less 'down-time' in use of existing facilities in building extensions. Modular construction reduces the time on site, is much less noisy and produces negligible waste. Furthermore, deliveries to site can be timed to suit the local conditions.

In addition, buildings designed and built in a modular fashion are inherently adaptable. They have been described as the key to offsite construction techniques in UK because it offers customers distinctive advantages over traditional construction techniques in terms of labor productivity, project schedule, product quality and a safer working environment (Gibb, 2001). They allow easy and standard access during maintenance hence improves safety and sustainability. Modular construction is driven by the two key imperatives: to build quickly on site, and to improve quality by off-site activities. The factory building environment makes efficient use of labour and materials and can help to shorten the duration of a project, all of which add up to significant savings.



**Figure 2.11: Modular Construction and low cost housing units**

Source: <http://www.bauhu.com/style/images/art/bg2.jpg>

### **2.7.6 Three Dimension (3D) Panels Systems**

According to Journal of Material Science (2006), 3D panel system is an alternative building system using prefabricated polystyrene panels with wire mesh. It becomes a structural wall when concrete; Portland cement, plaster and stucco are put into place. Unlike other building systems, 3D Panel is an environmentally friendly product, withstands extreme temperatures and earthquakes and is a recycled green product. The 3D panel system comprises of Expanded Polystyrene (EPS) foam sandwiched between a galvanized steel wire mesh that is plastered on both sides by pneumatically spraying it onto the surface a process known as shoot concreting.

The 3D Panel building system has tremendous flexibility; it can be used in place of wood or metal-framed walls, masonry block walls or pre-cast concrete panels. It is an excellent structural system that can be used in floors, ceilings, and roofs. The 3D Panel building system saves construction time while providing greater structural integrity. 3D Panel components are manufactured with all recycled plastics and steel wires. No forest products are used hence it is safe and friendly to humans and wildlife therefore considered eco-friendly alternative building system. (Sam Rhea, 2004).

For instance a standard two-bedroom house measuring about 100 square meters requires about seventy (70) panels each weighing 15 kilogrammes; meaning an entire house can be carried in a single lorry load. Despite the low weight, buildings constructed using the EPS panels are strong enough to withstand natural calamities better than houses build using the conventional stone and mortar. Also EPS panels can be used to construct up to twenty storey building structures. Mass production of factory houses using the EPS panels is expected to drastically reduce the cost and time taken to put up a house (Okumu, 2014).



**Figure 2.12: EPS Residential house at Balozi estate, Nairobi**

**Source:** Primeventures International website

Expanded Polystyrene (EPS) is widely available and is currently being used in many countries worldwide to provide housing. With developments in integrated computer design, engineering and manufacturing systems, the frame of the building is produced quickly and accurately within the controlled environment of a modern factory. With a fixed priced and timelines, it eradicates the possibility of increasing construction costs.

## **2.8 Conclusion**

### **2.8.1 Theoretical Framework**

What is observed from the literature is that ACTs have various advantages. They have been used elsewhere to improve speed of housing delivery. In most instances,

the ACTs have been used to reduce cost of delivery of houses. This is due to the efficiency in terms of increase in construction speeds, lessened project schedules, reduced site wastage and improved labour productivity. From the literature, it is also evident that the uptake and acceptability of ACTs is rather low, more so in Africa.

The reasons for the low adoption rates have not been addressed; and especially so in the Kenyan context due to lack of historical data.

### **2.8.2 Literature Gap**

The performance of the ACTs has however not been evaluated to find out their effects and impacts in the delivery of housing. This glaring gap has created the need to carry out post occupancy evaluation on buildings erected using ACTs. This evaluation process assessed the quality and physical characteristics to determine the weaknesses and strengths of ACTs. It assessed the users' knowledge, perceptions, satisfaction and comfort levels of ACTs. It also assessed the economic benefits realized by the developers and contractors. It assessed the lessons learnt by the projects consultants. Finally, it interrogated the adoption constraints of ACTs.

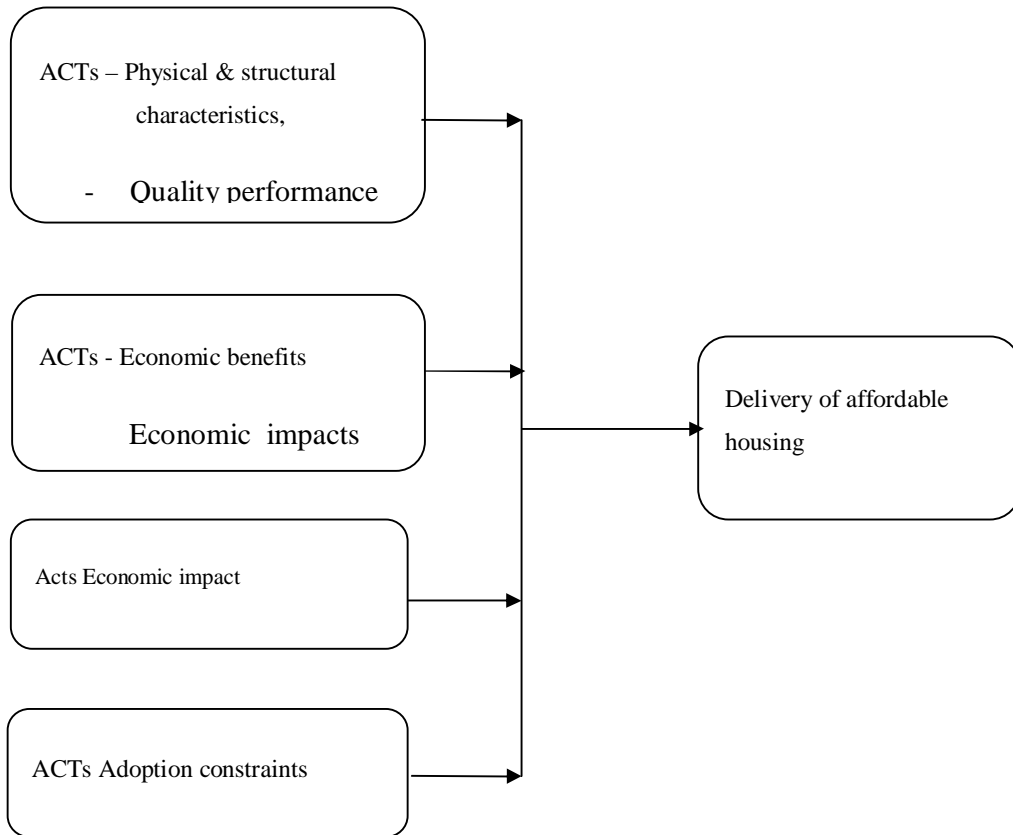
The findings would put into perspective the fears on quality and failure on reliability of ACTs as a means of housing provision. The findings would also put into perspective the economic benefits of the ACTs which would contribute to affordable housing delivery. Finally the findings will provide adoption guidelines to improve acceptability of the ACTs.

### **2.9 Conceptual Framework**

Conceptual framework is defined as the result of when a researcher conceptualizes the relationship between variables in the study and shows the relationship graphically or diagrammatically (Mugenda, 2003). Based on the discussion of the various variables, the study was guided by the following conceptual framework.

**Independent Factors**

**Dependent**



**Figure 2.13 Conceptual Framework**

Source: Own construction (2015)

## CHAPTER THREE

### RESEARCH DESIGN AND METHODOLOGY

#### 3.1 Introduction

Chapter two identified the gap in literature related to lack of evaluation on performance of ACTs in Kenya. This chapter describes the methodology used to collect data and to analyze it. The chapter is organized around five major topics namely: research design, research strategy, population, sampling techniques, research method, data collection approach, variables in the study and finally concludes with data analysis method.

#### 3.2 Research Design

The research was an assessment of knowledge and information from the five selected cases that exemplified use of ACTs in their delivery. Therefore the research was designed to explore and evaluate the information from consultants, contractors, developers and users of the completed buildings. The study adopted cross sectional design to carry out the evaluation. This entailed collection of data on more than one respondent at any one selected case so as to collect a body of data related with more than one variable. The data was then looked at in different perspectives and patterns of connection.

Nevertheless the participants in this design needed to have met expert requirements, knowledge and experience with issues under investigation, capacity and willingness to participate, (Usman, Soomro, & Brohi, 2014).). What required being determined was the sample composition, the sample size, orientation; whether qualitative or quantitative, number of cycles for seeking data and the mode of interaction. The number of cycles for interaction was two and the mode of interaction was face to face interviews. Skulmoski *et el* (2007), qualified two cycles as adequate to allow for generalization. Moreover it gave a good spread for all categories that the study had targeted and was aimed at evaluating arising facts and information available to come up with critical conclusions (Maina, 2012).

### **3.3 Research Strategy**

The study adopted a case study design which combined quantitative and qualitative research strategies. The two strategies were employed to complement each other in covering aspects of the evaluation which would not have been sufficiently covered by either of the strategies if it were used alone. As explained in Bryman (2012), quantitative and qualitative research strategies can both be combined to complement each other. This strategy was also preferred since the aim of the study was to gather information from in-depth interviews with the respondents. The respondents had experience in using ACTs hence had valuable information required for this research (Bryman 2012).

### **3.4 Population, Sample and Sampling**

#### **3.4.1 Target Population**

Population as defined by Mugenda and Mugenda (2003) is an entire group of individuals, events or objects having a common observable characteristic. The target population for this study was building structures that have been constructed using ACTs within the Nairobi County for the last ten years. This is the period when there has been increase in construction of housing projects and application of alternative construction materials and new building techniques. A list comprising of sixteen (16) of housing projects and buildings constructed using ACTs within the Nairobi County and its suburbs; used as sampling frame, is annexed as " *appendix F*".

#### **3.4.2 Sample and Sampling Techniques**

The study employed purposive sampling technique as part of a multi stage selection procedure. According to Mugenda and Mugenda (2003), purposive sampling is a sampling technique that allows a researcher to use cases that have the required information with respect to the objectives of a study. The population comprised of completed building projects where ACTs had been used within the Nairobi County was short listed from the Nairobi County City Planning Department register. The

study further selected the projects provided residential housing from the sample frame or population. This resulted in the five (5) study samples used as case studies.

Mugenda and Mugenda (2003) indicate that a representative sampling needs to be a minimum of 30 items. The five sampled cases had 63 participants who were considered for the interviews. These comprised of 24 consultants, 15 contractors and subcontractors, 5 developers and a representation of 19 building users. According to Warren (2002) and Bryman (2012), for a qualitative research to be published, it requires a minimum of between twenty and thirty interviews. The study therefore fulfilled this threshold.

To test the validity and reliability of the interviews and availed data, the study sort two cycles for interaction and seeking data. Same questions were repeated to different participants in the study and their response documented. The pilot data was also used to validate the data collected at the later stage in the study. Archival data of the project was also used to confirm the accuracy of the data availed through the interviews and questionnaires.

### **3.5 Research Method**

The research method used in this study was Delphi Method. This method is an interactive process to collect and distil the anonymous judgment of experts using a series of data collection and analysis techniques interspersed with feedback, (Skulmoski et al, 2007). It is an appropriate method when the research goal is to understand problems, improve opportunities and find solutions to problems. In this study, we needed to know how facilities constructed using alternative technologies had performed in terms of physical and structural characteristics which included weathering, defects, durability and aesthetics. Also explored were the social and economic benefits and the adoption rate of the technologies. The Delphi method helped uncover data on the lessons learnt by the project team and their effects on buildings built using the alternative technology.



### **3.6 Data Collection Tools**

The study employed the following data collection tools. These were:

- 1) Documentary search: Archival - to obtain the constructions historical facts and information and manufactures' information (construction techniques).
- 2) Field data: two instruments were used;
  - Questionnaires
  - Checklists and observations

The questionnaires were administered and dropped off in person. The process of answering the questionnaire was intertwined with a short interview with the respondents. Participants were allowed to refine their views as interviews progressed. They were provided with opportunity to clarify or change views to allow for qualitative analysis and interpretation of data. Rowe and Write (1999) describes the Delphi Method as a method where participants freely express respective opinions on decisions evaluated on own merit rather than individual who propose the idea. It is used as a structured process within which both qualitative and quantitative research methods are applied to answer many research questions as possible.

#### **3.6.1 Source of Data**

Data was sourced from the selected five (5) building projects used as the sample case studies described in the sample, sampling, and target population '3.4.2 above'. The buildings were selected because this is where alternative construction materials and technologies had been applied to provide residential housing

The cases selected were: police housing scheme in Ruai, Nairobi which comprised of 24 one bedroom, 16 two bedroom and 4 three bedroom bungalows units. All the 44 units were delivered within a construction period of six months. EPS panels were used in both substructure and superstructure. Roof cover was standard IT 4 pre painted roofing sheets on normal timber carcass structure.

The second case constituted of ten town houses (maisonettes) in Balози estate along Thika road, Nairobi. They were each delivered and occupied within a period four months. Apart from EPS wall panels, precast concrete hollow pot blocks were used for suspended slabs but without the standard reinforced concrete beams.

The third case was a mixed use apartment block and offices in Roysambu, Kasarani Nairobi. This is a six storey structure built using EPS floor and wall panels. It was delivered within a period of seven months.

The fourth case was extension of apartment blocks at Kahawa Wendani estate along Thika road, Nairobi. It comprises of three storey extension built using EPS floor and wall panels on an existing framed building initially in-filled with natural stones. The 18 two bedroom units were delivered within four months.

The fifth case was a block of flats comprising of 25 one bedroom units delivered within a period of twelve months in Githurai estate, Nairobi. It was a framed building but used precast concrete waffle slabs. The building was in-filled and partitioned with natural stones.

### **3.6.2 Types of Data**

**(a) Primary Data:** Primary data was collected through questionnaires and face to face interviews. Two rounds of interviews were conducted. The first round; the pilot interview, was undertaken with a few of the sampled respondents and the second round of interview with all the selected respondents in all the five selected cases for the study.

The primary data collected was:

- 1) Satisfaction and comfort level by users.
- 2) Whether objectives of the user/owner had been met.
- 3) Cost savings by developer e.g. interest on borrowed funds

4) Defects on the buildings e.g. weathering, cracks, aesthetics, etc.

5) Awareness level of the alternative construction materials.

**(b) Secondary Data:** Secondary data was archival data which was collected in three ways; firstly, it was collected from the Physical Planning Department of Nairobi City County; secondly, archival information was obtained from both the developers' and the consultants' offices; and thirdly, archival data was obtained from the contractors' records, construction drawings and the site works programme charts.

The secondary data collected was:

- 1) Type of construction method used to deliver the project.
- 2) Type of construction materials used to deliver the project.
- 3) Wastage component
- 4) Construction periods of the facilities.
- 5) Skilled and unskilled labour component used.
- 6) Construction costs for different methods

These combined methods were used in order to cross check the information obtained. This cross checking ensured that data was validated as reliable.

### **3.7 Fieldwork Plan**

To gain access to information on the different alternative construction materials and technologies, the study selected five residential housing projects that have been constructed using ACTs within the Nairobi County. Through the Nairobi County Physical Planning Department, the researcher identified the buildings' owners and the project consultants. The study obtained permission from the respective authorities to interview the people involved in the selected projects and the users of the facilities.

The researcher made telephone contacts with the respondents and contact persons, booked appointments, administered questionnaires and had face to face interviews with them. Face to face interview with the respondents was preferred since it necessitated probing of the interviewee to obtain exhaustive information (Bryman, 2012). The interview period spread over 3 weeks. On average, two interviews were undertaken per day with the interviews taking an average of forty five minutes. The data collection involved specific narration of facts of each alternative construction method. It also included visitations and inspections of built facilities to establish physical conditions and characteristics concerning particular construction technology.

The discussions and interviews with the building owners and users assisted in establishing the comfort and satisfaction levels. They indirectly verified the performance claimed by the alternative materials manufacturers. The discussions and interviews with the consultants, the developers and the contractors helped explain the detailed procedures involved for each of the construction method. Indeed they directly verified and confirmed the findings gathered by the checklist. Data and information obtained was later verified with other participants in the same project.

### **3.8 Data Analysis Procedure**

The data analysis procedure used was partially quantitative and partially qualitative. The collected data was transcribed on a daily basis and analyzed. Firstly the data was tabulated under different sub- themes that reflected the objective of the study. Any discrepancy in the data was crossed checked the following day by revisiting the building facilities. To enhance validity, the data was then again discussed by a selected group of participants. Their objective comments were used for amendments.

The tabulated data was in a manner that it would easily be analyzed by the Statistical Package for Social Sciences (SPSS).

### **3.9 Ethical Considerations**

All the necessary precautions were taken to ensure that this study was conducted in an ethical manner. Four ethical considerations were made as follows:

- 1) Firstly, JKUAT human research ethics conditions were satisfied and ethics approval obtained before the interviews were conducted in the field. This entailed clearance and approval of the research proposal by both the JKUAT Department of Construction Management and Board of Postgraduate Studies (BPS). Further, BPS appointed two supervisors to facilitate the study. Additionally, ethical procedures were strictly followed in the fieldwork. A plain language statement of invitation was sent to potential interviewees.
- 2) The participants were informed about the purpose of the study beforehand. The major ethical issues that were addressed by the study included informed consent, privacy and confidentiality, as well as anonymity and researcher responsibility (Ritchie, 2005). These documents are shown in as Appendix A, B1, B2 and C.
- 3) Secondly, this study was officially authorized by the National Commission for Science, Technology and Innovation (NACOSTI) and the Nairobi County Government Authorities through the County Commissioner and County Director of Education and a research permit was granted. This authorization is shown as appendix D and E.
- 4) Thirdly, all the transcriptions of statements made by the interviewees are what the interviewees actually said. The questionnaires are available and the data source documents are listed in Appendix F.
- 5) Finally the researcher verified that all the references given in this study do actually say what the study report says they do.

### **3.10 Conclusion**

This study adopted a case study design with a multi-strategy approach, the choice of which was dictated by the research questions. In this chapter, the research design, research strategy, data collection and analysis procedures, variables in the study and ethical considerations made in the study were elaborated. In brief, appropriate methodological procedure was followed in the study and they provided a strong foundation for the resultants observations. The next two chapters - chapter 4 and 5 - present the result of the data analysis.

## **CHAPTER FOUR**

### **DATA ANALYSIS AND RESULTS**

#### **4.1 Introduction**

In chapter 3, the research methodology used in this study was discussed. This chapter presents the results of the data analysis addressing objectives 1, 2, and 3 stated section 1.3 of chapter 1. It also includes the interpretations and discussions of the study from the data collected.

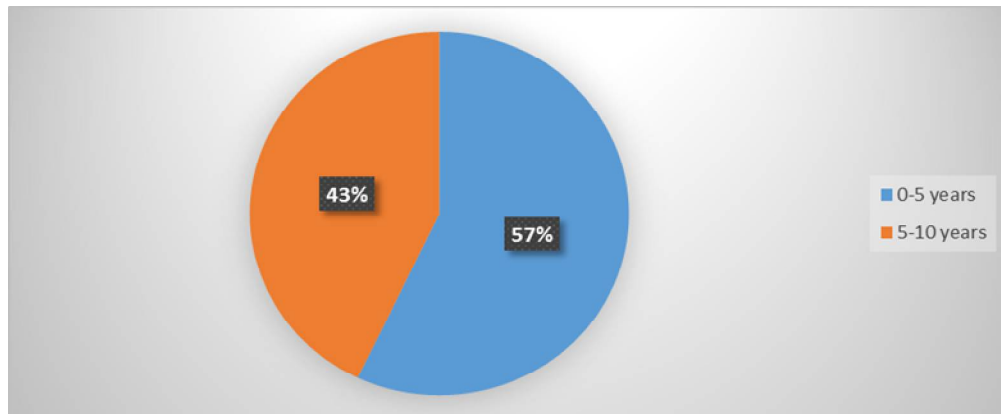
#### **4.2 Response to Questionnaires**

The sampled cases had 24 consultants, 15 contractors and subcontractors, 5 developers and a representation of 19 building users. A total of 63 questionnaires were administered or sent out. The response rate was 57.14%, distributed as follows: 13 consultants; 11 contractors and sub contractors; 5 developers and 8 building users who in 3 cases doubled up as the buildings maintenance supervisors. This falls within the acceptable minimum range of between twenty and thirty interviews for a qualitative research.

#### **4.3 Data collected**

##### **4.3.1 Respondents' experience with the ACTs**

Fifty seven per cent, 57%, of the participants revealed that they had experience with the ACTs for a period of 1 to 5 years. However 43% indicated that they had 5 to 10 years of experience with the ACTs. The results are displayed in figure 4.1.



**Figure 4.1: Experience with the ACTs**

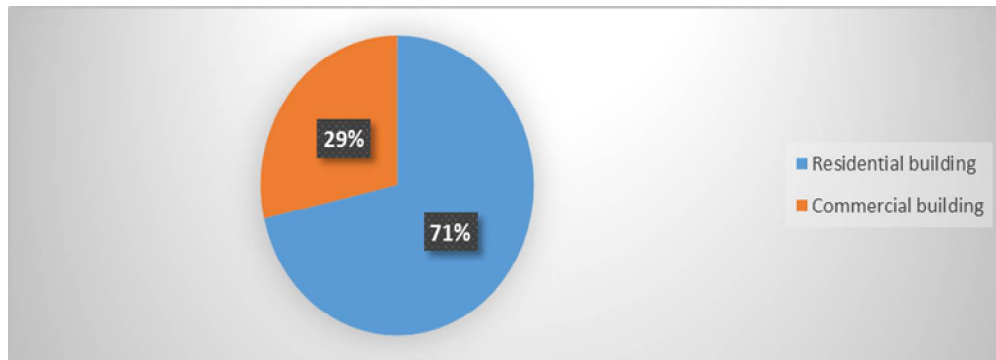
Source: Survey Data (2015)

These finding shows that some ACTs have been recently established in Kenya i.e. less than 10years. This is more pronounced in the EPS panel building system. The consultants and the contractors however were fairly well aware of the ACTs and had used the EPS panels and precast waffles slabs in other projects. The developers' and building users had little knowledge of the recently introduced ACTs and most had not previously used them especially the EPS panels. The knowledge of hollow blocks and precast slabs was well known across the whole set of respondents.

#### **4.3.2 Type of building and materials constructed**

Out of the respondents, 71% who were the majority indicated that they had been involved in construction of residential buildings and 29 % in commercial building. The results are displayed in figure 4.2. Of the 5 cases studied, 3 cases were commercial buildings where in 1 case, precast concrete waffle slabs had been used for suspended slabs; and in 2 cases, EPS floor and wall panels had been used. In all 3cases, pre-painted roof sheets had been used as cover. The other 2 cases constituted of 44 bungalows and 10 maisonettes. EPS wall panels and pre-painted roof sheets as cover had been used in the 44 bungalows. In the maisonettes, EPS wall panels, hollow pot blocks - as suspended slabs - and sand coated tile profile roofing sheets had been used. Chapter 3.6.1 details each case.





**Figure 4.2: Type of building constructed**

Source: Survey Data (2015)

#### **4.3.3 Type of Technology Used**

On the type of alternative construction technology used in other different projects, all the 13 consultants who responded indicated that they had previously used ACTs in other projects. The various types of technologies used included: pre-cast waffles slabs, hollow blocks and premix concrete but only 5 out of the 13 had previously used EPS panels, space frame technology panels, and EPS sandwich panels. All the 11 contractors and sub contractors who responded indicated that they had previously used ACTs in other projects. The ACTs used included: pre-cast waffles slabs, hollow blocks and premix concrete; but only 6 out of the 11 had previously used EPS panels, space frame technology panels, and EPS sandwich panels. Only 2 of the 5 developers had previously used any form ACTs in other projects apart from the conventional stone and mortar. 5 users of the 8 had occupied houses where ACTs such as hollow blocks and pre-cast waffles slabs had been used, and only 1 had an earlier experience in house built with EPS wall panels.

#### **4.4 Performance of Alternative Construction Technology**

The respondents rated the performance of the alternative construction technology that had been used in constructing the buildings being evaluated in the study. This

was in terms of structural and physical characteristics, costs and installation process effectiveness. The visual observations noted by the study are also given.

#### **4.4.1 Physical and structural performance**

The respondents rated the physical and structural performance of the alternative construction technology used in the buildings under evaluation in the study in terms of quality and physical characteristics. The visual observations such as weathering, cracks, deformation, warping, sagging among others were noted. The results are given in terms of average mean as shown in table 4.1 below.

**Table 4.1 Performance of the Mentioned Technology**

<b>Statement</b>	<b>Mean</b>
Aesthetics / beauty	4.1311
Cracks	4.0992
Structure	4.1429
Sound proofing	3.7429
Thermal insulation	4.0000
Stability	3.9857
User satisfaction	3.2090

Source: Survey Data (2015)

The performance rating was in a Likert scale of 1-5 where 1 is poorest and 5 is excellent. This means that the higher the average mean; closer to 5, the better the performance. The respondents indicated that to a great extent the technology they had used had good aesthetics with a mean of 4.1311, good structure with a mean of 4.0992 and good sound proofing with a mean of 4.1429. They also indicated that the technology used had good thermal insulation to a great extent with a mean of 4.0000. Had stability mean of 3.9857 and to a great extent too, the technology had a high user satisfaction level at a mean of 3.2090.

The results suggest that facilities constructed using alternative technologies had performed well in terms of quality, physical and structural characteristics which included weathering, defects, durability and aesthetics. There were no visible cracks, warping or sagging noticed in the buildings. All the items rated obtained an average

mean above 3.2 which suggests good performance and an encouraging user satisfaction level. Good temperature control and sound insulation was an added advantage.

#### 4.4.2 Performance of the Technology in terms of Cost

In terms of costs, the respondents rated the performance of the alternative construction technology they had used. The performance rating was in a Likert scale of 1-5 where 1 is lowest and 5 is very high. This indicates that the higher the mean; closer to 5, the higher the costs. The results are displayed in the table 4.2 below.

**Table 4.1 : Performance of the technology in terms of cost**

<b>Statement</b>	<b>Mean</b>
Cost of construction	3.0000
Speed of construction	4.4286
Construction period	3.5714
Cost of materials	4.1714
Waste reduction	3.1429
Financial returns	4.0000
Maintenance costs	2.3571
Variations in the construction	3.2414
Better relationship with suppliers	2.4286
Installation of electrical conduits	4.0000
Installation of plumbing pipes	4.1429

Source: Survey Data (2015)

The results indicated that the technology they had used was high in terms of speed of construction with of mean of 4.4286. Additionally the results showed that the technology used was fair in terms of construction period at a mean of 3.5714. The technology used was high in terms of financial returns with a mean of 4.0000. The turnaround on borrowed construction finances was also reduced to a larger extent. It was also high in terms of installation of electrical conduits and plumbing pipes at mean of 4.0000 and 4.1429 respectively. Majority of the respondents indicated that the technology they had used was fair in terms of cost of construction and the mean was 3.0000. In terms of variations in the construction, the mean was 3.2414.

However it was observed that in terms of cost of materials, the technology used was high at mean of 4.1714. Nevertheless, the technology used was low in terms of maintenance costs at mean of 2.3571. In terms of better relationship with suppliers the mean was fairly low at 2.4286.

High speed of construction result in reduced construction period, early delivery of housing which in turn leads early turnaround on borrowed construction finances. Reduced construction period means reduced overhead costs, salaries, and other charges related to time. The low mean rating in terms of maintenance indicates low costs of maintenance which is good for the developers and users. These combined aspects contribute positively towards economic benefits of ACTs. The mean of 4.1714 in terms of cost of materials, shows that the technology used was expensive. This high cost contributes negatively towards the delivery of affordable housing.

#### **4.4.3 Technology and process effectiveness**

The researcher further sought to investigate the extent to which the respondents considered the technology used in their project as a relatively economic method Where; (1) No extent, (2) Little extent, (3) Moderate extent, (4) Great extent, (5) Very great extent. The results are displayed on the table below.

**Table 4.1: Technology and process effectiveness**

<b>Statement</b>	<b>Mean</b>
Time schedule	3.2857
Productivity	3.1867
Quality control	4.4286
Waste reduction	4.4286
Better handling of materials	4.0000
Transport aspect	3.8571
Improving follow up and supervision	4.1429
Efficiency	4.4286
Output of labour crew	4.0000

Source: Survey Data (2015)

The respondents to a moderate extent considered technology used in their project as relatively economical method in terms of time schedule with a mean of 3.2857. Respondents to a moderate extent also considered the technology used in their project as relatively economic method in terms of productivity with mean of 3.1867. It was observed that to a great extent, respondents considered the technology used in their project as a relatively economical method in terms of quality control, waste reduction, better handling of materials, transport aspect, improving follow up and supervision, efficiency and output of labour crew with means of 4.4286, 4.4286, 4.1429, 4.0000, 3.8571, 4.4286 and 4.0000 respectively.

These findings show that the technology used improved time scheduling of the work hence high speed of construction, better handling of materials, reduced transport costs and improved productivity. High wastage reduction meant saving on materials costs, and increasing efficiency and better quality control. The reduced time create business-related benefits to the client by early return on capital invested, or less 'down-time' in use of the building. The contractor benefits from less labour costs and overheads. The follow up and supervision costs by consultants are reduced. Secondary data from manufacturers showed that off cuts materials can be re-cycled with minor adjustments and weight of materials low hence ease of handling and transport.

## **4.5 Economic impact.**

The respondents rated the economic impact of the alternative construction technology that had been used in constructing the buildings being evaluated in the study. This was in terms of quality performance and costing of constructions; effects and implications thereof. The secondary data obtained for instance drawings and programmes was noted and shared by the study.

### **4.5.1 Quality performance of the technology**

The respondents ranked the quality performance of the alternative construction technology they had used. The performance rating was in a Likert scale of 1-5 where 1 is lowest and 5 is highest. This shows that the higher the mean; closer to 5, the higher the issue affects performance of the technology. The results are displayed in the table 4.4 below.

**Table 4.3: Quality Performance of the Technology**

<b>Statement</b>	<b>Mean</b>
Time	4.6913
Durability	3.7803
Completeness	4.7343
Consistency	4.7143
Neatness	4.5714
Compatibility with other services	4.2857
Risk allocation	3.8571

Source: Survey Data (2015)

The results indicated that the quality performance of the technology was highest in terms of time, completeness, consistency and neatness at the mean of 4.6913, 4.7343, 4.7143 and 4.5714 respectively. It was also observed that the quality performance of the technology was high in terms of durability and risk allocation with a mean of 3.7803 and 3.8571 respectively.

This shows that in terms of time, completeness, consistency and neatness, the technology used performed well and had good compatibility with other surfaces. The mean of 3.78 in terms of durability showed that the respondents were not sure of the technology used since it is not well established in the construction which leads to the high risk allocation mean.

#### 4.5.2 Costing of the construction

In terms of economic impact, the respondents rated the extent to which the listed statements influenced costing of the ACTs they had used. The results are shown in the table 4.5 below.

**Table 4.4: Costing of the Construction**

<b>Statement</b>	<b>Mean</b>
Choice of work method	3.3810
Labour	3.3124
Selection of appropriate wastage allowance	3.4286
Overheads	3.2571
Weather	3.0000
Foundation laid	2.7043
Construction levies	1.5714
Remoteness of the site	2.1429
Design considerations (related to location)	1.7143
Vandalism and site security	2.5714
Power and Water	3.0000
Construction equipment costs	2.7143
Indirect Job costs	2.7350
<b>Subcontractor quotations</b>	<b>2.7143</b>
<b>Contingency and risk allocation</b>	<b>2.2857</b>
Errors in estimate formulation	<b>2.5714</b>
Basis of information used to formulate estimate	<b>2.7621</b>
Market forces	3.0000
Staging and project startup costs	2.1429
Escalation costs	2.5714

Source: Survey Data (2015)

The results indicated that choice of work method, labour, selection of appropriate wastage allowance, overheads, weather, foundation laid, vandalism and site security, power and water, construction equipment costs, indirect job costs, subcontractor quotations, errors in estimate formulation, basis of information used to formulate estimate, market forces and escalation costs, influenced the costing of the construction to a very moderate extent as demonstrated by the average means of 3.3810, 3.3124, 3.4286, 3.2571, 3.0000, 2.7043, 2.5714, 3.0000, 2.7143, 2.7350, 2.7143, 2.5714, 2.7621, 3.0000 and 2.5714 respectively.

Further the results revealed that construction levies, remoteness of the site, design considerations (related to location), contingency and risk allocation, staging and project startup costs with a mean of 1.5714, 2.1429, 1.7143, 2.2857 and 2.1429 respectively, influenced the costing of the construction to a little extent.

The low mean averages indicate that the costing of construction using ACTs is only moderately influenced by the auxiliary items raised. Nevertheless, managing a construction project typically needs a balance between the competing projects constraints not limited to: scope, quality, schedule, budget, resources, and risk PMI, (2008). Therefore activity-based costing is required on all the inputs to keep track of the total project expenses.

#### **4.6 Rate of Adoption**

The respondents rated the acceptance and adoption rate of the alternative construction technology that had been used in constructing their buildings. This was carried out in terms of evaluating the public knowledge on the technology, reception and utilization in other projects and finally as means of delivering relatively cheaper and affordable houses. General questions and opinions were sort from the respondents.



#### **4.6.1 Public knowledge on the technology used.**

The study sought to establish the public knowledge of the technology used in the various projects. Where: Very little (1), Little (2), Averagely well (3), Fairy Well (4), Very well (5). The results are shown below.

**Table 4.2: Public knowledge on the technology used in construction project**

<b>Rate</b>	<b>Percentage</b>
Very little	28.6%
Little	57.1%
Averagely well	14.3%
Total	100.0%

Source: Survey Data (2015)

The majority, 57.1% of the respondents, indicated that the public knowledge of the technology used in their project was little. 28.6% rated public knowledge of the technology used to be very little and only 14.3 % of the respondents indicated that public knowledge of the technology used was averagely well known. This implies that the public does not have enough knowledge on the ACTs in use and the access to information about the technologies is inadequate.

#### **4.6.2 Adoption rate of the technology used in construction project**

The percentage of new buildings taking up alternative technology was assessed. Where: very low (1), low (2), average (3), high (4), very high (5). The results are shown below.

**Table 4.3: Adoption rate of the technology used in construction project**

<b>Rate</b>	<b>Percentage</b>
Low	59.1%
Average	27.7%
High	13.2%
Total	100.0%

Source: Survey Data (2015)

59.1% of the respondents indicated that the adoption rate of the technology used in their construction project as low. Respondents (27.7%) also indicated that there was an average rate of adoption of the technology used in their project. A small percentage of 13.2% of the respondents indicated that the rate of adoption of the technology used in their project was high. These results amplify the slow adoption of alternative building technologies. This could be attributed to the strong bias towards traditional materials and techniques, specifically stone and cement. It could also be due to the human nature of not wanting to change preference of status quo. Lack of awareness of the products could also be a contributing factor.

#### **4.6.3 Technology delivering relatively cheaper and affordable houses**

The study sought to establish how the respondents rated the technology used in delivering relatively cheaper and affordable houses. Where: (1) very low, (2) low, (3) average, (4) high and (5) very high. The results are shown below.

**Table 4.4: Technology use in delivering relatively cheaper and affordable houses**

<b>Rate</b>	<b>Percentage</b>
Low	11.3 %
Average	17.3%
High	71.4%
Total	100.0%

Source: Survey Data (2015)

71.4% of the study respondents rated the technology used in delivering relatively cheaper and affordable houses as high. 17.3% rated the technology as average and 11.3% rated as low. This would imply that the public is interested in sustainable ACTs but there is a perceived higher initial cost of the construction materials. This is supported by the fact that over 83% of the respondents indicated that the price of the raw materials was high in their projects.

#### **4.7 Conclusion**

In brief three major observations have been made in this chapter.

- 1) Firstly, the performances and characteristics data obtained shows very many advantages associated with ACTs. However, these social and economic advantages have not been well explained and articulated to the public.
- 2) Secondly, housing output in Kenya is significantly influenced by the choice of building materials and ACTs offer different mode of housing delivery. The cost of raw materials was however found to be high.
- 3) Finally, the rate of adoption and uptake level of the ACTs were found to be low. Public knowledge on the ACTs was also found to be low.

The lack of life cycle cost and benefit data therefore presents significant barriers in the implementation of these techniques. Managing construction projects typically needs a balance between all the competing projects constraints.

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Introduction**

This chapter presents the summary of the findings, and also gives conclusions and recommendations of the study based on the objectives of the study. The aim of the study was to evaluate the performance of ACTs in Kenya. The specific objectives were to; assess the characteristics, quality and performance of building elements built with ACTs; describe the social and economic impact of ACTs and finally gauge the adoption rate of ACTs by developers, consultants and contractors. In addition, areas of further studies are also given.

#### **5.2 Summary of findings**

The study set out to investigate the physical and structural performance of houses built using alternative construction methods in Kenya. It also endeavoured to establish the economic benefits of ACTs in an attempt to provide affordable housing. The study was a post occupancy evaluation. It relied on both quantitative and qualitative research methods. Data was collected in Nairobi from police housing scheme in Ruai; selected town houses in Balози estate, Muthaiga North, apartments in Githurai, flats in Kahawa Wendani and combined mixed use block in Roysambu. The various logistics involved and used in the construction of the projects were reviewed and interrogated. The uptake and adoption of the different technologies were also evaluated. Structured interviews with checklists were conducted in the selected study cases where ACTs had been used. The data collected was analyzed and the results presented in tables and figures.

The results showed that 57% of the respondents had had experience with the ACTs for a period of 1 to 5 years. However, 43% had 5 to 10 years of experience with the ACTs. This indicates that ACTs have been utilized by construction firms in Kenya for at least the last 10 years especially the EPS panel building system. The

consultants and the contractors were moderately aware of the ACTs and had used the EPS panels, hollow blocks and precast waffles slabs in other projects.

It was also established that the developers' and building users had little knowledge of the ACTs and most had not previously used them especially the EPS panels. The knowledge of hollow blocks and precast slabs was however fairly well known across the respondents. 71% of the respondents indicated to have had used ACTs to construct residential buildings. The various types of ACTs used in the cases under study included: pre-cast concrete waffle slabs, hollow blocks, premix concrete, EPS floor and wall panels and space frame technology panels.

In terms of quality, physical and structural characteristics which include weathering, defects, durability, and aesthetics, the results showed that facilities constructed using alternative technologies had performed well. The buildings were firm and stable in structure. There were no visible structural cracks, faded painting, or sagged beams noticed in the buildings. The buildings walls built with EPS panels were said to have good sound proofing and good temperature control which resulted in increased user satisfaction.

On the performance of the technology in terms of costs, the findings indicated that ACTs were high in terms of speed of construction. Additionally the findings established that ACTs were reasonable in terms of construction period. According to the results, ACTs used by various respondents were high in terms of financial returns. In terms of installation of electrical conduits and plumbing pipes, the performance was high. It was also noted that ACTs were low in terms of maintenance costs and in terms of better relationship with suppliers.

High speed of construction usually result in reduced construction period, early delivery of housing which in turn leads early turnaround on borrowed construction finances. Reduced construction period results in reduced overhead costs, salaries, and other charges related to construction time. The low cost of maintenance is good tidings to the developers and users. These combined aspects contribute positively towards social and economic benefits of ACTs.

However, the high mean of 4.1714 in terms of materials cost indicate that the technologies used were expensive. This high cost contributes negatively to the cost performance of ACTs. Notwithstanding, the majority of the respondents indicated that the technology they had used was fair in terms of the overall construction cost. Also the turnaround time on borrowed construction finances was also reduced to a larger extent as a result of the high speed of construction.

On the technology and process effectiveness; Table 4.3, .it was observed that to a great extent, over 80% of the respondents considered ACTs used in their project as relatively economic method in terms of quality control, waste reduction, better handling of materials, reduced transport costs of materials, improvement on follow up, and supervision, efficiency and in terms of output of labour crew and durability.

These findings proved that the ACTs used improved time scheduling of the work during construction hence improved productivity. The reduced time created business-related benefits to the client by early return on capital invested, or less ‘down-time’ in use of the building. The high wastage reduction and re-cycling of off cuts meant saving on materials costs. The contractor benefits from less labour costs and overheads, increased efficiency and better quality control. The follow up visits and supervision costs by consultants are also reduced.

On quality performance of the technology, the results indicated that the quality performance of the ACTs was highest interms of time, completeness, consistency and neatness. This shows that the technology used performed very well and had good social benefits as indicated in the checklists and questionnaires. Conversely, the quality performance was also high in terms of construction material and risk allocation. This means in terms of durability, the respondents were not sure of the ACTs which have a short history locally and are not well established in the construction which leads to high risk and fear of the unknown.

On the economic costing of the construction, the findings indicated that the choice of work method, labour, selection of appropriate wastage allowance, overheads, weather, foundation laid, vandalism and site security, power and water, construction

equipment costs, indirect job costs, subcontractor quotations, errors in estimate formulation, basis of information used to formulate estimate, market forces and escalation costs influenced the costing of the construction only moderately.

Further, the findings revealed that construction levies, remoteness of the site, design considerations (related to location), staging and project startup costs influenced the costing of the construction to a little extent. This was an indication that ACTs could be relatively cheaper in terms of cost of the construction and applicable in many places. Nevertheless, managing construction projects typically needs a balance between the competing projects constraints however small and is not only limited to: scope, quality, schedule, budget, resources, and risk PMI, (2008). Therefore activity-based costing is required on all the inputs to keep track of the total project expenses.

On rate of adoption and public knowledge on the technology used in the construction projects, 57.1% of the respondents indicated that public knowledge of the technology used in their project was little and 28.6% rated public knowledge of the technology used to be very little. This implies that 85.7% of the public do not have enough knowledge on the ACTs in use and the access to information about the technologies is inadequate. These results amplified the low adoption rate of alternative building technologies in Kenya.

### **5.3 Conclusion**

Construction projects require a wide range of inputs, from labour to various types of materials and tools. Identifying the exact cost of all inputs and activities for a project can be challenging but useful to keep track of the total project costs. Based on the findings, the study confirmed that ACTs have performed well in terms of physical and structural aspects. The houses built with ACTs were found to be firm, structurally sound and stable. The quality and functional performance of ACTs was found to be above 60% average. Uncertainty on ACTs materials quality, ACTs characteristics, house collapse and unknown failure fears, are cleared by the study findings.



The study findings were that there are several economic benefits achieved by ACTs during stage of houses. These competitive advantages of the ACTs could be used in reducing costs of housing provision. These cost savings should be transferred down to the house owner resulting in affordable housing. The study findings showed positive social impact data which could be utilized to improve ACTs uptake and enhance housing delivery.

The study findings confirmed that the adoption rate of the ACTs was low in Kenya. Simple ignorance of ACTs has played a big part in the low adoption pace. The study concluded that effective dissemination and widespread adaptation of alternative technologies and materials is constrained by lack of knowledge and requisite skills in the usage of alternative building materials

The other factor contributing greatly to the low adoption and acceptability rate of the ACTs is the high costs of the raw materials. This has resulted in the public taking the technologies as not really being appropriate in terms of costs. Hence the paradigm shift from the stone and mortar construction is taking long to be felt. The study concluded that lack of full project cost benefits arising from use of ACTs greatly acts as a barrier and contributes to the low adoption pace.

The safety of construction and durability of alternative building technologies is directly dependent on the construction speed, waste reduction, skills and competence of the labour. Therefore the use of alternative building process which on the overall is cheaper and fast in production will lead to promotion of provision of improved, affordable, quality and decent housing in Kenya. This will also lead to transfer of knowledge on available technologies and materials; enhance the rural-urban balance in shelter delivery; promote wider use and adoption of alternative building technologies as well as serve as a vehicle for curbing mushrooming of slums, and in upgrading the existing ones.

#### **5.4 Recommendations**

The study recommends periodic post occupancy assessment on buildings erected using ACTs. This will obtain performance data of their usage and as an approach to reduction of construction cost leading to affordable housing. The findings of the study should be applied in future projects as a way to promote adoption of the ACTs.

In order to be more effective, the adopted standards and specifications for these alternative building technologies have to be complemented by corresponding adjustments in building codes and regulations, tendering and contractual documents, and codes of practice. There would be a danger, for instance, if the standards for specific alternative building materials and technologies were to be issued as an independent publication without cross-referencing such standards in other regulatory instruments which support the building industry. Widespread adaptation of alternative building materials and technologies is determined to a large extent by the market conditions hence encouragement of their use is paramount.

The study established the high cost of ACTs raw materials in Kenya. In light of the findings, the study recommends that the Governments be the enabler in housing cost reduction by subsidizing tax, zero rating or reducing tax for alternative building materials. Reducing materials costs and enticing local production would culminate in increased usage of ACTs, for both public and private stakeholders' participation which would eventually bring cost of housing delivery.

The study recommends the sensitizing and education of the public through open forums, printed pamphlets, show houses, physical demonstrations of construction speeds, active public participation and other promotion methods. The many advantages of alternative building technologies should be demonstrated, propagated and well articulated to the general public. This knowledge would encourage acceptability and adoption of ACTs.

As the main stake holders, the study recommends the suppliers, professionals and developers in the housing sector to embrace and adopt alternative building technologies and lead from the front.

## **5.5 Further Research**

The study evaluated the performance of ACTs in Nairobi, Kenya. In the course of the study, it was observed that the following area relating to the ACTs need further research:-

- 1) The unit cost benefits arising from use of ACTs. The consolidated unit costs of all the advantages and benefits resulting from the use of ACTs could be useful to the construction industry body of knowledge.
- 2) The performance aspects of various technologies those are potentially viable for adoption in Kenya. This would widen the range of alternative construction materials being used locally.
- 3) The efficiency levels exhibited by various alternative building materials already adopted and are in use in Kenya. This could determine the specification levels which may assist in reducing raw material production costs.
- 4) Explore diverse ways of dissuading the public perception on the conventional construction methods and encouraging them to use ACTs for posterity sake and encouraging the paradigm shift.
- 5) Explore mass production of low cost housing utilizing speed and labour efficiency as catalysts.

## REFERENCES:

- A guide to the project management body of knowledge (PMBOK Guide)*, (2008) – fourth edition, Project Management Institute, 14 campus Blvd., Newtown square, PA 19073-3299 USA.
- Al-Araidah O., Momani A, AlBashabsheh N., Mandahawi N., Fouad R.H (2012), *Costing of the Production and Delivery of Ready Mix Concrete Jordan Journal of Mechanical and Industrial Engineering* 6, (2), 163 -173.
- Arditi, D., Ergin, U. and Gunhan, S. (2000), *Factors affecting the use of precast concrete systems, Journal of Architectural Engineering*, 6 (3), 79\_86.
- Barrett, P. (2003), *Hybrid concrete: improved processes and performance, Proceedings of the Institution of Civil Engineers, Structures and Buildings*, 156(SB2), 193-203.
- Blayse, A.M & Manley, K. (2004), Key influences on construction innovation, *Construction Innovation*, 4 (3), 143\_54.
- Blismas, N. & Wakefield, R. (2009), *Drivers, constraints and the future of offsite manufacture in Australia, Construction Innovation*, 9 (1), pp. 72\_83.
- Bryman, A. (2012), *Social Research Methods*, New York: Oxford University Press.
- Carlson, D. O. (Ed.). (1995). *Automated builder: dictionary/encyclopedia of industrialized housing*. Automated Builder Magazine, Publications Division, CMN Associates.
- Chandra, S., Beal, D., & McKendry, B. (1998). Energy efficiency and indoor air quality in manufactured housing. *Affordable Comfort*, 98.

- Collaborative Engineering, *Journal of Management in Engineering*, 15(1), 39-45.
- Constitution of Kenya (2010) and Kenya Vision 2030, *attainment of adequate, affordable housing and reasonable standard of sanitation*. Nairobi: Government Printer
- Danson Kagai, (2014, June Sunday 29,). *NHC factory eases Kenya building costs, Construction business review*.
- Dawkins, C. J., & Koebel, C. T. (2009). Overcoming barriers to placing manufactured housing in metropolitan communities. *Journal of the American Planning Association*, 76(1), 73-88.
- Dulaimi, M.F., Ling, F., Ofori, G. and Silva, N.D. (2002), *Enhancing integration and innovation in construction, Building Research & Information*, 30(4), 237-7.
- Easton, D. (1996), *The Rammed Earth House*, Vermont: Chelsea Green Publishing Company
- Edge, M., Craig, A., Laing, R., Abbott, L., Hargreaves, A., Scott, J., & Scott, S. (2002). Overcoming client and market resistance to prefabrication and standardisation in housing. *Robert Gordon University, Aberdeen*.
- Elias, P., & Omojola, A. (2015). Case study: The challenges of climate change for Lagos, Nigeria. *Current Opinion in Environmental Sustainability*, 13, 74-78.
- Fleming, M. C. (1965). 'Economic aspects of new methods of building with particular reference to the British Isles, the Continent and America'. - Dublin. *Journal of the Statistical and Social Inquiry Society of Ireland* , XXI, ( Part III), 120.

- Freedman, S. (2001). Design Factors Influencing the Aesthetics of Architectural Precast Concrete. *PCI Journal*, 46(2), 44-61.
- Gibb, A. G. (1999). *Off-site fabrication: prefabrication, pre-assembly and modularisation*. John Wiley & Sons.
- Gibb, A., & Isack, F. (2003). Re-engineering through pre-assembly: client expectations and drivers. *Building Research & Information*, 31(2), 146-160.
- Glass, J., & Baiche, B. (2001). Perceptions of hybrid concrete construction in the UK construction industry. *Engineering Construction and Architectural Management*, 8(1), 67-77.
- Goodchild, C. H. (1995). *Hybrid concrete construction: combining structural materials for speed, quality and economy in buildings*. British Cement Association.
- Goodchild, C. H. (2001). *Hybrid concrete construction for the UK market: Final report on research into using combinations of in-situ and precast concrete in structural frames to achieve better value for UK customers*. London: British Cement Association..
- Goodier, C., & Gibb, A. (2007). Future opportunities for offsite in the UK. *Construction Management and Economics*, 25(6), 585-595.
- Green, S. (1999). The dark side of lean construction: exploitation and ideology. In I. D. Tommelein, & G. Ballard (Ed.), *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction, 26\_28 July*, (pp. 21\_32.). Berkeley, California: University of California .

- Green, S. (1999). The dark side of lean construction: exploitation and ideology. In I. D. Tommelein, & G. Ballard (Ed.), *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction, 26\_28 July*, (pp. 21- 32.). Berkeley, California: University of California .
- GTZ/GATE (1994), *Low Cost Housing Technologies in Kenya, A Kenyan – German Co-operation Project Report*. Nairobi: GTZ
- GTZ/GATE (1996), *Low Cost Housing Technologies in Kenya, A Kenyan – German Co-operation Project Report*. Nairobi: GTZ
- Haas, Carl T., O'Connor J.T., Tucker R. L., Eickmann J. A., and Fagerland W. R. (2000), *Prefabrication and Preassembly Trends and Effects on the Construction Workforce, Austin, Texas*, Center for Construction Industry Studies.
- HABRI (2003), *Manual for Selection, Testing and Production of Stabilized Soil Blocks*, University of Nairobi.
- Hartley A. and Blagden A. (2007), *Current Practices and Future Potential in Modern Methods of Construction*, Banbury, UK, Wrap.
- Hartmann A., Reymen I.M.M.J. and Oosterom G. (2008), *Factors constituting the innovation adoption environment of public clients*, *Building Research & Information*, 36 (5), 436\_49.
- Henderson R. and Clark K. (1990), *Architectural innovation, The reconfiguration of existing product technologies and the failure of established firms*, *Administrative Science, Quarterly*, 35, 9-30.
- Houben, H. and Guillaud H. (1994), *Earth Construction, A Comprehensive Guide*, Intermediate Technology Publications, London.

- Howell G.A. (1999), *What is Lean Construction – 1999*, in Tommelein, I.D. and Ballard, G. (Eds), *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction*, 26\_28 July, (pp. 1\_10). Berkeley: University of California ,
- Innovation on site (2008), *Modern methods of construction*. American Society of Civil Engineers. Retrieved from <http://www.innovationonsite.co.uk/modernmethods-of-construction.aspx>
- International Journal of Research in Engineering Technology and Management* 2(3),1-4 Retrieved from @ <http://www.ijretm.com>| Paper id - IJRETM-2014-02-03-442
- Ivory C. (2005), The cult of customer responsiveness: Is design innovation the price of a client\_focused construction industry? *Construction Management and Economics*, 23(8), 862\_70.
- Jain, S. (2014). To Study on Structural Performance of Precast Concrete.
- Kagai, D. (2014, August 20). Kenya taps SA technology to lower building costs, . *Construction Business Review* .
- Kagai, D. (2014, August 20). Kenya taps SA technology to lower building costs, *Construction Business Review*
- Kageni L. G. (2014), *Use of expanded polystyrene as a solution to Low cost housing in Kenya (Thesis)*, University of Nairobi.
- Koebel C.T. (2008),Innovation in homebuilding and the future of housing, *Journal of the American Planning Association*, 74(1), 45-58.



- Lawson, B., & Rudder, D. (1996). *Building materials energy and the environment: Towards ecologically sustainable development*. Royal Australian Institute of Architects.
- Lim L.Y. and Low S.P. (1992), *Just\_In\_Time Productivity in Construction*, Singapore: SNP Publishers,
- Low S.P. and Chan Y.M. (1997), *Managing Productivity in Construction, JIT Operations and Measurements*, Aldershot, UK: Ashgate,
- Lstiburek, J. W. (2009). Advanced framing. *ASHRAE Journal*, 51(11), 46-51.
- Lu, N. (2007). *Investigation of the designers' and general contractors' perceptions of offsite construction techniques in the United States construction industry* (Doctoral dissertation, Clemson University). Department of Career and Technology Education, Clemson University, Clemson, G.A.
- Maathai W. (1991), *The Green Belt Movement Manual*, Nairobi: Marketing links.
- Mahapatra, K., & Gustavsson, L. (2008). Multi-storey timber buildings: breaking industry path dependency. *Building Research & Information*, 36(6), 638-648.
- Maina S.M. (2012), *Qualitative and Quantitative Research Methods simplified*, Nairobi: Froja Printers mall.
- Manley, K. (2006). The innovation competence of repeat public sector clients in the Australian construction industry. *Construction Management and Economics*, 24(12), 1295-1304.
- McCoy, A. P. Towards Establishing an Innovativeness Index for Construction Sites. In *Building a Sustainable Future* (pp. 91-100). Reston, VA : ASCE.

- McIlvaine, J., Chandra, S., Barkaszi, S., Beal, D., Chasar, D., Colon, C., ... & Lubliner, M. (2006). *Building America Industrialized Housing Partnership (BAIHP)*. University Of Central Florida.
- Mugenda O.M. & Mugenda A.G (2003), *Research Methods: Quantitative and Qualitative approaches*, Nairobi: Acts Press.
- Mullens M.A. (2011), *Factory Design for Modular Homebuilding, Equipping the Modular Factory for Success*, Winter Park, FL: Constructability Press,.
- Mullens M.A. and Arif M. (2006), Structural insulated panels: impact on the residential construction process, *Journal of Construction Management*, 132 (7), 786-794.
- Nadim W. & Goulding J.S. (2010), *Offsite production in the UK: the way forward? A UK construction industry perspective*, *Construction Innovation*, 10 (2), 181\_202.
- Nadim W. and Goulding J.S. (2011), Offsite production: a model for building down barriers: a European construction industry perspective, *Engineering, Construction and Architectural Management*, 18(1), 82\_101.
- Nahmens, I., & Reichel, C. (2013). Adoption of high performance building systems in hot-humid climates-lessons learned. *Construction Innovation*, 13(2), 186201.
- National Association of Home Builders (NAHB) Research Center (2002), *PATH Technology Roadmap: Information Technology to Accelerate and Streamline Home Building*, US Department of Housing and Urban Development, Washington, DC.

- Okumu, E. A. (2014). *Strategy, technology and innovation in low cost housing by Elsek and Elsek (Kenya) limited* (Doctoral dissertation, School Of Business, University of Nairobi). Nairobi: UON
- Neale R.H., Price A.D.F. & Sher W.D. (1993), *prefabricated modules in construction: a study of current practice in the United Kingdom*. London: Chartered Institute of Building, U.K.
- Noppen A.V. (2012), *The ABC's of Affordable Housing in Kenya*, the Acumen Fund report. Nairobi:
- North G. (1994b), Earth building as seen in New Zealand *The Owner Builder Magazine*, 62, 32\_4.
- Owen, C., Treloar, G. J., & Fay, R. (1999, December). "Embodied energy assessment of rammed earth". In *SOLAR99 Conference: Opportunities in a Competitive Marketplace* (pp. 1-3).
- Permanent Modular Construction 2011: Annual Report (2011), *Construction and Environment Resources Habitat for Humanity International 121 Habitat St., Americus GA 31709ph 912-924-6935*.
- Pheng, L. S., & Chan, R. Y. (1996). The application of just-in-time principles to process layout for precast concrete production. *Singapore management review*, 18(2), 23.
- Pietroforte, R., Gregori, T., & Falagario, M. (2009). The changing input structure of the US construction industry: a longitudinal analysis. *Construction Management and Economics*, 27(11), 1089-1098.

- Poon C.S., Ann T. W. & Ng L. H. (2003), Comparison of low\_waste building technologies adopted in public and private housing projects in Hong Kong, *Engineering, Construction and Architectural Management*, 10 (2), 88 – 98
- Quirk A. & Taylor M. (2014), *Health facilities management, health forum on speed to market, Hospitals tap modular construction to meet building demand*, New York City: Modular Building Institute
- Quirk A. & Taylor M. (2014), *Health facilities management, health forum on Emergency management survey*, feature article, New York City: Modular Building Institute
- Republic of Kenya (1997), *National Development Plan 1997 - 2007*, Nairobi, Government printers.
- Republic of Kenya (2008), *Housing Strategic Plan 2008 - 2013*, Nairobi, Government printers.
- Republic of Kenya (2012), *Population Policy for National Development, (Sessional Paper No. 3)*, Nairobi, Government Printers.
- Ritchie, J. and Lewis D. (2005). *Qualitative research practice: a guide for social science students and researchers*. London: Sage Publications Ltd,
- Rogers E.M. (1995), *Diffusion of Innovations*, 5th edition, New York, The Free Press.
- Rojas E.M. & Songer A.D. (1999), Web-Centric Systems: A new Paradigm for
- Rowe G. & Wright G. (1999), The Delphi technique as a forecasting tool, Issues and analysis, *International Journal of Forecasting*, 15 (4), 353 - 375.

- Samuelson W. & Zeckhauser R. (1988), *Status quo bias in decision making*, *Journal of Risk and Uncertainty*, 1(1), 7-59.
- Sarcia S. R. (2004), *Design and Analysis of a concrete modular housing system construction with 3D panels*, Massachusetts: Department of Mechanical Engineering, Massachusetts Institute of Technology.
- Sarcia, S. R. (2004). *Design and analysis of a concrete modular housing system constructed with 3D panels* (Doctoral dissertation, Massachusetts Institute of Technology).
- Saunders, M. N., & Bezzina, F. (2015). Reflections on conceptions of research methodology among management academics. *European Management Journal*, 33(5), 297-304.
- Shepherd S. (2006), *Back to the future*, PATH Report, 12, Professional Builders.
- Skat – Swiss Resource Centre and Consultancies for Development International Federation of Red Cross and Red Crescent Societies, 2012
- Skulmoski G. and Hartman F. (2007), *The Delphi Method of Graduate Research*, *Journal of Information Technology Education*, 6. 1-21
- Syagga P. M. (1993). Promoting the Use of Appropriate Building Materials in Shelter Provision in Kenya, *Habitat Intl.* 17(3), 125-136
- Syverson, C. (2007). Prices, spatial competition and heterogeneous producers: an empirical test. *The Journal of Industrial Economics*, 55(2), 197-222.
- Tom Hardiman (2014), *Health facilities management, Changing the way the world builds; Greener, Faster, smarter*, New York City: Modular Building Institute,

- Tommelein I.D. and Li A.E.Y. (1999), *Just\_In\_Time concrete delivery: mapping alternatives for vertical supply chain integration*, in Tommelein, I.D. and Ballard, G. (Eds), *Proceedings of the Seventh Annual Conference of the International Group for Lean Construction*, 26\_28 July, (pp. 97\_108). Berkeley: University of California
- Toole T.M., Hallowell, M. and Chinowsky P. (2013), A tool for enhancing innovation in construction organizations, *Engineering Project Organization Journal*, 3(1), 32–50.
- Toole, T. M. (1998). Uncertainty and home builders' adoption of technological innovations. *Journal of Construction Engineering and Management*, 124(4), 323-332.
- Tykkä, S., McCluskey, D., Nord, T., Ollonqvist, P., Hugosson, M., Roos, A., ... & Bajric, F. (2010). Development of timber framed firms in the construction sector—Is EU policy one source of their innovation?. *Forest Policy and Economics*, 12(3), 199-206.
- UN-Habitat (2004), *The State Of The Worlds Cities 2004/2005: Globalization and Urban Culture*, London, Earthscan, UN Habitat, 2009
- UN-Habitat (2010), *The State of African Cities 2010: Governance, Inequality and Urban Land Markets*, Nairobi, UN-Habitat.
- UN-Habitat (2011), *Africa affordable housing* (report), volume 3; Slum Dwellers to double by 2030, UN HABITAT report, 2007.
- UN-Habitat (2011). *Alternative building systems and methods to reduce housing deficit*, Nairobi: UN-Habitat.

UN-Habitat(2009),*Interlocking Stabilised Soil Blocks – Appropriate earth technologies in Uganda*, Retrieved from [www.unhabitat.org](http://www.unhabitat.org).

US DoE (2009b), *Builders Challenge Technical Bulletin, Dual Certification with the National Green Building Standard, Building Technologies Program*, United State Department of Energy.

Usman, M., Soomro, T. R., & Brohi, M. N. (2014). Embedding project management into XP, SCRUM and RUP. *European Scientific Journal*, 10(15), 293-307

Warren C. (2002), *Qualitative Interviewing*. In: *Gubrium, J., and Holstein, J., eds., (2002) Handbook of Interview Research: Context and Method*. New York: Sage Publications Limited.

Zeelenberg, M. (1999), *Anticipated regret, expected feedback and behavioral decision making*, *Journal of Behavioral Decision Making*, 12(2), 93\_106.

## **APPENDICES**



## Appendix A: Interview Invitation Letter



**JOMO KENYATTA UNIVERSITY**

**OF**

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Date: 8<sup>th</sup> October, 2015.

Dear .....

**Ref: Invitation to participate in a Research Project**

My Name is **Peter N. Ngigi**, I am a Post Graduate student undertaking a masters degree in Construction Project Management at Jomo Kenyatta University of Agriculture and Technology, School of Architecture and Building Sciences, department of Construction Management. In partial fulfillment of the requirements for the award of the degree, I am conducting an **\_Evaluation of Alternative Construction Technologies in the Delivery of Affordable Housing in Kenya\_**.

I am undertaking this research study under the supervision of Dr Stephen Diang'a and Dr Ahmad Alkizim both of Jomo Kenyatta University of Agriculture and Technology. The project has been approved by Board of Post Graduate Studies of JKUAT. I am inviting you to participate in this research project.

You have been selected to participate in this study as a stakeholder in one of the selected cases for the study. The aim of the study is to evaluate the performance of ACTs in Kenya. About sixty five respondents are expected to participate in the study. If you agree to participate, you will be required to attend a 25-35 minute interview on the performance evaluation of the ACTs. The interview will be conducted at your place of work or at a mutually convenient place of your choice.

The specific objectives of the study are to: (1) Assess the characteristics, quality and performance of building elements built with ACTs. (2) Describe the economic impact of ACTs. (3) Gauge the adoption rate of ACTs by developers, consultants and contractors.

Kindly consider my request.

Thank you in advance.

Yours faithfully,

**Peter N. Ngigi**

## Appendix B1: Questionnaire

### Respondent's particulars

1. Name and expertise of respondent:

.....  
.....

2. Experience with the alternative construction technologies:

1-5 years [ ]                                      5-10 years [ ]

11-20 years [ ]                                      More than 20 years [ ]

3. Location of the project undertaken using an alternative construction technology

.....

4. Type of building constructed:

a) Residential building [ ]

b) Commercial building - Retail [ ]

- Office [ ]

- Mixed use [ ]

c) Social building - Stadium [ ]

- Theatre [ ]

- Church [ ]

d) Industrial building [ ]

e) Civil works [ ]

5. Type of technology used:

.....

.....

6. On a scale of 1 – 5 where; (1) Poorest, (2) Poor, (3) Fair, (4) Good, (5) Excellent, rate the performance of this technology in terms of the following aspects:

	1	2	3	4	5
Aesthetics / beauty					
Cracks					
Structure					
Sound proofing					
Thermal insulation					
Stability					
User satisfaction					

7. On a scale of 1 – 5 where; (1) Lowest, (2) Low, (3) Fair, (4) High, (5) Very high, rate the performance of the technology in terms of the following aspects:

	1	2	3	4	5
Cost of construction					
Speed of construction					
Construction period					
Cost of materials					
Waste reduction					
Financial returns					
Maintenance costs					
Variations in the construction					
Better relationship with suppliers					
Installation of electrical conduits					
Installation of plumbing pipes					

8. To what extent would you consider the technology used in your project as a relatively economic method? Use a scale of 1 – 5 where; (1) No extent, (2) Little extent, (3) Moderate extent, (4) Great extent, (5) Very great extent

	1	2	3	4	5
Time schedule					
Productivity					
Quality control					
Waste reduction					
Better handling of materials					
Transport aspect					
Improving follow up and supervision					
Efficiency					
Output of labour crew					

9. Please rank the quality performance of the technology used in the building using the scale of 1 – 5 where: (1) Lowest, (2) Low, (3) Average, (4) High, (5) Highest

	1	2	3	4	5
Time	( )	( )	( )	( )	( )
Durability	( )	( )	( )	( )	( )
Completeness	( )	( )	( )	( )	( )
Consistency	( )	( )	( )	( )	( )
Neatness	( )	( )	( )	( )	( )
Compatibility with other services	( )	( )	( )	( )	( )
Risk allocation	( )	( )	( )	( )	( )

10. To what extent did the following influence costing of the construction? Use a scale of 1-5 where; (1) No extent (2) Little extent, (3) Moderate extent, (4) Great extent and (5) Very great extent

	1	2	3	4	5
Choice of work method					
Labour					
Selection of appropriate wastage allowance					
Overheads					
Weather					
Foundation laid					
Construction levies					
Remoteness of the site					
Design considerations (related to location)					

Vandalism and site security					
Power and Water					
Construction equipment costs					
Indirect Job costs					
Subcontractor quotations					
Contingency and risk allocation					
Errors in estimate formulation					
Basis of information used to formulate estimate					
Market forces					
Staging and project start up costs					
Escalation costs					

11. How do you rating the public knowledge of the technology used in your project?

Very little (1 ), Little (2 ), Averagely well (3 ), Fairy Well (4 ), Very well (5 ).

12. How would you rank the adoption rate of the technology used in your project?

Very low (1 ), Low (2 ), Average (3 ), High (4 ), Very high (5 ).

13. On a scale of 1 -5, where (1) Very low, (2) Low, (3) Average, (4) High and (5) Very high, how would you rating the technology used in delivering relatively cheaper and affordable houses.

1	2	3	4	5
---	---	---	---	---



14. What would be your suggestions to reduce errors in the technology used?

.....  
.....  
.....

15. What process improvement guidelines would you give to achieve better results?

.....  
.....  
.....

**Thank you for your co-operation and participation.**

## Appendix B2: Checklist

tem	Description	Comments
	<b>Structure</b>	
1	Substructure failure/settlement	
2	Superstructure structural defects : sagging/bent beams and columns	
3	Walls alignment: deflects/leaning /verticality	
4	Cracked walls	
5	Weathering – wearing away	
6	Roof structure	
7	Leaking roof cover	
	<b>Finishes:</b>	
8	Floors – chipped/cracked screeds/backing	
9	Wall – Cracked plaster	
10	Painting - discoloured/faded	
11	Ceilings	
12	Doors	
13	Windows	
	<b>Services defects</b>	
14	Electrical defects:	
	- Conduits	
15	Plumbing and Drainage defects	
	- Pipework	
16	Built in fittings and fixtures	
	- Wardrobes	
	- Kitchen cupboards	

**Appendix C1: Approved research letter from JKUAT Appendix C2:**

Appendix C1: Approval research letter from JKUAT



**JOMO KENYATTA UNIVERSITY  
OF  
AGRICULTURE AND TECHNOLOGY**



**DIRECTOR, BOARD OF POSTGRADUATE STUDIES**

P.O. BOX 62000  
NAIROBI - 00200  
KENYA  
Email: [director@bpps.jkuat.ac.ke](mailto:director@bpps.jkuat.ac.ke)

TEL: 254-067-52711/52181-4  
MOBILE: 0708-602225

REF: JKU/ BPS /AB343-0707/2013

17<sup>th</sup> October, 2014

Mr. Ngigi Peter Njoroge  
C/o Construction  
JKUAT

Dear Mr. Ngigi,

RE: APPROVAL OF MSc. RESEARCH PROPOSAL AND SUPERVISORS

Kindly note that your research proposal entitled: "Investigation of alternative economic construction methods- A case study of economic delivery of housing in Kenya " has been approved. The following are your approved supervisors:-

1. Dr. Stephen Diang'a
2. Prof. Crispino C. Ochieng

Yours sincerely

  
PROF. MATHEW KINYANJUI  
DIRECTOR, BOARD OF POSTGRADUATE STUDIES

Copy to: Dean, SABS  
COD, Construction

M




JKUAT is ISO 9001:2008 Certified  
Setting Trends in Higher Education, Research and Innovation

## Approved research Letter

### Appendix J: Factory panels Price list

**Appendix J: Factory Panels Price List**

**NATIONAL HOUSING CORPORATION**



National Housing Corporation  
P. O. Box 30257-00100 NAIROBI  
Tel: +254 312147/312149  
Fax : +254 (020) 311318  
E-mail: info@nhckenyaco.ke  
Website: www.nhckenyaco.ke

Your Ref: \_\_\_\_\_ Date: 27<sup>th</sup> November 2013

Our Ref: \_\_\_\_\_

RE: NHC-EPS FACTORY PANELS PRICE LIST

DESCRIPTION	WEIGHT IN KGS	SALE PRICE VAT INCLUSIVE KSHS
Single Panels 80mm	15.4	5,720
Single Panels 80mm	16.2	6,200
Double Panels 60mm-Density 15	32.2	9,530
Double Panels 60mm-Density 25	35.8	10,880
Floor Panels 200mm	34.6	10,400
Floor Panels 150mm-Density 15	19.2	7,140
Floor panels 150mm-Density 25	21.4	7,940
Concrete Wall flat mesh	1.8	640
Concrete Wall U-mesh 80mm	2.4	750
Concrete Wall angle mesh	1.8	690
Concrete Wall angle mesh	2.2	720

**Note:**  
1. All prices are inclusive of VAT  
2. Transport shall not be provided by the Factory

General Manager-M  
For: Managing Director

HOUSING FOR THE NATION

**Appendix C2: Approval research letter**



**JOMO KENYATTA UNIVERSITY  
OF  
AGRICULTURE AND TECHNOLOGY  
DEPARTMENT OF CONSTRUCTION MANAGEMENT**

P.O. BOX 62000-00200, NAIROBI, KENYA. TEL: (020)-8008485  
Fax: (067)-5352711 EXT 2475 Thika. Email: [conmgmt@naba.jkuat.ac.ke](mailto:conmgmt@naba.jkuat.ac.ke)

5<sup>th</sup> August, 2015

TO: To Whom It May Concern

Dear: Sir/Madam

**REF: PETER NJOROGI NGIGI AB343-0707/2013**

The above named is a bonafide student of Jomo Kenyatta University of Agriculture and Technology pursuing a Master Degree in Construction Project Management.

He is currently undertaking a research thesis titled "Economic Alternative Construction Methods a Study of Economic Housing Delivery in Nairobi.

Any assistance accorded to him will be highly appreciated.

Yours faithfully,

**DR. A. ALKIZIM  
COD. CONSTRUCTION MANAGEMENT**



*JKUAT/JKUAT is ISO 9001:2008 & ISO 14001:2004 Certified  
Setting trends in higher Education, Research and Innovation*



Appendix D: Permit

THIS IS TO CERTIFY THAT  
**MR. PETER NJOROGE MOGI**  
of JOMO KENYATTA UNIVERSITY OF  
AGRICULTURE & TECHNOLOGY,  
00062-000 NAIROBI, has been permitted  
to conduct research in Nairobi County

on the topic: **INVESTIGATION OF  
ALTERNATIVE ECONOMIC  
CONSTRUCTION METHODS - A CASE  
STUDY OF ECONOMIC DELIVERY OF  
HOUSING IN KENYA**

for the period ending:  
18th September, 2016

  
Applicant's  
Signature

Permit No : SACOST/P/16/1170/2009  
Date of Issue : 18th September, 2016  
Fee Received (KSh 1,000)



**The Director General**  
National Commission for Science,  
Technology & Innovation

Appendix D: Permit

**CONDITIONS**

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, digging and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two (2) hard copies and one (1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

  
REPUBLIC OF KENYA

  
National Commission for Science,  
Technology and Innovation

**RESEARCH CLEARANCE  
PERMIT**

Serial No. A **6552**

CONDITIONS: see back page

## Appendix E: Appendix NACOSTI Letter

**Appendix E: NACOSTI Letter**



**NATIONAL COMMISSION FOR SCIENCE,  
TECHNOLOGY AND INNOVATION**

Telephone: +254-20-2213471,  
2241349, 310571, 2219420  
Fax: +254-20-318245, 318249  
Email: secretary@nacosti.go.ke  
Website: www.nacosti.go.ke  
When replying please quote

9<sup>th</sup> Floor, Utalii House  
Uhuru Highway  
P.O. Box 30623-00100  
NAIROBI-KENYA

Ref. No. \_\_\_\_\_ Date: \_\_\_\_\_

18<sup>th</sup> September, 2015

NACOSTI/P/15/3170/7589

Peter Njoroge Ngigi  
Jomo Kenyatta University of Agriculture  
And Technology  
P.O. Box 62000-00200  
NAIROBI.

**RE: RESEARCH AUTHORIZATION**

Following your application for authority to carry out research on *"Investigation of alternative economic construction methods – A case study of economic delivery of housing in Kenya"* I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for a period ending **18<sup>th</sup> September, 2016**.

You are advised to report to **the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

  
SAID HUSSEIN  
FOR: DIRECTOR GENERAL/CEO

Copy to:

The County Commissioner  
Nairobi County.

The County Director of Education  
Nairobi County.

**COUNTY COMMISSIONER  
NAIROBI COUNTY  
P. O. Box 30134-00100, NBI  
TEL: 341555**

**COUNTY DIRECTOR OF EDUCATION  
NAIROBI  
24 SEP 2015  
MINISTRY OF EDUCATION  
P. O. Box 74629, NAIROBI**

National Commission for Science, Technology and Innovation is ISO 9001:2008 Certified

## **Appendix F: Sampling Frame:**

### **Projects Constructed Using ACTs (2004-2014)**

1. Silver Springs hotel extension (2007)
2. Balozi housing (2005)
3. Residential house extension, Ngei estate Lang'ata road
4. Residential maisonettes in Ongata Rongai
5. Ruai police housing scheme
6. Mixed use (office and apartments) Roysambu, Thika road
7. Students hostels at state house
8. Flats extension in Kahawa Wendani, Thika road
9. Flats development at Githurai
10. Conversion of school to hotel, Adams Arcade, Nairobi
11. Office block in Kilimani, Nairobi, Lenana road – steel/glass
12. Canadian Embassy extension, Gigiri, Nairobi
13. Children housing in Ministry of Culture and Social Services, Kangundo road, Nairobi.
14. Flats development in Ongata Rongai, Kajiado County.
15. Residential maisonette housing in Kitengela, along Namanga road
16. Residential bungalow housing along Mombasa road



## Appendix G: Interviewed Respondents

### LIST OF INTERVIEWED RESPONDENTS

<b>Case study project</b>	<b>Consultants</b>	<b>Contractors</b>	<b>Developers</b>	<b>Users/ Residents</b>	<b>Total</b>
Githurai Block of Flats	5	3	1	1	<b>10</b>
Ruai Police Housing Scheme	2	2	1	3	<b>8</b>
Balozi housing scheme	4	3	1	3	<b>11</b>
Mixed development (offices & apartments)	1	2	1	1	<b>5</b>
Kahawa wendani (flats)	1	1	1	-	<b>3</b>
<b>Totals</b>	<b>13</b>	<b>11</b>	<b>5</b>	<b>8</b>	<b>37</b>

## **Appendix H: Costs Comparison**

### **Conventional and Alternative Construction Technology**

#### **Secondary Data**

The conventional construction cost for residential houses in Nairobi averages KES 38,250 per m<sup>2</sup> (The Quantity Surveyor, 2013). Comparatively, the construction cost per square meter using EPS wall panels is KES 25,520/- per m<sup>2</sup>. This means a reduction of construction cost by approximately 33% (Kenyan magazine \_\_, The Joint Building Council price list October – December 2013)

The construction of a square meter of wall using expanded polystyrene technology, material costs were KES 2,290/- and labour costs KES 1,500/- with an additional 10% of total cost for contingencies, totaling to KES 4,169/- (Kageni, 2014).

Construction of a square meter of wall using stone and mortar method, material costs were KES 1,360/- and labour costs KES 3,000/- with an additional 10% of total cost for contingencies, totaling to KES 4,906/- (ibid)

A standard fifty (50) square meter two bedroom house built with EPS wall panels is estimated to cost KES 700,000. This is before finishing (Kagai, 2014). It is nearly half the cost when using stones and bricks. Thus lowering construction cost by up to 30%.

## **Appendix I: Manufacturers Data on Alternative Construction**

### **Technology**

#### **Secondary Data**


Using EPS technology, a three bedroom stand alone house takes approximately 14 days to build, a two storey maisonette can be built in 40 days and a five storey building takes approximately six months to build. Classrooms take as little as 10days (Boleyn Magic Wall (BMW) Panel Ltd.), a Panels Construction Company.

A sample house has been built in Mlolongo area in Machakos County at a cost of Kshs. 18,000/= per square meter. Conventional building methods cost above Kshs. 30,000/= per square meter for a standard building (B.M.W. Construction Co.). The above cost of construction is exclusive of the cost of fencing, septic tank, sewer line, and power supply and water connection. The rate also excluded transport costs of transporting the building materials from the factory.

## Appendix J: Factory panels Price list

**Appendix J: Factory Panels Price List**

**NATIONAL HOUSING CORPORATION**



National Housing Corporation  
P. O. Box 30257-00100 NAIROBI  
Tel: +254 312147/312148  
Fax : +254 (020) 311318  
E-mail: info@nhkenya.co.ke  
Website: www.nhkenya.co.ke

---

Your Ref: \_\_\_\_\_ Date: **27<sup>th</sup> November 2013**

Our Ref: \_\_\_\_\_

**RE: NHC-EPS FACTORY PANELS PRICE LIST**

---

DESCRIPTION	WEIGHT IN KGS	SALE PRICE VAT INCLUSIVE KSHS
Single Panels 60mm	15.4	5,720
Single Panels 80mm	16.2	6,200
Double Panels 60mm-Density 15	32.2	9,530
Double Panels 60mm-Density 25	35.8	10,880
Floor Panels 200mm	34.6	10,400
Floor Panels 150mm-Density 15	19.2	7,140
Floor panels 150mm-Density 25	21.4	7,940
Concrete Wall flat mesh	1.8	640
Concrete Wall U-mesh 80mm	2.4	750
Concrete Wall angle mesh	1.8	690
Concrete Wall angle mesh	2.2	720

**Note:**  
1. All prices are inclusive of VAT  
2. Transport shall not be provided by the Factory

General Manager-M  
For: Managing Director

---

HOUSING FOR THE NATION

## Appendix K: EPS Factory panels price list

Appendix K: EPS Factory Panels Price List

27/01/2015

 **BOLEYN MAGIC WALL PANEL LTD.**  
P. O. BOX 18056-00500, NAIROBI, KENYA TEL: +254-20-3591088

Your Ref:

Our Ref:

### RE: EPS FACTORY PANELS PRICE LIST

<u>DESCRIPTION</u>	<u>Thickness</u>	<u>SALE PRICE VAT INCLUSIVE</u> <u>KSHS</u>
Single panels	80mm	5600 - 5500
Double panels	80mm	9500 x
Floor panel	200mm	8500 - 7500
Concrete wall flat mesh	80mm	200
Concrete wall u-mesh		200
Concrete wall angle mesh		200
Staircase Panel(Pair)		35000

#### Note:

- All prices are inclusive of VAT.
- Transport to be provided for by the company for clients within Nairobi area.
- All Panels Size: 3m high by 1.2m length.

Sales Manager


For Sales Executive

---

MAKING HOUSING AFFORDABLE A REALITY

## Appendix I: concrete price list

Appendix I: Concrete Price List



# Bamburi

*Quality you  
can build on...*

**2011 PRICE GUIDE**  
This price guide supersedes all previous lists  
and is subject to change without notice.

CONCRETE CLASS	C15		C20		C25		C30		C40	
	Pump	Skip	Pump	Skip	Pump	Skip	Pump	Skip	Pump	Skip
Unit Price	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>	M <sup>3</sup>
Price M <sup>3</sup>	8,900.00	8,750.00	9,157.00	9,119.00	10,091.00	9,912.00	10,542.00	10,421.00	12,264.00	11,903.00
Pump M <sup>3</sup>	660.00	-	660.00	-	660.00	-	660.00	-	660.00	-
Mobile Pump per M <sup>3</sup>	495.00	-	495.00	-	495.00	-	495.00	-	495.00	-
Transport-Radius of 25KM M <sup>3</sup>	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00	1,328.00

NB: Rates for distance more than 25 Km will be calculated separately.  
Hiring of Boom pump at the rate of 35,000.00 per DAY

All prices are subject to applicable V.A.T.  
This document must be read in conjunction with Bamburi Special Products Ltd. standard conditions of sale