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An Investigation on the Influence of Factors Causing Material Waste on Construction Cost of Residential Building Frame. A Case of Northern Region of Nairobi.

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Abstract:- **Production systems of residential building construction projects in the Northern region of Nairobi are predominantly conventional, which results in large amounts of material waste. Reduction of material waste in residential construction results in cost saving to the client and to the contractor. The main objective of this study was to suggest an alternative approach to construction of residential buildings in Nairobi, whose utilization results in minimization of material waste. The study investigates the influence of factors causing material waste, and establishes the extent to which these factors explain the cost of residential building construction in the Northern region of Nairobi. A survey and case study type of a research is conducted. Northern region of Nairobi is purposively sampled, because of its high concentration of residential housing projects. Primary data is collected through structured interviews and observation. Descriptive statistics and multiple regression, aided by the Statistical Package for Social Sciences (SPSS) is used for data analysis. The results of the analysis 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. Recommendations for minimization of materials waste during construction include: effective supervision, control of construction activities and materials during construction .There is also the need to adopt new technology in construction of residential buildings in this region, with a view to material waste reduction.**

Key words: Building frame, Construction cost, Material waste, Nairobi, residential buildings.

1.0 INTRODUCTION

Production systems of residential building construction projects in the Northern region of Nairobi are predominantly conventional, which results in large amounts of material waste. Kenya vision 2030(2007) charged the Ministry of Land, Housing and Urban Development with the responsibility of facilitating Kenyans to access quality, affordable and sustainable housing, through research on cost-effective building materials and technologies. This however, has been hampered by a number of challenges, the main one being the high cost of building materials.

Construction material waste in Kenya 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). 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 county dump sites.

Residential building construction sector generates unacceptable levels of material waste whereby the amount and type depends on stage of construction, type of construction work and practices on site. This leads to manpower waste; financial setbacks to contractors; significant impacts on health, aesthetics and the general environment. Waste minimization in implementation of a residential building project is a major area of concern, including waste management. Materials in a residential building project amounts to about 60% to 70% in the overall cost of construction. Various studies have confirmed that, waste represents a large percentage of production costs and can result to between 1-10% by weight of purchased materials (Bosinnk and Brouwers, 1996., Masudi et al, 2012). Nugroho et al (2013) opine that, construction waste may increase the project cost to about 6% and therefore, if managed properly, a saving of 6% of the project cost can be realized.

According to Muhwezi, Chamuriho, and Lema, (2012), building construction activities which produce material waste can be categorized as off-site or 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. 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). In Nigeria sites, improper control of materials during different stages of construction produces large quantities of construction material waste. This leads to high cost of construction and becomes a hindrance to good affordable housing (Oradiran and Olatunji, 2009). 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 and Brouwers, (1996).

1.1. Building construction material waste.

There are many aspects of waste in a building construction project, which may be attributed to a number of factors. 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. Shingo (1989), cited in Meghani et al (2011) argues 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 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 (Formoso, Isatto, and Hirota, 1999).

1.2. Material waste categories in building projects.

In a residential building frame construction process, different categories of material waste and factors leading to their waste are diverse. According to Howard (1970) cited in Muhwezi, Chamuriho, and Lema, (2012*),* construction material wastage can be classified into six broad categories: conversion waste, cutting waste, application waste, stockpile waste, residue waste and transit waste. In conventional residential building, the materials commonly used to erect the structural frame include concrete, wood, stones or blocks and steel, roof coverings (tile, metal sheets, asphalt, bitumen felts) and mortar.

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 delivering (Wang,Kang and Tam 2008). According to Shen, Vivian, Tam, and Drew (2002), 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. Formoco et al (2002), argues that the main causes of concrete waste are lack of constructability 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.

Wood waste refers to timber products, such as formwork, false work, plywood, framing, roof truss and others not properly utilized (Lau, Whyte, and Law 2008, Wang,Kang and Tam 2008). This may be attributed to periodic usage of formwork, storage, construction activities, un- standardized design operations, human behavior among other causes. Wilson et al (1997) argue 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, Whyte, and Law (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.

Natural stone industry generates large volume of stone waste, which causes environmental, health and economical drawbacks. Huge amounts of stone waste generated in construction sites result in vast sums of money spent on its transportation to landfills (Shirazi, 2011).

Mortar is used to set stones, blocks and bricks as well as finishing work on walls and floors of buildings. The main cause of waste is scraping of mortar while pointing, mixing too much and spills around the site. Excess unused mortar at the end of day hardens ending up as waste. Roof tile waste is mainly caused by sawing when insufficient attention is paid of available tile sizes and shapes during design phase. Corroboration between construction parties would improve on material waste minimization. Breakages during transportation can result to 15% of amount purchased Bosinnk and Brouwers (1996).

1.3. Building material waste causes in construction projects.

Different construction processes impacts on material waste generation and the quantity produced. This may be attributed to a number of factors such as: inaccurate or surplus ordering of materials, handling errors, inadequate storage, poor co-ordination with other trades, rework, inefficient use of materials and temporary works materials (WRAP 2007). Oladiran and Olatunji (2009) and Branco (2007) 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.

The generation of excessive construction material waste may also be attributed inadequate waste management policy within an establishment. According to a study carried out by Muhwezi, Chamuriho, and Lema, (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.

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.

1.4. Quantifying construction waste

Masudi et al (2012) aver that, various models for quantification of construction waste are available but cannot be universally applicable. This is due to the fact that, the amount of construction waste generated in any region depends on the general economic conditions of the vicinity, the weather, major disasters, special projects, and local regulations According to Nugroho et al, (2011) the construction waste may increase the project cost to about 6%.

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 (Jilali, 2007). 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.

1.5 Reduction of building material waste.

According to Josephson and Saukkoriipi (2007,the first step in reducing waste in building projects 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. Resource venture (2005), proposes three strategies to reduce a construction project's waste: reducing, reusing and by recycling. Studies by Wang, et al (2008), Al-Hajj and Hamani (2011) recommends: enforcement of legislation, training and education, involving environmental consideration in design and tendering reports, on-site management systems and improvement of communication for reduction of material waste. Hendriks and Pietersen(2000) argues that, reduction of construction waste can be realized by careful design, waste prevention and improvement of the quality of the remaining waste on site. The study further opines that, the client, the architect and contractor can significantly contribute towards waste minimization.

Muhwezi, Chamuriho, and Lema, (2012) infer that, 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. Dainty and Brooke (2004) suggests the following measures to curb building construction wastes: Standardization of design to improve buildability and reduce the quantity of off-cuts; stock control measures to avoid the over ordering of materials; improved education of the workforce; supply chain alliances with suppliers/recycling companies; provision of waste skips for specific materials; just-in-time delivery strategy; dedicated specialist sub-contract package for on-site waste management; contractual clauses to penalize poor waste performance; design management to avoid over specification of materials; additional tender premiums where waste initiatives are to be implemented; increased use of off-site prefabrication; on-site materials compactors; educate clients about measures to reduce waste levels; supplier ability to provide smaller quantities of materials.

A study carried out by Angaya (2012) sought to determine the extent of waste material management influence in the performance of housing building projects in Nairobi. The study examined lean construction as a system for putting up housing building units with an aim of minimizing waste of materials, time; improve safety and effort in order to generate the maximum possible amount of value for the stakeholders. He noted that parameters describing the overall process of lean construction are considered important determinants of the performance of housing and building projects.

1.6 Construction approaches.

Conventional Building.

Oxford dictionary (n.d)defines conventional as anything pertaining to or established by general consent or accepted usage, ordinary rather than different or original, in accordance with an accepted manner, model, or tradition in art, or pertaining to a compact or convention.

According to Foster and Greeno (2006), 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 three building systems are mainly industrialized building systems where components of a building are conceived, planned, fabricated, transported and erected on site.

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 and Greeno 2006). According to Kamar et al (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 and Greeno (2006) 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.

1.7 Building construction cost

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-composed of detailed estimate of various items of work and then determine the cost of each item by calculating quantities and estimated overhead costs.

Plinth area method- The cost of construction is determined by multiplying plinth area with 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 - Used for multi storeyed buildings. The cost of a structure is calculated approximately as the total cubical contents multiplied by local cubic rate.

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 1 student and in case of hospital, the unit is 1 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. 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))

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 its 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. National building cost manual (2014), an online preview of current building costs suggested elemental estimates for residential single dwellings and multi-dwellings.

1.8 Cost of building materials.

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. The study avers 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).

Cost impact of building materials.

According to Mwaniki, W. (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.

1.9 Systems theory.

According to Capra (1997) cited in Mele et al (2009), a systems theory is an interdisciplinary theory about every system in nature, in society and in many scientific domains

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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 and 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).

Systems theory and circular economy.

WRAP (2015) infer that circular economy is an alternative to a traditional linear economy (make, use, dispose) where resources are kept in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life. Circular economy creates new opportunities for growth, reduce waste and drive greater resource productivity. A study by Xiao and Wang (2013) suggests that the models of circular economy embodies mainly the clean production within individual enterprises, by making use of clean raw material and promote clean production by clean procedures. A study by Greyson (2015) suggests that an approach designed to prevent waste and other global impacts could be based upon the established practices of circular economic policy and recycling insurance.

Systems theory and Lean production.

Lean production uses the just-in-time practices and aims at the rational use of resources, the strategies to improve the production process and the elimination of waste, and the use of managerial scientific techniques (Manea 2013).

According to Greg andTariq (2012), Lean construction is a production management based approach to project delivery. It is a philosophy based on the concepts of lean manufacturing. Lean construction extends from the objectives of a lean production system, maximizes value and minimizes waste to specific techniques, and applies them in a new project delivery process. Aziz and Hafez (2013) argues that one approach for improving the productivity of the construction industry is using lean construction which results from the application of a new form of production management to construction.

1.10 Controlling construction waste.

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.

Integrated waste management plan (IWMP).

United Nations Environment Program (n.d) opines that, 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 ,land filling and incineration.

2.0 CONCEPTUAL FRAMEWORK

Residential building construction projects in the Northern region of 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, concrete, natural walling stones, timber and roof coverings forms the bulk of the materials used in the structural component. Conventional construction methods generate a lot of material waste which are not properly utilized due to a number of 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 the Northern region of Nairobi would be explored in this study, whose utilization results in minimization of material waste.

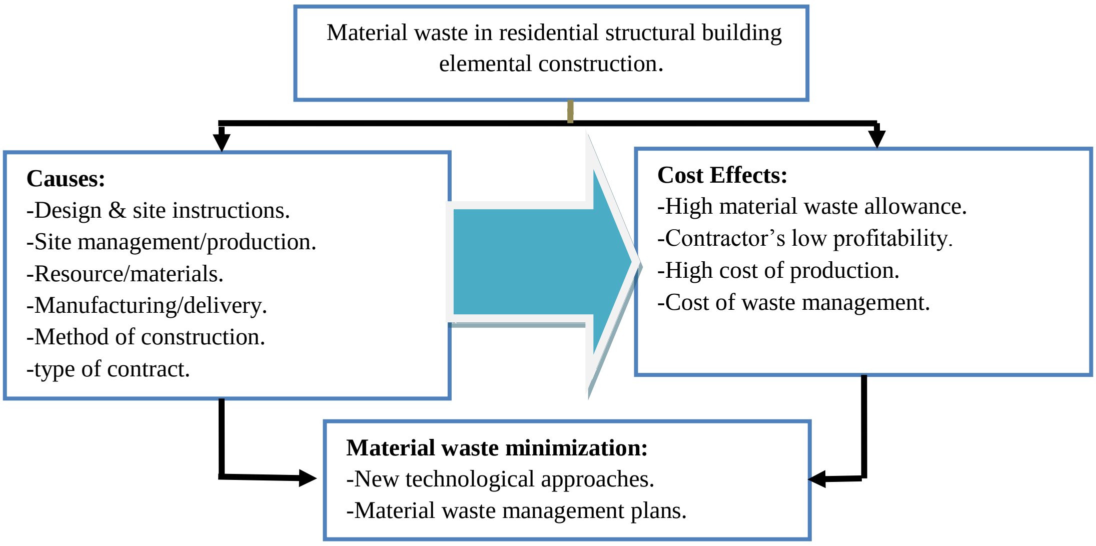

Figure 1 summary of conceptual framework

3.0 RESEARCH METHODOLOGY

The main objective of this study was to suggest an alternative approach to construction of residential buildings in the Northern region of Nairobi, whose utilization leads to minimization of material waste and reduction of construction cost. The study specifically focused on the residential building frame projects, and delves into establishing the extent of impact of various causes of material waste on cost of residential building frame construction in this region.

This research is a survey and case study design and suggests measures for material waste minimization in conventional construction in this region. Primary data was gathered through interviews and observations. Purposive sampling technique was used to identify Clay City and Kasarani estates in the Northern region of Nairobi, due to the high concentration of diverse residential building projects which were in progress. Through a reconnaissance survey, 33 residential building projects in progress had reached roof level, of which 5 were maissonettes, 28 walk-up flats. Using Krejcie & Morgan (1970) formulae for determining sample size, a population size of 33 at 95% confidence and a degree of accuracy of 0.05 gives a sample size of 32 projects.

Factors attributed to material waste in construction of residential building frame in this region were grouped in five main thematic areas: design and site instruction factors, site production and management factors, material resource factors, manufacturing/delivery factors and environmental factors. Journal of 'The institute of quantity surveyors–Kenya' (IQSK), Jan-March 2015 issue suggested the current unit cost of different categories of residential building construction in Nairobi region (table 1). National building cost manual (2014) highlights the elemental costs for multifamily residences up to roof level as 44% of total cost while single family residences has been estimated at 54% of the total cost.

Table 1 Building costs per m2 in central, coast and western regions (Kenya) March 2015

Item	Building type	Cost per m2 (excluding VAT) Nairobi region kshs
1	High class single units (Maisonettes)	41,000.00
2	Low cost, low rise flats(upto 4 floors)	32,000.00
3	Low cost, high rise flats(above 4 floors)	36,000.00

Data collection.

Primary data collection from site managers was through structured interviews and observation. Data collected through observation in sampled projects included built up areas number of floors, type of contract and type of residential project, which was recorded on paper manually. Data obtained was analyzed using multiple regression statistics. Statistical Package for Social Sciences (SPSS), facilitated in organizing the raw data, then frequencies, percentages and other statistical functions were generated.

4.0 RESEARCH RESULTS AND DISCUSSION

To determine the predictive rating of impact of the factors on cost of residential building frame in the Northern region of Nairobi, a 5 point Likert scale questionnaire was developed. From the five point Likert scale of 1- very low, 2- low, 3- medium,4- high and 5- very high, 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.

4.1 Regression analysis

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 regression essentially does multiple regression, removing the weakest correlated variables and the variables that explain the distribution best are left. The response data, from site managers in percentages and the ranking in level of material waste contribution for each attribute is presented in table 4.2

Table 4.2: Response data from site managers.

	Factors	*percentages*					
A	*Design and site instruction factors.*						
		V.L	L	M	H	V.H	Rank in waste contrib.
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 equipments	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 workerscontractor	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	***Resource material 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	Non standard 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

Design and site instruction factors: These included: site instructions/change of design midway, poor/complex design, unclear specifications, lack of proper documentation, inadequate co-ordination and inadequate consultation. The model summary table 3 indicate, for poor/complex design R^2 =0.138. Therefore this factor in this category explains 13.8% the cause of material waste in relation to cost of residential building frame construction in

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this region. The study results also indicates the F–tests for poor/complex design has p= 0.036.Therefore, only this factor can significantly predict the cost of residential building frame construction at 95% confidence in this category as noted in ANOVA model table 4.

Table 3: Model Summary

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 bld. frame_000

Table 4: 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 bld. frame_000

Site production and management waste factors include: inadequate control/supervision, management work attitude, inadequate/improper equipments, craftsmen inadequate training, demolition/rework, poor work conditions, inexperienced workers/ contractor, poor site layout and change of contractors midway in this category. The model summary table 4 indicate, lack of security, poor work conditions has value of R^2=0.348. This implies 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 6, lack of security and poor work conditions at 99% confidence are the factors which can significantly predict the construction cost in a residential building frame in the northern region of Nairobi.

Table 5: Model Summary[c]

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 bld. frame_000

Table 6: ANOVA[c]

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 bld. frame_000

Material resource waste factors: The independent variables in this category includes: improper handling, sub quality purchases, excessive/inadequate quantity, poor storage, misuse, theft /vandalism. The model summary table 7 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 8 was used to test whether any of the factors significantly predicted the cost of residential building frame construction. The value p= 0.065 was 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 7: Model Summary[b]

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

a. Predictors: (Constant), improper handling, subquality purchases, excessive/inadequqte quantity, poor storage, misuse, Theft/vandalism
b. Dependent Variable: cost of bld. frame_000

Table 8: 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/inadequqte quantity, poor storage, misuse, Theft/vandalism

b. Dependent Variable: cost of bld. frame_000

Manufacturing/Delivery waste factors: improper packaging, sub quality materials, specification for use, poor handling in transportation, non standard sizes are the independent variables considered in this category. The model summary table 9 indicate that, the value of R^2 = 0.151, with implications that about 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 10 was used to test whether any of the factors significantly predicted the cost of residential building frame construction. The value p= 0.479 was 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 9: Model Summary[b]

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 bld. frame_000

Table 10: ANOVA[b]

Model		Sumof 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 bld. frame_000

Environmental waste factors: material deterioration/contamination, damage by insects, natural calamities and topography are the factors considered in this category. The model summary table 11 indicate that, R^2 =.380 for topography. Therefore, this factor explains 38% the cause of material waste in relation to cost of residential building frame construction in this region. The study results indicates the F–tests for topography has p= 0.00.Therefore, only topography can significantly predict at 99% confidence,the cost of residential building frame construction in this category as noted in ANOVA model table 12.

Table 11: Model Summary[b]

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 bld. frame_000

Table 12: 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 bld. frame_000

Designs which have complicated floor and roof plan shapes, irregular sizes, many recesses and corners results in materials wastage. This is as a result of rework and off cuts if correct shapes are to be achieved. These findings 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 of construction waste after residual materials.

In production and management waste factors, lack of security at 95% confidence and poor work conditions at 99%confidence are the factors which can significantly predict the construction cost in a residential building frame in the northern region of Nairobi. Olusanjo, Panos, and Ezekiel (2014) opine that, operation 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. Where there is a high number of 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 basic 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, 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, Panos, and Ezekiel (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, mortar, reinforcement bars, roof coverings, stones or blocks and if properly handled would results in minimal wastage. Other studies (Adewuyi and Otali 2013, Muhwezi, Chamuriho and Lema 2012), rate material resource as a major material waste attribute. However, the findings were based on the entire building construction process which includes fixings, internal finishes, external finishes and external works.

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. Other studies Adewuyi and Otali (2013), Muhwezi, Chamuriho and Lema 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 significant variable that can significantly predict the cost of residential building frame construction with a 99% confidence in Environmental factors 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, Chamuriho and Lema(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.

5.0 CONCLUSIONS

Designs which have complicated floor and roof plan shapes, irregular sizes, many corners, recesses, results in material off cuts, changes during construction and rework so as to achieve desired shapes. The designers would be encouraged to integrate modular designs and proper consultation carried out between the various parties in a particular project before the work begins.

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 basic working environment. The workers are likely to throw materials away when the day is over if no overtime hours are compensated.

These findings were based on the elemental building construction frame 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 before the works are completed.

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.

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 or were washed away when heavy El Nino rains were experienced.

6.0 RECOMMENDATIONS

For improved low wastage of materials during construction of residential building frame, the following are among the recommendations:
Effective supervision, control of construction activities and materials during construction has been found to be the overriding aspect in material waste control in this form of construction. This can be affected if properly trained site supervisors are engaged by the clients.

The use of new technology, in approach to construction of residential buildings, in the Northern region of Nairobi, such as Lean construction. This seeks to achieve a properly integrated system of design and production, leading to continuity in production operations. The facility and its delivery process are designed together; work is structured throughout the process to maximize value and to reduce waste.

The study also recommends sensitization of the effects of material waste in the region to the main players in the process of construction. These will include mainly site supervisors, and workers with possible periodical briefs on waste minimization measures. Project consultants would also be expected to update themselves with the current technology trends so as to recommend different approach to construction of residential buildings within this region.

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