AN INVESTIGATION INTO FACTORS CAUSING MATERIAL WASTE AND THEIR INFLUENCE ON RESIDENTIAL CONSTRUCTION COST IN NORTHERN NAIROBI.

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An Investigation into Factors Causing Material Waste and their Influence on Residential Construction Cost in Northern Nairobi.

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DECLARATION.

This thesis is my original work and has not been presented for a degree 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.

I dedicate this thesis to my family, who are my wife Winnie Mbote, our children Salphina, Samuel, Miriam, Ann and Alex for standing with me throughout this thesis programme.

ACKNOWLEDGEMENT.

I give special thanks to the staff at Construction Management department of Jomo Kenyatta University of Agriculture and Technology, for their support in providing me with necessary assistance whenever the need arose. I also appreciate the respondents who participated in providing the data which formed the core for this research.

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Since this has been my original work, i do take full responsibility for any errors and omissions which may be contained herewith in this thesis.

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ACRONYMS /ABBREVIATIONS

IBS	Industrialized building systems.
IQSK	Institute of quantity surveyors of Kenya.
KBS	The Kenya bureau of standards.
NCA	National construction authority.
NCC	Nairobi City County.
NEMA	National environmental management authority.
TQM	Total Quality Management.
SPSS	Statistical Package for Social Science.
UNDP	United nations Environmental Program.
IWMP	Integrated waste management plan.
TOC	Theory of constraints.
TPB	Theory of planned behavior

DEFINITION OF TERMS.

Conventional building. The common accepted traditional building construction practices.

Industrialized Building. The prefabrication and construction industrialization concept using mass-production.

Lean Construction. A production management-based approach to project delivery.

Building element. A major part of the building, which always performs the same function irrespective of location or specification.

Residential building frame. Residential building composed of substructures, superstructures and the roof without any finishes.

ABSTRACT

Large amounts of material waste are generated in residential building construction in Northern Nairobi, where conventional construction methods are predominant. This may be attributed to lack of cost effective building materials, technologies and material waste management systems in the region. The main objective of this study was to recommend an alternative approach to construction of residential buildings in Northern Nairobi, whose utilization results in material waste minimization. Reduction of material waste in residential construction results in cost saving to the client and to the contractor. The study investigates factors causing material waste, and establishes the extent to which these factors explain the cost of residential building construction in Northern Nairobi. The research was designed as a case study and survey. Purposive sampling was used in selection of the Northern Nairobi because of its high concentration of residential housing projects. Convenience sampling was used to select project consultants in the research area. Primary data was collected through interviews and observations. Descriptive statistics, correlation and multiple regression aided by the Statistical Package for Social Sciences (SPSS) was used for data analysis. The results show poor or complex designs, lack of security, poor work conditions and topography as the factors causing material waste which can significantly predict the cost of residential building frame construction in this region. The study noted that, 69% of building developers prefer labour contracting option despite its high contribution to material wastage. Significant factors to be addressed in minimization of materials waste during construction include: quality purchases, experienced artisans/materials handlers, adequate supervision on material handling, scheduled material delivery and good material storage practices. There is also need to adopt new technologies in construction of residential buildings in this region.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study.

Construction of residential buildings, using the conventional methods produces a variety of material waste. Residential construction sector generates unacceptable levels of material waste leading to: misuse of manpower, financial loss to contractors, significant impacts on health, aesthetics and environmental degradation. The amount and type of material waste depends on stage of construction, type of construction work and practices on site. Waste minimization in implementation of a residential building project is a major area of concern, including waste management. Bosinnk and Brouwers (1996), assert that, materials in a residential building project amounts to about 60% to 70% in the overall cost of construction. It is difficult to systematically measure all wastes in a residential building project but various studies have confirmed that waste represents a large percentage of production costs. This can result to between 1-10% by weight of purchased materials (Bosinnk & Brouwers, 1996; Masudi, Hassan, Mahmood, Mokhtar, & Sulaiman, 2012). Reduction in material waste during construction of a residential building project can increase a contractor's competitiveness through lower production costs. Generally, residential building construction activities which produce material waste can be grouped into off-site and on-site operational activities. Off-site activities include: prefabrication, project design (architectural, structural, mechanical and electrical design), manufacturing, transporting of materials and components. On-site construction activities relate to construction of a physical facility which consists of the substructure and superstructure of the building (Muhwezi, Chamuriho, & Lema, 2012).

The amount of construction waste generated in any region or nation depends on the general economic conditions of the vicinity, the weather, major disasters, special projects, and local regulations. Waste generated in construction sites varies from one country to another (Masudi, et al. 2012).Previous studies indicate that the total waste generated in Netherlands, Australia, U.S.A, Germany and Sweden ranges between 19-35% of construction project cost (Bosinnk & Brouwers, 1996). A study by Mahayuddin and Zaharuddin (2013) in Malaysia proposes four steps in quantification of waste in conventional construction: identification of construction stages and materials used; identification of construction sites; weighing of construction waste and calculation of waste generated according to each stage of construction.

In Nigeria, construction sites are characterized with large quantities of construction material waste. This leads to high cost of construction and becomes a hindrance to good affordable housing. This is as a result of improper control of materials during different stages of construction (Oradiran & Olatunji, 2009). Muhwezi,et al. (2012) carried out a study in Uganda and outlined the following factors as main contributor to material waste: defective procurement procedures; changes made to the design while construction is in progress; lack of skills of workers or contractors; purchased products that do not comply with specifications; inappropriate storage facilities on site leading to damage or deterioration; changing instructions by supervisors or architect; severe weather conditions; each with different categories of waste generation.

In Kenya, material waste in construction is not only focused on the quantity of waste of materials on site, but also to several activities in design and construction phase (Kioko, 2007). These factors are significant in cost, quality and time performance of a project. The construction industry in Kenya predominantly employs the conventional method of construction. This method of construction generates considerable volumes of material waste such as concrete rubble, natural stone rubble, and block rubble and timber off-cuts. According to Angaya (2012), the lean method of construction, a major focus for waste reduction in construction process is rare in Nairobi. The material waste generated ends up being used as fire wood, rubble filling while other materials are thrown away into Nairobi city county dump sites. Nugroho et al. (2013) opine that, construction waste may increase the project cost to about 6%. Therefore, if managed properly, a saving of 6% of the project cost can be realized.

1.2 Statement of the problem.

Production systems of residential building construction projects in the Northern Nairobi are predominantly conventional, which generates large amounts of material waste. There is lack of cost effective building materials, technologies, and material waste management systems in residential building sites in this region. Whereas some proportion of construction waste is inevitable, even under perfect conditions of design and construction, generation of excessive material waste in the construction process is an area that has not been accorded proper attention by studies in Nairobi built environment.

Kenya vision 2030(2007) envisaged production of 200,000 housing units annually by 2012 through different initiatives. The Ministry of Land, Housing and Urban Development was charged with the responsibility of promoting and improving living environment for the citizens, promotion of low cost housing development through research on cost-effective building materials and technology. The main objective was to facilitate Kenyans access quality, affordable and sustainable housing. This however, has been hampered by a number of challenges, the main one being the high cost of building materials. According to “Economic survey” (2014), cited in Mwaniki (2014), the cost of construction materials increased, with the impact being reduction of completed residential houses from 7339 to 6016 in the year 2012.The article further notes that the overall cost of materials increased to 5.7% in 2013 from 4.3% in 2012 and the overall total cost increasing to 7.2% in 2013 from 5.6% in 2012.

Similar studies which have been undertaken in other parts of the world have identified factors contributing to construction material waste. This study sought to identify and establish the predictive strength of various factors that contribute to materials waste on overall building cost in Northern Nairobi.

1.3 Study hypotheses.

The null and alternative hypotheses for the study are as follows:

$H_{O.}$ There is no relationship between factors causing materials waste and construction cost of residential building frames in Northern Nairobi.

$H_{A.}$ There is a relationship between factors causing materials waste and construction cost of residential building frames in Northern Nairobi.

1.4 Objectives of the study.

The main objective of this study is to suggest an alternative approach of technology and management in construction of residential building frame in Northern Nairobi.

Specific objectives are as follows:

1. To identify factors that contributes to material waste in construction of residential building frame in Northern Nairobi.
2. To establish the extent of impact of various causes of material waste on cost of construction of residential building frame in Northern Nairobi.
3. Develop measures for minimizing material waste in construction of residential building frame in Northern Nairobi.

1.5 Research questions.

The questions guiding this study are as follows:

1. What are the main factors that contribute to material waste in construction of residential building frame in Northern Nairobi?
2. What is the extent of relationship between factors contributing to material waste and the construction cost of residential building frame in northern Nairobi?
3. What measures can be put in place to minimize material waste generated in construction of residential building frame in Northern Nairobi?

1.6 Study justification.

Reduced cost of residential building construction would encourage home developers to increase the production of residential buildings and thereby alleviate the shortage of housing in Nairobi. Large amounts of material waste are generated in residential building construction projects in Northern Nairobi, where conventional methods are predominant. There is need for studies to be undertaken so as to establish the extent to which factors contributing to residential building construction material waste predict the overall building cost in Northern Nairobi.

A study carried out in the northern Nairobi serves to inform the best approach in reduction of material waste in residential building construction. This is also in line with the Government initiative of carrying out research in providing cost effective housing to the Kenyan citizens (Kenya vision 2030, 2007).

1.7 Significance of the study.

The research explores the factors attributed to material waste and the cost effect in construction of residential housing in Northern Nairobi. The results of the findings provides an understanding of the predictive material waste cost effect in conventional construction of residential buildings with a view to exploring alternative new technology to minimize cost of construction. This will encourage residential house developers and the government to realize the dreams of affordable housing to the citizens.

The study contributes to the body of knowledge in residential building waste management systems. The research also forms a basis for contribution to policy in minimization and sustainable management of material waste in residential building projects in the city of Nairobi.

1.8 Scope of the study.

1.8.1 Geographical scope.

Northern of Nairobi city is a middle class area composed of several residential estates, each with different categories of residential building projects. The land in this area is subdivided in sizes of 1/16, 1/8 and I/4 acre plots where residential apartments and maissonettes are built. These estates are next to Thika superhighway which has encouraged residents to start many projects within the region.

This research is confined to Kasarani and Clay City estates indicated in figures 1.1 and 1.2 within Northern Nairobi.

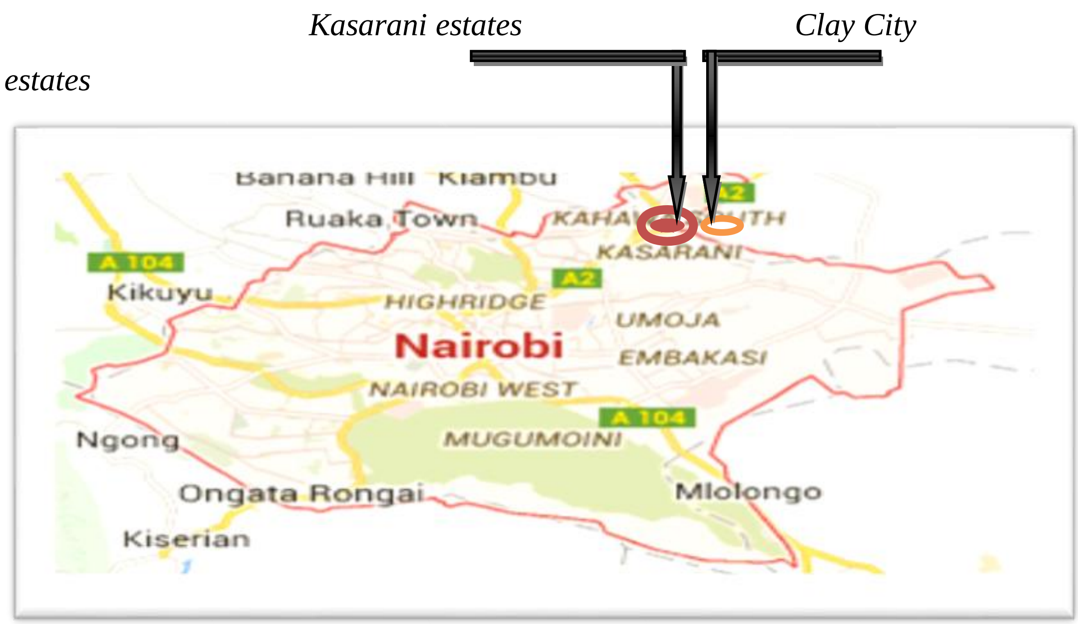

Figure 1.1 Nairobi province map (Source: Google map 2015).

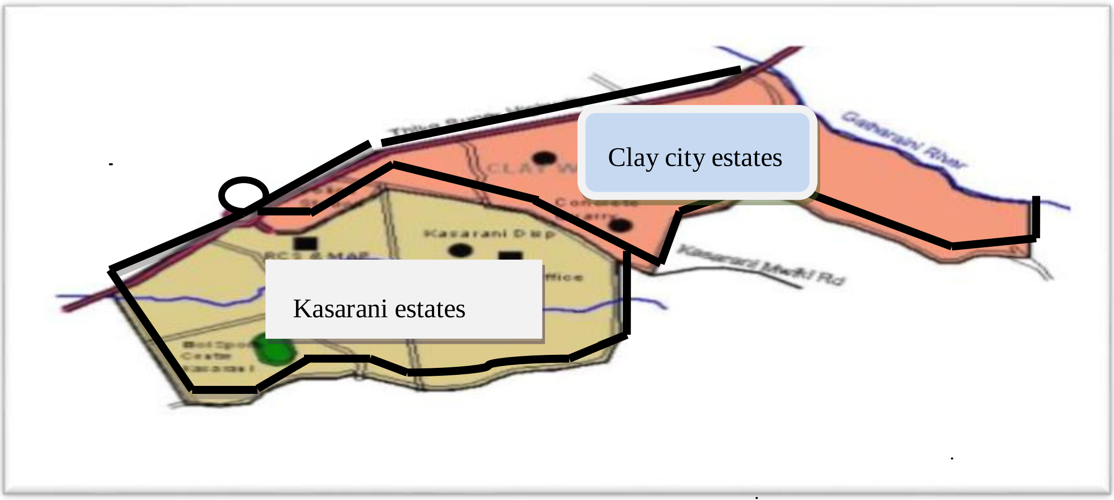

Figure 1.2 Kasarani and Clay City estates (source: Survey of Kenya1997)

1.8.2 Scope of residential building projects.

Residential building projects within the Northern Nairobi city are wide and varied. These projects include bungalows, maissonettes, and walk-up flats. The projects are developed for individual residential use, multiple residential houses for sale or multiple rental residential houses. This study explored factors attributed to material waste on maissonettes and residential walk-up flats which were the only categories with required criteria for this study within the Northern Nairobi.

1.8.3 Methodological scope.

Purposive sampling is used to select the region in Nairobi City with the appropriate residential building projects for a detailed inquiry. Convenience sampling is used to identify project consultants, operating within the area of study, to provide data required for this study. Structured interviews and structured observation formed the primary data collection instruments for this study. Data collected was analyzed through descriptive statistics, correlation and multiple regression aided by the Statistical Package for Social Sciences (SPSS).

1.9 Organization of the study.

The first chapter in this study introduces the study background, the problem statement and also describes the specific problem addressed in the study, including design components. The second chapter presents a review of literature and research materials associated with the problem addressed in the study. Chapter three contains the procedure and methodology used for data collection and analysis. Chapter four is composed of data analysis and results presentation. Chapter five contains a summary and discussion of research findings, implication for practice, including recommendations and a suggestion of areas for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature associated with material waste in residential building construction projects is presented in this chapter. The review is generated from research journals, text books, research theses, conference papers and other published works relevant to this study. The chapter also highlights the theoretical framework and conceptual framework underpinning this study.

2.2 Concept of construction waste.

2.2.1 Waste.

Formoso, Isatto, and Hirota, (1999) defines waste as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client or contractor.

Regarding the possibility to control the incidence of waste, Shingo (1989), cited in Formoso, et al. (1999), argue that, there is an acceptable level of waste, which can only be reduced through a significant change in the level of technological development. The study suggests that, waste can be classified in: Unavoidable waste, in which the investment necessary to its reduction is higher than the economy produced; avoidable waste where the cost of waste is significantly higher than the cost to prevent it. The research by Shingo (1989), cited in Formoso, et al. (1999), further notes that the percentage of unavoidable waste in each process depends on the organization and on the particular site. Waste can also be classified according to its origin, i.e. the stage that the main root cause is related to. Although waste is usually identified during the production stage, it can be originated by processes that precede production, such as materials manufacturing, training of human resources, design, materials supply, and planning. The causes of material waste in building projects can mainly be classified based on overproduction, substitution, waiting time, transportation, processing, inventories and movement.

The production process of residential building construction requires an integrated and rationalized approach so as to minimize material waste and realize an economical product. The technological techniques used in a particular site may play a major role in mitigating the generation of construction waste. Conventional method of construction which is common in the Northern Nairobi generates considerable level of material waste and these methods do not provide a well-coordinated approach during construction, with a view towards waste minimization.

2.3 Categories of material waste in building sites.

There are different categories of material waste in the building construction process. Factors leading to their waste are many and quite diverse. Shen et al (2004) cited in Nurzalikha, Zulhabri and Zarina (2016) defines construction wastes as any building materials, concrete, steel, timber and other materials which are arising from various construction activities. Muhwezi, et al. (2012) describes waste as the extravagant or ineffectual use of resources and to some extent is inevitable. However, the cause, nature and amount of waste can be controlled right from design, through manufacture, to the construction processes. Classification of construction waste can be organized under Shingo's seven wastes) as cited in Meghani, Bhavsar, Vyas, and and. Hingu (2011) and Formoso, et al. (1999): Overproduction, substitution, waiting time, transportation, processing, inventories, movement and production of defective products. Also other waste of any nature such as burglary, vandalism, inclement weather and accidents are also considered.

According to Howard (1970) cited in Muhwezi,et al. (2012), construction materials wastage can be classified into six broad categories: conversion waste, cutting waste ,application waste, stockpile waste, residue waste and transit waste. Classification of wastes as suggested by (Shingo, 1989) cited in Meghani, et al. (2011) and Formoso, et al. (1999) delves on production processes where there is technological advancement, standardization and rationalized approach to construction processes. There is need however for proper statutory regulations and policies for the industry at large to help curb the ever increasing construction material waste which poses environmental and financial setbacks during construction.

2.3.1 Concrete wastes in construction sites.

Concrete wastes constitute the major proportions of the total waste generation in a construction project (Shen, Vivian, Tam, & Drew 2004). The main causes of concrete waste generation include: demolished concrete, over-ordering, variations between drawings and construction work, poor communication, on-site concreting activities, default from design drawings; design variations and default from deliveries (Wang, Kang & Tam 2008). According to Shen, et al. (2004), concrete is the most widely used material both for substructure and superstructure of buildings. The wastage is mainly from the mismatch between the quantity of concrete ordered and that required in the case of ready mix concrete supply. The contractor may not know the exact quantity because of imperfect planning, leading to over-ordering. Waste also results from project delays and unnecessary waste handling processes.

Formoso, Soibelman, Cesare, and Isatto (2002), argues that the main causes of concrete waste are lack of proper procedures in construction of some structural elements, poor design of the concrete formwork system, imprecision of the measuring devices, and flaws in the formwork assembling process. He also states that some waste of concrete is generated during the handling and transportation operations on site, related to site layout problems and to the use of inadequate equipment. Site managers often order an additional allowance of concrete so as to avoid interruptions in the concrete-pouring process, which sometimes results in a surplus of concrete. This may be attributed to uncertainty in actual material consumption needed.

Concrete as a construction material can be quantified depending on the location to be concreted. There is need for qualified personnel and enhanced management in material waste control practices since these are likely to be the major contributor of concrete waste in construction sites.

2.3.2 Steel reinforcement waste in construction sites.

Steel reinforcement provides reinforced concrete the tensile strength, stiffness, and ductility needed to make it an efficient, durable, versatile, and safe building material

Formoso et al. (2002) infer that, controlling use of steel reinforcement in building sites is difficult since it is cumbersome to handle due to its weight and shape. The study suggests three main reasons for steel reinforcement waste during construction: short unusable pieces when bars are cut; some bars may have excessively large diameters which cause fabrication problems and pilfering. The study also reveals that more waste is experienced in sites where the structural design is not standardized in detailing, due to non-optimized cutting of bars. Desale and Deodhar (2013) points out improper bar bending schedules, cutting of reinforcement, scrap management improper bending, small pieces not used and negligence as the major factors causing wastage of reinforcement on site and amounts up to about 6% to 14%.

2.3.3 Wood waste in construction sites.

Wood waste refers to timber products, such as formwork, false work, plywood, dimensional lumber, framing, roof truss and others not properly utilized (Lau, Whyte, & Law 2008). According to Wang, et al. (2008), major sources of timber wastes are unused timber due to deformation or deterioration on site and unnecessary timber offcuts. This may be attributed to periodic usage of formwork timber, storage, construction activities, none-standardized design, human behavior, inexperience among workers and supervision on site.

A study carried out in by Wilson, Skitmore, Martin, and Seydel (1997), opine that the majority of timber waste is generated during the formwork process. Waste occurred from work undertaken on the materials to make them suit the required shape, size of the formed concrete and due to rough stripping methods. Good planning by the contractor to make formwork 'fit' with minimal modification and better care during the stripping of formwork would have contributed to reduction of waste. Problems also included the careless contamination of timber with foreign substances such as mortar or other waste. Lau, et.al.(2008) carried out a pilot study in Malaysian construction waste management and found that 30 % of the wood turned into waste at the end of the construction, where the remaining 70 % would be reused. Reuse of construction wood material would be considered as a waste if not used for its original purpose.

2.3.4 Natural stone waste in construction.

Natural stone industry generates large volume of stone waste. The stone waste cause environmental, health and economical drawbacks. Due to the huge amounts of stone waste generated in construction sites, vast sums of money is spent on its transportation to landfills (Shirazi,2011).

2.4 Causes of building material waste on construction sites.

Different construction processes impacts on material waste generation, including the quantity of waste produced. This may be attributed to a number of factors such as: inaccuracy in ordering, oversupply handling errors, damages, inadequate storage, co-ordination, rework, low quality work and inefficiency (Waste & Resource Action Programme WRAP 2007).

Oladiran and Olatunji (2009) argues that the causes of material waste in construction process are: uneconomical shape of the building and components due to design, building failure/defects, workers' mistakes, theft, vandalism, inconclusive specifications, estimators' errors, ineffective communication, unfamiliarity with alternative products, design changes, lack of proper supervision, loading and unloading of materials, various forms of materials packaging, substandard materials, poor site layout, misinterpretation of drawings, poor site conditions, setting out errors, and improper transportation of materials.

A study by Branco (2007) concurs with Oladiran and Olatunji (2009) and reveals that the most dominant types of waste occurring in construction projects are: waste of materials, over allocation of materials, rework, clarifications, unnecessary handling of materials, inefficient movement of workers, waste of space on site, and delays. The most common causes, for the occurrence of these types of waste include: poor design and specifications, not enough information, ambiguous information, poor jobsite layout, poor planning, lack of control, excessive quantity of materials, lack of work place available, weather conditions, poor qualification of production team, and ineffective work methods.

According to a study carried out by Muhwezi, et al. (2012) in Uganda, changes made to the design while construction is in progress; changing orders/instructions by supervisors; inappropriate storage facilities on sites, lack of coordination between the main contractor and subcontractor, purchased materials that do not comply with specifications and severe weather conditions rank as the most significant waste attributes on sites in their respective categories. A study carried out by Kioko (2007) highlights thirteen factors which are significant variables that influence waste: productivity, contractors influence over design, method of communication between contractors and design consultants, incorporation of waste minimization in processes, lack of trade skills, slow and poor decision making, poor planning and scheduling, inappropriate construction methods, poor design, delay in equipment arrival, frequent equipment breakdown, materials not meeting specifications and lack of effective supervision. These factors are significant in cost, quality and time performance of a project.

The generation of excessive construction material waste may also be attributed to lack of a proper waste management policy within an establishment. Most construction companies and residential house developers needs to be educated on the benefits of proper waste management practices and need for better approach in technology with a view to minimize residential construction material waste.

2.5 Quantifying construction waste

There are a number of models for quantification of construction waste which cannot be universally applicable, as the amount of construction waste generated in any region or nation depends on the general economic conditions of the vicinity, the weather, major disasters, special projects, and local regulations (Masudi, et al. 2012). According to Bosinnk and Brouwers (1996), waste generated in construction sites varies from one country to the other. The total waste generated in Netherlands amounts 26% (Lanting, 1993) cited in Bosinnk and Brouwers (1996), in Australia about 20-30% (craven, et al 1994) cited in Bosinnk and Brouwers (1996). In U.S.A about 20% of waste is generated (Minks, 1994) cited in Bosinnk and Brouwers (1996) and 19% is generated in Germany (Brooks et al., 1994) cited in Bosinnk &

Brouwers (1996). After carrying out inventories of waste in Sweden, Josephson and Saukkoriipi (2007), observed that 30-35% of construction projects cost goes to waste although it varies between projects.

In a study carried out by Jilali (2007), quantification of wastes by relevant type is essential for the management and organization of a construction site, as well as the provision of logistics for waste management. Prior to the start of actual construction activities, it is essential to carry out a thorough analysis of the project, construction processes and materials that will be used. The schedule of the construction work is an essential tool, as it provides the timetable for waste generation and thus the required information on the logistics of the waste management for any given time span. Jilali (2007) also proposes the following approaches for the estimation of construction wastes:

- *Global index approach.*

  This is based on the global data from similar construction types that provides the amount of waste per square meter of construction. The global data is gathered from previous construction works and registered on data files and are used as a global index for a given construction. This index can be used for quantification of waste from a region or even from the whole country.

- *Component index.*

This approach provides the amount of waste generated from each construction Component or component that composes the project. The construction component has a specific function in the building and is usually performed by a given professional on the site. The construction component has a unit of its own such as unit area or volume.

A study by Mahayuddin and Zaharuddin (2013) in Malaysia on waste quantification for conventional construction infer that, successful, practicable and unified quantification of waste should be addressed to the expected waste for every stage of construction, parameters for waste generation developed to help construction personnel in proper planning of construction waste management, standard parameters for construction stages, the building elements, construction activities and its expected major types of construction waste identified and developed, quantification of construction waste should be conducted for every stage of construction, cooperation from the construction personnel and standardization of classification of construction waste type. The study proposes four steps in quantification of waste in conventional construction: identification of construction stages and materials used; identification of construction sites; weighing of construction waste; calculation of waste generated according to each stage of construction. The construction waste generation rate can be calculated using the equation. $C = \frac{W}{GFA}$

Where: W = total waste generated from each construction stages of the project (ton)

GFA = gross floor area, *C* = waste generation rate (i.e. construction of 1 m^2 floor area generates C ton of waste). Poon, et al. (2007), cited in Mahayuddin and Zaharuddin (2013).

Nugroho, Tongthong, and Shin (2013) proposed a system for quantification of construction waste based on images as data and digital image processing as a technique. Measurement of volume is based on the geometric shape of the waste stack. It was tested on conical and validation using the truck capacity. The system showed the difference of volume was 0.53 cubic meters (the percentage error about 11.71%) compared to the truck capacity. The quantification system proposes ordinary image and the smoothed shape to measure the volume of construction waste.

The models for material waste quantification in the various studies dwells mainly on construction and demolition waste. There is need however to differentiate construction waste and demolition waste if the goal is to establish the predictive cost of construction due to materials which goes to waste during construction. Demolition in construction is carried out as an end of life of a facility, make modifications to the construction or due to mistakes during construction. This aspect of material waste ought to be categorized separately so as to understand its cost and environmental implication in construction process.

2.6 Waste minimization in construction.

2.6.1 Reduction of building waste.

According to Josephson and Saukkoriipi (2007), reducing waste in building projects is one of the main challenges and should be among the priorities in the building sector as a whole. The first step is to create broad insight into and ability to judge what activities increase value and those that create waste. This can be achieved by: Broad education to all workers and suppliers, strong focus on main process in the project, focus on manufacture and make inventories to gain knowledge of the size of different types of waste.

According to Resource venture (2005), three strategies to reduce a construction project's waste can be grouped as: Reduce by finding ways to prevent and identify potential wastes early in the design process; reuse by identifying waste that can be salvaged for reuse on current project, on another project or donated and recycle by figuring out which waste materials can be recycled. Identifying potential waste early in the design process decreases waste generated during construction.

A study by Saukkoriipi (2007) on "Waste in construction projects" suggests possible directions to reduce material waste as: focus the key process of the project on the needs of the client; train and motivate every employee; focus on production; use the help of Local County. This concurs with a study by Wang, et al. (2008) which recommend: enforcement of legislation, training and education, involving environmental consideration in design and tendering reports, on-site management systems and improvement of communication. Al-Hajj and Hamani (2011) infer that to minimize material waste, staff training, adequate storage, and just- in time delivery of materials, waste measurement and waste segregation are areas that need more efficient implementation to achieve material waste minimization targets.

According to Rilem (2000), generation of construction waste can be reduced through careful design, waste prevention at the site and improvement of the quality of the remaining waste on site. The authors further argue that the client, the architect and contractor can significantly contribute towards waste minimization. The authors also suggests the following categorization of construction waste: Immediate reusable if in good condition (wood and steel); reuse and beneficial application after processing (masonry rubble and concrete); incineration (paper, wood, fabrics); production of new materials after processing (wood, metal, glass, plastics); contaminated non reusable materials (chemical waste and asbestos).

According to Muhwezi, et al. (2012), there are residual construction material waste which includes paints, glues and other materials which are normally delivered in containers and are never completely used. Excess materials like mortar, plaster can also harden in containers before use. Proper supervision should be emphasized to keep these types of waste to a minimum. The studies carried out by Saukkoriipi (2007), Al-Hajj and Hamani (2011), Wang, et al. (2008) emphasizes among others, staff training as a way to curb excessive material waste in construction process. Dainty and Brooke (2004) suggests the following measures to curb building construction wastes: Standardization of design, reduction off-cuts; stock control measures, staff training, supply chain alliance, provision of waste skips, just-in-time delivery strategy, sub-contract package for on-site waste management, penalty for poor waste performance, design management, enhance off-site prefabrication, education to clients and scheduled supply of small quantities of materials. According to Lau, et al. (2008), the major components of construction wastes generated are wood, concrete, bricks, metals and packaging of finishing materials.

A study carried out by Angaya (2012) examined lean construction as a system for putting up housing building units, with an aim of minimizing waste of materials, time; improve safety so as to generate the maximum possible savings for the stakeholders. The study notes that parameters describing the process of lean construction are important determinants of the performance of housing and building projects.

There is need however to highlight and embrace proper statutory policies and guidelines towards best practices in construction material waste minimization and management. With a highly mechanized process of construction and with advanced construction approaches, the goal of excessive material waste minimization can be realized. Lack of well qualified personnel to undertake the training of the construction personnel, lackluster interest of waste minimization by the management may act as a deterrent to sensitization of good practices in material waste reduction during construction.

2.7 Technology Application.

2.7.1 Conventional Building.

According to Foster (1979), conventional building is a mixture of traditional and new form of construction involving both old craft and use of expensive mechanized plants for most operations. Craftsmen carry out most of the work apart from specialized work in reinforced concrete and steelwork. With increasing size of buildings, there has been an increase in use of mechanical plants to increase the production.

Badir et al. (1998) cited in Kadir (2006) suggested four main categories of building system classification: conventional building system; cast in-situ formwork system (table or tunnel formwork); prefabricated system; and composite system. The last two building systems are mainly industrialized building systems where components of a building are conceived, planned, fabricated, transported and erected on site.

2.7.2 Industrialized Building System.

Industrialized building systems (IBS) are methods to reduce the amount of site labor involved in building operations and to increase the productivity of the industry generally. Such methods should produce buildings at no greater cost than by conventional methods (Foster 1979). According to Kamar, Hamid, Azman, and Ahamad (2011), IBS represents the prefabrication and construction industrialization concept and is an innovative process of building construction using concept of mass-production of industrialized systems, produced at the factory or onsite within controlled environments, which includes the logistic and assembly aspect of it, done in proper coordination with thorough planning and integration. Foster (1979) infer that IBS is continuity of production implying a steady flow of demand, standardization, and integration of different stages of the whole production process, a high degree of organization of work, mechanization, research and organized experimentation integrated with production. From these, continuous, 'flow-line' production, standardized production, planned production and mechanized production can be derived.

2.7.3 Lean construction.

Greg and Tariq (2012) define lean construction as a production management-based approach to project delivery, a new way to design and build capital facilities. Lean changes the way work is done throughout the delivery process and it extends from the objectives of a lean production system, maximize value and minimize waste, to specific techniques, and applies them in a new project delivery process. In lean construction, facility and its delivery process are designed together, work is structured throughout the process to maximize value and to reduce waste, the performance of the planning and control systems are measured and improved. A study carried out by Angaya (2012), noted that parameters describing the overall process of lean construction are considered important determinants of the performance of housing and building projects.

An article by Gustafsson, Vessby, and Rask (2012) infers that, lean is the engagement of all the employees in an organization, in the ongoing identification and elimination of waste. In lean thinking about waste within a process, seven waste factors are considered with the acronym “WORMPIT”; waiting, over production, rework, motion, processing, inventory and transportation. Kpamma, Kamil and Appiah (2012) argues that, to minimize waste and maximize value in the building construction process, lean construction principles needs to be embraced in wall construction which is one of the major components of the entire building construction process.

The industrialized system approach to residential building frame construction such as lean construction maximizes on workflow and eliminates systematic waste sources. The successful implementation of industrialization building system requires modular coordination of components. Modular coordination is an international system of dimensional standardization in building where buildings and components are sized in term of a basic unit or module. This helps to improve on workmanship and reduce cost of construction.

2.8 Building construction cost

2.8.1 Estimating Building construction cost

Suresh (2006) infers that, the approximate estimate is prepared from the practical knowledge and cost of similar works. A percentage 5 to 10% is allowed for contingencies. The author suggests the following methods can be applicable in estimation of cost of building:

Detailed estimate-consists of preparation of detailed estimate of various items of work and then determine the cost of each item by taking details of measurements, calculation of quantities and estimated overhead costs included.

Plinth area method- The cost of construction is determined by multiplying plinth area with plinth area rate. The area is obtained by multiplying length and breadth. In fixing the plinth area rate, necessary enquiries are made in respect of quality and quantity aspect of materials and labour, type of foundation, height of building, roof and number of storeys.

Cubical contents method -The method is generally used for multi storeyed buildings. It is more accurate than plinth area method and unit base method. The cost of a structure is calculated approximately as the total cubical contents multiplied by local cubic rate. The volume of building is obtained by length x breadth x depth or height.

Unit base method- the cost of structure is determined by multiplying the total number of units with unit rate of each item. In case of schools and colleges, the unit considered to be as one student and in case of hospital, the unit is one bed. The unit rate is calculated by dividing the actual expenditure incurred or cost of similar building in the nearby locality by the number of units. Cost analysis systematically breaks down cost data, generally on the basis of an agreed elemental structure. The process uses such an elemental structure, during the estimating process, to calculate approximately the cost of each of the elements (Ashworth 2004) cited in Soutos and Lowe (2011).

2.8.2 Elemental estimation of building construction cost.

Kirkham (2007) cited in Soutos and Lowe (2011) defines an element as a major part of the building, which always performs the same function irrespective of location or specification. According to Soutos and Lowe (2011), elemental cost analysis provides the data upon which elemental cost planning is based. The technique has been used by quantity surveyors to base their cost predictions during the design stage.

In a study by Ujene and Idoro (2015), practitioners should adopt elemental approach to cost anticipation and allocation because it helps to simplify planning and enhance cost management at different phases of work. The study also advocates use of developed models for prediction of direct costs for the low and medium rise buildings. Moselle (2014), suggests 2015 elemental estimates for residential single dwellings and multi-dwellings as shown in appendix F and G.

2.9 Cost of building materials.

2.9.1 Materials management

According to Kanimonhi and Latha (2014), materials management is defined as a coordinating function responsible for planning and controlling materials flow. This comprises purchasing, delivery, handling and minimization of waste and therefore materials management is an essential function if productivity in construction projects is to be improved. The study asserts that, construction materials and equipment may constitute more than 70% of the total cost for a typical construction project. The goal of material management is to ensure that materials are available at their point of use when needed; the right quality and quantity of materials are appropriately selected, purchased, delivered, and handled on site in a timely manner and at a reasonable cost (Ayegba, 2013).

2.9.2 Cost variance in material resource.

In a study carried out by Veronika, Riantini and Trigunarsyah (2006), the causes of cost variances and the corrective actions in materials management can be grouped as: Planning, organization, procurement, delivery, quality control, storage, and usage, change order, monitoring, and external factors. The study also argues that, material is the main component in construction projects and if not properly managed, it will create a major project cost variance. Georgekutty and Mathew (2012) argue that more than 50% of the construction cost is shared by materials and therefore has a dominating role in construction. If the materials are controlled dynamically, the total project cost would be reduced.

2.9.3 Cost impact of building materials.

According to "Economic survey" (2014), cited in Mwaniki, (2014), the cost of construction materials in Kenya increased, with the impact being reduction of completed residential houses from 7339 to 6016 in the year 2012. Ameh and Itodo (2013) infer that, the percentage contribution of building material waste to project cost overrun is between 21-30%. Generally, in construction projects, material and equipment are the two major components, which is about 50-60% of the total project cost. A research by Kerridge (1987) cited in Veronika, Riantini and Trigunarsyah (2006) infer that, material cost could amount to 60% of the total construction project cost. A study by Ayegba, (2013) argues that construction works depend on cost of materials and cost of labour and 30 to 70% of project cost is consumed by material with about 30 to 40% of labor. But labour cost is nearly the same for good construction work as well as bad construction. Attention therefore should mainly be directed to the cost of materials and management of materials.

2.10 Theory of waste management.

Theory of waste management is a unified body of knowledge about waste and waste management (Pongracz, 2002). It is founded on perception that waste management is to avoid waste from causing harm to human health, environment and promote resource use optimization. The theory is constructed under the paradigm of industrial ecology. Industrial ecology is equally adaptable to incorporate waste minimization and/or resource optimization measures, and ensures that resources are effectively circulated within ecosystems (Pongracz,2002).According to Pongracz and Pohjola (1997) cited in Pongrácz, Phillips, and Keiski (2004), waste management theory envisages that, waste can be grouped in four classifications:

Class 1: Non-wanted things, created not intended, or not avoided, with no purpose.

Class 2: Things with a finite purpose thus destined to become useless after fulfilling the purpose.

Class 3: Things with well-defined purpose, but their performance ceased being acceptable due to a flaw in structure or state.

Class 4: Things with well-defined purpose, and acceptable performance, but their users failed to use them for their intended purpose.

Waste management theory in the concept of this research is meant to integrate waste reduction practices, such as value engineering; an organized approach in identifying unnecessary costs in design and construction. The concept should also integrate alternative design or construction technology with a view to reduce construction costs while performance requirements are maintained. Contractors should also be willing to embrace such alternatives when offered incentives and share any savings with building owners. This subconsciously would prevent the wastage of materials in the construction planning and construction phase of the project. Waste management theory mainly addresses the functional, economic and performance criteria of the materials, but does not address the causes of material waste with a view to their minimization as a priority to reduce cost of construction.

2.11 Systems theory.

Alexander and Krippne (1997) define a system as a complex of interacting components together with the relationships among them that permit the identification of a boundary maintaining entity or process. Skyttner (1996) infers that a system can be described as a set of interacting units or elements that form an integrated whole intended to perform some function and can also be expressed as any structure that exhibits order, pattern and purpose which in turn implies some constancy over time. In the realm of management, a system is the organized collection of men, machines and material required to accomplish a specific purpose and tied together by communication link.

Systems theory is a general frame of enquiry concerned with the holistic and integrative exploration of phenomena and events. It pertains to both epistemological and ontological situations. Systems approach focuses attention on the whole, as well as on the complex interrelationships among its constituent parts (Laszlo & Krippner, 1998). According to Capra (1997) cited in Mele, Pels, and Polese (2009), a systems theory is an interdisciplinary theory about every system in nature, in society and in many scientific domains as well as a framework in which a phenomenal can be investigated from a holistic approach. These concepts and principles of organization provide a basis for their unification (Heylighen & Josylyn 1992). Systems theory focuses on the arrangement of and relationship between parts and how they would work together as a whole. The way the parts are organized and how they interact with each other determines the properties of that system. The behavior of the system is independent of the properties of the elements holistic approach to understanding a phenomenon (Shahid 2004).

2.12 Theory of planned behavior

Ajzen's "theory of planned behavior" (TPB) started as the "theory of reasoned action" in 1980 to predict an individual's intention to engage in a behavior at a specific time and place. The theory was intended to explain all behaviors over which people have the ability to exert self-control (Boston University of public health 2013). Ajzen (1981) infer that TPB distinguishes between three types of beliefs: behavioral, normative, and control and between the related constructs of attitude, subjective norm, and perceived behavioral control. All beliefs associate the behavior of interest with an attribute of some kind, be it an outcome, a normative expectation, or a resource needed to perform the behavior. It should thus be possible to integrate all beliefs about a given behavior under a single summation to obtain a measure of the overall behavioral disposition (Ajzen 1981).An article by Boston University of public health (2014) argues that, TPB is comprised of six constructs that collectively represent a person's actual control over the behavior: Attitudes, behavioral intention, subjective norms, social norms, perceived power and perceived behavioral control as shown in figure 2.1.

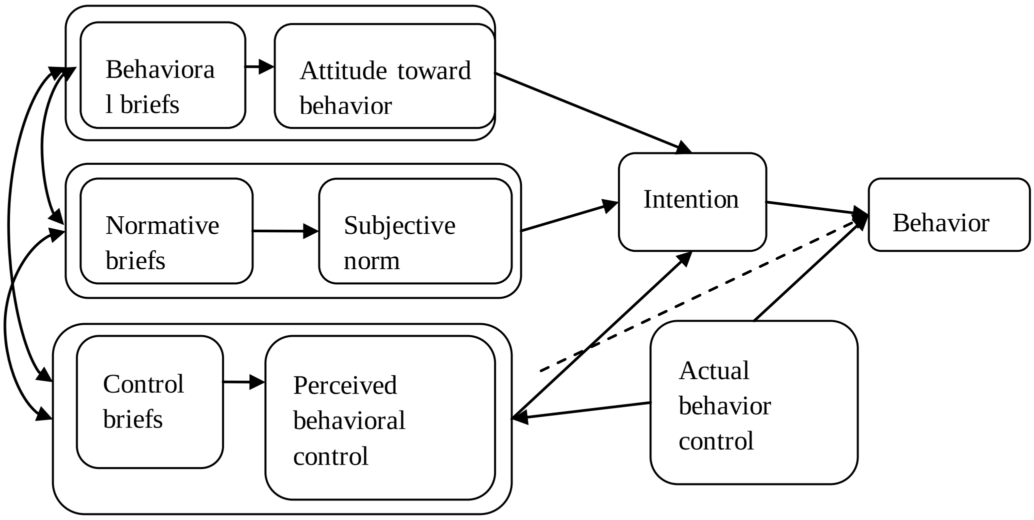

Figure 2.1: The Theory of Planned Behavior (source: Ajzen 2006)

A research by Teo and Loosemore (2001) on "a theory of waste behavior in the construction industry" used Ajzen's 'theory of planned behavior' to investigate the attitudinal forces that shape behavior at the operative level. It concludes that operatives see waste as an inevitable by-product of construction activity. Attitudes towards waste management are not negative, although they are pragmatic and impeded by perceptions of a lack of managerial commitment. Waste management is perceived as a low project priority, and there is an absence of appropriate resources and incentives to support it. The study conceptualized the forces that shape people's behavior towards waste in the construction industry at operative level and the findings were guided by the "theory of planned behavior" which were transposed into a theoretical framework as shown if figure 2.2

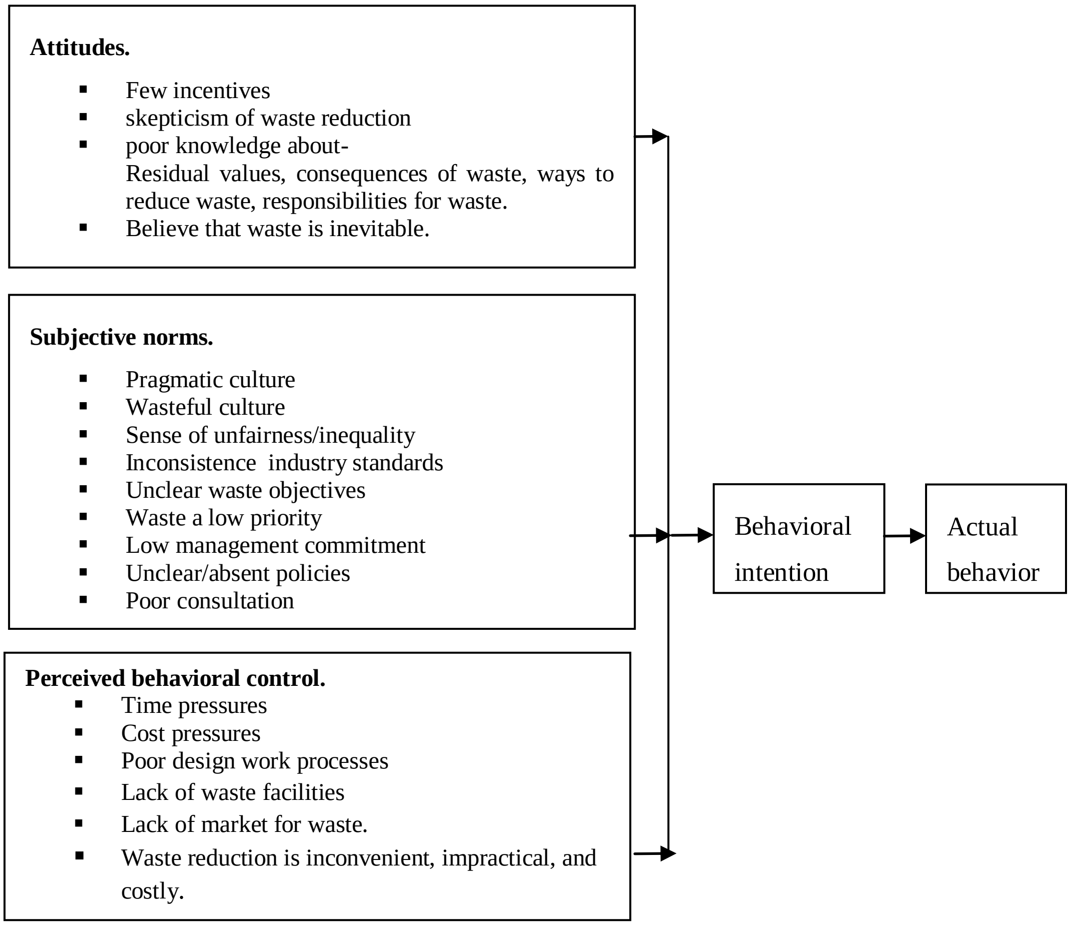

Figure 2.2: Expanded theory of planned behavior (source: Teo and Loosemore 2001)

2.13 Theory of constraints.

According to Rattne (2009) "The theory of constraints" (TOC) is an organizational change method which focuses on profit improvement. The essential concept of TOC is that every organization must have at least one constraint. A constraint is any factor or bottleneck that limits the organization from getting more of whatever it strives for. "The theory of constraints" defines a set of tools that change agents can use to manage constraints, thereby increasing profits. Since the focus only needs to be on the constraints, implementing TOC can result in substantial improvement without tying up a great deal of resources. The five steps of the theory of constraints include: Identify the system constraint; decide how to exploit the constraint: subordinate everything else, elevate the constraint; return to step one, but beware of inertia.

Rattne (2009) argues that the theory of constraints can serve as a highly effective mechanism for prioritizing improvement projects resulting to manufacturing effectiveness by eliminating waste from parts of the system that are the largest constraints on opportunity and profitability. Moore (1988) infer that TOC and lean thinking are two philosophies that are strikingly similar and in stark contrast. The Lean approach guides its practitioners to improve their organizations by focusing on the elimination of any and all waste. TOC guides its practitioners to improve their organizations by focusing on the constraints to ongoing profitability. Both philosophies focus on improvement and advocate techniques to control the flow of material on the shop floor. Both have demonstrated dramatic results of implementations profitability skyrockets, inventories and lead times are slashed, and operations are drastically simplified.

2.14 Techniques of controlling construction waste.

2.14.1 Construction waste management plan.

Resource venture (2005) describes waste management plan as the mechanisms for interaction and oversight for controlling materials and waste. The management plan addresses methods both identification of the materials that need special handling and to prescribe processes to minimize the risk of their unsafe use and improper disposal. Construction materials which end up as waste during construction needs to be reduced, reused or recycled. WRAP (2007) suggests the following roles for project participant with an aim for a better waste management strategy during construction: client communicates requirements on waste to the project team, main contractor deliver the clients requirements by developing a site waste management plan, sub–contractor produce accurate data on the actual level of wastage and how to minimize.

A construction waste management plan to reduce cost of wastes may include the following actions: Restate the project's waste reduction goal, designate a recycling coordinator responsible for implementing the plan, identify the waste materials expected, their disposal method and handling procedures and define how the plan will be communicated to the working crew (Resource venture 2005).

According to Wahab and Lawal (2011), waste index calculation on past projects could help in having prior understanding of the volume of waste to be generated, develop good planning of resources, and control the waste that may be generated by taking similar projects earlier handled as points of reference. The study makes the following recommendations: Contractors should ensure effective control of materials from design to construction stage, contractors evolve better means and facilities for storage, ensure sorting exercise is adequately carried out on site when wet trades are used; encourage use of prefabricated elements, develop a policy to mandate firms to carry out waste indices and incorporate a waste management plan, designer should co-ordinate dimensions between materials specified during design and those procured, contractors should create functioning sections through capacity building and manpower development, the site worker enlightened about the environmental and health risks associated with material waste generated.

Kioko (2007) argues that waste can significantly affect the business performance and productivity of contracting organizations. . The study also notes that waste in construction is not only focused on the quantity of waste of materials on-site, but also related to several activities in design and construction phases.

2.14.2 Integrated waste management plan (IWMP).

Chandak Surya (2009) defines IWM as prioritized approaches to management of waste for reduction reuse, recycling, and composting. These should be integrated during the construction process. IWMP is considered as the framework within which waste management is to be carried out. The main goal of IWMP is to optimize waste management by maximizing efficiency, and minimizing associated environmental impacts and financial costs. The aim is to assist responsible parties to have plans, which comprise an optimum approach to IWM planning in terms of resource allocation, time scheduling and allocation of responsibilities.

According to the department of environmental quality, Montana Government USA (2013), the hierarchy of integrated waste management includes: source reduction which includes the design, manufacture, purchase, or use of materials or products, including packaging, reuse by using a product in its original form for a purpose that is similar to or different from the purpose that it was designed for, recycling by remanufacturing all or part of a product into a new product; composting which is often considered a type of recycling because it changes biodegradable materials from one form to another; land filling and incineration.

2.15 Theoretical framework

The concept of this study is mainly hinged on systems theory. Residential construction process entails production work where interrelated activities are organized together to realize the objective of a complete built up project. This marries on well with systems approach where the process of building construction includes planning, designing, manufacturing and delivery, fabrication/ building process and post occupational evaluation. System approach to residential building process would ensure reduction of materials which goes to waste to the benefit of both the client and the contractor. A theoretical framework for a residential building process with a view to material waste minimization is shown in figure 2.2

Table 2.1: Theoretical framework-Residential construction project

	Attributes	Effects	Benefits
Material waste in a Residential construction project	**Planning** • Available resources • Source of materials • Availability of technology • Management/ implementation **Design** • Method of construction • Type of design • Statutory restrictions • Expertise for implementation **Manufacture/delivery** • Component specification • Component standardization • Methods of delivery • Storage • handling **Construction process** • Management • Material handling • Supervision • Experience • Variations • schedules **Training** Management and site Personnel **Evaluation** Process bottlenecks	Material waste minimization	-Environmental. -Economic.

2.16 Conceptual framework.

Residential building construction projects in the Northern Nairobi predominantly use conventional practices. This method of construction focuses on the uniqueness and the singularity of projects characterized by unique choices of technical solutions, a limited use of platforms, uniquely combined teams and scarcely developed logistics and procurement strategies (Angaya, 2012). In this construction method, reinforced concrete, natural walling stones, timber and roof coverings forms the bulk of the materials used in the structural frame component. Conventional construction methods generate a lot of materials waste due to different factors. These factors in effect cause low contractor's profitability, increases cost of production, increases cost of waste management, cause environmental degradation and need for high material waste allowance while preparing the bills of quantities. By integrating systems thinking in residential building production process, alternative approach to construction of residential building in Northern Nairobi was explored in this study, whose utilization results in minimization of material waste as in (figure 2.3).

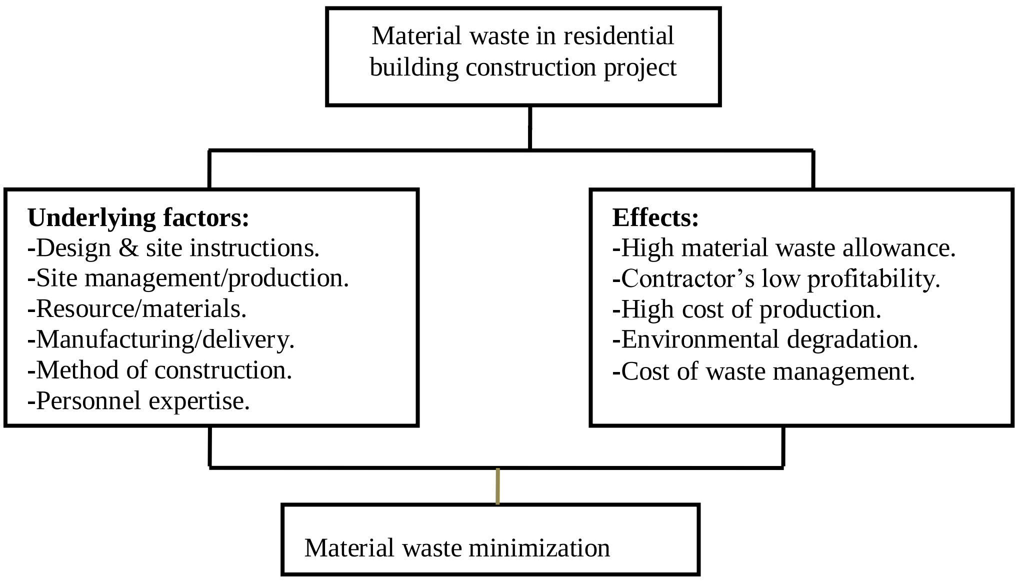

Figure 2.3 Summary of conceptual framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology employed in the study of factors causing material waste and their influence on construction cost of residential building frames in the Northern Nairobi. Central in the chapter is sampling design, methods and techniques of data collection, data analysis and interpretation. Ethical considerations underpinning the study are also presented.

3.2 Research approach.

This research is carried out in two phases through structured interviews, and observations. Phase one of the study identifies factors attributed to material waste in Northern Nairobi. Observations on construction material waste is by taking photographs and recording on paper the general site arrangement in regards to material waste management in each particular site. Phase two of the study establishes the extent of impact of various causes of material waste on construction cost of residential building frames.

3.3 Data needs and sources.

Primary data is gathered from respondents with relevant information for this research through interviews, focus group discussions and observations. This creates enough and reliable data for analysis. Secondary data from previous researches, newspapers, online sources and published journals also forms part of the information required to interrogate comprehensively on current state of the problem area under consideration.

3.4 Research design.

A mixture of survey and case study designs are used in this research. Survey type of design attempts to collect data from a population so as to determine the current status of that population in respect to one or more variables. It is a self-report study which requires the collection of quantifiable information from the sample and can take the form of descriptive, exploratory or statistical analysis (Mugenda & Mugenda, 2003). Case study design seeks to describe a unit in detail, in context and holistically (Kombo and Tromp, 2006; Mugenda & Mugenda, 2003). The case study areas in this research are Clay City and Kasarani estates.

3.5 Sampling design.

Purposive and convenience sampling designs are applied in this study. In purposive sample method, the researcher purposely targets a group of people or objects believed to be reliable for the study (Kombo & Tromp, 2006; Mugenda & Mugenda, 2003). Convenience sampling involves selection of units of observation as they become available to the researcher (Mugenda & Mugenda 2003).

3.5.1 Sampling of residential Estates.

Purposive sampling technique is used to identify the region, most appropriate within the study area, rich in residential building projects under construction up to roof level and with diverse residential building projects suitable for this study. Purposive sampling enables the researcher to generate the data required by choosing the appropriate region in which the units of observation have the required characteristics for the purpose of the study (Mugenda & Mugenda, 2003). Clay City and Kasarani estates in Northern Nairobi are purposively sampled, as indicated in figure 1.1 and 1.2.

3.5.2 Sampling of project consultants.

Convenience sampling is used to select respondents who have handled projects within the research area. This method of sampling involves selection of units of observation as they become available to the researcher (Mugenda & Mugenda 2003).This is informed by the fact that not all sites in this region have formal professional construction teams.

3.5.3 Establishment of study population.

The study area, purposively sampled, includes Clay City and Kasarani Estates in Northern Nairobi. Through a reconnaissance survey, 32 residential building projects had reached roof level which is the selection criteria of the projects for this study. Of these residential building projects, 1 maissonette, and 22walk-up flats are located within Clay City Estates. In Kasarani Estates, there were 4 maissonettes and 5 walk-up flat projects in progress. The projects in progress which had reached roof level within Clay City and Kasarani estates formed the population size for this study**.**

3.5.4 Sample size determination.

There are 32 number of projects purposively sampled which forms the sample size for this research.

Table 3.1 Sample size determination

project description	**project Location**	**No. of projects Upto roof level (population)**	**sample size**
Kasarani estates	Walk up flats	5	5
	maissonettes	4	4
Clay City estates	Walk up flats	22	22
	maissonettes	1	1
	Total	**32**	**32**

Source: Field survey 2016

3.5.5 Inclusion criteria of building projects.

Materials used in a building frame in conventional residential construction are composed of reinforced concrete, natural stones or concrete blocks, roofing timber and roof coverings. This research is confined to these materials. The study is also confined to residential walk-up flats and residential maissonettes, under construction within Clay City and Kasarani estates in Northern Nairobi, which had gone up to roof level.

3.6 Data collection methods and techniques.

3.6.1 Primary data

Primary data, collected from respondents are in two phases, through structured interviews, and observations. Phase one of the data collection is carried out on: skilled site personnel in focus group discussions through interviews and observations; project consultants through structured interviews. Phase one of data collection identified the various factors which are attributed to material waste in construction of residential building frames in Northern Nairobi. The respondents were requested to highlight the causes of material waste during the construction of residential building frame in Northern Nairobi. Responses which had similar features were organized in five main thematic areas as: Design and site instructions, site production and management, resource materials, environmental, manufacturing and delivery. The responses are summarized in Figures 4.1- 4.5.

Phase two of data collection was conducted on site managers through structured interviews and observation, based on their understanding on material waste in residential building construction in this region. Phase two of data collection established the extent of impact of various causes of material waste on cost of construction of residential building frame in Northern Nairobi. Data collected through observation in sampled projects is recorded through images and on paper manually.

3.6.2 Interviewing.

One set of interview was conducted in focus group discussions. The focus groups were composed of skilled site personnel in establishing causes of material waste in each project. The discussion captured information, based on workers understanding on factors causing material waste in residential building frame construction in Northern Nairobi. This was recorded on paper manually as primary data for analysis.

A structured interview was used in phase two of data collection from site managers as respondents. This was based on their understanding on material waste in residential building construction. The interviews were conducted on sampled sites by the researcher, to collect a detailed data, which provided a basis for the descriptions of the variables under consideration. The interviews also provided sufficient, complete and accurate information without bias to maximize reliability and validity of the data. This was by considering the diversity of the building projects within the sampled areas.

3.6.3 Observation

Structured observation was conducted within the sampled projects in this study, so as to capture the work procedures, handling procedures and general patterns adopted in dealing with materials on sampled projects. An observation schedule for measurement of project built up area, type of contract, images of waste materials on site and method of construction was conducted as part of data collection method. Data collected forms part of results which is analyzed, in understanding factors attributed to generation of material waste during construction of a residential building frame projects in northern Nairobi.

3.7 Data analysis and interpretation.

Data collected through focus group interviews and observations, structured interviews through project consultants in phase one was analyzed by describing, structuring, categorizing, and scrutinizing the information into themes to bring out factors attributed to materials waste in building frame construction of a residential building in Northern Nairobi. The data obtained through structured interviews in phase two of the data collection was analyzed using multiple regression statistics. Statistical Package for Social Sciences (SPSS), facilitated in organizing the raw data into an array, so that frequencies, percentages and other statistical functions are generated.

3.8 Response rate

There were 32 number of projects purposively sampled for the study. This includes: 5 apartments and 4 maisonettes in Kasarani estates, 12 apartments and 1 maisonette in Clay City estates. Interviews in form of focus group discussions were held between the researcher and tradesmen, accountants, storekeepers and purchasing officers in each of the 32 projects. This method of data collection ensures that there are no missing returns and the language of the interviewees is adapted to their educational level (Kothari, 2007). There were 32 project consultants conveniently sampled as respondents for phase one of this study. Each consultant was served personally by the researcher with unstructured interview schedule and all were duly completed.

Phase two of this research involves site managers in the sampled 32 projects. They were personally served by the researcher with a 5 point Likert scale questionnaire of 1-very low, 2- low, 3- medium, 4- high and 5-very high. The site managers were required to select the level of influence, in the listed attributes of residential building material waste on cost of residential building frame construction in their projects. All the 32 questionnaires were duly completed by site managers in the presence of the researcher.

3.9 Ethical considerations.

Ethical consideration was incorporated in this research. The researcher ensured that all the work contained herewith is original and no plagiarism or fraud occurred during the study. Permission to conduct the research was sought from each project site management and respondents, stating the reasons why research was being conducted. An introductory letter accompanied each interview and observation schedule to notify participants the nature of the study, their rights during the study and researcher's responsibility to safeguard privacy of the respondents. Participants were accorded right to voluntary participation without coercion or penalty and informed the reasons for the intended study. Participants will be accorded an opportunity to view research results after completion of the study if they so wish through the University internet repository system.

CHAPTER FOUR

RESEARCH RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and findings of the data collected in the study area according to research objectives. The data was collected in two phases. Data for phase one of the study was collected from project consultants, focus group discussions and researcher observations on individual sites. Data for phase two of the study, collected from construction site managers is also presented.

4.2. Objective one- main causes of materials waste.

4.2.1 Factors revealed by Project consultants.

a) Design and site instruction factors.

Table 4.1 indicates *design and site instruction* attributes which contribute to material waste in this region. Change of design during the progress of the project and complex design rated as the major factors with a 24% and 22% rating respectively in this category. Non modular designs and inadequate coordination each rated at 14%. Inadequate consultation, unclear specifications and lack of proper documentation rated 11%, 10% and 5% respectively.

Table 4.1 Design and site instruction factors.

code	*Attributes*	*Frequency*
A1	Site instructions	24
A2	Poor/complex design	22
A3	Unclear specifications	10
A4	Lack of proper documentation	5
A5	Inadequate co-ordination	14
A6	Non modular design	14
A7	Inadequate consultation	11

Source: Field survey 2016

Site instruction by the clients or the designers during the progress of the works and lack of coordination /consultation among project team member's results in repetition of works already carried out. This has been found to contribute highly in material waste during construction. The designers need to incorporate modular design parameters in their designs, use of less complicated drawings and specifications which are clearly explained. Proper documentation from relevant statutory bodies like NCA, NCC, and NEMA which may cause work stoppages should be processed in advance. Other studies by Adewuyi and Otali (2013), Olusanjo, Panos, and Ezekiel (2014) categorize project designs which do not conform to standards or modular sizes as a major contributor of construction waste.

b) Site production and management factors.

Table 4.2 shows site production and management waste factors, in projects within the region. Inexperience among the skilled craftsmen or the contractor rated at 41% in this category. Inadequate supervision, where workers are not closely supervised rated at 20%. Other factors which were highlighted in this category in order of merit included: Lack of security, poor work conditions, craftsmen inadequate training, demolition/rework, poor site layout, management work attitude, change of contractors midway, inadequate/improper equipment.

Table 4.2 Site production and management factors.

code	*Attributes*	*Frequency*
B1	Inadequate control	20
B2	Management work attitude	3
B3	Lack of security	8
B4	Inadequate/improper equipment	2
B5	Craftsmen inadequate training	6
B6	Demolition/rework	5
B7	Poor work conditions	7
B8	Inexperienced workers/contractors	41
B9	Poor site layout	5
B10	Change of contractors midway	3

Source: Field survey 2016

Site production and management attributes incorporates day to day management of the works on site. Inexperience among the skilled craftsmen or the contractor rated the highest. This may be attributed to demolitions or rework which leads to materials such as cement, broken stones, and concrete rubble going to waste. Inadequate supervision is also an indication that the management needs to have proper attitude towards material waste minimization, by engaging qualified supervisors, improve security, improve work conditions and improve on site layout to avoid double handling. Craftsmen will need basic training and adequate/proper equipment for each task assigned. Change of contractors/workers midway before the work is completed has also been found to contribute to material waste as a result of the new contractor/workers trying to adapt to new work environment. A study by Adewuyi and Odesola (2015) concur with these findings. Other studies (Muhwezi, et al. 2012, Al-Hajj & Karima 2011) rate inexperience highly as a cause of material waste during construction.

c) Material Resource factors.

Materials resource factors as a cause for residential building frame construction material waste in the region is presented in Table 4.3. Main materials associated with this form of frame construction are concrete, mortar, reinforcement bars, timber, stones, blocks or bricks and roof coverings. Excessive/ inadequate purchased quantities and misuse of materials both rated at 22% according to the response received. This explains why scheduled purchases, use of competent artisans and supervisors is crucial if reduction of material waste in residential construction was to be realized. Poor storage/poor storage facilities is another highly rated attribute at 19%. Materials like cement and paints get contaminated if not properly stored according to manufactures instructions. This was noted by the researcher as presented in plate 4.1 to 4.8. Theft of materials, sub quality purchases and improper handling of materials on site are other factors in this category with ratings of 15%, 13% and 9% respectively.

Table 4.3.Materials resource factors.

code	*Attributes*	*Frequency*
C1	Excessive/ Inadequate quantity	22
C2	Sub quality purchases	13
C3	Poor storage	19
C4	Misuse	22
C5	Theft /vandalism	15
C6	Improper handling	9

Field survey 2016

Materials resource factors highlights: scheduled purchases, use of competent artisans and supervisors, proper storage, theft of materials, sub quality purchases and improper handling of materials on site are factors which require close control. Materials like cement and paints get contaminated if not properly stored according to manufactures instructions. Other materials like timber, stones, sand and roof coverings breaks, deforms or deteriorate if not properly stored. Security and proper store keeping procedures need to be enhanced to avoid materials being vandalized by the workers or outsiders.

These findings closely compare with Adewuyi and Odesola (2015) where poor schedule of materials procurement, incorrect estimated quantity, over ordering or under ordering, theft / vandalism, wrong handling and poor storage are rated among the highest causes in their category

d) Manufacturing/Delivery factors.

Table 4.4 represents the manufacturing/delivery attributes in material waste during residential building frame construction in the region. Low quality materials were rated highest at 63% in this category. Poor handling in transportation rated second at 21% which indicates that materials should be properly handled during transportation. Nonstandard sizes, improper specification for use and improper packaging rated 6%, 5%and 5% respectively.

Table 4.4 Manufacturing/Delivery factors

code	*Attributes*	*Frequency*
D1	Low quality materials	63
D2	poor handling/transportation	21
D3	Nonstandard sizes	6
D4	Improper specification for use	5
D5	Improper packaging	5

Field survey 2016

Low quality materials are as a result of contraband materials in the market or poor control in production of materials by manufacturers. Such materials include reinforcement bars and roof coverings of lower quality than what was intended for use. Clients or contractors maybe duped in purchasing these materials due to their low cost. When there is poor handling in transportation, materials such as stones and timber are carelessly thrown from delivery trucks and some end up breaking to the disadvantage of the buyer. Nonstandard sizes, improper specification for use and improper packaging attributes are not so significant in material waste indicators in this region.

Other studies by (Muhwezi, et al. 2012), oladirani and olatunji 2013) opine that, manufacturing deficiencies, substandard materials, improper transportation are among the main causes of material waste in construction of buildings.

e) Environmental factors.

Table 4.5 indicates *environmental factors* attributed to material waste in residential building frame construction. The main cause in this category was attributed to material deterioration on site at a rating of 71%.This is also highlighted in plate 4.1, where poorly stored stones deteriorate and weather out as they are rained on. Topography of the ground rated at 18% which is associated mainly with rainy seasons when materials are washed away. Natural calamities which rated 7% are rare in the region although El Nino rains were thought to have caused some damage by the end of the year 2015. Damage by insects rated a paltry 4% which is attributed to timber stored for long and are affected by pests.

Table 4.5 Environmental factors.

code	*Attributes*	*Frequency*
E1	material deterioration/contamination due to weather	71
E2	Damage by insects	4
E3	Natural calamities	7
E4	Topography	18

Field survey 2016

These results concur with studies by Muhwezi, et.al. (2012), Adewuyi and Odesola (2015) where severe weather and effects of site conditions closely associated with topography of the site are the highest causes of material waste in their category.

4.2.2 Factors revealed in focus group discussion.

The focus groups in every site included tradesmen, accountants, storekeepers and purchasing officers. The factors suggested during focus group discussions were grouped in five relevant thematic areas as indicated in table 4.6. These are similar to thematic areas as generated from project consultants.

During the discussion, significant factors which cause material waste in a residential building frame construction were identified as site instructions and poor/complex design with frequencies of 33 and 15 in design and site instruction category. In site production and management factors, inadequate control, demolition/rework, poor work conditions, inexperienced workers with frequencies of 32, 25, 13 and 24 respectively were suggested as the significant factors which cause material waste in a residential building frame construction. Resource material factors reveal that excessive/ inadequate quantity, sub quality purchases, poor storage, misuse, theft /vandalism with frequencies of 22, 21, 28, 21 and 12 respectively are all significant factors in this category that cause material waste in a residential building frame construction. In manufacturing/delivery factors, low quality materials, poor handling/transportation breakages/deformation with frequencies of 30, 10, and 10 respectively were highlighted as the significant factors in this category that cause material waste in a residential building frame construction. work damage and contamination due inclement weather with frequencies of 16 and 29 respectively were suggested as the significant factors in this category that cause material waste in a residential building frame construction.

The findings closely agree with studies by Adewuyi and Odesola (2015), Adewuyi and Otali (2013), Muhwezi, et.al. (2012) Ameh and Itodo (2013) which gives high rating on site instructions and complex design, excessive quantity, sub quality purchases, poor storage, misuse, low quality materials, poor handling/transportation and inclement weather in their categories

Table 4.6 Factors revealed in focus group discussions.

code	Attributes	Frequency
A	***Design and site instruction factors.***	
A1	Site instructions	33
A2	Poor/complex design	15
A3	Unclear specifications	6
A4	Lack of proper documentation	5
A5	Inadequate co-ordination	5
B	***Site production and management factors.***	
B1	Inadequate control	32
B2	Management work attitude	4
B3	Lack of security	9
B4	Inadequate/improper equipment	6
B5	Craftsmen inadequate training	4
B6	Demolition/rework	25
B7	Poor work conditions	13
B8	Inexperienced workers	24
C	***Resource material factors.***	
C1	Excessive/ Inadequate quantity	22
C2	Sub quality purchases	21
C3	Poor storage	28
C4	Misuse	21
C5	Theft /vandalism	12
D	***Manufacturing/Delivery factors.***	
D1	Low quality materials	30
D2	poor handling/transportation	10
D3	Breakages/deformation	10
D4	Dimensional deficiency	8
E	**Environmental factors**	
E1	material deterioration/contamination due to weather	16
E2	Damage by insects	3
E3	work damage due to adverse weather	29

Source: Field survey 2016

4.2.3 Factors revealed through structured Observation.

An observation schedule (appendix D) for causes of material waste in each site guided the researcher items to be observed. They included: site activities, type of development, built up area, number of floors, manner of material storage and evidence of material waste on each site and type of contract used in the procurement of the project (figure 4.1). Factors attributed to material waste observed by the researcher include:

a) Substandard materials on site. Several construction sites were found to purchase materials which do not measure up to the expected quality standards, such as: stones, timber, sand and reinforcement. This leads to material wastage when project engineers recommend for their replacement (Plate 4.1).

Plate 4.1. Sub- quality stones weathering out in the open. Source:

Field survey 2015

b) Poor storage practices. Storage of materials in a number of sites was found to contribute to wastage of construction materials due to damage before use, deterioration and misuse. This may be attributed to the management attitude, workers attitude, inadequate supervision, over-ordering and unscheduled purchases which results in some materials going to waste before they are put to use. These materials include: roofing and formwork timber, roof tiles, stones and sand (Plate 4.2, 4.6).

Plate 4.2. Roof tiles poorly stored cause for breakage.

Source: Field survey 2015

c) Poor site layout. A well laid site ensures that double handling is avoided; efficiency is enhanced; minimizes incidences of theft and ensures overall control of materials. Most of the sites in this region lack good practices in site layout and this results in material wastage such as timber, stones and sand (Plate 4.3).

Plate 4.3 Formwork timber poorly stored on site.

Source: Field survey 2015

d) Inadequate supervision. Proper supervision of the workers in some construction sites has been found to be lacking. This creates an impression of neglect on the part of the management and the client. Workers were found to misuse materials such as:

unnecessary timber off-cuts; application of excess mortar where not required; throwing away excess concrete or mortar when time was up (Plate 4.4).

Plate 4.4 Mortar, concrete rubble dumped on site in cement bags for disposal

Source: Field survey 2015 .

e) Excessive materials on site. Materials for construction activities are ordered with no orderly sequence and this led to long storage on site. This obstructs operations and some materials went to waste. This is as a result of poor procurement practices and lack of proper technical advice on the part of supervisory staff. Such materials included timber, roof coverings, sand and cement (Plate 4.2).

f) Workers' attitude. Due to lack of proper supervision and sensitization to workers on best practices on material waste, all sites have workers unaware that materials are wasted. The workers tended to misuse the materials with the argument that construction materials waste is inevitable and project owners are contented with this reality. Material waste such as timber off-cuts, hardened cement mortar, hardened concrete and unnecessary roof sheet off-cuts were clearly visible in several construction sites (plate 4.5).

Plate 4.5. Off cut timber and roof coverings timber, concrete rubble dumped on site. Source: Field survey 2015

g) Weather effects. The research area does not experience severe weather effects. When materials are properly stored, waste due to this effect is minimal. However, some sites were found to have materials damaged as result of rain or deformation due to poor storage, such as cement, timber, stones and sand (Plate 4.1, 4.6)

Plate 4.6. Sand mixed up with soil & damaged due to weather effects.

Source: Field survey 2015

h) Excessive off-cuts. Construction sites in this region had excessive material off-cuts. This indicates that the workers and the supervisory team do not take much consideration with a view to minimize unnecessary cuttings. The Conventional methods of construction used within this region, where all materials are cut on site contribute to excessive waste. These materials with excessive off-cuts include timber, stones and roof sheets (Plate 4.7).

Plate 4.7 Timber off-cuts dumped for disposal. Source: Field survey 2015

j) Demolition and rework. A number of construction sites within the research area were noted to carry out demolitions so as to rectify errors or due to instructions to vary the design. This culminates in wastage of materials and manpower. Some sites found to have this practice were not well coordinated by all the parties in a construction set up. Notable materials which end up as waste include: mortar, concrete and stone rubble.

k) Unskilled or untrained workers. From a casual observation, some of the workers engaged as the skilled workmen do not produce good quality work. This may be due to lack of experience or training. The work carried out wrongly required rectification which led to wastage of materials originally used.

l) Unscheduled materials on site. The piles of materials on a number of sites which do not have immediate use were an indication that materials are procured without following proper procedures in this region. Unscheduled materials brought to site, not intended to be used immediately created storage problems. They are likely to deteriorate on site, get damaged before they are used or misused. Such materials included: Timber, cement, stones, sand and ballast (plate 4.8).

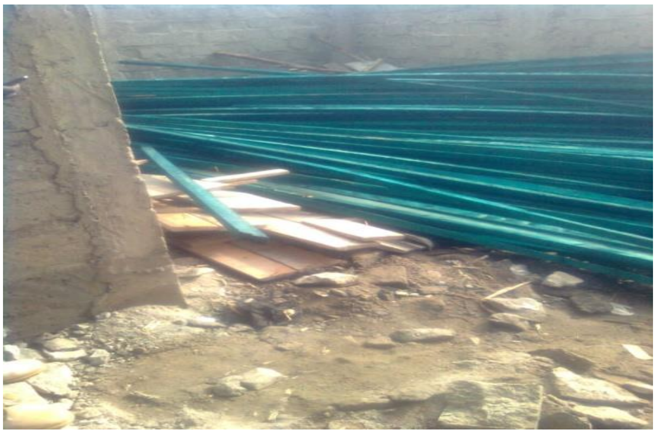

Plate 4.8. Unscheduled roof timber without specific lengths poorly stored

Source: Field survey 2015

m) Method of construction. There are different methods of residential building construction, each with different approaches. This region commonly uses the conventional methods and this culminates in high level of materials wastage. This method of construction is mainly by use of different craftsmen to put up various materials together with minimal mechanization.

g) Contract used in implementation.

Figure 4.1 represents the data indicating the type of contract used in implementation of various projects within the region. This was necessary to identify the general trend in residential project implementation in this region. The results indicate a high percentage of 69% as labour only contracts. Full contracts (with bills of quantities) at 22% and direct labour contracts at 9% follow in that order. Labour only contracting options have high contribution to material wastage (Ameh & Itodo, 2013)

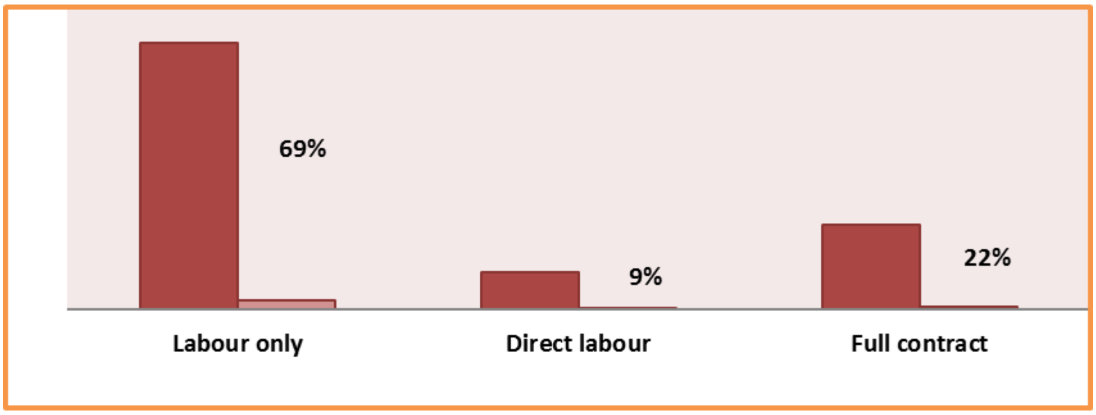

Figure 4.1 Contract used in implementation.

Source: Field survey 2016

The observed attributes are grouped in the following themes: design and site instruction factors, site production and management factors, resource material factors manufacturing/delivery factors and environmental factors. These are similar themes as those generated from project consultants and focus group discussion for an all-round summary of the factors causing material waste in construction of residential building frames in this region.

Table 4.7 Factors revealed through observation.

code	Attributes
A	**Design and site instruction factors.**
A1	Method of construction
B	**Site production and management factors.**
B1	Inadequate supervision
B2	Workers' attitude
B3	Type of contract
B4	Craftsmen inadequate training
B5	Demolition and rework
B6	Poor site layout
B7	Inexperienced workers
C	**Resource material factors.**
C1	Excessive materials on site
C2	Substandard materials on site
C3	Poor storage
C4	Excessive offcuts
C5	Unscheduled materials on site
D	**Manufacturing/Delivery factors.**
D1	Low quality materials
E	**Environmental factors**
E1	material deterioration or contamination due to weather

Source: Field survey 2016

4.3 Objective two- Extent of impact of causes of material waste on cost of residential building frames.

To determine the predictive rating of impact of the factors on cost of residential building frame construction in the Northern region of Nairobi, a 5 point Likert scale questionnaire of 1-very low, 2- low, 3- medium, 4- high and 5- very high was developed. The site managers in the sampled 32 projects were required to select the level of influence of the listed attributes of residential building material waste on cost of residential building frame construction in their projects. The response data, from site managers in percentages and the ranking in level of material waste contribution for each attribute is presented in table 4.8.

The response data from site managers table 4.8 shows the rankings for the material waste factors in each category. In design and site instruction factors, site instructions/change of design, non-modular design, and poor/complex design were ranked highest in that order. Designs which has irregular shapes, arbitrary dimensions, client or architect's instruction to vary the design while work is in progress were found to contribute to demolitions and excessive cutting of materials so as to fit into required sizes. Coordination between the various project consultants enables the flow of information on time as far as design aspects are concerned. The findings closely compare with Adewuyi and Otali (2013), Muhwezi, et al. (2012), where site instructions, change of design midway and complex shapes were ranked highest in material waste indicators.

In the category of site production and management factors, inadequate control/supervision, inexperienced workers /contractor, management work attitude and demolition/rework were ranked 1,2,3,4 respectively. Lackluster supervision capped with inexperience among the craftsmen would result in more material wastage during construction. The management also would need to sensitize the workers of the need to minimization of material wastage which occasionally may be caused by demolitions and rework due to improper instructions to the workers. Coordination of the various departments within the site is considered important to reduce excessive material wastage on site. These results compares with findings by Adewuyi and Odesola (2015) which shows inadequate supervision, inexperienced workers/technical staff and lack of waste management plan by management ranked highest.

Material waste resource factors involve day to day management of the materials used in a particular site. In this category, sub quality purchases, misuse, improper handling and poor storage /poor storage facilities are ranked highest in order of merit as the major contributors of material waste during construction of residential building frame in Northern Nairobi. The results compare very closely with Adewuyi and Odesola (2015) Ameh and Itodo ***(2013),*** Muhwezi, et al. (2012) where mishandling, control on site and poor storage are considered highest in contribution to material waste in that category.

In manufacturing / delivery factors, low quality materials, nonstandard sizes and improper specification for use ranked highest in that order. Materials of low quality when used results in damages, breakages and rework which is all associated with material wastage. Other studies (Adewuyi & Odesola, 2015; Adewuyi & Otali, ***2013;*** Muhwezi, et al. 2012) concur with these findings.

The Environmental factors considered in this study which included material deterioration/contamination, topography, natural calamities and damage by insects were ranked from highest to lowest respectively in that order. These results concur with findings by, Adewuyi and Otal ***(***2013) Muhwezi, et al. (2012) where severe weather conditions are associated with material deterioration.

Table 4.8 Response data from site managers.

	Factors	V.L	L	M	H	V.H	Rank in waste contrib.
A	**Design and site instruction factors.**						
A1	Site instructions/change of design	0	6.3	35.9	18.75	39.05	**1**
A2	Poor/complex design	3.13	18.75	31.25	31.25	15.63	**3**
A3	Unclear specifications	9.34	18.75	28.13	34.38	9.34	**7**
A4	Lack of proper documentation	9.34	18.75	25	31.25	15.63	**5**
A5	Inadequate co-ordination	3.13	18.75	34.38	25	18.75	**4**
A6	Non modular design	6.3	6.3	28.13	53.13	6.3	**2**
A7	Inadequate consultation	6.3	15.63	37.5	31.25	9.34	**6**
B	***Site production and management factors.***						
B1	Inadequate control/supervision	6.3	0	15.63	40.63	37.5	**1**
B2	Management work attitude	6.3	9.34	21.88	37.5	25	**3**
B3	Lack of security	12.5	18.75	18.75	18.75	31.25	**6**
B4	Inadequate/improper equipment	9.34	31.25	31.25	21.88	6.3	**9**
B5	Craftsmen inadequate training	3.13	15.63	37.5	28.13	15.63	**5**
B6	Demolition/rework	9.34	12.5	18.75	31.25	28.13	**4**
B7	Poor work conditions	3.13	12.5	46.88	21.88	15.63	**7**
B8	Inexperienced workers /contractor	0	0	31.25	37.5	31.25	**2**
B9	Poor site layout	0	28.13	43.75	21.88	6.3	**8**
B10	Change of contractors midway	15.63	28.13	31.25	15.63	9.34	**10**
C	***Material resource factors.***						
C1	Excessive/ Inadequate quantity	6.3	15.63	31.25	34.38	12.5	**5**
C2	Sub quality purchases	3.13	9.34	9.34	37.5	40.63	**1**
C3	Poor storage /poor storage facilities	3.13	25	12.5	50	9.34	**4**
C4	Misuse	0	18.75	21.88	25	34.38	**2**
C5	Theft /vandalism	21.88	6.3	21.88	21.88	28.13	**6**
C6	Improper handling	3.13	9.34	46.88	28.13	12.5	**3**
D	***Manufacturing/Delivery factors.***						
D1	Low quality materials	0	18.75	12.5	40.63	28.13	**1**
D2	poor handling/transportation	9.34	28.13	28.13	28.13	6.3	**4**
D3	Nonstandard sizes	6.3	18.75	37.5	31.25	6.3	**2**
D4	Improper specification for use	6.3	37.5	21.88	21.88	12.5	**3**
D5	Improper packaging	12.5	50	9.34	25	3.13	**5**
E	**Environmental factors**						
E1	material deterioration/contamination	15.63	53.13	18.75	12.5	0	**1**
E2	Damage by insects	53.13	28.13	12.5	3.13	3.13	**4**
E3	Natural calamities	46.88	40.63	3.13	6.3	3.13	**3**
E4	Topography	31.25	43.75	9.34	15.63	0	**2**

Key: V.L-Very low, L-low, M- moderate, H - High, V.H- very high

Source: Field survey 2016

Journal of 'The institute of quantity surveyors–Kenya' (IQSK) Jan-March 2015 issue suggests the current unit cost of different categories of residential building construction in Nairobi region (Appendix E). For purposes of this research, Maisonettes are taken as high class, flats up to 4 floors as low cost, low rise and flats beyond 4 floors Low cost, high rise. National building cost manual (2014) for 2015 highlights the elemental costs for multi-family residences up to roof level as 44% of total cost while single family residences has been estimated at 54% of the total cost (Appendix F and G).

4.3. Regression Analysis.

In this section, the study presents the multiple linear regression analysis results to show the relationship between the factors causing material waste and cost of residential building frame construction in the Northern region of Nairobi.

In order to establish factors causing material waste, that are good predictors on cost of residential building frame construction in the Northern region of Nairobi, a stepwise multiple regression is conducted. Stepwise linear regression is a method of regressing multiple variables while simultaneously removing those that aren't important. Stepwise regression essentially does multiple regression, removing the weakest correlated variables and the variables that explain the distribution best are left (Juliet 2005). The results are presented in Tables 4.9- 4.23

a) Design and site instruction waste factors in relation to cost of residential building frame construction.

Design and site instruction waste factors include: site instructions/change of design midway, poor/complex design, unclear specifications, and lack of proper documentation, inadequate co-ordination, and inadequate consultation. Table 4.9 shows the model summary for the analysis which indicate that, R^2 for poor/complex design =.138. Therefore this factor in this category explains 13.8% of the cost of residential building frame construction in this region.

The study results from multiple regression analysis indicates the F–tests for poor/complex design has p= 0.036.Therefore, only poor/complex design at 95% confidence can significantly predict the cost of residential building frame construction in this category as noted in ANOVA model 4.10. Table 4.11 indicates a negative 0.371 beta value for poor/complex design with the implication that this variable has an average correlation with cost of building frame of 0.371. A correlation below 0.3 is considered weak and above 0.7 is considered too high (Tabachnick & Fidell, 2001) cited in Julliet (2005).

Table 4.9 Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.371[a]	.138	.109	1.414

a. Predictors: (Constant), poor/complex design

b. Dependent Variable: cost of building frame _000 where R=0.371 R^2= 0.138

source : Field survey 2015

Table 4.10 ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9.595	1	9.595	4.797	. 036[a]
	Residual	60.009	30	2.000		
	Total	69.604	31			

a. Predictors: (Constant), poor/complex design
b. Dependent Variable: cost of building frame_000 where.
Df=1,30,31 F= 4.797

Source: Field survey 2015

Table.4.11 Coefficients

Model	*Unstandardized Coefficients* B	*Std. Error*	*Standardized Coefficients* Beta	*t*	*Sig.*
1(constant)	19.792	0.839		23.584	0
poor/complex design	-0.52	0.237	-0.371	-2.19	0.036

a. Dependent Variable: Cost of building frame_000

Source: Field survey 2015

b) Site production and management waste factors in relation to cost of residential building frame construction.

In this study, inadequate control/supervision, management work attitude, inadequate/improper equipment, craftsmen inadequate training, demolition/rework, poor work conditions, inexperienced workers/ contractor, poor site layout and change of contractors midway are the independent variables attributed to material waste factors in relation to cost of residential building frame construction in this category. The model summary in table 4.12 indicates that lack of security with a value R^2= 0.139 explains 13.9% the cause of material waste in relation to cost of residential building frame construction. Lack of security and poor work conditions has combined value of R^2=0.348 with implication that these two factors in this category explain 34.8 % of the cause of material waste in relation to cost of residential building frame construction in this region.

From the ANOVA table 4.13, the confidence level for lack of security is above 95%. For both lack of security and poor work conditions the confidence level is 99%.This is an indication that the two variables are the predictors in this category that can significantly explain the cost of residential building frame construction in this region. Table 4.14 shows lack of security has beta value of –0.511and poor work conditions beta value of 0.478 with implications that both variables are highly correlated to cost of building frame construction in this category.

Table 4.12 Model Summary

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.373[a]	.139	.110	1.413
2	.590[b]	.348	.303	1.251

a. Predictors: (Constant), lack of security

b. Predictors: (Constant), lack of security, poor work conditions

c. Dependent Variable: cost of building frame_000 where R=0.590 R^2=0.348

Source: Field survey 2015

Table 4.13 ANOVA

Model		*Sum of Squares*	*Df*	*Mean Square*	*F*	*Sig.*
1	Regression	9.679	1	9.679	4.846	.036[a]
	Residual	59.925	30	1.997		
	Total	69.604	31			
2	Regression	24.250	2	12.125	7.753	.002[b]
	Residual	45.354	29	1.564		
	Total	69.604	31			

a. Predictors: (Constant), lack of security.

b. Predictors: (Constant), lack of security, poor work conditions

c.Dependent Variable:cost of building frame_000where Df= 2,29,31 F=7.753. Source: Field survey 2015

Table 4.14 Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
1(constant)	19.355	0.649		29.84	0
lack of security	-0.39	0.177	-0.373	-2.201	0.036
2(Constant)	17.458	0.846		20.63	0
lack of security	-0.535	0.164	-0.511	-3.264	0.003
poor work conditions	0.714	0.234	0.478	3.052	0.005

a. Dependent Variable cost of building frame_000. Source: Field survey 2015

c) Material resource factors in relation to cost of residential building frame construction.

The independent variables in this category includes: improper handling, sub quality purchases, excessive/inadequate quantity, poor storage, misuse, theft /vandalism. The model summary table 4.15 indicate that, the value of $R^2 = 0.352$, with implications that about 35.2% of the factors causing material waste in relation to cost of residential building frame construction is explained by these variables in this category.

The ANOVA model in table 4.16 was used to test whether any of the factors significantly predicted the cost of residential building frame construction. The value p=0.065 is not statistically significant at 95% confidence. This implies that the predictor independent variables causing material waste in this category cannot significantly predict the cost of residential building frame construction in the region. Table 4.17 shows improper handling, misuse, theft/vandalism with a beta values of 0.608, 0.384 and 0.364 respectively. Variables with a correlation above ± 0.3 and below ± 0.7 with cost of building frame would be considered to have negative or positive impact (Tabachnick & Fidell 2001) cited in Julliet (2005). Beta values for Sub quality purchases, excessive/inadequate quantity, and poor storage are 0.199, 0.231 and 0.252 respectively which are considered too weak to make an impact.

Table 4.15 Model Summary

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.597[a]	.356	.202	1.339

a. Predictors: (Constant), improper handling, sub quality purchases, excessive/inadequate quantity, poor storage, misuse, Theft/vandalism

b. Dependent Variable: cost of building frame _000. where R=0.597 R^2=0.356

Source: Field survey 2015

Table 4.16 ANOVA[b]

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	24.810	6	4.135	2.308	.065[a]
	Residual	44.794	25	1.792		
	Total	69.604	31			

a.Predictors: (Constant), improper handling, sub quality purchases, excessive/inadequate quantity, poor storage, misuse, Theft/vandalism

b. Dependent Variable: cost of building frame _000 where Df= 6, 25, 31 F=2.308

Source: Field survey 2015

Table 4.17 Coefficients

	Unstandardized Coefficients		***Standardized Coefficients***		
Model	***B***	***Std. Error***	***Beta***	***t***	***Sig.***
1(Constant)	16.619	1.177		14.117	0
excessive/inadequate quantity	-0.318	0.289	-0.231	-1.1	0.282
sub quality purchases	0.274	0.347	0.199	0.788	0.438
poor storage	0.353	0.33	0.252	1.071	0.295
misuse	-0.506	0.323	-0.384	-1.566	0.13
Theft/vandalism	-0.362	0.251	-0.364	-1.44	0.162
improper handling	0.967	0.338	0.608	2.857	0.008

a.Dependent Variable cost of building frame _000 Source: Field survey 2015.

d) Manufacturing/Delivery waste factors in relation to cost of residential building frame construction.

The study identified improper packaging, sub quality materials, specification for use, poor handling in transportation, non-standard sizes as the independent variables attributed to material waste in relation to cost of residential building frame construction in this category. The model summary table 4.18 indicate that, the value of $R^2 = 0.151$, with implications that 15.1% of the factors causing material waste in relation to cost of residential building frame construction is explained by these variables in this category.

The ANOVA model in table 4.19 was used to test whether any of the factors significantly predicted the cost of residential building frame construction. The value p= 0.479 is not statistically significant at 95% confidence with implication that the predictor independent variables causing material waste in this category cannot predict the cost of residential building frame construction in this region. Table 4.20 shows improper packaging has a beta value of 0.485, poor quality materials -0.213, specification for use -0.213, poor handling in transportation 0.173 and non-standard sizes-0.316. Variables with a correlation with cost of building frame below 0.3 was considered too weak and above 0.7 too high to make proper impact (Tabachnick and Fidell, 2001) cited in Julliet (2005).

Table 4.18 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.389[a]	.151	-.012	1.507

a. Predictors: (Constant), improper packaging, quality_ materials, specification for use, poor handling in transportation, non-standard sizes.
b. dependent variable: cost of building frame _000 where R=0.389 R^2=0.151
Source: Field survey 2015

Table 4.19 ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.532	5	2.106	.927	.479[a]
	Residual	59.072	26	2.272		
	Total	69.604	31			

a.Predictors: (Constant), improper packaging, quality_ materials, specification for use, poor handling in transportation, non-standard sizes

b.dependent variable: cost of building frame_000 where Df=5,26,31 F=0.927

Source field survey 2015

Table 4.20 Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
1(Constant)	18.43	1.304		14.134	0
quality_ materials	-0.299	0.306	-0.213	-0.978	0.337
poor handling in transportation	0.234	0.337	0.173	0.695	0.493
nonstandard sizes	-0.469	0.372	-0.316	-1.262	0.218
specification for use	-0.057	0.259	-0.213	-0.219	0.829
improper packaging	0.657	0.362	0.485	1.815	0.081

Dependent variable: cost of building frame_000

Source: Field survey 2015

e) Environmental waste factors in relation to cost of residential building frame construction.

Table 4.21 shows the model summary for the analysis which indicate that, R^2 for topography =0.380. This factor in this category explains 38% the cause of material waste in relation to cost of residential building frame construction in this region.

The study results from multiple regression analysis indicates the F–tests for topography has p= 0.00.Therefore, only topography at 99.0% confidence can significantly predict the cost of residential building frame construction in this category as noted in ANOVA model 4.22. Table 4.23 indicates a positive 0.616 beta value for topography with the implication that this variable has a strong correlation with cost of building frame in its category.

Table 4.21 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.616[a]	.380	.359	1.199

a. Predictors: (Constant), Topography

b. Dependent Variable: cost of building frame_000 . Source: Field survey 2015

Table 4.22 ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.448	1	26.448	18.385	.000[a]
	Residual	43.157	30	1.439		
	Total	69.604	31			

a. Predictors: (Constant), Topography

b. Dependent Variable: cost of building frame_000 where Df=1,30,31 F=18.385

Source: Field survey 2015

Table 4.23 Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1(Constant)	16.155	0.488		33.136	0
Topography	0.899	0.21	0.616	4.288	0

a. dependent variable: cost of building frame_000

Source: Field survey 2015

Regression analysis results indicate that poor or complex design is a factor which can significantly predict the construction cost at 95% confidence in its category. Designs which have complicated floor and roof plan shapes, irregular sizes, many recesses and corners results in materials wastage, due to off cuts and rework if correct shapes are to be achieved. The results concur with Adewuyi and Otali (2013) that ranks uneconomical designs highly as a cause for materials waste in residential building construction leading to cost overrun. A study by Olusanjo, Panos, and Ezekiel (2014) also categorizes project design, which do not conform to standards or modular sizes as the second major contributor on cost of construction waste after residual materials.

In site production and management waste factors, lack of security at 95% confidence or combined lack of security and poor work conditions at 99% confidence are the factors in their category which can significantly predict the construction cost of residential building frame in the Northern region of Nairobi. Olusanjo, et al. (2014) opine that, operations in a construction project ranks highly in contribution of material waste cost indices. Construction materials are quite vulnerable to theft or vandalism and security has to be enhanced by use of lockable stores, day and night guards and proper record keeping arrangements. When there is a high number of building construction projects within the same region, materials can easily get stolen from one project only to end up in the next construction project. Poor work conditions include: underpayment, long working hours, lack of incentives and lack of proper working environment. The workers are likely to throw materials away when the day is over if no overtime hours are compensated. Workers were also found to take casual consideration for material waste with the argument that no one will reward their material minimization gesture. A study by Meghani et al (2011) suggest that, intensifying security and introducing incentive schemes to workers are measures in material waste reduction during construction of residential buildings.

Material resource waste factors in a residential building frame construction included: improper handling, sub quality purchases, excessive/inadequate quantity, poor storage, misuse and theft/vandalism. None of these factors were found to significantly predict the construction cost in a residential building frame in this region at 95% confidence. A study by Olusanjo, et.al. (2014) however categorizes handling, residuals and vandalism among significant cost streams on sources of construction waste. Construction of a building frame requires bulk materials such as concrete, timber, roof coverings, mortar, reinforcement bars, stones or blocks and if properly al. (2012), rate material resource as a major material waste attribute. The construction of a conventional building frame does not factor in internal finishes, external finishes and external works which would explain the difference in findings.
From the regression analysis, improper packaging, poor quality materials, specification for use, poor handling in transportation and non-standard sizes as factors to predict the cost of residential building frame in this region were not found to be statistically significant at 95% confidence in manufacturing and delivery factors. Studies by Adewuyi and Otali (2013), Muhwezi, et al. (2012) do not rate factors related to manufacturing highly as contributing to construction waste. Manufacturing and delivery attributes can best be enhanced by ensuring, products from the factory meet the specified standards and handling instructions during delivery are well addressed. Meghani, et al (2011) suggests improving transport system and improving material quality as some of the measures to minimize material wastage in building construction.

Topography of the ground was found to be the variable that can significantly predict the cost of residential building frame construction with a 99% confidence in its category. Environmental factors are mainly associated with weather, ground formation, site conditions and social effects. The ground formation in this region was sloppy and materials such as sand and ballast got damaged when heavy El Nino rains were experienced. Study results by Muhwezi, et al. (2012), Adewuyi and Odesola (2015) also infer that, severe weather and effects of site conditions closely associated with topography of the site are the highest causes of material waste in their category.

4.3.2 Hypothesis testing

The study findings in phase two of the study show that poor or complex designs, lack of security, poor work conditions, topography as the material waste attributes in their category, that can significantly predict the construction cost of a residential building frame.

From the study findings, the null hypothesis is rejected with a conclusion that a relationship exists between factors causing materials waste and construction cost of residential building frame in the Northern Nairobi.

Table 4.24-hypothesis testing result.

item	*Factors causing material waste*	*df*	*p-value (sig.)*	*Confidence level*	*Remarks*
1	poor/complex design	1,30,31	*0. 036*	95%	Hypothesis rejected
2	lack of security, poor work conditions	2,29,31	*0.002*	99%	Hypothesis rejected
3	Topography	1,30,31	*0.000*	99%	Hypothesis rejected

Source: Field survey 2015

4.4 Measures for minimizing material waste in residential building frame construction.

4.4.1 Suggested measures by project consultants.

Figure 4.2 represents suggested material waste minimization measures, by project consultants in construction of residential building frames in this region. Proper supervision at 24% and morning briefs at 23% rated as the two highest measures required. Other measures include: use of skilled labour, proper procurement procedures, enhanced security, modular designs, encourage reuse, proper storage, purchase quality goods, coordination between parties and use of new technology.

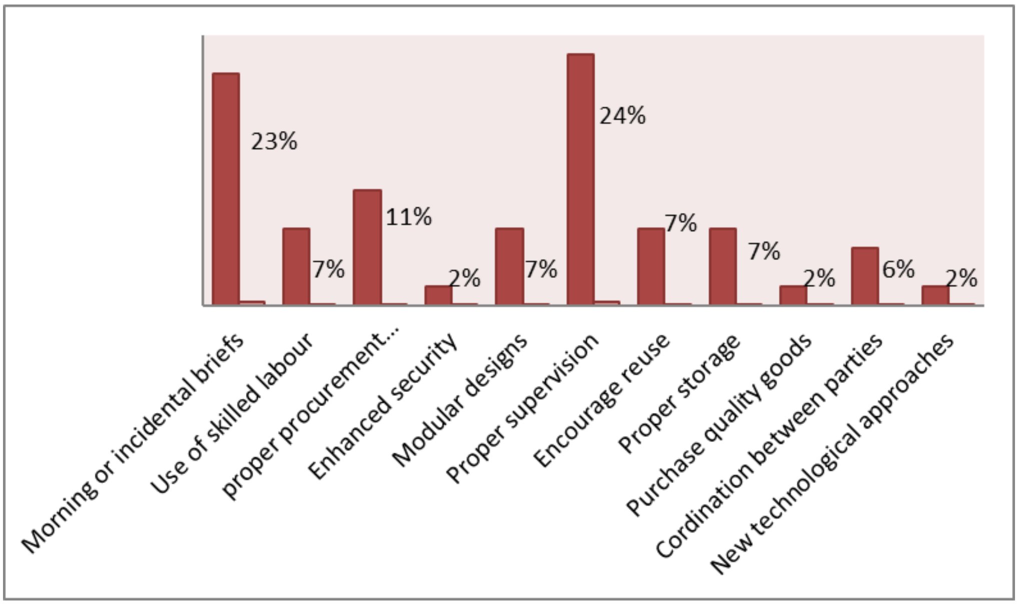

Figure 4.2 Project consultants' perspective: measures necessary to reduce excessive waste.

Source: Field survey 2015

The respondents were also required to state whether in design stage, there was collaboration between the designer and manufacturers. The results in Figure 4.3 indicate that 73% of respondents said there was none. Only 21% and 6% of the respondents respectively indicated there was minimal and none at all. This illustrates that, the designers in the region rarely produces modular designs, which would be integrated with the materials in the market, with a view to minimization of material waste in residential building frame construction.

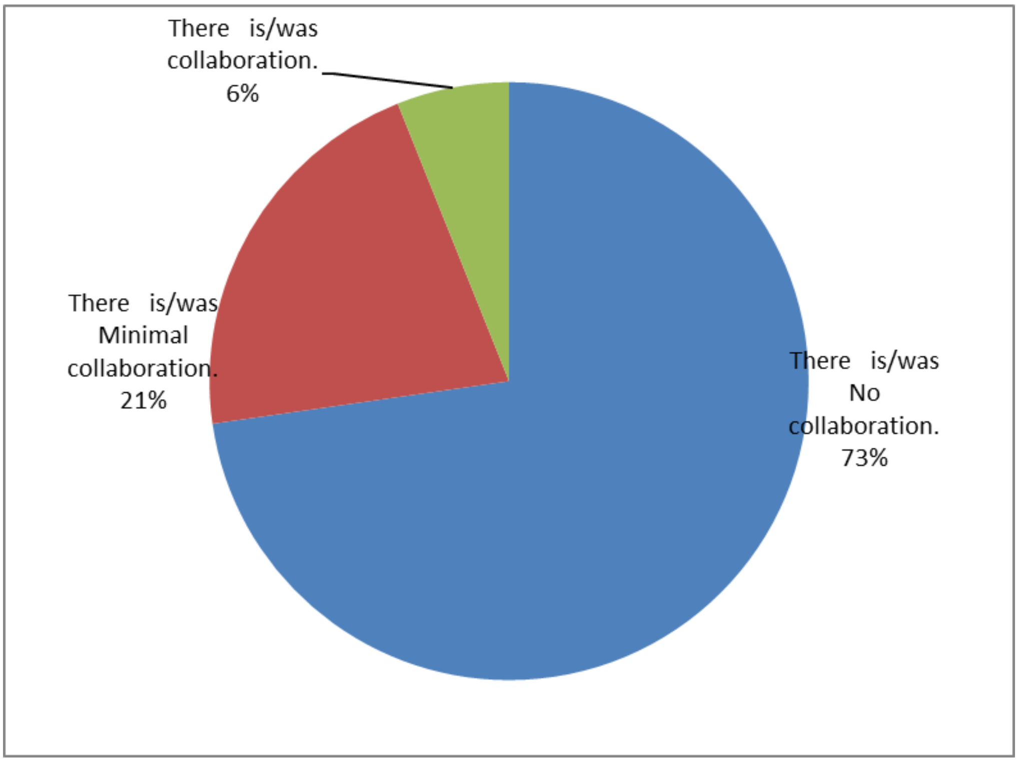

Figure 4.3 Project consultants' perspective: Collaboration between the designer and manufacturers.

Source: Field research data 2015

4.4.2 Suggested measures in focus group discussion.

Figure 4.4 represents the frequency of suggested measures to minimise material waste during residential building frame construction, in focus group discussions. Good quality material purchases is the highest rated at 15% . This is closely followed at 12% by proper storage/store keeping practices, scheduled purchases and use of experienced craftsmen. Adequate supervision at 11% is another measure highly rated to curb excessive material waste. Other measures suggested and their frequecy rating include: proper security at 8%, less complex designs at 4%, avoidance of design change midway at 4%, sensitization of material waste reduction at 3%, proper site layout at 2%, project coordination by parties involved at 2%, motivation of workers at 2 % and proper material delivery procedures at 1%.and delivery procedures at 1%.

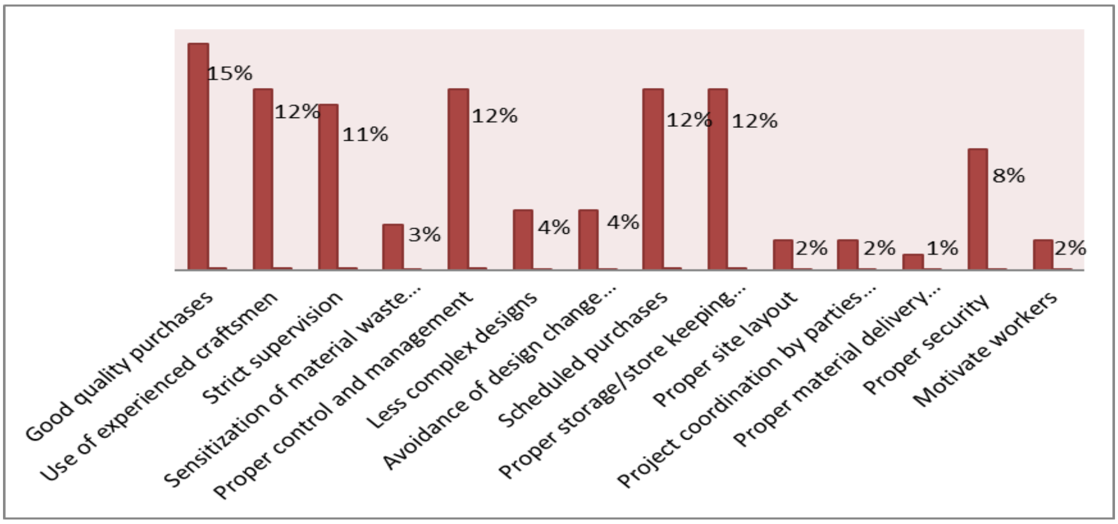

Figure 4.4 Focus group discussions: Frequency of measures to minimize material waste.

Source: Field survey 2015

4.5.3 Developing measures for minimizing material waste

Table 4.25. Significant factors for minimizing material waste

Active factors	Frequency
Morning briefs	23%
Proper supervision	24%
Proper procurement procedures	11%
Good quality purchases	15%
Proper storage and store keeping practices	12%
Utilize skilled and experienced workers	12%
Proper control by management	12%
Improved security	8%
Use of modular designs	7%

Source: Field survey 2015

Table 4.25 shows the Significant factors for minimizing material waste as suggested by both the project consultants and in focus group discussions. Proper supervision of the project activities and materials incorporation rates highly at 24%. Strict supervision ensures that materials are not wasted through breakages, poor workmanship leading to rework, unnecessary cuttings and strict adherence to the design to avoid repetitions. Sensitizing the working crew occassionary on the best practices on reduction of material wastage during construction is also rated highly at 23%. This has the implication that the workers who handles and deals with the materials directly have a major role to play in ensuring material wastage is reduced to a minimum during construction. Good quality purchases and proper procurement procedures rates 15% and 11% respectively. Construction materials in the market differ considerably in terms of quality. Poor quality materials are likely to cost less and are found to result to high wastage when being used during construction. When there is proper control in a project implementation, scheduled purchases ensures that materials are only brought to site when required to avoid long storage duration on site leading to breakages, contamination, misuse and theft. WRAP (2007) suggests the adoption of a robust system that enables the production of accurate estimates of material and action taken to reduce them.

Proper storage practices which rates at 12% should be encouraged on site. This ensures avoidance of double handling, breakages, contamination, deformation and theft. Vulnerable materials can be kept in lockable stores, in dustbins, in racks and also proper records kept to reduce pilferage. Trained and experienced craftsmen have also been rated as a significant factor which can help to curb material wastage in construction of residential building frames. Proper workmanship ensures that there is minimal materials wastage due to unnecessary cuttings, rework and mishandling.

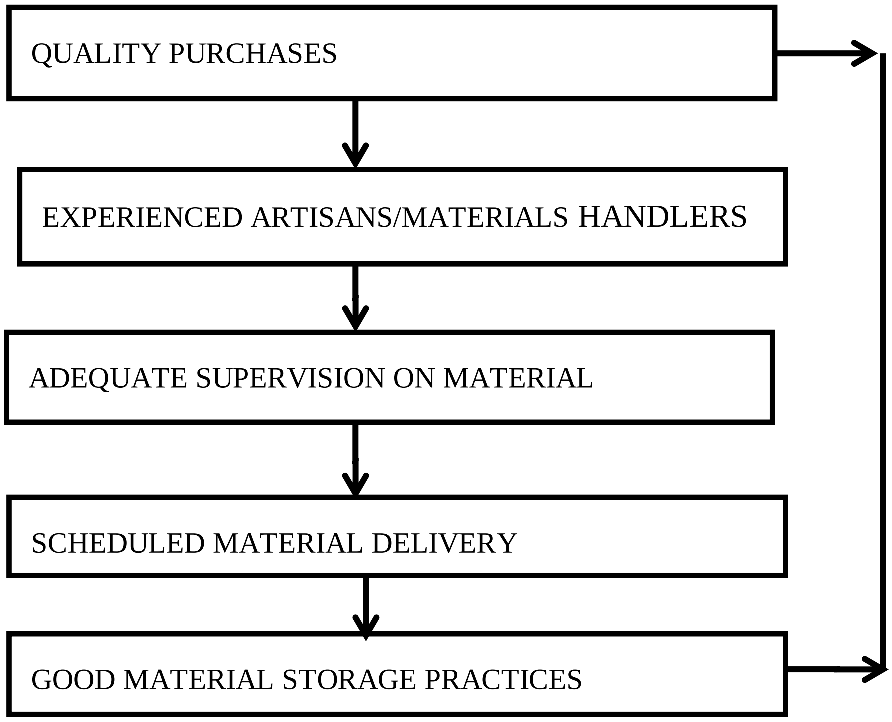

Figure 4.5: Material waste minimization procedures. Measurable stages (weighted index) in material waste management in building residential frame.
Source: Field survey 2015

Construction production incorporates among others materials flow, order sequence, quality purchases, good storage practices, strict supervision of materials use, and the product development process. The flow of materials from the suppliers through delivery must be integrated by means of just in time logistics and employees need to understand their roles. Each particular project management should understand their employees and participate in material waste reduction. This involves engagement, motivation, skill improvement and involvement in daily processes of material usage.

Table 4.26 shows the summary of material waste measures suggested by project consultants, focus group discussions and researcher observation.

Table 4.26. Summary of material waste reduction measures.

Responses	project consultants	Focus group discussions	Researcher observation
Good quality purchases	√√	√√	√√
Use of experienced craftsmen	√√	√√	√√
Strict supervision	√√	√√	√√
Sensitization of material waste reduction	√√	√√	
Proper control and management		√√	
Less complex designs		√√	√√
Avoidance of design change midway		√√	√√
Scheduled purchases	√√	√√	√√
Proper storage/store keeping practices	√√	√√	√√
Proper site layout		√√	√√
Project coordination by parties involved		√√	
Proper material delivery procedures and in use		√√	
Proper security	√√	√√	
Motivate workers		√√	
Modular designs	√√		√√
Encourage reuse and recycling	√√		√√
New technological approaches	√√		√√
Proper authorization documents			√√
proper management and workers attitude towards material waste			√√

Source: Field survey 2015

Measures suggested require rationalized approach to construction of residential buildings in the region. Also, products from manufactures should be integrated in the design to embrace modular sizing of components.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary and result findings whose objective was to suggest an alternative approach to construction of residential building frames in Northern Nairobi, with a view to minimization of material waste. Conclusions drawn from the findings and recommendations for lack of cost effective building materials, technologies, and material waste management systems in residential building sites in this region are presented. The study was underpinned on three key specific objectives:

1. To identify factors those contribute to material waste in construction of residential building frames in Northern Nairobi.
2. To establish the extent of impact of various causes of material waste on cost of residential building frame construction in Northern Nairobi.
3. Suggest measures for minimizing material waste in construction of residential building frames in Northern Nairobi.

Area for further research for material waste minimization in residential building construction is also advanced.

To realize the results of the research objectives, the study was carried out in two phases, where structured interviews were administered to respondents in phase one and two. Observation schedules in both phases enabled the researcher collect data on each site regarding the work procedures, handling procedures and general patterns in materials usage.

5.2 conclusions

5.2.1 Material waste causes

The results from the study findings identified the main causes of material waste in construction of residential building frames in Northern Nairobi. This region predominantly uses conventional methods of construction which is known to generate excessive material waste during construction. From the research findings there were three contracting options in use in the area. Labour contracting option had a rating of 69%. There is usually the tendency for the labour contractor to give less attention to material waste. Full contracting options ensure that the contractor takes full financial responsibility for any material waste in a given project. However, competent procurement officers need to be engaged and close control of material usage emphasized when labour only contracting option is preferred.

Phase one of the study delved in identifying the factors that cause materials waste in construction of residential building frame in Northern Nairobi**.** Researcher observation schedule also formed part of data collection tools for this phase. Literature reviews from previous studies (Muhwezi, et al. 2012, Adewuyi & Odesola 2015, Oladirani & Olatunji 2013) and result findings, enabled the researcher to group the results into five thematic areas namely: Design and site instruction factors, site production and management factors, material resource factors, manufacturing/delivery factors and environmental factors.

In design and site instruction factors, site instruction by the clients or the designers, coordination and consultation among project team member's rates highly in this category. These factors have been found to contribute highly in material waste during construction. The designers need to incorporate modular design considerations, use of less complicated drawings and specifications which are clearly explained. Proper documentation from relevant statutory bodies like NCA, NCC, and NEMA which may cause work stoppages should be processed in advance.

Site production and management attributes incorporates day to day management of the works on site. Inexperience among the skilled craftsmen or the contractor rates the highest at 41% in that category. This may be attributed to demolitions or rework which leads to materials such as cement, broken stones, and concrete rubble going to waste. Insufficient supervision is an indication that the management needs to engage qualified supervisors, improve security, improve work conditions and improve on site layout to avoid double handling. There is need also for craftsmen to be updated occasionally on material use and adequate/proper equipment provided for each task assigned.

In material resource factor, materials like cement and paints get contaminated if not properly stored according to manufactures instructions. Other materials like timber, stones, sand and roof coverings breaks, deforms or deteriorate if not properly stored. Security and proper store keeping procedures need to be enhanced to avoid materials being vandalized by the workers or outsiders.

In manufacturing and delivery, it has been found that low quality materials contribute highly to material waste. This maybe as a result of contraband materials in the market or poor control in production of quality materials by manufacturers, such as reinforcement bars, roof coverings of lower quality than what was intended for use. Clients or contractors maybe duped in purchasing these materials due to their low cost. Also in poor handling and transportation, materials such as stones and timber when carelessly thrown from delivery trucks, some end up breaking to the disadvantage of the buyer. Nonstandard sizes, improper specification for use and improper packaging attributes with a rating of 6%, 5% and 5% respectively are not so significant in material waste indicators in this region.

The main cause of material waste in environmental factors is attributed to material deterioration on site at a rating of 71%. Poorly stored stones weather out as they are rained on; sand, timber and paint deteriorate due to long duration of storage or improper storage. Topography of the ground is associated mainly with rainy seasons when materials are washed away. Damage by insects is attributed to improperly stored timber for long and is affected by ants.

5.2.2 Impact of factors causing material waste

Phase two of the study examined the rating of impact of the factors causing material waste on cost of residential building frame in Northern Nairobi. In design and site instruction factors, poor or complex designs was identified as the independent variable that can significantly predict the cost of residential building frame construction. Designs which have complicated floor and roof plan shapes, irregular sizes, and many corners results in material off cuts, changes during construction and rework if the desired shape is to be achieved. The designers would be encouraged to integrate modular designs and proper consultation carried out between the various parties in a particular project as work progresses.

Lack of security, poor work conditions are the predictors in site production and management waste factors that can significantly predict the cost of residential building frame construction in this region. Enhanced security for construction materials ensures that theft or vandalism is minimized, lockable stores for vulnerable materials are provided, day night guards are engaged and proper record keeping arrangements for material movement is improved. Poor work conditions include: underpayment, long working hours, lack of incentives and lack of good working environment. The workers are likely to throw materials away when the day is over if no overtime hours are compensated.

In material resource and manufacturing/delivery waste factors, none of the variables were found to predict cost of residential building frame construction at 95% confidence. These findings were based on the structural building frame construction which does not include fixings, internal finishes, external finishes and external works. Most of the bulk materials used for the building frame construction such as concrete, roof timber, stones, blocks and mortar are easily recycled within the same project. For material manufacture and delivery, there is need to ensure products from the factory meet the specified standards, proper handling instructions during delivery, scheduled delivery, quality assurance at the site and Government control on material standards. However materials used for conventional residential building frame construction such as sand, ballast, timber and reinforcement are bulk, they are not fragile and do not undergo delicate manufacturing processes.

In environmental waste factors, topography was the only variable that can significantly predict the cost of residential building frame construction. Environmental factors are mainly associated with weather, ground formation, site conditions and social effects. When the ground formation is sloppy, materials such as sand and ballast get damaged or would be washed away when heavy rains are experienced.

5.2.3 Material waste minimization measures.

The third objective suggests measures for minimizing material waste in residential building frame construction. Significant active factors include morning briefs, proper supervision, quality purchases, proper procurement procedures, proper storage and store keeping practices, use of experienced workers, and control by management, improved security and use of modular designs. There is therefore need to have emphasis on careful control, proper storage, security to minimize theft, proper handling and proper procurement procedures to avoid excessive supply or long duration of storage on sites.

5.3 Recommendations.

The research findings identified the main causes of material waste and their predictive strength on cost of residential building frame construction in Northern region of Nairobi. Use of new technologies in construction of residential buildings in Northern region of Nairobi such as Lean construction has the effect of material waste reduction. It is a rationalized building technique where production management-based approaches to project delivery, organizational techniques used in process of manufacture are applied to erection process. This leads to a properly integrated system of design and production waste reduction.

The researcher also recommends sensitization of the effects of material waste in the region to the project consultants to update themselves with the current trends in technology, so as to recommend different approach to construction of residential buildings within this region. Emphasis should also be put on: poor or complex designs, lack of security, poor work conditions and topography, factors which were found to significantly predict cost of residential building frame in the region.

Table 5.1 summarizes priority measures for material waste minimization in Northern Nairobi. The development of a robust waste management strategy for a particular site requires input from the employees and the management. Construction activities should be viewed as an industrial production and an integrated approach would ensure material wastes are minimized during construction. Priority however should be on site where the actual production is carried out in conventional construction.

Table 5.1: summary of priority measures for material waste minimization.

Measurable stages	measures	Mitigation remarks
QUALITY PURCHASES	-Specifications on material quality by consultants -Engage experienced material quality handlers.	-Use of experienced procurement employees. -Supervisors ensure quality products are procured.
EXPERIENCED ARTISANS/MATERIALS HANDLERS	-Use of Properly trained craftsmen. -Proper handling of the materials on site	-Experienced and trained craftsmen to curb material wastage. .-Minimizes on off-cut waste as the required building product is achieved
ADEQUATE SUPERVISION ON MATERIAL	-Follow manufactures instructions. -Close supervision	-Trained site supervisors to ensure materials are carefully handled, avoid breakages/misuse -Avoid ignorance on part of site personnel.
SCHEDULED MATERIAL DELIVERY	-Schedule material purchases. -Scheduled material deliveries	-Proper material estimates. -Materials ordered as required. --Supervisors ensure schedules are maintained.
GOOD MATERIAL STORAGE PRACTICES	-Proper storage. -Storm water management strategy. -Improved security	-Prevents loss of materials due to theft, lockable stores, day and night guards, security lighting, and proper store keeping practices. –Material deterioration /contamination is associated with adverse weather, poor storage and carelessness. -Curb uncontrolled rain water flow through the construction sites

Source: Field survey 2015

5.4 Area of further research.

This research was based on material waste on a residential building frame in conventional residential building construction in the Northern Nairobi. For further research, the quantification of the various materials at different stages of construction would give a better indication of the actual material quantities which go to waste. This can be taken as case studies for various construction sites from inception up to completion of the residential building frame in conventional construction.

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APPENDICES

Appendix A - Interview schedule for project consultants (Architects, Engineers, Quantity surveyors, project managers).

An Investigation into Factors Causing Material Waste and their Influence on Construction Cost of Residential Buildings in the Northern Region of Nairobi:

The case of Clay City and Kasarani Residential Estates.

Project location**: …………………………………………**

Type of residential Project**: …………………………**

Phase of study**: one………………………………**

Dear sir/madam,

I am carrying out a research on **"Factors causing material waste and their influence on construction cost of residential buildings in the Northern Region of Nairobi: The case of Clay City and Kasarani Residential Estates".** I request your co-operation in answering the following questions based on your current and previous experience in residential construction material waste in concrete, natural stones/ concrete blocks, roofing timber and roof coverings in this region. The answers will be treated with confidentiality and you are at liberty not to comment on any of the questions listed.

1. What type of contract was the project implemented.------------------------------------
----
----

2. Highlight the main causes of material waste in a residential building project in this region attributed to:

i) Project owner(s) --

----

ii)Contractor --

----

iii)Designers---
----

iv) Workers--
----

v)Environment --
----

vi) manufacturer--
----

vii) Others (specify)--

----

3. What is/was the level of collaboration between the designer and manufacturers during construction of this residential building project? -----------------------------------
----
----

4. What mechanism would you wish to be put in place to reduce excessive material waste in a residential building project? ---
----

Appendix B- Interview schedule for Focus group discussion (Trades men, accountants, storekeepers, purchasing officers).

An Investigation into Factors Causing Material Waste and their Influence on Construction Cost of Residential Buildings in the Northern Region of Nairobi:

The case of Clay City and Kasarani Residential Estates.

Project location**: ……………………………………**

Project type**: ……………………………………**

Phase of study**: ……one…………………………**

Dear sir/madam,

I am carrying out a research on **"Factors causing material waste and their influence on construction cost of residential buildings in the Northern Region of Nairobi: The case of Clay City and Kasarani Residential Estates".** I request your co-operation in answering the following questions based on your understanding about residential construction material waste in concrete, natural stones/ concrete blocks, roofing timber and roof coverings. The answers will be treated with confidentiality and you are at liberty not to comment on any of the questions listed.

1. What are the main causes of material waste in your project attributed to;

i)Projectowner(s)--

ii)Contractor--

----

iii)Designers--

----

iv)Workers--

----

v)Environment ---

----

vi)manufacturer---

----

vii) Others (specify)--

----

2. What measures are necessary to minimize material waste in a residential construction project?

Researcher observation:

1. Causes of material waste:---

---------- ---

2.photographs (materials waste piled up on site)

Appendix C –Interview schedule (Site managers)

An Investigation into Factors Causing Material Waste and their Influence on Construction Cost of Residential Buildings in the Northern Region of Nairobi:

The case of Clay City and Kasarani Residential Estates.

Project location**: ……………………………………………**

Type of residential Project**:……….………………………**

Phase of study**: ……two…………………………………**

Dear sir/madam,

I am carrying out a research on **"Factors causing material waste and their influence on construction cost of residential buildings in the Northern Region of Nairobi: The case of Clay City and Kasarani Residential Estates".** I request your co-operation in completing the following questions based on your understanding about residential construction material waste in concrete, natural stones/ concrete blocks, roofing timber and roof coverings. The answers given will be treated with confidentiality and you are at liberty not to answer any of the questions listed.

<u>Site managers</u>

<u>Part one:</u>

<u>Instructions:</u>

-From the Five point scale indicated, select the level of influence of the attributes of residential building material waste on cost of residential building construction.

1. Very low. 2. Low. 3. Moderate 4.High 5.Very high

-Tick the appropriate score for each question listed.

A. Design and site instruction factors.

A1. Site instructions/change of design midway 1.Very low 2.low 3.moderate 4.High 5.Very high

A2. Poor/complex design 1.Very low 2.low 3.moderate 4.High 5.Very high

A3. Unclear specifications 1.Very low 2.low 3.moderate 4.High 5.Very high

A4. Lack of proper documentation 1.Very low 2.low 3.moderate 4.High 5.Very high

A5. Inadequate co-ordination 1.Very low 2.low 3.moderate 4.High 5.Very high

A6. Non modular design 1.Very low 2.low 3.moderate 4.High 5.Very high

A7. Inadequate consultation 1.Very low 2.low 3.moderate 4.High 5.Very high

B. Site production and management factors.

B1. Inadequate control/supervision 1.Very low 2.low 3.moderate 4.High 5.Very high

B2. Management work attitude 1.Very low 2.low 3.moderate 4.High 5.Very high

B3. Lack of security 1.Very low 2.low 3.moderate 4.High 5.Very high

B4. Inadequate/improper equipments 1.Very low 2.low 3.moderate 4.High 5.Very high

B5. Craftsmen inadequate training 1.Very low 2.low 3.moderate 4.High 5.Very high

B6. Demolition/rework 1.Very low 2.low 3.moderate 4.High 5.Very high

B7. Poor work conditions 1.Very low 2.low 3.moderate 4.High 5.Very high

B8. Inexperienced workers or contractor 1.Very low 2.low 3.moderate 4.High 5.Very high

B9. Poor site layout 1.Very low 2.low 3.moderate 4.High 5.Very high

B10. Change of contractors midway 1.Very low 2.low 3.moderate 4.High 5.Very high

C. Resource material factors.

C1. Excessive/ Inadequate quantity 1.Very low 2.low 3.moderate 4.High 5.Very high

C2. Sub quality purchases 1.Very low 2.low 3.moderate 4.High 5.Very high

C3. Poor storage /poor storage facilities 1.Very low 2.low 3.moderate 4.High 5.Very high

C4. Misuse 1.Very low 2.low 3.moderate 4.High 5.Very high

C5. Theft /vandalism 1.Very low 2.low 3.moderate 4.High 5.Very high

C6. Improper handling 1.Very low 2.low 3.moderate 4.High 5.Very high

D. Manufacturing/Delivery factors.

D1. Low quality materials 1.Very low 2.low 3.moderate 4.High 5.Very high

D2. Poor handling/transportation 1.Very low 2.low 3.moderate 4.High 5.Very high

D3. Nonstandard sizes 1.Very low 2.low 3.moderate 4.High 5.Very high

D4. Improper specification for use 1.Very low 2.low 3.moderate 4.High 5.Very high

D5. Improper packaging 1.Very low 2.low 3.moderate 4.High 5.Very high

E. Environmental factors

E1. Material deterioration/contamination 1.Very low 2.low 3.moderate 4.High 5.Very high

E2. Damage by insects 1.Very low 2.low 3.moderate 4.High 5.Very high

E3. Natural calamities 1.Very low 2.low 3.moderate 4.High 5.Very high

E4. Topography 1.Very low 2.low 3.moderate 4.High 5.Very high

Part two:

1. Built up area: --

Appendix D. observation schedule for material waste.

summary of observation schedule for material waste							
S/no	Site location	Project type	contract type	Built up area	Number of floors	Images of material waste	Images of materials storage
1	Kasarani	Apartments	labour contract	718	3	√	√
2	Kasarani	Apartments	labour contract	1164	4	√	√
3	Kasarani	Apartments	labour contract	432	3	√	√
4	Kasarani	Apartments	labour contract	1063	4	√	√
5	Kasarani	Maissonette	Direct labour	432	2	√	√
6	Kasarani	Maissonette	labour contract	315	2	√	√
7	Kasarani	Maissonette	labour contract	288	2	√	√
8	Kasarani	Maissonette	labour contract	186	2	√	√
9	Kasarani	Apartments	Full contract with B/Q	1140	4	√	√
10	Clay city	Apartments	labour contract	880	3	√	√
11	Clay city	Apartments	labour contract	1125	4	√	√
12	Clay city	Apartments	Full contract with B/Q	1386	5	√	√
13	Clay city	Apartments	labour contract	1728	5	√	√
14	Clay city	Apartments	labour contract	2160	6	√	√
15	Clay city	Apartments	labour	748	3	√	√

			contract				
16	Clay city	Apartments	labour contract	580	3	√	√
17	Clay city	Maissonette	Direct labour	180	2	√	√
18	Clay city	Apartments	labour contract	900	4	√	√
19	Clay city	Apartments	labour contract	1400	5	√	√
20	Clay city	Apartments	labour contract	1417	5	√	√
21	Clay city	Apartments	labour contract	1122	5	√	√
22	Clay city	Apartments	labour contract	748	3	√	√
23	Clay city	Apartments	labour contract	880	4	√	√
24	Clay city	Apartments	labour contract	1134	4	√	√
25	Clay city	Apartments	labour contract	1900	5	√	√
26	Clay city	Apartments	Full contract with B/Q	2475	6	√	√
27	Clay city	Apartments	labour contract	2640	6	√	√
28	Clay city	Apartments	Full contract with B/Q	2227	5	√	√
29	Clay city	Apartments	Full contract with B/Q	2362	5	√	√
30	Clay city	Apartments	labour contract	1663	4	√	√
31	Clay city	Apartments	labour contract	770	4	√	√
32	Clay city	Apartments	labour contract	825	4	√	√

Source: Field survey 2016

AppendixE- Building costs per m2 in Central, Coast and Western regions.

Current building costs per m2 in central, coast and western regions March 2015

ITEM	BUILDING TYPE	COST PER M2 (EXCLUDING VAT)		
		CENTRAL REGION(NAIROBI) Kshs	**COASTAL REGION(MOMBASA) Kshs**	**WESTERN REGION (KISUMU) (Kshs.)**
A	**Office Blocks**			
	1) Low rise (Four Storey)	37,000.00	38,000.00	35,000.00
	2) High rise (With lifts)	46,000.00	47,000.00	44,000.00
B	**Industrial Complex**			
	3) Factories (Two storey)	31,000.00	29,000.00	32,000.00
	4) Warehouses (Ditto)	29,000.00	27,000.00	31,000.00
C	**Retail Outlets**			
	5) Small scale shopping centres	34,000.00	38,000.00	36,000.00
	6) Shopping mall	46,000.00	47,000.00	50,000.00
D	**Residential**			
	7) High class single units (Maisonettes)	41,000.00	44,000.00	44,000.00
	8) High class high rise flats	46,000.00	44,000.00	44,000.00
	9) Low cost, low rise flats	32,000.00	29,000.00	29,000.00
	10) Low cost, high rise flats	36,000.00	35,000.00	35,000.00
	11) Site & services schemes	18,000.00	20,000.00	20,000.00
E	**Social Centres**			
	12) Social clubs	31,000.00	33,000.00	32,000.00
	13) Churches (Double volume Height)	42,000.00	41,000.00	41,000.00
	14) Community Centres	36,000.00	41,000.00	40,000.00
F	**Hotels**			
	15) Urban low rise	36,000.00	47,000.00	44,000.00
	16) Urban high rise (With lifts)	46,000.00	54,000.00	53,000.00
	17) Game lodges (Remote areas)	48,000.00	66,000.00	63,000.00
	18) Tented camps	24,000.00	38,000.00	37,000.00
G	**Health facilities**			
	19) Simple clinics	24,000.00	34,000.00	30,000.00
	20) Urban areas clinics	32,000.00	42,000.00	37,000.00
	21) Dispensaries (Rural areas)	22,000.00	26,000.00	25,000.00
	22) Large referral hospitals	60,500.00	65,500.00	64,500.00
H	**Sports Facilities**			
	23) Stadiums	42,000.00	48,000.00	47,000.00
	24) Simple arenas	34,000.00	39,000.00	38,000.00
	25) Theatres (Double volume height)	47,000.00	54,000.00	53,000.00
	26) Health clubs	51,000.00	59,000.00	57,000.00
	27) Playing fields	12,000.00	18,000.00	14,000.00

Source: Journal of The institute of quantity surveyors –Kenya IQSK (jan-March 2015 vol 017 1ssue 004)

Appendix F -Multi-Family Residences elemental cost - Apartments

Quality Classification

	Class 1 Best Quality	Class 2 Good Quality	Class 3 High Average Quality	Class 4 Low Average Qlty	Class 5 Minimum Qlty
Foundation(9% of total cost)	Conventional crawl space built on a sloping site.	Conventional crawl space built on a sloping site.	Conventional crawl space, footing over 40" deep.	Concrete slab or crawl space with 30" footing.	Concrete slab.
Floor Structure(12% of total cost)	Engineered wood, steel or concrete exceeding code requirements, complex plan, changes in elevation.	Engineered wood or steel ,built to meet code requirements, changes in shape and elevation.	Standard wood frame with irregular shape and changes in elevation.	Standard wood frame or concrete slab, simple floor plan.	Simple slab on grade with no changes in elevation.
Walls and exterior finish(12% of total cost)	Complex wood or light Steel frame, stone or masonry veneer, 10" average wall height.	Wood or light steel frame, masonry veneer at entrance, good wood or stucco siding.	Wood or light steel frame, decorative trim at entrance, plywood or stucco siding, simple framing plan.	Wood frame, some ornamental details at entrance, plywood or hardboard siding.	Wood frame, little or no ornamentation, inexpensive stucco or hardboard siding.
Roof & Cover(10% of total cost)	Complex roof plan, good insulation, tile or good shake cover.	Good insulation, good shake, tile or 5-ply built-up roof.	4-ply built-up roof, some portions heavy shake or tile.	4-ply built-up roof,some portions shake or composition shingles.	4-ply built-up roof or minimum grade composition s ngle.

When masonry walls are used in lieu of wood or light steel frame walls, add 9% to the appropriate structural frame cost.

Source: 2015 National building cost manual (2014)

Appendix G- Single family Residence

Quality classification

	Class 1 luxury	Class 2 semi-luxury	Class 3 best std	Class 4 good std	Class 5 Avg std	Class 6 minimum std
Foundation(9% of total cost)	Reinforced concrete.	Reinforced concrete.	Reinforced concrete.	Reinforced concrete or concrete block.	Reinforced concrete or concrete block.	Reinforced concrete
Floor Structure(12 %of total cost)	Engineered wood or steel exceeding code minimums.	Engineered wood or steel or reinforced concrete slab.	Engineered wood or steel or reinforced concrete slab.	Wood frame or slab on grade, changes in shape and elevation.	Standard wood frame or slab on grade with elevation changes.	Slab on grade No changes in elevation
Wall Framing and exterior finish (14% of total cost)	wood or steel, very irregular walls, stone veneer, many architectural doors and windows.	Wood or steel,irregular shape, masonry veneer, better grade doors and windows	Wood or steel, several wall offsets, wood or masonry accents, good grade doors and windows	Wood or steel, stuco or wood siding, some trim or veneer ,av doors and windows	Wood or steel,stucco or wood siding, few offsets ,commodity grade doors and windows	Wood or steel ,stucco or side board siding ,minimum grade doors and winds
Roof(10% of total cost)	Complex plan, tile, slate or metal ,highly detailed	Multi-level, slate, tile or flat surface, decorative details	Multi-pitch, shake tile or flat surface ,large closed soffit	Wood trusses, tile or shingles, closed soffit	Wood frame, shingle or built up cover ,open 24" soffit	Wood frame, composition shingle cover, open soffit

Source: 2015 National building cost manual (2014)