MANAGEMENT OF MATERIAL WASTE AND COST OVERRUN IN THE NIGERIAN CONSTRUCTION INDUSTRY

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MANAGEMENT OF MATERIAL WASTE AND COST OVERRUN IN THE NIGERIAN CONSTRUCTION INDUSTRY

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by

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Abstract

While wastage of materials has become a serious problem requiring urgent attention in the Nigerian Construction Industry, cost overrun is a problem, which affects 90 percent of the completed projects in the world; the argument on how to reduce/eliminate cost overrun has been on-going for the past 70 years; as the on-site wastage of materials leads to increases in the final project cost. Studies from different parts of the world have shown that construction-material waste represents a relatively large percentage of the production costs. Consequently, as a result of low levels of awareness, the Nigerian construction industry pays little attention to the effects of generated material waste on cost overruns. Thus, this research aimed to investigate the relationship between material waste and cost overrun in the Nigerian construction industry. A comprehensive review of the related literature revealed that all material waste causes are related to cost overrun causes at both pre-contract and post-contract stages of a project; but not *vice versa.* The mixed method (quantitative and qualitative) approach that is rooted in the positivist paradigm was adopted for this study. Abuja, the federal capital territory of Nigeria was the selected geographical scope of this research, out of which thirty-one (31) construction projects were purposeful selected (projects to the value of 100 million Rand/1.6 billion Naira and above).The research instrument was an interview guide used in conjunction with a tick box. Other sources of data included field investigation (measurement of onsite material waste) and the collection of archival records from bills of quantities, project records, and specifications. Analyses of the findings lead to the conclusion that a relationship exists between material waste and cost overrun; at the pre-contract and at the post-contract stages of a project. The implication is that an increase in material wastage on-site leads to a corresponding increase in the amount of cost overrun, regardless of the percentage allowance for material waste in the process of bill preparation. The study also concluded that the average percentage contribution of material waste to project-cost overruns is four (4) percent. Material-waste sources, causes, and control measures were found to have significant effects (very high, high, medium, low, and very low), in causing or minimising cost overruns at both pre-contract and post-contract stages of projects. The research has developed a conceptual model for the management of material waste and cost overruns in the construction industry based on the results and informed by the theoretical framework. The research has also developed a mathematical model for quantifying the amount of material waste to be generated by a project; as well as a mathematical equation for the effective management of material waste and cost overrun for projects. The study has achieved its aim of establishing an understanding of the issues leading to the relationship between material waste and cost overruns, as well as their management in the Nigerian construction industry. The study recommends that the management of material waste and cost overrun should be revised, based on the findings of this research and included as part of the procurement process. The mathematical models for quantification of onsite material waste, and the mathematical equation for managing material waste and cost overruns developed in the study, could be usefully adopted to improve management of material waste and cost overrun in the Nigerian construction industry.

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Declaration

I, Ibrahim SAIDU with student number 214344924 hereby declare that the thesis for the award of the degree of Doctor of Philosophy in Construction Management is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification at another University.

Signed: **……………………………..**

Date: **……..…………………………**

Dedication

This study is dedicated to:

- Almighty Allah (God), for his unparalleled grace, superior protection, and guidance throughout my life and the PhD journey.
- To the memories of my late father, Alhaji Saidu Mohammed Muye, may your gentle soul rest in the most cherished and the exalted abode in the here-after; and my mother, Hajiya Hannatu (Adi) Saidu Muye--not only a visionary human resources practitioner, but also someone, who has supported, encouraged and inspired me along every step of my life to this PhD journey.......Thanks mama.
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Definition of Terms

Waste: According to Ma (2011: 118), waste could be defined as follows: any disposable item, which could be useful to further add value; valueless activity; whatever is rejected by the client; difference between input and output, or that representing a source of money to pay for sustainability.

Construction Waste: This could be defined as that, which does not only focus on the amount of wasted materials on site, but also associated with numerous activities such as overproduction, waiting time, material handling, processing, inventories, movement of workers, time and cost overrun (Nagapan, Abdul-Rahman and Asmi*,* 2012: 2253).

Demolition Waste: Any material resulting from site upgrading or improvement, causing either partial/total destruction of an existing structure (United States Environmental Protection Agency), (USEPA, 2007: 2).

Material Waste: This could be defined as any material which is conveyed from the construction sites or used within the construction project for either land filling, combustion, reprocessing, or reuse which is different from the specific purpose on the project due to material damage, left-over, non-use, or non-compliance with the specifications of the construction process (Babatunde, 2012: 328).

Recycling: The Chartered Institute of Purchasing and Supply (CIPS, 2007: 8), defines recycling as the recovery of material waste, into the same product or a different one for re-use.

Re-use: The act of recovery or salvaging of various construction waste material and subsequent integration into the work (Winkler, 2010: 21).

Disposal: This is defined as the removal from site of construction or demolition material waste and subsequent sale or recovery of the same material, or deposit in a landfill or incinerator (CIPS, 2007: 9).

Construction and Demolition Waste: This is defined as any waste material arising from construction of a new work, renovating an existing structure, or demolition activities. It might include extra and damaged construction materials used temporarily during the process of on-site activities (Lu and Yuan, 2011: 1256).

Building Material Wastage: Is defined as the difference between the value of building materials supplied and accepted on site; and those properly used as specified, and accurately measured in the work after deducting the cost saving of the substituted materials transferred elsewhere. (Adewuyi and Otali, 2013: 746).

Cost Overrun: The inability of a project to be completed within the expected cost or budget (Memon, 2013: 9).

Waste Minimization: Is defined as the reduction of waste from the beginning of a project by reviewing the sources and causes and using the best management practices to reduce its generation (Osmani, 2011: 208).

Waste Management: Is the process of controlling and co-ordinating the resources involved in dealing with generated waste, including site planning, transportation, storage, material handling on site, segregation, re-use, recycling, and final disposal (Osmani, 2011: 208).

Zero Waste: Is a broadly used term referring to the process of re-using and recycling of material waste without incinerating or landfilling (Bartl, 2011: 167).

Incineration: Is the most common thermal treatment process for organic pollutants in the metropolitan waste. It refers to the process of heating waste in the presence of oxygen to oxidize organic compounds (Vallero, 2011: 221).

Commingled/Single-stream Recycling: This is a system whereby, all recyclable waste materials are placed in a container for conveyance to a recycling plant, where each material is segregated either manually, or by mechanical equipment (Winkler, 2011: 10).

Source Separation: The act of keeping each recyclable waste material in a different container from the first time they become waste as distinct from comingled recycling (EPAUS, 2007: 2).

Toxic Waste: This is material that can cause death, injury, or birth defects to living creatures. It is waste that is poisonous to humans and the environment either instantly or after a long period of exposure (Vallero, 2011: 294).

Hazardous Waste: The hazardous feature of waste is usually based on its essential physicochemical properties displaying the features of dangerous substances. For instance: ignitability, explosion, corrosiveness, toxicity, or reactivity with water (Vallero, 2011: 294).

Abbreviations used in the Study

ACWC:	Actual Cost of Work Completed
ANOVA:	Analysis of Variance
AUD:	Australian Dollar
BRE:	Building Research Establishment
BSI:	British Standards Institution
C&D:	Construction and Demolition
CIPS:	Chartered Institute of Purchasing and Supply
CN:	Cost Now
CO:	Cost Overrun
CSFs:	Critical Success Factors
CSR:	Corporate Social Responsibility
CWMG:	Construction Waste Management Guideline
DC:	Design Complexity
EC:	Estimated Cost
ECMWM:	Effective Construction Material Waste Management
ECWC:	Estimated Cost of Work Completed
ECWM:	Effective Construction Waste Management
EDP:	Environment Protection Department
EGE	Environment and Growth Economy
EMAS	Eco-Management Audit Scheme
EQA:	Environmental Quality Act
ET:	Estimated Time
EWM:	Effective Waste Management
FCDA:	Federal Capital Development Agency
FCT:	Federal Capital Territory
FMWH	Federal Ministry of Works and Housing
FTA	Federal Transit Administration
GBRSG:	Green Building Rating System Guides
GDP:	Gross Development Product
GFA:	Gross Floor Area
GMS:	Green Manager Scheme
H:	Hypothesis
INDOT	Indian Department of Transport
KG:	Kilogram
LHSBCN:	Light House Sustainable Building Centre for Natural wood
MSE:	Mean Sum square due to Error
MST:	Mean sum square due to treatment
MW:	Material Waste
MWR:	Material Waste Rate
PMA:	PEMBINAAN Malaysia Act
PSES:	Pay for Safety and Environment Scheme
QCPSM:	Quality of Construction, Procurement and Site Management
POP	Plaster of Paris
QPEDM:	Quality of Planning, Estimating and Design Management
QS:	Quantity Surveyor

SCM	Supply-Chain Management
SNAB	Swedish National Audit Bureau
SSBW:	Standard Specifications for Building Works
S-p:	Sub-problem
SSE:	Sum of Square due to Error
SST:	Sum of Square due to Treatment
SWMR	Site Waste Management Regulations
SWPCMA:	Solid Waste Public Cleansing Management Act
TN:	Time Now
TRPL	Transport and Road Research Laboratory
UK:	United Kingdom
UKBRE:	United Kingdom Building Research Establishment
US:	United States
$\cup$**:**	Union of Set
U:	Universal Set
USEPA:	United States Environmental Protection Agency
USGBC:	United States Green Building Council
WDCS:	Waste Disposal Charging Scheme
WDO:	Waste Disposal Ordinance
WG	Waste Generated
WGRs:	Waste Generation Rates
WRAP:	Waste Resources and Action Program
WRFP:	Waste Reduction Framework Plan
% **of WC:**	Percentage of Work Completed

Chapter 1: The Research Problem and its Setting

1.1 Introduction

The construction industry is one of the driving forces behind the socio-economic development of any nation. It plays a leading role in improving the quality of the built environment (Osmani, Glass and Price, 2008: 1147). A common characteristic is the growing demand for construction projects, especially in developing nations, as a result of the rising standard of living and urbanization; and the associated need to provide shelter for their citizens (Nagapan, Abdul-Rahman, Asmi, Memon, and Latif, 2012a: 325). The provision of facilities involves a large financial outlay, which makes the construction industry focus more on materials, personnel and machinery (Babatunde, 2012: 238).

On the other hand, the construction industry is a major exploiter of natural non-renewable resources and a polluter of the environment. Construction activity contributes to environmental degradation through resource depletion, land use and deterioration, power consumption, air pollution, and the generation of waste in the acquisition of raw materials (Dania, Kehinde and Bala, 2007:122; Tam, 2008: 1073). The majority of this waste has not been well managed, thus causing substantial health and environmental problems (Imam, Mohammed, Wilson and Cheesman, 2008: 469), and affecting the performance of many projects in Nigeria (Adewuyi and Otali, 2013: 746; Ameh and Itodo, 2013: 748; Oladiran, 2009: 1).

Studies from different parts of the world have shown that material waste from the construction industry represents a relatively large percentage of the production costs. Consequently, the poor management of materials and waste leads to an increase in the total cost of building projects (Ameh and Itodo, 2013: 745). In addition, Teo, Abdelnaser and Abdul (2009: 258) opined that on-site wastage of materials contributes to cost overruns, which lead to non-completion of projects within the estimated or budgeted cost.

In view of the above attributes of the construction industry, Nagapan, Abdul-Rahman, Asmi, and Hameed (2012b: 23) suggested that the construction industry needs to improve its awareness, as material wastage can affect the success of a construction project and have an impact on construction cost, time, quality, and sustainability.

1.1.1 The international state of construction waste

Construction and demolition waste represents almost 50 percent of the solid waste generated globally. It has a serious impact on the environment at every stage of a construction project, from the extraction of raw materials, processing, manufacturing, transportation and construction processes, to the final disposal of this waste after demolition at the end of a building's life [Construction and Demolition Waste Guide], (CDWG, 2011: 1). Furthermore, Ameh and Itodo (2013: 748) mentioned that, in their opinion, for every 100 houses built, there is sufficient waste material to build another 10 houses.

Around the world, the problem of construction waste remains unresolved, as has been shown by various authors reporting on the situation (Dania, Kehinde and Bala, 2007: 122; Winkler, 2010: 1; Osmani, 2011: 209; Ameh and Itodo, 2013: 749). In the United States (U.S.), about 136 million tonnes of construction waste are generated annually, representing 30 percent of the total amount of waste generated in the country. This estimate excludes roads, bridges, site clearance and excavation waste, which is an important part of total construction and demolition (C&D) waste materials [United States Green Building Council], (USGBC, 2001: 2). If C&D waste is added argues Winkler (2010: 1), the U.S. generates more than 164 million tons of construction waste per annum, representing 25 to 40 percent of the discarded solid waste in the country. In the view of Osmani (2011: 209), the U.S. generated about 170 million tonnes of construction and demolition waste in 2003. However 48 percent of the stated amount was recovered through re-use and recycling.

In Brazil, the construction industry consumes about 75 percent of its natural resources and 44 percent of the energy used in the country, as well as being responsible for more than 40 percent of the nation’s entire generated solid waste (Ameh and Itodo, 2013:

749). Moreover, 21-30 percent of the procured materials for projects end up as waste in the Brazilian construction industry (Poon, Ann, Yu, and Jailon, 2004: 1).

In the late nineties, the United Kingdom (UK) construction industry generated about 70 million tonnes of construction and demolition waste materials with a 10–15 percent estimated wastage rate, which ended up in landfills (Poon, 2007: 1716). Recently, the amount of construction and demolition waste in the UK rose to about 120 million tonnes per annum, including an estimated 13 million tonnes of unused materials (Osmani, 2012: 37). In another vein, Osmani (2011: 209) asserts that 10 percent of the materials delivered to sites in the UK construction industry end up as waste, as a result of over-ordering, losses and damages. Furthermore, Adams, Johnson, Thornback, and Law (2011: 12) reported that the Waste Resources and Action Program (WRAP) revealed in 2008 that, out of the 76.36 million tons of construction and demolition waste generated in England, a significant amount was recovered through the re-use and recycling process, which led to the diversion of a considerable amount from landfills to the transfer stations.

In Australia, about one ton of solid waste was sent to the landfill per person each year in the mid-nineties; while construction and demolition waste was estimated to account for 16–40 percent of all waste generated in that country (Osmani, 2011: 209). Additionally, between 2008-2009, a total of 19.00 million tonnes of construction and demolition waste, was generated in Australia, of which 10.5 million tonnes, representing 55 percent was recycled; and the remaining 8.5 percent mllion tonnes, representing 45 percent was disposed of at landfills (Dania, Kehinde and Bala, 2007:122). In reality, Zaman (2014: 407) argues that the zero waste strategy developed and implemented in the Adelaide city of Australia may not yield the desired results because, achieving a 100 percent diversion from landfill would not be possible; since it does not reflect the main theory of the zero-waste viewpoint.

Over the past thirty years, China has witnessed an exceptional economic growth, with an annual GDP increase of 9.8 percent. This development has led to a severe environmental degradation by generating large amounts of construction and demolition waste, as a result of the growing urbanization (Lu and Yuan, 2010: 201).

Furthermore, China alone generates about 30 percent of the world's municipal solid waste, with construction and demolition waste representing about 40 percent of the country's total municipal waste; while the construction activities consume about 40 percent of the natural resources and energy (Lu and Yuan, 2010: 203). The Environment Protection Department (EDP) of Hong Kong estimated that landfills in Hong Kong received about 3,158 tons of construction waste per day in 2007. Recently, 15.4 million tonnes of construction and demolition waste were sent to landfills, representing 23 percent of the total waste disposed of annually (Ameh and Itodo, 2013: 749). Poon (2007: 1716) contended that the annual generation of construction and demolition waste in Hong Kong more than doubled between 1993 and 2004, amounting to 20 million tons.

Moreover, timber formwork alone in Hong Kong, accounts for about 30 percent of the total waste generated on-site; and this problem is also similar in the Shenzhen construction industry (Poon, 2007: 1717; Lu and Yuan, 2010: 206). These issues, however, led to the initiation and implementation of several plans and policies by the government of Hong Kong to enhance the management of construction waste. These include: Waste Disposal Ordinance (WDO), Green-Manager Scheme (GMS), Waste Reduction Framework Plan (WRFP), Waste Disposal Charging Scheme (WDCS), Pay for Safety and Environment Scheme (PSES) and so on; but all these initiatives have failed to attain the goal of environmental sustainability (Nagapan *et al.,* 2012a: 326).

The European countries generate about 200 to 300 million tons of construction and demolition waste annually, which covers closely a 400 square-kilometre area with a metre high of demolition waste (Dania, Kehinde and Bala, 2007: 12). Osmani (2011:209) argues that the European countries generate more than 450 million tonnes of construction and demolition waste every year, of which 75 percent is sent to landfills. However, over 80 percent recovery rate of construction waste materials has been successfully accomplished in Germany and Netherlands.

In Asia, Singapore was also able to recover about 94 percent of its construction and demolition waste in 2005, with its set goal of no landfill (Mou, 2008: 16). Moreover, 9 percent of the total purchased materials end up as waste in the Dutch construction industry (Polat and Ballard, 2005: 4; Babatunde, 2012: 328).

In the central and southern regions of Malaysia, 28.34 percent of the total amount of waste sent to landfills emanates from industrial and construction activities (Begum, Siwar, Pereira and Jaafar, 2007: 191).

Nagapan *et al.* (2012a: 326) assert that, despite the solid waste regulatory policies in Malaysia, including: the Solid Waste and Public Cleansing Management Act, 2007 (SWPCMA), Standard Specifications for Buildings Works (SSBW), the Environmental Quality Act 1974 (EQA) and the *Pembinaan* Malaysia Act 1994 (PMA), the problem of illegal dumping along roadsides and in tropical mangrove swamps did not improve because the policies did not completely cover the whole aspect of construction waste management.

The above situation is a cause for concern. This waste has negative impact on the environment. Hence, the need for appropriate waste management strategies to contribute to environmental sustainability (Kareem and Pandey, 2013: 345).

1.1.2 Construction material waste situation in Nigeria

Material wastage has become a serious problem, which requires urgent attention in the Nigerian construction industry. This constraint harmfully affects the delivery of many projects (Adewuyi and Otali, 2013: 746). Teo, Abdelnaser and Abdul (2009: 258) observed that extra construction materials are usually purchased due to material wastage during the construction process. Adewuyi and Otali (2013: 746) argue that despite the 5 percent allowance made to take care of material wastage in the course of preparing an estimate for a project, this is usually inadequate because there is a lot more waste generated by construction projects in Nigeria. Babatunde (2012: 238) emphasises that the problem of construction material waste is well known in Nigeria; but it seems not to be given the recognition or the attention it deserves.

Similarly, Wahab and Lawal (2011: 248) revealed that in the last decade, little attention has been paid to the management of waste generated in the Nigerian construction industry. This could be as a result of the low level of awareness of the construction workers, a low level of available means of waste disposal, or the slow adoption of environmentally sustainable practices.

Akanni (2007: 45) identified the contribution of various waste sources to material wastage on site, and found the following percentages: on-site storage (43 percent), transportation and delivery to site (14 percent), theft on site (14 percent), incorrect specifications from the Architect (6 percent), intra-site transportation (5 percent), fixing and setting of materials (5 percent), incorrect usage (5 percent), conversion of waste (3 percent), carelessness of the workers (3 percent), and administration and management (2 percent). Wahab and Lawal (2011: 254) concluded that 85.72 percent of the respondents in the Nigerian construction industry disclosed that a sorting exercise of the generated material waste is not common on the construction sites.

Most of the material waste is sent to landfills without considering its economic importance through recycling or reprocessing into new products, which would reduce the burden on the landfill, as well as the environmental effects (Wahab and Lawal, 2011: 254).

The factors contributing significantly to construction material wastage in the Rivers State of Nigeria, as outlined by Adewuyi and Otali (2013: 746) are: ‘’rework as a result of non-compliance with drawings and specifications”; “variation and modification in design”; and “waste from inefficient and wasteful shapes”, respectively. Insufficient construction materials waste was rated least among the factors. Adewuyi and Otali (2013: 746) highlighted the fact that contractors and consultants have the same insight on the factors causing construction waste generation in the Delta state of Nigeria. In the view of Ameh and Itodo (2013: 754), poor supervision of construction workers is the major factor contributing to material wastage in the Nigerian construction industry.

Dania, Kehinde and Bala (2007: 129) found that the waste management practices adopted in the Nigerian construction industry were inadequate and deficient; and these practices are exacerbated by insufficient legislation enforcing sustainable construction.

Wastage of material is common in construction projects in Nigeria; and this is a result of several sources and causes. These occurrences pose a lot of challenges and have negative implications for the stakeholders in the form of high transportation cost to landfills and so on. The identification of these causes and the application of relevant control techniques to minimise their occurrence could be a step towards alleviating the consequences (Oladiran, 2009: 1-2).

1.1.3 Cost overruns in the construction industry

The construction industry contributes to the socio-economic growth of any nation by improving the quality of life and providing infrastructure, such as roads, hospitals, schools, and other basic facilities. Hence, it is imperative that construction projects are completed within the scheduled time, within the budgeted cost, and meet the anticipated quality. However, being a complex industry, it is faced with severe problems of cost overruns, time overruns, and construction waste (Abdul-Rahman, Memon and Abd. Karim 2013:268).

Construction cost overrun is a common issue in both the developed and the developing nations, which makes it difficult for many projects to be completed within budget. Most developing countries experience overruns exceeding 100 percent of the initial budget (Memon, Abdul-Rahman, Zainun, and Abd. Karim, 2014: 180). Allahaim and Liu (2012: 2) reported that cost overruns were found across twenty (20) nations and five (5) continents of the world. Cost overruns are a problem, which affects 90 percent of completed projects (Memon, 2013: 1; Abdul-Rahman, Memon and Abd. Karim, 2013: 268).

The World Bank reported that in the last 15 years, 63 percent of 1,778 of its funded construction projects were faced with a cost overruns of about 40 percent of the start-up costs and 88 percent of 1,627 projects were also faced with cost overruns of up to 70 percent of the start-up time (Ameh, Soyingbe and Odusami, 2010: 49).

Turcotte (1998: 2) believed that cost overruns would only add value to projects when they can improve on the project from its original design. They can add value where additional work is done to produce a better result for the citizens, such as adding an access road to a project. Cost overruns may also add value, when an initially omitted work is now clearly required to be included in the project, such as planting grass to control erosion. On the other hand, most overruns do not add value; and they signify wastage; since they do not produce any better result. For instance, there is no value if a contractor removes an asphalt road; and then replaces it as a result of an error in the design specifications (Turcotte, 1998: 2).

The argument in the construction industry on how to reduce or totally remove cost overruns from a project has been ongoing among the built environment professionals, the project owners, and the users for the past seventy (70) years (Apolot, Alinaitwe and Tindiwensi, 2010: 305; Allahaim and Liu, 2012: 1). However, there is no substantial improvement, nor any significant solution for mitigating its detrimental effects (Allahaim and Liu, 2012: 1).

Consequently, studies from different countries have revealed that cost overruns represent a large percentage of the production costs. For instance, 33.33 percent of the construction project owners in the UK are faced with the problem of cost overruns (Olawale and Sun, 2010: 511; Abdul-Rahman, Memon and Abd. Karim 201 3: 268;). The Big Dig Central Artery/Tunnel project in Boston could not be completed within its budgeted cost; and it had an overrun of 500 percent. The Wembley stadium in the UK had a 50 percent cost overrun; and the Scottish parliament project, which had a time overrun of more than three (3) years also experienced a cost overrun of 900 percent (Love, Edwards and Irani 2011: 7).

A study conducted by the US department of transportation on eight railway transport projects with an initial cost of $24.5 billion, had a cost overrun of 61 percent, with individual projects ranging from 10 to 106 percent (Allahaim and Liu, 2012: 3). Similarly, another study conducted on 15 road and railway projects in Sweden, revealed an average cost overrun of 86 percent for eight road projects, with individual projects ranging from - 2 to +182 percent; while the average cost overrun for the seven rail projects was 17 percent, ranging from -14 to +74 percent (Allahaim and Liu, 2012: 3).

In Malaysia, the construction industry drives economic growth and development; however, its projects frequently suffer from cost overruns (Shehu, Endut, Akintoye, and Holt, 2014: 1). Abdullah, Aziz and Rahman (2009: 54) highlight that only 46.8 percent of the public sector and 37.2 percent of private sector projects in Malaysia were completed within the budgeted cost. In the same vein, Shehu *et al.,* (2014: 10) argue that more than half of the Malaysian construction projects (55 percent) had cost overruns, and that private sector projects performed on a lower level than public sector projects. Shehu *et al.* (2014: 10) found that projects executed through the design and build method of procurement had the least amount of cost overruns, followed by traditional project management of construction.

The above situations have shown that the problem of cost overrun is common across the world (Memon *et al.,* 2013: 180). The next section examines the problem of cost overrun in the Nigerian construction industry.

1.1.4 Cost overruns in the Nigerian construction industry

The Nigerian construction industry is also faced with the problem of poor cost performance, which describes the inability to complete a project within the budget (Ogunsemi and Jagboro, 2006: 253; Malumfashi and Shuaib, 2012: 19).

Accordingly, Malumfashi and Shuaib (2012: 21) argue that infrastructural projects in Nigeria are similar to those of commonwealth countries, such as the United Kingdom; but the problem of cost overruns in Nigeria is more severe, when compared to those in other countries. Cost overruns are frequent; and they are a more severe problem than time overruns in the Nigerian construction industry (Ubani, Okorocha and Emeribe, 2011: 74).

Jackson and Steven (2001: 5) studied the problem of cost overrun by investigating 15 projects in Ilorin, Nigeria. The result disclosed that 73.7 percent of the projects faced cost overruns with an average of 34.7 percent of the initial project cost.

In another vein, Olatunji (2008: 1) concluded that out of 137 projects in Nigeria, 55 percent were faced with the problem of cost overruns. These overruns ranged from 5 percent to a maximum of 808 percent of the estimated project cost. Consequently, Ameh, Soyingbe and Odusanmi (2010: 49) noted that the cost of projects in Nigeria escalated by 14 percent (the minimum average percentage); and the period of projects in Nigeria escalated, on average, by 188 percent (of the minimum average percentage). Hussain, Abdul-Rahman and Memon (2013: 32) assert that, in Nigeria, the lowest average reported percentage of cost overrun on a project was 14 percent.

Ubani, Okorocha and Emeribe (2011: 74) assert that construction projects in South-Eastern Nigeria have suffered from severe time and cost overruns, which have led to the abandonment and failure of many projects. This has a negative impact on the economy of the country leading to massive losses of scarce resources and poor infrastructural development. For instance, the fly-over projects at Owerri, the Onitsha-Enugu, and Enugu-Port Harcourt expressways, were abandoned, as a result of time and cost overruns. Consequently, Ogunsemi and Jagboro (2006: 257) attributed the problem of cost overruns in Nigeria to a wrong cost estimation method adopted at the early stage of the building projects.

1.1.5 The relationship between waste and cost overruns in the construction industry

Cost is considered as one of the most significant issues, and a driving force of project success. It has been regarded as a major concern throughout the project management life-cycle. In spite of its recognised significance, it is common for a construction project to fail to achieve its goals within the budget. Therefore, cost overrun is a very common issue; and it affects most projects in the construction industry (Azhar, Farooqui and Ahmed 2008: 499), while waste can have a significant effect on the success of a construction project; since it specifically has a major impact on the construction costs (Nagapan *et al.,* 2012b: 22).

Furthermore, Ameh and Itodo (23: 748) assert that material wastage on site leads to an increase in the final cost of the building project. This assertion is supported by Teo, Abdelnaser, and Abdul (2009: 262), who believe that building material wastage on construction sites contributes to project cost overruns. As materials are wasted, more are procured; and this thereby affects the estimated cost.

Moreover, Ameh and Itodo (2013: 748) reported that in the UK, material waste accounts for an additional 15 percent to construction project cost overruns and also accounts for about 11 percent of construction cost overruns in Hong Kong. In the same vein, a study conducted in the Netherlands revealed a cost overrun of between 20-30 percent as a result of construction-material wastage.

> *"It is believed that building material wastage on construction sites accounts for cost overruns; and any improvement in the building materials management on construction sites has the potential to enhance the construction industry's performance with cost-saving benefits" (Ameh and Itodo, 2013: 748).*

Ameh and Itodo (2013: 749) stated that the contribution of the following material waste to the total project cost is: concrete 4 percent; block work 10 percent; waste from screeding and plastering 15 percent; packaging 5 percent; and formwork is based on the number of times it is re-used.

Research evidence has shown that the main factors causing construction material waste are almost similar to those causing construction-cost overruns on site; hence, Nagapan, Abdul-Rahman and Asmi (2012: 1-10) categorised cost overruns and time overruns as non-physical waste; while other material waste is the physical waste on a construction site.

This shows that cost overruns, time overruns and construction material waste are generally categorised as waste. This is further supported by Ma (2011: 118), who defines waste as anything that does not add value. Time overruns, cost overruns, and material waste do not add value to any project. Therefore, Nagapan, Abdul-Rahman and Asmi (2012: 1-10) assert that construction waste is not all about the quantities of materials that are wasted; but it is also focused on factors, such as overproduction, waiting time, material handling, inventories, and the unnecessary movement of workers, which constitute a significant part of non-physical waste, but are always given the least attention in the construction industry.

Ameh and Itodo (2013: 747) suggested that a relationship exists between subcontracting options, cost overruns, and the waste generated from building material during construction.

Therefore, there is hardly any research evidence showing an appreciable relationship between construction material waste and cost overruns in the Nigerian construction industry. Hence, it is necessary that, a research pertaining to these issues be conducted to enable the identification of strategies for effective waste management, and for understanding the contributions of waste to cost overruns in the Nigerian construction industry.

1.2 Problem Formulation

The rapid urbanization in developing nations has resulted in a substantial increase in construction activities, which in turn, has led to the generation of a large quantity of construction-material waste (Chikezirim and Mwanaumo, 2013: 498). This waste originates from different stages of projects, including the planning, estimating, design, and construction stage (Mou, 2008: 20; Nagapan *et al.,* 2012b: 23). The lack of attention to waste management at the planning and design stage of projects is common in the local construction project (Begum, Siwar, Pereira and Jaafar, 2009: 321).

The recovery (reduce, re-use and recycle) of construction-material waste is not widely implemented in the Nigerian construction industry (Dania, Kehinde and Bala, 2007: 121). This is attributed to a lack of awareness of the benefits of reducing/minimising construction-waste materials and the poor experience in reclaiming waste materials among many professionals (Akinkurolere and Franklin, 2005: 980). Dania, Kehinde and

Bala (2007: 121) added that the waste-management strategies adopted in the Nigerian construction industry are ineffectual.

Nguyen, Gupta and Faniran (nd: 2) emphasise that despite the studies that have highlighted the future benefits of reducing construction waste, there has been little progress in implementing the waste-management options available, in order to ensure that construction waste is minimised. This is, however, attributed to poor understanding among the Nigerian construction professionals of the causes and sources of material waste generation at the different stages of a project (Dania, Kehinde and Bala, 2007:121).

In Nigeria, not all materials supplied on site are used during the construction process; the leftover remains a waste that may not be accounted for (Akinkurolere and Franklin 2005: 980). Construction estimators often allow wastage factors in pricing a bill of quantities; but experience has shown that wastage can often exceed by a large amount the figure allowed in the tender documents if the site management is not efficient (Wahab and Lawal, 2011: 248). The UK Building Research Establishment (UKBRE) also studied the construction material waste level, and found that the estimated waste allowances were less than the actual material wasted on site (Wahab and Lawal, 2011: 248).

In a similar vein, a study in Nigeria revealed that the actual construction waste figure is consistently more than the estimated figure (Ekanayake, and Ofori, 2004: 852; Babatunde, 2012: 328).

Therefore, Wahab and Lawal, (2011: 247) suggest that a more effective control of materials on site should be adopted; as the problems of material wastage cannot be fully treated without efficient material control. Hence, Begum *et al.,* (2007: 191) propose various construction material waste management approaches.

Ameh and Itodo (2013: 748) assert that most managers of the Nigerian construction industry put little emphasis on the effects of generated material waste on project cost overruns. Moreover, cost overruns have become a common problem in the construction industry, which constrains many projects from being completed within budget. It may, at times, even exceed 100 percent of the estimated cost (Memon, 2013: 1). Construction waste accounts for about 30-35 percent of most project construction costs and construction materials wasted on site account for about 9 percent by weight of the procured materials (Memon, 2013: 10).

Begum, Siwar, Pereira and Jaafar (2006: 88), therefore, opined that implementing waste-management approaches, such as recycling and re-using materials could save up to 2.5 percent of the total budget.

Furthermore, the insufficient attention given to material-waste generation in developing nations during the past decades has meant that the statistical data on the quantity of material-waste generation are not readily available (Yuan and Shen, 2011: 670). This is supported by Babatunde (2012: 328), who believes that the situation is not any different in the Nigerian construction industry.

Currently, the relationship between material waste and cost overrun is little understood. There is need to address this problem by providing a clear theoretical understanding of the basic constructs and related concepts of effective management of material waste and cost overrun in the construction industry.

1.3 Statement of the Problem

As a result of the low level of awareness, the Nigerian construction industry pays little attention to the effects of generated material waste on cost overruns.

1.4 Statement of Sub-Problem (S-P's)

S-p 1: There is poor understanding of the sources, causes and control measures for construction-waste generation at the pre-contract and post-contract stages of a project

S-p 2: There is little understanding of the effects of waste generated from S-p 1 on project-cost overruns.

S-p 3: There is little experience of the benefits of recovering construction waste material (re-use and recycling) and its effects on cost overruns.

S-p 4: There is little understanding of the percentage of additional cost contributed by material wastage to construction-cost overruns.

S-p 5: Data on the quantities of material waste have not been well documented.

1.5 Research Hypotheses

H1.1: Knowledge of the sources, causes and control measures of construction-waste generation at the pre-contract and post-contract stages of a project is sub-optimal.

H2.2: Knowledge of the effects of waste generated on construction-cost overruns is minimal.

H3.3: Experience with the benefits of recovering construction waste material (re-use and recycling) is sub-optimal.

H4.4: Knowledge of the additional cost contributed by material wastage is minimal.

H5.5: Statistics on the waste generated are minimal.

1.6 Research Aim and Objectives

The aim of the research is to investigate the relationship between material wastage and construction-cost overruns. To achieve the aim, the following objectives were formulated:

Objective 1: To identify the sources, causes and control measures for material waste generation at the pre-contract and at the post-contract stages of a project.

Objective 2: To examine the effects of the waste generated from Objective 1 above on project cost overruns.

Objective 3: To examine the benefits of recovering construction waste materials (re-use and recycling) and their effects on cost overruns.

Objective 4: To investigate the percentage of additional cost contributed by material wastage to project cost overruns.

Objective 5: To develop a statistical model for quantifying the amount of materials and material waste generated in the Nigerian construction industry.

Table 1.1: The relationship between sub-problems, research hypotheses and research objectives

Statement of Sub-problems (S-ps)	Corresponding Hypothesis (H)	Objectives
Sub-problem 1 (S-p 1)	Hypothesis 1 (H1.1)	Objective 1
Sub-problem 2 (S-p 2)	Hypothesis 2 (H2.2)	Objective 2
Sub-problem 3 (S-p 3)	Hypothesis 3 (H3.3)	Objective 3
Sub-problem 4 (S-p 4)	Hypothesis 4 (H4.4)	Objective 4
Sub-problem 5 (S-p 5)	Hypothesis 5 (H5.5)	Objective 5

Source: Researcher's construct, 2015

1.7 Importance of the Research

Material-waste management is not a new field of knowledge and expertise. Many studies have been carried out by many authors in the field; but still there is a need for a research project that provides an objective assessment of the effect of material waste on construction cost overruns in the Nigerian construction industry.

The success in waste management, according to Vallero (2011: 1), depends on three factors, namely: awareness, decision making, and action. Therefore, this study creates awareness and provides guidance on the efficient use of materials by contractors and sub-contractors, as well as construction practitioners, focusing on: the effective estimating of material waste and cost overruns; developing and implementing waste reduction solutions; and the production of accurate records of waste to the built environment professionals in the Nigerian construction industry.

The recommendations of the study, if properly implemented, would achieve the best value for money to the client. There would be a reduction in the amount of construction waste that would be sent to landfills; the impact of the waste on the natural environment would also be reduced; as well as a reduction in the amount of cost overruns on projects.

The problems of cost overruns still prevail in the study area, despite the increased funding by clients in building construction activities. Dania, Kehinde and Bala (2007: 121) and Oladiran (2009: 2) attributed these problems to the lack of awareness among the construction professionals on the effects of material waste on cost overruns for a project.

Over the years, research interests in addressing construction and demolition waste management issues across the world have resulted in a large number of publications. Previous studies from developed and some developing nations have concentrated on construction and demolition waste, and the necessary tools, models, and techniques for their management, as discussed in section 1.1.3 of the study.

Moreover, research evidence has shown that previous studies from different parts of Nigeria have centred on waste-management practices, as also discussed in section 1.1.4 of the study. Nonetheless, these studies have failed to effectively address the problems of material waste and cost overruns throughout the stages of a construction project.

Additionally, there is a dearth of empirical research on material-waste generation in the construction industry in most developing countries (Yuan and Shen, 2011: 678).

In conclusion, there is little specific research that deals with material-waste management in the study area. None of the studies have given a clear indication of the effects of material waste on construction cost overruns.

In other words, there have been relatively few studies on this issue. These concerns provide the basis or rationale for this study. The research should, therefore, increase awareness among the construction professionals and clients in Nigeria's construction industry.

1.8 Delimitations of the Scope of the Study

The study was limited to the management of construction-material waste and cost-overruns in building projects in the Federal Capital Territories of Nigeria (FCT). Abuja was selected because it has the highest population of professionals in the built environment; and it has many ongoing construction projects.

WRAP (2007: 1) stated that all the participants in the construction process have an important role to play in the drive to reduce waste from construction sites.

In this study, the following professionals were contacted for providing the required information within the study area: Architects, Builders, Quantity Surveyors, Site Engineers, Contractors and Sub-contractors. Most of these professionals constitute the project managers and the senior technical officers met on-site.

The data were sourced from both public and private construction projects, handled or supervised by a reputable firm/organisation within the study area. The public organisations include: the relevant government ministries or parastatals that are into property development, such as the Federal Ministry of Works and Housing (FMWH) and the Federal Capital Development Agency (FCDA) with a project value of up to 1.6 billion Naira (R100 million) and above. The basis or rationale for this selection is that projects of this value and above are likely to produce large quantities of waste and huge cost overruns when compared with projects of less value.

The study considered all the building materials used in projects, which also constitute part of the waste materials on site, such as blocks/bricks, aggregates (both fine and coarse), mortar, cement, roofing sheets, glazing, aluminum, timber, reinforcements, partition materials, paints, cables and conduits in the electrical services, pipes and associated materials in the mechanical services, and so on. The results of the research are based on the information provided by the professionals.

1.9 Key Assumptions of the Study

Assumptions are the actions accompanied by temporariness that lead to subsequent courses of action of different duration (Corbin and Strauss, 2008: 7). They are the conditions that are taken for granted and accepted as true without any validation or proof (Leedy and Ormrod, 2013: 5).

In relation to the sub-problems, the following assumptions will provide a way to understand the study:

- Access to the required information was not problematic;

- Both public and private organisations visited engage in projects likely to produce waste and cost overruns;
- The respondents are knowledgeable and experienced enough to give convincing feedback on the data sought;
- Material waste-management systems differ among construction firms/organisations; and
- Responses received from building professionals on material waste and cost overruns represent the position of the Nigerian construction industry as a whole.

1.10 Structure of the Thesis

This thesis is reported in seven (7) chapters; and the contents of the chapters are outlined below:

Chapter 1: This begins with an introduction to the research setting, the problems and sub-problems. It discusses the general state of material waste and cost overruns in the construction industry; particularly in Nigeria. The chapter also introduces the formulation of the problem, the statement of the problem and sub-problems, as well as the related hypotheses. It also describes the research aim, the objectives, the justification and an outline of the methodology. This is then followed by a delimitation of the scope of the study, the key assumptions, and the structure of the thesis. The chapter concludes with a concluding remark.

Chapter 2: This chapter provides an overview of material waste and cost overruns in the construction industry; the concepts of waste and cost overruns; the classification of waste and cost overruns; the project stages and associated material waste; the causes and sources of waste and cost overruns; the control measures for material waste; and a construction waste recovery system in the construction industry.

The chapter also discusses the relationship between material waste and cost overruns in the construction industry. The chapter concludes with a concluding remark.

Chapter 3: The chapter provides an understanding of the theoretical basis of the research, which is anchored in the concepts of material waste and cost overruns. The chapter further assesses the underlying concepts of material waste and cost overruns in the Nigerian construction industry, which have led to the development of a mathematical equation for managing material waste and cost overruns in the construction industry. This chapter concludes with a concluding remark.

Chapter 4: This chapter discusses the methodology adopted for the conduct of the research and the fundamental basis for the choice of the research method and associated instruments. The chapter also assesses the various philosophical underpinnings of the research; the research paradigms; and the justification of the research's philosophical position and methodology. The chapter further describes the research design/strategy, data collection instruments, and their subsequent validity. The chapter concludes with a concluding remark.

Chapter 5: The chapter presents and analyses the research data, including the testing of the hypotheses. The steps leading to the development of the mathematical models for quantifying the amount of material waste on construction projects are presented and discussed. The chapter concludes with a concluding remark.

Chapter 6: This chapter summarises and discusses the research findings. Mathematical models for quantifying the amount of material waste on site are also presented and discussed. This chapter concludes with a concluding remark.

Chapter 7: This chapter presents the summary of the research findings, conclusions and recommendations, the contribution of the research to knowledge, and areas for further research on this topic.

1.11 Concluding Remarks

Chapter 1 has presented the background of the material wastage and cost overruns in the Nigerian construction industry. The research problem and the research questions have been stated; the aim, objectives, and the hypotheses have also been documented and highlighted. The delimitation of the scope and importance of the study, the assumptions and the structure of the thesis have been carefully presented.

Based on the matters raised, Chapter 1 has been able to show that a problem exists, which needs to be addressed. The next chapter presents a review of the related literature on material waste and cost overruns in the construction industry.

Chapter 2: A Review of the related Literature

2.1 Introduction

To lay a theoretical background/framework for this study, a review of the related literature on the management of material waste and cost overruns in the construction industry is necessary.

This chapter provides an overview of the concepts of material waste and cost overruns in the construction industry. The chapter also discusses the literature on the sources and causes of material waste and cost overruns; the existing relationship between material waste and cost overruns at different stages of a project; material waste recovery strategies; as well as the procedures for the quantification of material waste on construction sites.

2.2 The Concept of Waste in the Construction Industry

Construction waste is a global challenge facing both construction practitioners and researchers. It can have a significant impact on time, cost, quality and sustainability, as well as the success of projects (Nagapan *et al.,* 2012b: 22). It is the difference between the materials delivered to a site, and those bought for use on construction projects (Al-Hajj and Hamani, 2011: 2). Nagapan *et al.* (2012b: 22) contend that waste is any surplus or unwanted material persistently causing environmental difficulties and global warming. Consequently, waste has been described as any constituent generated, as a result of construction work, and abandoned whether or not it has been processed, or stocked up before being abandoned (USEPA, 2000: 2; Hassan, Ahzahar, Fauzi, and Eman, 2012: 176; Yuan, Lu and Hao, 2013: 484).

On the other hand, construction waste is viewed by many scholars as any human activity that consumes resources, but creates no value, such as mistakes that require rectification, waiting time/waste of time, cost, unwanted production/overproduction, management of work programmes and poor constructions (Ma, 2011: 127-134; Nagapan *et al.,* 2012b: 22; Nagapan, Abdul-Rahman and Asmi*,* 2012: 2253; Chikezirim and Mwanaumo, 2013: 500). Therefore, Ma (2011: 137) concludes that waste is anti-sustainability that paves the way towards sustainability.

2.2.1 Classification of waste in construction industry

Construction waste is normally characterised into two major components: those of composition and quantity. The composition entails the included constituents of the waste; while the quantity deals with either the volume, or the weight of the waste (Dolan, Lampo, Dearborn, 1999: 15; Nzeadibe, 2009: 137).

In the opinion of Babatunde (2012: 239-240), construction material waste could be classified into four categories, namely: cutting waste, transportation waste, theft and vandalism waste, and application waste.

- Cutting waste is occasioned by the cutting of materials on-site, such as: reinforcement bars, roof structure, roofing sheets, ceiling noggins, ceiling sheets, wires and cables, and pipes for both electrical and plumbing services.
- Transit waste is caused as a result of transporting materials from manufacturing or wholesale point to the site; and it includes: blocks, bricks, glazing, prefabricated windows, ceramic tiles, sanitary appliances, and so on.
- Theft and vandalism waste: Theft refers to waste resulting from loss of materials delivered to site but not incorporated because it is stolen and vandalism waste is waste resulting from having to conduct rework because work which had been previously completed or incorporated has been damaged by action of vandals.
- Application waste: This means waste resulting from incompetence of workers, for instance, rework as a result of poor workmanship. The application waste materials include: mortar through screeding and rendering, concrete on structural members (columns, beams, and lintels), paints and POP (Plaster Of Paris) ceilings.

In another study, Ekanayake and Ofori (2004: 852) categorised construction waste in to six major sources, namely: waste generated as a result of design; the procurement of materials; the handling of materials; operations; residual related waste; and other waste.

Moreover, Swinburne, Udeaja and Tait (2010: 34) classified construction waste into three major groups, namely: material waste, labour waste, and machinery waste. However, the Waste Resources and Action Program (WRAP), (2007: 3) highlights material waste as the major concern; as most of the raw materials used during the construction process originate from non-renewable resources.

In addition, WRAP (2007: 3) suggests two characteristics of construction material waste as:

- ***Waste generated as a result of 'design and specifications'***

Design and specifications contribute to waste generation; especially when uneconomical designs are chosen, or when unsuitable materials are specified. The examples of this type of waste, as highlighted by WRAP (2007: 3) are stated below:

- Flooring: cuttings of floor tiles to fit room outlines;
- Ceilings: cuttings of ceiling tiles and fixings to fit room lay-outs;
- Cutting of insulation boards to fit openings;
- Cutting of paving slabs to fit the design; and
- Cuttings of bricks and blocks to fit the space, in the case of bonding types.

It is, therefore, economical for this waste to be designed in such a way, that the waste from the design could be estimated, controlled and minimised at an early stage. For instance, plasterboards may be ordered pre-cut without the need for site cutting, or flooring designs may be fixed to fit the modular size (WRAP, 2007:3);

- ***Waste generated as a result of 'construction activities'***

Construction activities impact on the quantity of waste generated on-site. This waste is referred to as being 'accidental'; and produced as a result of the following reasons: handling waste; insufficient storage; poor co-ordination with other trades; rework, as a result of poor quality; ineffective use of materials; over-ordering of materials, and waste from temporary work materials, such as fencing and hoarding (WRAP, 2007: 3).

Akinkurolere and Franklin (2005:980) reported that the Building Research Establishment (BRE) categorises material wastage into four groups, namely: design waste; taking-off and ordering waste; supply waste; and contract waste. And so, each stage has the potential to contribute to material wastage on a construction site.

Furthermore, Ma (2011: 127-134) contends that construction waste does not occur, as a result of materials alone, but opines that the following are some of the issues that contribute to waste on construction sites:

- Waiting: While a worker hangs around, resources like water and electricity, are being wasted by paying for what was not used. Plant and equipment are idle, causing workers to be demotivated. These issues have economic, social, and environmental implications.
- Over complex procedures: Simplifying procedures on-site helps in reducing waste. Complex procedures may result in mistakes. For instance, difficult design/design complexity.
- Not working to plan: The consequences are lost time, effort, resources, and materials.
- Over-doing or re-doing: The problem of poor communication results in over-doing things; while change in design results in the need to re-do the work.
- Excessive transport: Poor design, poor communications, wrong procurement, and poor training-all these cause excessive transport, which is expensive.
- Overstocking: The rate of materials preservation is less when they are loaded on-site.
- Defects, mistakes and errors: Occasioned by poor communication, faulty design and poor training.
- Lost ideas and innovations: This is the most serious waste of all.

In another study, Okorafor (2014: 19-22) classifies construction waste into four (4) major classes namely: waste according to the type of resources consumed; waste according to its nature; waste according to its origin; and waste according to its control.

- *Waste according to the type of resources consumed:* This type of waste includes additional amounts of material relative to those specified in the project; increases in the number of working hours due to delay in the arrival of materials and so forth.

- *Waste according to its nature:* This includes direct waste, related to physical waste of materials, more specifically, the debris and indirect waste, related to financial waste and the use of materials in excess of the specified amounts, such as over-production.

- *Waste according to its origin:* Waste is typically identified throughout the production phase. It can also emanate from the processes that occur before production such as: materials manufacturing, designs, materials supply, and planning.
- *Waste according to its control:* This includes the possibility of controlling or reducing the magnitude of generated waste. Therefore, waste in this category could be classed as avoidable and unavoidable waste (Okorafor, 2014: 19-22).

Baldwin, Poon, Shen, Austin and Wong (2009: 2070) classify construction material waste as natural, direct and indirect. “Natural waste” is inevitable waste. This is mostly allowed for, while preparing the tender documents. “Indirect waste” are materials used for other purposes, as opposed to the original purposes, and “direct waste” is material, which is unaccounted for. All these categorisations may need to be properly examined when considering the impact of design decisions.

2.2.2 Project stages and construction material waste

Construction material waste occurs from various stages of a project ranging from foundation works to finishing (Ameh and Itodo, 2013:749). Hence, it becomes pertinent for control measures to be adopted at each stage of the project (Nguyen, Gupta and Faniran, nd: 7; Kareem and Pandy, 2013: 348). Moreover, Kareem and Pandy (2013: 348) noted that construction waste material in a project could be controlled at the following stages, namely: the design stage, the procurement stage, the material management-operation stage and the material storage stage.

Furthermore, Baldwin, Shen, Poon, Austin and Wong (2008: 334) sought the views of practitioners regarding the design decisions that are most appropriate for waste minimisation in high-rise residential buildings. The study found that, unless for specific client's requirements, little or no attention is given to the issue of construction waste in the design stage. Client's interests and the initiative of the construction team are the best solutions to these problems.

Additionally, Lu and Yuan (2010: 202) noted that the management of construction waste should include the whole project lifecycle; and all stakeholders. Memon, Abdul-Rahman and Memon (2014: 500) supported this assertion by dividing the whole life cycle of the project into four (4) stages, namely: planning, design, construction and the finishing phase. The design phase entails the preparation of a detailed design, drawings and specifications for the entire project.

The planning phase involves developing a clear and complete plan for the project. It includes describing the size and scope, the purpose and goals of a project, as well as an estimation of the resources, time and cost. This is to ensure that projects are completed within the scheduled time and within the budgeted cost.

The construction phase is a key part of any project, where the actual project execution is done. It comprises the execution of the project plan, communication between other parties, a progress report, and controlling the time, cost, and quality of the work. The finishing phase is the final phase of the construction work. It involves the finishing work for the entire structure or building.

Figure 2.1 presents the four (4) phases of a project life cycle.

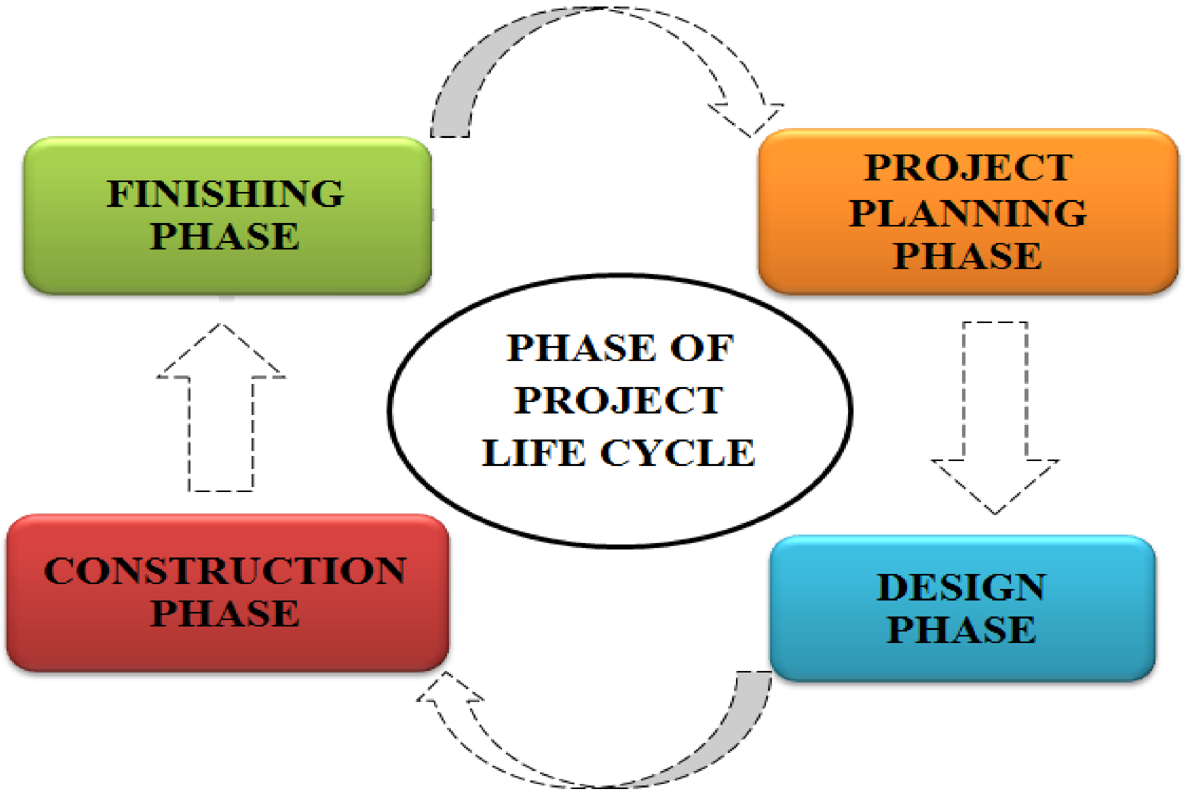


Figure 2.1: The phases of a project life cycle

Source: Memon, Abdul-Rahman and Memon (2014: 20)

- *Design, Planning, Construction and Finishing phases:* The four (4) phases are affected by insufficient planning and scheduling, lack of experience, a change in the size of the project, delays in decision making, lack of co-ordination and communication between parties, and slow information flow between the parties.

- *Construction and finishing phase:* These phases are influenced by poor site management and supervision, incompetent subcontractors, schedule delay, inaccurate time and cost estimates, mistakes during construction, inadequate monitoring and control, mistakes and errors in design, delay in preparing and approval of designs, cash-flow difficulties faced by contractors, poor financial control on site, financial difficulties of client, delay in progress payment by the owner, delays in the payment to suppliers/subcontractors, contractual claims, such as an extension of time with cost claims, labour productivity, shortage of site workers, shortage of technical personnel (skilled labour), shortages of materials, poor project management, and inaccurate quantity estimates (Memon, Abdul Rahman and Memon, 2014: 20).

- *Construction phase alone:* This phase is affected by high labour costs, labour absenteeism, late delivery of materials and equipment, and equipment availability and/or failure.
- *Planning, construction and finishing phase:* Frequent design changes go round the three phases (Memon, Abdul Rahman and Memon, 2014: 20).

2.2.3 Sources and causes of material waste in construction

Construction waste levels do not only relate to the construction type or the firm/industry alone, but also to the site and the people involved in the project (Chikezirim and Mwanaumo, 2013: 449). And achieving an effective waste minimisation depends on the level to which construction participants change their behaviour towards waste issues (Al-Hajj and Hammani, 2011: 2).

Nagapan *et al.* (2012a: 327) emphasise that construction waste is generated throughout the project lifecycle from the pre-construction stage through to the construction stage, and on to the finishing stage; and recommend the identification and understanding of the causes at source. Al-Hajj and Hammani (2011: 2) believe that waste sources and causes revolve around four factors, namely: procurement, handling, operation and culture. The analysis of the main origins of material waste appropriate to each category is summarised in Figure 2.2.

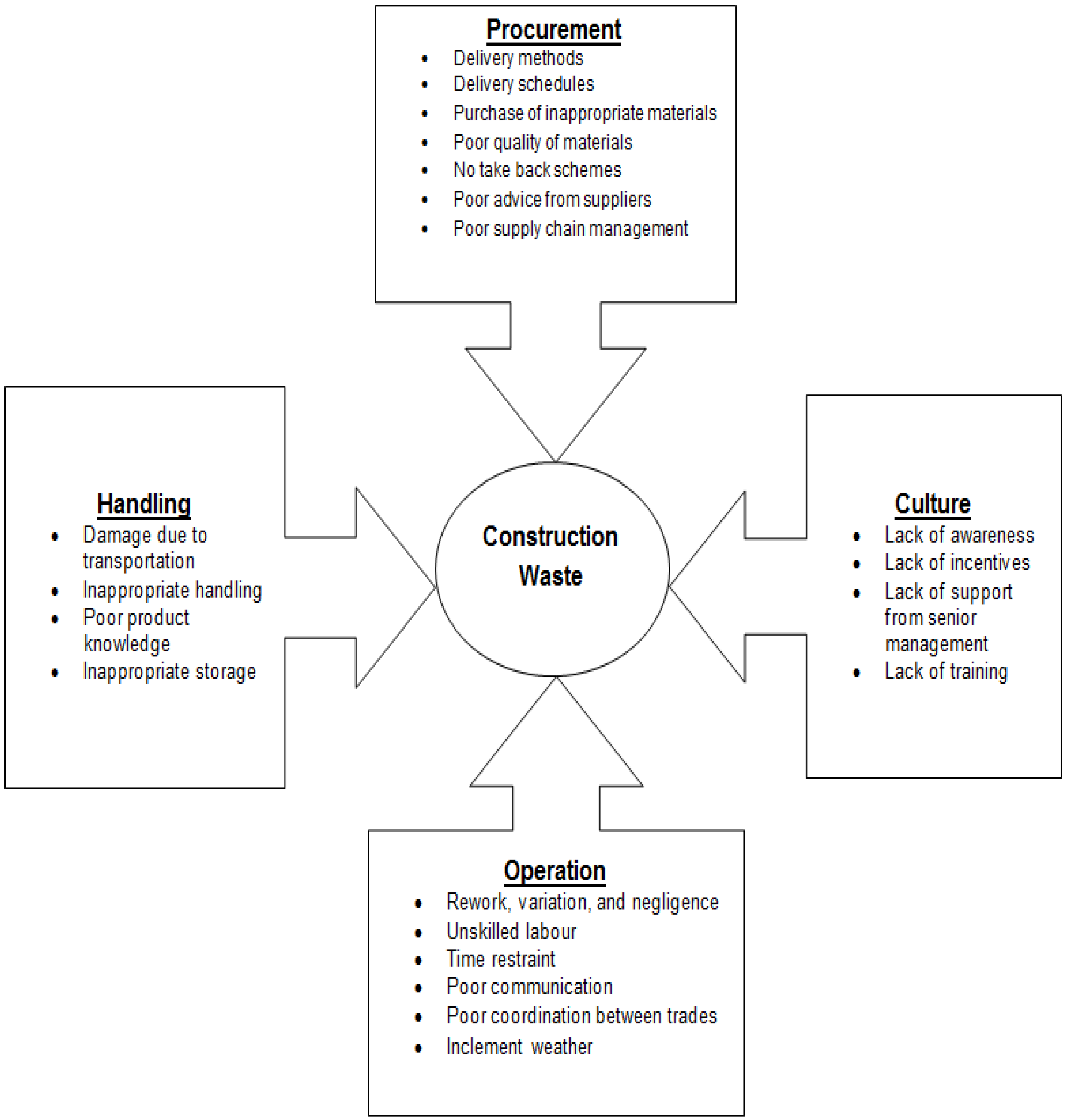


Figure 2.2: Origin of Construction Waste

Source: Al-Hajj and Hamani (2011: 2)

Okorafor (2014: 209) highlighted that construction waste originates from many sources, these include the processes that occur before production, such as: materials manufacturing, design, material supply and planning, as shown in the Figure 2.3.

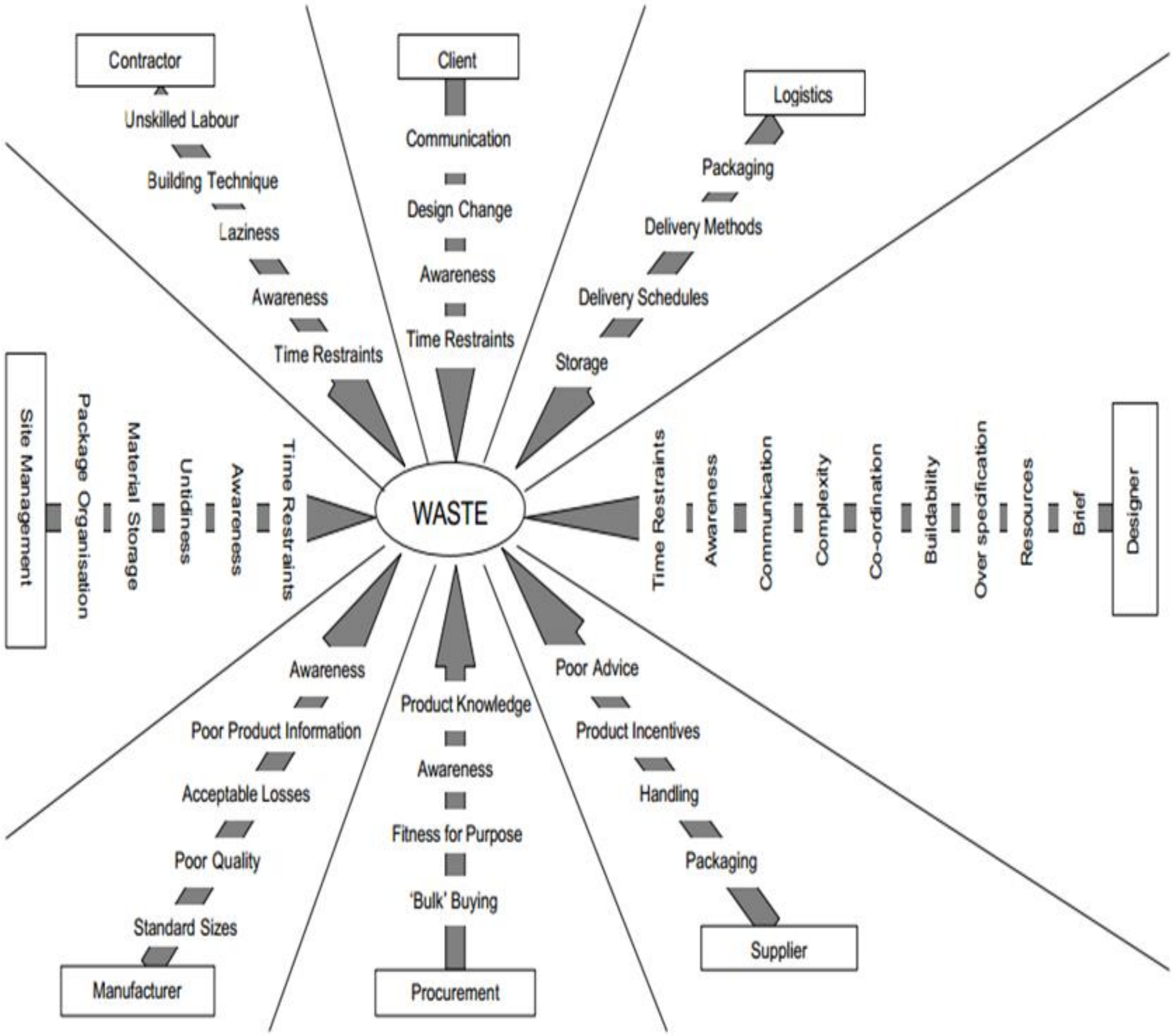


Figure 2.3: Origin of Construction Waste

Source: Okorafor (2014: 209)

There are different approaches to assessing the main origins, the sources, and the causes of construction waste (Osmani, Glass and Price, 2008: 1149; Osmani, 2011: 209). It has been estimated that 33 percent of all the on-site material waste is generated because of the architect's inability to implement waste-minimisation measures during the design phase of a project (Osmani, Glass and Price, 2008: 1149).

Additionally, clients also contribute directly or indirectly to on-site waste generation. There is a general consensus in the literature that design changes occurring whilst construction is in progress are one of the main source of construction waste (Osmani, Glass and Price, 2008: 1149). However, Kareem and Pandy (2013: 348), contend that construction waste could arise from different sources, depending on the complexity of the project, namely: design stage, procurement stage, operation stage, material management stage, and material storage area.

In another study, poor site management and supervision, the lack of experience, inadequate planning and scheduling, mistakes and errors in design, and construction were ranked as the top causes of waste in a project (Nagapan *et al*., 2012b: 22; Babatunde, 2012: 240). Furthermore, Al-hajj and Hamani (2011: 8) summarised that "design error leading to unnecessary off-cuts", "low-quality products", "lack of awareness", "rework and variations", and "temporary works" are the major causes of material waste on construction sites.

Nagapan *et al.* (2013: 102) conducted a survey on the causes of material waste at three construction sites in Malaysia. The study revealed the following: inappropriate storage of materials, poor materials handling, low quality of materials, error in material ordering, mistakes in estimation, bad attitudes of workers, inadequate supervision, and the lack of waste management plans.

Physical construction waste is mostly caused by 'improper preparation and handling, the misuse of materials, and improper materials processing (Baldwin *et al.,* 2008: 333). Adewuyi and Otali (2013: 748) found that, rework, design changes, waste from uneconomical outlines, inclement weather, and bad quality materials contrary to specification were ranked as the top causes of waste in the Rivers State of Nigeria.

Nguyen, Gupta and Faniran (nd: 4) identified the major sources of material waste with their causes at the pre contract and post-contract stages of a project, as follows:

1. ***Planning and designing: (the pre-contract stage)***

Variation to design: lack of co-ordination in the standardisation of materials.

Over-estimation to accommodate the variation: The extra materials ordered are discarded, instead of being carried over to the next project.

2. Estimating and purchasing (the pre-contract stage)

Over-allowance: for site losses and breakages, materials' variable dimensions, skill and work ethics of the trade people.

Under-ordering: the minimum quantity is often more than required to compensate; and the extra is consigned to waste.

3. Manufacturers and suppliers (the pre-contract stage)

Insufficient projection for materials: materials are damaged during delivery and loading.

Moreover, Nguyen, Gupta and Faniran (nd: 4), therefore, suggested the following at the post-contract stage of a project:

4. Operational waste (the post-contract stage)

Due to the nature of the construction process, there is waste generated by the type of work, time pressure, poor craftsmanship, lack of supervision, and poor work ethics.

5. Transporting and delivery waste (the post-contract stage)

This is caused by factors dependent on access to the site, and methods of loading and offloading. The amount of waste generated depends on the situation.

6. Storage (the post contract stage)

Improper stacking methods, transferring materials from remote storage location to the point of application, damage by other trades and weather conditions. Waste incurred due to bad site management, and failing to provide adequate protection for the materials stored.

7. Crimes and theft (the post-contract stage)

Insufficient site security: There is need to prevent vandalism or pilferage of materials by both outsiders and insiders.

Nagapan *et al.* (2012a: 327) identified 81 causes of material waste and categorised them into seven sources. These include: design, workers, management, procurement, site condition, handling and external factor groups. The identification of these causes could help in increasing awareness amongst the construction practitioners to control material waste.

Osmani, Glass and Price (2008: 1149) and Osmani (2011: 209), categorised waste into eleven sources, thereby showing that construction waste is generated throughout the project from commencement to conclusion, and emphasising that the pre-construction stage provides a significant share.

1. *Contractual waste:* Client-driven or enforced waste; mistakes in contract documents; and incomplete contract and tender documents at the commencement of construction.
2. *Procurement:* The lack of early stakeholders' involvement, poor communication flow, improper co-ordination amongst the parties and trades, and lack of allocated duties for decision making.
3. *Design:* Changes in design, complexity in design and specifications, mistakes in design and construction details, insufficient or incoherent specifications; poor co-ordination and communication (late information, last-minute client requirements, slow in drawing revision and distribution).

Osmani, Glass and Price (2008: 1153) concluded that the following four factors are responsible for causing waste at the design stage of a project: last-minute changes in design, errors in detailing, inaccurate specifications, lack of information on drawings and delays due to drawing revision and distribution.

4. *On-site Management and Planning:* improper site management; improper planning for the required quantities; delayed information on the kinds and size of materials and components to be used; the lack of on-site material control; and inappropriate site supervision.

Osmani, Glass and Price (2008: 1149) and Osmani (2011: 210) added that the following waste originates from the post-contract stage of a project:

- Site operation: accidents on site; unused materials; equipment breakdown; poor workmanship; use of inappropriate materials; time pressure to complete a work; and inappropriate work ethics.
- Transportation: damage of materials during transportation; difficulties of vehicles in accessing construction sites for delivery of materials; poor protection during loading and unloading; and methods of unloading.
- Material ordering: mistakes in ordering (for instance, items not in accordance with specification); over-allowances (difficulties in ordering lesser quantities); conveyance and suppliers' errors.
- Material storage: poor site-storage area resulting in deterioration; inappropriate storage methods, and long distance from storage to application point.
- Material handling: material supplied in loose form; onsite methods of conveying materials from storage space to construction point; improper handling of material.
- Residual-waste sources: these are occasioned as a result of application processes (for instance, excess mixture of mortar); wrong cutting of materials to length; cutting uneconomically shaped materials; and packaging waste.
- Other sources: waste could arise as a result of severe weather conditions; sabotage and theft.

Nagapan *et al.* (2012b: 25) examined the causes of material wastage in the central region peninsula of Malaysia. The result revealed the following: improper management of site and supervision; lack of experience; inadequate planning and detailing; errors in design; mistakes during construction; incompetent subcontractors; rework; frequent design changes to meet the client's requirement; labour output; improper monitoring and control; inaccurate measurement and estimation; scarcity of site workforce; improper co-ordination amongst the parties; slow movement of information between parties; scarcity of skilled labour; variations in material specifications and type; the availability of equipment and failure; and inclement weather.

In the opinion of Wahab and Lawal (2011: 250), construction material waste could arise from the following sources: excessive material consumption; errors in design; exposure and damage of materials due to inclement weather conditions, and inappropriate storage facilities; poor handling and delivery of materials; vandalism; rework/lack of improvement on concluded work; inappropriate records of materials.

Nagapan *et al.* (2013: 103) conducted a study on three sites in Johor, Malaysia. The study revealed six types of construction material waste, namely: timber, metal, bricks, concrete, packaging waste and mortar. Timber had the highest waste rate at all the three sites, with 46 percent of the total waste produced at site “A”; 50 percent at site “B”; and 80 at site “C”.

The various causes of material wastage in the Nigerian construction process as identified by Oladiran (2009: 3) are: changes in design, errors and mistakes of workers; improper flow of communication amongst the parties; waste resulting from uneconomical shape; poor specifications; unfamiliarity of designers with alternative products; improper supervision; wrong interpretation of drawings; vandalism; poor site conditions; poor transportation of materials; building failure/defects; loading and unloading of materials; poor setting out; theft of material, use of substandard materials; bulk material delivery; and errors in estimation.

Therefore, a comprehensive construction waste management strategy is urgently required on every construction project. After identifying these causes of construction waste; the next logical step seems to be that of organising ways to reduce it as a part of the solution to waste problems of any kind. Indeed, it should be made mandatory that every construction company should have its construction waste management plan that suits its way of business; so that every employee, from management level to operatives can focus on the same goal of waste management (Tam and Tam, 2006: 1650).

2.3 Construction Waste Recovery Systems (Re-use and Recycling)

The recovery of construction waste, according to the United State Environmental Protection Agency [USEPA], (2000: 3) encompasses the choice of the material to be recovered, which depends on factors, such as the type of project, on-site space, the existence of markets for secondary materials, the cost-effectiveness of recovery, the project duration, and the contractor's experience.

Countries such as China, Australia, Japan, USA, Germany, and the United Kingdom have successfully recovered numerous materials: (for instance, paper, plastic, metals, and glass). However, Germany has the highest recovery rates for paper, plastic, metals, and 88 percent for glass, respectively (Tam and Tam, 2006: 1649).

Tam and Tam (2006: 1649) noted that the re-use and recycling of material waste are the only options to recover the generated waste. The benefits of recovering construction materials are summarised by USEPA (2000: 1) as: reducing the project costs through avoided disposal costs; reduction in purchases of new materials; revenue earned from secondary material sales, compliance with State and local regulations, such as disposal bans and recycling goals; raising the public image of companies, and reserving space in existing landfills.

2.3.1 Re-use of construction waste materials

In the context of material waste recovery, the word 'reuse' was mostly used to signify the salvage or rescue of building materials for subsequent resale and use in another project (Winkler, 2010: 87). However, if waste generation could not be prevented or minimised to a certain degree, the subsequent stage was to re-use or recycle, as much as possible (Esin and Cosgun, 2007: 1665-1666). Apart from prevention and minimisation, most countries used this approach to reduce construction waste on-site, before disposing the waste to landfills (Wang and Li, 2011: 3).

The best strategy for minimising the environmental impact of material waste is mainly by avoiding its generation, or by reducing it as much as possible. This would reduce the rate of re-use, recycling, and the need for disposal by providing economic benefits (Esin and Cosgun, 2007: 1665-1666).

Winkler (2010: 88) believes that the re-use of material waste is more advantageous than other means of waste recovery, and for the following reasons:

- Re-use does not require energy and reprocessing. All costs related to these issues are curtailed when re-using waste materials.
- Re-use demonstrates the essential idea of recycling "cradle-to-grave-to-cradle" re-used materials are restored back to their original state.
- The most profitable and economical means of material waste recovery for contractors is to re-use such materials.

The Siemens Company in Germany uses a very advanced waste-handling technology for the re-use of construction materials. The process includes drying, distillation and burning to enable the waste material to be re-used (Wang and Li, 2011: 3).

In Hong Kong, the sorting process of waste materials is common among the construction practitioners; and this action promotes the re-use of some of the generated waste (Poon *et al.,* 2004: 686). Consequently, a trip-ticket scheme in Hong Kong encourages the separation of inert waste for possible re-use (Nagapan *et al.,* 2012a: 332).

Many techniques are adopted when selecting the "re-use" option in the construction process. However, some contractors may prefer to use broken bricks and stones as sub-grade for an access road to a construction site. Construction materials, such as timber or plywood can often be re-used to build temporary sheds at the site (Nagapan *et al.,* 2012a: 332). Winkler (2010: 93) believes that it is easier to re-use waste material when the floor finish is made of terrazzo, granite, marble, or ceramic tile on concrete slabs. Any unpleasant cracking or bruising of the floor should render it suitable for re-use. Winkler (2010: 21) added that various framing materials, such as board and insulation waste may be generated on-site; and the best management skill to apply is to save them in a bin for a subcontractor to make use of them to avoid any further cutting of new materials.

2.3.2 Construction waste recycling (benefits and challenges)

The global increase in the rate of material waste generation has led to the practice of recycling to become re-usable (Mueller, 2012: 508). Winkler (2010: 2) added that as raw materials are becoming more expensive and scarce; and municipalities are resisting landfill extensions, so, the practice of waste management becomes more economical and important. Therefore, policy-makers and construction managers must select which recycling practices to implement from the available options, in order to best divert material waste from going to landfills (Mueller, 2012: 508).

Winkler (2010: 39) believes that new construction waste is faced with more challenges and opportunities than demolition waste. However, the recycling of material waste is consistently easier during the construction of new projects than it is with the demolition of old works, and with renovation works. This is because, waste generated can be source-separated by the crews, as they are produced. However, demolition and renovation project-waste materials often consist of mixed materials; and they require on-site or off-site sorting (USEPA (2000: 1). Therefore, project contractors have the opportunity to co-ordinate with suppliers and shippers to reduce the quantity of waste entering the worksite. This early intervention is important for recycling efforts on the site (Winkler, 2010: 39).

Winkler (2010: 1) argued that it was easier and cheaper to send demolished building materials and construction materials to landfills than it is to recycle them; because recycling markets hardly existed for demolition materials ten (10) years ago. Manufacturers had not yet produced any product using recycled waste; and they prefered to use new materials in order to control the quality and the cost.

The recovery of construction and demolition waste, according to USEPA (2000: 3) encompases the choice of what and how construction and demolition materials can be recovered. This depends on factors, such as the type of project, on-site space, the existence of markets for materials, the cost-effectiveness of recovery, the projects duration, and the contractor’s experience.

Moreover, Kartam, Al-Mutairi, Al-Ghusain and Al-Humoud (2004: 1051) highlight the basic requirements that need to be put in place before the practice of waste recycling can be successfully achieved, and these are: The shortage of raw materials and appropriate disposal sites; a reliable supply of appropriate recycled materials; organised conveyance by means of the recycled materials; careful sorting at the construction or special treatment site; re-processing means of the materials into appropriate materials and products; the availability of markets for the materials; and recycled products that are competitive and equivalent with natural resources in terms of cost and quality.

Winkler (2010: 3) identified the reasons why recycling is a smoother, more profitable and more sustainable way to deal with construction waste:

- *Generates employment opportunities:* For each job in a landfill, 10 other people are employed elsewhere in processing the recycled products; and another 25 are employed in manufacturing products from the recycled materials.
- *Costs:* Landfills and incinerators are economic disasters. Roughly 20 percent of the superfund sites on the U.S. (EPA) list are landfills, and landfills require long-term monitoring to check the toxic leachate or debris liquid. While incinerators require large capital investments and a continuous stream of garbage to remain economical.
- *Energy:* Recycling saves energy through reducing the net amount of energy expended in mining and using raw materials. For example, for every one million tons of aluminum material recycled, there would be a saving equivalent of 35 million barrels (5.6 million m^3) of oil.

Furthermore, USEPA (2000: 1) summarised some of the benefits of recovering construction waste materials, as follows:

- Reducing the project costs through avoided disposal costs, no purchases of new materials, revenue earned from materials sales, and tax breaks gained for donations.
- Compliance with State and local regulations, such as disposal bans and recycling goals.
- Raising the public image of companies and organisations that reduce disposal
- Preserving space in the existing landfills.

In the opinion of Tam and Tam (2006: 1649), material waste recycling, being one of the strategies of waste minimising, offers three major benefits:

(i) It reduces the demand for new materials;
(ii) It cuts down transportation costs and production-energy costs; and
(iii) Re-using of waste materials, which could be lost to landfills.

In the view of Dolan, Lampo and Dearborn (1999: 33), the recycling of construction waste offers many benefits including: The conservation of resources by diverting them from the landfill, thereby, resulting in fewer related environmental impacts, such as groundwater contamination, lower material costs and disposal costs in the long term, serving as new sources of revenue for waste generators, cost saving, the availability of markets for recycled products, and profit on salvaged materials.

On the other hand, Winkler (2010: 4) argues that the recycling of both construction and demolition-waste materials in the USA is facing challenges from one point to the other; and these challenges are limited to some selected areas of the country:

- Despite the significant growth in the construction-recycling industry, the EPA USA, estimated in 2013 that only 34.3 percent of the generated waste on the average construction site was being recycled or re-used.
- Despite the dramatic growth in the recycling industry, more recycling markets are needed to enable contractors to constantly market their recycled products.
- According to an EPA report, demolition waste accounts for 53 percent, renovation 38 percent, and new work 9 percent; making a total of 100 percent of construction-industry generated waste.

Additionally, Mou (2008: 21) highlights the challenges facing the process of construction waste recovery, as follows:

- The mindset of individuals at all stages of the construction process, and the lack of awareness in waste minimisation;

- Poor training of construction workers, designers, estimators, developers, contractors, buyers and other participants in the construction process;
- Lack of incentives for companies to recycle, in terms of both company reputation building and financial incentives;
- Lack of markets for recycled products;
- A local boom in construction that renders the cost and time spent on reclaiming waste material an uneconomical option;
- Availability of economical virgin resources that reduce the incentives to make use of the recycled materials;
- Inadequate co-ordination and communication among the participants in the construction industries;
- Shortage of local resources, equipment and system to implement waste-processing technologies;
- Underdevelopment of the recycling industry;
- Inefficient separation of non-inert construction waste; and the
- Availability of most economical options to manage and treat waste. For instance low landfilling fees.

Therefore, to improve the position of the recycling market in the construction industry, Tam and Tam (2006: 1659) suggested the following significant options:
Higher landfill charges; setting up of a centralised recycling environment for recyclable materials; the availability of a vast area of land for intending recyclers; the best sorting method should be encouraged; the availability of an easy access route to drop recyclable materials; in the case of demolition, the client should allow a flexible demolition period to allow for the proper sorting of materials; and there should be sustainable legislation available to balance the demand and supply of recyclable materials (Tam and Tam, 2006: 1659).

2.3.3 Drivers and barriers to material-waste minimisation in construction

The three main drivers of waste management in the construction industry are: the legislative, financial and business drivers (Osmani, 2012: 37).

In another study, Osmani *et al.* (2006) categorised the drivers of waste minimisation in the UK into four main groups, namely: environmental, industrial, economic, and legislative. From these broad categories, the following can be considered as the key drivers:

- *Government policies and contractual terms:* the UK government had, until recently been reluctant in the first place to devise an effective waste-management plan, which would lead to the implementation of policies and legislation on waste management. The common example is the landfill tax.
- *Environmental standards and assessment tools:* Environmental management system standards began after the Rio de Janeiro Summit in 1992. The world's first standard, BS7750, was developed by the BSI in 1992; and this was followed by the Eco-Management and Audit scheme (EMAS) published by the European Union (EU) in 1993. One of the main requirements of ISO 14001 is waste minimisation, and the development of a waste-management plan, as part of the EMS (Al-Hajj and Hamani, 2011: 221).
- *Financial benefits:* The actual disposal cost of waste is more than the cost of paying a waste contractor to remove a skip from a site (Al-Hajj and Hamani, 2011: 221).

Osmani (2012: 40) added that the current legislative and fiscal measures are absolutely the key drivers for construction-waste reduction in the UK, relating directly to the rising landfill tax, increasing waste-disposal cost, and the requirements to comply with the Site Waste-Management Regulations (SWMR) of 2008.

Moreover, Langdon (2010: 13) suggests the six (6) key drivers for waste minimisation in the UK's construction industry as:

- The landfill tax and aggregates levy, 2008/2009;
- Site waste-management plan regulations of England, 2008;
- The financial drivers, principally the savings available from greater material-resource efficiency and the avoidance of waste-disposal costs and taxes;

- Environmental drivers, including reduced resource extraction, processing and consequential carbon emissions from transport and manufacture, as well as the depletion of landfill capacity;
- Corporate Social Responsibility (CSR) drivers, especially for businesses that want to demonstrate their commitment to sustainable construction and good environmental management; and,
- Project-specific drivers, particularly in relation to the adoption of good waste minimisation and management practices, in order to meet the requirements for improved performance and the achievement of targets.

Additionally, Al-hajj and Hamani (2011: 8) noted that the benefits of any waste minimisation include the four major factors as: savings in cost, environmental protection, improvement in health and safety, and improving the corporate image of the company. Osmani, Glass and Price (2008:1155), therefore, established that factors, like financial rewards, a waste-management policy in place, and training and educational programme are the major incentives or solutions to the waste-minimisation barrier in the construction industry.

Therefore, the design of waste-minimisation programme would only be achieved if: the contract language (waste-minimisation clause) is incorporated into the conditions of a contract; the issues relating to design and construction methods to reduce cut-off and residual waste are considered. Waste could also be minimised by specifying standard building materials; and an education programme for training and development could help the construction stake-holders to understand the benefits of waste minimisation (Osmani, Glass and Price, 2008:1150).

The Construction Waste Management Guideline [CWMG], (2014: 3) highlights the fact that key objectives of any construction waste management strategy are to:

- Reduce the quantity of waste generated, as part of the project plan;
- Maximise the volume of materials sent for re-use, and the recycling or salvaging of waste; and to,
- Reduce the amount of waste material sent to landfills.

On the other hand, Osmani, Glass and Price (2008:1155) opined that factors, such as: lack of interest from clients; waste accepted as inevitable; poorly defined individual responsibilities; and the lack of training are the major barriers to waste minimisation in the construction industry.

In the view of Adams *et al.* (2011: 18), the key challenges in ensuring that the construction industry meets the 2012 goal of halving waste to landfill targets are:

- Improper information on the amount of waste generated, and where it is disposed;
- Lack of awareness of the benefits of resource efficiency;
- Poor communication and teamwork between the supply-chain members;
- The lack of encouragement by the procurement system on waste minimisation;
- Opportunities to identify waste reduction at the design stage were not encouraged;
- Legislative barriers preventing the easy re-use of soils and stones;
- Poor delivery, storage, and handling of materials; and
- The lack of a satisfactory infrastructure for material-waste management.

2.5 The Concept of Cost Overrun in the Construction Industry

Cost overruns have plagued governments for decades, even centuries (Edward, 2009: 3). It is also known as "cost increase" or "budget overrun"; and it involves unanticipated costs incurred in excess of the budgeted amounts (Shanmugapriya and Subramanian, 2013: 735). The UK Essays (2010: 1) suggested the simplest definition of cost overrun on a construction project as an overrun, which incurs more than the presumed cost. This is referred to as budget increase, budget escalation, cost increases, or budget overrun (Memon, 2013: 14). It is defined as a percentage difference between the final completion cost and the contract-bid cost (Shanmugapriya and Subramanian, 2013: 735; Shrestha, Burns and Shields, 2013: 2). It has also been referred to as the percentage of actual or final costs above the estimated or tender costs of the project (Ubani, Okorocha and Emeribe 2011: 74; Jenpanistub, 2011: 19; Memon, 2013: 15).

Nega (2008: 48) defines cost overrun as an occurrence, in which the delivery of contracted goods/services is claimed to require more financial resources than was originally agreed upon between a project sponsor and a contractor/constructor.

Also, Azhar, Farooqui and Ahmed (2008: 500) view cost overrun as simply an occurrence, where the final or actual cost of a project surpasses the original or initial estimates. It is expressed as a percentage of the actual or final costs, minus the estimated cost over the estimated/tender costs of a project (Memon, 2013: 15; Ubani, Okorocha and Emeribe 2011: 74) This is reprepented mathematically:

$$Cost\ Overrun = \frac{Actual\ Cost - Estimated\ Cost}{Estimated\ Cost} X\ 100$$

The actual costs are referred to as the real and accounted construction costs realised at the completion of a project; while the estimated costs are the budgeted, estimated or forecasted construction costs determined at the inception of projects after the actual design has been developed (Ubani, Okorocha and Emeribe 2011: 74; Memon, 2013: 15).

Therefore, Azhar, Farooqui and Ahmed (2008: 500) suggest that the problem of cost overruns is critical; and they recommended that more study is required, in order to prevent or minimise any future occurrence.

2.5.1 Cost overrun in developed countries

The history of the construction industry worldwide is full of projects that were completed with a significant amount of cost overrun, despite the use of modern technologies and software packages in the construction industry (Memon, 2013: 16).

In the UK, Barrick in 1995 revealed that almost one-third of the clients complained that their construction projects generally overran budget (Memon, 2013: 16). Also, construction of the channel tunnel between the UK and France experienced a cost overrun of about 80 percent over budget (Flyvbjerg, 2005: 5).

In the US, only 16 percent of 8,000 surveyed projects in 1994 could satisfy the following three requirements: timely completion within the budget, and maintaining a high standard of quality (Ameh, Soyingbe and Odusanmi, 2010: 51).

Moreover, the Government Accountability Office of the USA also stated that 77 percent of highway projects in the US were completed with a significant amount of cost overruns (Memon *et al.,* 2014:179). Edward (2009: 5) asserted that in Washington, D.C., the "Capitol Visitor Center project" costing $265m in year 2000 was completed at the cost of $621m in 2008 with a cost overrun of about 234 percent. The "Kennedy center opera house project" was awarded at $18.3m in 1995; and it was completed at $22.2m in 2003 with an average cost overrun of 21 percent. The Kennedy center concert hall, with an initial value of $15.1m in 1995 was only completed at $21.3m in 1997.

A study conducted by the Federal Transit Administration (FTA), covered 10 major transit capital investment projects in the US with a total amount of $15.5 billion. As many as 9 of the 10 projects experienced an average cost overrun of 52 percent (Jenpanitsub, 2011: 22). In another study, the FTA investigated 21 railway and bus-way projects that commenced between 1990 and 2002. The actual or completed costs of these projects on average were 21 percent greater than the original estimated cost (Jenpanitsub, 2011: 23).

In Canada, 50 road construction projects were investigated; and the results revealed a cost overrun of up to 82 percent in 2006 (Odeck, 2014: 71).

Brunes and Lind (2014: 3) noted that cost overruns were slightly lower in Europe when compared with North America, and other geographical areas.

Cantarelli *et al.* (2012: 87) noted that the Dutch construction projects were reported to have an average cost overrun of 10.6 percent for railways, 18.6 percent for roads, and 21.7 percent for fixed links.

Another study conducted by the Auditor General of Sweden in 1994, covering 15 road and rail projects, revealed that the average cost overrun on 8 road projects was 86 percent. The range for road projects was from -2 to +182 percent; while the average cost overrun for the seven rail projects was 17 percent, ranging from -14 to +74 percent (Allahaim and Liu, 2013: 2).

The Swedish National Audit Bureau (SNAB) investigated the cost performance of 8 road projects and 7 rail projects in Sweden with a total cost of 13 billion SEK. The average cost overrun for the road projects was 86 percent, ranging from -2 to +182 percent; and the average overrun for the rail projects was 17 percent, ranging from -14 to 74 percent (Jenpanitsub, 2011: 22) Similarly, a study on 21 projects in some EU countries revealed a cost overruns of about 9.4 percent in 2009 (Odeck, 2014: 71).

In Portugal, construction projects face, on average, a minimum of 12 percent of cost overrun (Abdul Rahman, Memon, Abdul-Azis and Abdullah, 2013: 1964). In Norway, a study was conducted to establish the impact of compulsory quality assurance on cost overrun. The study examined 31 major public projects, including transportation projects. The results revealed that the magnitude of the cost overrun was reduced after a mandatory quality assurance process was introduced (Magnussen and Olsson, 2006: 286).

The Western Australian Perth Arena project, with an estimated budget value of AUD 168 million experienced a cost overrun, which more than tripled the original budget (Love, Edward and Irani, 2011: 3).

2.5.2 Cost overruns in developing countries

The Transport and Road Research Laboratory (TRRL) of England studied the performance and impact of rail mass transit in twenty-one (21) developing countries. Almost all of the underground rail systems experienced a significant cost overrun (Jenpanitsub, 2011: 22). Abdul-Rahman, Memon and Abd. Karim (2013: 287) reported that in a study of 53 building projects in Bosnia and Herzegovina, 29 new construction projects experienced a cost overrun of 6.84 percent on average; while the remaining 24 re-construction projects had a cost overrun of 9.23 percent on the average. This means that re-construction projects experienced, on average, more cost overruns than new projects.

Le-Hoai, Lee and Lee (2008: 374) identified the three major factors causing cost overruns in Vietnam as: increase in the cost of materials due to inflation; inaccurate estimations; and an increase in the cost of labour due to environmental restrictions.

The reply Statistics minister of India disclosed that 179 out 555 ongoing projects were reported to have experienced cost overruns. The minister also revealed that "The major reasons for cost overruns are under-estimation of the original cost, change in the rates of foreign exchange and statutory duties, an escalation in the cost of land, the high cost of environmental safeguards and rehabilitation measures, and inflation and delay in projects".

Furthermore, the Indian Department of Transport (INDOT) 2004 revealed that 2,668 roads construction and maintenance projects executed by the INDOT between 1996 and 2002 experienced a cost overrun rate of 4.5 percent, on average. Furthermore, 55 percent of all INDOT contracts experienced cost overruns (Jenpanitsub, 2011: 24).

In Pakistan, the minimum amount of cost overrun was reported to be around 10 percent for the small-sized firms, 40 percent for large construction firms, and this percentage could increase to 60 percent for the medium-sized firms (Azhar, Farooqui and Ahmed 2008: 506).

Aziz (2013: 54) surveyed 15 different projects in Kuwait; and the results revealed that only one project had been completed without a cost overrun. Aziz (2013: 54) added that 95 percent of the respondents disclosed that they had never handled a project without variation orders. Aziz (2013: 52-53) also reported that 70 percent of building construction projects in Oman experienced a delay; and they were completed with cost above the initially estimated budget.

Moreover, a study conducted on 359 projects (308 public and 51 private projects) in Malaysia, revealed that only 46.8 percent and 37.2 percent of public sector and private sector projects, respectively, were completed within the budget, with an average cost deviation of 2.08 percent (Endut, Akintoye and Kolley, 2009: 244). Baloyi and Bekker (2011: 53) reported that the construction of FIFA 2010 world cup stadia at different cities in South Africa was completed with cost overruns ranging from 5 percent to a maximum of 94 percent. Baloyi and Bekker (2011: 53) reported that the soccer city stadium in Johannesburg was completed with a cost overrun of 60 percent; while the Ellis park stadium in Johannesburg had a cost overrun of about 5 percent. The Moses Mabida stadium in Durban had a cost overrun of 94 percent. The Mbombela stadium at Nelspruit had a cost overrun of 67 percent. And the Green Point stadium in Cape Town with an initial estimate of R 2.9 billion and completed at R4 billion had a cost overrun of 38 percent. The Royal Bafokeng stadium in Rustenburg had a 34 percent cost overrun. And the Mangaung stadium, in Bloemfontein was completed with a cost overrun of 47 percent; and the Loftus Versfeld stadium in Pretoria had only a 7 percent cost overrun.

The Northern by-pass construction project in Kampala, which was to be completed in two and a half years, instead took more than 5 years; and it had a cost overrun of more than 100 percent (Apolot, Alinaitwe and Tindiwensi 2010: 305).

In Nigeria, Olawale and Sun (2010: 602) conducted a survey on cost overrun; and they found that 41 percent of the respondents had experienced a cost overrun of less than 10 percent of their projects; while 59 percent of the respondents had experienced a cost overrun of 10 percent or more on their projects.

Kaliba, Muya and Mumba (2009: 523) noted that road projects in Zambia were also faced with more than 50 percent of cost overruns, as a result of delay and other factors.

Similarly, Apolot , Alinaitwe and Tindiwensi (2010: 310) reviewed 30 projects of the civil Aviation Authority of Uganda; and found that 53 percent of the projects, although not fully completed experienced cost overruns; and 40 percent of these projects were within the budgeted cost; and 7 percent of the projects were still below the budget. A total of 84 percent of the cost overruns were occasioned by changes in the scope of the work; while the remainder were largely attributed to material-price inflation.

Memon *et al.* (2014: 179) reported from the 61 projects studied in Nigeria, that the result revealed that all the projects had an average cost overrun of 17.34 percent; while the average time overrun of the building projects studied were 92.64 percent for projects ranging from 0 to 10 million, and 59.23 percent for those projects ranging from 10 million Naira and above, respectively. They further recommended that 17.34 percent of the project cost estimates should be included in the pre-contract estimate as a contingency sum in Nigerian building projects against the usual practice of between 5 and 10 percent.

2.5.3 The causes of construction cost overruns

The success of a project is evaluated after comparing the estimated and the completion cost, with respect to the level of the realised objectives. A project can be considered to be successful, if its technical performance is maintained, according to the schedule; and it is completed within the estimated budget (Ejaz, Ali and Tahir, 2011: 2). Hence, the cause of cost overruns is critical to the success of any project (Allahaim ad Liu, 2013: 2). Therefore, this section seeks to comprehend the main causes of cost overruns; and it presents the results of different studies over the years on cost overruns in different types of construction projects, and in different countries.

Cost overruns in the construction industry have been attributed to a number of sources, including technical errors in design or estimation, managerial incompetence, risks and uncertainties, suspicions of foul play, deception and delusion, and even corruption (Ahiaga-Dagbui and Smoth, 2014: 683).

The probable causes of cost overruns are many, depending on the exclusive features and context of individual projects (Allahaim and Liu, 2013: 1). For that reason, the two main causes of cost overruns in a project, according to Flyvbjerg, Holm and Buhl (2004: 7) are: optimism bias and strategic misrepresentations. Optimism bias summarises the systematic tendency of decision-makers to be more positive about the results of planned actions; whereas strategic misrepresentations have to do with confusing or misleading actions used in politics and economics, and by planners, to ensure that projects proceed.

Allahaim and Liu (2012: 2) contend that the practical causes of cost overruns are the lack of experience among the project team, contract size/ complexity, and design error.

Furthermore, other surveys have identified the four major factors that cause cost overruns for a project. They are variations in design; insufficient project planning; inclement weather conditions; and building materials' price fluctuation (Allahaim and Liu 2014: 2).

Consequently, the three important causes of cost overruns in Kuwait, according to Koushki, Al-Rashid and Kartam (2005: 285) are: contractors' errors, material-related problems, and owners' financial constraints.

In another study, Love, Edwards and Irani (2011:7), opined that design error at the pre-contract stage of a project is the major cause of cost overruns for hospital and school buildings.

Al-Najjar (2008: 160) investigated the causes of cost overruns in the Gaza strip, and found that "fluctuations in the prices of construction materials", as a result of border closure, was the major cause of cost overruns. Other factors were: "delays in the delivery of materials and equipment to site", and "inflation of the prices of materials."

In another study, Subramani, Sruthi and Kavitha (2014: 1) surveyed the causes of cost overruns in India. The results indicated that, slow decision-making at the planning stage of a project, poor project schedules and management, increases in the prices of materials and machines, poor contract management, poor design/delay in producing design, rework due to mistakes or wrong work, land-acquisition problems, poor estimation or estimation techniques, and the long-time taken between the design and the time of bidding/tendering are the major causes of cost overruns.

Shanmugapriya and Subramanian (2013: 734) investigated the causes of cost overruns in the Indian construction industry. The results revealed that the high cost transportation, modification in material specifications, and material-price escalation were the major causes of cost overrun.

In another study, the top five (5) important causes of cost overruns in large projects in Vietnam were: poor site management and supervision, poor subcontractors and project management assistants, owners' financial constraints, contractors' financial difficulties, and changes in design (Le-Hoai , Lee and Lee, 2008: 367). Additionally, Aziz (2013: 51) examined the factors causing cost overruns in waste-water projects in Egypt, and concluded that (1) lowest tendering procurement method; (2) additional works that are not included in the original work; (3) bureaucracy in tendering or offering methods; (4) wrong cost-estimation methods; and (5) funding problems by client were the major causes of cost overruns; while (1) inaccurate quantity take off; (2) payment mode for completed works; (3) unforeseen ground conditions; (4) inflation; and (5) fluctuations in the prices of materials were found to be of less importance.

The major factors causing cost and time overruns according to Apolot, Alinaitwe and Tindiwensi (2010: 306) were: inadequate working plants and equipment, and unreliable material sources from local markets.

Shanmugapriya and Subramanian (2013: 734) examined 54 causes of cost overruns and categorised them in to eight (8) major groups, namely: financial group, construction parties, construction items, environmental group, political group, materials, labour and equipment, and owner's responsibility group.

- The "financial group" comprises: the fluctuating exchange rate, and the lack of sound financial management and planning;
- The "construction-item group" comprises: mistakes during construction; wastages on-site; inadequate design; the lack of co-ordination at design stage; and the rework needed due to mistakes or errors;
- The "construction-parties group" includes: the lack of co-ordination between designers, and poor information flow;
- The "environmental group" has to do with material fluctuations;
- "The political group" entails difficulties in importing equipment and materials;
- "The material group" has to do with: changes in material specifications, material price increases, and material shortage;
- "The labour and equipment group" encompasses: the high cost of machinery, high maintenance costs of machinery, frequent breakdown of the construction plant and equipment, and high transportation costs; and

- The final group is the "owner's responsibility group"; and this entails: additional work called for by the owners, and the high quality of work required (Shanmugapriya and Subramanian, 2013: 738).

Ameh, Soyingbe and Odusami (2010: 49) concluded that the lack of experience by the contractor, the high cost of importing materials, and the materials' price fluctuation are the significant factors causing cost overruns in the telecommunication projects in Nigeria.

Ejaz, Ali and Tahir (2011: 1) discovered that increases in material prices, poor project control techniques, shortage of technical personnel, delays in work approval, and the shortage of materials and plant/equipment are the major causes of cost overruns in Pakistan.

Other studies have identified a variety of causes of cost overruns. These include: technical factors, such as the lack of experience; the project size; errors in design; price fluctuations; wrong estimates; and scope changes (Love, Edward and Irani, 2011: 6; Memon, Abdul-Rahman and Abdul Aziz, 2011: 59).

Abdul-Rahman, Memon and Abd. Karim (2013: 268) found that the three most important issues leading to cost overruns in the Malaysian construction industry were: materials' price fluctuation, cash-flow problems, and the financial difficulties faced by contractors; in addition to poor site administration and supervision.

Baloyi and Bekker (2011: 61) conducted a study on the causes of cost overruns in the 2010 FIFA world cup stadia in South Africa. The result revealed that project complexity, increases in labour costs, inaccurate quantity estimations, differences between the selected bid and the consultants' estimates, variation orders by clients during construction, and manpower shortage were the main causes of cost overruns.

Studies have shown that the practical causes of cost overruns on construction sites are the lack of experience among the project team, the scope of the contract and its complexity, errors in design, fluctuations in the prices of materials, and inaccurate cost estimates (Allahaim and Liu, 2012: 2).

Le-Hoai , Lee and Lee (2008: 369) identified the three most important causes of cost overruns in Vietnam as: the inflated prices of materials, inaccurate quantity take off for the project, and increases in the cost of labour due to environmental constraints.

Kaliba, Muya and Mumba (2009: 524) concluded that the problem of cost overruns in Zambia were caused by inclement weather conditions, changes in the size of projects, the cost of environmental sustainability, delays in the work programme, civil unrest, technical constraints, and increases in material prices.

Azhar, Farooqui and Ahmed (2008: 503) categorised the top ten (10) identified cost overrun factors in Pakistan into three (3) classes as:

1. *Macro-economic factors:* The cost of construction is basically the cost of money, the cost of material, the cost of labour and the cost of management. The top three factors identified under this class are: "fluctuations in the prices of raw materials," "the unstable cost of manufactured materials", and the "high cost of machinery". Unlike a manufactured commodity, the construction industry is mainly market-focused. Prices can, and sometimes do, change on almost a daily basis.
2. *Management factors:* Some cost overruns appear unavoidable; because they cannot be reasonably prevented, such as those due to unexpected events. However, overruns due to design issues or project management events are avoidable; because they could have practically been foreseen and prevented. The project control procedure can help management to identify its current position relative to a future position. Factors, such as: "poor project (site) management/poor cost control"; "additional work"; and "improper planning" can be controlled by the management.
3. *Business and regulatory environment:* The majority of contractors are small players, who have weak financial positions, outdated labour-intensive technology, and poor organisational structures, in addition to a vision for growth and development. They are all highly vulnerable to government policies. These factors are affected by causes, such as the "wrong method of cost estimation";

“inappropriate government policies”; “long periods between the design and the time of bidding/tendering”; and the “lowest bid procurement methods”.

Omoregie and Radford (2006: 5) examined the causes of cost overruns in the infrastructural projects in Nigeria. The result revealed the major causes as: “fluctuations in material prices”, “financing and payments made for completed works”, “inefficient contract management”, “delays in scheduling”, “variations in site condition”, “inaccurate cost estimates”, and “material shortages”.

In another study, Kasimu (2012: 775) found that “fluctuations in materials prices”, “insufficient time”, ”lack of experience in contracts works”, and “incomplete drawings” were the major causes of cost overruns in building construction projects in Nigeria.
Additionally, Malumfashi and Shuaibu (2012: 19) conducted a study on the causes of cost overruns in the infrastructural projects in Nigeria. The results revealed the major causes as “improper planning”, “material-price fluctuations”, and “inadequate finance from the project’s inception”.

It can be deduced from the evidence above (causes of cost overrun and material waste) that the major causes of cost overruns for projects are: the macro-economic factors and material waste.

To gain more insight on the causes of cost-overrun for projects, section 2.7 of this research summarises the major causes of cost overrun provided by different authors.

2.6 Procedures for Construction Materials Waste Quantification

The quantification of the amount of construction-material waste is important for the building practitioners to properly plan and control the disposal thereof (Jingkuang, Yousong and Yiyong, 2012: 398). Li, Ding, Mi and Wang (2013: 20) highlight that researchers quantify construction site waste in many ways.

In the Netherlands, construction waste has been measured in three ways: as a percentage of the total amount of waste, the purchased amount of material, and the total waste costs. It was also found that the amount of waste for each building material lies between one (1) percent and ten (10) percent of the amount purchased (Ekanayake and Ofori, 2004: 852; Liatas, 2011:1263).

The quantification of material waste is based on the volume of stockpiled waste, which is determined either on the basis of a rectangular prism, or in a pyramidal shape (Nagapan, *et al.* 2013: 102)

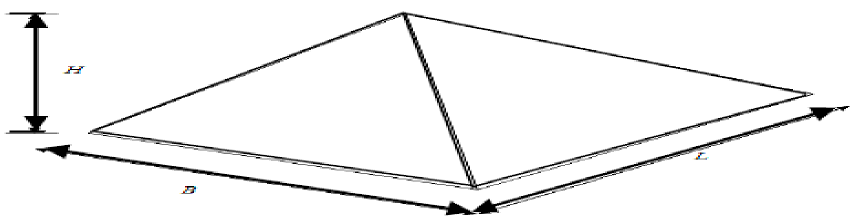


Figure 2.4: The volume method of pyramid shape

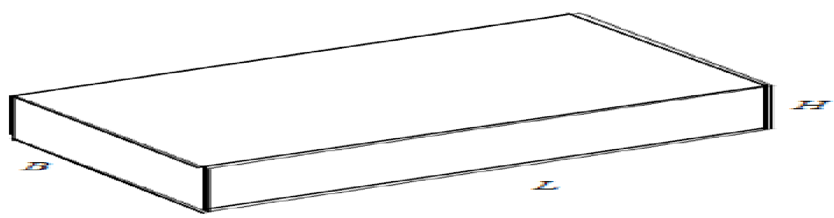


Figure 2.5: The volume method of rectangular shape

Source: Nagapan *et al.* (2013: 102)

For the pyramidal shape, the volume= 1/3 (B x L x H); and for the rectangular prism form, the calculated volume is = L x B x H. Where L is the length, B is the base, and H is the height.

The Waste Generation Rates (WGRs) are useful variables that lie at the core of many efforts for understanding waste management in the construction sector. WGRs can provide quantitative information for benchmarking different construction waste-management practices (Lu, Yuan, Hao, Mi and Ding, 2011: 680). This is achieved by measuring the quantity of construction waste generated by weight (tons) for every square metre of normalised floor space at the construction sites (Lachimpadi, Pereira, Taha and Mokhtar, 2012: 93).

Lu *et al.* (2011: 681) suggested that different practices can be used to measure waste: either by weight (kg or ton), or by volume (cubic metres/m^3). However, the WGRs are calculated by dividing the waste by either the amount purchased, the amount required by the design, or per square metre/m^2 of Gross Floor Area (GFA). Therefore, the four typical measurements for WGRs are: (1) the percentage of purchased materials (2) the percentage of material required by the design; (3) kg/m^2 of GFA; and (4) m^3/ m^2 of GFA.

$$WGR = \frac{\text{Total construction waste (tons)}}{\text{Total floor space (m2 of normalized floor space)}}$$ (Lu *et al.,* 2011: 682).

Table 2.1 shows the previous studies from different countries on waste- generation rates.

Table 2.1: Previous studies on waste generation rates

Previous studies of waste generation rates.

Author	Country	Measurement of WGRs	Methodology	Conclusions
Skoyles (1976)	UK	Percentage by weight (of the amount required according to design)	Direct observation and comparing contractors' records	2–15% by weight according to the amount purchased for 37 materials
McGregor et al. (1993)	USA	Weight and percentage of total waste from an individual project	Questionnaire and telephone survey	Varied with construction type and project cost
Bossink and Brouwers (1996)	Netherland	Percentage by weight (of purchased materials)	Sorted and weighed the waste materials	1–10% by weight of the amount purchased for seven materials, with an average of 9%
Mcdonald and Smithers (1998)	Australia	The volume (m^3) of waste generated per m^2 of gross floor area	Sort in waste bins and delivery records of bins	Total waste rate: 0.084 m^3/m^2
Forsthe and Marsden (1999)	Australia	Waste = ordered materials – in situ quantities	In situ quantities were from drawing or site measurement; ordered materials were from delivery and order documents	Maximal and minimal generation rate for eight materials by percentage in two projects
Poon et al. (2001a)	Hong Kong	Percent by weight or volume according to different materials	Site observation and questionnaire	1–8% for public housing; 1–100% for private housing
Morris Specifications Inc. (2001)	Canada	NA	NA	WGRs for main construction materials (wood, drywall, metal, concrete, other) are given
Formoso et al. (2002)	Brazil	Waste (%) = $[(M_{purchased} - \text{Inv}) - M_{designed}]/M_{designed}$ where Inv indicates the final inventory of materials	Direct observation and contractors' records	19.1–91.2% by weight according to the amount purchased for eight materials
Treloar et al. (2003)	Australia	Not clear	Consultation with construction company employees	3–10% for eight materials
Poon et al. (2004)	Hong Kong	The volume (m^3) of waste generated per m^2 of gross floor area	Visual inspection, tape measurement, truck load records	The total waste generation rate: 0.176 m^3/m^2 (C); 0.4–0.65 m^3/m^2 (D)
Lin (2006)	Taiwan	The volume (m^3) of waste generated per m^2 of gross floor area	The Neural Network Method	0.85 m^3/m^2 for factory (D); 0.54–0.66 m^3/m^2 for residential (D)
Tam et al. (2007)	Hong Kong	Wastage level (%T) = (Mp – Mu)/Mu × 100 where Mp is the purchased material and Mu is the used material (in m^3 for concrete, in ton for reinforcement, in m^2 for formwork, in m^2 for brick/block and in m^2 for tile)	Interview with people involved in the industry	8.9–20% and 4.11–6.62% by weight for five materials according to different sub-contracting arrangements

Source: Lu *et al.* (2011: 682)

Li *et al.* (2013: 21) believe that material-waste quantification commences with the following steps: (1) Listing the major types of construction material; (2) the purchased amount of major materials; and (3) the actual Material Waste Rate (MWR) of each type of material listed in 1, by dividing the amount of waste by either the amount of purchased material (Tam *et al.,* 2007), or by the amount of material required by the design. And, lastly, (4) Estimation of the percentage of the remaining waste. Major materials account for nearly 90 percent of the total construction waste. The remaining waste occupies approximately 10 percent of the total waste (Li *et al.,* 2013: 22-23).

1. Listing the major types of construction materials

Although buildings across the world are varied in structure and construction techniques, typical construction waste components include: concrete, bricks and blocks, steel reinforcement, timber, cement and mortar, ceramic tiles, plastic and cardboard packaging materials, and so on (Li *et al.,* 2013: 22-23).

2 Investigating the purchased amounts of the major materials

The amount of material purchased can be determined from the purchasing records of the finished projects, or from the budget documents of ongoing projects. The amount in the budget document generally includes normal material loss during construction, and thus is close to the actual purchased amount (Li *et al.,* 2013: 22-23).

3 Investigating the actual material waste rate

MWR is measured by dividing the amount of waste by either the amount of purchased material (Tam, Shen and Tam, 2007), or by the amount of material required by the design. The two possible rates would differ to a very small extent, unless the rate is huge. MWR is evaluated as the ratio of waste material to purchased material, expressed as a percentage (Li *et al.,* 2013: 22-23).

4 Estimation of the percentage of remaining wastes

In addition to the waste generated from the major materials listed in the first phase, there are also numerous types of small quantities of waste, such as cardboard

packaging, plastic pile, iron wire, and so forth. These remaining wastes include numerous categories; but they comprise only a small part of the total waste by weight.
Previous studies have revealed that the waste generated from major materials accounts for nearly 90 percent of the total construction waste. It can be deduced that in this situation, this remaining waste comprises approximately 10 percent of the total waste (Li *et al.,* 2013: 22-23).

- **Calculation of waste generation per gross floor area (WGA)**

In the first step, the total construction waste generated on site is calculated using Eq (1):

WG= $\sum_{i=1}^{n}(Mi\ (ri) + wo)$ ……………………………………………………1

where WG refers to the total construction waste generated from the project by weight (kg), Mi means the purchased amount of major material i in the identified list by weight (kg); ri is the MWR of major material i; W0 is the remaining waste; n is the number of major material types.

In the second step, the total WGA is calculated using Eq. 2

$WGA = \frac{WG}{GFA},$ ……………………………………………………………………2

Where GFA is the gross floor area of the building project in meter square (m^2).

For the third step, the WGA for major material i is calculated using Eq. 3

$WGAi\ = \frac{Mi \times ri}{GFA},$……………………………………………………………3

(Li *et al.,* 2013: 22-23).

2.7 Relationship between Material Waste and Construction Cost Overrun

Construction waste is generally classified into two main classes, namely: the physical waste and the non-physical waste (Nagapan, Abdul-Rahman and Asmi (2012: 2-3).

Physical construction waste is the waste from construction, renovation activities, including civil and building construction, demolition activities, and roadwork. It is, however, referred by some directly as solid waste: the inert waste which comprises mainly sand, bricks, blocks, steel, concrete debris, tiles, bamboo, plastics, glass, wood, paper, and other organic materials (Nagapan, Abdul-Rahman and Asmi, 2012: 2-3).

This type of waste consists of a complete loss of materials, due to the fact that they are irreparably damaged or simply lost. The wastage is usually removed from the site to landfills (Nagapan, Abdul-Rahman and Asmi, 2012: 2-3).

On the other hand, the non-physical waste normally occurs during the construction process. By contrast with material waste, non-physical waste relates to time and cost overruns for a construction project. Similarly, Ma (2011: 118) defines waste as not only associated with wastage of materials, but also to other activities such as repair, waiting time, and delays.

Besides that, waste can be considered as any inefficiency that results in the use of equipment, materials, labour, and money in the construction process. In other words, waste in construction is not only focused on the quantity of materials on-site, but also overproduction, waiting time, material handling, inventories, and unnecessary movement of workers (Nagapan, Abdul-Rahman and Asmi, 2012: 2-3). Consequently, Memon, Abdul-Rahman and Memon (2014: 417) added that non-physical waste includes undesired activities, which can cause the physical waste, such as rework, unnecessary material movements, and so forth.

Figure 2.4 shows that since construction waste entails both the physical and the non-physical waste, there is a relationship between material waste originating from physical waste and cost overruns from the non-physical waste.

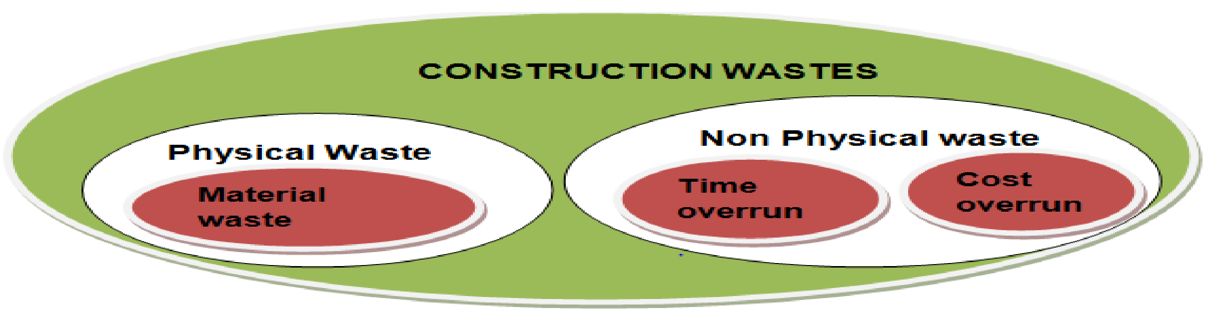


Figure 2.6: Classification of construction waste
Adapted from Nagapan, Abdul-Rahman and Asmi (2012: 2-3).

Furthermore, the causes of material waste and the causes of cost overruns identified from the literature are similar. These causes occur as a result of one, or combination of several causes at different stages of a project (the pre-contract and the post-contract stages), and they are very important to identify for effective cost performance and sustainable construction.

2.7.1 The pre-contract stage of a project

The pre-contract stage of a project comprises a lot of activities from inception to the final stage of award of contract. These activities include:

- Feasibility: This involves meeting the client, receiving the client's brief, contributions from all the consultants, collecting survey information, and initial design ideas and programming the design period.
- Outline proposal: This involves establishing a concept in principle from the design brief requirements;
- Scheme design: This involves developing an agreed idea into a coherent working design;
- Detail design by fully developing the idea, incorporating specialist design work proposition; construction information by providing detailed working drawings and specifications; preparation of bills of quantities with numerical measurement; and tendering arrangements (Dennis, 2010: 1).

These activities, if not properly managed and controlled, contribute to the generation of material waste and cost overruns. Hence, it is appropriate to understand the main causes of material waste that relate to the causes of cost overruns at the pre-contract stage of a project.

Therefore, the causes of material waste and cost overruns in this stage (pre-contract) are identified in four major phases namely: the quality of planning, the quality of design management, design complexity, and the quality of estimating.

2.7.1.1 Quality of planning

This section seeks to relate the results of different studies over the years on the causes of cost overruns and material waste at the planning stages of different types of construction projects.

Chitkara (2011:55) outlined the main controllable causes of cost overruns at the planning stage of a project as:

- Inadequate project formulation: Poor field investigation, inadequate project information, bad cost estimates, lack of experience, inadequate project formulation and feasibility analysis, poor project appraisal leading to incorrect investment decisions.
- Poor planning for implementation: Inadequate time plan, inadequate resource plan, inadequate equipment supply plan, poor organisation, and poor cost planning.
- Lack of proper contract planning and management: Improper pre-contract actions, poor post-award contract management.
- Lack of project management during execution: Insufficient and ineffective working, delays, changes in scope of work and location, law and order.

The causes of material waste that are similar to the causes of cost overruns at the planning stage of a project are presented in Table 2.2.

Table 2.2: The relationship between the cause of material waste and cost overruns (Quality of planning)

Sn	Causes of material waste that are similar to the causes of cost overruns	Material Waste		Cost overruns	
		Author and date	Geographical location	Author and date	Geographical location
1	Improper planning	Babatunde (2012); Nagapan *et al*. (2012)	Nigeria; Batu, Malaysia	Zewdu and Aregaw (2015); Allahaim and Liu (2012);	Ethiopian projects; Saudi Arabia
2	Over estimation to accommodate variations	Nguyen, Gupta and Faniran (nd); Odusanmi, Oladiran and Ibrahim (2012)	Geelong, Australia; Nigeria	Ahiaga-Dagbui and Smith (2014); Zewdu and Aregaw (2015)	UK; Ethiopian projects
3	Lack of legislative enforcement	Nagapan *et al.* (2012)	Malaysia	Allahaim and Liu (2012)	Saudi Arabia
4	Inadequate site investigation	Osmani, Glass and Price (2008); Nagapan *et al.* (2012)	UK; Malaysia	Subramani Shruthi and Kavitha (2014); Chiktara (2011)	India; India; Turkey
5	Inadequate scheduling	Nagapan *et al*.(2012)	Batu, Malaysia	Subramani Shruthi and Kavitha (2014)	India
6	Poor communication flow among members	Okorafor (2014); Nagapan *et al*. (2012)	South Africa; Malaysia	Abdul Rahman, Memon and Abd Karim (2013)	Malaysia
7	Improper co-ordination of the entire project and professionals	Al-Hajj & Hamani(2011); Nagapan *et al*. (2012)	UAE; Malaysian construction	Abdul Rahman *et al.* (2013); Zewdu and Aregaw (2015)	Malaysia; Ethiopian projects

8	Unsatisfactory budget for waste management	Al-Hajj & Hamani (2011)	UAE construction	Jackson (2002)	Reading
9	Insurance problem	Osmani (2011)	UK	Allahaim and Liu (2012);	Saudi Arabia
10	Communication error between client &designer	Okorafor (2014); Nagapan *et al*. (2012)	, South Africa; Malaysia	Abdul Rahman *et al.* (2013)	Malaysia
11	Frequent demand for design change	Osmani, Glass and Price (2008); Nagapan *et al*. (2012)	UK; Malaysia	Abdul Rahman *et al.* (2013); Zewdu and Aregaw (2015)	Malaysia; Ethiopian projects
12	Lack of awareness	Okorafor (2014)	South Africa	Ameh Soyingbe and Odusanmi (2010)	Nigeria

2.7.1.2 Quality of design management

This section relates the results of different studies on the causes of cost overruns and material waste at the design management stage of projects. These causes are presented in Table 2.3.

Table 2.3: The relationship between the cause of material waste and cost overruns (Quality of design management)

Sn	**Causes of material waste and relationship between the causes of cost overruns**	**Material Waste**		**Cost overruns**	
		Author and date	**Geographical location**	**Author and date**	**Geographical location**
1	Frequent design changes and material specification	Osmani, Glass and Price (2008); Nagapan *et al.* (2012); Adewumi and Otali (2013)	UK; Batu, Malaysia; Rivers state, Nigeria	Allahaim and Liu (2012); Abdul Rahman *et al.* (2013); Shamugapriya and Subramani (2013)	Saudi Arabia; Malaysia; India
2	Error in design and detailing	Al-Hajj & Hamani (2011); Babatunde (2012); Wahab and Lawal (2011); Ameh and Itodo (2013); Nagapan *et al*. (2012)	UAE Construction; Nigeria; Nigeria;Nigeria; Malaysia	Ahiaga-Dagbui and Smith (2014); Allahaim and Liu (2012); Love, Edward and Irani (2011)	UK; Saudi Arabia; UK
3	Lack of design information	Nagapan *et al.* (2012); Oladiran (2009); Wahab and Lawal (2011)	Batu, Malaysia; Nigeria; Nigeria	Shanmugapriya and Subramanian (2013); Abdul Rahman *et al.* (2013)	India; Malaysia
4	Design complexity/complication	Nagapan *et al.* (2012); Osmani, Glass and Price (2008); Wahab and Lawal (2011)	Batu, Malaysia; UK; Nigeria	Allahaim and Liu (2012); Baloyi and Bekker (2011)	Saudi Arabia;South Africa
5	Poor communication flow among design team	Al-Hajj & Hamani (2011); Osmani, Glass and Price (2008)	UAE construction; UK	Abdul Rahman, Memon and Abd Karim (2013); Shanmugapriya and Subramanian (2013)	Large construction in Malaysia; India
6	Poor knowledge of the	Nagapan *et al.*	Malaysia	Nega (2008)	Ethiopia

	changing design requirements	(2012)			
7	Poor management of design process	Osmani, Glass and Price (2008)	UK	Abdul Rahman *et al.* (2013)	Malaysia
8	Inexperienced designer or design team	Adewuyi and Otali (2013); Nagapan *et al.* (2012)	Nigeria; Malaysia	Allahaim and Liu (2012); Abdul Rahman *et al.* (2013)	Saudi Arabia; Malaysia
9	Interaction between various specialists	Nagapan *et al.* (2012)	Malaysia	Aziz (2012)	Egypt

2.7.1.3 Design complexity

This section relates the results of different studies over the years on the causes of cost overruns and material waste that might emanate from design complexity of a project. These causes are presented in Table 2.4.

Table 2.4: The relationship between the cause of material waste and cost overruns (Design complexity)

Sn	**Causes of material waste related to the causes of cost overruns**	**Material Waste**		**Cost overruns**	
		Author & date	**Geographical location**	**Author & date**	**Geographical location**
1	Designing uneconomical shapes and outlines	Osmani, Glass and Price (2008); Oladiran (2009); Adewuyi and Otali 2013)	UK; Nigeria; Nigeria	Nega (2008)	Ethiopia
2	Sophisticated systems and components/complexity	Nagapan *et al*. (2012)	Malaysia	Allahaim and Liu (2012)	Saudi Arabia
3	Difficulties in interpreting specification	Osmani, Glass and Price (2008)	UK	Allahaim and Liu (2012)	Saudi Arabia
4	Designing irregular shapes and forms	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Kasimu (2012)	Nigeria
5	Designing non-standard dimensions, allowing cutting and chiseling	Nagapan *et al*.(2012)	Malaysia	Kasimu (2012)	Nigeria
6	Lack of experience	Adewuyi and Otali (2013); Nagapan *et al.* (2012)	Nigeria; Malaysia	Shanmugapriya and Subramanian (2013); Love Edward and Irani (2011);Allahaim and Liu (2012)	India; UK;Saudi Arabia
7	Incomplete drawings	Osmani, Glass and Price (2008)	UK	Kasimu (2012); Lee-Hoai, Lee and Lee (2008)	Nigeria; Vietnam

2.7.1.4 Quality of estimating

This section relates the results of different studies over the years on the causes of cost overruns and material waste at the estimating stage of construction projects. These causes are presented in Table 2.5.

Table 2.5: The relationship between the cause of material waste and cost overruns (Quality of estimating)

Sn	Causes of material waste related to the causes of cost overruns	Material Waste		Cost overruns	
		Author & date	**Geographical location**	**Author & date**	**Geographical location**
1	Wrong (over/under) estimation and allowance	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Ahiaga-Dagbui and Smith (2014); Love Edward and Irani (2011); Baloyi and Bekker (2011); Allahaim and Liu (2012); Subramani Shruthi and Kavitha (2014); Zewdu and Aregaw (2015);	UK; South Africa; saudi Arabia; India; Ethiopian projects
2	Inaccurate quantity take-off	Nagapan *et al.* (2012)	Malaysia	Abdul Rahman, Memon and Abd Karim (2013); Subramani, Sruthi and Kavita (2014); Aziz (2013); Lee-Hoai, Lee and Lee (2008)	Large projects in Malaysia; India; Egypt; Vietnam
3	Insufficient time for estimate	Nagapan *et al.* (2012)	Malaysia	Allahaim ad Liu (2014); Kasimu (2012)	Saudi Arabia; Nigeria
4	Different methods used in estimation	Nagapan *et al*. (2012)	Malaysia	Abdul Rahman, Memon and Abd Karim (2013)	Malaysia
5	Late engagement of estimator	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Abdul Rahman, Memon and Abd Karim (2013)	Malaysia

2.7.2 Post-contract stage of a project

The activities involved in the post contract stage of a project include the following:

Construction on site: supervision, inspection, approvals, and valuations.

Completion: hand over to client and user occupation, correction of defects, completion of contract requirements and settlement of the final accounts. However, this aspect of research focuses on construction related issues.

The causes of material waste and cost overruns in this stage (post-contract) are identified in three major phases namely: the quality-of-procurement management, the quality-of-construction management, and the quality-of-site management.

2.7.2.1 Quality of procurement management

This section relates the results of different studies over the years on the causes of cost overruns and material waste at the procurement management stage of construction projects. These causes are presented in Table 2.

Table 2.6: The relationship between the cause of material waste and cost overruns (Quality of procurement management)

Sn	Causes of material waste related to the causes of cost overruns	Material Waste		Cost overruns	
		Author & date	Geographical location	Author and date	Geographical location
	Procurement and Transportation				
1	Errors/mistakes in material ordering/procurement	Nagapan *et al.* (2013)	Malaysia	Allahaim and Liu (2012)	Saudi Arabia
2	Procuring items not in compliance with specification	Adewuyi and Otali (2013); Osmani, Glass and Price (2008)	Rivers, Nigeria; UK	Allahaim and Liu (2012)	Saudi Arabia
3	Errors in shipping/supply	Osmani, Glass and Price (2008); Nagapan *et al*. (2012)	UK; Malasian construction industry	Nega (2008)	Ethiopia
4	Mistakes in quantity surveys: Poor estimate for procurement (over procuring)	Nagapan *et al.* (2013); Nagapan *et al*.(2012)	Malaysia	Aziz (2012); Allahaim and Liu (2012)	Egypt; Saudi Arabia
5	Wrong material delivery procedures	Nagapan *et al*.(2012)	Malaysia	Aziz (2012)	Egypt
6	Delivery of substandard materials	Nagapan *et al.* (2013)	Malaysia	Nega (2008)	Ethiopia
7	Damage of material during transportation	Osmani, Glass and Price (2008)	UK	Nega (2008)	Ethiopia
8	Late delivery /Inadequate delivery schedule	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Al-Najjar (2008); Abdul Rahman *et al.* (2013); Allahaim and Liu (2012)	Gaza Strip; Malaysia; Saudi Arabia
9	Poor material handling	Osmani, Glass and Price (2008); Nagapan *et al.* (2013)	UK; Malaysia	Ameh Soyingbe and Odusanmi (2010)	Nigeria
10	Poor protection of materials and damage during transportation	Osmani, Glass and Price (2008); Aiyetan and Smallwood (2013)	UK; Lagos, Nigeria	Nega (2008)	Ethiopia
11	Over allowance (difficulties in ordering less)	Osmani, Glass and Price (2008); Nagapan *et al.* (2012)	UK; Batu, Malaysia	Allahaim and Liu (2012)	Saudi Arabia
12	Frequent variation orders	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Aziz (2012); Baloyi and Bekker (2011)	Egypt; South Africa
13	Poor product knowledge	Nagapan *et al*. (2012)	Malaysia	Jackson (2002)	Reading
14	Difficulties of vehicles in accessing site	Osmani, Glass and Price (2008); Nagapan *et al.* (2012)	UK; Batu, Malaysia	Allahaim and Liu (2012); Zewdu and Aregaw (2015);	Saudi Arabia; Ethiopia
	Manufacturers				
15	Poor quality of materials	Adewuyi and Otali (2013)	Nigeria	Ameh Soyingbe and Odusanmi (2010)	Nigeria
16	Non-standard sizes of materials	Osmani (2011)	UK	Lee-Hoai, Lee and Lee (2008)	Vietnam
17	Poor product information	Nagapan *et al*. (2012)	Malaysia	Allahaim and Liu (2012)	Saudi Arabia
18	Lack of awareness	Al-Hajj & Hamani (2011)	UAE construction	Ameh Soyingbe and Odusanmi (2010)	Nigeria
	Suppliers				
20	Poor supply chain management	Al-Hajj & Hamani (2011)	UAE construction	Ameh Soyingbe and Odusanmi (2010)	Nigeria
21	Supplier errors	Odusanmi, Oladiran	Nigeria	Nega (2008)	Ethiopia

		and Ibrahim (2012)			
22	Poor product incentive	Nagapan *et al*. (2012)	Malaysia	Allahaim and Liu (2012)	Saudi Arabia
23	Poor handling of supplied materials	Osmani, Glass and Price (2008); Ameh and Itodo (2013)	UK; Nigeria	Ameh and Itodo (2013)	Nigeria
24	Poor methods of unloading materials supplied in loose form	Adewuyi and Otali (2013)	Nigeria	Nega (2008)	Ethiopia

2.7.2.2 Quality of construction management

This section relates the results of different studies over the years on the causes of cost overruns and material waste at the construction management stage of construction projects. These causes are presented in Table 2.7.

Table 2.2: The relationship between the cause of material waste and cost overruns (Quality of construction management)

Sn	Causes of material waste related to the causes of cost overruns	Material Waste		Cost overruns	
		Author and date	**Geographical location**	**Author and date**	**Geographical location**
	Contractors				
1	Incorrect scheduling and planning	Osmani, Glass and Price (2008)	UK	Abdul Rahman *et al.* (2013); Subramanian Shruthi and Kavita (2014)	Malaysia; India
2	Inappropriate contractor's policies	Nagapan *et al.* (2012)	Malaysia	Aziz (2012)	Egypt
3	Lack of awareness	Al-Hajj & Hamani (2011)	UAE construction	Aziz (2012)	Egypt
4	Lack of experience	Nagapan *et al.* (2012)	Batu, Malaysia	Abdul Rahman *et al.* (2013);Ameh Soyingbe and Odusanmi (2010)	Malaysia; Nigeria
6	Poor site management and supervision	Nagapan *et al.* (2012); Ameh and Itodo (2013)	Malaysia; Nigeria	Lee-Hoai, Lee and Lee (2008); Allahaim and Liu (2012)	Vietnam; Saudi Arabia
7	Poor building techniques	Nagapan *et al.* (2012)	Malaysia	Aziz (2012); Ejaz, Ali and Tahir (2011)	Egypt; Pakistan
8	Incompetent subcontractor/supplier	Nagapan *et al.* (2012)	Malaysia	Ameh Soyingbe and Odusanmi (2010)	Nigeria
9	Poor financial controls on site	Al-Hajj and Hamani (2011: 2)	UAE construction	Shanmugapriya and Subramanian (2013)	India
10	Use of unskilled labour to replace skilled ones	Nagapan *et al.* (2012)	Malaysia;	Memon (2013)	Malaysia

	Culture				
11	Lack of incentive	Al-Hajj and Hamani (2011: 2)	UAE construction	Memon (2013)	Malaysia
12	Lack of training and development	Al-Hajj and Hamani (2011: 2); Adewuyi and Otali (2013)	UAE construction; Nigeria	Olawole and Sun (2008)	UK
13	Lack of support from senior management	Al-Hajj and Hamani (2011: 2)	UAE construction	Aziz (2012); Allahaim and Liu (2012)	Egypt; Saudi Arabia
14	Lack of awareness among practitioners on waste management	Al-Hajj & Hamani (2011)	UAE construction	Ameh Soyingbe and Odusanmi (2010)	Nigeria
	Workers				
15	Workers' mistakes or errors during construction	Al-Hajj & Hamani (2011)	UAE construction	Shanmugapriya and Subramanian (2013)	India
16	Incompetent workers	Nagapan *et al.* (2012)	Batu, Malaysia	Aziz (2012); Olawole and Sun (2008)	Egypt;UK
17	Poor workers' attitude	Nagapan *et al.* (2012)	Malaysia	Aziz (2012)	Egypt
18	Lack of experienced workers	Nagapan *et al.* (2012)	Malaysia	Shanmugapriya and Subramanian (2013); Love Edward and Irani (2011)	India;UK
19	Shortage of skilled workers	Nagapan *et al.* (2012)	Malaysia	Abdul Rahman, Memon and Abd Karim (2013); Shanmugapriya and Subramanian (2013); Olawole and Sun (2008)	Malaysia; India;UK
20	Inappropriate use of materials and equipment	Wahab and Lawal (2011)	Nigeria	Allahaim and Liu (2012)	Saudi Arabia
21	Poor workmanship	Odusanmi, Oladiran and Ibrahim (2012) Aiyetan and Smallwood (2013)	Nigeria; Lagos Nigeria	Nega (2008)	Ethiopia
22	Damage caused by workers	Nagapan *et al.* (2012); Al-Hajj & Hamani (2011)	Malaysia; UAE construction	Allahaim and Liu (2012)	Saudi Arabia

2.7.2.3 Quality of site management

This section relates the results of different studies over the years on the causes of cost overruns and material waste at the site management stage of construction projects. These causes are presented in Table 2.8.

Table 2.8: The relationship between the cause of material waste and cost overruns (Quality of site management)

Sn	Causes of material waste related to the causes of cost overruns	Material Waste		Cost overruns	
		Author and date	**Geographical location**	**Author and date**	**Geographical location**
1	Wrong material/equipment storage/stacking	Nagapan *et al.* (2013)	Malaysia	Ubani Okorocha and Emeribe (2011)	Nigeria
2	Transfer of materials from storage to application	Osmani, Glass and Price (2008)	UK	Ubani Okorocha and Emeribe (2011)	Nigeria
3	Damage of materials by other trades	Aiyetan and Smallwood (2013)	Lagos, Nigeria	Jackson (2002)	Reading
4	Poor site storage area	Osmani, Glass and Price (2008); Odusanmi, Oladiran and Ibrahim (2012)	UK; Nigeria	Jackson (2002)	Reading
5	Long distance from storage to application point	Osmani, Glass and Price (2008);	UK;		
6	Damage by weather	Osmani, Glass and Price (2008); Wahab and Lawal (2011)	UK; Nigeria	Allahaim and Liu (2012); Memon (2013)	Saudi Arabia; Malaysia
	Security				
7	Inadequate site security/Fencing	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Allahaim and Liu (2012)	Saudi Arabia
8	Theft	Osmani, Glass and Price (2008); Ameh and Itodo (2013)	UK; Nigeria	Allahaim and Liu (2012)	Saudi Arabia
9	Vandalism, sabotage pilferage, and material damage	Osmani, Glass and Price (2008); Ameh and Itodo (2013)	UK; Nigeria	Allahaim and Liu (2012)	Saudi Arabia
10	Power and lighting problems on site	Nguyen, Gupta and Faniran (nd)	Geelong, Australia	Allahaim and Liu (2012)	Saudi Arabia
	Site conditions				
11	Poor site management	Odusanmi, Oladiran and Ibrahim (2012)	Nigeria	Abdul Rahman, Memon and Abd Karim (2013); Le-Hoai, Lee and Lee (2008)	Large projects in Malaysia; Vietnam
12	Poor site and unforeseen ground conditions	Wahab and Lawal (2011); Aietan and Smallwood (2013)	Nigeria; Lagos, Nigeria	Aziz (2013); Ameh Soyingbe and Odusanmi (2010); Allahaim and Liu (2012)	Egypt; Nigeria; Saudi Arabia
13	Leftover materials on site	Osmani (2011)	UK	Ubani Okorocha and Emeribe (2011)	Nigeria
14	Waste resulting from packaging	Osmani (2011)	UK	Allahaim and Liu (2012)	Saudi Arabia
15	Lack of environmental awareness	Nagapan *et al.* (2012)	Malaysia	Ubani Okorocha and Emeribe (2011)	Nigeria
16	Difficulties in accessing construction site	Nagapan *et al.* (2012)	Batu, Malaysia	Allahaim and Liu (2012)	Saudi Arabia

17	Site congestion and Interference of other crews	Osmani (2011)	UK	Le-Hoai, Lee and Lee (2008)	Vietnam
18	Inadequate site investigation	Osmani, Glass and Price (2008)	UK	Subramanian Shruthi and Kavita (2014); Allahaim and Liu (2012)	India; Saudi Arabia
19	Disputes on site	Adewuyi and Otali (2013)	Nigeria	Ameh Soyingbe and Odusanmi (2010); Allahaim and Liu (2012); Olawole and Sun (2008)	Nigera; Saudi Arabia;UK
20	Extra materials ordered are discarded instead of carrying over to next site	Oladiran (2009)	Nigeria	Allahaim and Liu (2012)	Saudi Arabia
21	Equipment failure on site	Adewumi and Otali (2013)	Nigeria	Shanmugapriya and Subramanian (2013)	India
22	Rework	Al-Hajj and Hamani (2011); Adewuyi and Otali (2013); Oladiran (2009); Ameh and Itodo (2013)	UAE construction; Rivers, Nigeria; Nigeria; Nigreia	Subramani, Sruthi and Kavita (2014); Shanmugapriya and Subramanian (2013); Le-Hoai, Lee and Lee (2008)	India; India; Vietnam
23	Site accidents	Odusanmi, Oladiran and Ibrahim (2012	Nigeria	Allahaim and Liu (2012); Le-Hoai, Lee and Lee (2008)	Saudi Arabia; Vietnam
24	Lack of communication	Wahab and Lawal (2011)	Nigeria	Abdul Rahman *et al.* (2013); Memon (2013)	Malaysia

Furthermore, all the causes of **material waste** were also found to be identified as the causes of **cost overrun** at all the stages of a project but not *vice versa.*

For instance, Table 2.9 shows the relationship between the causes of cost overruns and those of material waste. 31 out of the 32 causes of **cost overruns** considered at the pre-contract stage of a project also cause material waste showing a 96.88 percent relationship (pre-contract stage).

Table 2.9 causes of material waste found in the causes of cost overruns at the pre-contract stage of a project

S/N	Causes of Cost overrun	Cost overrun	Material waste
1	Design error	✓	✓
2	Deficiencies in cost estimates	✓	✓
3	Insufficient time for estimate	✓	✓
4	Improper planning at on stage	✓	✓
5	Political complexities	✓	✓
6	Insurance problems	✓	✓
7	Changes in material specification	✓	✓
8	Laws and regulatory framework	✓	✓
9	Poor design management	✓	✓
10	Practice of assigning contract to the lowest bidder	✓	x
11	Lack of experience of local regulations	✓	✓
12	Communication error among parties in planning	✓	✓
13	Poor knowledge of the changing requirements	✓	✓
14	Lack of design information	✓	✓
15	Designing irregular shapes and forms	✓	✓
16	Different methods used in estimation	✓	✓
17	Improper coordination	✓	✓
18	Delays in design	✓	✓
19	Optimism bias	✓	✓
20	Complicated design	✓	✓
21	Inadequate specifications	✓	✓
22	Incomplete drawings	✓	✓
23	Inexperience designer	✓	✓
24	Error in design and detailing	✓	✓
25	Inadequate site investigation	✓	✓
26	Difficulties in interpreting specification	✓	✓
27	Delay in preparation and approval of drawings	✓	✓
28	Designing uneconomical shapes and outlines	✓	✓
29	Frequent demand for design changes	✓	✓
30	Poor communication flow among design team members	✓	✓
31	Unsatisfactory budget for waste management	✓	✓
32	Lack of communication among parties at pre contract stage	✓	✓
	Summary=31/32X100=96.88%		

(**Source:** Flyvbjerg, Holm and Buhl, 2004; Koushki, Al-Rashid and Kartam, 2005; Le-Hoai, lee and lee, 2008; Osmani, Glass and Price, 2008; Oladiran, 2009; Singh 2009; Olawole and Sun, 2010; Ejaz, Ali and Tahir 2011; Memon, Abdul-Rahman and Abdul Aziz, 2011; Wahab and Lawal; 2011; Love, Edward and Irani, 2011; Kasimu, 2012; Malumfashi and Shuaibu, 2012; Nagapan *et al.,* 2012; Allahaim and Liu, 2013; Ameh and Itodo, 2013; Aietan and Smallwood, 2013; Osmani, 2011).

Figure 2.7 shows that at the pre-contract stage of a project, the causes of cost overruns also cause material waste. This means that all causes of material waste also cause anticipated cost overrun at the pre-contract stage of a project. But only 96.88 percent of the causes of cost overrun cause material waste. The remaining 3.12 percent are not related. This implies that, managing material waste at this stage denotes managing a 96.88 percent of cost overruns.

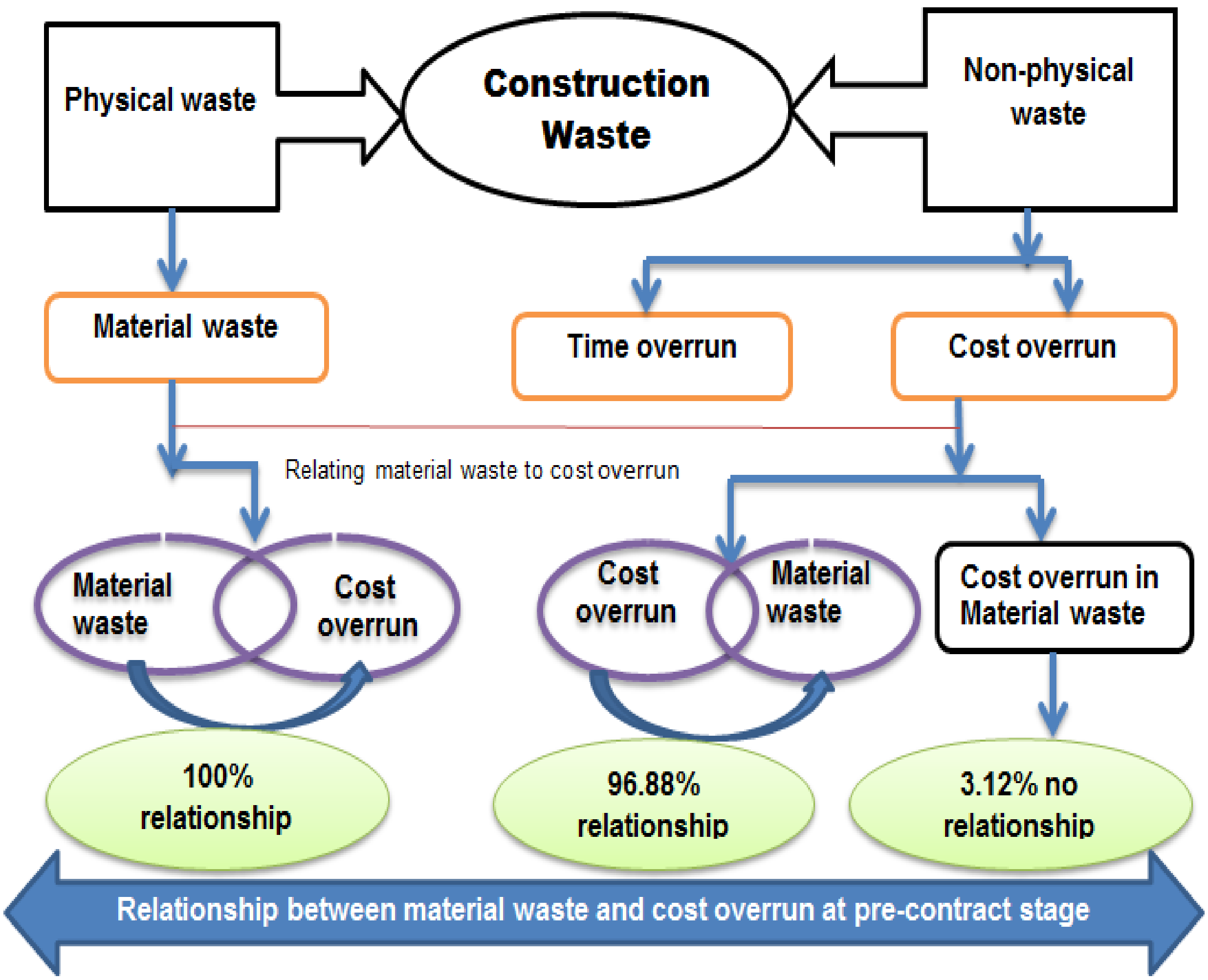


Figure 2.7: Relationship between cost overruns and material waste at pre-contract stage

Source: Researcher's construct, 2015.

Table 2.2 shows the relationship between the causes of cost overruns and material waste at the post-contract stage of a project.

Out of the 66 causes of cost overruns considered, 54 causes also cause material waste showing an 81.81 percent relationship at the post-contract stage of a project.

Table 2.10: Causes of material waste found in causes of cost overrun at post-contract stage

sn	Causes of Cost overrun (post-contract stage of project)	Cost overrun	Material waste	sn	Causes of Cost overrun (post-contract stage of project)	Cost overrun	Material waste
1	Monthly payment difficulties	✓	x	**34**	Unforeseen geological conditions	✓	✓
2	Poor planning by contractors	✓	✓	**35**	Financial difficulties of contractor	✓	✓
3	Heritage material discovery	✓	✓	**36**	Social and cultural impact	✓	✓
4	Market conditions	✓	x	**37**	Inaccurate site investigation	✓	✓
5	Cash flow and financial difficulties faced by contractors	✓	x	**38**	Inadequate use of modern equipment & technology	✓	✓
6	Slow information flow between the parties	✓	✓	**39**	Obtaining materials at official current prices	✓	x
7	Escalation of material prices	✓	x	**40**	Labour problems	✓	✓
8	Increase in wages	✓	x	**41**	Increase in material prices	✓	x
9	Poor management assistance	✓	✓	**42**	Owner interference	✓	✓
10	Exchange rate fluctuation	✓	x	**43**	Slow payment of works	✓	x
11	Deficiencies in the social structure	✓	✓	**44**	High interest rate charged by banks on loans	✓	x
12	Additional works	✓	x	**45**	Fraudulent practices	✓	✓
13	Optimism bias	✓	✓	**46**	Labour disputes and strike	✓	✓
14	Labour cost increases due to environment restriction	✓	**x**	**47**	Improper coordination amongst parties at post contract stage	✓	✓
15	Insufficient equipment	✓	✓	**48**	Poor technical performance	✓	✓
16	Deficiencies in the infrastructure	✓	✓	**49**	Equipment availability/failure	✓	✓
17	Lack of communication among parties	✓	✓	**50**	Number of works being done at same time	✓	✓
18	Change in the scope of work	✓	✓	**51**	Poor financial control on site	✓	✓
19	Delay of payment to supplier/subcontractors	✓	✓	**52**	Poor site management and supervision	✓	✓
20	Shortage of materials	✓	✓	**53**	Site constraints	✓	✓
21	On-site waste	✓	✓	**54**	Lack of skilled labour	✓	✓
22	Project size	✓	✓	**55**	Mistakes during construction	✓	✓
23	Lack of constructability	✓	✓	**56**	Delay in decision making	✓	✓
24	Unrealistic contract duration	✓	✓	**57**	Shortage of site workers	✓	✓
25	Delay in material procurement	✓	✓	**58**	Disputes on site	✓	✓
26	Poor site management and supervision	✓	✓	**59**	Late materials/ equipment delivery	✓	✓
27	Inexperienced contractor	✓	✓	**60**	Unpredictable weather condition	✓	✓
28	Shortage of site workers	✓	✓	**61**	Mistakes during construction	✓	✓
29	Work security problems	✓	✓	**62**	Unforeseen site conditions	✓	✓
30	Re-work	✓	✓	**63**	Geo-technical conditions	✓	✓
31	Experience in contracts	✓	✓	**64**	Management-labour relationship	✓	✓
32	Workers health problems	✓	✓	**65**	Inexperience with project location	✓	✓
33	Unexpected subsoil conditions	✓	✓	**66**	Lack of experience of project type	✓	✓
	Summary=54/66X100=81.81%	✓	✓			✓	✓

(Source: Flyvbjerg, Holm and Buhl, 2004; Koushki, Al-Rashid and Kartam, 2005; Le-Hoai, lee and lee, 2008; Osmani, Glass and Price, 2008; Oladiran, 2009; Singh 2009; Olawole and Sun, 2010; Ejaz, Ali and Tahir 2011; Memon, Abdul-Rahman and Abdul Aziz, 2011; Wahab and Lawal; 2011; Love, Edward and Irani, 2011; Kasimu, 2012; Malumfashi and Shuaibu, 2012; Nagapan *et al.,* 2012; Allahaim and Liu, 2013; Ameh and Itodo, 2013; Aietan and Smallwood, 2013; Osmani, 2011).

Figure 2.8 shows that, at the post-contract stage of a project, there was also a 100 percent relationship between the causes of material waste and those of cost overruns. This means that, all material waste causes are also responsible for cost overruns. But on the other hand, when causes of cost overruns are considered, there is an 81.81 percent relationship with causes of material waste. The remaining 18.19 percent were not related. This implies that managing material waste at this stage denotes managing 81.81 percent of cost overruns

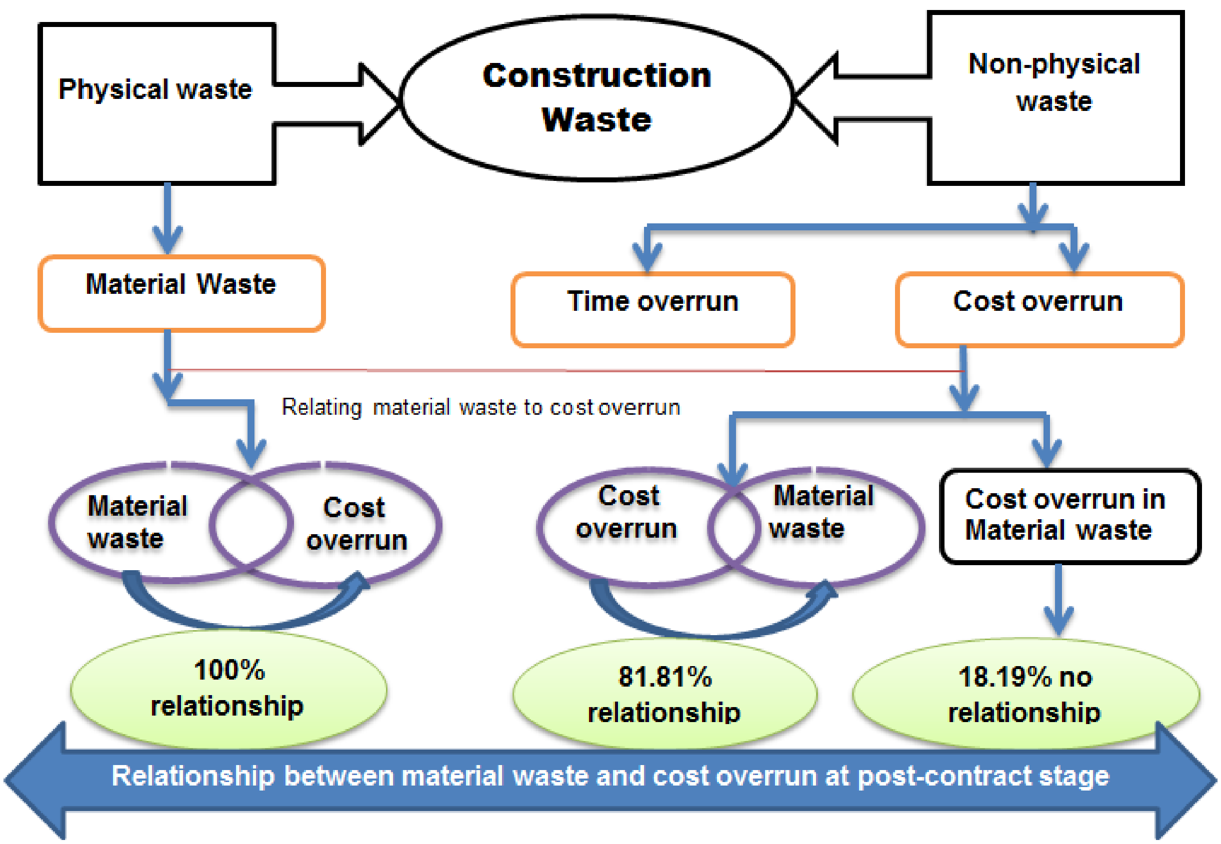


Figure 2.8: Relationship between cost overrun and material waste at the post-contract stage of projects

Source: Researcher's construct, 2015.

Summing all the causes at both the pre-contract and the post-contract stages, 32+66 =98, a total of 85 out of 98 causes of cost overruns also cause material waste showing 85/98X100=**86.74** percent relationship. These findings are also graphically represented in the Figure 2.9.

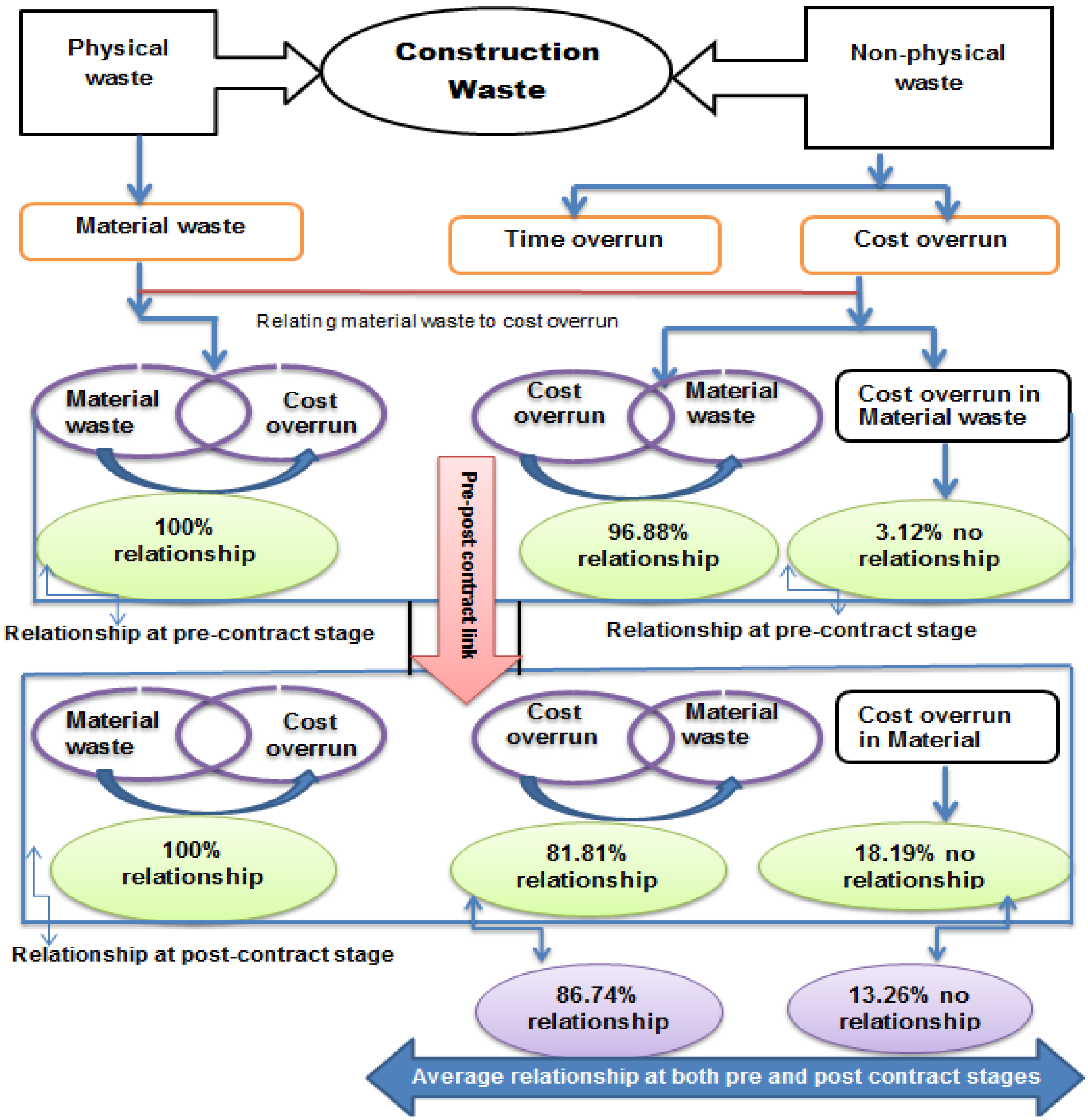


Figure 2.9: Relationship between material waste and cost overrun at all stages of a project

Source: Researcher's construct, 2015.

Furthermore, Figures 2.10 and 2.11 show the interrelationship between waste management (control measure), project stages, waste sources, waste causes and the identified percentage of cost overrun (86.74 percent) as stated in objective 2 of this study.

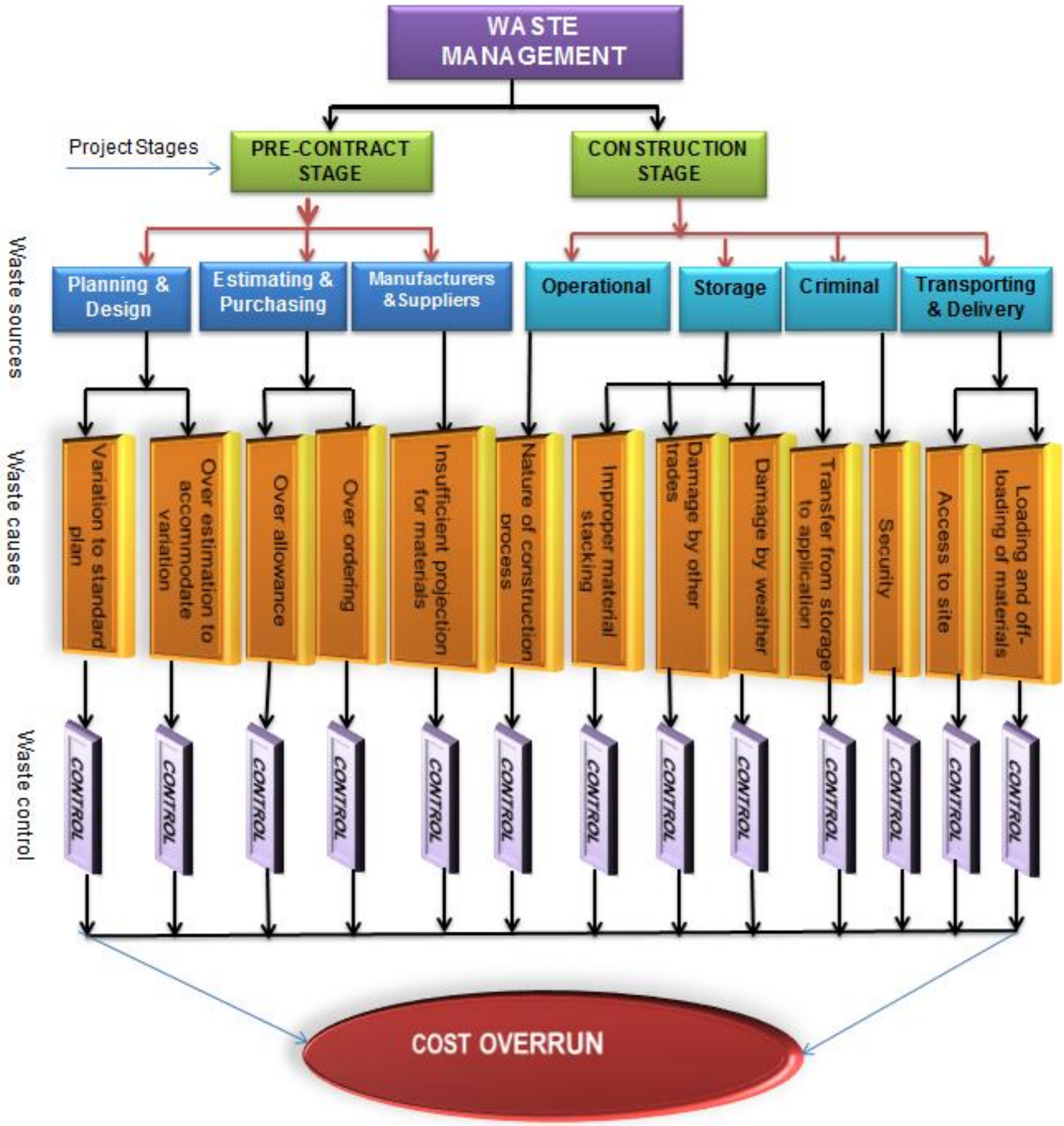


Figure 2.10: Summary of the relationship in Figure 2.9

Source: Researcher's construct, 2015.

This interrelationship is further represented in Figure 2.11.

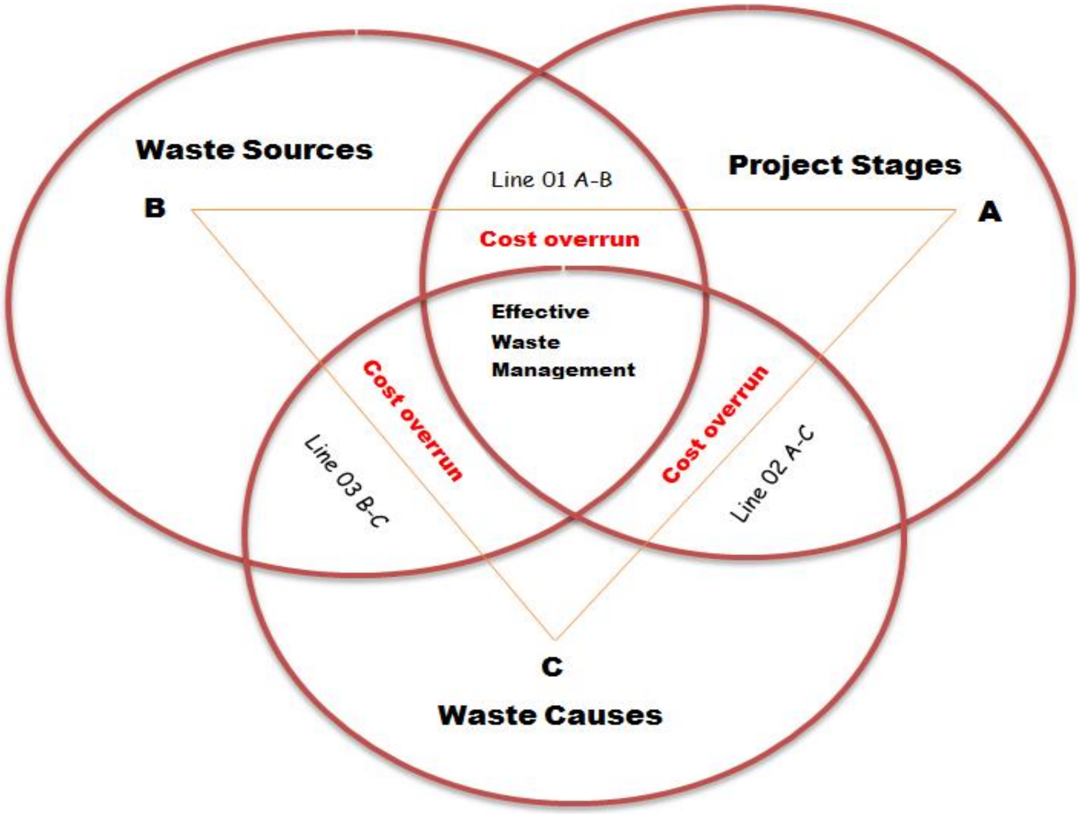


Figure 2.11: Relationship between project stages, waste sources, waste causes, management and cost overrun.

Source: Researcher's construct, 2015.

This relationship is further represented mathematically showing how cost-overrun is minimised with an Effective Waste Management (EWM) from each scenario. The 86.74 percent is the identified relationship between material waste and cost overrun.

Line 01, A-B:

$Project\ stage\ +\ waste\ sources - EWM = 86.74\%\ Cost\ overrun \ldots\ldots\ldots\ldots .01a$

Making "EWM" the subject, by having a positive EWM, the equation would therefore, minimise cost overrun by 86.74%. This means that an effective management (EWM) of waste sources at the project stages would effectively minimise project cost overrun by 86.74 percent.

$EWM = Project\ stage\ +\ waste\ sources - 86.74\%\ Cost\ overrun. \ldots\ldots\ldots ...01b.$

Line 02, A-C:

$Project\ stage\ +\ waste\ Causes - EWM =\ 86.74\%\ Cost\ overrun \ldots..02a$

$Project\ stage\ +\ waste\ Causes - 86.74\%\ Cost\ overrun =\ EWM \ldots..02b$

This means that an effective management (EWM) of waste causes at project stages would effectively minimise project cost overrun by 86.74 percent.

Line 03, B-C:

$Waste\ causes\ +\ Waste\ Sources\ - EWM =\ 86.74\ \%\ Cost\ overrun.\ldots..03a$

Collecting the like terms by making “EWM” the subject, the equation will be:

$Waste\ causes\ +\ Waste\ Sources - 86.74\%\ Cost\ overrun\ =\ EWM \ldots.03b.$

Therefore, an “EWM” would minimise the occurrence of “cost overrun” by 86.74%. However, Poor “EWM” would lead to occurrence of “cost overrun” as shown in the following equation:

$-EWM\ =\ Project\ stage\ +\ waste\ sources + 86.74\%\ Cost\ overrun.$

Scenario 1 (Line 01, A-B), shows that **waste sources** within the **project stage.** From Figure 2.9, it can be seen that waste sources and project stages cause an 86.74 percent cost overrun. Therefore, to effectively control the project waste, there must be an Effective Waste Management (EWM) at the ***project stages*** and at the ***waste sources,*** which will in turn, minimise ***cost overrun*** *to* ***13.26 percent.*** The same applies to the remaining two scenarios.

2.7 Concluding Remarks

Chapter 2 has presented a literature review on the general and contextual issues of the research. The chapter has also highlighted the relationship between construction material waste and cost overrun at stages of a project. In the next chapter, the theoretical framework and conceptual framework for effective management of construction material waste and cost overrun will be discussed.

Chapter 3: The Research Theoretical and Conceptual Frameworks

3.1 Introduction

This chapter discusses the central issues that relate to the conduct of this research. It presents the components of the research and the general framework for data collection and analysis. A theoretical framework has the ability to reveal the meaning and understanding of a phenomenon; guides the research by allowing for prediction and increased understanding of the boundary criteria for the discipline (Okolie, 2011: 75; Anfara, 2008: 872). It refers to the structure which holds/supports the research theory and assists in the development of a conceptual model of how one makes logical sense of the relationship among variables that have been identified as important to the problem under investigation (Anfara, 2008: 872; Okolie, 2011: 75). In this regard, the theoretical framework presents the theory that explains why the problems highlighted in section 1 of this research exists. This frame leads to the development of the research conceptual framework for the study.

The theoretical framework of the research is described in section 3.4 and the conceptual framework is presented in section 3.5.

3.2 Construction Material Waste Control and Management

The history of waste management emanates from health and hygiene reasons by alleviating the impact on humans and the environment in general. However, waste management has been recently escalated from a disposal problem to an integrated issue (Shen, Tam, Tam and Hao, 2004: 476; Mou, 2008: 21). It requires a change in the state of mind from all participants to include waste reduction, minimisation and recovery throughout the stages of a project (Mou, 2008: 21). This awareness has led to the elevation of waste management as a significant aspect of construction management (Shen *et al.,* 2004: 475; Dania, Kehinde and Bala 2007: 123).

The Construction Waste Management Guideline (CWMG), (2014: 3) highlights that the key objectives of any construction waste-management strategy: to reduce the quantity of waste generated as part of the project plan; to maximise the volume of materials, which are sent for re-use, recycling or salvaging; and to reduce the amount of material sent to landfills.

In the light of these objectives, the Green Building Rating System Guides (GBRSG, 2011: 1) suggest that construction-waste management should be incorporated in design, by establishing a plan for waste management at an early design stage, so as to achieve the project objectives from the onset. Osmani (2012: 40) added that, for waste minimisation to be effective and self-sustaining, it is necessary for all the stakeholders of the construction project to adopt a more proactive measure by designing out waste at the onset.

Osmani, Glass and Price (2008: 1154), therefore, view the strategies for material waste minimisation during the design stage of a project as: designing for deconstruction; the use of standard dimensions and units; the use of prefabricated components; the specifying of recycled materials; the use of standard materials with economical shapes to avoid cutting; the prevention of late changes in design; and guidance for hazardous waste management.

Furthermore, Langdon (2010: 16) reported that WRAP identified five (5) basic design principles that can be adopted to reduce the waste burden on projects through design, namely: design for re-use and recovery; design for offsite construction; design for material optimisation; design for waste-efficient procurement; and design for deconstruction and flexibility. These principles have been applied by WRAP; and they have provided a practical method of achieving waste reduction through the design process.

1. Design for off-site construction

The benefits of offsite-factory production include the potential to significantly reduce waste, particularly when factory-manufactured elements and components are used extensively. Its application also has the potential to significantly change operations on-site, for reducing the amount of trades and site activities, and for changing the construction process into one of a rapid assembly of parts that can provide many environmental, commercial and social benefits, including:

- Reduced construction-related transport movements;
- Improved health and safety on-site, through the avoidance of accidents;
- Improved workmanship quality and reduction of on-site errors and re-work, which can cause considerable on-site waste, delay and disruption; and
- To reduce construction timescales and improve programmes (Langdon, 2010: 20).

2. *Design for material optimisation*

This entails the principles of 'good practices' initiatives in the design process, which means adopting a design approach that focuses on material-resource efficiency, so that less material is used in the design (for instance, lean design), and less waste is generated in the construction process, without compromising the design concept and quality. This includes the following:

- The minimisation of excavation;
- The simplification and standardisation of materials and component choices; and
- Dimensional co-ordination (Langdon, 2010: 23).

3. *Design for waste-efficient procurement*

Designers have considerable influence on the construction process, both through specifications, as well as in setting contractual targets, prior to the formal appointment of a contractor. It is, therefore, the responsibility of designers to consider how work sequences affect the generation of construction waste, and to work with the contractor and other specialist subcontractors to understand the possible ways of minimising these sources of waste. Once the work sequences that cause site waste are identified and understood, they can often be 'designed out' (Langdon, 2010: 24).

4. *Design for deconstruction and flexibility*

It is also the responsibility of a designer to consider how materials can be recovered effectively during the life of the building, when maintenance and refurbishment are undertaken, or when the building comes to the end of its life. Therefore, adequate information is needed, so that future designers can have a better understanding of the material/component attributes, in order to facilitate their future re-use, and making this available in an accessible place, where it can be easily referenced in future (Langdon, 2010: 27).

5. Design for re-use and recovery

Research evidence has shown that material re-use has significant potential to reduce the key environmental burdens (for instance, embodied energy, waste, and so on) resulting from construction. So, with re-use, the effective life of the materials is extended; and thus, annual burdens are spread over a number of years. Thus re-use is generally considered to be preferable to recycling in the hierarchy of waste management, where additional processes are involved, some of which would have their own environmental burdens (Langdon, 2010: 18).

Furthermore, the important elements to be considered before coming up with any construction waste management plan are: identification of probable project waste streams; focusing on waste avoidance; selecting an expert contractor in waste management; knowledge of on-site waste management system; assigning and communicating responsibilities; engaging and educating personnel; planning, implementation by proper site monitoring; and evaluation of estimates in the plan against the actual data for waste generated (CWMG, 2014: 4).

On the other hand, material waste minimisation during construction requires an improved logistics management, supply chain management, modern construction methods, training and incentives (WRAP, 2007: 77; Al-Hajj and Hamani, 2011: 221).

In a similar vein, Chikezirim and Mwanaumo (2013: 506) identified some issues involved in developing strategies for waste management by construction firms on site: the firm must have a waste management goal, including employment of good materials abstracting and investigating site waste to be generated by material before procuring; site meetings on material waste management; issuing procedures for management of hazardous waste; preparing a list of salvageable waste material, setting a target for material waste reduction; on site re-use of waste material; an easy access road provided for delivery; appropriate material storage and on-site and off-site re-use of waste material.

To achieve effective control of material waste on site, the following measures must be put in place: proper material inspections on delivery to the site; proper records and documentation of materials’ in and outflows; better transportation of materials; daily record-taking; the usage of materials’ request booklets; and regular site meetings on materials issues (Al-Hajj and Hamani, 2011: 1; Oladiran, 2009: 6). The Light House Sustainable Building Centre for Natural Wood (LHSBCN) (2011: 2) suggests the inclusion of adequate weather protection for exposed wood features.

In the light of the above management strategies, Yuan (2013: 479) highlights the economic benefits of construction-waste management as selling the precise waste materials which could be re-usable, and the subsequent removal from site of other waste at no charge. This leads to reduction in the amount of waste entering the landfills at a higher fee. Moreover, Winkler (2010: 2) suggests that the benefits could also be achieved, in accordance with the waste-management hierarchy, which has been broadly accepted as a guide for construction managers, in accordance with the ideologies of sustainable construction. It recommends that where waste could not be further reduced, then it could be re-used for the same or different purposes; and if all of these options are inappropriate, then waste should be disposed of by using the best method (Dania, Kehinde and Bala, 2007: 124; Al-Hajj and Hamani, 2011: 1). Nonetheless, the Environment and Growth Economics (EGE), (2011: 7) contends that economic issues are not considered in the hierarchy; and as such, they cannot be considered as a comprehensive guide to any waste plan. It is, therefore, essential to consider the economics of the hierarchy.

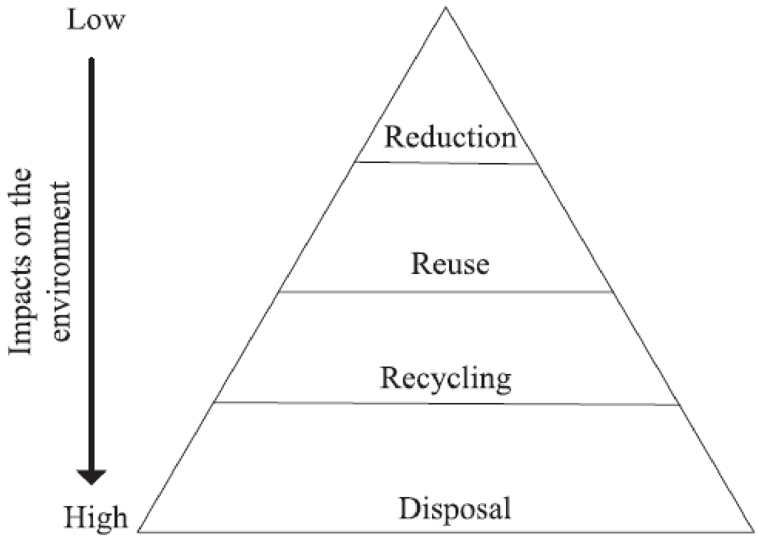


Figure 3.1 Hierarchy of waste

Adapted from Winkler (2010: 2)

Consequently, factors, such as financial rewards, a waste-management policy in place, and a training and education programme are the major incentives for waste minimisation (Osmani, Glass and Price, 2006: 22; Osmani, Glass and Price 2008: 1155; Al-Hajj and Hamani, 2011: 221; Osmani, 2012: 37).

In spite of the above discussed issues, some construction organisations are facing difficulties in implementing waste-management plans, due to: low financial motivation, the rise in overhead costs, a complex subcontracting scheme, waste-minimisation measures are not promoted, inappropriate waste-management systems, the low cost of disposal, inadequate training and education, and a reasonable market (Tam, 2008: 1076).

In the opinion of Zhong (2010: 162), cost saving, less demand for landfill spaces, improved management of resources, the maximisation of profit, quality improvement, image improvement, and increases in productivity are the resultant benefits of material waste management on construction sites.

In the view of Adams, Johnson, Thornback and Law (2011: 18), the key challenges in ensuring construction industry meets the 2012 halving waste to landfill target are:

- Improper information on the amount of waste generated;
- Lack of awareness of the benefits of resource efficiency;
- Poor communication and teamwork between supply chain members;
- Lack of encouragement by the procurement system on waste minimisation;
- Opportunities to identify waste reduction at the design stage were not encouraged;
- Legislative barriers preventing the easy re-use of soils and stones;
- Inadequate consideration by material manufacturers on resource efficiency;
- Poor delivery ,storage, and handling of materials;
- Lack of adequate markets for certain recovered waste materials; and
- Lack of satisfactory infrastructure for material waste management.

According to Kofoworola and Gheewala (2009: 732), the problem of construction waste management in Thailand is related to that of Hong Kong in a number of aspects, namely:

1. Unsatisfactory budget for material waste management;
2. Lack of better and/or an active plan for creating a common disposal facility among adjacent communities;
3. Lack of positive guidelines for managing the construction-waste hierarchy from source, as well as the separation, collection, conveyance, monitoring and disposal of waste;
4. Inadequate skilled personnel for treating waste and efficient waste collection, and disposal;
5. The lack of any training on waste recycling in most communities;
6. Existing legislation does not simplify an efficient waste-management system in an effective direction;
7. Poor public co-operation and contribution; and
8. The lack of any government's legal enforcement, amongst others (Kofoworola and Gheewala, 2009: 732).

Dania, Kehinde and Bala (2007: 124) believe that a waste hierarchy has been broadly accepted as a guide for construction managers, in accordance with the ideologies of sustainable construction. The Waste hierarchy, therefore, recommends the following:

1. The most sustainable solution to the environment might regularly be to minimise the amount of waste generated.
2. Where construction material waste could not be further reduced, then they could be re-used for the same or different purposes.
3. If all of these options are inappropriate, then waste could be disposed by using the best method available.

In conclusion, Tam (2008: 1075) has highlighted some benefits that could be derived if the waste-management plan is properly implemented:

Tam (2008) proposes methods for waste reduction; suggests an on-site method for the re-use of materials; recommends procedures for waste segregation; proposes disposal methods for different categories of waste; recommends methods of dealing with packing materials; formulates an organisational structure for waste management; proposes estimating methods for on-site waste disposal; monitors and audits a waste-management programme; proposes ways for waste processing; suggests ways of storing and for disposal of hazardous waste; estimates the amount of recognised waste; suggests spaces for waste storage; and suggests the number of materials that could be re-used or recycled.

In spite of the above discussed benefits, some construction organisations are facing difficulties in implementing the plan due to: low financial motivation; the rise in overhead costs; a complex subcontracting scheme; waste minimisation measures are not being promoted; the culture and behaviour of construction workers; inappropriate waste management systems; the low cost of disposal; inadequate training and education, and a reasonable market (Tam, 2008: 1076).

3.2.1 Critical success factors (CSFs) for construction-waste management

This approach has been used as a management measure since the 1970s; and it is currently a common research approach across different professions, including construction management. It may be referred to as those few, but important, components a manager should highlight in realising his goals for either present or future challenges. The variables could be used in the company's planning process, which helps in improving communication among the construction team to make planning of information easier (Adnan, Yusuwan, Yusof and Bachik, 2014: 108).

Wang, Yuan and Lu (2010: 933) define critical success factors as those few key issues that must be properly focused on to ensure success for an organisation. At the level of operation, CSFs are the main issues defining the success of an organisation in accomplishing its goals. Adnan *et al.* (2014: 108) view CSFs as important factors from which effective plans and positive outcomes could be derived.

Consequently, Lu and Yuan (2010: 201) suggest that the identification of CSFs eases the complexity of construction waste-management into manageable options. The procedures for identifying CSFs, according to Lu and Yuan (2010: 201), are summarised as: (1) Identifying the set of certain success factors; (2) Studying each of the factors and its related significance to the objectives; (3) Calculating their importance index value; (4) Extract CSFs from the number of factors following the results of the importance index; and (5) Interpreting and analysing the extracted CSFs.

Based on these procedures, Lu and Yuan (2010: 201) identified the following critical success factors for construction-waste management in Shenzhen as: The availability of waste management regulations; awareness among the construction practitioners; a reduction in the rate of design change; research and development in the discipline of waste management; vocational training and education; a programme on housing industrialisation; improved methods of usage and storage of materials; improving conventional construction systems; a proper on-site waste-supervision system; the re-use and recycling of waste; improving and providing a strong communication amongst the participants; waste management throughout the entire lifecycle of a project; on-site material waste sorting; and considering waste management in bidding and tendering processes.

Moreover, Wang, Li and Tam (2014: 1) conducted a study in Shenzhen, China; and they recommended the following success factors for waste management at the design stage: (1) The incorporation of large-panel metal formworks; (2) the use of prefabricated components; (3) less design changes; (4) the utilisation of modular designs; (5) proper investment in waste reduction; and (6) an economic incentive and motivation.

On-site sorting of material waste, as one of the CSFs for managing material waste, according to Wang Yuan and Lu (2010: 935) is further classified it into three (3) groups, namely:

- **The cost consideration of waste sorting:** the availability of manpower, the availability of a market for recycled materials, and equipment for the sorting of construction waste;
- **The feasibility of on-site sorting of waste:** waste-sort ability and site space; and
- **Proper management:** this relates to the managerial issues within the construction-waste sorting process.

3.3 Mitigation Measures for Project Cost Overruns

Project cost overrun is minimised and mitigated when maximum attention is given to well-developed technical skills in modern projects (Doloi, 2013: 267). Therefore, Olawole and Sun (2010: 513) noted that a critical investigation of cost overrun mitigation measures would result in their categorisation according to the broad function they perform. Thus, Olawole and Sun (2010: 513) identified the top five (5) leading causes of cost overrun for a project; and recommend a total of ninety (90) mitigation measures, which were further categorised into four (4) major classes, namely: preventive, predictive, corrective, and organisational. However, some of these measures (categories) are fluid and can sometimes look as though they could be classified into more than one category depending on their actual usage during the project. They include: corrective-preventive and corrective-predictive measures.

Preventive measures**:** These are defensive and precautionary measures that are put in place during the planning stage of a project, in order to prevent the cost overruns from occurring. For instance, a preventive measure against the problem of design changes of projects is needed to ensure that the project is designed to a great detail at the onset; while a preventive measure for risk and uncertainty is to appropriately identify the risks before the commencement of the project, and to devise a strategy for managing the detrimental effects.

Predictive measures**:** They are put in place, in order to spot future problems, so that they can be stopped from happening, or be prepared for them should they happen. Most of these measures actually utilise some tools or techniques to look into the current situation in a bid to spot potential future problems.

Corrective measures**:** They are used to mitigate the effect of the project cost overruns by acting as a remedy. They are also known as reactive measures that only act after the event. They may not be as effective as preventive or predictive measures but they aim to bring the situation back on track, or at least to ‘stop the rot’. These measures have also been further classified as; corrective-preventive measures, which are meant to correct, and in the process prevent future problems; and corrective-predictive measures, which could remedy the current situation; but then go on to predict what the situation is going to be in the future using the currently available information.

Organisational measures**:** These measures generally encompass practices that go wider than the actual control process; but they have an effect on project control; they are normally in place because of the company’s belief, orientation, management style or philosophy; and they have the tendency of not being specific to one project; but they would normally affect all the projects being undertaken by the company; as they reflect how the wider organisation works (Olawole and Sun, 2010: 513).

The interrelationship between the mitigation measures is presented in Figure 3.2.

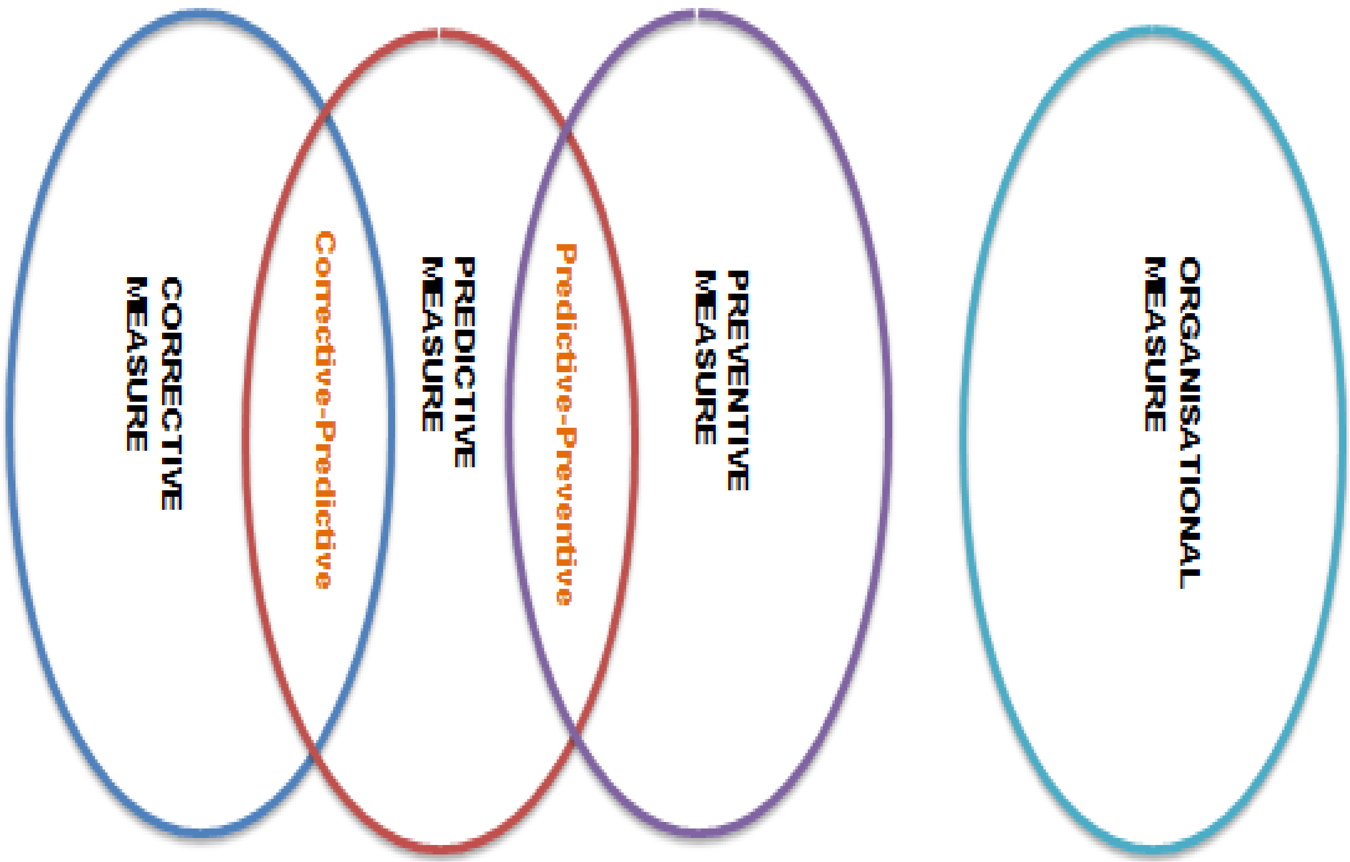


Figure 3.2: Measures for mitigating cost overruns on construction projects

Source: Researcher's construct, 2015

Olawole and Sun (2010: 513) identified five major causes of cost and time overrun and further devised mitigation measures for these causes. The causes are further classified into five major categories as shown in Table 3.1.

Table 3.1 Mitigation measures for project cost overruns

Type of measure	Design change	Risks and uncertainties	Inaccurate evaluation of project duration	Complexity of work	Non-performance of contractor
Preventive	Freezing of design at various project stages; the explicit detailing of design; ensure no one changes design without due authorization; and prompt resolution of design queries	Having a risks register in place; ensuring the register is open to relevant members of the project team; and proper identification, allocation and management of risks	Prepare project programme with input from construction site management; developing the programme from experience; advising client in case of unrealistic time scale; and sufficient time allowance during tendering process	Breaking the project into manageable size; proper understanding of project at onset; experienced personnel on complexity; sufficient time and design for complex work; co-ordination of design; and seeking advice from specialist	Directing sub-contractors to their responsibilities; Incorporating a progress-performance-payment rule in the subcontract; ensure subcontractors are guided by internal project planning; select a subcontractor based on performance track; sufficient time allocation to subcontractors
Predictive	Identification of potential design change and devising a means of managing it.	A workshop on risks involving the relevant parties; regular update of risks register; running a risks analysis; and assigning cost implication to each identified risk	Conducting a process mapping exercise to validate the time allocated to a project	Conducting a workshop on complexity related issues; acquiring information on the complex aspect of project; monitoring progress; and ensuring that every element of design is not compromised.	Using performance measurement to measure the output of a subcontractor; have a system for early identification of nonperformance in subcontract work; and understand and compare the strategy intended by a subcontractor to see it fits with the project cost
Corrective	Determination of the provision of the design change within the building contract; and proper resource allocation to cope with the design.	A developed strategy for solving the identified risks if they occur; and improving cost and time performance during risk analysis	Informing the relevant project parties if unforeseen circumstances affect the programme	Having sufficient resources to deal with complexity	Process that allows non-performing subcontractors to be removed from the supply chain; and understanding the root causes of non-performance and acting on it.
Organisational	Open discussion by project parties before construction; and putting in place a change management procedure before commencement	Encourage risks sharing if possible; ensure risk management is a sincere and open exercise; ensure the risks register is not only kept but communicated to the team; and constant review of risk register at progress meetings	Ensure that the planner is well trained and experienced; and reject unrealistic time frame by client	Ensuring where possible and practical that one team runs with the complex work/project from beginning to the end.	Good working relationship with subcontractor; ensure a committed supply chain; collaborative relationship with subcontractor; integration of subcontractor into site management team; and stringent process for selection of subcontractors.
Corrective-predictive	Determining the cause of design change; presenting the case of design change during team meetings; and efficient analysis of the consequences of design change				Sharing with individual subcontractors their results and reviewing their weaknesses with them so that they can improve on it.

Source: Adapted from Olawole and Sun (2010: 513)

In a similar study, Abdul-Azis *et al.* (2013: 2627) identified and categorised cost overruns mitigation strategies into three (3) major classes, namely: proactive, reactive and organisational strategies.

The proactive and organisational approaches are similar or almost the same as the preventive and organisational measures recommended by Olawole and Sun (2010: 513). However, the reactive strategies are adopted to mitigate the effect of the factor that actively contributes to cost overruns; while the organisational strategies are the normal measures put in place by an organisation, which must not be specific to one project; but would normally affect all projects. Some of these measures are classified in more than one strategy. For instance, proactive and organisational; reactive and organisational; pro-active and reactive; and pro-active, reactive, and organisational-control measures.

The interrelationship of these issues is further represented in the Figure 3.3.

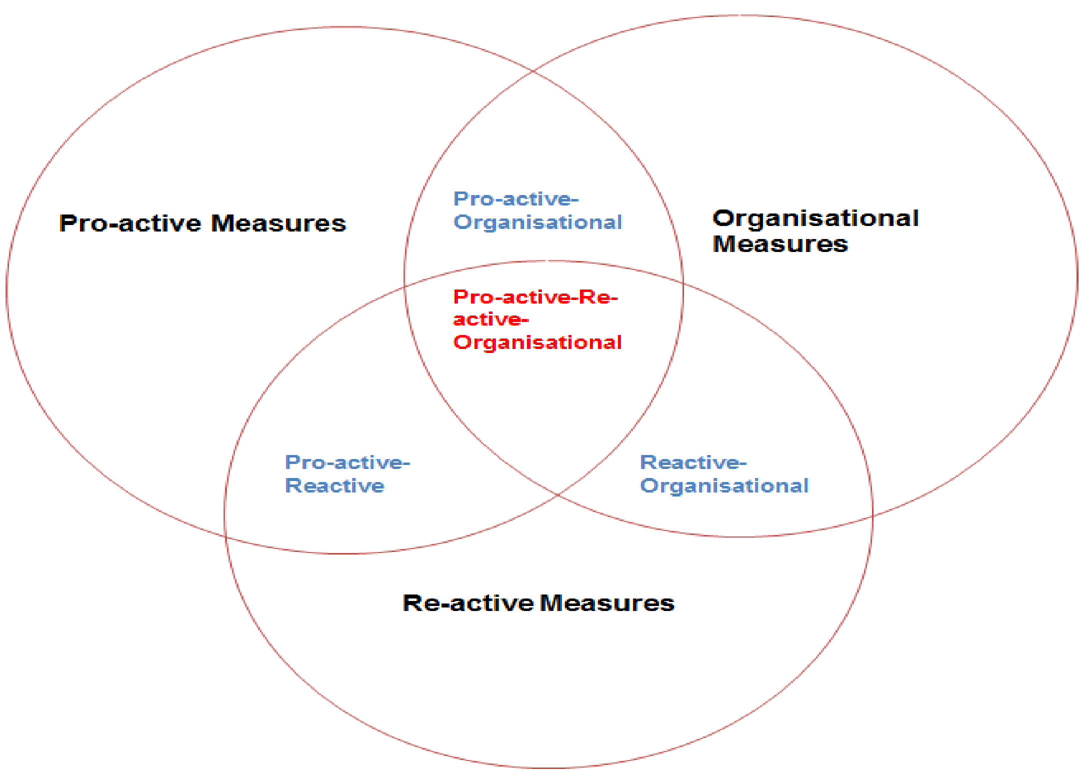


Figure 3.3: Interrelationship of the cost overruns mitigation strategies

Source: Adapted from Abdul-Azis *et al.* (2013)

Figure 3.4 shows a further relationship and the factors emanating from cost overrun mitigation measures

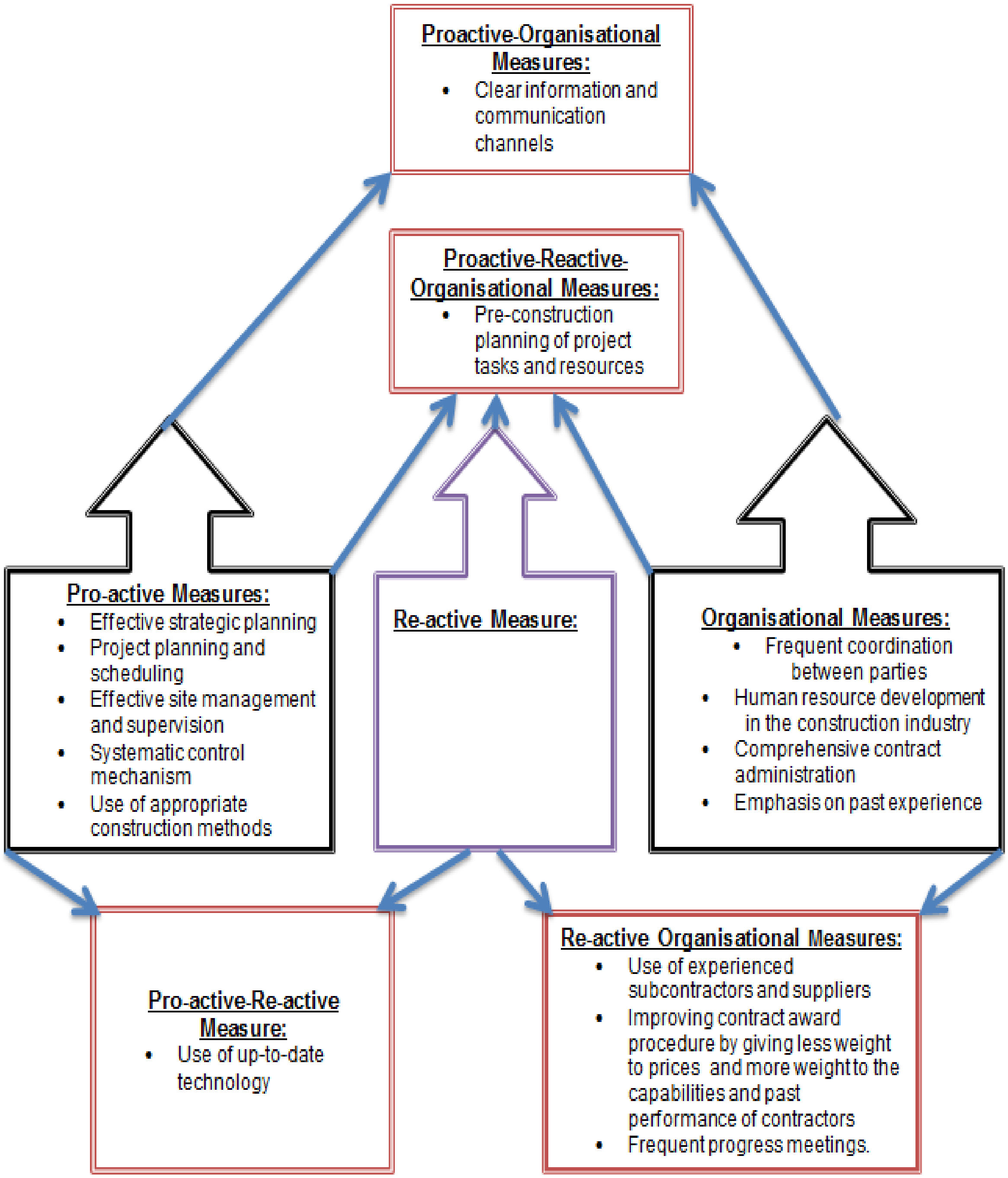


Figure 3.4 Cost overrun factors from each mitigation measure

Source: Adapted from Abdul-Azis *et al.* (2013)

Furthermore, Flyvbjerg (2008: 6-7) suggested two main concepts for minimising the cost overruns on construction projects, namely: reference-class forecasting and increased public sector accountability through more involvement by the private parties.

- **Reference-class forecasting**

This method allows a construction company to do both the inside and outside prediction of project costs, and to compare the results with those of earlier/similar projects (Brunes and Lind, 2014: 5). This method has been endorsed by the American Planning Association; and it has achieved accuracy in projections, by basing project costs on the actual performance in a reference class of comparable actions (Bent Flyvbjerg, 2008: 6).

Brunes and Lind (2014: 5) and Flyvbjerg (2008: 8) suggested three important steps in reference-class forecasting for a project:

- Identification of a relevant reference class of past, or similar projects. The class must be broad enough to be statistically meaningful, but narrow enough to be truly comparable with the specific project.
- Establishing a probability distribution for the selected reference class. This requires access to credible, empirical data for a sufficient number of projects within the reference class, in order to draw statistically meaningful conclusions.
- Comparing the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

- **Increased public sector accountability through private-party involvement**

In this method, two types of accountability are recommended: public-sector accountability through transparency and public control, and private-sector accountability through competition and market control. Both types of accountability could be effective tools to control planners' misrepresentation in forecasting, and to promote a culture, which deals effectively with project cost overrun risks.

In another study, Memon *et al.* (2013: 1970) concluded that site-management factors are the important factors causing cost overrun; and therefore, suggest that “improved site management and supervision of contractors could result in better control of cost overruns.

Brunes and Lind (2014: 1) suggested three key areas on how cost overruns could be reduced in a project:

- The decentralization of budgets, where cost overruns in one project in a region lead to less cost overruns in other projects in the specific region.
- Organisational quality: It should be easy to see when and where cost overruns occur, and who was primarily responsible. There should be a well-developed knowledge-management system in the organisation and an organisational culture of openness with a focus on improvements.
- Organisational processes: ensuring a systematic use of external reviewers at the different stages of a project.

Brunes and Lind (2014: 10) conducted a study on the measures that could reduce cost-overruns in the Swedish projects. The contractor’s staff revealed the following: Better control of documents; higher margins for unpredicted costs in the budgets; an increase in client competence; more contacts between client and contractor in the early stages.

Moreover, the Transport Authority Staff disclosed the following: better educated politicians that think more in the long term; budgets should not be set before design is determined; increased quality of design documents, better control of implementing ability; higher client competence concerning calculation; more continuous monitoring of projects, more centrally controlled internal reviews, faster reaction when there are signs of cost overruns; more feedback, less prestige; more co-operation between client and contractor (partnering); bonus systems for those involved; and changes in the procurement process, less on lowest price, and more on documented competences (Brunes and Lind, 2014: 10).

In conclusion, Peeters and Madauss (2008: 81) recommend a five-step approach to mitigating the effects of cost overruns in a project: realistic cost estimation; considering the project's life cycle cost; appropriate contractual framework; cost control and risk management during the project phase; and a communication-managed insurance approach.

3.4 A Theoretical Framework for Effective Construction Material Waste Management

Effective construction-waste management has become one of the main environmental issues in many countries; as the available space for waste disposal is becoming less and less (Poon, 2007:1715). Research in the field of construction-waste management is shifting from the traditional focus on cost-benefit analysis to a wider view of sustainability (Yuan and Shen 2011: 678). In this regard, WRAP (2007: 76) suggests that to achieve an efficient and effective management of material waste on construction sites, there must be an association of the following factors:

- Logistics management: logistics management on-site has been proven to prevent double handling, and to ensure the satisfactory handling of equipment to minimise damage to materials (WRAP, 2007: 76);
- Supply-chain management (SCM): This is needed because of the long-term relationship and commitment with suppliers and subcontractors, and on the win-win arrangements. A good SCM can help to achieve the just-in-time delivery of materials, to avoid waste due to long storage periods (WRAP, 2007: 77; Al-Hajj and Hamani, 2011: 221);
- Modern construction methods: a study published by WRAP (2007: 77) shows that "the substitution of some modern methods of construction instead of traditional building systems resulted in a net reduction in the amount of waste levels; and
- Training and incentivizing: Many studies insist on staff training, as one of the first steps in dealing with construction waste (WRAP 2007:77). In addition, a good incentive for better performance contributes to sustainable waste minimisation.

Moreover, construction waste was categorised into physical and non-physical waste, which has a major impact on the environment and the social and economic performance of every nation (Nagapan, Abdul Rahman and Asmi, 2012: 2252; Marzouk and Azab, 2014: 41). It is reported that every year, a large quantity of construction waste is generated worldwide, resulting in many economic, environmental and social problems; although the gravity of these problems varies from country to country (Yuan, 2012: 1218).

Therefore, for the practice of waste management to be effective in any construction process, there must be a stable association and development of three performance indicators, namely: Social, economic, and environmental performance (Yuan, 2013: 477).Yuan, Hao and Lu (2014: 1100) relate these factors to the principles of sustainable construction which is defined as a holistic process, aiming to restore and maintain harmony between the natural and the built environments, and to create a settlement that affirms human dignity and encourages economic equity.

Also, Dania, Larsen and Yao (2013: 2) added that sustainable construction covers a broad range of concerns, which entail resolving the conflict between various competing goals, and involves the simultaneous pursuit of economic prosperity, environmental quality, and social equity, as shown in Figure 3.5.

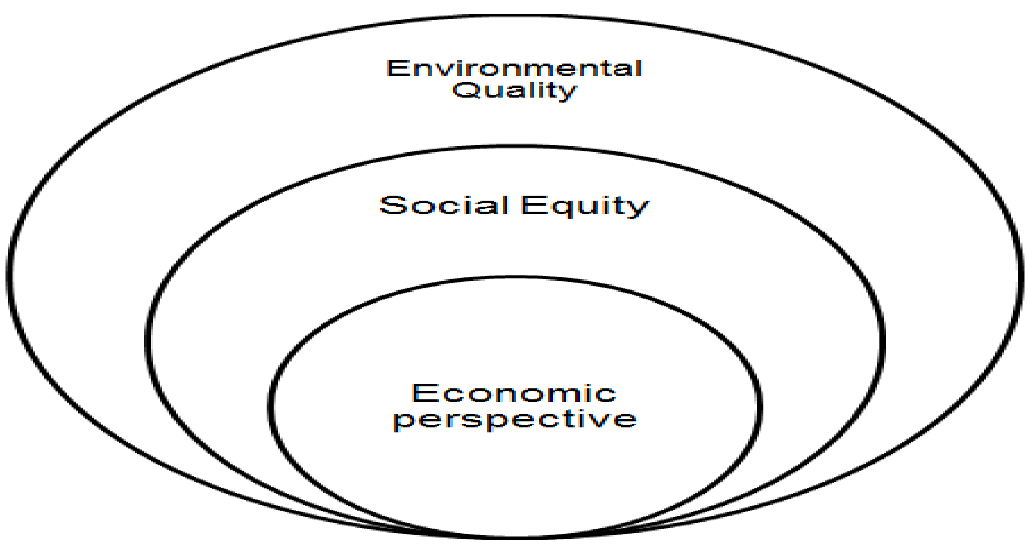


Figure 3.5: The triple bottom line of sustainability

Source: Dania, Larsen and Yao (2013: 2)

To this end, the construction sector is expected to evolve its processes of protecting the built environment, as it is very important in the sustainability debate. It is strategically poised at the interface of being a vehicle for improving the quality of life, and the actor that will determine how sustainable the environments are going to be (Dania, Larsen and Yao, 2013: 2).

Therefore, since the efficient control and the effective management of construction material waste comprise the fundamental ways for achieving sustainability in construction, then effective management should not concentrate on economic performance alone; but it should also dwell on the related social and environmental aspects. Without these indicators, the entire effectiveness of waste management cannot be well appreciated, or subsequently improved on (Yuan, 2013: 477).

The Figure 3.6 shows that the management of construction material waste would affect its entire effectiveness, which is clearly established by the areas of: “socially effective”, “environmentally effective”, “economically effective”, “social-environment”, “environmental-economics” and “social-economics”. However, only those construction projects that fall in the central area are seen to be adequately effective in construction waste management (Yuan, 2013: 477). This central area is, therefore, the location of the effective construction waste management theoretical framework which is later, in section 3.5, used to formulate the conceptual framework for this research.

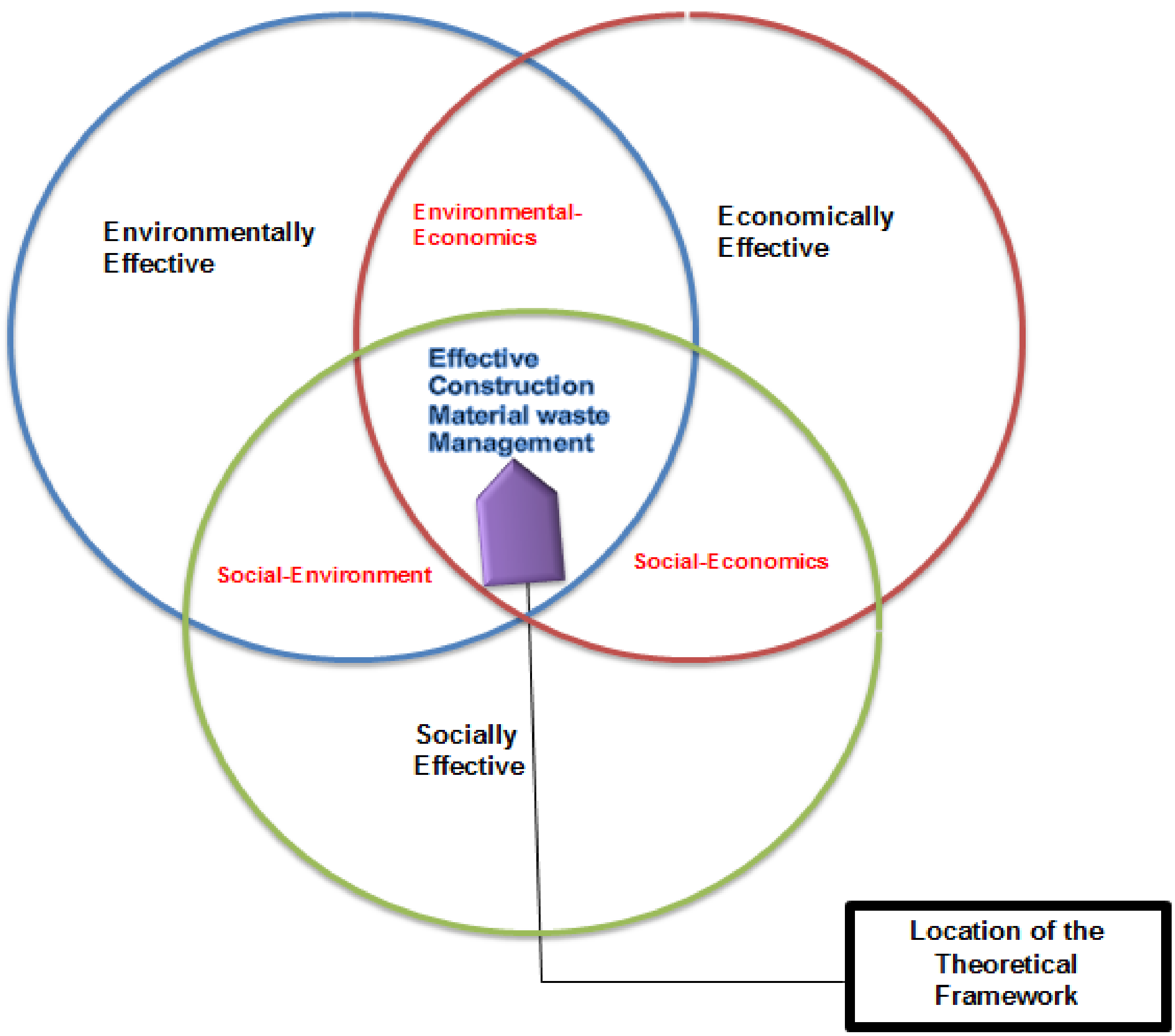


Figure 3.6: Effective construction material waste management theoretical framework
Adapted from (Yuan, 2013: 477)

3.4.1 Environmental-performance indicators

It is globally recognised that construction activities can improve public facilities and the overall living environment in a number of ways. However, the construction industry has long been criticised for causing environmental degradation worldwide (Poon *et al.,* 2004: 461). Construction waste increases the burden on landfill sites, which are becoming increasingly scarce. In addition, if waste is not managed properly, materials such as solvents and chemically treated wood could cause soil and water pollution (Business Division, 2013: 1).

The generation of material waste has been extensively recognised as not being environmentally friendly, owing to its adverse impacts on the natural environment. Basically, material waste can harmfully affect the entire environment by land deterioration, toxic-waste discharge, and by consuming a vast area of land for landfilling (Poon, Yu and Ng, 2003: 89; Yuan, 2012: 1218; Yu *et al.,* 2013: 138).

Yuan (2013: 479-480) reports that the promulgation of government legislation has revealed the following five (5) indicators requiring urgent attention for construction-waste management as: the consumption of land space for landfills; water pollution; noise pollution; air pollution, and environmental impact on humans (Yuan, 2013: 479-480).

In another study, Lee (nd) suggested the inclusion of the problem of traffic during construction on the scope of the environmental impact on waste management.

Ayomoh, Oke, Adedeji and Charles-Oweba (2008: 11) proffer the following environmental impacts of waste management: respiratory difficulties generated by pollution; it catalyses high blood pressure; and causes soil pollution.

Therefore, it is essential that construction companies reduce waste, so as to minimise any environmental damage and to conserve natural resources. Organisations are encouraged to follow guidelines to reduce, re-use and recycle waste (Business Division, 2013: 1).

3.4.2 Economic-performance indicators

The economic instrument is useful for encouraging or motivating contractors to conduct environmentally friendly construction practices (Yuan *et al.,* 2011: 604). However, despite considerable research on waste management, the environmental protection has not been given the attention it deserves by industry players (clients, contractors, and engineers). Additional economic benefits for the implementation of waste management practices should be encouraged; as the lack of economic incentives and motivation have hampered the development of construction waste management (Yuan, 2013: 479; Yuan *et al.,* 2011: 605; Shen, Yao and Alan, 2006: 242).

Yuan (2013: 479) suggests that the major indicators for assessing the cost-benefit analysis, or the economic performance of waste management are: The cost of waste collection, sorting and segregation, the cost of re-use and recycling, the cost of transporting waste from site to landfills, cost of landfill disposal, cost of unlawful dumping, the revenue from the sale of waste, the saving in waste-transportation costs from construction sites to landfills, and the cost saving for landfill waste disposal.

Hill and Bowen (1997: 229) established that the social underpinning of sustainable construction would be more easily achieved if the practitioners were to address the following issues:

- Promote employment creation; and, in some instances, rigorous labour construction.
- Ensure the selection of environmentally responsible contractors and suppliers, who could actively participate in environmental preservation.
- Improve the competitiveness in the market place by implementing strategies that could lead to improved sustainability.
- Useful cost accounting and real cost pricing to set prices and tariffs.
- Ensure financial affordability for intended beneficiaries (Hill and Bowen, 1997: 229).

Research evidence suggests that the effectiveness of construction waste management activities is hampered by economic incentives to manage construction waste. In other words, there are hardly any extra benefits for properly conducting construction-waste management (Shen, Yao and Alan, 2006: 242; Yuan *et al.,* 2011: 605).

3.4.3 Social-performance indicators

The evaluation of the social performance of construction-waste management requires a good understanding of the entire management process, ranging from construction waste generation to the final disposal thereof (Yuan, 2012: 1219). Yuan (2012: 1227) concluded that poor social performance is largely attributable to the ‘‘physical working environment in waste management'', ''operatives' safety'' and ''practitioners' long-term health.

In another study, Hill and Bowen (1997: 227) found that the social underpinning of sustainable construction would be better achieved if the practitioners were to resolve the following issues:

- Improve the quality of human life. This is done by ensuring secure and adequate utilisation of basic needs, such as food, clothing, shelter, health, education, comfort, identity and choice. These are in line with the global goal of poverty alleviation.
- The protection of human health through a hygienic and safe working environment, by managing better the risk of accidents and the use of substances that are hazardous to human health.
- Ensuring adequate skill training and capacity development of disadvantaged people, to ensure their reasonable participation in a project. The human development in this aspect ensures that human resources are lasting legacy in the construction industry.
- Ensure that the development process after completion is compatible with local human technology and organisations.
- Ensure reasonable or impartial distribution of the social costs of construction. Where this is not achieved, then the harmfully affected people by the construction operation should be given a fair compensation (Hill and Bowen, 1997: 227).

3.5 The Research Conceptual Framework

A concept is a plan, vision, or a symbolic representation of an abstract idea**.** A conceptual framework in research shows the researcher's position on the research problem, which gives direction to the study, and further shows the relationships that exist between different constructs that the study intends to investigate. It may be an adoption of a model used in a previous study with modifications to suit the present investigation. Thus, it is referred to as, an organisation, or matrix of concepts that provide a focus for enquiry. The conceptual framework therefore, gives direction and rationale for undertaking the subsequent stage (methodology) of this research process.

The literature reveals that quality of planning, quality of estimating, quality of design management, and design complexity at the pre-contract stage, and quality of construction management, procurement management, and quality of site management at the post-contract stage of a project all have a major influence on effective construction material waste management (referring to section 2.7). The interrelationships between these issues are important for an effective construction material waste management.

Furthermore, based on the concepts originating from the theoretical framework of effective material waste management in the previous sections, which is central to this study, the conceptual framework of this research (Venn-diagram of effective construction material waste management concept) is therefore, located at the boundary line (universal set of the effective construction material waste management), which borders the intersection of the variables that constitute the project stages, material waste, and coefficient of cost overruns.

Figure 3.7 presents a conceptual framework to guide the method of the research for the management of material waste and cost overrun in the Nigerian construction industry.

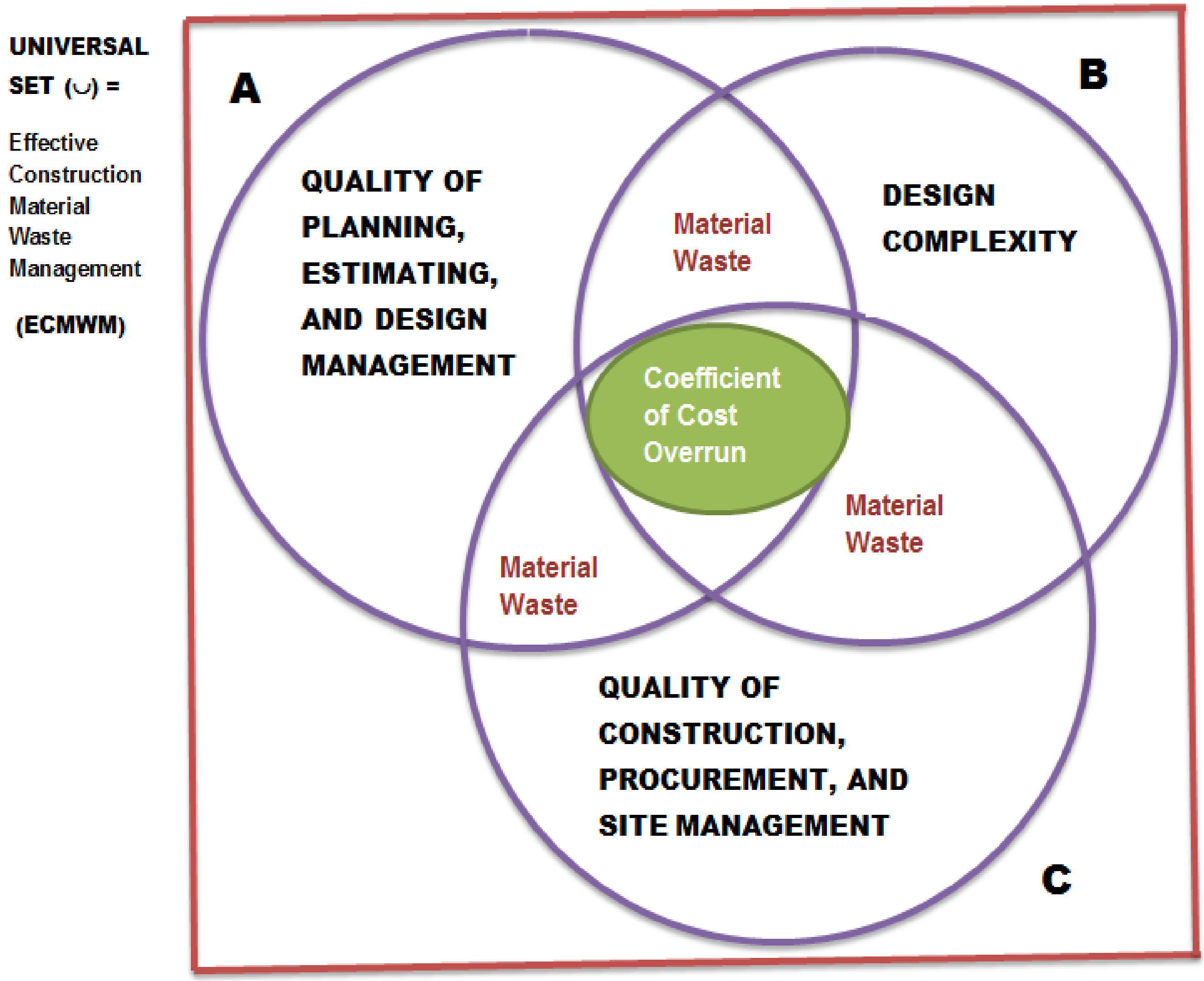


Figure 3.7: The Venn diagramme conceptual framework for this research

Source: Researcher's construct, 2015.

The interrelationships of the variables in the conceptual framework above are summed up in a mathematical equation for achieving an effective waste management in a project using the Venn diagram SET theory.

The Figure 3.7 shows a relationship between "Quality of Planning, Estimating, and Design Management ($\boldsymbol{QPEDM}$)"; "Design Complexity ($\boldsymbol{DC}$)"; and Material Waste($\boldsymbol{MW}$).

This means that a negative change in ($\boldsymbol{QPEDM}$) or positive change in ($\boldsymbol{DC}$) will lead to Material Wastage ($\boldsymbol{MW}$) which will in turn result into Cost Overruns ($\boldsymbol{Co}$).

The same applies to "Quality of Planning, Estimating, and Design Management ($\boldsymbol{QPEDM}$)" $\boldsymbol{and}$ "Quality of Construction, Procurement, and Site Management ($\boldsymbol{QCPSM}$)". A negative change in any of these results in Material Waste ($\boldsymbol{MW}$) which also results in cost overrun ($\boldsymbol{Co}$).

There is also a relationship between "Design Complexity ($\boldsymbol{DC}$)"; "Quality of Construction, Procurement and Site Management ($\boldsymbol{QCPSM}$)"; and Material Waste ($\boldsymbol{MW}$).

This means that a negative change in ($\boldsymbol{QCPSM}$) or a positive change in ($\boldsymbol{DC}$) variable will lead to material wastage ($\boldsymbol{MW}$) which will in turn result into Cost Overrun($\boldsymbol{Co}$).

3.5.1 Mathematical equation

Based on the issues originating from the conceptual framework of material waste and cost overruns, the steps for developing a mathematical equation for managing construction material waste and cost overrun are presented below:

$\cup$= Effective Construction Material Waste Management ($\boldsymbol{ECMWM}$)

$\boldsymbol{A}$= Quality of Planning, Estimating, and Design Management ($\boldsymbol{QPEDM}$)

$\boldsymbol{B}$= Design Complexity ($\boldsymbol{DC}$)

$\boldsymbol{C}$= Quality of Construction, Procurement and Site Management ($\boldsymbol{QCPSM}$)

$\boldsymbol{x}$= Material Waste ($\boldsymbol{MW}$)

y= Cost Overrun ($\boldsymbol{Co}$)

$\boldsymbol{a}$= Coefficient of cost overrun = (*0.87)*

$\boldsymbol{i}$= Lower limit

$\boldsymbol{n}$= Number of designs

Therefore,

Poor "$\boldsymbol{A}$" (-) =======>Leads to====>"$\boldsymbol{x}$"; Poor "$\boldsymbol{C}$" (-) =======>Leads to==="$\boldsymbol{x}$"

Increased "$\boldsymbol{B}$" (+) = (Leads to=== "$\boldsymbol{x}$"; and "$\boldsymbol{x}$"==================$\mathbf{0.87}\boldsymbol{y}$.

To reduce letter “x” to negative (-), then,

Good “$\boldsymbol{A}$” (+) leads to negative x $(-\boldsymbol{x})$; Good “$\boldsymbol{C}$” (+) leads to a negative x $(-\boldsymbol{x})$ $as\ well$; $\boldsymbol{and}$ Reduced “$\boldsymbol{B}$” (-) leads to a negative x $(-\mathbf{x})$.

Negative variables = $\boldsymbol{X, Y, and\ B}$. They have to be negative because practically, material waste, cost overrun and design complexity have to be reduced to achieve the ‘Effective construction material waste management’ $(\boldsymbol{ECMWM})$ $\boldsymbol{or}$ $(\cup)$ $\boldsymbol{or}$ $(\boldsymbol{A}$ $(\boldsymbol{B}$ $(\boldsymbol{C})$.

Therefore, since $"\boldsymbol{x}"$ “material waste” is shared between all the intersections showing a relationship between the main variables in the SET and $"\boldsymbol{x}"$ which is negative that is $(-\boldsymbol{x})$ can be equal to: $\left(-\frac{\boldsymbol{1}}{\boldsymbol{3x}}\right)+\left(-\frac{\boldsymbol{1}}{\boldsymbol{3x}}\right)+\left(-\frac{\boldsymbol{1}}{\boldsymbol{3x}}\right)=-\boldsymbol{x}$

This means that, a complete material waste is found at the completion of all the required stages of a project.

Therefore, from the Venn diagram of SET theory in mathematics,

$$(A \cup B \cup C) = n(A) + n(B) + n(C) + n(A \cap B) + n(A \cap C) + n(B \cap C) + n(A \cap B \cap C)$$

Substituting the variables:

$$(A \cup B \cup C) = A + (-B) + C + \left(-\frac{1}{3x}\right) + \left(-\frac{1}{3x}\right) + \left(-\frac{1}{3x}\right) + (-0.87y)$$

$$(A \cup B \cup C) = A + C - B - x - 0.87y$$

Substituting the original variables:

$$ECMW = QPEDM + QCPSM - DC - MW - 0.87Co$$

The final equation will be:

$$\boldsymbol{ECMWM} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{QPEDM} + \boldsymbol{QCPSM} - \boldsymbol{DC} - \boldsymbol{MW} - \boldsymbol{0.87Co}$$

This above equation means that:

To achieve an effective construction material waste management (from one to any number of projects), there must be “Good Quality of Planning, Estimating, and Design Management $(\boldsymbol{QPEDM})$” and “Good Quality of Construction, Procurement and Site Management $(\boldsymbol{QCPSM})$”; there must be a decrease in “Design Complexity $(\boldsymbol{DC})$” which will reduce “Material Waste ($\boldsymbol{MW}$)” and subsequently reduce the amount of “Cost overrun ($\boldsymbol{Co}$)” by 0.87 (87 percent).

3.6 Concluding Remarks

This chapter has discussed the theoretical and conceptual framework of the research that is anchored in the concept of material-waste management and cost overruns in the Nigerian construction industry. The theoretical framework dealt with the inter-relationship between the theoretical issues, leading to the achievement of effective construction material-waste management in the construction industry. The conceptual framework highlighted the inter-relationship of the issues leading to material waste and cost overruns, as well as their management at different stages of a project. This construct is in line with the research problem and objectives of the study, as stated in section 1.3 and 1.6 of the study.

These issues in the conceptual framework further led to the development of a mathematical equation for achieving effective construction material-waste management and cost overruns in the construction industry.

The theoretical and conceptual framework given in this chapter have been provided from the construction management perspective. The next chapter presents the philosophy, the methodology and the techniques of the research.

Chapter 4: The Research Methodology and Techniques

4.1 Introduction

This chapter presents the research concepts and principles that were followed to achieve the objectives and hypotheses of the study, as outlined in sections 1.4, 1.5 and 1.6 of this research project. It begins by bringing into focus the problems, aim and objectives of the research; and it then proceeds with the explanation of the methodology and methods. Subsequently, the philosophical underpinning/assumptions and paradigms of the research are presented. The research design/strategies and methods adopted; the nature of the data, their treatment, interpretation, ethical considerations, and the research validity are all discussed.

4.2 The Research Problem, Aim and Objectives

The main problem addressed by this research is, as stated in section 1.3. In view of the problem statement, the sub-problem statements originating from the main problem were formulated, as stated in section 1.4 of this study. With reference to the above problem and sub-problems, the aim of the research was to investigate the relationship between material waste and construction cost overrun in the Nigerian construction industry. Therefore, the objectives, methodology, and method of the research must reflect the aim and the variables in the problem as well as the conceptual frame work highlighted in section 3.5 of this study.

4.3 The Research Design

Research design is referred to as the method of changing a research idea into a research plan, which can be carried out in practice by a researcher (Cheek, 2008: 763). It entails a number of considerations, from the use of specific research methods, to data storage and analysis (Cassim, 2014: 53). The purpose of a research, and research questions, is to develop a research design; because they provide important clues about the problem that a researcher is aiming to assess (Wahyuni, 2012: 72). It also provides a researcher with the strategies for solving an identified research problem (Leedy and Ormrod, 2013: 74). The problem identified in this research (referring to section 1.3), is that "as a result of low awareness, the Nigerian construction industry pays little emphasis to the effects of generated material wastes on project-cost overruns".

Hughes (2008: 196) highlighted the fact that the significance of any research method would be judged in terms of its appropriateness to the nature of the questions being asked; and sensitivity of the methods must, therefore, match the requirements of the research question. Cheek (2008: 763) noted that the theoretical assumptions and underpinnings about a research project, as comprehended by the researcher, provide an important frame that shapes and influences the research design at every point.

For this research, the consideration of the research problem began with an explanation of the background of material waste and cost overruns in the Nigerian construction industry. Furthermore, a theoretical framework of construction-material waste, which allows for the development of a conceptual framework that guides the proposed research method, was established.

In addition, the designs in research describe the procedures for collecting and analysing/treating the data, in order to answer the research questions posed, which would subsequently provide a way for conducting the research (Dainty, 2008: 3). Cheek (2008: 763) extends the assumption of research design beyond simply identifying techniques that could be used to collect the data; but it also involves the theoretical, methodological, philosophical, and ethical considerations that shape both the design, and aim of the research.

Moreover, the choice of a research technique also depends on the willingness of a researcher to accept the assumptions underlying each set of tools (Rubin and Rubin, 2011: 1). Thus, a research design is influenced by certain philosophical assumptions; because it is difficult to separate a researcher's assumptions and beliefs from the manner of which the research was carried out.

The next section presents the philosophical issues relating to this research.

4.4 The Philosophical Underpinning or basis of a Research

Philosophy is primarily concerned with thoroughly establishing, regulating and improving the methods of inquiry in all fields of intellectual endeavours (Shakantu, 2014: 51). The philosophical positions often shape and orient people towards particular strategies for undertaking research. And, consequently, a favourite philosophical position should not be adopted; neither should a preferred tool be used in all research (Shakantu, 2014: 56).

The nature of any research problem will determine its means of solution, and the methodological framework and methods employed in a research must also reflect these features. This would pave the way for establishing the most appropriate philosophical position for the research, before the selection of an appropriate method (Shakantu, 2014: 57).

In social science research, the perceptions, beliefs, assumptions, and the nature of reality and truth are described by the ontological and epistemological assumptions. They influence the methods of undertaking a research, from design through to the conclusions. Hence, it is essential to understand and discuss these features, so that approaches similar to the nature and aims of a particular inquiry are adopted; and to ensure that the researcher's biases are understood, exposed, and minimised (Flowers, 2009: 1).

In order to establish the philosophical position of a research, it is necessary to examine the: sociological, epistemological, and ontological background of the research. Thereafter, it is necessary to situate the research background in the relevant research paradigm (Wahyuni, 2012: 69; Shakantu, 2014: 47). The choice of a paradigm has implications on both the methodology and on the research methods. And so, the paradigm is determined by the nature of the research problem being investigated.

Rubin and Rubin (2011: 17) highlighted the four important reasons for choosing a philosophy in research:

- The philosophical assumptions provide the necessary guidance for conducting a research by prescribing the research role. This includes the type of evidence gathered and its origin, the way the evidence is interpreted; and how it helps to answer the research questions.
- Compliance with the research standards specific to the research paradigm employed, rather than those that guide any possible alternative approaches. This allows the researcher to be creative and innovative in the selection of the appropriate research method.
- Readers/assessors may be unwilling to accept the legitimacy of a research approach, unless the underlying assumptions are made clear.
- Understanding the theoretical assumptions helps the researcher to recognise the right or wrong philosophical techniques to be adopted for a research.

This section seeks to discuss the three major scopes or levels of research methodology, namely:

- The research philosophy and paradigms;
- The research reasoning; and,
- The research data.

These levels of research are necessary; because the philosophical position of the research strongly influences the reasoning of the research; and both (the philosophy and the reasoning) influence the data requirements and the analysis of the research (Okolie, 2011: 123).

The philosophical discourse has been presented in the preceding section; the next section will look at ontological and epistemological assumptions.

4.4.1 The ontological assumptions

In classical and speculative philosophy, ontology was the philosophical ‘science of being’ (Jeff, 2008: 577). Flowers (2009: 2) describes ontology, as ‘the science or study of being’. The existence of reality is external and independent of the social actors and their interpretations of it, which are termed objectivist (Wahyuni, 2012: 69).

Ontological assumptions are concerned with the nature of social reality. These assumptions make claims about what kind of social phenomena do or can exist, the conditions of their existence, what they look like, what units they comprise, and the ways in which they are related (Blackie, 2010: 92; Wahyuni, 2012: 69). Thus, ontology asks questions about what really is, and what the fundamental categories of reality are. When we do a study, we are making assumptions about what we will study, and about its place in the world (Neumann, 2011: 92). Shakantu (2014: 52) added that ontology deals with the study of being and knowing, in which the questions of the nature of reality are regarded to be central.

In short, ontology describes human views (whether claims or assumptions) on the nature of reality, and specifically, whether this is an objective reality that really exists, or only a subjective reality, created in human minds (Flowers, 2009: 2).

Therefore, every human has a number of rooted ontological assumptions, which would affect their opinion on what is real, and whether they attribute their existence to one set of things, rather than to another. If these underlying assumptions are not identified and considered, the researcher would not be able to envisage certain aspects of the investigation, because, they are implicitly assumed, taken for granted; and therefore, they are not open to questions, or discussion (Blackie, 2010: 93). The general aim was to provide reasoned, deductive accounts of the fundamental kinds of things that exist.

Ontology was not concerned with the specific nature of empirical entities, but rather with the more basic questions of the universal forms of existence (Blackie, 2010: 93).

Furthermore, Jeff (2008: 577) has shown that questions relating to classical ontology are as follows: are bodies the only things that exist, or are immaterial forms real? Is there a supreme Intelligence in the universe, or is all activity reducible to mechanical motions? Are individuals alone real, or are collectives independently real? Are there real objects of universal terms, or are universals simply names that humans give to mental abstractions? These questions mean that they would always have some connection to the investigation of natural and social phenomena. However, in the contemporary era, it would be wrong to continue to think of ontology as an important science given that hypothetical empirical methods of research have permanently displaced the deductive rationalistic methods of classical philosophy.

The ontological assumptions according to Blackie (2010: 92-94) are classified into six categories namely:

- **Shallow realist:** This assumes that the phenomena being studied exist independently of the researcher; they can be observed (experienced by the senses), and only that which can be observed is relevant to the science. Furthermore, there are sequences in observable phenomena, and the challenge for science is to descover and describe them.

- **Conceptual realist:** This assumes that reality has an existence independent of human minds; It is not the property of any individual, or the construction of any social community; and it is a collective consciousness, or structure of ideas, and is not directly observable.

- **Cautious realist:** This assumes that reality exists independently; but, because of imperfections in the human senses, and the fact that the act of observing is an interpretive process, it cannot be observed directly or accurately; and hence, a cautious and critical attitude must be adopted at all times.

- **Depth realist:** Here, reality consists of three areas ranging from what can be observed (the empirical domain), through what exists independently of the observer (the actual domain), to an underlaying domain of structures and mechanisms that may not be readily observed (the real domain); and therefore, reality is stratified and has ontological depth; and unlike natural structures, social structures are less enduring and do not exist independently of the activities they influence, or of the social actors' conceptions of what they are doing in these activities.

- **Idealist:** The idealist ontology assumes that reality consists of representations that are the creation of the human mind; social reality is made up of shared interpretations that social actors produce, and reproduce as they go about their everyday lives; and the idealist ontologist takes a variety of forms: one considers there is a reality that exists independently of socially constructed realities; another sees such an external reality, as placing constraints on, or providing opportunities for reality constructing activities; and in a third, the constructions of reality are regarded as different (multiple) perspectives on an external world (Blackie, 2010: 92-94).

- **Subtle realist:** Here, an independent and understandable reality exists independently of the social scientists; and the cultural assumptions prevent any direct access to this world; as all knowledge is based on assumptions and purposes; and it is therefore, a human construct which is not certain.

Put simply, Shakantu (2014: 53) argues that the two opposing ontological underpinnings on which researchers can base their methodology are the **Parmenidean** and the **Heraclitean** ontologies. While the Heraclitean ontologist emphasises the prevalence, or importance of a fluxing, modifying, changeable and emergent world, the Parmenidean ontologist maintains the permanent and unchangeable nature of reality. The opposition between a Heraclitean ontology of becoming and a Parmenidean ontology, provides researchers with the key for understanding contemporary debates in the philosophy of the social sciences, and their implications for management research.

Flowers (2009: 2), therefore, noted that when considering that different views exist regarding what constitutes reality, another question must be: How is that reality measured, and what constitutes knowledge of that reality? This leads us to questions of epistemology; because every ontological position has a corresponding epistemological position (Eriksson and Kovalainen, 2008: 13).

4.4.2 Epistemological assumptions

Epistemology is an area of philosophy concerned with the creation of knowledge that focuses on ‘how we know’, ‘what we know’, or ‘what are the valid ways to reach truth’. It includes the sources and limits, as well as the rationality and justification of knowledge (Neumann, 2011: 93). It is therefore, the most appropriate way of enquiring into the nature of the world (Easterby-Smith, Thorpe and Jackson, 2008: 46). Shakantu (2014:55) added that epistemology deals with questions about how, and what it is possible to know. Stone (2008: 264) believes that the following three questions are basic to epistemology: What is knowing? What is the known? And what is knowledge?

Thus, Shakantu (2014: 55) emphasises that epistemology is the study of the verification of knowledge.

Also, Flowers (2009: 2) views epistemology as the theory/science of the method/ grounds of knowledge and expanding this into a set of claims or assumptions about the ways in which it is possible to gain some knowledge of reality.

Furthermore, Blackie (2010: 92) suggests that epistemological assumptions are concerned with what kinds of knowledge are possible; how we can know these things; and with the criteria for deciding when knowledge is both adequate and legitimate. Consequently, each of the research strategies entails a particular combination of ontological and epistemological assumptions.

Therefore, a realist says there is an empirical world “out there” that exists apart from our inner thoughts and perceptions of it (Neumann, 2011: 93). Thus, epistemology is summarised as ‘knowing how you can know’, and expanding this by asking how is knowledge generated? What criteria discriminate good knowledge from bad knowledge? And how should reality be represented or described? (Flowers, 2009: 2).

Blackie (2010: 94) maintains that epistemological assumptions can be further categorised into six different classes, namely:

- **Empiricism:** Here knowledge is produced and verified by the use of human sense; a neutral, trained observer, who has accurate contact with reality, can arrive at reliable knowledge; and knowledge is certain, when it accurately represents the external world.

- **Rationalism:** Knowledge comes from the direct investigation of the structure of human thought; and thus evidence for an unobservable collective consciousness can be found in the consequences it has on people's lives, or in the thought processes and structures of the mind itself; and logic and mathematics provide the standards for judging the claims of knowledge.

- **Falsificationism:** According to this approach, knowledge is produced by a process of trial and error in which theories are proposed and tested against the empirical evidence; because of our inability to observe reality directly, or to test, theories must be directed towards trying to falsify them, rather than to confirm them; and as it is not possible to establish whether knowledge is true; it must be regarded as tentative, and, therefore, open to possible revision.

- **Neo-realism:** Here, knowledge of the causes of observed regularities is derived from the structures and/or mechanisms that produce them; the discovery of these structures and/or mechanisms may necessitate the postulation, or the selection of entities and processes that go beyond surface appearances; and this view of causation allows for the possibility that, completing or cancelling mechanisms may be operating when no event or change is observed.

- **Constructivism:** Everyday knowledge is the outcome of people having to make sense of their encounters with the physical world and other people; and social scientific knowledge is the outcome of social scientists reinterpreting this every day knowledge into technical language; because it is impossible for fallible human beings to observe an external world unencumbered by concepts, theories, background knowledge and past experiences. It is only possible for humans to make true discoveries about the world; all social enquiries reflects the standpoint of the researcher; and all observation is theory-laden; and hence, there are no permanent, unvarying criteria for establishing whether knowledge can be regarded as true, or for rejecting it as false.

- **Conventionalism:** Here scientific theories are created by scientists as convenient tools for dealing with the world; theories do not describe reality; they determine what is considered by the scientist to be real; and decisions about what are good theories. Here, the better of two competing theories, is a matter of judgment, rather than of proof.

Consequently, the two basic examples of epistemology are objectivism and subjectivism (Eriksson and Kovalainen, 2008: 14; Shakantu, 2014: 57). The objectivist assumes that knowledge about the external world is accessible with little or no influences; while the subjectivists believe that knowledge about the external world could be accessed by observation and interpretation (Eriksson and Kovalainen, 2008: 14).

4.4.3 The combination of ontological and epistemological assumptions

The epistemological and ontological assumptions form two pairs of research philosophy. It is not really possible or sensible to think of them as being independent of one another. Therefore, the purpose of the separation was simply to highlight the fact that there are two types of assumptions; and that other combinations are possible, and might be sensible (Blaikie, 2010: 95). Thus, the ontological assumptions affect the epistemological assumptions, which in turn, affect the methodological assumptions of a research. Therefore, some research could begin with abstract thinking, logically connecting ideas in theory to concrete evidence; and these ideas would then be tested against the available evidence (Shakantu, 2014: 56-71).

Blaikie (2010: 94) further noted that the sixth subtle realist ontology and the epistemology of conventionalism do not combine in the same way. They are alternatives to some of the others; and they can be used to produce variations in the combinations in Table 4.1.

The common combinations of these assumptions are shown in Table 4.1.

Table 4.1: Common combinations between ontology and epistemology

	Ontology	Epistemology
1	Shallow realist	Empiricim
2	Conceptual realist	Rationalism
3	Cautious realist	Falsificationism
4	Depth realist	Neo-realism
5	Idealist	Constructionism

Source: Blaikie (2010: 94)

4.5 The Research Paradigm

Research paradigms address the philosophical dimensions of research in the social sciences. They comprise a set of assumptions, concepts, theories and beliefs, as to how the world is perceived, which then serves as a thinking framework that guides the behaviour of the researcher (Wahyuni, 2012: 69). Moreover, Shakantu (2014: 59) views the research paradigm as a shared and common framework for understanding and undertaking research problems.

Social research is usually conducted against the background of some tradition of theoretical and methodological ideas. These traditions, which have developed and transformed over more than a hundred years, are referred to as the research paradigms. They are the source not only of the theoretical ideas but also of the ontological and epistemological assumptions (Blaikie, 2010: 96). They are referred to as the fundamental models or frames-of-reference used to organise observation and reasoning (Babbie, 2010: 33).

A paradigm is a basic orientation to theory and research. Scientifically, it is a whole system of thinking, including the basic assumptions, the important questions to be answered, or the puzzles to be solved, the research methods to be used, and the examples of what good scientific research is like (Neumann, 2011: 94). Babbie (2010: 33) believes that paradigms are often difficult to recognise; because they are so implicit, assumed, and taken for granted. They seem more like “the way things are” than like one possible point of view among many.

Babbie (2010: 33), highlights the two main benefits of operating within a paradigm as:

- The strange actions and opinions of other researchers who are operating from a different paradigm that can be better understood.
- At times, we could profit from stepping outside our paradigm suddenly. Then new ways of seeing and explaining things might be seen.

Moreover, paradigms examine how members of research communities view both the event their particular community studies and the research methods that should be employed to study those events (Donmoyer, 2008: 591).

Blaikie (2010: 97) opined that each research paradigm does not necessarily incorporate just one combination of ontological and epistemological assumptions, although some do. Hence, the role of the research paradigms in social research is much broader. Blaikie (2010: 97-104) categorised research paradigm into two major classes, namely:

The classical research paradigm, and the contemporary research paradigm.

4.5.1 The classical research paradigm

These paradims represent the ealiest attemps at, either applying the methods of the natural sciences in the social sciences, or rejecting such applications. Most of the contributors were writing during the nineteenth century and the early part of the twentieth century; although many of the ideas predate this period. The four identified classical paradigms, according to Blaikie (2010: 97-104) are: Positivism, critical rationalism, classical hermeneutics, and interpretivism.

4.5.1.1 The positivist paradigm

This is the code word for a package of philosophical ideas that most probably no-one has ever accepted in its entirety. These ideas include a distrust of concepts, a preference for observation unencumbered by too much theory, a commitment to the idea of a social science that is not widely different from the natural sciences, and a profound respect for quantification (Paley, 2008: 646).

Positivism provides a researcher with a clear focus of the research at an early stage, which makes the control of the research much easier. Nonetheless, positivism is weak in providing any in-depth understanding of phenomena (Raddon, 2007: 7). The positivists believe that the social world exists externally; and that its properties should be measured through objective measures, in which the observer must be independent of that which is being observed (Paley, 2008: 647).

Positivism is a philosophical position held within the natural and social sciences that combines logic and rationality with empirical observation. In positivism, reality is assumed to exist independently of the perceptions, beliefs and biases of the researcher (Shakantu, 2014: 60). The two fundamental forms to positivism are: empiricism (for instance, there is knowledge only from experience) and logical analysis, by means of which philosophical problems and inconsistencies would be resolved, and the structure of scientific theory made clear. It is, of course, the second of these commitments that represents logical positivism's distinctive contribution to the empiricist tradition (Paley, 2008: 647).

The essential sequence of positivistic scientific inquiry, according to Shakantu (2014: 61-65) revolves around four main stages, namely:

- **The observation stage:** A phenomenon is observed in its natural state, in order to establish the dynamic of the process; and observation is critical to the establishment of the dependent and independent variables of the process.

- **The hypothetical construct stage:** A hypothesis is a tentative explanation for an observation, phenomenon, or scientific problem that is used as the basis for further investigation; and the classic positivistic approach is the formulation of a hypothesis from observed facts, and research that is geared towards either the 'proof' or 'disproof' of the original research hypothesis.

- **The testing stage:** Once a hypothetical construct is in place, the researcher must design an experimentation or sampling strategy that permits the researcher to identify any precise relationships between the variables; and these variables are studied intensively in controlled conditions. Quantitative analytical techniques can be used, with a view to making generalisable statements applicable to real-life situations.

- **The analysis stage:** This stage involves the analysis of large amounts of data; this is essential to define and describe the underlying laws and principles governing observed phenomena; within a positivistic analytical context, data integrity and density, allied to statistical significance are the cornerstones of effective research.

Blaikie (2010: 97-98) believes that positivism regards reality as consisting of discrete events that can be observed by the human senses. The knowledge is often derived from experience.

Once all the relevant data have been analysed, a positivistic researcher should be in the position of being able to support or reject the hypotheses (Shakantu, 2014: 66).

4.5.1.2 The critical rationalist paradigm

This paradigm believes that the process of observation must begin with a tentative theory. This is done by collecting the data relevant to the theory. If these data are not consistent with the theory, then the theory must be rejected, or at least modified and retested (Blaikie, 2007: 185-7; Blaikie, 2010: 98).

4.5.1.3 The classical hermeneutical paradigm

In this paradigm, understanding came to be seen as important to human existence and the task of ordinary people. It was argued that there is no understanding out of history; human beings cannot step outside their social world, or the historical context in which they live. The social world should be understood on its own terms, in the same manner as its participants do, from the inside as it were, not from some outside position occupied exclusively by an expert (Blaikie, 2010: 99; Blaikie, 2007: 195).

4.5.1.4 The phenomenological/interpretivist paradigm

The research methods used in this approach are the collection of interpretative approaches, which seek to describe, translate, and otherwise come to terms, with meaning, not the frequency of certain more or less naturally occurring phenomena in the social world (Shakantu, 2014: 68).

Phenomenology is associated with research questions and phenomena of interest that require the exploration of detailed in-depth data, aimed at description, comparison or prescription. Thereby, the researcher gains a deeper understanding of a social phenomenon (Raddon, 2007: 7; Shakantu, 2014: 68).

The fundamental assumption of interpretivism is that paying attention to the meaning and interpretation of a phenomenon enables the research to gain an understanding of the phenomena under investigation (Ormston, Spencer, Barnard and Snaoe, 2013:12).

Interpretivism ensures that social reality is regarded as the product of its inhabitants. It is the world that is interpreted by the meanings which participants produce and reproduce as a necessary part of their every day activities together (Blaikie, 2010: 99).

Therefore, the latest contribution to interpretivism argues that the meanings used in social theories must be derived from social actors' concepts and meanings (Blaikie, 2007: 187; Blaikie, 2010: 99).

4.5.2 The contemporary research paradigm

The six contemporary research paradigms entirely reject both positivism and critical rationalism, and to some extent, they use/build on classical hermeneutics and interpretivism.

They include: "The critical theory, ethnomethodology, social realism, contemporary hermeneutics, structuration theory, and feminism" (Blaikie, 2007: 187; Blaikie, 2010: 99).

4.5.2.1 The critical theory

As the subject matter of the natural and social sciences are fundamentally different, consequently, their logic must also be different. The use of common logic must be rejected. This is, however, common with interpretivism and structuration. This paradigm rejects the interest of the emperical/analytical sciences; and it uses the historical hermeneutical techniques and rational criticism in the interests of human emancipation (Blaikie, 2010: 99).

4.5.2.2 Ethnomethodology

Since maintaining order becomes a practical problem that members of a society have to solve together in any particular circumstance, ethnomethodology, therefore, took as its basis, the study of the way ordinary members of society achieve and maintain a sense of order in their everyday practical activities (Blaikie, 2010: 99).

4.5.2.3 Social realism

This paradigm is another form of critical realism that has come to dominate the contemporary philosophy of science. It is designed to replace both positivism and critical rationalism. It claims to reflect what scientists do and also believe that reality consists not only of events that are experienced, but also of the events that occur whether they are experienced or not and of the structures that produce these events. This paradigm disagrees with the ontological status of social structures and mechanisms, which have resulted in two versions of the research paradigm: the structuralist and constructionist (Blaikie, 2010: 99).

4.5.2.4 Contemporary hermeneutics

This assumption has, however, developed into the two traditions of classical hermeneutics. Instead of looking for what the author of a text intends, or the real meaning, the text must be engaged in dialogue. This ensures that understanding involves the ‘fusion of horizon’ of the text and the interpreter. Different interpreters, at different times, could therefore produce different understandings. Therefore, a text creates a distance from the spoken discourse. As texts have no social context, and an unknown audience; consequently, no dialogue is possible between the reader and the author: they can be read in many ways (Blaikie, 2010: 99).

4.5.2.5 The structuration theory

This was developed as an attempt to bridge the gap between the traditions of social theory concerned with the experiences of social actors (agencies), and the traditions concerned with the existence of forms of social structure. It is based on the views that dualities, such as ‘subject’ and ‘object’, or ‘action’ and ‘structure’, need to be reconceptualised under the concept of duality of structure (Blaikie, 2010: 99).

4.5.2.6 Feminism

The feminist standpoint methodology rejects the legitimacy of traditional scientific norms and practices; and it recognises that a researcher’s background and location have a critical bearing on the research outcomes. Initially, it was argued that members of oppressed groups have a clearer understanding of the problems that need to be investigated; since they have had experiences that provide a more appropriate foundation for knowledge than those of the dominant groups. Hence, basing knowledge on women’s own experiences was regarded as providing more reliable knowledge, on which to base any subsequent political action. However, a major difficulty was to find a standard that would make such knowledge defendable in the face of opposition (Blaikie, 2010: 99).

4.5.3 The pragmatist paradigm

This is another branch of research paradigms that refuse to join the ‘paradigm war’ between the positivist and the interpretivist research philosophies. Instead of questioning ontology and epistemology, as the first step, the pragmatist supporters start off with the research question, in order to determine their research framework. They emphasise that one should view research philosophy as a field, rather than as various options that stand in opposite positions (Wahyuni, 2012: 71).

The pragmatist believes that objectivist and subjectivist perspectives are not mutually exclusive. Hence, a mixture of ontology, epistemology and axiology is acceptable to this approach, and in understanding social phenomena. Here, the emphasis is on what works best to address the research problem at hand.

Pragmatic researchers favour working with both quantitative and qualitative data; because this enables them to better understand social realities (Wahyuni, 2012: 71).

In order to have additional understanding about the relationship between research methodology and methods, Table 4.2 illustrates how to conduct a methodology, or to choose a method for a research.

Table 4.2: How to choose a research method

Research Methodology					Research Method			
Philosophy **(Approach to knowledge generation**	**Epistemology**	**Ontology**	**Social reality**	**Paradigm**	**Data**	**Direct observation of object reality**	**People's perception of object reality**	**Output**
Empiricist (a posteriori knowledge)	Objectivist	Parmenidean	Discrete and identifiable objects and phenomena	Positivist	-Numbers -Empirical, - Statistical, -Experimental Quantitative	-Field studies -Field experiments	-Structured interviewing -Survey research	-Data Processing and Presentation -Model
Rationalism (a priori knowledge)	Subjectivist	Heraclitean	Fluxing, changeable and emergent world	Phenomenological	-Words Observations Qualitative	-Action research -Case studies	-Historical analysis -Delphi/ Expert panel -Intensive interviewing	Development and Validation -Research Report (Treatise, Dissertation, Thesis)

(Source: Shakantu, 2014)

4.5.4 The Philosophical position of the research

This particular field of research falls within the built environment research; and since the built environment is at the centre of the natural and social sciences, the combined approach is considered suitable for this research project.

To determine the underlying issues about material waste and cost overrun in the Nigerian construction industry, the study adopts the following philosophical positions:

- Epistemologically, the problem being addressed by this research is an objective problem in need of measurement (volume of on-site material waste, building volume, archival records, and so on). It is based on the falsificationist and conventionalist assumptions. Therefore the research must be objectivist rather than interpretivist.
- Paradigmically, the research is positivist; because the problem being investigated is an objective social reality, requiring investigation and a survey of discrete and identifiable objects and phenomena.

- The ontological position of the research is Parmenidean and realist (caution, depth and subtle); because investigating the relationship between material waste and cost overruns in the Nigerian construction industry provides some sort of evidence to support generalizations about the management of material waste and cost overruns.

The philosophical position of the researcher strongly influences the research reasoning and consequently, the research data. Therefore, the next sections discuss the research reasoning, the research data, and the methods adopted for this thesis.

4.6 The Research Strategies/Reasoning

In answering research questions, social researchers are faced with the task of choosing the best research strategy or strategies to answer them. These strategies are normally used in the background of a research paradigm; and some are closely associated with a particular research paradigm (Blaikie, 2010: 80).

A research strategy, or logic of enquiry, provides a foundation and a set of steps by means of which 'what' or 'why' questions can be answered.

The choice of a research strategy, according to (Blaikie, 2010: 80), can be influenced by the following five factors:

- The familiarity or lack of familiarity of the researcher with the strategies;

- A researcher’s understanding of utility of certain ontological and epistemological assumptions;
- A researcher’s perceived link between the research methods and the research strategies.
- The preferences of audiences and consumers of the research, and associated politics; and
- A range of pragmatic factors, such as time, cost and the availability of equipment.

The four fundamental research strategies, according to Blaikie (2010: 79), each with its logic of enquiry, and its particular combination of ontological and epistemological assumptions are the: “Inductive, deductive, abductive, and retroductive strategies”.

4.6.1 The deductive research strategy

Deductive reasoning commences when a researcher works from the more general information to the more specific. It is sometimes referred to as the “top-down” approach; because the researcher starts at the top with a very broad spectrum of information and narrows down to a specific conclusion. For instance, a researcher might begin with a theory about his or her topic of interest. From there, he/she would narrow that down into more specific set of hypotheses that can be tested. The hypotheses are then narrowed down even further, when observations are collected to test the hypotheses.

This ultimately leads the researcher to be able to test the hypotheses with specific data, leading to a confirmation (or not) of the original theory, and arriving at a conclusion (Crossman, 2012: 1). A deductive researcher has to be able to answer the ‘why’ research questions, in order to explain patterns that he or others have observed when using an existing concept, or creating a new theory (Blaikie, 2010: 85).

Aqil-Burney (2008: 4) summarises the following points on the deductive research strategy:

- It works from the more general to the more specific;
- It is informally called a "top-down" approach; and
- The conclusion follows logically from the premises (the available facts).

Blaikie (2010: 85), therefore, concluded that a deductive research strategy is seen to have a number of essential steps:

- Putting forward an uncertain idea, a conjecture, or a hypothesis/hypotheses that form a theory;
- Specifying the conditions under which the hypotheses are going to work, and deducing a conclusion/conclusions;
- Explaining the conclusions and the logic of the argument that produced them;
- Testing the conclusion by gathering the relevant and appropriate data, and making the necessary observations, or conducting the necessary experiments.
- If the test fails, that is, if the data are not consistent with the conclusion; then it follows that the theory must be false.
- If however, the conclusion passes the test, for example the data are consistent with it; then the theory is temporarily supported. It is corroborated, but not yet proven to be true.

The important point is that a theory has to be invented or borrowed, and expressed as a deductive argument, the conclusion of which is the proposition that is to be explained. The theoretical ideas that lead to the conclusion should provide the explanation (Blaikie, 2010: 86).

In conclusion, a deductive research strategy in its original form was seen to produce explanations that were regarded as being tentative, and therefore, subject to modification or replacement; since the aim was to find the 'true' explanation (Blaikie, 2010: 87).

4.6.2 The inductive research strategy

Inductive reasoning is the opposite of the deductive approach, moving from the specific observations to broader generalisations and theories. This is sometimes called a "bottom-up" approach. The researcher begins with specific observations and measures, begins to then detect patterns and regularities, formulates some tentative hypotheses to explore, and finally ends up developing some general conclusions or theories (Crossman, 2012: 1).

The inductive reasoning is used in pursuit of understanding and knowledge, establishing a relationship between the observations and theory. It is used to establish theories, the purpose of which is to remove the need for continual observation, so as to make statements about reality, using past experience to generalise with reasonable levels of certainty about the future (Fox, 2008: 430).

Providing insight into inductive research, Sutrisna (2009: 9) states that it intends to learn about the phenomena under investigation by applying a less-structured methodology to obtain richer and deeper information. In an attempt to provide answers to the phenomena in question, inductive researchers try to keep their minds open for any possible results, while proposing further steps for the data collection.

In social science research, inductive reasoning is particularly relevant in qualitative methods that are used to extend the existing theory into a new setting, or to develop understanding and theory where none currently exists. Methodologies, such as grounded theory, use induction to systematically develop higher-level propositions that explain the structure of data (Fox, 2008: 430). Blaikie (2010: 83-85) asserts that in the inductive approach, a researcher describes social phenomena, in order to answer the 'what' research questions. The answer to a 'what' research question would be influenced by one's background knowledge, from both theory and previous research, as well as from traditions within a discipline, which would be limited in time and space. These descriptions are not, however, universal laws, as claimed by the original proponent.

Aqil-Burney (2008: 5) summarises the following points in inductive research strategy:

- It works the other way, moving from specific observations to broader generalisation and theories;
- Informally, it is called a "bottom-up" approach;
- The conclusion should be based on the premises; and,

- It involves a degree of uncertainty.

4.6.3 The retroductive research strategy

The logic of the retroductive approach refers to the process of building hypothetical models of structures and mechanisms that are assumed to produce empirical phenomena.

This approach involves working from the data to an explanation. The first stage is to provide an adequate description of the regularity to be explained. This is followed by an investigation of the characteristics of the context under study, and a consideration of any opposing mechanisms. The central problem for the retroductive research strategy is how to discover the structures and mechanisms that are proposed to explain the observed regularities (Blaikie, 2010: 87).

4.6.4 Abductive reasoning

Whereas the inductive strategy can be used to answer 'what' questions; and the deductive and retroductive strategies can be used to answer the 'why' questions, the abductive research strategy answers both types of questions. It answers the 'why' questions by producing understanding rather than an explanation and it does so by providing reasons, rather than causes. This involves constructing theories that are derived from social actors' language, meanings and accounts in the context of everyday activities (Blaikie, 2010: 89).

The abductive research approach combines what the inductive and deductive research strategies seem to ignore: the meaning and the interpretations, the reasons and the purposes, that people use in their everyday lives, and which direct their behaviour, and elevate them to a central place in research (Blaikie, 2010: 89).

In conclusion, abductive research can answer both the "why" and the "what" questions; and, together with the constructionist version of the retroductive strategy, they can deal with the purpose of understanding with their particular ontological and epistemological assumptions and the logic of their enquiry (Blaikie, 2010: 79).

The inter-relationship of research question/purpose, research strategies, research philosophy and paradigm is depicted in Figure 5.1.

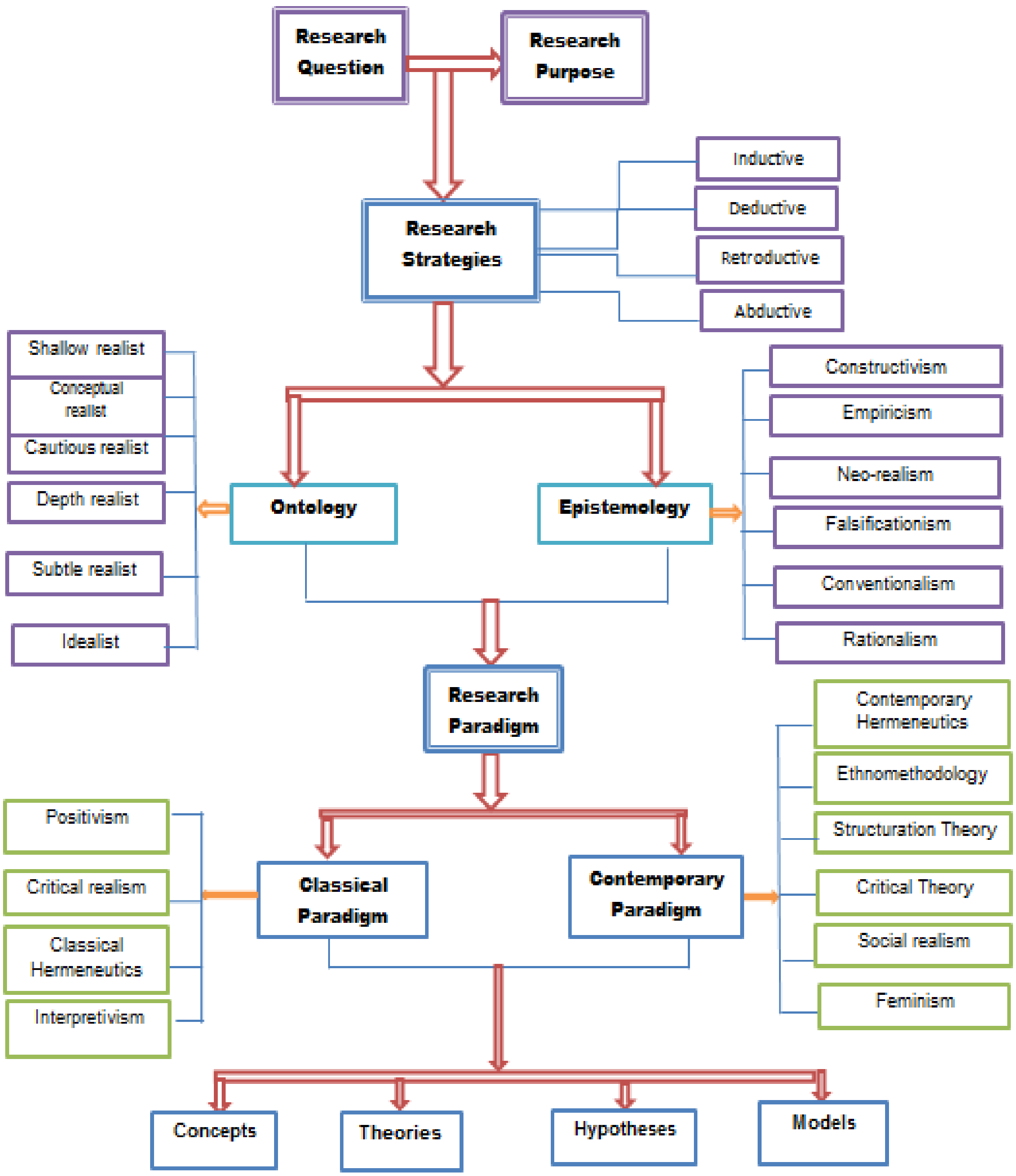


Figure 4.1: Research strategies and paradigms

Source: Adapted from Blaikie (2010)

Table 4.3 presents the logic of the four research strategies and their interrelationship with research aim, ontology, and epistemology.

Table 4.3: The logic of the four research strategies

	Inductive	Deductive	Retroductive	Abductive
Aim	To establish descriptions of characteristics and pattern	To test theories, to eliminate false ones and corroborate the survivor	To discover the underlying mechanisms to explain observed regularities	To describe and understand social life in terms of social actors' meanings and motives
ontology	Cautious, depth or subtle realist	Cautious or subtle realist	Depth or subtle realist	Idealist or subtle realist
Epistemology	Conventionalism	Falsificationism conventionalism	Neo-realism	Constructivism
Start	Collect data on characteristics and/or patterns. Produce descriptions	Identify a regularity that needs to be explained. Construct theory and deduce hypotheses	Document and model regularity and motives. Describe the context and possible mechanisms	Discover every day lay concepts, meanings. Produce a technical account from lay accounts
Finish	Relate these to research questions	Test hypotheses by matching them with data explanation in that context	Establish which mechanism provides the best	Develop a theory and elaborate it iteratively

Source: Blaikie (2010)

Additionally, it can be seen that there is an association between the research paradigm and the research reasoning employed for an enquiry. Deductive or objective reasoning can be associated with the positivist paradigm; while the inductive approach is mostly associated with the phenomenological or constructivist research paradigm.

4.6.5 Reasoning strategy for the research

The reasoning strategy adopted in this thesis is both deductive and inductive. The rationale behind this selection is explained as follows:

- Deductively, the research moves from theory to data. This is obvious in the review of the pre-existing/current body of knowledge in material waste and cost overruns in the construction industry (referred to in sections 2 and 3 of this study). They are used as a source of reference for this research. The review further identifies the important academic theories in the effective management of construction-material waste and cost overruns. In addition, the hypotheses are formulated to facilitate the testing, and to provide an explanation of the variables advanced in the research problems (as stated in sections 1.3 and 1.4 of this study).

- Inductively, the exploratory method is used to improve the understanding on the subject and the study area by using an in-depth interview schedule. This allows the researcher to obtain information (narrative data) on the professionals' (project managers, quantity surveyors, site engineers, and a senior technical officer) perceptions about the issues leading to material waste and cost overruns, as well as their management in the Nigerian construction industry at different stages (pre-contract and post-contract stages) of a project.

4.7 The Research Methods

Research methods are the techniques and principles used in conducting a research; while the research methodology is the discipline, or the body of knowledge, that utilises these methods (Kinash, 2008: 3). Vansteenkiste (2014: 1) views method as 'with the road' striving for a goal with a systematic approach. This subsequently becomes the defining approach of scientific thinking and research. The road signifies the means to gather such knowledge: through learning and research.

There are two types of methods in research: the quantitative and the qualitative methods. A third is the mixed-method approach which combines both the quantitative and qualitative methods, when investigating a phenomenon.

4.7.1 Quantitative research method

The quantitative research technique entails looking at the amounts or quantities of one or more variables of interest. A quantitative researcher measures the variables in some numerical form, by using the commonly accepted measures of the physical world, for instance, rulers and thermometers (Leedy and Ormrod, 2014: 97). Farrell (2011: 6) added that the quantitative method involves the analysis of numbers. It requires a choice between four different levels of measurement: nominal ordinal, interval and ratio. But the most basic level is the nominal measurement, in which objects, events, and people are assigned to specific categories in terms of their shared characteristics (Blaikie, 2010: 206). Put simply, the term ‘quantitative research’ refers to the approach to empirical investigation that collects, analyses, and displays the data in numerical, rather than in narrative form (Donmoyer, 2008: 718).

4.7.2 Qualitative research method

The qualitative method involves analysing words; it refers to issues relating to people, objects and situations; and it focuses on naturally occurring, ordinary events in their natural settings (Farrell, 2011: 6).

Amaratunga, Baldry, Sarshar and Newton (2002: 21) outlined some of the major characteristics of a qualitative research as:

- Firstly, it focuses on naturally occurring, ordinary events in natural settings, so there is a view on what “real life” is like.
- Secondly, it enriches, with strong potential for revealing complexity; it also provides rich descriptions that are valid and reflect elements of the truth.
- Thirdly, because the data are collected over a sustained period of time, this makes it powerful for studying any process.
- Fourthly, the essential flexibility of the qualitative method gives further confidence that what has been going on is fully understood.

On the basis of these features, qualitative research has been encouraged as the best strategies for discovery, exploring new ideas, and developing the hypotheses. However, the approach is faced with four major constraints, as follows:

The volume of the data; the complexity of the analyses; the details of the classification records; and the flexibility and the momentum of the analyses (Amaratunga *et al.*, 2002: 21). The qualitative research method is useful when one needs to complement, validate, explain, illuminate, or re- interpret the quantitative data gathered from the same settings (Amaratunga *et al.,* 2002: 21).

Table 4.4 presents the differences between the quantitative and the qualitative research approaches.

Table 4.4: The differences between qualitative and quantitative methods

Sn	Quantitative Method	Qualitative Method
1	Considered hard science	Considered soft science
	Basis of knowing—cause and effect relationships	Basis of knowing—meaning, discovery
	Ask specific narrow questions	Ask broad, general questions
2	Fixed response options	Unstructured or semi-structured response options
	Seek measurable and observable data	Seek to understand the participants experience
3	Data consisting largely of numbers	Data consisting largely of words (text) or images
4	Analysing numbers using statistics	Descriptions and analysis of words of theme
5	More objective: provides observed effects (interpreted by researchers) of a program on a problem or condition	More subjective: describes a problem or condition from the point of view of those experiencing it
6	Primarily deductive process used to test pre-specified concepts, constructs, and hypotheses that make up a theory	Primarily inductive process used to formulate theory or hypotheses
7	Deductive reasoning used to synthesise data	Inductive reasoning used to synthesise data
8	Statistical tests are used for analysis	Statistical tests are an option not obligatory
9	Surveys, structured interviews and observations, and reviews of records or documents for numeric information	Methods include focus groups, in-depth interviews, and reviews of documents for types of themes
10	Less in-depth but more breadth of information across a large number of cases	More in-depth information on a few cases
11	Can be valid and reliable: largely depends on the measurement device or instrument used	Can be valid and reliable: largely depends on skill and rigor of the researcher
12	Tests theory	Develops theory
13	Single reality that can be measured and generalised	Multiple realities that are continually changing with individual interpretation
14	More generalisable	Less generalisable

Source: Adapted from (Amaratunga *et al.,* 2002; Donmoyer, 2008; Cresswell, 2008; Leedy and Ormrod, 2014).

4.7.3 Methods adopted for the research (the mixed or multi-method)

The research method/technique whereby a researcher collects and analyses the data, integrates the findings, and draws inferences using both the qualitative and the quantitative approaches or methods in a single study is referred to as the mixed method, or multi-methodology (Cresswell, 2008: 529). It combines the strengths of both approaches to best understand the research problems. Therefore, researchers need to be aware of the possibility of combining qualitative and quantitative methods, when appropriate, for addressing the research questions (Cresswell, 2008: 529).

The important assumptions of the quantitative and qualitative methods to research come from the two extremes of the data range. While the quantitative approach is related to the deductive-objective-generalising domain, the qualitative approach is associated with the inductive-subjective-contextual domain (Morgan, 2008: 683).

From the above mentioned, the elements of both the quantitative and the qualitative methods applying to this research are presented as follows:

- Quantitatively, the data generated from the numeric measurement of the volume of on-site material waste, the amount of the project cost overrun, and the tick box of questions from the interview are analysed and interpreted by using descriptive and inferential statistics. This provides evidence to support any generalisation about material waste and cost overruns in the Nigerian construction industry.

- Qualitatively, the research tends to produce rich and subjective data due to the level of involvement of the researcher in the data-collection process. For instance, the data are acquired from the narrative from the respondents leading to material waste and cost overruns in the construction industry. This requires the use of a qualitative tool (for in-depth interviews) to capture the experiences of the respondents.

4.8 Data, their Treatment and Interpretation

This section describes the nature of the data, the population and the sample, their treatment and interpretation.

4.8.1 The data

The data for a research could either come from a primary source, or from a secondary source, or from a combination of primary and secondary sources (Wahyuni, 2012: 73).

In view of the problems and sub-problems advanced in this study, the data were derived from both primary and secondary sources.

4.8.1.1 The secondary data

Secondary data are pre-existing data that have been collected for a different purpose, or by someone other than the researcher (McGinn, 2008: 801). They are published or unpublished work that is one step away from its original source (University of Victoria Library, 2014:1).

The relevant secondary data for this research were used to lay a theoretical foundation for the study. These include published materials (books, journals) and unpublished reports, such as periodicals, conference proceedings, building codes, and policies and guidelines relating to material waste and cost overruns in the construction industry.

4.8.1.2 The primary data

The primary data are the original materials on which the research is based. They are the first-hand testimony or direct evidence concerning a topic under consideration, which are collected or observed by the researcher. They present information in its original form (Babbie, 2007; University of Victoria Library, 2014: 1).

This study focused mainly on the primary data, which included: the field investigation, interviews, and data from the archival records (drawings, bills of quantities, project progress reports, and specifications). A semi-structured, but in-depth interview was conducted with the project professionals (Project Managers, Quantity Surveyors, Site Engineers, and staff of waste management departments) on the issues relating to material waste and cost overruns in the Nigerian construction industry. These were based on the established structure related to the conceptual model of this study in order to ascertain what actually happens in practice.

4.9 The Data-Collection Methods

Based on the objectives of the study, the following data-collection methods were employed:

4.9.1 Interview schedules

The interview schedule is a method of data collection, which allows for a conversation between the interviewer and the respondents on those issues that relate to the problems of a research, where the interviewer becomes an attentive listener (Haigh, 2008: 112).

The data for this research were generated through a semi-structured, but in-depth interviews conducted in conjunction with a tick box of questions marked/ticked by the researcher in the course of the interview, in order to evaluate the rate of occurrence of the issues leading to material waste and cost overruns in the construction industry in the study area.

This approach allows for clarifications of both the answers and questions during the interview session. The interviews were conducted mostly at the interviewees' offices; and they lasted from 45 to 75 minutes each.

The respondents of the interviews were construction industry stakeholders (stated in 4.8.1.2) to solicit their opinions on those issues leading to material waste and cost overruns, based on the established structure, and relating to the conceptual model of this study.

4.9.2 Archival records

The volume of materials used for each building project was generated from the measured quantities of each material from the priced/unpriced bills of quantities (BOQ) prepared for the project. The measurement units of materials, as contained in the BOQ (linear, square and cubic metre, number, kilogram, tonne, and so on) were each converted to a common standard unit (volume/cubic metre). The converted volumes were summed up to achieve the total volume of material for a building.

Where access to BOQ was denied, the building volume was also generated by taking direct measurements of the quantities from drawings, and by making the necessary adjustment (for openings, plastering, finishes and so on), in accordance with the rules of the standard method of measurement for building works (SMM), in order to determine the net building volume.

The data on estimated cost (EC), estimated time (ET), cost now (CN), and time now (TN), the percentage of the work completed $(\%\ of\ WC)$, the estimated cost of the work completed $(ECWC)$, and the actual cost of work completed $(ACWC)$ for different projects were collected from the records of projects compiled by the Quantity Surveyor. The collected value of "$ECWC$" was deducted/subtracted from the value of "$ACWC$" to determine the project's cost overruns.

4.9.3 Field investigations

The data on the volume of on-site material waste were generated by physical on-site measurements with the aid of measuring instruments, such as tape and measurement rule.

Where the generated on-site material waste has already been disposed and removed from site, a request was made to access the total volume (material waste) disposed/removed from the project's onsite records.

The collected data (waste volume) were used to determine the contribution of material waste to the generated amount of cost overruns; and these were utilised to develop a statistical model, as stated in the objectives (Section 1.6) of the study.

4.10 Research Population and Sample

This section presents the population, the sample frame, and the sampling techniques for the research.

4.10.1 The research population

The research population is a complete set of elements (persons or objects) that possess some common and distinct characteristic, according to the sampling criteria identified by the researcher (Cassim, 2014: 73).

It is necessary to define the population of a research, from which the sample is to be drawn. Thus, a population is referred to as a collection of all those cases that conform to some selected set of criteria. The population elements are single members or the units of a population: for instance, people, social actions, social situations, events, places, time or things (Blaikie, 2010: 172).

A researcher is, therefore, allowed to define a population in whatever way deemed appropriate, in order to address the research questions. However, any count of all the population elements used to describe the characteristics of the population is referred to as a census (Blaikie, 2010: 172).

4.10.2 The research sample

A sample is the selection of elements (members or units) from a population; and this may be used to make a general statement on the whole population. The ideal sample is the one that provides a perfect representation of the population with all the relevant features of the population included in the sample in the same proportions (Blaikie, 2010: 172). A sample is a smaller group of individuals which must represent the target population, so that the data from the sample would accurately represent what is happening in the target population (Cassim, 2014: 73).

A sample comprises the data set of the actual data sources that are drawn from a larger population of potential data sources. Within the broad process of sampling, choosing the actual sample is the second step in a two-step process, which begins with defining the population that is eligible for inclusion in the sample. Approaches to selecting samples are typically divided between probability sampling and non-probability sampling (Morgan, 2008: 797).

Given that a research sample is the selection of 'units' from a population, Boyd (2008: 929) argued that, following common practice, a study's units of analysis may be different from its units of observation.

- **The unit of observation:** This is a basic concept in quantitative research that represents the objects that are observed and about which information is systematically collected. This is determined by the method by which observations have been selected. Researchers base conclusions on the information that is collected and analysed. Using defined units of observation in a survey or other study helps to clarify the conclusions that can be drawn from the data collected.

- **The unit of analysis:** One of the most important ideas in a research project is the unit of analysis. This could be defined as those entities about which research data is collected and the object about which generalisations are made based on an analysis. This is determined by an interest in exploring or explaining a specific phenomenon. For instance, a unit of observation might be an individual person, but a unit of analysis might relate to the neighborhood in which the individual lives, based on data collected about individuals in the neighborhood (Boyd, 2008: 929).

For the purpose of this research, the **unit of study** is the construction project site; the **unit of observation** is the volume of onsite material waste; and the **unit of analysis** is the effect of the observed volume of material waste on project-cost overrun.

4.10.2.1 The sample frame

A sampling frame defines the members of the population who are eligible to be included in a given sample in the sense of drawing a boundary or frame around those cases that are acceptable for inclusion in the sample. This is most common in survey sampling, where it is associated with a countable listing of all the data sources in the population that are accessible for sampling (Morgan, 2008: 800-801). Babbie (2010: 208-209) believes that the sample frame is the list of elements, from which the probability sample is selected. However, a sample frame must be in agreement with the entire population of the study.

Babbie (2010: 209) compiled the following issues relating to the sample frame and the research population:

- The findings based on the sample can be taken as representing only the aggregation of elements that compile the sampling frame itself; and
- Frequently, sampling frames do not truly include all the elements their names might imply. Omissions are inevitable. Thus, a first concern of the researcher must be to assess the extent of omission, and to correct this if possible.

To be generalised to the population constituting the sampling frame, all the elements must have equal representation in the frame.

4.10.2.2 The sample size

Sample size is the number of data sources that are actually selected from the total population. The basic principles of statistical sampling prescribe that the accuracy of an estimate from a probability sample is strongly influenced by the size of the sample itself. The importance of sample size in determining the accuracy of the results is the reason that larger samples produce more accurate estimates than do smaller samples (Morgan, 2008: 798).

4.10.2.3 Sampling technique/method

The two main extremes of the sampling method, according to Blaikie (2010: 172), are the probability and the non-probability sampling.

Probability samples require that every member of the population has a known and non-zero chance of being included/selected in the sample. The most basic form of probability sampling is simple random sampling, where every member of the population has an equal chance of being included in the sample. Thus, a simple random sample of 100 people from a population of 10,000 gives each person a 100 to 10,000 or a 0.01

probability of being in the sample (Morgan 2008: 681, Leedy and Ormrod, 2014: 213; Blaikie, 2010: 159; Leedy and Ormrod, 2013: 195).

For quantitative research, the statistical analyses that are possible, occur only with probability samples which can justify the demands of knowing the population size, determining the probability of selection for each sample member, and gathering large samples. However, in qualitative research, statistical analyses are not only of little interest; but they are also largely unrealistic; because of the small sample sizes employed in those studies (Morgan, 2008: 681).

Morgan (2008: 681) highlighted the two basic advantages of probability samples when considering the quantitative approach:

- Firstly, they must allow statistical statements about the accuracy of the sample's numerical results. For example, a political poll may say that there is a 95 percent likelihood that its results are within 3 percent either way of the actual population value.
- Secondly, they are essential for tests on statistical significance of the sample.

The probability sample includes the following:

- **Simple random sampling:** Every data source in the population has an equal chance of being included in the sample (Morgan, 2008: 725, Leedy and Ormrod, 2014: 213; Blaikie, 2010: 159; Leedy and Ormrod, 2013: 195). The units comprising a population are allotted numbers, and a set of ramdom numbers is generated, and the units having those numbers are included in the sample (Babbie, 2010: 211).

- **Systematic sampling:** This allows every unit in a list to be selected for inclusion in the sample (Babbie, 2010: 211); it involves selecting individuals or clusters/groups, according to a predetermined order; and the order must originate by chance. The population elements can be put in a list, and be counted (Leedy and Ormrod, 2014: 218).

The systematic sampling method, according to Blaikie (2010: 174), can be used for two purposes:

- Firstly, when a researcher wishes to ensure that the particular groups in the population are represented in the sample, in the same proportion, as they are to be found in the population. Then, it must be possible to identify the population elements in terms of the appropriate features, so that the population elements can be grouped into the desired strata before any selection is made.
- Secondly, it is to ensure that there are sufficient numbers in the sample from all those categories that are to be examined.

- **Cluster sampling**: This sampling method is mostly used when it is difficult to list all the elements in the population; it concentrates on a number of areas, rather than being scattered over a wide area; and it is less accurate than simple random sampling (Blaikie, 2010: 175). Clusters should be as similar to one another, as is possible, with each cluster containing an equally heterogeneus mix of individuals (Leedy and Ormrod, 2014: 218).

- **Stratified sampling:** This divides the total population into separate subsets or strata before drawing random samples from each of these strata; and it has the advantage of guaranteeing equal representation for each of the identified strata. It is most appropriate when the strata are roughly equal in size in the overall population (Blaikie, 2010: 174; Leedy and Ormrod, 2014: 213).

On the other hand, the non-probability sample does not give every population element a chance of being selected. The relationship between the size of the sample and the size of the population is known as the sampling ratio (Blaikie, 2010: 172).

Moreover, the size of non-probability samples is influenced by the purpose of the research, and by the type of analysis that is to be undertaken. Therefore, while compromise may be necessary in non-probability sampling, care must be taken not to jeopardise the possibility of answering the research questions (Blaikie, 2010: 159).

The non-probability sampling methods include the following:

- **Convenience/accidental sampling:** It is likely to generate an unrepresentative sample; and, hence, it is regarded as the most unsatisfactory form of non-probability sampling. The use of such a method may be a sign of laziness or inexperience on the part of the researcher (Blaikie, 2010: 177). However, convenience sampling may be relatively appropriate for some research problems (Leedy and Ormrod, 2014: 220). A typical convenience sample is obtained when an interviewer stands on the street and selects people accidentally as they pass. Such respondents are representative of no particular population. Therefore, in some circumstances, a researcher may have to use such a sampling method as a last resort; but the results from such a study would need to be heavily qualified (Blaikie, 2010: 177).

- **Quota sampling:** This is the commonly used non-probability method of sampling, which is an improvement on accidental sampling, and is commonly practised when it is impossible, difficult or costly to identify the members of a population. It has the advantage of producing a sample with a similar distribution of characteristics to those that are considered to be important in the population, which it is supposed to represent (Blaikie, 2010: 177). Leedy and Ormrod (2014: 220) opined that quota sampling selects respondents in the same proportion that they are found in the general population, but not in a random approach. Therefore, it is a variant of the convenience sampling method.

- **Snowball sampling:** This method is sometimes referred to as the network, chain referral, or reputational sampling. The analogy is of a snowball growing in size, as it is rolled in the snow. For instance, in a difficult situation of identifying a population, such as intravenous drug users, it may be possible to contact one or two users who could then be asked for the names and addresses of other users. In this way, other members could be found and interviewed (Blaikie, 2010: 179).

- **Purposive /judgmental sampling:** This is a type of sampling technique, where the subjects are selected on the basis of some characteristic; and it is more consequently popular in qualitative research. Included in this, is the idea that who a person is, and where that person is located within a group, are important considerations compared to other forms of research, where people are seen as essentially interchangeable (Palys 2008: 697). Leedy and Ormrod (2014: 221) highlight the fact that purposive sampling ensures that the researcher chooses people or other units, as the name implies, for a particular purpose. Blaikie (2010: 178) added that judgmental sampling is used for selecting some cases of a particular type in the population. For instance, a study of organisational behaviour may use a few cases of organisations that have been particularly successful in achieving what a researcher is interested in.

Palys (2008: 697-698), therefore, outlined the seven (7) examples of the purposive alternatives available as follows:

i. ***Stakeholder sampling****:* This involves identifying who the major stakeholders are; who are involved in administering the programme being evaluated; and who might otherwise be affected by it.

ii. ***Extreme or deviant case sampling:*** Sometimes extreme cases are of interest, as they accurately represent the occurrence of a phenomenon, in which a researcher is interested.

iii. ***Typical case sampling:*** Sometimes researchers are interested in cases simply because they are not unusual in any way.

iv. ***Criterion sampling:*** This involves searching for cases or individuals who meet a certain criterion.

v. ***Theory-guided sampling:*** Researchers who are following a more deductive or theory-testing approach would be interested in finding individuals or cases that embody certain theoretical constructs.

vi. ***Critical case sampling:*** Here, the researcher might be looking for a decisive case that would help make a decision about which of several different explanations is the most acceptable.

vii. ***Expert sampling:*** The researcher here is looking for individuals who have a particular expertise that is most likely to be able to advance the researcher's interests, and potentially open new doors.

Others include: Disconfirming or negative case sampling, paradigmatic case sampling, and maximum variation sampling (Palys, 2008: 697-698).

4.11 The Population and Sample of this Research

This study covers building construction projects within Abuja, the Federal Capital Territory of Nigeria, from which a sample of 33 projects was selected. The sample comprises both public and private projects, with a value of 1.6 billion Naira/100 million Rand and above, using both criterion-based and expert-purposive sampling techniques. The rationale for the selection (criterion and expert purposive sampling) is that building construction projects of this value and above are likely to generate large quantities of material waste and huge cost overruns, when compared with projects of less value. Also, it is possible to have more experts (experienced professionals) than in smaller-sized/lower-valued projects.

The choice of targeting building construction projects in this area is done for the following reasons:

- The proximity of the researcher's state of origin to the study area (FCT, Abuja)
- Abuja has the highest population of built environment professionals in the country; and it has many on-going building construction projects.
- The location of the construction projects in the same area makes the study more economical in terms of cost and time.

4.11.1 Sample characteristics

The interviews were carried out from January to March, 2015, and targeted the construction professionals, including the project managers, Quantity Surveyors, Site Engineers, and Senior Technical Officers (Waste management) of the Nigerian construction industry.

In total, thirty-eight (38) requests for interviews were sent to the management of different projects in the Nigerian construction industry. Thirty-two (32) respondents agreed to be interviewed; while six (6) others declined and two (2) of the responses were considered not valid to the researcher (the responses were not in line with the questions being asked), thereby making a total of thirty (30) valid responses.

The overall response rate was 78.95 percent, which is adequate. The reason for not achieving a 100 percent rate was attributed to two major issues. Firstly, most of the respondents explained that they were overwhelmed with the amount of work during the period; and thus they declined to be interviewed. Secondly, several were reluctant to be interviewed because the questions involved a number of sensitive issues, which they did not want to disclose to the public. Again this was in spite of the researcher's assurance on the issues of anonymity and confidentiality.

Additionally, those who participated in the interview had all demonstrated great enthusiasm in the research, and provided much precious information for the researcher, enabling him to come to a better understanding of the framework and operation of material-waste management and cost overruns in the Nigerian construction industry.

4.12 Analyses and Treatment of the Data

Data analysis is the systematic organisation of the raw data into a meaningful pattern, which involves inspecting, categorising, transforming, and modelling the data (Babbie, 2007 : 378).

For the purpose of this study, descriptive, narrative, and inferential analyses of the data were employed.

4.12.1 Descriptive analysis

The descriptive tools that were used to analyse the data included: the frequency distributions, percentage distributions, cross-tabulation, and ranking methods. The results were presented in tables, charts, and graphs.

4.12.2 Narrative (interview) analysis

Pheng, Arain and Ting (2010: 79-134) categorised the methods of analysing the generated interview data into two major classes, namely:

- The deductive approach: This involves constant comparative analysis after the interview data have been sorted and coded to generate knowledge about any common pattern within the interviewees' evidence on material waste and cost overrun in the Nigerian construction industry. This method is mostly suitable for larger samples of interviews, with the same series of questions being asked.
- The case-study approach: This involves analysing the interview results separately, according to the individual interviewees' response (case by case). This method is suitable for smaller samples of the interview data.

Based on the theoretical and conceptual framework of material waste and cost overrun, eight main issues were identified, namely: The quality of the planning, the quality of design management, the design complexity, the quality of estimating, the quality of procurement management, the quality of construction management, the quality of site management, and the material-waste minimisation and the management thereof.

For the purpose of this study, the recorded, transcribed and interpreted interview data were analysed by using the deductive approach.

The analysis began by comparing the opinions made by the first two interviewees. The process continued with a comparison of the data from the comments and inputs from each new interviewee until all the responses had been compared with each other. The similarities and differences among the interviewees' responses were used to develop a conceptualisation of the possible relationship between the various data items.

4.12.3 Inferential analysis

In order to draw useful inferences and generalise the results of the sample to the whole population, the inferential tools that were used included: regression analyses, Pearson moment-correlation analyses, and an analyses of variance (ANOVA).

The linear-regression equation was used to develop the statistical models (as stated in section 1.6 of the study).

For a linear regression equation: $y = a + bx,\ \ and\ \ x = a - \frac{y}{b}$

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\ \sum x^2 - (\sum x)^2}$$

Where "y" is the dependent variable (Volume of waste); "x" is the independent variable (building volume); "b" is the coefficient of "x; and "a" is a constant.

The analysis of variance (ANOVA) was used to analyse the variance and compare the differences in the views of the construction professionals (Project Managers, Quantity Surveyors and Site Engineers) on: the effects of sources, causes, and control measures for material waste on cost overruns for each item in the conceptual framework of the study (Osborne, 2008: 222).

The $ANOVA$ equation is given as $F = \frac{MST}{MSE}$, where F= the ANOVA coefficient, MST= the Mean sum square from the treatment, and MSE= Mean sum square due to error.

$MST = \frac{SST}{P-1}$, $and\ SST$= $\sum n\ (x - \bar{x})^2,$ where $\boldsymbol{SST}$ = Sum of square due to treatment,

$\boldsymbol{P}$= the total number of populations, and $\boldsymbol{n}$= the total number of samples in the populations.

$$\boldsymbol{MSE = \frac{SSE}{N-1}\ \ and\ \ SSE = \sum(n-1)\,S^2}$$

Where $\boldsymbol{SSE}$= Sum of square due to error, $\boldsymbol{S}$=standard deviation of samples, and $\boldsymbol{N}$= Total number of observations (Osborne, 2008: 222).

A Pearson moment-correlation analysis was used to determine the contribution of material waste to the project's cost overrun. Material waste was represented by the independent variable(x); and the cost overrun was represented by the dependent variable (Y); since material waste can cause cost overruns.

The Pearson moment correlation is represented mathematically as:

$$r = \frac{\mathbf{n}(\sum \mathbf{xy}) - (\sum \mathbf{x})(\sum \mathbf{y})}{\sqrt{[\mathbf{n}\sum x^2 - (\sum x)^{\mathbf{2}}][\mathbf{n}\sum \mathbf{y}^{\mathbf{2}} - (\sum \mathbf{y})^{\mathbf{2}}]}}$$

Where:

$r =$ Pearson moment-correlation coefficient

$x =$ Values in the first data set

$y =$ Values in the second data set

$n =$ Total number of values

For testing the reliability of the analyses, a Statistical Package for Social Science (SPSS), Statistica, and Microsoft Excel softwares were employed for the analyses.

In order to gain more insight into the research approach, Figure 4.2 presents a summary of the research methodology.

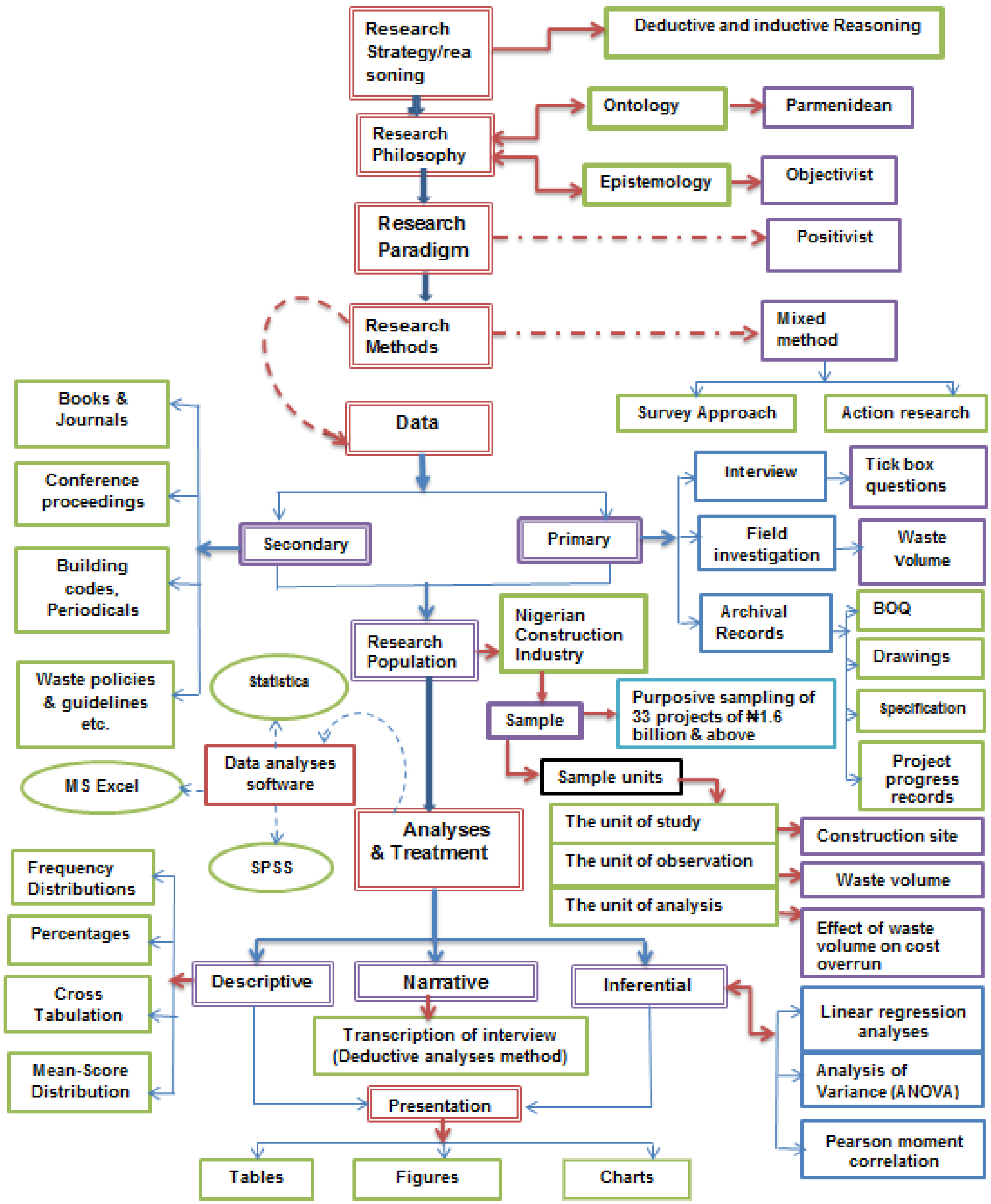


Figure 4.2: Summary of the research methodology

Source: Researcher's construct, 2015

4.12.4 Validity and reliability of the data

Research reliability is generally defined as the ability of a collected data, and the interpretation or the analysis to be dependable, trustworthy, uniform, and repeatable (Miller, 2008: 754). The extent to which the results are consistent over time and an accurate representation of the total population under study is referred to as the reliability; and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable (Golafshani, 2003: 598).

Miller (2008: 754) argues that the understanding of reliability is dissimilar in the qualitative research from the quantitative research view point.

Therefore, in the quantitative field; reliability precisely deals with the degree to which many researchers of the same problem/study using identical procedure arrive at similar results. This allows variation in results to be regarded as measurement error.

Consequently, from a quantitative research viewpoint, reliability is however, defined, sought, measured, and recognised as an important factor for indicating the quality of a study (Miller, 2008: 754). But, reliability has not been viewed with much uniformity in qualitative research approach, due to the diversity in paradigm and methodology in the field (Miller, 2008: 754).

Research validity on the other hand, determines whether the research truly measures that which it was intended to measure, or how valid the research results are (Golafshani, 2003: 599).

For the purpose of this study, all the information presented are factual, substantiated by the nature of face-to-face pre-interviews, respondents' opinions expressed in the preliminary pre-testing amongst a purposive sample of the firm/companies not necessarily included in the survey. All the feedbacks are incorporated in the study instrument in the research report.

4.12.5 Ethical considerations

Ethical issues in research are concerned about privacy, consent, confidentiality, deceit and avoiding harm to those involved in the research (Morton and Wilkinson, 2008: 43). They are referred to as, the norms that differentiate between the right, and the wrong behaviour in research (David and Resnik, 2011: 1). Therefore, this research considered the following ethical issues:

- *Plagiarism*: The research acknowledges the work of others used as materials in the research work. All sources of information are identified and appropriately referenced.

- *Confidentiality and anonymity*: The individual rights to confidentiality and privacy are protected in this research. Responses/data generated from the field work and interviews on material waste were treated with absolute confidentiality and used for academic research purposes only.

- *Compliance with law and standards*: The research was undertaken within and does not contravene the rules and regulations of the Nelson Mandela Metropolitan University as regards research;

- *Honesty and trust*: The research reported the data, the methods, and the results as they are, without fabrication, or misrepresentation;

- *Integrity*: The research was conducted with sincerity, strive for consistency of thought, and action.

- *Informed consent*: The consent of the participants (project managers and other professionals) in this research was duly obtained.

4.13 Concluding Remarks

This chapter has discussed the research design, the strategy/reasoning, the philosophy, the paradigm, and the method adopted. The chapter has also discussed the research population; sample, type of data, sources, collection, and the methods of analyses. In the next chapter, the data will be presented, analysed and interpreted.

Chapter 5: The Data Presentation, Analysed Results, and Interpretation

5.1 Introduction

In this chapter, the research presents and discusses the results of the exploratory interviews conducted with project professionals on the issues relating to the management of material waste and cost overruns in the Nigerian construction industry.

The chapter also presents the results of the archival records and of the field investigations on material waste and cost overruns.

Inferential statistics are used to evaluate the main hypotheses postulated for the study. Tables, figures, and charts are used for data presentations, analyses, and for the interpretation of the results.

The results of the interviews conducted are coded as: PM-01, PM-02, PM-03---PM-15 (Project Managers, 1 to 15); QS-01, QS-02--- QS-09 (Quantity Surveyors, 1 to 9); SE-01, SE-02 ---SE05 (Site Engineers, 1 to 5); and STO (Senior Technical Officer of a waste-management unit).

The responses on the effects of material-waste sources, causes, and the control measures on project cost overruns are rated, on the basis of the cut-off points highlighted by Morenikeji (2006) in a five-point Likert scale. The cut-off points, which are in frequencies (less than 1.5 to 5), are further converted to percentages; because the results of the cross-tabulation analyses for this study are expressed in percentages, as indicated in Table 5.1.

Table 5.1 shows that the material-waste sources, the causes, and the control measures that have percentages of between 90 and 100 are rated “very high effect” on cost overruns; 70 to 89 percent are rated as “high effects”; 50 to 69 percent are rated as “moderate effect” which is average; 30 to 49 percent are rated as “little effect”; and between 1 and 29 percent are rated as “very little effect” on cost overruns.

Consequently, the material-waste sources, causes, or control measures that have a frequency of 0.0 percent are rated as “no response”; because none of the respondents mentioned them in the course of the interview.

Table 5.1: Cut-off points for deciding the effects of material waste on cost overruns

S/n	Cut-off (5 to 1)	Cut off in % (100 to 1%)	Decision
1	4.5 to 5.0	90 to 100%	Very high effect
2	3.5 to 4.49	70 to 89%	High effect
3	2.5 to 3.49	50 to 69%	Moderate effect
4	1.5 to 2.49	30 to 49%	Little effect
5	Less than 1.5	29 to 1%	Very little effect

Source: Researcher’s construct, 2015

Furthermore, the material-waste sources, causes, or control measures that started with the sign (*) in subsequent tables are the newly identified issues in the course of the interview with the respondents, which were not originally included in the interviewer’s tick box.

5.2 The Outline of the Research Data

The research data, which were sourced through the use of a semi-structured, but an in-depth interview, a field survey, and the archival records sought to achieve six issues:

Firstly, the profiles of the interviewees were collected via the first nine (9) questions of the interview.

Next, the effects of material-waste sources, causes, and the control measures on project-cost overruns were identified from the interview and the tick box of questions using a cut-off point Likert-scale statement.

Thirdly, the narrative data from the interviews were discussed as appropriate.

Fourthly, the benefits of recovering construction-waste materials (re-use and recycling) and their effects on cost overruns were examined.

Fifthly, the percentages of additional cost contributed by material wastage to project cost overruns were identified.

Lastly, the data for developing the statistical models used for quantifying the amount of material waste generated in the Nigerian construction industry were collected and analysed as appropriate.

5.2.1 Profile of the interviewees

The construction stakeholders/professionals were contacted to elicit their participation in the research. The people contacted for each project in every organisation were those who are in the know, or are authorised to provide necessary information. Assurances were made to them that the purpose of the study was to analyse the effects of material waste on project cost overruns in the Nigerian construction industry for academic purposes; and that none of the provided information would be revealed or reflected in any way.

Figure 5.1 shows that 50 percent of the interviewees were project managers; 30 percent were project Quantity Surveyors; 16.67 percent were Site Engineers; and 3.33 percent were Senior Technical Officer (waste-management unit) for the visited projects.

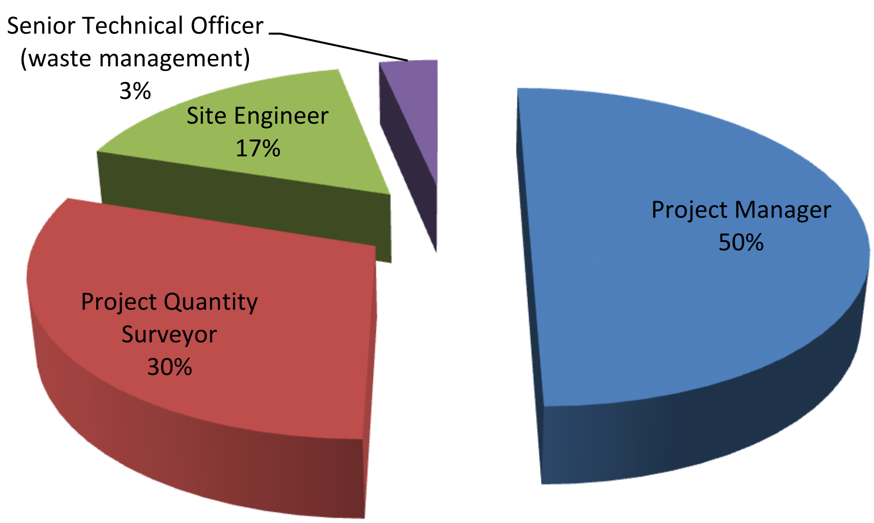


Figure 5.1: Profile of interviewees

Source: Researcher's field survey, 2015.

5.2.2 Interviewees' working experience profile

The analysis of the interviewees' working experience profile revealed in Figure 5.2 that 44 percent had a working experience of 16 to 20 years; 27 percent had worked for 11 to 15 years; 13 percent had worked for 21 to 25 years; while another 13 percent had worked for 6 to 10 years; and only 3 percent had worked for 1 to 5 years in the construction industry.

Therefore, the number of work-experience years the interviewees had had in the construction industry ranged from 5 to 25 years:

A vast majority of the interviewees (83 percent) had practised for more than 10 years in the construction industry; and 57 percent had more than 15 years' working experience in the construction industry. Therefore, these results also show a high degree of reliability in the interviewees' responses.

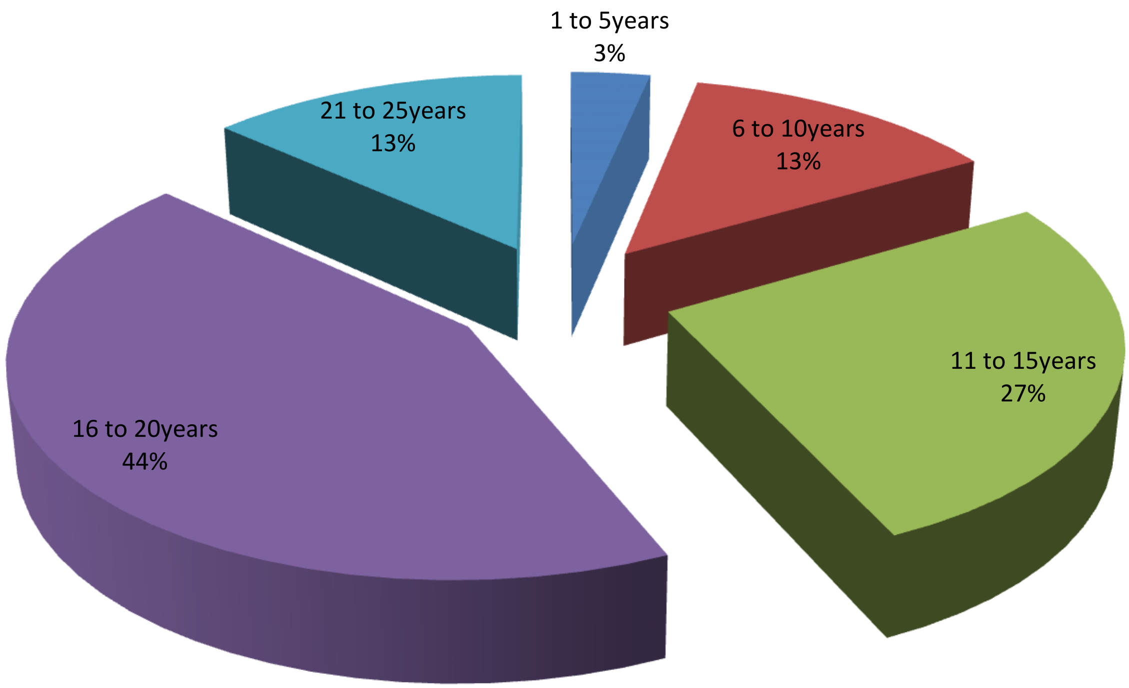


Figure 5.2: Interviewees' working experience profile

Source: Researcher's field survey, 2015.

5.2.3 Type of projects visited

Figure 5.3 shows that 53 percent of the projects visited within the study area were government-owned; while 47 percent were privately-owned projects.

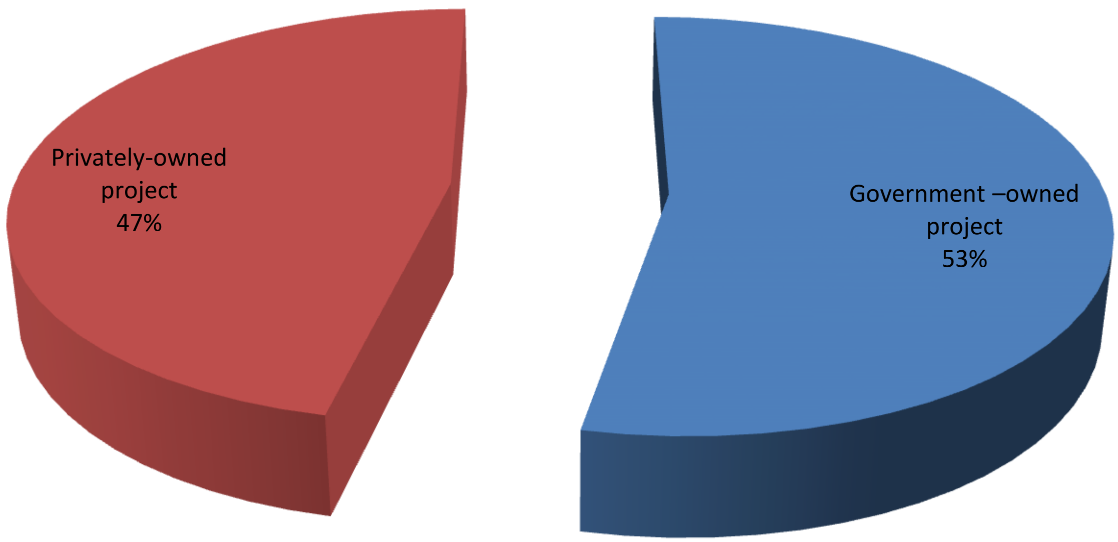


Figure 5.3: Type of projects

Source: Researcher's field survey, 2015.

5.2.4 Educational background of the interviewees

An analysis of the educational attainments of the interviewees shows that 'Bachelor's Degrees' were the most common type of certification possessed. However, 47 percent of the sample held B.Tech/BSc/B. Eng. Degrees, compared with 17 percent for MSc/M. Tech Degrees. Diploma qualifications were fewer, with 23 percent of the sample having PGDs, and 13 percent having High National Diplomas.

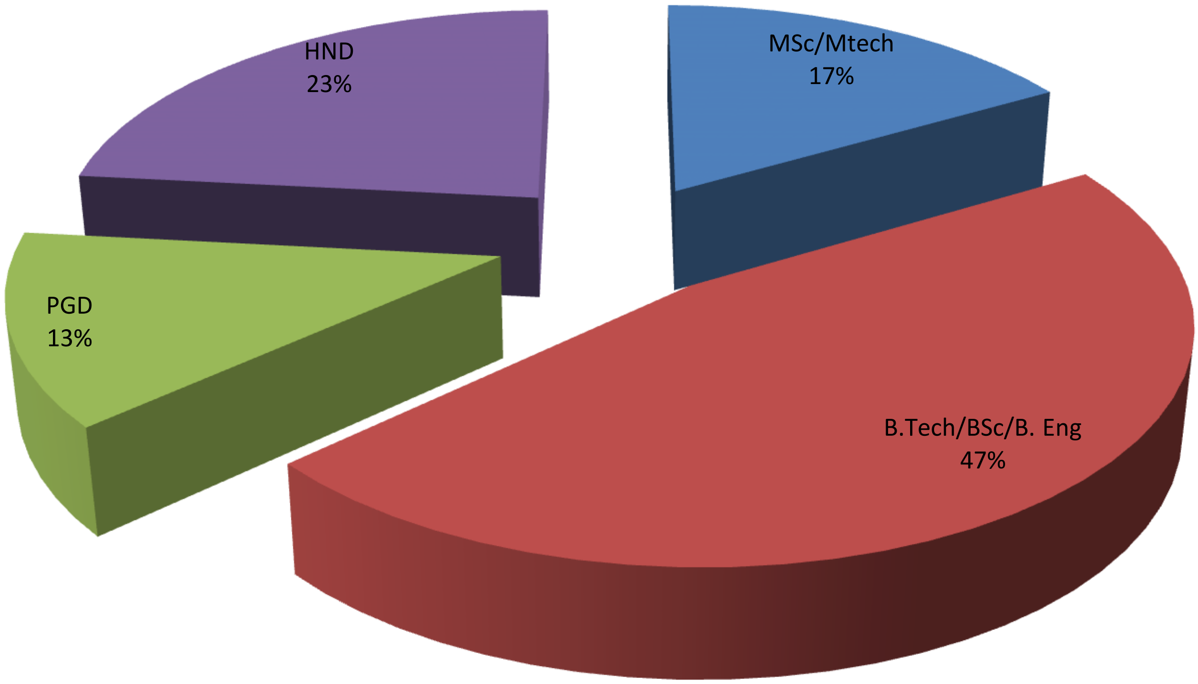


Figure 5.4: Educational attainment of interviewees

Source: Researcher's field survey, 2015.

5.2.5 Interviewees' designation

The interviewees' designation in their respective projects, as shown in Table 5.2, indicate that they had insightful knowledge and years of work experience in the construction industry, thus ensuring the credibility and accuracy of their responses.

Table 5.2: Designation of interviewees

S/n	Interviewee code	Designation	Years of experience	Highest educational qualification	Type of project
1	PM-01	Project Manager	20	MSc (Arc)	Government–owned
2	PM-02	Project Manager	11	HND	Government–owned
3	PM-03	Project Manager	18	MSc	Government–owned
4	PM-04	Project Manager	25	BSc	Privately-owned project
5	PM-05	Project Manager	20	B.Eng. (Civil)	Privately-owned project
6	PM-06	Project Manager	18	B.Eng. (Civil)	Government–owned
7	PM-07	Project Manager	22	MSc. (Civil)	Privately-owned project
8	PM-08	Project Manager	22	MSc (Arc)	Privately-owned project
9	PM-09	Project Manager	23	BSc (Project Management)	Government–owned
10	PM-10	Project Manager	07	HND (Civil)	Privately-owned project
11	PM-11	Project Manager	15	BSc	Government–owned
12	PM-12	Project Manager	20	HND	Privately-owned project
13	PM-13	Project Manager	10	B.Eng. (Civil)	Privately-owned project
14	PM-14	Project Manager	08	B.Tech	Privately-owned project
15	PM-15	Project Manager	20	HND	Privately-owned project
16	QS-01	Quantity Surveyor	16	BSc (QS)	Privately-owned project
17	QS-02	Quantity Surveyor	13	BSc (QS)	Government–owned
18	QS-03	Quantity Surveyor	16	HND (QS)	Government–owned
19	QS-04	Quantity Surveyor	18	BSc (QS)	Privately-owned project
20	QS-05	Quantity Surveyor	16	PGD (QS)	Privately-owned project
21	QS-06	Quantity Surveyor	17	MSc (QS)	Privately-owned project
22	QS-07	Quantity Surveyor	12	B.Tech(QS)	Government–owned
23	QS-08	Quantity Surveyor	16	PGD (QS)	Government–owned
24	QS-09	Quantity Surveyor	04	B.Tech(QS)	Government–owned
25	SE-01	Site Engineer	08	BSc (Building	Privately-owned project
26	SE-02	Site Engineer	11	BSc	Government–owned
27	SE-03	Site Engineer	10	HND (Civil)	Government–owned
28	SE-04	Site Engineer	08	HND	Government–owned
29	SE-05	Site Engineer	16	PGD (Civil)	Government–owned
30	STO	Senior Technical Officer (waste management)	10	HND, PGD	Government–owned

Source: Researcher's own field survey, 2015

5.2.6 Summary of the collected field investigations and archival data

Table 5.3 shows that 31 valid construction projects were visited in the study area. The projects' values ranged from ₦1.635 billion to ₦63 billion (R102.3 million to R3.94

billion) with a mean average of ₦7.864 billion (R491.31million), which are above the target of ₦1.6 billion (R100 million) stated in section 3.2 of this study.

The table also shows that the recorded cost overruns for the 31 projects visited ranged from ₦115 million to ₦7.562 billion (R7.188 to 472.63 million) with a mean average of ₦1.076 billion (R67.25million). The projects had attained between 5 to 100 percent completion with a total average completion of 52.4 percent. The estimated time for the projects ranged from 16 to 68 months, with an average of 27 months; while the actual time (time now) ranged from 3 to 96 months, with an average of 25.8 months.

It is apparent from the table that the recorded volume of buildings (L*W*H) ranged from 17,486.6 to 5,181,480.0 cubic metres with an average of 387,600.8 cubic metres. The estimated volume of materials used for the projects ranged from 4,982.4 to 673, 592.4 cubic metres, with an average of 45,468.1 cubic metres. The volume of material waste recorded ranged from 36.0 to 4,005.2 cubic metres, with an average of 455.6 cubic metres.

Table 5.3: Summary of the archival and field investigations for the data collected

Descriptive Statistics	Valid No of projects	Mean	Minimum	Maximum	Standard Deviation
Estimated Cost of Project (EC)	31	7,864, 085, 426.0	1,635,000, 000.0	63, 000, 000, 000	13,009, 813, 196.0
% of work completed	31	52.4%	5.0%	100.0%	30.9
Estimated Cost of work Completed	31	3, 694, 412, 838.0	387, 049, 950.0	56, 000, 000, 000.0	9, 850, 767, 725.0
Actual Cost of work Completed (Cost Now)	31	4, 802, 931, 683.0	580, 574, 925.0	62333222000.0	11, 068, 479, 998.0
Cost Overrun	31	1, 076, 260, 781.0	115, 000,000.0	7, 562, 312, 832.0	1, 672, 000, 129.0
Estimated Time for the Project (Month)	31	27.0 month	16.0 month	68.0 month	12.1
Time Now (Month)	31	25.8 month	3.0 month	96.0 month	23.0
Building Volume (L*W*H)	31	387600.8 m^3	17486.6 m^3	5181480.0m^3	1, 061, 644.6
Estimated volume of materials for Project (M^3)	31	45468.1 m^3	4982.4 m^3	673592.4 m^3	122, 643.0
Volume of material used (M^3)	31	14972.4 m^3	1146.0 m^3	190723.1 m^3	33, 437.7
Volume of material waste recorded	30	455.6 m^3	36.0 m^3	4005.2 m^3	721.3
100% Volume of waste	30	1273.9 m^3	156.6 m^3	14145.4 m^3	2, 584.0

Source: Researcher's own field survey, 2015.

5.3 Quality of Planning

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher in the course of the interviews on the issues relating to material waste and cost overruns at the quality-of-planning stage of a project.

5.3.1 The components and quality of construction planning and waste management at the pre-contract stage of projects

The issues that relate to the planning of construction activities are the primary concern among many construction organisations. Therefore, some of these issues were captured during the interview sections with the construction professionals (the respondents) in this study.

All of the interviewees (15 project managers, 9 quantity surveyors, 5 site engineers, and a senior technical officer) viewed "adequate site investigation", "co-ordination of the entire planning process", and "proper communication flow among the professionals" as the most important components of construction planning and waste management at the pre-contract stage of a project.

PM-03 explained that:

"Adequate and early site/sub-soil investigation is needed for a project, in order to discover the conditions and nature of the site, such as: the site topography, the water table, the soil-bearing capacity, and the soil type, in order to reduce the risks of material wastage or additional cost on the project."

Additionally, PM-14 suggested that "regular meetings" at the planning stage of a project would help in supporting a free flow of communication among the members/professionals. Also, 3PMs and QS-02 stated that "proper project brief harmonization" amongst the professionals would be made easier through regular meetings.

Moreover, eighteen (18) interviewees (7PMs, 6QSs, 4SEs, and STO) noted that "liaising with local authorities in the case of local laws" is another issue that contributes to good quality planning for projects and waste management. The respondents in this study stressed the need for construction projects within Abuja (the study area), to comply with the laws and regulations enforced by the Abuja Environmental Protection Board (AEPB). The Board is saddled with the responsibilities of protecting the Abuja metropolis by removing all the generated material waste from the many construction sites and disposing thereof in the landfills.

Furthermore, as "proper planning for project" is important; 5PMs, 2QSs, and 1SE highlighted that "planning for site organisation" (site offices, fencing, site security, site storage, and other preliminary items) is crucial to achieving good quality planning at an early stage of any project. 2PMs, 3QSs, and 1SE believed that achieving a better plan for site organisation would require competent and experienced professionals in the planning stage of the project.

Furthermore, three (3) interviewees (2PMs, 1QS, and STO) advocated the need for engaging in "early feasibility and viability studies on project purpose." This would require experienced professionals to decide whether the project would be feasible for commercial, residential, industrial, recreational, or institutional purposes.

Also, eight (8) of the respondents (2PMs, 4QSs, and 2SEs) explained that "proper planning of project risks" is a key component of project planning and waste management. This consists of project-risk evaluation, analysis, and apportionment. Therefore, for the fear of unforeseen project risks, eighteen interviewees (10PMs, 3QSs, 4SEs, and the STO) viewed the "insurance of construction project" as an important component that contributes to good project planning and waste management in the construction industry.

QS-02 explained that:

"Since the planning of project risks is crucial to project success, we engage in risk analyses by establishing the project-risk factor. This is done by identifying the project

requirements to establish the deliverables and constraints from the design and construction process, such as the cost risks, quality risks, scheduling risks, in order to find a better means of minimising/managing their detrimental effects on the project."

Furthermore, owing to the increasing global recognition of the role of law-enforcement agencies in protecting parties or individuals in the construction industry, eleven (11) interviewees' (7PMs, 3QSs, and an 1SE) encouraged the inclusion of "adequate legislative enforcement" as a component in achieving quality in project planning.

Coincidentally, three (3) interviewees (2PMs and 1QS) supported the inclusion of "plan for program of work" and "preparation of schedule of materials and labour" at an early planning stage; because these issues contribute to achieving the required quality of planning for projects. Nonetheless, 2SEs emphasised that it would be beneficial if "material-waste management were to be included in the bidding and tendering process of a project.

Accordingly, two (2) interviewees' (QS-01 and PM-01) explained that the "plan for early materials standardisation before production of design" would contribute to achieving a better-quality planning and waste-management schedule for a project. This would give the designer an insight into what type and size of materials to design for a project. Also, the same respondents advised that "for a site with space, it is easy to purchase and keep the required materials for the project; while the fragile ones be left with the manufacturer/wholesaler until the need for such should arise.

Consequently, four (4) project managers (PM-02, PM-05, PM-10, and PM-15) stressed that "sourcing and ensuring the availability of the right quality materials at the planning stage before the production of design" would reduce the risks of subsequent re-design in case of future non-availability of such materials to complete the project.

Lastly, on the issues relating to project cost, 3QSs and 2PMs suggested that proper cost management is the primary concern of both the clients and the professionals, in that, a better way should be devised to manage project costs at an early planning stage.

5.3.2 Methods of planning for material waste and cost overruns in the construction industry

Eighteen (18) respondents (6QSs, 7PMs, and 5SEs) highlighted that material waste is planned for, at an early planning stage of a project, by establishing a waste-management unit/department, which would handle any issues relating to material waste and waste management on site. SE-01 added that a reasonable budget is always planned for the department to carry out its activities. In this department/unit, educated and experienced personnel/professionals in waste management are engaged to ensure that material waste is minimised/controlled (7PMs, 3QSs, 2SEs, and STO). Members of the department (waste management) work with the general management and ensure that progresses are communicated through regular meetings at all stages of the project. The department and the management plan for an on-site company yard/space, where generated material waste is organised and kept. The waste is, therefore, separated for further re-use, recycling, incineration, disposal or re-sale for profit (2QSs, 5PMs, and 1SE).

PM-08 and PM-14 stated that:

"We are very conscious about the materials we use for projects. For instance, marine-plywood formwork has more re-usable quality/value than ordinary plywood."

Thus, 4QSs, 6PMs, 3SEs, and 1STO explained that:

"We always include it in our plan to establish a quality-control unit for evaluating, and controlling the quality of materials supplied/procured."

The unit ensures that materials delivered to the site are in accordance with the quantity ordered and the specifications prescribed.

PM-01 explained that:

"Material waste cannot be fully eliminated, despite the available waste-management approaches adopted. For instance, a timber formwork becomes waste after use and re-use. Thus, we minimise material waste to a barest minimum by engaging experienced

and educated personnel; and giving a priority to any waste management from the start to the completion of a project."

Moreover, sixteen (16) respondents (6QSs, 9PMs, and 1SE) highlighted that planning for site storage and security are important in planning for material waste and cost overruns. This helps in avoiding any pilferage and damage to the materials on site.

For managing cost overruns, PM-01 cautioned that:

"Sufficient time should be allowed for quantity surveyors/estimators to conduct a market survey, in order to have some idea of the market forces, and to ensure that project risks are properly evaluated and estimated. We also plan for cost-overrun by ensuring that issues relating to site security are included in the planning stage, in order to prevent material theft and pilferages."

Additionally, 4PMs, QS-02, SE-05 and STO stated that project cost overrun is planned for by establishing-project risks factors, as explained in section 5.3.1 (i). To achieve a comprehensive estimate for a project, a thorough check and cross-check is necessary by the estimating department to ensure that errors and omissions are corrected before execution. This contributes to managing any cost overruns (4QSs, 5PMs, and SE-04).

Coincidentally, nine (9) respondents (4QSs, 2PMs, 2SEs, and 1STO) stressed the need for the addition of a contingency sum in the bill of quantities to take care of unforeseen circumstances that might result in a cost overrun. PM-11 added that accuracy in estimation must be fully achieved; since it has a strong potential in reducing cost overrun for any project. Thus, SE-01, SE-02 and PM-10 suggested the engagement of an experienced estimator in order to avoid the problems of wrong (under or over) estimation for a project.

SE-01 recommended a proper communication flow between the clients, the designers, and other professionals at an early planning stage, to avoid the problems of variation and rework for projects. 2PMs and QS-01 outlined that they manage cost overruns by informing project clients about what they intend to do, after the necessary briefing and sketch design; they work with the client's opinion to reduce the risks of subsequent variation and rework.

In conclusion, PM-06 suggested that construction materials that have the capacity of minimising waste should be recommended at the planning stage.

5.3.3 The relationship between the quality of planning, material-waste generation, and cost overruns

Six (6) respondents (2QSs and 4PMs) stated that poor quality planning negatively affects all the project stages, including planning, design, construction, and so on. Thus, wasted materials, as a result of mistakes/errors and rework, would subsequently affect the project cost. This could even lead to the need for an extension of time; thereby incurring more on the project's final cost (PM-02, PM-03 and QS-07).

Therefore, proper planning would lead to the selection of better materials and workmanship. For instance, block/brickwork and formwork that could be re-usable would generate less waste compared to non-reusable types, which would require additional money for loading, disposing, or landfilling (PM-12, PM-05 and QS-08).

PM-01 quoted that:

"He, who fails to plan, is planning to fail; and what is being planned for, is what is expected to be executed."

Therefore, all the respondents in this category agreed that proper planning minimises material waste and cost overruns for projects and *vice versa.*

5.3.4 Effects of material-waste sources and causes on project cost overruns (Quality of planning)

Table 5.4 shows that the percentages of 100, 96.7, 93.3 and 90, relative to "inadequate site investigation", "poor communication flow among members", "inadequate waste management unit", and "the lack of regular site meetings at the planning stage" respectively, were the causes of material waste deemed by the respondents to have had 'very high effects' on project cost overruns at the planning stage of a project;

because they fall between 90 and100 percent. While the percentages of 80, 73.3, 73.3 73.3, and 70 relative to “improper co-ordination of the entire project and professionals”, “improper planning”, “communication error between clients and designers”, “inexperienced personnel/professionals in planning and waste management” and “compliance with local authority in the case of local laws”, respectively, were deemed by the respondents to have had ‘high effects’ in causing cost overruns because they fall between 70 and 89 percent.

“Lack of legislative enforcement”, “insurance problem”, “unsatisfactory budget for waste management”, and “improper planning of project risks” were deemed to have ‘moderate effects’ on project-cost overruns; because they fall between 50 and 60 percent.

“Improper planning for material-waste minimisation (re-use, reduce, and disposal)” was considered by the respondents to have had ‘little effect on cost overruns’; because it falls between 30 and 49 percent.

Moreover, other causes, such as “improper plans for the establishment of a quality-control unit”, “over-estimation to accommodate variations”, “poor plans for material standardisation”, “improper programming of the work”, “improper planning and understanding of the method statement”, and “the lack of inclusion of waste management in the bidding process” by the respondents were deemed to have ‘very little effect’ on cost overruns at the planning stage of the projects; because they fall between 1 and 29 percent, as highlighted by the morenikeji (2006) cut-off point.

Table 5.4: The results of cross-tabulation for the effects of material-waste causes and sources (Quality of planning)

S/n	Causes of material waste at planning stage of a project	PM	QS	SE	STO	TOTAL	Ranking	Decision
1	Improper planning	12(80%)	7 (77.8%)	3(60%)	0(0%)	22(73.3%)	6	High
2	Over estimation to accommodate variations	2 (13.3%)	0 (0%)	0 (0%)	0 (0%)	2 (6.7%)	30	Very little
3	Lack of legislative enforcement	9 (60%)	4(44.4%)	2(40%)	0 (0%)	15 (50%)	13	Moderate
4	Inadequate site investigation	15(100%)	9 (100%)	5(100 %)	1(100%)	30(100%)	1	Very high
5	Inadequate scheduling	8(53.3%)	4(44.4%)	1(20%)	1(100%)	14(46.7%)	15	Little
6	Poor communication flow among members	15 (100%)	8 (88.9%)	5 (100%)	1 (100%)	29 (96.7%)	2	Very high
7	Improper coordination of the entire project and professionals	11 (73.3%)	8 (88.9%)	4 (80%)	1 (100%)	24 (80%)	5	High
8	Unsatisfactory budget for waste management	11 (73.3%)	5 (55.6%)	3 (60%)	1 (100%)	20 (66.7%)	11	Moderate
9	Insurance problem	10(66.7%)	5(55.6%)	4(80%)	(100%)	20(66.7%)	11	Moderate
10	*Poor plan for material standardization	3 (20%)	1 (11.1%)	0 (0%)	0 (0%)	4 (13.3%)	23	Very little
11	*Inadequate waste management unit	13 (86.7%)	9 (100%)	5 (100%)	1 (100%)	28 (93.3%)	3	Very high
12	*Improper plan for material waste re-use & disposal	7 (46.7%)	2 (22.2%)	2 (40%)	0 (0%)	11 (36.7%)	16	Little
13	*Improper program of work	3(20%)	0 (0%)	0 (0%)	0(0%)	3 (10%)	27	Very little
14	*Improper plan for site organization and layout	5 (33.3%)	2 (22.2%)	1 (20%)	0 (0%)	8 (26.7%)	17	Very little
15	*Lack of regular site meetings	14(93.3%)	9 (100%)	4(80%)	0(0%)	27 (90%)	4	Very high
16	*Liaise/ compliance with local authority in case of local laws	9 (60%)	6 (66.7%)	5 (100%)	1 (100%)	21 (70%)	9	High
17	*Improper planning and understanding of method statement	3 (20%)	0 (0%)	1 (20%)	0 (0%)	4 (13.3%)	23	Very little
18	*Improper planning of project risks	8 (53.3%)	6 (66.7%)	2 (40%)	0 (0%)	16 (53.3%)	12	Moderate
19	Lack of inclusion of waste management in bidding process	0 (0%)	0 (0%)	1 (20%)	0 (0%)	1 (3.3%)	35	Very little
20	*Improper plan for the establishment of a quality control unit	5 (33.3%)	0 (0%)	0 (0%)	0 (0%)	5 (16.7%)	16	Very little
21	*Inexperienced personnel in planning and waste management	10 (66.7%)	6 (66.7%)	5 (100%)	1 (100%)	22 (73.3%)	6	High
22	*Lack of re-improving process (learning from	2 (13.3%)	0 (0%)	1 (20%)	0 (0%)	3 (10%)	27	Very little

	previous mistakes)							
23	*Poor harmonization of brief	2(13.3%)	1(11.1%)	2(40%)	0(0%)	5(16.7%)	21	Very little
24	*Poor knowledge of site conditions	1 (6.7%)	2 (22.2%)	0 (0%)	0 (0%)	3 (10%)	27	Very little
25	*Cost related problems	1(6.7%)	3(33.3%)	0(0%)	0(0%)	4(13.3%)	23	Very little
26	*improper plan for adequate staff training and development	4 (26.7%)	1 (11.1%)	2 (40%)	0 (0%)	7 (23.3%)	19	Very little
27	*Poor material estimation	3 (20%)	1 (11.1%)	0(0%)	0(0%)	4(13.3%)	23	Very little
28	*Lack of feasibility and viability studies	4 (26.7%)	1 (11.1%)	1 (20%)	1 (100%)	7 (23.3%)	19	Very little
29	*Inadequate identification of construction techniques	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	35	Very little
30	*Plan for adequate site organization	4 (26.7%)	3 (33.3%)	1 (20%)	0 (0%)	8 (26.7%)	17	Very little
31	*Improper plan for record of material inventory	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	35	Very little
32	*Improper plan for adequate site exploration	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	35	Very little
33	*Excess material delivery	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	35	Very little
	Client							
34	Communication error between client and designer	11 (73.3%)	7 (77.5%)	4 (80%)	0 (0%)	22 (73.3%)	6	High
35	Frequent demand for design change	4 (26.7%)	1 (11.1%)	0 (0%)	0 (0%)	5 (16.7%)	21	Very little

Source: Researcher's field survey, 2015

5.3.5 Effects of material-waste control measures on project cost overruns (Quality of Planning)

It is apparent from Table 5.5 that percentages of 100 and 96.7, relative to “plan for early sub-soil investigations” and “proper co-ordination and communication among members at planning stage”, respectively, by the respondents were considered to be the material waste control measures that have ‘very high effects’ in controlling project cost overruns at the planning phase of the pre-contract stage of a project; because they fall between 90 and 100 percent.

Furthermore, percentages of 86.7, 73.3, and 70, in respect of the “establishment of a good waste-management unit”, “regular site meetings”, “improved planning and scheduling”,” setting a target for material-waste reduction”, and “engaging experienced personnel in planning”, respectively, were deemed by the respondents to have ‘high effects’ in managing project-cost overruns at the planning stage of a project; because they fall between 70 and 89 percent. However, moderate effect control measures include: “adequate legislative enforcement” and “planning of project risks”; because they fall between 50 and 69 percent.

The two control measures that have little effect on cost overruns and fall between 30 and 49 percent are: “the proper planning of construction projects lay-out” and “proper investment into waste reduction.”

Furthermore, percentages of 26.7, 20, 16.7, 16.7, 16.7, and 3.3 in relation to “enhancing regulation execution of related government departments” “proper insurance of work”, “plan for the inclusion of waste management in bidding and tendering process”, “adequate material-waste estimation”, “re-improving process (learning from previous mistakes)” and “interaction between different designers (Architects and Engineers)”, respectively, by the respondents are the material waste causes deemed to have very ‘little effect’ in controlling cost overruns on the quality of planning for projects; because they fall between 1 and 29 percent.

Table 5.5: The results of cross-tabulation for the effects of material waste-control measures on project cost overruns (Quality of planning)

S/n	Control measures for material waste (Quality of Planning)	PM	QS	SE	STO	Total	Ranking	Decision
1	Plan for early sub-soil investigations	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
2	Proper investment into waste reduction	6 (40%)	3 (33.3%)	3 (60%)	0 (0%)	12 (40%)	10	Little
3	Proper planning of construction projects layout	6 (40%)	5 (55.5%)	0 (0%)	0 (0%)	11 (36.7%)	11	Little
4	Plan for inclusion of waste management in bidding and tendering process	2 (13.3%)	2 (22.2%)	1 (20%)	0 (0%)	5 (16.7%)	16	Very little
5	Enhance regulation execution of related government departments	3 (20%)	3 (33.3%)	1 (20%)	1 (100%)	8 (26.7%)	12	Very little
6	Improved planning and scheduling	10(66.7%)	7(77.8%)	5(100%)	0(0%)	22(73.3%)	5	High
7	Proper coordination and communication	15(100%)	8(88.9%)	5(100%)	1(100%)	29(96.7%)	2	Very high
8	Proper insurance	2(13.3%)	4(44.4%)	0(0%)	0(0%)	6(20%)	15	Very little
9	Set a target for material waste reduction	13 (86.7%)	3 (33.3%)	4 (80%)	1 (100%)	21 (70%)	7	High
10	Improve major project stakeholders' awareness on resource saving & environmental protection	2 (13.3%)	1 (11.1%)	0 (0%)	0 (0%)	3 (10%)	22	Very little
11	*Plan that will reduce frequent design change	5 (33.3%)	2 (22.2%)	0 (0%)	0 (0%)	7 (23.3%)	14	Very little
12	*Plan for material standardization	3(20%)	2(22.2%)	0(0%)	0(0%)	5(16.7%)	16	Very little
13	*Carrying design team along	2(13.3%)	1(11.1%)	0(0%)	0(0%)	3 (10%)	22	Very little
14	*Regular site meetings	14(93.3%)	7(77.8%)	5(100%)	0(0%)	26(86.7%)	3	High
15	*Establishment of good waste management unit	12 (80%)	8 (88.9%)	5 (100%)	1 (100%)	26 (86.7%)	3	High
16	*Re-improving process (Learning from previous mistakes)	2 (13.3%)	1 (11.1%)	2 (40%)	0 (0%)	5 (16.7%)	16	Very little
17	*Legislative enforcement	11(73.3%)	5(55.6%)	1(20%)	0(0%)	17(56.7%)	8	Moderate
18	*Adequate material waste estimation	4(26.7%)	1(11.1%)	0 (0%)	0(0%)	5(16.7%)	16	Very little
19	*Planning of project risks	9(60%)	3(33.3%)	3(60%)	0(0%)	15(50%)	9	Moderate
20	*Proper harmonization of brief	3 (20%)	0 (0%)	2(40%)	0 (0%)	516.7(%)	16	Very little
21	*Experienced personnel in planning	11(73.3%)	6(66.7%)	4(80%)	1(100%)	22(73.3%)	5	High
22	*Identification of construction technique	1 (6.7%)	0 (0%)	0 (0%)	0 (0%)	1(3.3%)	27	Very little
23	*Feasibility and Viability studies	4 (26.7%)	1(11.1%)	2(40%)	1(100%)	8 (26.7%)	12	Very little
24	*Buildability Analysis	3 (20%)	0(0%)	0(0%)	0 (0%)	3(10%)	22	Very little
25	*Consideration of available technology, resources and materials	3 (20%)	2 (22.2%)	0 (0%)	0 (0%)	5 (16.7%)	16	Very little
26	*Geophysical surveys	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	27	Very little
27	*interaction between different designers (Architects and Engineer)	1 (6.7%)	0 (0%)	0 (0%)	0 (0%)	1 (3.3%)	27	Very little

Source: Researcher's field survey, 2015.

5.3.6 Comparative views of respondents on the 'effects of material-waste sources, causes, and control measures on project cost overruns' (Quality of planning)

Table 5.6 shows the results of ANOVA analyses performed to compare the views of the respondents (Project managers, Quantity Surveyors, Site engineers and Senior Technical Officer) on the 'effects of material-waste sources, causes, and control measures on cost overruns' at the quality of planning stage of a project.

It was apparent from the analyses that the values of f-calculated (1.016 and 0.826) for the two analyses (material waste sources and causes, and control measures) were both less than the f-tabulated value (1.701), respectively.

The probability values (0.376 and 0.449) were both greater than the 0.05 (5 percent) significance level at 95 percent confidence level within the mean-squared group of 4.11 to 4.18 and 6.16 to 7.45, respectively.

The findings here are not statistically significant. The alternative hypotheses are rejected in favour of the null hypotheses.

These imply that the respondents were of the same views on the effects of material waste sources and causes; and control measures on cost overruns in the construction industry (Quality of planning).

Table 5.6: The results of ANOVA analyses for the test of differences in the professional views on the "effects of material-waste sources, causes and control measures on project cost overruns" (Quality of planning)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
1	PM	QS	SE	STO	One-way ANOVA	4.18 4.11	1.016	1.701	0.376	Not statistically significant	Accept Ho & reject Hi
	Sources and causes										
2	PM	QS	SE	STO	One-way ANOVA	6.16 7.45	0.826	1.701	0.449	Not statistically significant	Accept Ho & reject Hi
	Control measures										

Source: Researcher's field survey, 2015.

5.4 Quality of Design Management

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher in the course of the interviews on the issues relating to material waste and cost overruns at the quality-of-design management stage of a project.

5.4.1 Relationship between the quality-of-design management, material-waste generation and cost overruns

Good quality design management would generate the necessary specifications, details, constructability, and maintainability issues. A good quality-design management agenda should be able to envisage the issues relating to geo-physical surveys for the type of foundations to be selected; and the project stakeholders must define their requirements at an early design stage, in order to avoid variation, rework and cost overruns. However, it could entail a colossal loss to the project, if these issues are wrongly handled. This information should improve the accuracy of the project estimates and reduce the rate of cost overruns for the project (QS-02, PM-02, PM-03, SE-01, PM-13, and STO).

QS-02, QS-08 and SE-04 disclosed that experienced designers/design-teams would produce an easily achievable design, which would consider the material specifications and contribute to the minimisation of material waste and cost overruns for projects.

In a similar vein, QS-01, QS-03, PM-01 and PM14 added that where you have experienced designers, materials would be designed in their standard sizes/units to allow tolerances, which would reduce the rate of cutting, chiselling and material wastages that could negatively affect the project cost. Additionally, PM12 stressed that a graduate designer cannot be compared with an experienced designer, who has acquired the skills on how to design-out the waste from projects.

Coincidentally, 3QSs, 2PMs and SE-01 believed that an inexperienced designer could either under-design or over-design for a project, which could lead to a wrong estimate, rework, and variation both of which have a strong impact on the generation of material waste and cost overruns.

Moreover, eight respondents (6PMs, SE-03, and STO) concluded that good quality design management has the capacity to minimise the rate of material waste to be generated and any subsequent cost overrun for a project.

On the relationship between the quality of design, material-waste generation, and cost overruns, QS-05 and QS-09 responded that “at times, it takes extra time, effort, resources, and labour to achieve a particular building shape, which may not have been anticipated at the pre-contract stage; and all of these have a significant impact on material waste generation and cost overruns”. Thus, PM-08 and PM-15 suggested that project designers and professionals should be engaged at an early stage of a project to ensure that the issues relating to material waste and cost overruns are tackled as early as possible.

QS-07 and PM-10 indicated that the lack of design information, frequent design change, and incompetent designers contribute to material-waste generation and cost overruns for projects.

Finally, all the respondents (100 percent) mentioned that “poor quality-design management” contributes negatively to the generation of material waste and project-cost overruns and *vice versa.*

5.4.2 Contribution of quality-of-design management to design complexity

A complex design does not necessarily mean a bad design; but inexperienced designers may contribute to the complexity in design, which may lead to material wastages and cost overruns (3QSs, 4PMs, SE-01, and QS-06). Therefore, good design management should consider all the ambiguous design problems, which might reduce the complexity and the cost overruns for projects (PM-12).

Consequently, all the respondents interviewed disclosed that quality of design management contributes to the design complexity, especially when inexperienced designers are engaged, and when the project requirements are not clearly defined to the professionals involved.

5.4.3 Effects of material-waste sources and causes on project-cost overruns (Quality of design management)

Table 5.7 indicates that the percentages of 100, 93.3, 90, and 90 relative to “error in design and detailing”, “lack of design information”, “design complexity/complication”, and “inexperienced designer or design team”, respectively, by the respondents were the causes of material waste deemed to have had ‘very high effects’ on project cost overruns at the quality of design management stage of a project; because they fall between 90 and 100 percent. While the percentages of 86.7, 86.7, and 80 relative to “difficulty in interpreting material specifications”, “readability, constructability and maintainability problems of design”, and the lack of standardisation in design/sizes and units”, respectively, were deemed to have ‘high effects’ on cost overruns because they fall between 70 and 89 percent.

Percentages of 66.7, 63.3, 56.7, 56.7, and 53.3 in respect of “poor harmonization of clients brief”, “designing uneconomical shapes and outlines”, “poor communication flow among design team”, “lack of buildability analysis”, and “poor management of design process”, respectively, were the material waste causes deemed to have ‘moderate effects’ on project-cost overruns; because they fall between 50 and 69 percent.

The percentages of 40, 33.3, 33.3, and 30, relative to “frequent design changes and material specification at design stage”, “interaction between various specialists”, “designing unavailable technology”, and “insufficient time for design”, respectively, were considered by the respondents as the material waste causes that have ‘little effect on cost overruns’ because they fall between 30 and 49 percent.

Other material waste causes of percentages between 1 and 29 percent were deemed to have ‘very little effects’ on cost overruns at the quality–of-design management stage of a project. They include: “designing dead spaces”, “poor knowledge of the changing design requirements”, and “aesthetic considerations”.

Table 5.7: The results of cross-tabulation for the sources and causes of material waste on cost overruns (Quality of design management)

S/n	Sources and causes (Quality of Design Management)	PM	QS	SE	STO	Total	Ranking	Decision
1	Frequent design changes and material specification	9 (60%)	3 (33.3%)	0 (0%)	0 (0%)	12 (40%)	12	Little effect
2	Error in design and detailing	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
3	Lack of design information	13(86.7%)	9(100%)	5(100%)	1(100%)	28(93.3%)	2	Very high
4	Design complexity/complication	13(86.7%)	9(100%)	5(100%)	0(0%)	27(90%)	3	Very high
5	Poor communication flow among design team	8 (53.3%)	6 (66.7%)	3 (75%)	0 (0%)	17 (56.7%)	10	Moderate effect
6	Designing dead spaces	2(13.3%)	1(11.1%)	0(0%)	0(0%)	3 (10%)	19	Very little
7	Poor knowledge of the changing design requirements	0 (0%)	2 (22.2%)	2 (40%)	0 (0%)	4 (13.3%)	18	Very little effect
8	Poor management of design process	8 (53.3%)	3 (33.3%)	5 (100%)	0 (0%)	16 (53.3%)	11	Moderate
9	Inexperience designer or design team	14 (93.3%)	8 (88.9%)	4 (80%)	1 (100%)	27 (90%)	3	Very high
10	Interaction between various specialists	6 (40%)	3 (33.3%)	1 (20%)	0 (0%)	10 (33.3%)	13	Little effect
11	*Designing uneconomical shapes and outlines	12 (80%)	6 (66.7%)	0 (0%)	1 (100%)	19 (63.3%)	9	Moderate
12	*Lack of standardization in design/ sizes and units	12 (80%)	8 (88.9%)	5 (100%)	1 (100%)	26 (86.7%)	5	High effect
13	*Lack of buildability analysis	7(46.7%)	6(66.7%)	3(60%)	1(100%)	17(56.7%)	23	Moderate
14	*Difficulty in interpreting material specifications	14 (93.3%)	6 (66.7%)	5 (100%)	1 (100%)	26 (86.7%)	5	High
15	*Readability, constructability and maintainability	13 (86.7%)	6 (66.7%)	4 (80%)	1 (100%)	24 (80%)	7	High
16	*Insufficient time for design	3(20%)	2(22.2%)	4(80%)	0(0%)	9(30%)	15	Little effect
17	*Poor harmonization of clients brief	9(60%)	7(77.8%)	3(75%)	1(100%)	20(66.7%)	16	Moderate
18	*Over or under designing	4(26.7%)	3(33.3%)	1(20%)	0(0%)	8(26.7%)	8	Very little
19	*Poor structural arrangement of a design	2 (13.3%)	3 (33.3%)	0 (0%)	0 (0%)	5 (16.7%)	16	Very little effect
20	*Aesthetic considerations	0(0%)	2(22.2%)	0(0%)	0(0%)	2(6.7%)	21	Very little
21	*Poor planning of design process	1(6.7%)	2(22.2%)	0 (0%)	0(0%)	3(10%)	19	Very little
22	*Poor design functionality	0(0%)	2(22.2%)	0(0%)	0(0%)	2(6.7%)	21	Very little
23	*Designing unavailable technology	6(40%)	2(22.2%)	2(40%)	0(0%)	10(33.3%)	13	Little effect
24	*Lack of geo-physical survey	0(0%)	1(11.1%)	0(0%)	0 (0%)	1(3.3%)	23	Very little

Source: Researcher's field survey, 2015.

5.4.4 Effects of control measures for material waste on project-cost overruns (Quality of design management)

It is apparent from Table 5.8 that the percentages of 100, 100, 93.3, 93.3, and 93.3 relative to “explicit detailing in design”, “interpretable designs and specifications”, “engaging experienced designer”, “error-free design”, and “proper design information and consultation”, respectively, by the respondents were considered to be the material waste-control measures that have ‘very high effects’ in controlling project-cost overruns at the quality-of-design management of the pre-contract stage of a project; because they fall between 90 and 100 percent. Furthermore, 76.8 percent of the respondents mentioned “readability, constructability, and maintainability in design” as the material waste-control measure that has an effect on cost overruns. It is rated as a ‘high effect’; because it falls between 70 and 80 percent.

Also, “designing economic shapes and outlines” and the “proper management of design process” were rated as having a ‘moderate effect’ in controlling cost overruns by the respondents; because they fall between 50 and 69 percent.

Consequently, percentages of 30, 30, and 40 in relation to “communication and co-ordination of design process”, “sufficient time for design”, and “reduction in the rate of design change”, respectively, were the material waste-control measures deemed to have ‘little effect’ on the project cost overruns; because they fall between 30 and 49 percent.

“The use of prefabricated units and standardised material sizes”, the “early engagement of designer”, “improving on previous design mistakes”, “design for materials optimisation”, and “design for offsite construction” were considered by the respondents to have ‘little effect’ in controlling the project-cost overruns at the quality-of-design management stage for a project.

“Incorporation of large-panel metal formworks” was rated as having ‘no effect’; because none (100 percent) of the respondents mentioned it as a control measure for managing project-cost overruns at the design stage.

Table 5.8: The results of cross-tabulation for the effects of control measures for material waste on cost overruns (Quality of design management)

S/n	Control measures for material waste (Quality of Design Management)	PM	QS	SE	STO	Total	Ranking	Decision
1	Design for materials optimization	2 (13.3%)	1(11.1%)	0(0%)	0 (0%)	3 (10%)	17	Very little
2	Design for reuse and recovery	2 (13.3%)	2(22.2%)	0(0%)	0(0%)	4(13.3%)	16	Very little
3	Design for offsite construction	3(20%)	0(0%)	0(0%)	0(0%)	3(10%)	17	Very little
4	Designing for deconstruction	2(13.3%)	0(0%)	0(0%)	0(0%)	2 (6.7%)	19	Very little
5	Use of prefabricated units and standard materials	2 (13.3%)	4 (44.4%)	0 (0%)	1 (100%)	7 (23.3%)	14	Very little
6	*Communication & coordination of design process	4 (26.7%)	4 (44.4%)	1 (20%)	0 (0%)	9 (30%)	12	Little effect
7	*Designing economic shapes and outlines	12 (80%)	6 (66.7%)	0 (0%)	1 (100%)	19 (63.3%)	9	Moderate
8	Incorporation of large-panel metal formworks	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	23	No effect
9	Reduction in the rate of design change	9 (60%)	3 (33.3%)	0 (0%)	0 (0%)	12 (40%)	11	Little effect
10	Utilization modular designs	2(13.3%)	0(0%)	0(0%)	0(0%)	2(6.7%)	19	Very little
11	Reduced design complexity	12 (80%)	9(100%)	5(100%)	0(0%)	26(86.7%)	6	High
12	*Explicit detailing	15 (100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
13	*Interpretable design and specifications	15 (100%)	8 (88.9%)	4 (80%)	1 (100%)	28 (93.3%)	3	Very high
14	*Experienced Designer	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
15	*Proper management of design process	8 (53.3%)	4 (44.4%)	5 (100%)	0 (0%)	17 (56.7%)	10	Moderate
16	*Error-free Design	13(86.7%)	9(100%)	5(100%)	1(100%)	28(93.3%)	3	Very high
17	*Standardization in Design	10(66.7%)	5(55.6%)	4(80%)	1(100%)	20(66.7%)	8	Very little
18	*Readability, constructability and maintainability	11 (73.3%)	7 (77.8%)	4 (80%)	1 (100%)	23 (76.7%)	7	High effect
19	*Proper design Information and consultation	13(86.7%)	9(100%)	5(100%)	1(100%)	28(93.3%)	3	Very high
20	*Adherence to Clients brief	2(13.3%)	2(22.2%)	1(20%)	0(0%)	5(16.7%)	15	Very little
21	*Sufficient time for design	3(20%)	2(22.2%)	4(80%)	0(0%)	9(30%)	12	Little
22	*Early engagement of designer	0(0%)	1(11.1%)	0(0%)	0 (0%)	1 (3.3%)	21	Very little
23	*Improving on previous design mistakes	1 (6.7%)	0 (0%)	0 (0%)	0 (0%)	1 (3.3%)	21	Very little

Source: Researcher's field survey, 2015.

5.4.5 Comparative views of respondents on the effects of material-waste sources, causes, and control measures on project cost overruns (Quality of Design management)

Table 5.9 shows the results of ANOVA analyses performed to compare the views of professionals (Project managers, Quantity Surveyors, Site engineers and senior technical officer) on the 'effects of material waste sources, causes, and control measures on project-cost overruns' at the quality-of-design management stage of a project.

It was apparent from the analyses that the values of f-calculated (0.150 and 0.319) for the two analyses (material waste sources and causes, and control measures), respectively, were both less than the value of f-tabulated (1.701); and the probability values (0.861 and 0.730) were greater than 0.05 (5 percent) level of significance within the mean-squared group of 0.90 to 6.02 and 1.39 to 4.35, respectively.

The evidence is not statistically significant. The alternative hypotheses are hereby rejected in favour of the null hypotheses. These results imply that the respondents were of the same views on the effects of material-waste sources, causes, and the control measures on cost overruns in the construction industry (Quality-of-design management).

Table 5.9: The results of ANOVA analyses for the test of differences in professional views on the "effects of material-waste sources, causes and control measures on project cost overruns" (Quality of design management)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
1	PM	QS	SE	STO	One-way ANOVA	0.90 6.02	0.150	1.701	0.861	Not statistically significant	Accept Ho &reject Hi
	Sources and causes										
2	PM	QS	SE	STO	One-way ANOVA	1.39 4.35	0.319	1.701	0.730	Not statistically significant	Accept Ho & reject Hi
	Control measures										

Source: Researcher's field survey, 2015

5.5 Design Complexity

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher in the course of the interview on the issues relating to material waste and cost overruns at the design-complexity stage of a project.

5.5.1 Definition of design complexity by the respondents

The respondents have different opinions on the meaning of design complexity in projects.

They view design complexity as follows:

QS-02 defines design complexity as: The design that exceeds the traditional/general design techniques; a design that does not use available human or material resources; a design requiring a laboratory build-up, special technology and consultants; and a design that does not follow the norms of traditional or normal practice is said to be a complex design. QS-03 stated that design complexity has to do with the nature of the design, depending on how simple or irregular it is; the ability of the specifications to consider local materials; and the clarity of the specifications and detailing of the design.

Consequently, PM-03 and PM-13 define design complexity as a design that is not solving the design problems, requiring specialty in construction, and designing materials that are not locally obtainable, unclear, and not simple.

In a similar vein, QS-05, QS-07, and QS-08 highlighted that a design is said to be complex when the processes of achieving the desired quality is not readily available, or when the constructors lack the technical know-how of interpreting or realising the design.

On the other hand, other respondents viewed design complexity differently, as relating to design shapes and outlines. PM-05 stated that a design is said to be complex, when it carries a lot of curves, geometric shapes, and irregular outlines requiring materials to be cut to fit the shapes. Thus, PM-06 believes that circular-shaped buildings are not compared with squared-shaped buildings in terms of waste generation. Consequently, PM-08 stressed that design complexity entails the shapes and outlines of the design, such as simple, irregular and complicated. PM-02, SE-02, STO, and PM-15 believe that design complexity could be referred to as any irregular, complicated outlines, not clear and not simple. SE-05 views design complexity as a design that does not consider the collective input of the other designers.

Put differently, QS-04, PM-10, SE-03, and SE-04 regard design complexity as a design that is difficult to understand and execute; lacking details and requiring assumptions. SE-01 added that it is a design not being able to be translated by the site engineers, thus, one with unclear details and specifications. Therefore, PM-06 noted that nobody is in the mind of the designer to interpret what s/he means.

QS-01, PM-01, PM-04, PM-07, PM-09 and PM-19 perceived design complexity as a design that lacks standardisation in material sizes/units and requiring constant cuttings to fit in position. Nonetheless, QS-01 believes that, to the quantity surveyors, design is said to be complex when the necessary details, dimensions, and the specifications to be used for preparing their quantity take or estimate are not clear, or are not available.

5.5.2 Contributions of design complexity to material-waste generation and cost overruns

Lack of standardisation in material sizes leads to constant cuttings of materials to fit in position, which results in material-waste generation; and thereby contributes to project cost overruns (3PMs and 2QSs). Four respondents (QS-07, PM-13, PM-05 and PM-10) believed that complex construction techniques and cuttings in material sizes due to design complexity lead to material-waste generation and contribute thereby to cost overruns.

Coincidentally, fifteen (15) respondents (5PMs, 6QSs, 3SEs, and 1STO) stated that the more complex the design, the more likely the generation of on-site waste; but a good understanding of the complexity would reduce the magnitude of the waste to be generated.

In other words, QS-09 added that constant change in design scope, as a result of complexity would result in waste generation.

Finally, PM-07 stated that design complexity could lead to re-design, variation, and re-work and contribute to project cost overruns. PM-08 demonstrated that straight and regular designs generate less waste compared to irregular and complex designs.

5.5.3 Relationship between design complexity and the occurrence of variations in a project

Variation is the modification of design quality or quantity. QS-02, PM-02, PM-03, SE-01, and SE-02 believed that the more complex the design, the more likely the variation, which might impact on the project cost. QS-05 and QS-08 concluded that variations could occur in a project when the designed/specified materials are not readily available. QS-02, PM-02, and PM-03, highlighted that the ability to maintain a specification in complex designs is very difficult, because of the market trends; as some materials might not be readily available in the local markets. Some of the materials might have to be manufactured abroad. Thus, the originally specified materials may be replaced with local ones, as a result of design complexity.

Furthermore, PM-01, PM-07 and SE-03 noted that variation is also noticed in projects with simple design. Nevertheless, complication in the nature of a design could lead to the occurrence of variation. Eight respondents (3QSs, 3PMs, SE-04, and 1STO) added that a complex design due to its nature could result in variation. QS-03 and PM-05 stated that a complex design must always be linked with a method statement to avoid variation.

Moreover, QS-04, PM-08, and PM-10 indicated that assumption due to difficulty in interpreting project specifications could also lead to variation. PM-06 and PM-09 noted that if a design is not fully detailed, the construction could be subject to re-measurement and re-work, thereby causing a variation. QS-06 and PM-12 explained that complex design always requires unique skills and the availability of sophisticated equipment; as a shortage of skilled manpower and poor workmanship as result of complexity could give rise to a variation in design.

Additionally, unclear design and specifications, as well as different interpretations of design could lead to variation and rework (QS-06, PM-12, PM-11, PM-13 and SE-05).

5.5.4 The effects of material-waste sources and causes on project cost overruns (Design complexity)

Table 5.10 indicates that 100 and 93.3 percent of the respondents agreed that "inexperienced designer", and "difficulties in interpreting specification", respectively, were the material-waste causes that have 'very high effects' in causing project cost overruns, as a result of complexity in design; since they fall between 90 and100 percent.

Percentages of 80, 76.71, and 73.3 in relation to "designing unstandardised dimensions requiring cutting and chiselling", "designing uneconomical shapes and outlines", and "inadequate design information", respectively, were deemed by the respondents to have 'high effects' on project cost overruns in dealing with design complexity; because they fall between 70 and 80 percent.

"Designing irregular shapes and forms" (66.74 percent) was regarded by the respondents to have 'moderate effects' on project-cost overruns in this stage; as it falls between 50 and 60 percent.

Furthermore, the material-waste causes that have 'little effects' (30-49 percent) in causing project-cost overruns at the design complexity stage were the "use of sophisticated systems and components", "errors in design" and "designing materials that are not readily available/locally obtainable".

Percentages of 16.7, 13.3, 6.7, 3.3, 3.3, and 3.3 relative to "buildability analysis", "lack of monitoring and improving on previous mistakes", "prefabrication and pre-casting of concrete panels", "lack of prioritizing re-use in designs and specifications", "improper planning for waste management", and "poor monitoring of design process", respectively, were considered by the respondents to have 'very little effect' in causing cost overruns; because they fall between 1 and 29 percent.

Table 5.10: The results of cross-tabulation on the sources and causes of material waste on cost overruns (Design complexity)

S/n	Causes and sources of material waste on cost overrun (Design complexity)	PM	QS	SE	STO	Total	Ranking	Decision
1	Designing uneconomical shapes and outlines	10 (66.7%)	9 (100%)	3 (60%)	1 (100%)	23 (76.7%)	4	High
2	Sophisticated systems and components	4 (26.7%)	4 (44.4%)	1 (20%)	0 (0%)	9 (30%)	9	Little
3	Difficulties in interpreting specification	14 (93.3%)	9 (100%)	4 (80%)	1 (100%)	28 (93.3%)	2	Very high
4	Designing irregular shapes and forms	11 (73.3%)	4 (44.4%)	4 (80%)	1 (100%)	20 (66.7%)	6	Moderate
5	Designing substandard dimensions, requiring cutting and chiseling	13 (86.7%)	7 (77.8%)	3 (60%)	1 (100%)	24 (80%)	3	High
6	*Errors in design	9(60%)	2(22.2%)	2(40%)	1(100%)	14(46.7%)	7	Little
7	*Inexperienced designer	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
8	*Designing materials that are not readily available/locally obtainable	4 (26.7%)	5 (55.6%)	2 (40%)	0 (0%)	11 (36.7%)	8	Little
9	*Use of specialised technology and consultant	3 (20%)	1 (11.1%)	0 (0%)	0 (0%)	4 (13.3%)	11	Very little
10	*Buildability analysis	3(20%)	1(11.1%)	1(20%)	0(0%)	5(16.7%)	10	Very little
11	*Lack of monitoring and Improving on previous mistakes	2 (13.3%)	2 (22.2%)	0 (0%)	0 (0%)	4 (13.3%)	11	Very little
12	*Inadequate design information	13(86.7%)	5(55.6%)	3(60%)	1(100%)	22(73.3%)	5	High
13	*Lack of prioritizing reuse in designs and specifications	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	18	Very little
14	*Improper planning for waste management	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	18	Very little
15	*Lack of thorough understanding of design before construction	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	18	Very little
16	*Prefabrication and pre-casting of concrete panels	0 (0%)	2 (22.2%)	0 (0%)	0 (0%)	2 (6.7%)	18	Very little
17	*Poor communication among designers (Architect and Engineers)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	18	Very little
18	*Poor monitoring of design process	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)	18	Very little

Source: Researcher's field survey, 2015

5.5.5 Effects of material-waste control measures on project cost overruns (Design complexity)

The responses given in Table 5.11 show that most respondents (100, 96.7 and 90 percent), respectively, were of the opinion that “engaging an experienced designer”, “designing readable dimensions and specifications”, and “standardisation in designs and units”, respectively, have a ‘very high effect’ (between 90 and100 percent) in controlling project-cost overruns that may arise as a result of design complexity. This is probably because the respondents believe that an experienced designer must have learnt from his previous mistakes on how to design materials/units in their standard sizes, in order to avoid any unnecessary cutting, chiselling, or wastage that could contribute to cost overruns.

Consequently, “designing economic shapes and outlines” has ‘high effect’ with 76.7 percent. Although, percentages of 40 and 33.3 relative to “interpretable design” and “design recommending available human resources and local materials”, respectively, were considered by the respondents to have ‘little effect’ in controlling material waste and cost overruns in this stage; because they fall between 30 and 49 percent.

Furthermore, percentages of 16.7 and 13.3 relative to “engaging in buildability analysis at the planning stage”, “proper monitoring and supervision of work”, “improving on previous design mistakes/errors”, and the “use of specialised technology and consultants” were considered to have ‘very little effect in controlling cost overruns; because they fall between 1 and 29 percent.

Table 5.11: The results of cross-tabulation on the control measures for material waste on cost overruns (Design complexity)

S/n	Control measures for material waste (Design complexity)	PM	QS	SE	STO	Total	Ranking	Decision
1	*Experienced designer	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
2	*Standardization in design and units	14(93.3%)	8(88.9%)	4(80%)	1(100%)	27(90%)	3	Very high
3	*Interpretable designs	5(33.3%)	5(55.6%)	2(40%)	0(0%)	12(40%)	5	Little
4	*Readable dimensions and specifications	14 (93.3%)	9 (100%)	5 (100%)	1 (100%)	29 (96.7%)	2	Very high
5	*Designing economic shapes and outlines	10 (66.7%)	9 (100%)	3 (60%)	1 (100%)	23 (76.7%)	4	High
6	*A design recommending available human resources and local materials	4 (26.7%)	4 (44.4%)	2 (40%)	0 (0%)	10 (33.3%)	6	Little
7	*Use of specialized technology and consultants	3 (20%)	1 (11.1%)	0 (0%)	0 (0%)	4 (13.3%)	10	Very little
8	*Proper monitoring and supervision of work	3 (20%)	1 (11.1%)	0 (0%)	0 (0%)	4 (13.3%)	10	Very little
9	*Improving on previous design mistakes	1 (6.7%)	2 (22.2%)	1 (20%)	0 (0%)	4 (13.3%)	10	Very little
10	*Engaging in buildability analysis at the planning stage	3 (20%)	1 (11.1%)	1 (20%)	0 (0%)	5 (16.7%)	7	Very little

Source: Researcher's field survey, 2015

5.5.6 Comparative views of respondents on the "effects of material-waste sources, causes, and control measures on project cost overruns" (Design complexity)

Table 5.12 shows the results of ANOVA analyses performed to compare the views of the respondents (Project Managers, Quantity Surveyors, Site Engineers and a Senior Technical Officer) on the 'effects of material-waste sources, causes, and control measures on project-cost overruns'.

It was apparent from the analyses that the values of f-calculated (1.606 and 1.026) for the two analyses (material waste sources and causes and control measures) were both less than the value of f-tabulated (1.701), respectively. The probability values (0.22 and 0.372) were both greater than the critical value of the 5 percent level of significance within the mean squared group (2.4-3.86 and 1.53-1.57), respectively.

This indicates that the evidence is not statistically significant; and so the alternative hypotheses are rejected in favour of the null hypotheses.

The above results show that there were no differences in the opinions of the respondents on the effects of material-waste sources, causes, and control measures on project-cost overruns at this stage (Design complexity).

Table 5.12: The results of ANOVA analyses for the test of difference in professional views on the "effects of material waste sources, causes and control measures on project cost overrun" (Design complexity)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F cal	F tab	Probability value	Remark	Action on H
1	PM	QS	SE	STO	One-way ANOVA	3.86 2.40	1.606	1.701	0.220	Not statistically significant	Accept Ho & reject Hi
	Sources and causes										
2	PM	QS	SE	STO	One-way ANOVA	1.57 1.53	1.026	1.701	0.372	Not statistically significant	Accept Ho & reject Hi
	Control measures										

Source: Researcher's field survey, 2015

5.6 Quality of Estimating

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked/ticked by the researcher during the course of the interview on the issues relating to material waste and cost overruns at the quality of estimating stage of a project.

5.6.1 Contribution of quality-of-estimating to material-waste generation on construction sites

Twenty-two (22) respondents (12PMs, 6QSs, 4SEs, and 1STO) believe that wrong (under/over) estimation for a project has a strong link with material-waste generation resulting in cost overruns. They stressed that if over-estimation occurred, more materials would be procured onsite, which would be over the required quantity and the remaining materials would result in waste, and thereby contribute to cost overruns.

Also, under-estimation would require the additional cost of transportation, loading and unloading materials for more procurement, resulting in the waste of resources and contributing to the cost overrun.

Furthermore, PM-01 stated that a less-experienced estimator could either under-or over-estimate for a project. QS-01 reported that a less-experienced estimator might not be able to envisage what it takes to prepare an accurate estimate for a project. For instance, fresh graduate estimators/QSs estimate exactly (net) without taking cognisance of bulking in concrete, or other related percentage additions allowed for in a project. SE-02 believes that an experienced estimator should be able to minimise waste, as far as possible for a project.

QS-05 and PM-10 suggested that poor quality estimation results in poor unit rates and wrong procurement, thereby leading to material waste and cost overruns.

5.6.2 Contributions of quantity take-off/cost estimating to waste generation and cost overruns

QS-02, PM-02, PM-03 and SE-01 highlighted that quantity take-off, which is the process of estimation contributes to good or wrong estimation for a project; and wrong estimation contributes to material-waste generation and cost overruns.

Therefore, all the respondents interviewed disclosed that wrong quantity take-off would result in over-or under-estimation and contribute to waste generation and project cost overrun.

PM-12 cited an example that:

"Sharp sand has a shrinkage allowance of 30 percent; and the absence of this allowance in taking-off for sharp sand would result in under-estimation."

5.6.3 'Insufficient time for estimate' as a factor that contributes to material waste and cost overruns (Quality of estimating)

All the interviewees' responded that insufficient time for estimates contributes to material waste and cost overrun "to a very high degree". Eight respondents (4QSs, 3PMs, and SE-03) explained that pressure on the estimator to produce an estimate earlier than when due could lead to making incorrect assumptions. Thus, the estimator needs ample time to conduct market surveys/analysis or market intelligence, in order to have an idea on the current prices of materials. This would reduce the risks of assumptions that might contribute to waste generation and cost overruns.

Coincidentally, PM-12, SE-04 and PM-15 disclosed that project estimators need sufficient time to study project particulars, such as the designs/drawings and specifications; and they would need to conduct a market survey to come up with a comprehensive and an error-free estimate. QS-07 added that insufficient time for estimate results in inaccurate estimation of quantities, leading to re-measurement and additional work, which might impact negatively on the project cost. QS-03 highlighted that a design may sometimes specify foreign materials, which might not be locally available; thus, sufficient time must be given to the estimator to avoid assuming the estimation figures.

5.6.4 Effects of material waste sources and causes on project-cost overruns (Quality of estimating)

Table 5.13 indicates that "inaccurate quantity take-off", and "insufficient time for estimate" were the highest ranked (100 percent) material-waste causes in the quality-of-estimating stage by the respondents, followed by a "lack of detailed (readable and interpretable) drawings and specifications for estimating" (93.3). They were deemed to have a 'very high effect' in causing project-cost overruns. This is probably because the respondents think that accurate quantity take-off leads to accurate estimation; and insufficient time for estimates might compel the estimator to make some unnecessary assumptions that could give rise to under-or over-estimation for a project.

The three other material waste causes with 'high effect' on cost overruns were "over-or under-estimating and allowance" (80 percent), "inadequate project risks evaluation, analysis, and estimation" (76.7 percent), and "inadequate knowledge of site conditions" (73.3 percent).

Furthermore, material waste causes with percentages of 66.7, 53.3, 53.3, and 50, relative to "inexperienced estimator", "different methods used in estimation", "poor knowledge of fluctuating market conditions/prices", and "lack of estimating information", respectively, were deemed by the respondents to have a 'moderate effect' on project cost overruns.

"Improper monitoring and improvement on previous mistakes", "design requiring frequent change", "late engagement of estimators" with percentages of 23.3, 3.3 and 3.3, respectively, were considered to have 'very little effect' in causing project cost overruns; because they fall between 1 and 29 percent.

Table 5.13: Results of cross-tabulation on the effects of material-waste sources and causes on project cost overrun (Quality of estimating)

S/n	Causes and sources of material waste on cost overrun (Quality of estimating)	PM	QS	SE	STO	Total	Ranking	Decision
1	Over/under estimating	15(100%)	5(55.6%)	3(60%)	1(100%)	24 (80%)	4	High
2	Inaccurate quantity take-off	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
3	Insufficient time for estimate	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
4	Different estimation methods	7(46.7%)	3(33.3%)	5(100%)	1(100%)	16(53.3%)	8	Moderate
5	*Inexperienced estimator	9(60%)	6(66.7%)	4(80%)	1(100%)	20(66.7%)	7	Moderate
6	*Lack of detailed drawing and specifications (readable & interpretable)	15 (100%)	7 (77.8%)	5 (100%)	1 (100%)	28 (93.3%)	3	Very high
7	*Inadequate project risks evaluation, analysis, and estimation	12 (80%)	7 (77.8%)	3 (60%)	1 (100%)	23 (76.7%)	5	High
8	*Inadequate knowledge of site conditions	9 (60%)	8 (88.9%)	4 (80%)	1 (100%)	22 (73.3%)	6	High
9	*Lack of estimating information	6(40%)	4(44.4%)	4(80%)	1(100%)	15(50%)	10	Moderate
10	*Poor knowledge of fluctuating market conditions/prices	8 (53.3%)	5 (55.6%)	2 (40%)	1 (100%)	16 (53.3%)	8	Moderate
11	*Improper monitoring and improvement on previous mistakes	4 (26.7%)	1 (11.1%)	2 (40%)	0 (0%)	7 (23.3%)	11	Very little
12	* Frequent design change	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	12	Very little

13	*Late engagement of estimators	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	13	Very little

Source: Researcher's field survey, 2015

5.6.5 Effects of control measures for material waste on project-cost overruns (Quality of estimating)

Analysis of the effects of control measures for material waste on project cost overruns at the quality of estimating stage in Table 5.14 revealed that 100 percent of the respondents believe that "sufficient time for estimate", and "accurate quantity take-off" have a 'very high effect' in controlling material waste and cost overruns. This is followed by "engaging experienced estimator" and the "availability of detailed drawings, dimensions, and specifications" with 96.7 percent. This is probably because the respondents believe that designs, dimensions, and specifications are the primary source of project estimates. Therefore, inadequate detailing and dimensioning could lead to inaccurate quantity take-offs and to wrong project estimation and cost overruns.

Additionally, percentages of 86.7 and 83.3, relative to "error-free estimation" and "proper risks estimation for project", respectively, were deemed to have a 'high effect' in managing cost overruns for projects. This is probably because the respondents think that achieving an error-free estimation would require proper project risks evaluation and analysis. To achieve this, the estimator has to be experienced enough, and the documents (drawings and specifications) must be detailed and unambiguous.

Furthermore, percentages of 53.3 and 50 in relation to "knowledge of fluctuating market prices of materials", and the "availability of estimating information", respectively, were deemed by the respondents to have 'moderate effects' in controlling cost overruns; since they fall between 50 and 69 percent.

Moreover, "thorough design check and estimate", and "monitoring and improving on previous estimating mistakes" were considered to have 'very little effect' on cost overruns; because they fall between 1 and 29 percent, as stated by Morenikeji (2006).

Table 5.14: Results of cross-tabulation on the effects of control measures for material waste on cost overruns (Quality of estimating)

S/n	Control measures for material waste (Quality of Estimating)	PM	QS	SE	STO	Total	Ranking	Decision
1	Ensure a good knowledge of material estimation (Unified method of estimating)	5 (33.3%)	4 (44.4%)	2 (40%)	0 (0%)	11 (36.7%)	10	Little
2	Error free estimation	15 (100%)	6 (66.7%)	4 (80%)	1 (100%)	26 (86.7%)	4	High
3	Knowledge of fluctuating market prices of materials	8 (53.3%)	4 (44.4%)	3 (60%)	1 (100%)	16 (53.3%)	6	Moderate
4	*Thorough checking of design and the prepared estimate	2 (13.3%)	1 (11.1%)	1 (20%)	0 (0%)	4 (13.3%)	12	Very little
5	*Experienced estimator	15 (100%)	8 (88.9%)	5 (100%)	1 (100%)	29 (96.7%)	2	Very high
6	*Detailed drawings, dimensions and specifications	15 (100%)	8 (88.9%)	5 (100%)	1 (100%)	29 (96.7%)	2	Very high
7	*Proper risks estimation	12 (80%)	8 (88.9%)	4 (80%)	1 (100%)	25 (83.3%)	5	High
8	*Knowledge of site conditions	4 (26.7%)	5 (55.6%)	3 (60%)	1 (100%)	13 (43.3%)	9	Little
9	*Sufficient time for estimate	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
10	*Availability of estimating information	5 (33.3%)	5 (55.6%)	4 (80%)	1 (100%)	15 (50%)	7	Moderate
11	*Accurate quantity take-off	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
12	*Monitoring and improving on previous estimating mistakes	4 (26.7%)	1 (11.1%)	2 (40%)	0 (0%)	7 (23.3%)	11	Very little

Source: Researcher's field survey, 2015

5.6.6 Comparative views of respondents on the "effects of material-waste sources, causes, and control measures on project-cost overruns" (Quality of estimating)

The comparative analyses of the respondents' views on the effects of material-waste sources, causes, and control measures on project-cost overruns in Table 5.15 reveal that the values of f-calculated (0.952 and 0.917) were less than the value of f-tabulated (1.701), respectively. The probability values (0.399 and 0.412) were both greater than the critical value of the 5 percent (0.05) significance level at the 95 percent confidence level within the mean square group (2.35-2.47 and 2.00-2.18), respectively.

The evidence here is not statistically significant. The alternative hypotheses are hereby rejected in favour of the null hypotheses. These results imply that the respondents were of the same view on the effects of material-waste sources, causes, and control measures on cost overrun in the construction industry (Quality of estimating).

Table 5.15: Results of ANOVA analyses for the test of difference in professional views on "effects of material-waste sources, causes and control measures on project cost overruns" (Quality of estimating)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
4a	PM	QS	SE	STO	One-way ANOVA	2.35 2.47	0.952	1.701	0.399	Not statistically significant	Accept Ho & reject Hi
	Sources and causes										
4b	PM	QS	SE	STO	One-way ANOVA	2.00 2.18	0.917	1.701	0.412	Not statistically significant	Accept Ho& reject Hi
	Control measures										

Source: Researcher's field survey, 2015

5.7 Quality of Procurement Management

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher during the course of the interview on the issues relating to material waste and cost overruns on the quality of the procurement management stage of a project.

5.7.1 The quality of procurement-management in the respondents' organisation/industry

All the respondents disclosed that their organisation/company does procure materials, in accordance with the project specifications.

PM-01 disclosed that:

"We have experts heading our procurement unit. They have the knowledge of current material prices both locally and internationally and the procurement is done strictly, in accordance with project specifications."

QS-03 further explained that:

"We have a procurement department both locally and internationally such as France and Australia because our company has a special network in case a project is designed and is requiring foreign materials."

PM-12 stated that:

"We have a procurement department with an operation manager, the purchaser, and the transport section; and all of them are sufficiently experienced."

QS-04, PM-08, and PM-09 disclosed that their organisations have a very efficient and a well-organised procurement-management plan; because they ensure that right quantities and qualities of materials are delivered at the right time. QS-05, PM-06, QS-07, PM-11, PM-14, SE-04, and SE-05 added that they have good quality procurement team/personnel; because they have the know-how of what to procure, what quantity to procure, at what cost to procure, and where to procure all, in accordance with the projects' specifications.

In that line, PM-07, PM-10, PM-13, QS-09 and PM-15 also stated that they have experienced and market-oriented personnel, who procure construction materials, in accordance with the specifications. QS-06, QS-08 and SE-03 disclosed that they follow due process in both contractor and material selection process.

Consequently, QS-01, PM-04, STO and PM-05 stated that procurement in their organisation was at an average level; and they further noted that their procurement-management unit is different from estimating department. The estimating unit does the estimating for the procurement department.

SE-01 and SE-02 added that accredited suppliers are engaged in their procurement process to ensure that material quality is not compromised.

5.7.2 Contributions of material procurement to waste-generation and cost overruns

Most of the respondents stated that procuring the right materials at the right time in accordance with the specifications would reduce material waste and cost overruns**.**

SE-01 and SE-02 explained that good material handling, good product knowledge, and procuring the appropriate materials in accordance with specifications would reduce material waste and cost overruns.

5.7.3 Contribution of quality of firms' procurement management to material waste and cost overruns

Fourteen (6PMs, 3QSs, 4SEs and 1STO) explained that in the absence of a competent procurement management, a job would probably be given to an incompetent contractor, who might end up in wasting materials, thereby leading to cost overruns. QS-01, QS-03, QS-09, PM-05, PM-12, PM-14, PM-15 and SE4 stated that inexperienced procurement personnel can procure substandard materials, which could result in waste; and thereby contribute negatively to the project's final cost. PM-08 and PM-11 clarified that lack of control in procurement to ensure that good quality materials, as stated in the project specifications, are delivered to site could end up as waste; and the accumulated waste contributes to cost overruns.

Furthermore, PM-04 believes that a good quality procurement-management team should envisage better transportation of materials, ordering the appropriate quantity of materials, the provision of an easy access road, and so forth. Where these cannot be envisaged, then waste would inevitably occur, which would contribute to cost overrun.

PM-01, QS-05, QS-07, and PM-07 emphasised that wrong estimation (over-estimation) of materials to be procured, and procuring contrary to specifications both have a strong effect on waste generation and cost overruns. Over-procuring of materials leads to waste generation; because of on-site material damage/sabotage and pilferaging.

5.7.4 Effects of material-waste sources and causes on project-cost overruns (Quality of procurement management)

Table 5.16 indicates that 100 percent of the respondents agreed that “procuring items not in compliance with project specifications” and “engaging inexperienced personnel in estimation and procurement” were the major material-waste causes that have a ‘very high effect’ on project-cost overruns at the procurement-management stage.

The percentages of 76.7, 73.3, and 73.3 relative to “mistakes in quantity surveys (poor estimate for procurement)”, “procuring wrong quantity of materials at the wrong time”, and “delivery of substandard materials”, respectively, were the main material waste causes considered by the respondents to have a ‘high effect’ in causing cost overruns; because they fall between 70 and 89 percent.

Additionally, percentages of 60, 56.7, 53.3, 53.3, 53.3, and 50, in relation to “wrong material delivery procedures”, “lack of quality control/assurance for evaluation of procured product”, poor material handling”, “poor product knowledge”, “poor supply-chain management” and “damage of material during transportation”, respectively, were deemed by the respondents to have a ‘moderate effect’ on cost overruns.

“Inadequate delivery schedule” and “incompetent procurement management” were considered by the respondents to have ‘little effect’ on cost overruns; because they fall between 30 and 49 percent.

Other causes, such as “errors in shipping”, “market conditions” “damage of material during transportation”, and “lack of awareness” were deemed to have ‘very little effect’ on cost overruns at the procurement-management stage of a project; because they fall between 1 and 29 percent.

Table 5.16: Results of cross-tabulation on the sources and causes of material waste on cost overruns (Quality of procurement management)

S/n	Causes and sources of material waste on cost overrun (Quality of procurement management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Procurement and transportation***							
1	Mistakes in material procurement	6 (40%)	1 (11.1%)	0 (0%)	0 (0%)	7 (23.3%)	15	Very little
2	Procuring items not in compliance with specification	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
3	Errors in shipping	2(13.3%)	0 (0%)	3(60%)	0(0%)	5(16.7%)	18	Very little
4	Mistakes in quantity surveys: Poor estimate for procurement	11 (73.3%)	7 (77.8%)	4 (80%)	1 (100%)	23 (76.7%)	3	High effect
5	Wrong material delivery procedures	10 (66.7%)	6 (66.7%)	2 (40%)	0 (0%)	18 (60%)	6	Moderate
6	Delivery of substandard materials	11 (73.3%)	5 (55.56%)	5 (40%)	1 (0%)	22 (73.3)	4	High effect
7	Damage of material during transportation	10 (66.7%)	4 (44.4%)	1 (20%)	1 (3.3%)	16 (53.3%)	8	Very little
8	inadequate delivery schedule	5 (33.3%)	4 (44.4%)	2 (40%)	0 (0%)	11 (36.7%)	12	Little effect
9	Market conditions	2(13.3%)	0(0%)	1(20%)	0(0%)	3(10%)	26	Very little
10	Poor material handling	7(46.7%)	6(66.7%)	3(60%)	0(0%)	16(53.3%)	8	Moderate
11	Waiting for replacement	0(0%)	0(0%)	0(0%)	0(0%)	0 (0%)	32	No response
12	Poor protection of materials and damage during transportation	10 (66.67%)	4 (44.4%)	2 (40%)	1 (3.3%)	17 (56.7%)	7	Very little
13	Over allowance	3(20%)	4(44.4%)	0(0%)	0(0%)	7(23.3%)	15	Very little
14	Frequent variation orders	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	32	No response
15	Poor product knowledge	7(46.7%)	4(44.4%)	4(80%)	0(0%)	15(50%)	9	Moderate
16	Difficulties of vehicles in accessing site	3(20%)	1(11.1%)	0(0%)	0(0%)	4(13.3%)	20	Very little
17	*Procuring substandard materials	3 (20%)	0 (0%)	0 (0%)	0 (0%)	3 (10%)	26	Very little
18	*Inexperienced personnel in estimation and procurement	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
19	*Procuring wrong quantity of materials at the wrong time	11 (73.3%)	5 (55.6%)	5 (100%)	1 (100%)	22 (73.3%)	4	High effect
20	*Lack of quality control assurance for evaluation of procured product	9 (60%)	5 (55.6%)	3 (60%)	0 (0%)	17 (56.7%)	7	Moderate
21	*Competent procurement management	3 (20%)	2 (22.2%)	4 (80%)	0 (0%)	9 (30%)	13	Little effect

22	*Lack of professionalism and transparency in procurement	4 (26.7%)	1 (11.1%)	0 (0%)	0 (0%)	5 (16.7%)	18	Very little
23	*Lack of early materials requisition	1 (6.7%)	0 (0%)	0 (0%)	0 (0%)	1 (3.3%)	30	Very little
b	**Manufacturers' source**							
24	Poor quality of materials	3(20%)	3(33.3%)	0(0%)	0(0%)	6(20%)	17	Very little
25	Poor product information	1(6.7%)	3(33.3%)	0(0%)	0(0%)	4(13.3%)	20	Very little
26	Lack of awareness	1(6.7%)	3(33.3%)	0(0%)	0(0%)	4(13.3%)	20	Very little
27	Poor projection for materials	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	32	No response
c	***Suppliers' source***							
28	Poor supply chain management	10 (66.6%)	3 (33.3%)	2 (40%)	1 (100%)	16 (53.3%)	8	Moderate
29	Poor packaging	1(6.7%)	2(22.2%)	0(0%)	0(0%)	3(10%)	26	Very little
30	Supplier errors	1(6.7%)	1(11.1%)	0(0%)	0(0%)	2(6.7%)	29	Very little
31	Poor product incentive	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	32	No response
32	Poor handling of supplied materials	8(53.3%)	5(55.6%)	3(60%)	0(0%)	16(53.3)	8	Moderate

Source: Researcher's field survey, 2015

5.7.5 Effects of material waste-control measures on project cost overrun (Quality of procurement management)

It is apparent from Table 5.17 that percentages of 100 and 96.7 relative to "procuring in accordance with specification" and "experienced personnel in estimation and procurement", respectively, by the respondents were considered to be the material waste-control measures that have 'very high effects' in controlling project-cost overruns on the quality of procurement management of a project; because they fall between 90 and100 percent. "Procuring the right quantity of materials at the right time" was considered by the respondent as the only factor that has a 'high effect' on cost overruns; because it falls between 70 and 80 percent.

Furthermore, percentages of 63.3, 60, 56.7, and 53.3 relative to "standard evaluation and comparing with specification", "efficient methods of unloading materials supplied in loose form", "adoption of unified method of estimating for procurement"," formation of a quality-control unit for evaluation of procured product" and "enhanced construction material handling by workers", respectively, were considered to have a moderate effect in controlling cost overruns by the respondents because they fall between 50 and 69 percent.

Consequently, “materials should be manufactured in standard units”, “timely delivery of materials”, “ordering of appropriate quantities of materials”, “improved supply-chain management”, and “competent procurement management” with percentages of 46.7, 40, 36.7 and 30, respectively, were deemed to have ‘little effect’ on project-cost overruns; because they fall between 30 and 49 percent.

“Improved quality of materials”, “knowledge of product to be manufactured”, “better delivery of materials on site”, “adopting good material abstraction processes”, and “provision of an easy access road for vehicle deliveries” were considered to have ‘very little’ effect on cost overruns; because they fall between 1 and 29 percent.

Table 5.17: Results of cross-tabulation on the control measures for material waste on cost overruns (Quality of Procurement management)

S/n	Control measures for material waste (Quality of Procurement management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Procurement & transportation***							
1	Better transportation of materials	3 (20%)	0 (0%)	1 (20%)	0 (0%)	4 (13.3%)	16	Very little
2	Enhanced construction material handling by workers	7 (46.7%)	6 (66.7%)	3 (60%)	0 (0%)	16 (53.3%)	8	Moderate
3	Adopting good materials abstracting	1 (6.7%)	2 (22.2%)	1 (20%)	0 (0%)	4 (13.3%)	16	Very little
4	Provision of easy access road for vehicles delivery	3 (20%)	1 (11.1%)	0 (0%)	0 (0%)	4 (13.3%)	16	Very little
5	Adoption of unified method of estimating for procurement	8 (53.3%)	6 (66.7%)	4 (80%)	0 (0%)	18 (60%)	6	Moderate
6	Ordering appropriate materials quantity	5 (33.3%)	4 (44.4%)	2 (40%)	0 (0%)	11 (36%)	11	Little
7	Timely delivery of materials	6(40%)	4(44.4%)	1(20%)	1(10%)	12(40%)	10	Little
8	*Standard evaluation and comparing with specification	12 (80%)	2 (22.2%)	5 (100%)	0(0%)	19 (63.3%)	4	Moderate
9	*Procuring in accordance with specification	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
10	*Experienced personnel in estimation and procurement	14 (93.3%)	9 (100%)	5 (100%)	1 (100%)	29 (96.7%)	2	Very high
11	*Insurance of the procured materials	1 (6.7%)	1 (11.1%)	1 (20%)	0 (0%)	3 (10%)	21	
12	*Procuring the right quantity of materials at the right time	11 (73.3%)	5 (55.6%)	5 (100%)	1 (100%)	22 (73.3%)	3	High
13	*Formation of a quality control unit for evaluation of procured product	9 (60%)	5 (55.6%)	3 (60%)	0 (0%)	17 (56.7%)	7	Moderate

14	*Competent procurement management	3 (20%)	2 (22.2%)	4 (80%)	0 (0%)	9 (30%)	13	Little
15	*Professionalism and transparency in procurement	4 (26.7%)	1 (11.1%)	0 (0%)	0 (0%)	5 (16.7%)	15	Very little
b	***Manufacturers source***							
16	Improved quality of materials	3 (20%)	3(33.3%)	0(0%)	0(0%)	6(20%)	14	Very little
17	Materials should manufactured in standard units	9 (60%)	3 (33.3%)	2 (40%)	0 (0%)	14 (46.7%)	9	Little
18	Knowledge of product to be manufactured	1 (6.7%)	3 (33.3%)	0 (0%)	0 (0%)	4 (13.3%)	16	Very little
c	***Supplier source***							
19	Better and improved supply chain management	5 (33.3%)	4 (44.4%)	2 (40%)	0 (0%)	11 (36.7%)	11	Little
20	Efficient methods of unloading materials supplied in loose form	11 (73.3%)	5 (55.6%)	3 (60%)	0 (0%)	19 (63.3%)	4	Moderate
21	*Better materials delivery to site	1(6.7%)	2(22.2%)	0(0%)	0(0%)	3(10%)	21	Very little

Source: Researcher's field survey, 2015

5.7.6 Comparative views of respondents on the effects of material-waste sources, causes, and control measures on project-cost overruns (Quality of procurement management)

Analyses of the differences in the professional views on the effects of material-waste sources, causes, and control measures on project-cost overruns in Table 5.18 reveal a non-statistically significant difference between the values of f-calculated (0.238 and 0.236) less than the value of f-tabulated (1.701) and the probability values (0.790 and 0.792) greater than the critical value of the 5 percent level of significance within the mean-squared group (1.81-7.59 and 1.16-4.92), respectively.

The evidence here is not statistically significant. The alternative hypotheses are hereby rejected in favour of the null hypotheses. These imply that the respondents were of the same view on the effects of material-waste sources, causes, and control measures on cost overrun in the construction industry (Quality of procurement management).

Table 5.18: Results of ANOVA analyses on the effect of material waste sources, causes and control measures on cost overruns (Quality of procurement management)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
1	PM	QS	SE	STO	One-way ANOVA	1.81	0.238	1.701	0.790	Not statistically significant	Accept Ho & reject Hi
	Sources and causes					7.59					
2	PM	QS	SE	STO	One-way ANOVA	1.16	0.236	1.701	0.792	Not statistically significant	Accept Ho & reject Hi
	Control measures					4.92					

Source: Researcher's field survey, 2015

5.8 Quality of Construction Management

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher during the course of the interviews on the issues relating to material waste and cost overruns on the quality of design management stage of a project.

5.8.1 Quality of construction management based on the experiences of the respondents

PM-06, PM-10, PM11, PM-14, SE-03, and STO explained that achieving quality construction management entails managing the entire construction process from inception to completion with all the necessary management tools. QS-02 added that this is the practical way of achieving design success. QS-01, PM-01, PM-02, PM-04, PM-5, and PM-09 noted that there must be proper co-ordinating, controlling, organising, communicating, scheduling, motivating, proper building techniques, and good workmanship. PM-07 and QS-06 disclosed that construction management is the pillar of every construction work, which has to do with the management of people, plant, materials, equipment, money, time, and the entire construction process.

Moreover, ten respondents (2PMs, 6QSs, and 2SEs) noted that the quality of construction management entails proper management (controlling, co-ordinating, communicating, organising, motivating, and scheduling) of the 5Ms (men, machines, money, materials, and management) to achieve the project objectives. It has to do with the management of human and material resources, in order to achieve the project objectives (SE-01and PM-15). PM-08 and QS-07 mentioned the need for the inclusion of all the project stages in the management process, such as planning, design, construction and so forth.

However, SE-04 believes that to achieve quality construction management, every individual must be carried along with the rest of them.

5.8.2 Relationship between interviewee firms' construction management, material-waste generation, and cost overruns

The interviewees responded as follows:

PM-01 explained that:

"We are still far below average! We lose money when waste is generated; thus, we adopt re-use in order to minimise the amount of waste generated." QS-04 added that: *"we re-use material waste, wherever this is possible."*

QS-02 clarified that:

"We still have a long way to go! There are situations where projects are not delivered on time, and sometimes are not delivered within the required cost because of inadequate planning."

Some respondents explained that:

"We are at average!" (PM-07 and PM-14); *"we are above average!"* (QS-06, PM-11, and STO); *"we are trying our best!"* (SE-03); *"we are experienced enough and always plan ahead; hence, we generate less waste"* (6PM, 2QS, and SE-04); *and "we generate less*

waste! Knowing what to procure how to procure, where to procure, the cost to procure, and at what time to procure" (4PM, 3QS, and 3SE).

PM-08 concluded that a good material storage, the procurement of best quality materials, as stated in the specifications, and adequate site security would help in minimising material waste and cost overrun on construction site.

5.8.3 Contributions of sub-contractors and suppliers to material-waste generation and cost overruns

QS-01, PM-01, PM-04, PM-13, PM-14, and SE-03 agreed that both sub-contractors and suppliers contribute to material-waste generation. QS-04 and SE-05 stated that an incompetent subcontractor can waste materials on the site.

However, ten more respondents (5QS, 4PM, and STO) reported that:

"Some of our jobs are sub-contracted and incompetent sub-contractors are likely to generate waste right from their estimating stage. But a clause is stated in the contract document requiring that sub-contractors must deliver a project within a particular cost. In this case, the wastage of materials would only affect their own profit, and not the project cost."

For the suppliers, the quality-control department evaluates the supplied product to ensure that they are in conformity with the project's specifications."

Furthermore, eleven (11) respondents comprising 7PMs, 2SEs, and 2QSs explained that subcontractors are profit-oriented and the waste generated by them directly affects their profits. They noted that most contract agreements require subcontractors to generate waste at their own risks, which makes them more careful about the amount of waste they generate.

5.8.4 Impact of rework and mistake/error on material-waste generation and cost overruns

All the respondents (100 percent) believed that most of the issues stated in Table 5.16, for instance, inexperienced professionals/personnel or working contrary to project specification/contract, lead to rework, mistakes/errors.

Abortive work is already a waste; and would require the same materials, the same labour, and the same costs to re-build. Therefore, rework and mistake/error contribute tremendously to material-waste generation, which subsequently affects the final cost of a project.

5.8.5 Effects of material-waste sources and causes on project-cost overruns (Quality of Construction Management)

Table 5.19 shows the results of the analyses of the effects of material-waste sources and causes on project-cost overruns.

The table shows that 100 percent of the respondents agreed that “engaging incompetent workers” and “rework” (contractors’ source), respectively, were the major material-waste causes that have a ‘very high effect’ on cost overruns. This is probably because the respondents think that an incompetent worker could contribute to rework on the construction site, and removing a work that has been completed, and replacing it with new one would require new labour, materials and supervision, all of which would negatively affect the budgeted cost of a project.

The percentages of 83.3, 76.7, 73.3, 73.3, and 70 relative to “Incorrect scheduling and planning” (contractors’ source), “shortage of skilled workers” (workers’ source), “lack of experience”, “poor financial controls on site“ (contractors’ source), and “lack of proper organisation” (contractors’ source), respectively, were deemed by the respondents to have ‘high effects’ on cost overruns; because they fall between 70 and 89 percent.

Furthermore, percentages of 66.7, 60, 56.7, 56.7, 53.3, 50, and 50 relating to “poor communication and co-ordination”, “workers’ lack of enthusiasm” “lack of training and development”, “lack of support from senior management”, “poor site management and supervision", "poor workmanship" and "damage caused by workers", respectively, were considered to have a 'moderate effect' on cost overruns; since they fall between 50 and 69 percent.

Consequently, 40, 33.3, 30, and 30 percent of the respondents considered "poor motivation", "incompetent subcontractor/supplier", "lack of regular site meetings", and "poor workers attitude", respectively, were the material-waste causes that have 'little effect' on project-cost overruns; since they fall between 30 and 49 percent. However, material waste causes considered to have 'very little effect' on cost overruns include: "poor staff workers relationship", "lack of awareness on waste management", "use of unskilled labour to replace skilled ones", "lack of incentives", and " lack of a quality control unit" because they fall between 1 and 29 percent.

Unfortunately, none of the respondents remembered to speak about the "inappropriate use of materials and equipment." It was therefore rated as 'no response'.

Table 5.19: Results of cross-tabulation on the effects of material-waste sources and causes on cost overruns (Quality of construction management)

S/n	Causes and sources of material waste on cost overrun (Quality of construction management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Contractors' source***							
1	Incorrect scheduling and planning	12(80%)	8(88.9%)	4(80%)	1(100%)	25(83.3%)	3	High
2	Inappropriate contractor's policies	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)	36	Very little
3	Lack of awareness	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)		Very little
4	Lack of experience	9(60%)	9(100%)	3 (60%)	1(100%)	22(73.3%)	5	High
5	Laziness	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)		Very little
6	Poor site management supervision	10(66.7%)	4(44.4%)	1(20%)	1(100%)	16(53.3%)	9	Moderate
7	Poor building techniques	7(46.7%)	8(88.9%)	3(60%)	0(0%)	18(60%)	8	Moderate
8	Incompetent subcontractor/supplier	6(40%)	4(44.4%)	0(0%)	0(0%)	10(33.3%)	12	Little
9	Poor financial controls on site	11(73.3%)	6(66.7%)	4(80%)	1(100%)	22(73.3%)	5	High
10	Use of unskilled labour to replace skilled ones	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	36	Very little
11	*Improper management of plant	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	36	Very little
12	*Rework	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high

13	*Poor communication and co-ordination	9(60%)	7(77.8%)	4(80%)	0(0%)	20(66.7%)	7	Moderate
14	*Lack of proper organisation & control	8(53.3%)	8(88.9%)	4(80%)	1(100%)	21(70%)	6	High
15	*Lack of a quality control unit	2(13.3%)	2(22.2%)	1(20%)	0(0%)	5(16.7%)	18	Very little
17	*Poor motivation	6(40%)	4(44.4%)	2(40%)	0(0%)	12(40%)	13	Little
18	*improper monitoring of the construction process	1 (6.7%)	0 (0%)	0 (0%)	1 (100%)	2 (6.7%)	20	Very little
19	*Lack of regular site meetings	5(33.3%)	2(22.2%)	1 (20%)	1(100%)	9(30%)	14	Little
b	***Culture source***							
20	Lack of incentives	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	36	Very little
21	Lack of training and development	8(53.3%)	5(55.6%)	3(60%)	1(10%)	17(56.7%)	9	Moderate
22	Lack of support from senior management	10 (66.7%)	4 (44.4%)	2 (40%)	1 (10%)	17 (56.7%)	9	Moderate
23	Lack of awareness on waste management	1 (6.7%)	1 (11.1%)	0 (0%)	1 (100%)	3 (10%)	19	Very little
c	***Workers' source***							
24	Workers' mistakes or errors during construction	5 (33.3%)	1 (11.1%)	0 (0%)	0 (0%)	6 (20%)	17	Very little
25	Incompetent workers	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
26	Poor workers' attitude	4(26.7%)	3(33.3%)	1(20%)	1(100%)	9(30%)	14	Little
27	Lack of experienced workers	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	36	Very little
28	Shortage of skilled workers	11(73.3%)	7(77.8%)	4(80%)	1(100%)	23(76.7%)	4	High
29	Too much over time for workers	2(13.3%)	0(0%)	0(0%)	0(0%)	2(6.7%)	20	Very little
30	Inappropriate use of materials and equipment	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	37	No response
31	Poor workmanship	4(26.7%)	6(66.7%)	4(80%)	1(100%)	15(50%)	11	Moderate
32	Damage caused by workers	7(46.7%)	5(55.6%)	2(40%)	1(100%)	15(50%)	11	Moderate
33	Worker's lack of enthusiasm	7(46.7%)	8(88.9%)	3(60%)	0(0%)	18(60%)	36	Very little
34	*Inappropriate re-use of materials	0(0%)	0(0%)	1(20%)	0(0%)	1(3.3%)	36	Very little
35	*Poor management and workers' relationship	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)	36	Very little
36	*Poor adherence to specifications	0 (0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	36	Very little

Source: Researcher's field survey, 2015

5.8.6 Effects of control measures for material waste on project-cost overruns (Quality of construction management)

It is apparent from Table 5.20 that percentages of 83.3 and 76.7 relative to "proper scheduling and planning" and "engaging competent workers", respectively, were considered by the respondents to be the material waste-control measures that have a 'high effect' in controlling cost overruns.

Percentages of 66.7, 60, 56.7, 56.7, 53.3, and 50 in respect of “better storage facilities and environment/area”, “staff vocational training and development”, “establishing systems of rewards and punishments for material saving”, “improve contractors’ onsite construction management”, “adequate site control and supervision”, and “ensuring the achievement of good quality workmanship on site”, respectively were considered by the respondents to have a ‘moderate effects’ on cost overruns; because they fall between 50 and 69 percent.

As many as 33.3 percent of the respondents agreed that “competent contractor and supplier” and “appropriate material utilization for project”, respectively, were deemed to have ‘little effect’ in controlling cost overruns; since they fall between 30 and 49 percent. This percentage of respondents should be understood relative to major causes of cost overrun on projects. For instance, proper scheduling and planning, engaging competent workers, proper communication and coordination, and so forth.

Furthermore, 26.7 percent of the respondents believed that “process improvement techniques/improving on previous mistakes” would assist in controlling cost overruns for the project. However, 20 percent suggested the inclusion of “improved material handling methods” and “error-free construction processes”, respectively. Another 10 percent explained that “use of skilled and experienced labour” and “proper management support for workers”, respectively would contribute to the minimising of project cost overruns. Only 3.3 percent (one respondent) considered “holding regular site meetings” as a way for controlling cost overruns in the quality-of-construction management stage of a project. They were all deemed by the respondents to have ‘very little effect; since they all fall between 1 and 29 percent.

Table 5.20: Result of cross-tabulation on the effects of control measures for material waste on cost overruns (Quality of construction management)

S/n	Control measures for material waste (Quality of Construction Management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Contractors’ source***							
1	Competent contractor	6 (40%)	4 (44.4%)	0 (0%)	0 (0%)	10 (33.3%)	9	Little

2	Proper scheduling and planning	12 (80%)	8 (88.9%)	4 (80%)	1 (100%)	25 (83.3%)	1	High
3	Use of skilled and experienced labour	0 (0%)	3 (33.3%)	0 (0%)	0 (0%)	3 (10%)	18	Very little
4	Adequate site control and supervision	10 (66.7%)	4 (44.4%)	1 (20%)	1 (100%)	16 (53.3%)	7	Moderate
5	Integrate waste management into the assessment of construction contractor	1 (6.7%)	1 (11.1%)	1 (20%)	0 (0%)	3 (10%)	18	Very little
6	Improve contractors' onsite construction management	7 (46.7%)	5 (55.6%)	4 (80%)	1 (100%)	17 (56.7%)	5	Moderate
7	*Competent supplier	5 (33.3%)	4 (44.4%)	1 (20%)	0 (0%)	10 (33.3%)	9	Little
8	*Proper communication & coordination	10 (66.7%)	7 (77.8%)	4(80%)	0(0%)	21(70%)	3	High
9	*Error-free construction process	2 (13.3%)	1 (11.1%)	3(60%)	0(0%)	6(20%)	15	Very little
10	*Process improvement techniques	3 (20%)	4 (44.4%)	1 (20%)	0 (0%)	8 (26.7%)	12	Very little
11	*Adequate building technique	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	27	Very little
b	***Culture source***							
12	Establish systems of rewards and punishments for material saving	8 (53.3%)	6 (66.7%)	2 (40%)	1 (100%)	17 (56.7%)	5	Moderate
13	Proper management workers support	2 (13.3%)	0(0%)	0 (0%)	1(100%)	3(10%)	18	Very little
14	Awareness among practitioners on managing waste	4 (26.7%)	2 (22.2%)	1 (20%)	0 (0%)	7 (23.3%)	13	Very little
15	Staff vocational training	10 (66.7%)	5 (55.6%)	2 (40%)	1 (100%)	18 (60%)	5	Moderate
c	***Workers' source***							
16	Ensuring that good quality workmanship is achieved	8 (53.3%)	5 (55.6%)	2 (40%)	0 (0%)	15 (50%)	8	Moderate
17	Appropriate material utilization	3 (20%)	4 (44.4%)	3 (60%)	0 (0%)	10 (33.3%)	9	Little
18	Availability of good work-life balance	1 (6.7%)	3 (33.3%)	0 (0%)	0 (0%)	4 (13.3%)	17	Very little
19	Engaging competent workers	11 (73.3%)	7 (77.8%)	4 (80%)	1 (100%)	23 (76.7%)	2	High
20	*Adoption of re-use of materials	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)	27	Very little
21	*Adherence to specifications	0(0%)	1 (11.1%)	0(0%)	0(0%)	1(3.3%)	27	Very little
22	*Regular site meetings	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.3%)	27	Very little
d	***Storage source***							
23	Better storage facilities and environment/area	8 (53.3%)	7 (77.8%)	4 (80%)	1 (100%)	20 (66.7%)	4	Moderate
24	Improved method of material usage	4 (26.7%)	1 (11.1%)	2 (40%)	0 (0%)	7 (23.3%)	13	Very little
25	Appropriate material	2	4	0	0	2	21	Very little

	storage	(13.3%)	(44.4%)	(0%)	(0%)	(6.7%)		
26	Proper material protection against weather	0 (0%)	2 (22.2%)	0 (0%)	0 (0%)	2 (6.7%)	21	Very little
27	Improved material handling method	3 (20%)	3 (33.3%)	0 (0%)	0 (0%)	6 (20%)	15	Very little

Source: Researcher's own field survey, 2015

5.8.7 Comparative views of respondents on the effects of material-waste sources, causes, and control measures on project-cost overruns (Quality of construction management)

The results of the analyses of differences in professional views on the "effects of material-waste sources, causes, and control measures on cost overruns" in Table 5.21 revealed a non-statistically significant difference with the probability values (0.472 and 0.320) greater than 5 percent (0.05) significance level at the 95 percent confidence level, respectively.

The evidence here is not statistically significant. The alternative hypotheses are hereby rejected in favour of the null hypotheses. These results imply that respondents were of the same view on the effects of material-waste sources, causes, and control measures on cost overruns in the construction industry (Quality of construction management).

Table 5.21: Results of ANOVA analyses for the test of difference in professional views on the "effects of material-waste sources, causes and control measures on project cost overruns" (Quality of construction management)

S/n	**Variables**				**Type of Analysis**	**Observation**				**Inferences**	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
6a	PM	QS	SE	STO	One-way ANOVA	56.74	0.774	1.701	0.472	Not statistically significant	Accept Ho & reject Hi
	Sources and causes					73.35					
6b	PM	QS	SE	STO	One-way ANOVA	17.03 14.30	1.191	1.701	0.320	Not statistically significant	Accept Ho & reject Hi
	Control measures										

Source: Researcher's field survey, 2015

5.9 Quality of Site Management

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked by the researcher during the course of the interview on the issues relating to material waste and cost overruns on the quality of site-management stage of a project.

5.9.1 Definition of site management by the respondents

A total of twenty-three (23) respondents (6QSs, 11PMs, 3SEs, and 1STO) described site management as an aspect of construction management that deals with the planning, controlling, co-ordinating, communicating, motivating, scheduling, and organising of the entire activities on the site including the 5Ms (men, machines, money, materials, and management) to achieve the desired project objectives. They described the site organisation as including: organising the site offices, the stores, the fencing, and placing the right materials, right plant and equipment at the right place. PM-07 added that it involves adequate site security, access road, minimisation of wasteful time, timely provision of materials, and site safety.

QS-06 believes that site management involves management of the routine activities on site, including planning, programme of work, good access road to site, and so on. QS-07 added that it is the act of managing a site, using all the necessary management tools, skills, and technology to achieve the desired result. PM-12, PM-15, QS-09, and SE-05 believed that it is a group of people that administer the day-to-day running of a site from the inception to completion of a project. These would include the site organisation: fencing, site storage, availability of a workable site security, site meetings, site offices; proper material inspection on delivery to site; daily site record taking; proper documentation; good communication flow on site; on site re-use of materials; adherence to waste management regulations; plan to avoid rework, mixture of appropriate mortar quantities and so forth.

5.9.2 Contribution of site management to material waste and cost overruns

All the respondents (100 percent) highlighted the fact that the quality of site management contributes to material waste and cost overruns, especially when the management of site or the issues stated in Tables 5.16 and 5.17 are not properly managed/addressed. For instance, poor site organisation, wrong placement of equipment, plants, and materials, and so forth.

5.9.3 Contribution of site security, site accident and site dispute to material-waste generation and cost overruns

Twenty-six (26) respondents (7QSs, 13PMs, 5SEs and STO) explained that inadequate site security would lead to pilfering and damage/sabotage of materials on site; when the site is not properly organised and disciplined, accidents are bound to occur; and these might affect the workers, the structure, or even both. For instance, an improperly positioned crane fell on the surface of a finished high-rise building (25 floors) within the study area. And that part (curtain wall) was wasted and removed for rework, which significantly affected the project cost.

QS-05 and SE-02 explained that a major dispute between a client and a contractor, or between the managers/contractors and workers could lead to the abandonment of the work for some time, which could result in waste generation and cost overruns. PM-08, PM-11, and STO added that when accidents occur on-site, the workers leave their work; and that some materials (mortar) get caked or hardened, and thereby, result in waste.

QS-06 concluded that the falling of scaffolds or cranes on the surface of a fresh/delicate work also leads to material wastage and cost overruns.

5.9.4 Effects of material-waste sources and causes on project cost overruns (Quality of site management)

The Table 5.22 indicates that 100 percent of the respondents highlighted the fact that "rework", "site accidents" and "inadequate site security/fencing", respectively, were deemed to have a 'very high effect' on project-cost overruns. They believe that a porous project site with inadequate security would lead to constant pilfering/theft and the damage/sabotage of construction materials, which could seriously impact the amount cost overruns. Other causes with very high effect on cost overruns include: “poor site organisation and discipline” (96.7 percent) and “construction-site disputes (90 percent).

Moreover, percentages of 86.7, 80, 73.3, and 70 relative to “poor site management and the 5Ms”, “lack of experience”, “poor construction planning and control”, and “lack of co-ordination among the parties”, respectively, were deemed to have ‘high effects on cost overrun; since they fall between the response rates of 80 and 90 percent.

Percentages of 66.7, 66.7, 63.3, and 60 referring to “poor-site storage area”, “lack of waste management plans”, “communication problems”, and “poor site supervision”, respectively, were considered by the respondents to have ‘moderate effects’ on cost-overruns; because they fall between 50 and 69 percent.

As many as 43.3 percent of the respondents emphasised that “problems relating to on-site health and safety”, ”wrong location of cranes on site”, and “inappropriate records of materials” have little effect on cost overruns. A total of 33.3 percent pointed out that “lack of environmental awareness”, and “scarcity of equipment”, respectively, were deemed to have little effect on cost overruns. Similarly, percentages of 36.7 and 30 relative to “lack of construction knowledge and methods” and “power and lighting problems on site”, respectively, were deemed to have ‘little effects’ on cost overruns.

Percentages of 26.7, 23.3, 20, 13.3, 10, 6.7 and 3.3 in respect of “inappropriate delegation of responsibilities”, “late information flow among parties”, “equipment failure on site”, “difficulties in accessing construction site”, “wrong placement of equipment on site”, “long storage distance from application point” and “late delivery of materials”, respectively, were considered to have ‘very little effect’ on cost overruns; because they fall between 1 and 29 percent.

On the other hand, material waste causes such as “leftover materials on site”, “transfer of materials from storage to application”, “wastage resulting from packaging”, “site congestion and interference of other crews”, and “damages caused by third parties” were not responded to, by the interviewees. Therefore, they were decided and termed "no response", as shown in the Table 5.19.

Table 5.22: Result of cross-tabulation on the effects of material-waste sources and causes on cost overruns (Quality of site management)

S/n	Causes and sources of material waste (Quality of site management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Storage source***							
1	Wrong material/equipment storage/stacking	6 (40%)	3 (33.3%)	2 (40%)	0 (0%)	11 (36.7%)	19	Little
2	Transfer of materials from storage to application	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	49	No response
3	Damage by other trades	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)		
4	Poor site storage area	8(53.3%)	7(77.8%)	4(80%)	1(100%)	20(66.7%)	12	Moderate
5	Long storage distance from application point.	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	35	Very little
6	Damage by weather	2(13.3%)	2(22.2%)	1(20%)	0(0%)	5(16.7%)	28	Very little
b	***Security source***							
7	Inadequate site security/Fencing	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
8	Theft	9(60%)	7(77.8%)	4(80%)	1(100%)	21(70%)	10	High
9	Vandalism, sabotage pilferage, and material damage	10 (66.7%)	7 (77.8%)	4 (80%)	1 (100%)	22 (73.3%)	8	High
10	Power and lighting problems on site	5(33.3%)	2(22.2%)	1(20%)	1(100%)	9(30%)	21	Little
c	***Site conditions***							
11	Poor site management and the 5ms	13 (86.7%)	8 (88.9%)	4 (80%)	1 (100%)	26 (86.7%)	6	High
12	Poor site and unforeseen ground conditions	3 (20%)	2 (22.2%)	1 (20%)	0 (0%)	6 (20%)	25	Very little
13	Leftover materials on site	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	49	No response
14	Waste resulting from packaging	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	49	No response
15	Lack of environmental awareness	5 (33.3%)	4 (44.4%)	0 (0%)	1 (100%)	10 (33.3%)	21	Little
16	Difficulties in accessing construction site	1 (6.7%)	2 (22.2%)	0 (0%)	1 (100%)	4 (13.3%)	30	Very little
17	Problems relating to on-site health and safety	8 (53.3%)	3 (33.3%)	1 (20%)	1 (100%)	13 (43.3%)	16	Little
18	Site congestion and Interference of other crews	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	49	No response
19	Inadequate site investigation	2(13.3%)	1(11.1%)	0(0%)	1(100%)	4(13.3%)	30	Very little
20	Disputes on site	13(86.7%)	8(88.9%)	5(100%)	1(100%)	27(90%)	5	Very high

21	Extra materials ordered are discarded instead of carrying over to next site	2 (13.3%)	0 (0%)	0 (0%)	1 (100%)	3 (10%)	31	Very little
22	Equipment failure on site	3(20%)	3(33.3%)	1(20%)	0(0%)	7(23.3%)	24	Very little
23	Concurrent execution of numerous activities	2 (13.3%)	0 (0%)	0 (0%)	0 (0%)	2 (6.7%)	33	Very little
24	*Poor site organization and discipline	15 (100%)	9 (100%)	4 (80%)	1 (100%)	29 (96.7%)	4	Very high
25	*Wrong location of cranes on site	4 (26.7%)	6 (66.7%)	3 (60%)	0 (0%)	13 (43.3%)	16	Little
26	*Wrong placement of equipment on site	1 (6.7%)	1 (11.1%)	1 (20%)	0 (0%)	3 (10%)	31	Very little
27	Site accidents	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
28	*Site meetings	4(26.7%)	1(11.1%)	0(0%)	0(0%)	5(16.7%)	28	
29	*Lack of adherence to program of work	1 (6.7%)	0 (0%)	0 (0%)	0 (0%)	1 (3.3%)	35	Very little
30	*Late delivery of materials	1(6.7%)	0(0%)	0(0%)	0(0%)	1(3.3%)	35	Very little
d	***Operation source***							
31	Nature of construction process	0(0%)	1(11.1%)	0(0%)	0(0%)	1(3.33%)	35	Very little
32	Tools not suitably used	0(0%)	0 (0%)	1(20%)	0(0%)	1(3.3%)	35	Very little
33	Damage caused by third parties	0(0%)	0 (0%)	0(0%)	0(0%)	0(0%)	49	No response
34	Lack of waste management plans	10(66.7%)	5(55.6%)	5(100%)	0(0%)	20(66.7%)	12	Moderate
35	Communication problems	11(73.3%)	7(77.8%)	1(20%)	0(0%)	19(63.3%)	14	Moderate
36	Non-availability of appropriate equipment	2 (13.3%)	1 (11.1%)	1 (20%)	0 (0%)	4 (13.3%)	30	Very little
37	Lack of construction knowledge and methods	2 (13.3%)	5 (55.6%)	4 (80%)	0 (0%)	11 (36.7%)	19	Little
38	Scarcity of equipment	5(33.3%)	2(22.2%)	3(60%)	0(0%)	10(33.3%)	21	Little
39	Late information flow among parties	3 (20%)	1 (11.1%)	2 (40%)	0 (0%)	6 (20%)	25	Very little
40	Lack of co-ordination among parties	13(86.7%)	5(55.6%)	2(40%)	1(100%)	21(70%)	10	High
41	Poor construction planning and control	12 (80%)	7 (77.8%)	2 (40%)	1 (100%)	22 (73.3%)	8	High
42	Poor site supervision	8(53.3%)	6(66.7%)	4(80%)	0(0%)	18(60%)	15	Moderate
43	Rework	15(100%)	9(100%)	5(100%)	1(100%)	30(100%)	1	Very high
44	Inappropriate records of materials	6 (40%)	3 (33.3%)	3 (60%)	1 (100%)	13 (43.3%)	16	Little
45	*Lack of adherence to material waste regulations	0 (0%)	1 (11.1%)	1 (20%)	0 (0%)	2 (6.7%)	33	Very little
46	*Inappropriate delegation of responsibilities	3 (20%)	3 (33.3%)	2 (40%)	0 (0%)	8 (26.7%)	23	Very little
47	*Lack of experience	12(80%)	7(77.8%)	5(100%)	0(0%)	24(80%)	7	High
48	*Lack of learning from previous mistakes	2 (13.3%)	2 (22.2%)	2 (40%)	0 (0%)	6 (20%)	25	Very little
49	Lack of quality control	4(26.7%)	1(11.1%)	1(20%)	1(100%)	7(23.3%)	24	Very little

Source: Researcher's field survey, 2015

5.9.5 Effects of control measures for material waste on project-cost overruns (Quality of site management)

The analysis of the effects of control measures for material waste on project cost overruns on site management in Table 5.23 was discussed under the following waste sources, namely: security, operations, residual, and site conditions and management sources.

- ***Security source:*** it was apparent from Table 5.23 that 100 percent of the respondents believe that “tight security on site” was the major control measure that has a “very high” effect on cost overruns. However, only 30 percent of the respondents highlighted “adequate temporary site fencing” and the “availability of workable security lighting on site” as the control measures that have ‘little effect’ on cost overruns; since they fall between 30 and 49 percent.

- ***Operation source:*** 90 percent of the respondents emphasised that “adequate site organisation and discipline” has a ‘very high effect’ in controlling material waste and cost overruns at this stage of a project. Moreover, percentages of 83.3, 80, 76.7 and 70, in respect of “waste management throughout the entire lifecycle of a project”, “use of experienced personnel”, “promotion of construction waste re-use on site”, and “proper site planning and control”, respectively, were deemed by the respondents to have a ‘high effect’ in controlling material waste and cost overruns at this stage of a project.

  Additionally, percentages of 66.7, 66.7 and 56.7, relative to “site meetings on material waste management”, “adequate site supervision”, and “adherence to waste management regulations”, respectively were deemed to have ‘moderate effects’ in controlling project-cost overruns.

  Consequently, 33.3 percent of the respondents believe that “learning from previous mistakes” has ‘little effects’ in controlling material waste and cost overruns. Nonetheless, 6.7 percent of the respondents stated that “issuing procedures for managing hazardous waste" has "very little effect' in controlling cost overruns in this category; because it falls between 1 and 29 percent.

- ***Residual source:*** It was apparent from the analysis that 20 and 13.3 percentages of the respondents emphasised that "reduced off-cut of materials and re-use" and "the mixture of an appropriate quantity of mortar", respectively, have very little effect in controlling material waste and cost overruns; since they fall between 1 and 29 percent response.

- ***Site conditions and management sources:*** 90 percent of the respondents assured that "on-site and offsite re-use of waste materials" have a 'very high effect' in controlling material waste and cost overruns at this stage. 80 percent stated that the "proper administration of the 5Ms on site" has a 'high effect' on cost overruns. The 5Ms include: men, money, materials, machines, and management on site.

  Furthermore, percentages of 66.7, 66.7 and 63.3, in respect of "proper materials inspections on delivery to site", "regular site meetings on materials", and "good communications flow on site", respectively, were deemed by the respondents to have a 'moderate effect' on cost overruns in this stage; because they fall between 50 and 69 percent.

  The material-waste control measures considered by the respondents to have 'little effect' in controlling cost overruns were: "daily record taking", (46.7 percent) and "proper records and documentation of materials" (36.7). Nonetheless, a percentage of 6.7 in respect of "implementation of onsite material waste sorting" was deemed to have 'very little effect' in controlling cost overruns; because it falls between 1 and 29 percent.

Table 5.23: Result of cross-tabulation on the control measures for material waste on cost overruns (Quality of site management)

S/n	Control measures for material waste (Quality of site Management)	PM	QS	SE	STO	Total	Ranking	Decision
a	***Site conditions and management sources***							
1	Proper materials inspections on delivery to site	8 (53.3%)	7 (77.8%)	4 (80%)	1 (100%)	20 (66.7%)	8	Moderate effect
2	Proper records and documentation of materials	8 (53.3%)	4 (44.4%)	2 (40%)	0 (0%)	14 (46.7%)	13	Little effect
3	Daily record taking	7 (46.7%)	2 (22.2%)	2 (40%)	0 (0%)	11 (36.7%)	14	Little effect
4	Usage of materials request booklets	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	31	No response
5	Regular site meetings on materials	8 (53.3%)	7 (77.8%)	3 (60%)	1 (100%)	19 (63.3%)	11	Moderate effect
6	On-site material quality evaluation	5 (33.3%)	1 (11.1%)	1 (20%)	1 (100%)	8 (26.7%)	18	Very little
7	On-site and offsite re-use of waste material	14 (93.3%)	7 (77.8%)	5 (100%)	1 (100%)	27 (90%)	2	Very high effect
8	Separation of hazardous waste from others	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	31	No response
9	Adherence to design and specifications	3 (20%)	4 (44.4%)	1 (20%)	0 (0%)	8 (26.7%)	18	Very little
10	Good communications flow on site	11 (73.3%)	7 (77.8%)	1 (20%)	0 (0%)	19 (63.3%)	9	Moderate effect
11	Implementing on-site material waste sorting	0 (0%)	1 (11.1%)	1 (20%)	0 (0%)	2 (6.7%)	23	Very little effect
12	Recycle generated waste materials	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	31	No response
13	*Proper administration of 5Ms on site	12 (80%)	8 (88.9%)	4 (80%)	0 (0%)	24 (80%)	5	High effect
b	***Security***							
14	Tight security on site	15 (100%)	9 (100%)	5(100 %)	1(100%)	30(100 %)	1	Very high effect
15	Availability of a workable security lighting on site	5 (33.3%)	2 (22.2%)	1 (20%)	1 (100%)	9 (30%)	16	Little effect
16	*Adequate site temporary fencing	2 (13.3%)	6 (66.7%)	1(20%)	0(0%)	9(30%)	16	Little effect
c	***Operation source***							
17	Issuing procedures for managing hazardous waste	2 (13.3%)	0 (0%)	0 (0%)	0 (0%)	2 (6.7%)	23	Very little effect
18	Prepare a list and record of salvageable waste	1 (6.7%)	2 (22.2%)	0 (0%)	0 (0%)	3 (10%)	22	Very little effect
19	Site meetings on material waste management	8 (53.3%)	8 (88.9%)	3 (60%)	1 (100%)	20 (66.7%)	8	Moderate effect
20	Adherence to waste management regulations	9 (60%)	7 (77.8%)	3 (60%)	1 (100%)	20 (66.7%)	8	Moderate effect

21	Encouraging management of the environment	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	31	No response
22	Waste management throughout the entire lifecycle of a project	13 (86.7%)	7 (77.8%)	4 (80%)	1 (100%)	25 (83.3%)	4	High effect
23	Promotion of construction waste re-use on construction sites	12 (80%)	7 (77.8%)	4 (80%)	0 (0%)	23 (76.7%)	7	High effect
24	Research and development in the discipline of waste management	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	31	No response
25	*Use of experienced personnel	12(80%)	7 (77.8%)	5 (100%)	0(0%)	24(80%)	5	High effect
26	*Adequate site organization and discipline	14 (93.3%)	9 (100%)	3 (60%)	1 (100%)	27 (90%)	2	Very high effect
27	Adequate site supervision	5 (33.3%)	8 (88.9%)	3 (60%)	1 (100%)	17 (56.7%)	12	Moderate effect
28	*Learning from previous mistakes	5 (33.3%)	3 (33.3%)	1(20%)	1(100%)	10(33.3 %)	15	Little effect
29	*Proper site planning and control	11 (73.3%)	7 (77.8%)	2(40%)	1(100%)	21(70%)	9	High effect
c	***Residual sources***							
30	Reducing off-cuts of materials and their re-use	0 (0%)	3 (33.3%)	1 (20%)	0 (0%)	4 (13.3%)	21	Very little effect
31	Mixture of appropriate quantity of mortar	3 (20%)	3 (33.3%)	0 (0%)	0 (0%)	6 (20%)	20	Very little effect

Source: Researcher's field survey, 2015

5.9.6 Comparative views of respondents on the effects of material-waste sources, causes, and control measures on project-cost overruns (Quality of site management)

The results in Table 5.24 show that the values of f-calculated (0.259 and 1.28) were less than the tabulated value (1.701) respectively. The probability values (0.774 and 0.309) were less than the significance value (0.05) at the 95 percent confidence level within the mean-squared groups (6.61 to 25.54 and 11.31 to 38.95), respectively.

The evidence here is not statistically significant. The alternative hypotheses are rejected in favour of the null hypotheses. These results imply that the respondents were of the same view on the effects of material-waste sources, cause, and control measures on project-cost overruns.

Table 5.24: Results of ANOVA analyses for the test of difference in professional views on the "effects of material-waste sources, causes and control measures on project cost overruns" (Quality of site management)

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Proba bility value	Remark	Action on H
7a	PM	QS	SE	STO	One-way ANOVA	6.61	0.259	1.701	0.774	Not statistically significant	Accept Ho & reject Hi
	Sources and causes					25.54					
7b	PM	QS	SE	STO	One-way ANOVA	13.89 11.31	1.228	1.701	0.309	Not statistically significant	Accept Ho & reject Hi
	Control measures										

Source: Researcher's field survey, 2015

5.10 Material-Waste Minimisation and Management

This section presents the results of the interviews conducted with the respondents and the tick box of questions marked/ticked by the researcher during the course of the interview on the issues relating to material-waste minimisation/management and their effects on project-cost overruns.

5.10.1 Material waste recovery system adopted in the respondents' firm/organisation

SE-03 was the only construction company in the study area that practised both the re-use and the recycling of material waste. SE-03 explained that they have a site where generated material waste is sorted and separated for recycling. This is probably because the firm/organisation is a strong foreign company working in Nigeria.

On the other hand, all the other respondents (97 percent) disclosed that their firms/organisations are not into recycling; but they only re-use waste materials that have minimal damage, such as timber form works, off-cut reinforcement bars, broken blocks and other re-usable waste materials in the project. PM-10 explained that off-cuts, reinforcement bars and timber formwork used for slab construction are re-used for casting lintels for openings; because of the short length of the materials.

PM-02, PM-03 and SE-05 noted that at times, off cut reinforcement bars are sold to smaller-sized project owners.

QS-05 and PM-05 noted that their firm/organisation re-uses broken blocks and re-uses timber formwork.

5.10.2 The influence of material waste (re-use and recycling) on project-cost overruns

All the respondents (100 percent) highlighted the fact that material waste recovery system (re-use and recycling) helps in reducing the amount of waste materials on site, as well as project-cost overruns. Eight (8) respondents (2QSs, 3PMs, and 3SEs) believe that the profit made from re-using and recycling waste materials goes back into the project. This could contribute significantly to minimising the amount of project-cost overrun. PM-08, PM-11, and STO added that, if a timber formwork cannot be re-used for two or three times in a project, then waste from formwork would be bound to accumulate.

5.10.3 The training and education programmes for employees on how to minimise material waste and cost overruns

PM-06, QS-06, and PM-15 disclosed that their staff only learn on the job, and not through any formal training. However, they also encourage them to attend workshops, seminars and conferences on their own. Moreover, twelve (12) respondents (7PMs, 2QSs, 2SEs, and STO) explained that they train and retrain their staff (in-house only). PM-12 added that they have what they call an “every morning pep-talk”. This is a medium where they educate their staff on ’health and safety issues’ and ‘waste management’. SE-03 emphasised that their firm organizes a monthly and yearly seminar for their staff on how to minimise (re-use and recycle) material waste on site. QS-02 added that they engage their staff on an in-house monthly training on material-waste management.

Furthermore, QS-03 and SE-04 stated that their staff are sent out to attend conferences, workshops/professional workshops, and seminars on material waste management.

In another vein, nine (9) respondents (5PMs, 3QSs, and SE) concluded that their staff are engaged in both in-house and external training (workshops, seminars, and conferences) on how to manage material waste and cost overruns.

5.10.4 Benefits of recovering material waste on cost overruns

This section presents the results of the tick box of questions marked/ticked by the researcher in the course of the interview on the benefits (social, environmental, and economic) of recovering material waste and their effects on project-cost overruns.

5.10.4.1 Economic benefits of recovering material waste and their effects on cost overruns

Table 5.25 shows the economic benefits of recovering material waste and their effect on cost overruns. It was apparent from Table 5.25 that 100 percent of the respondents believed that “profit-making on salvaged materials” was the major benefit that had ‘very high effect’ on project-cost overruns. They maintained that the profit made goes back into the project; and it thereby reduces the rate of the cost overruns for the project. This is followed by the percentages of 93.3, 93.3 and 90, in respect of “project-cost saving through avoided disposal costs”, “reduced project-cost overruns”, and “saves costs on new materials”, respectively.

Percentages of 83.3, 76.7, and 73.3 in respect of “reduces demand for new materials”, “realizes the value of recovered materials”, “cuts down/reduces disposal cost”, respectively, were considered by the respondents to have a ‘high effect’ on cost overruns; because they fall between 70 and 89 percent.

Causes with a ‘moderate effects’ on cost overruns were: “cut down transportation cost” (60 percent) and “generate values by producing financial returns” (50 percent); because they fall between 50 and 65 percent.

Percentages of 6.7 and 3.3 relative to “reduce energy cost” and “conserving resources by diversion from landfill”, respectively, were deemed by the respondents to have ‘very little effect’ on cost overruns. Other causes with percentages of 0.0 had no response from any of the interviewees.

Table 5.25: Results of cross-tabulation on the effects of recovering material waste on cost overruns (economic benefits)

S/n	Economic benefits of recovering material waste on cost overrun	PM	QS	SE	STO	Total	Ranking	Decision
1	Profit making on salvaged materials	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high
2	Reduces demand for new materials	12 (80%)	8 (88.9%)	4 (80%)	1 (100%)	25 (83.3%)	5	High
3	Realize value of recovered materials	13 (86.7%)	7 (77.8%)	3 (60%)	0 (0%)	23 (76.7%)	6	High
4	Cut down transportation cost	10 (66.7%)	4 (44.4%)	3 (60%)	1 (100%)	18(60%)	8	Moderate
5	Reduced energy cost	2 (13.3%)	0 (0%)	0 (0%)	0 (0%)	2 (6.7%)	9	Very little
6	Cut down disposal cost	11 (73.3%)	6 (66.7%)	4 (80%)	1 (100%)	22 (73.3%)	7	High
7	Conserving resources by diversion from landfill	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)	1 (3.3%)	10	Very little
8	New source of revenue for waste generators	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	14	No response
9	Tax break gained for donation	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	14	No response
10	Cheaper exercise as a result of landfill tax	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	14	No response
11	Project cost saving through avoided disposal cost	14 (93.3%)	9 (100%)	4 (80%)	1 (100%)	28 (93.3%)	2	Very high
12	*Generate values by producing financial returns	5 (33.3%)	6 (66.7%)	3 (60%)	1 (100%)	15 (50%)	6	Moderate
13	*Saves cost on new materials	14 (93.3%)	8 (88.9%)	4 (80%)	1 (100%)	27 (90%)	4	Very high
14	*Reduces project Cost overrun	15 (100%)	8 (88.9%)	4 (80%)	1 (100%)	28 (93.3%)	2	Very high

Source: Researcher’s field survey, 2015

5.10.4.2 Environmental benefits of recovering material waste and their effects on project cost overruns

The analyses of the effects of environmental benefits of recovering material waste on project-cost overruns in Table 5.26 reveals that 73.3 percent of the respondents agreed that “re-using material, which could be lost to landfills” has a ‘high effect’ in controlling cost overruns.

Moreover, 50 percent of the respondents considered “reducing environmental pollution”, “preserving space in existing landfills”, and “environmental conservation” to have ‘moderate effects’ in controlling cost overruns; because they fall between 50 and 69 percent. This is probably because the respondents think that in all cases, the wasted materials have to be recovered back to the project, and that they thereby minimise the amount of cost overruns.

Consequently, percentages of 33.3 and 30 relative to the “curtailing of the negative environmental Impact” and “minimising environmental impact, such as contamination of ground water”, respectively, were deemed by the respondents to have “little effect’ on cost overruns; since they fall between 30 and 49 percent.

Table 5.26: Results of cross-tabulation on the effects of recovering material waste on project cost overruns (Environmental benefits)

S/n	Environmental benefits of recovering material waste on cost-overrun	PM	QS	SE	STO	Total	Ranking	Decision
1	Preserve space in existing landfills	8(53.3%)	5 (55.6%)	2 (40%)	0 (0%)	15 (50%)	2	Moderate
2	Minimise environmental impact (contamination of ground water)	4 (26.7%)	4 (44.4%)	1 (20%)	0 (0%)	9 (30%)	6	Little effect
3	Re using material which could be lost to landfill	12 (80%)	7 (77.7%)	3 (60%)	0 (0%)	22 (73.3%)	1	High effect
4	*Reduction in carbon emission	4 (26.7%)	6 (66.7%)	4 (80%)	1 (100%)	15 (50%)	2	Moderate
5	*Environmental conservation	4(26.7%)	6(66.7%)	4(80%)	1(100%)	15(50%)	2	Moderate
6	*Curtailing the negative environmental Impact	4 (26.7%)	4 (44.4%)	1 (20%)	1 (100%)	10 (33.3%)	5	Little

Source: Researcher’s field survey, 2015

5.10.4.3 Social benefits of recovering material waste and their effects on cost overruns

The analysis of the social benefits of recovering materials on cost overruns in Table 5.27 indicates that 100 percent of the respondents believed that “waste materials are sold to developers of small-sized projects" was the major social benefit of recovering material waste; and it was considered to have a 'very high effect' on project-cost overruns. This is probably because the respondents think that as wasted materials are recovered and sold, the profit goes back into the project.

Furthermore, percentages of 80 and 73.3, relative to "waste is used as a benefit to community by helping in disposal"; and the "timber formwork is used as firewood by the local community" were deemed to have a 'high effect' on cost overruns. This is probably because the respondents think that removing the timber waste formwork from the site would save the project the cost of transportation and disposal to a landfill.

Percentages of 20, 13.3, and 10 relative to the "creation of job opportunity", "compliance with State and local regulations", and "raising the public image of a company", respectively, were deemed to have "very little" effect on project cost overruns; since they fall between 1 and 29 percent.

Table 5.27: Results of cross-tabulation on the social benefits of recovering material waste and their effects on cost overruns

S/n	Social benefits of recovering material waste on cost overrun	PM	QS	SE	STO	Total	Ranking	Decision
1	Creation of job opportunity	2 (13.3%)	1 (11.1%)	2 (40%)	1 (100%)	6 (20%)	4	Very little effect
2	Raises the public image of a company	1 (6.7%)	1 (11.1%)	1 (20%)	0 (0%)	3 (10%)	6	Very little effect
3	Compliance with state and local regulations	2 (13.3%)	1 (11.1%)	1 (20%)	0 (0%)	4 (13.3%)	5	Very little effect
4	*Timber formwork is used as fire wood by the local community	11 (73.3%)	5 (55.6%)	5 (100%)	1 (100%)	22 (73.3%)	3	High effect
5	*Waste is used as a benefit to community by helping in disposal.	12 (80%)	8 (88.9%)	3 (60%)	1 (100%)	24 (80%)	2	High effect
6	*Waste materials are sold to developers of small sized projects	15 (100%)	9 (100%)	5 (100%)	1 (100%)	30 (100%)	1	Very high effect

Source: Researcher's field survey, 2015

5.10.4.4 Comparative views of respondents on the benefits of recovering construction-waste materials (re-use and recycling) and their effects on cost overruns

Table 5.28 shows the results of ANOVA analyses, which compared the views of respondents on the benefits (economic, social, and environmental) of recovering (re-use and recycling) of construction-material waste and their effects on cost overruns. The results depict that the values of f-calculated (0.265 and 0.938) were less than f-tabulated values (1.701). Nonetheless, the f-calculated value for 'environmental benefits' (2.883) was greater than the f-tabulated value. The probability values (0.74, 0.299, and 0.404) were greater than the 5 percent (0.05) significance level respectively. The hypotheses were tested at the 95 percent confidence level within the mean squared group of between (1.89-2.39; 1.19-3.43; and 0.64-0.68), respectively.

The evidence here is that these results are not statistically significant. The alternative hypotheses are hereby rejected in favour of the null hypotheses. These results imply that the respondents were of the same view on the benefits (economic, social, and environmental) of recovering (re-use and recycling) material waste and their effects on cost overruns in the construction industry.

Table 5.28 Results of ANOVA analyses for the test of differences in professional views on the "benefits of recovering construction waste materials (re-use and recycling) and their effects on cost overruns

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Proba bility value	Remark	Action on H
8a	PM	QS	SE	STO	One-way ANOVA	2.39 1.89	0.265	1.701	0.299	Not statistically significant	Accept Ho & reject Hi
	Economic benefits										
b	PM	QS	SE	STO	One-way ANOVA	3.43 1.19	2.883	1.701	0.74	Not statistically significant	Accept Ho & reject Hi
	Environmental benefits										
c	PM	QS	SE	STO	One-way ANOVA	0.64 0.68	0.938	1.701	0.404	Not statistically significant	Accept Ho & reject Hi
	Social benefits										

Source: Researcher's field survey, 2015

5.10.5 Benefits of the re-use of material waste and their effects on cost overruns

Table 5.29 indicates that the percentages of 80 and 73.3, relative to "re-use is the most profitable means of recovery for contractors"; and "re-use does not require hauling and transportation", respectively; since these were deemed by the respondents as the benefits of re-use that have a 'high effect' on project-cost overruns; because they fall between 70-89 percent.

As many as 66.7 percent of the respondents believed that "re-use does not require energy"; and 60 percent agreed that "re-use does not require reprocessing". They were deemed to have a 'moderate effect' on cost overruns; because they fall between 50 and 69 percent.

Table 5.29 Results of the cross-tabulation on the benefits of re-use of material waste on cost overruns

S/n	Benefits of Re-use in minimizing cost overrun	PM	QS	SE	STO	Total	Ranking	Decision
1	Re-use does not require reprocessing	8 (53.3%)	6 (66.7%)	3 (60%)	1 (100%)	18 (60%)	4	Moderate effect
2	Re-use does not require hauling and transportation	10 (66.7%)	6 (66.7%)	5 (100%)	1 (100%)	22 (73.3%)	2	High effect
3	Re-use is the most profitable means of recovery for a contractor.	14 (93.3%)	7 (77.8%)	2 (40%)	1 (100%)	24 (80%)	1	High effect
4	Re-use does not require energy	12 (80%)	5 (55.6%)	2 (40%)	1 (100%)	20 (66.7%)	3	Moderate effect

Source: Researcher's field survey, 2015

5.10.6 Comparative views of the respondents on the "benefits of re-use of construction-waste materials and their effects on cost overruns"

Table 5.30 shows the results of the ANOVA analysis, which compared the views of the respondents on the benefits of re-use of construction-material waste and their effects on cost overruns. The results show that the f-calculated value (0.448) was less than the f-tabulated value (1.701); the probability value (0.644) was greater than the 5 percent (0.05) significance level; and the hypothesis was tested at the 95 percent confidence level within each mean square group of between (0.59-1.31), respectively.

Statistically, it can be inferred that the evidence is statically not significant. This implies that there was no significant difference between the views of respondents on the benefits of re-use and the recycling of waste material and their effects on cost-overrun in the construction industry.

Table 5.30: Results of ANOVA analyses for the test of differences in professional views on the "benefits of re-use and the recycling of construction-waste materials and their effects on cost overruns"

S/n	Variables				Type of Analysis	Observation				Inferences	
	$X1$	$X2$	$X3$	$X4$		Mean square within group	F-cal	F-tab	Probability value	Remark	Action on H
9	PM	QS	SE	STO	One-way ANOVA	0.59 1.31	0.44 8	1.701	0.644	Not statistically significant	Accept Ho and reject Hi

Source: Researcher's field survey, 2015

5.10.7 Respondents' general comments on how to minimise material waste and cost overruns in the construction project

PM-05, PM-04, PM-07, SE-02, QS-07, PM-14, SE-04, QS-09, and STO responded that they had "No comments" on the question being asked.

However, other respondents commented as follows:

QS-01 explained that:

"A square peg in a round hole is not good enough; the right personnel should be deployed to the right positions, in order to achieve good expertise on a project, and to obtain any long term effect in reducing material wastage and cost overruns."

"*Adequate planning would put into consideration the available technology to deliver the project with less waste, by avoiding unnecessary cuttings. Training and education on waste management should be considered as a continuous process throughout the project lifecycle"* (QS-02).

“Every good thing has to start from scratch or else, waste is bound to occur, therefore, early planning and supervision of the entire project must be given a priority; in order to achieve the desired project goal” (PM-01).

“We should try as much as possible to understand the trend of construction, listen to people in the field, and have a very good relationship” (QS-02).

“Adequate estimating, good site management, good construction and procurement management would help in minimising material waste and cost overruns” (PM-02).

“To manage material waste and cost overrun, you need prudence, experience and methods” (PM-03).

“Adequate planning is the bedrock of any construction; therefore, management of material waste should be considered at the planning stage to curtail the detrimental effects of material wastage leading to project-cost overruns” (SE-01).

“Too much material should not be delivered to site at the same time” (QS-04)!

“Engaging in the prefabrication of elements/components would minimise/reduce a lot of wastage on project” (QS-05).

“Human beings adapt to situations, in which they find themselves; but if they are managed with laxity, they are bound to waste materials, and thereby affect the project cost” (PM-06).

“From the beginning of every project, each design professional works on his/her own; therefore, a forum should be created where different professionals can freely criticize the procedures, in order to ensure that design errors are, if not eliminated, at least minimised to the lowest level” (QS-06).

“He, who fails to plan, is planning to fail. The best thing is to have a good plan as early as possible, in order to minimise wastage and cost overrun” (PM-08).

“Management of waste is very important; because time is money” (PM-09).

“All materials delivered to site must be judiciously and wisely used. This would minimise material waste, as well as project-cost overruns” (PM-10).

“It is important to have regular site meetings, in order to constantly address the construction-related issues that could lead to the wastage of materials and cost overruns” (PM-11).

“If material waste is properly handled, project-cost overruns would be reduced to the barest minimum; just as good waste management moves from waste to wealth” (PM-12).

“In order to minimise material waste on site, there should be a constant orientation of the workers on how to minimise/manage material waste and its effects on the project cost” (SE-03).

“Waste is inevitable on any construction site. This can be minimised if only the market sizes of materials would be manufactured exactly to fit the sizes in the design. Therefore, the best possible waste-management principles should always be employed, in order to achieve the best value for money” (PM-13).

“As most of the issues relating to material-waste generation revert back to the planning stage of a project, the management of material waste and cost overruns should be given as much attention as possible at the planning stage of a project” (QS-08).

“Wastage of material is inevitable in any construction work; but this should be minimised as far as is possible, in order to achieve good sustainability and value for money for the client” (SE-05).

“On site material waste generation has a significant impact on the total project cost; hence, proper attention must be given to waste management, in order to keep the project cost within the budgeted limit” (PM-15).

5.11 The Contributions of Material Waste to Project Cost Overruns

Table 5.31 shows the results of correlation analysis between a 52.4 percent average volume of on-site material waste recorded (independent variable "x") and the calculated amount of cost overrun (dependent variable "y").

It was observed from the analysis that the probability value (0.0027) was less than the 0.05 (5 percent) significance level and the hypothesis was tested at the 95 percent confidence level. The R-square value (52.82 percent) shows a strong relationship between the variables.

Therefore, it is inferred that the relationship was statistically significant; and the null hypothesis is rejected in favour of the alternative hypothesis.

Consequently, the result implies that, any increase in material waste on the construction site would result in a corresponding increase in the amount of cost overrun for a project.

Table 5.31 Results of the Pearson moment-correlation analysis between the volume of material wasted (52.4 percent completion) and the cost overruns

S/n	Variables		Type of Analysis	Observation		Inference		
	X	Y		R square	Probability value	Strength of relationship	Remarks	Action on H
7	Volume of material wasted (52.4% average completion)	Cost-overrun	Pearson Moment correlation	52.82%	0.0027	Strong	Statistically significant	Accept Hi and reject Ho

Source: Researcher's field survey, 2015

Since it has been statistically established that material waste contributes significantly to project-cost overruns, therefore, Table 5.32 further explains the percentage contribution of material waste to project-cost overruns in a descriptive format.

The project values ranged from a minimum of ₦1.635 billion to a maximum of ₦63 billion and the percentage of work completed also ranged from a minimum of 4 percent to maximum of 100 percent.

It is apparent from the Table 5.32 that contributions of material waste ranged from the minimum ₦31,220,528.06 (1.96 percent) to a maximum ₦39,933,360.29 (8.01 percent), with an average contribution of approximately four (4) percent to the project-cost overrun.

Furthermore, this percentage (4 percent) is different from the (5 percent) normally allowed for materials, to take care of waste in the process of compiling a bill of quantities. The contribution of material waste to cost overrun in Table 5.32 was determined by dividing the "material waste volume" by the "volume of material used for the project" multiplied by the amount of cost overrun. It is given as:

$$Contribution = \frac{Volume\ of\ material\ waste\ recorded}{Volume\ of\ material\ used\ for\ project} X\ cost\ overrun$$

$$Percentage\ contribution = \frac{contribution\ of\ waste\ to\ cost\ overrun}{cost\ overrun} X\ 100$$

Source: Researcher's construct, 2015.

Table 5.32: Average contributions of material waste to project-cost overrun

S/n	Estimated Cost of projects (EC) (₦)	% of work Completed	Volume of materials used (m^3)	Volume of waste recorded	Cost overrun (₦)	Contribution of material waste to cost overrun in (₦)	%Contribution of material waste to cost overrun
1	3,200,000,000.00	17%	1,517.25	65.24	256,000,000.00	11,007,704.73	4.30%
2	14,000,000,000.00	47%	16,686.60	634.09	1,960,000,000.00	74,479,906.03	3.80%
3	1,650,000,000.00	59%	3,024.84	124.02	181,500,000.00	7,441,593.61	4.10%
4	6,000,000,000.00	35%	3,759.38	155.49	300,000,000.00	12,408,163.05	4.14%
5	5,880,000,000.00	43%	3,092.29	196.23	1,081,000,000.00	68,597,909.64	6.35%
6	1,800,000,000.00	63%	12,022.09	963.40	498,321,000.00	39,933,360.29	8.01%
7	15,900,782,413.00	30%	22,510.10	891.85	908,078,720.00	35,978,072.35	3.96%
8	7,300,000,000.00	30%	4,395.42	128.04	1,095,000,000.00	31,897,702.61	2.91%
9	1,800,000,000.00	68%	3,785.40	232.14	457,100,000.00	28,031,699.16	6.13%
10	6,000,000,000.00	23%	3,222.36	136.34	420,000,000.00	17,770,453.95	4.23%
11	1,650,000,000.00	65%	11,180.74	572.45	378,800,000.00	19,394,428.28	5.12%
12	1,900,000,000.00	25%	3,488.40	108.14	125,000,000.00	3,874,985.67	3.10%
13	2,580,333,000.00	15%	2,194.95	57.72	193,524,975.00	5,089,073.35	2.63%
14	40,000,000,000.00	5%	33,679.62	707.27	4,321,562,000.00	90,752,542.81	2.10%
15	20,940,557,219.00	17%	2,944.52	57.71	1,592,955,087.00	31,220,528.06	1.96%
16	3,450,000,000.00	23%	1,145.96	36.01	500,012,000.00	15,712,094.77	3.14%
17	1,666,345,702.00	31%	6,445.36	223.01	317,164,997.00	10,973,935.67	3.46%

18	2,300,000,000.00	25%	4,301.80	141.96	230,000,000.00	7,590,032.08	3.30%
19	2,300,000,000.00	90%	17,117.24	701.81	115,000,000.00	4,715,021.23	4.10%
20	15,031,447,866.00	11%	7,412.42	158.85	282,172,900.00	6,047,035.27	2.14%
21	1,880,000,000.00	48%	9,266.67	398.47	631,600,000.00	27,159,017.42	4.30%
22	1,686,920,734.00	100%	9,522.10	400.88	1,413,079,266.00	59,490,576.25	4.21%
23	1,635,000,000.00	56%	4,049.59	247.03	320,630,936.00	19,558,883.77	6.10%
24	1,800,000,000.00	68%	7,446.82	156.38	140,562,110.00	2,951,743.53	2.10%
25	1,686,951,106.00	100%	5,322.35	NR	1,013,048,894.00	NR	NR
26	1,700,000,000.00	60%	9,248.40	322.74	340,000,000.00	11,864,927.99	3.49%
27	2,860,000,000.00	88%	14,720.64	529.94	646,031,000.00	23,256,982.59	3.60%
28	7,621,687,168.00	100%	15,585.50	568.87	7,562,312,832.00	276,024,054.50	3.65%
29	2,635,001,302.00	95%	18,200.68	893.65	482,081,763.00	23,670,124.83	4.91%
30	1,931,621,700.00	98%	16,130.75	645.23	268,323,734.00	10,732,948.69	4.00%
31	63,000,000,000.00	90%	190,723.05	4,005.18	5,333,222,000.00	111,997,548.70	2.10%
	Average percentage contribution of material waste to cost overruns = 4.00%						

Source: Researcher's field survey, 2015.

5.12 Results of Linear-regression Analyses for Developing the Mathematical Models for Quantifying the Amount of Construction Materials and Material Waste for Projects

This section presents and interprets the results of linear-regression analyses that lead to the development of mathematical models for quantifying the amount of materials and material waste generated for a project.

The research hypotheses for the linear regression analysis in each case are stated below:

- H_i. Alternate hypothesis: There is a statistically significant relationship between the table variables (X and Y)
- H_o. Null hypothesis: There is no statistically significant relationship between the table variables (X and Y).

5.12.1 Relationship between 'the average volume of materials used for projects (52.4% average projects completion) and the building volume (L*W*H)'

Table 5.33 shows the result of the regression analysis between the 'building volume (L*W*H)' and the average estimated volume of the materials used (52.4%). The result depicts a linear and a strong correlation with the R-square (R^2) value of 61.62 percent.

The probability value (0.0002) is less than the five percent (0.05%) significance level; and the hypothesis was tested at the 95 percent confidence level.

Therefore, the relationship is statistically significant; and the alternative hypothesis is accepted; while the null hypothesis is rejected.

Moreover, to predict the **volume of materials used** for a project (52.4%) using the building volume (L*W*H) for that project, the regression equation variable from the analysis will be given as:

$y = a + bx$

$y = 52.4\%\ Volume\ of\ material\ used\ (dependent\ variable)$

$x = independent\ variable\ (Building\ volume\ \{L * W * H\})$

$a = 7449.7315\ (constant\ value)$

$b = 0.0194\ (coefficient\ of\ independent\ variable\ 'x')$.

Table 5.33 Result of regression analysis between building volume (L*W*H) and the estimated volume of materials used for the projects (52.4%)

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R square	Probability value	Strength of relationship	Remarks	Action on H
1	Building volume (m^3) (L*W*H)	Estimated volume of materials used (m^3) 52.4%	Linear regression	Estimated volume of materials used =7449.7315+0.0194*(x)	61.62%	0.0002	Strong	Statistically significant	Accept Hi and reject Ho

Source: Researcher's field data analysis, 2015

5.12.2 Relationship between the 100% estimated volume of materials for projects and the building volume (L*W*H)

The results of the regression analysis between the 'building volume (L*W*H)' and the '100 percent estimated volume of materials used for projects' in Table 5.34 reveals a linear and a very-strong correlation with the (R-square) value of 96.3 percent. The probability value (0.000) was less than the 0.05 (5 percent) level of significance; and the hypothesis was tested at the 95 percent confidence level.

The relationship is statistically significant; and the alternative hypothesis is accepted; while the null hypothesis is rejected.

Therefore, to predict the **100%** volume of **material used** for a project using the building volume (L*W*H) for that project, the regression equation variables from the analysis are given below:

$y = a + bx$

$y = 100\,\%\, Volume\ of\ material\ used\ (dependent\ variable)$

x= $independent\ variable\ (Building\ volume\ \{L * W * H\})$

$a = 334.7586\ (constant\ value)$

$b = 0.1113\ (coefficient\ of\ independent\ variable\ `x')$.

Table 5.34 Result of regression analysis between the building volume (L*W*H) and the estimated volume of materials for the project (100%)

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R^2	Probability value	Strength of relationship	Remarks	Action on H
2	Building volume (m^3) (L*W*H)	Estimated volume of materials	Linear regression	Estimated volume of materials=2 334.7586+0.1113*(x)	96.3 %	0.000	Very strong	Statistically significant	Accept Hi and reject Ho

Source: Researcher's field survey, 2015

5.12.3 Relationship between the average recorded volume of on-site material waste (52.4%) and the building volume (L*W*H)

Table 5.35 shows the result of the linear-regression analysis between the building volume (L*W*H) and the average recorded volume of on-site material waste (52.4%). The results indicate a strong correlation between the variables with an R-square value of 55.43 percent and a probability value of 0.0015, which is less than the 5 percent significance level at the 95 percent confidence level.

It is inferred that a statistically significant relationship exists between the variables; and the alternative hypothesis is accepted; while the null hypothesis is rejected.

Therefore, to predict the volume of onsite **material waste** for a project (52.4%) using the building volume (L*W*H) for that project, the regression equation variables from the analysis are given as follows:

$y = a + bx$

$y = 52.4\%\ Volume\ of\ onsite\ material\ waste (dependent\ variable)$

$x = independent\ variable\ (Building\ volume\ \{L * W * H\})$

$a = 333.5738\ (constant\ value)$

$b = 0.0004\ (coefficient\ of\ independent\ variable\ `x')$.

Table 5.35 Result of regression analysis between the building volume (L*W*H) and the recorded volume of onsite material waste (52.4%)

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R^2	Probability value	Strength of relationship	Remarks	Action on H
3	Building volume (m^3) (L*W*H)	recorded volume of onsite material waste (52.4% completion)	Linear regression	Volume of material waste recorded=333.5738+0.0004*x	55.43 %	0.0015	Strong	Statistically significant	Accept Hi & reject Ho

Source: Researcher's field survey, 2015

5.12.4 Relationship between the building volume (L*W*H) and 100 percent volume of on-site material waste

The 52.4% volume of on-site material waste in Table 5.35 was upgraded to 100%, in order to determine a complete relationship.

The result is presented in Table 5.36; and it shows the relationship between building volume (L*W*H) and the 100 percent volume of material waste. The result shows a very-strong correlation between the variables with an R-square value of 95.2 percent and a probability value of 0.000.

It is inferred that a statistically significant relationship exists between the variables and the alternative hypothesis is accepted; while the null hypothesis is rejected.

Consequently, to predict the 100% volume of onsite **material waste** for a project using the building volume (L*W*H) for that project, the regression-equation variables from the analysis are given as follows:

$y = a + bx$

$y = 100\% \; volume\ of\ onsite\ material\ waste (dependent\ variable)$

$x = independent\ variable\ (Building\ volume\ \{L * W * H\})$

$a = 361.9173\ (constant\ value)$

$b = 0.0023\ (coefficient\ of\ independent\ variable\ 'x').$

Table 5.36: Results of the regression analysis between the building volume (L*W*H) and an 100% volume of material wastage

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R square	Probability value	Strength of relationship	Remarks	Action on H
4	Building volume (m^3) (L*W*H)	100% volume of material waste	Linear regression	100% volume of material waste =361.9173 +0.0023*x	95.2%	0.000	Very strong	Statistically significant	Accept Hi & reject Ho

Source: Researcher's field survey, 2015.

5.12.5 Results of relationship between 'estimated volume of materials for projects and the volume of material waste recorded' (52.4% completion)

Table 5.37 shows the results of the relationship between the estimated volume of materials for the projects, and the volume of on-site material waste recorded from the projects.

The result shows a non-statistically significant relationship; because the probability value (0.0698) is greater than the significance value (0.05); and the hypothesis was tested at the 95 percent confidence level. The R-squared value of 33.57 percent was weak. The alternative hypothesis was rejected in favour of the null hypothesis.

So, to predict the volume of onsite **material waste** for a project (52.4%) using the estimated volume of materials for that project, the regression-equation variables from the analysis are given below:

$y = a + bx$

$y =$ 52% *volume of onsite material waste(dependent variable)*

x= *independent variable* (estimated volume of materials for project)

$a = 390.8538$ (*constant value*)

$b = 0.0019$ (*coefficient of independent variable* 'x').

Table 5.37: The results of regression analysis between the estimated volume of material for the project (m^3) and the volume of on-site material waste recorded

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R^2	Probability value	Strength of relationship	Remarks	Action on H
5	Estimated volume of material for project	volume of material waste recorded (52.4% completion)	Linear regression	Volume of onsite material waste recorded =390.8538+ 0.0019*x	33.57 %	0.0698	Weak	Not statistically significant	Accept Hi & reject Ho

Source: Researcher's field survey, 2015

5.12.6 Results of the relationship between the 'estimated volume of materials for the project and a 100% volume of material waste'

The results in Table 5.38 show how the 52.4% onsite material waste volume in Table 5.37 was upgraded to 100%. The result shows a very strong correlation between the variable with an R-squared value of 99.29 percent and a probability value (0.000) less than the significance level (0.05). The hypothesis was tested at the 95 percent confidence level.

The relationship is statistically significant; and the null hypothesis was accepted and alternative was rejected.

Therefore, to predict the **100%** volume of onsite **material waste** for a project using the estimated volume of materials for that project, the regression-equation variables for the analysis are given below:

$y = a + bx$

$y = 100\%\ volume\ of\ onsite\ material\ waste\ (dependent\ variable)$

$x = independent\ variable$ (estimated volume of materials for project)

$a = 309.4626\ (constant\ value)$

$b = 0.0206\ (coefficient\ of\ independent\ variable\ `x')$.

Table 5.38: The results of the regression analysis between the estimated volume of material for project (m^3) and the100% volume of material waste

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R^2	Probability value	Strength of relationship	Remarks	Action on H
6	Estimated volume of material for project	100% material waste volume	Linear regression	Volume of waste =309.4626 +0.0206*x	99.29 %	0.000	Very strong	Statistically significant	Accept Hi & reject Ho

Source: Researcher's field survey, 2015

5.12.7 Results of the relationship between the 'estimated volume of materials for the project and the volume of material used for the project'

Table 5.39 shows the results of the relationship between the estimated volume of materials for the project and the volume of material used for the project. The results revealed a weak correlation between the variables with an R-squared value of 38.81 percent. The probability value (0.0310) was less than the significance value (0.05) at the 95 percent confidence level. The relationship is statistically significant; and the null hypothesis is rejected in favour of the alternative hypothesis.

Therefore, to predict the **volume of material used** for a project using the estimated volume of materials for that project, the regression-equation variables for the analysis are given below:

$y = a + bx$

$y =$ $volume\ of\ material\ used\ (dependent\ variable)$

$x = independent\ variable$ (estimated volume of materials for project)

$a = 10160.9075\ (constant\ value)$

$b = 0.1058\ (coefficient\ of\ independent\ variable\ `x')$.

Table 5.39: The result of the regression analysis between the estimated volume of material for project (m^3) and the actual volume of material used for the project

S/n	Variables		Type of model	Observation			Inference		
	X	Y		Regression Equation	R^2	Probability value	Strength of relationship	Remarks	Action on H
7	Estimated volume of material for building	Volume of material used (52.4%)	Linear regression	Volume of waste =10160.9075+0.1058*x	38.81 %	0.0310	Weak	Statistically significant	Accept Hi & reject Ho

Source: Researcher's field survey, 2015

5.13 Concluding Remarks

This chapter has presented the research data; analysed and interpreted the results of the archival records, the field investigations, as well as the tick-box questions on material waste and cost overruns in the Nigerian construction industry. It has also interpreted the textual analysis of the interviews that were conducted.

Correlation analyses were performed to establish the relationships between the material waste and the cost overruns in the Nigerian construction industry.

The next chapter presents a summary and discussion of the research results, as well as the mathematical model for the quantification of material waste in the Nigerian construction industry.

Chapter 6: Summary and Discussion of the Research Results

6.1 Introduction

This chapter summarises the research results presented and interpreted in Chapter 5 of this study, and relates the results to the findings in the literature. The chapter also presents the mathematical models for quantifying the volume of materials and material waste for a project.

6.2 Quality of Planning

This section summarises and discusses the results of the issues relating to material waste and cost overruns at the planning stage of a project.

6.2.1 The components and quality of construction planning and waste management at the pre-contract stage of projects

The most important components with respect to quality of construction planning and waste management at the pre-contract stage of projects were: (a) adequate site investigation; (b) co-ordination of the entire planning process; (c) proper communication flow among the professionals; (d) regular meetings at the planning stage of a project; and (e) proper planning for site organisation (site offices, fencing, site security, site storage, and other preliminary items). These results are in line with the findings of Abdul-Azis *et al.* (2013: 2625-2627), that regular progress meetings at planning stage are necessary to improve the project performance at onset and resolve the uncertainties faced during project execution. This allows an in depth discussion of project related matters and subsequent re-planning for further work.

Additional components include: (e) proper project brief harmonization; (f) liaising with local authorities in the case of local laws; (h) early feasibility and viability studies on project purpose; (i) proper planning of project risks; (j) insurance of construction project; (k) adequate legislative enforcement; (l) planning for programme of work and preparation of schedule of materials and labour; (m) inclusion of material waste management in the bidding and tendering process of a project; (n) plan for early materials standardisation before production of design; (o) sourcing and ensuring availability of the right quality materials at the planning stage; and (p) proper cost management.

All these issues constitute good quality construction planning and waste management for a project. Most of these results support the findings of Chen, Li and Wong (2002: 256) and Ameh and Osegbe (2011: 24) who highlighted the fact that most of the problems relating to cost overruns occur at the planning stage of a project.

6.2.2 Methods of planning for material waste and cost overrun in the construction industry

Material waste is planned for, by establishing a waste management unit/department with a planned budget. Educated and experienced personnel/professionals in waste management are engaged. The department works with general management and progress is communicated through regular meetings. The department and the management plan for an on-site company yard/space, where generated material waste is organised and kept. The waste is separated for further re-use, recycle, incineration, disposal or re-sale for profit. The unit (waste management) ensures that materials delivered to the site are in accordance with the quantity ordered and the specifications prescribed. Moreover, site storage and security are also planned for, to avoid any pilferages and damages to materials on the site.

However, cost overruns are planned for, by: (i) allowing sufficient time for the quantity surveyors/estimators to conduct market surveys; the estimation; and evaluation of the project to establish the risks factors; (ii) inclusion of site security issues in planning; in order to prevent material theft and pilferages; (iii) thorough check and cross-check of the project estimate, in case of errors and omissions; (iv) addition of a contingency sum in the bill of quantities; (v) engaging an experienced estimator, in order to avoid the problems of wrong estimation; (vi) proper communication flow between the client, the designer, and other professionals at an early planning stage, in order to avoid the problems of variation and rework for projects; (vii) informing project clients about designer's intentions, after the necessary briefing and sketch design to reduce the rate of variation and rework; and (vii) recommending construction materials that have the capacity of minimising waste. Some of the results validate the conclusions of Jackson (2002: 4-5) that adequate contingency allowance and project risk assessment would help in reducing the rate of cost overruns.

6.2.3 The relationship between the quality-of-planning, material-waste generation, and cost overruns

The study reveals that poor quality planning negatively affects the entire project stages, including planning, design, construction, and completion. Thus, wasted materials, as a result of mistakes/errors and rework, would subsequently affect the project cost. This could even lead to the need for an extension of time; thereby incurring more on the project's final cost. The study reveals that proper planning would minimise material waste and cost overruns for a project*.* These results support the findings of Ameh and Itodo (2013: 748); Teo, Abdelnaser, and Abdul (2009: 262), as stated in Section 1 of this study.

6.2.5 Effects of material-waste sources and causes on project-cost overruns (Quality of planning)

The material-waste sources and causes that have 'very high effects' on project-cost overruns at the planning stage of a project were: (i) Inadequate site investigation; (ii) poor communication flow among members; (iii) inadequate waste management unit; and (iv) the lack of regular site meetings at the planning stage. These results corroborate the findings of Le-Hoai, lee and lee (2008); Memon *et al.* (2010); Memon, Abdul-Rahman and Abdul-Aziz, 2011); Love, Edward and Irani (2011); Flyvbjerg, Holm, and Buhl (2004), Singh (2009), and Allahaim and Liu (2013: 13-14). They identified these issues as the major causes of cost overruns in construction projects.

Coincidentally, the same results validate the findings of Babatunde (2012); Nagapan *et al.* (2012); Osmani, Glass and Price (2008); Okorafor (2014); and many others on the causes of material waste as outlined in section 2 of this study.

However, the material waste causes that have very little effect on cost overruns were: (1) improper plan for the establishment of a quality-control unit; (2) improper planning and understanding of the method statement. These results are in line with the findings of Malumfashi and Shuaib (2012: 19) that improper planning is one of the causes of project-cost overruns.

6.2.6 The effects of material-waste control measures on project-cost overruns (Quality of planning)

The material-waste control measures that have very high effects in controlling cost overruns at the planning stage of a project were; (i) plan for early sub-soil investigations; and (ii) proper co-ordination and communication among members at the planning stage. The causes with high effects on cost overruns were: (a) establishment of a good waste-management unit (b) regular site meetings (c) setting a target for material-waste reduction; and (d) engaging experienced personnel in planning. These results are in line with the findings of Abdul-Azis *et al.* (2013: 2625-2627) as stated in section 6.2.1.

On the other hand, the material-waste control measures with very little effect on cost overruns were: (1) proper insurance of work; (2) plan for the inclusion of waste management in bidding and tendering process; and (3) re-improving process (learning from previous mistakes). These are important measures for improving project performance at the planning stage of a project. Learning from previous experience helps in solving the current problems. Hence, if these measures are adopted as organizational policy, they would simplify other stages of a project. These results support the conclusions of Abdul-Azis *et al.* (2013: 2627); and Brunes and Lind (2014: 10) on the control measures for cost overruns as stated in section 3 of this study.

6.3 Quality of Design Management

This section summarises and discusses the results of the issues relating to material waste and cost overruns relating to quality-of-design management at the pre-contract stage of a project.

6.3.1 Relationship between the quality-of-design management, material waste generation, and cost overruns

A relationship exists between the quality-of-design management, material waste generation, and cost overruns. This relationship is summarised as follows:

A good quality design management should generate the necessary specifications, drawing details, constructability, maintainability issues, and envisages the issues relating to geophysical surveys for the type of foundations to be selected for a project.

Good quality design management allows project stakeholders to define their requirements at an early design stage, in order to avoid variation, rework, and cost overruns. It also allows early engagements of experienced designers/professionals, as inexperienced designers could either under-design or over-design a project.

Furthermore, materials would be designed to their standard sizes/units to allow tolerances, which would reduce the rate of cutting/chiseling and material wastages that could negatively affect the project cost. Therefore, it could be a colossal loss to the project, if these issues are wrongly handled.

These results corroborate the findings of Adewumi and Otali (2013); and Nagapan *et al.* (2012) on the issues relating to construction material waste as stated in section 2 of this study.

The results also validate the findings of Love, Edward and Irani (2011: 7); Allahaim and Liu (2012); Abdul Rahman *et al.* (2013) on the issues relating to cost overruns as highlighted in section 2 of this research.

6.3.2 Contribution of quality-of-design management to design complexity

A complex design does not necessarily mean a bad design; but inexperienced designers may contribute to the complexity, or when the project requirements are not clearly defined to the professionals involved. Therefore, good design management should consider all the ambiguous design problems, which might reduce the complexity, the material waste, and the cost overruns for projects. This result corroborates the findings of Ameh, Soyingbe and Odusanmi (2010: 49); Osmani, Glass and Price (2008); and Allahaim and Liu (2012) as stated in section 2 of this study.

6.3.3 Effects of material-waste sources and causes on project-cost overruns (Quality of design management)

The material-waste sources and causes that have ‘very high effects’ on project-cost overruns at the quality of design management stage of projects were: (i) error in design and detailing; (ii) lack of design information; (iii) design complexity/complication; and (iv) inexperienced designer or design team. These results imply that design and detailing errors are mostly caused by an inexperienced designer. These could lead to a wrong estimation; because, the estimates are lifted and solely depend on the design, and thereby having a serious impact on the project cost. These are in line with the findings of Ameh, Soyingbe and Odusanmi (2010: 49); Love, Edward and Irani (2011: 7); Memon, Abdul-Rahman and Abdul-Aziz (2011: 59); Baloyi and Bekker (2011: 61); Allahaim and Liu (2012: 2); and Shamugapriya and Subramanian (2013: 734) on the practical causes of cost overruns and material waste as stated in section 2 of this study.

However, the material waste sources and causes that have very little effect on cost overruns were: (a) designing dead spaces; (b) poor knowledge of the changing design requirements; and (c) aesthetic considerations. This is probably because; the respondents believe that dead spaces and aesthetic issues must have been included in the design, which the estimator must have considered in the estimating process. Therefore, have little effect in causing cost overruns.

6.3.4 Effects of material waste control measures on project-cost overruns (Quality of design management)

The material-waste control measures that have very high effects in controlling cost overruns at the quality-of-design management stage of a project were: (i) explicit detailing in design; (ii) interpretable designs and specifications; (iii) engaging an experienced designer; (iv) error-free design; and (v) adequate design information and consultation. These are the major causes of material waste and cost overruns identified in section 6.3.3 of this study. The results are also in line with the findings of Abdul-Azis *et al.* (2013: 2625-2627) on the control measures for project-cost overruns. Also, the results confirm the findings of Osmani, Glass, and Price (2008) on the management measures for material waste at the design stage of a project.

On the other hand, the material waste control measures that have very little effect in controlling the project-cost overruns at the quality-of-design management were: (a) design for materials optimization; (b) design for offsite construction (c) improving on previous design mistakes. These results support the findings of Abdul-Azis *et al.* (2013: 2625-2627) on the control measure for project-cost overruns.

6.4 Design Complexity

This section summarises and discusses the results of the issues relating to material waste and cost overruns at the design-complexity stage of projects.

6.4.1 Definition of design complexity

The definition of design complexity by the respondents is summarised as follows:

A design that exceeds the traditional design techniques; a design that does not follow the norms of traditional practice; a design that does not use available human or material resources; requiring a laboratory build-up, special technology and consultants; or when the processes of achieving the desired quality is not readily available.

Relating to the shape of a design, design complexity relates to the simplicity or irregularity of a designed shape (geometric shapes, curves, and irregular outlines) requiring materials to be cut to fit into a position. This result is in line with the definition of Seeley (1999), on design complexity.

The site engineers view design complexity as a design that is difficult to understand and execute; lacking details and requiring assumptions; not being able to translate by site engineers with unclear details and specifications; a design that lacks standardization in material sizes/units and requiring constant cuttings and chiseling to fit into position.

The quantity surveyors perceive design complexity as, when the necessary details, dimensions, and the specifications used for preparing the quantity take-off or estimate are not clear or not available.

6.4.2 Contribution of design complexity to material-waste generation and cost overruns

Lack of standardization in material sizes leads to constant cuttings of materials to fit in position, which results in material-waste generation; and thereby contributes to project-cost overruns. Also, a complex construction technique and cuttings in material sizes due to design complexity lead to material-waste generation, and thereby contribute to cost overruns. However, good understanding of complexity in design would reduce the magnitude of the material waste to be generated. These results corroborated the findings of Osmani (2008: 1147) as stated in the section 2 of the study.

In other words, design complexity could lead to re-design, variation, and rework and thus contribute to project-cost overruns.

Also, straight and regular shaped designs generate less waste compared to irregular and complex designs.

6.4.3 Relationship between design complexity and the occurrence of variations in a project

The relationship between the design complexity and occurrence of variations revealed that; the more complex the design, the more likely the variation, and a wrong interpretation of design leads to rework and variation.

Moreover, the ability of maintaining specifications in a complex design is very difficult, as some of the materials might not be readily available in the local markets, while some may be required to be manufactured abroad. Thus, the originally specified materials may be replaced with local ones, and non-availability of designed or specified materials, as a result of complexity would lead to variation.

Consequently, a design that is not fully detailed, the construction could be subject to re-measurement and re-work, thereby causing a variation. Complex designs always require unique skills and the availability of sophisticated equipment; and a shortage of skilled manpower and poor workmanship, as result of complexity, could give rise to a variation in design. This result also corroborates the findings of Aziz (2013: 51) as stated in section 2 of this study.

6.4.5 The effects of material-waste sources and causes on project-cost overruns (Design complexity)

The material-waste sources and causes that have 'very high effects' on project-cost overruns in this category (design complexity) were: (i) inexperienced designer; and (ii) difficulties in interpreting specifications.

Consequently, the material-waste causes that have high effect on project-cost overruns were: (a) designing unstandardised dimensions requiring cutting and chiseling; (b) designing uneconomical shapes and outlines; and (c) inadequate design information. These results support the findings of Kasimu (2012: 775), who identified the problem of incomplete drawing as a major cause of cost overruns. Others are: Shanmugapriya and Subramanian (2013: 734); Osmani (2008: 1147); and Ameh, Soyingbe and Odusanmi (2010: 49) as stated in section 2 of this study.

The material waste sources and causes that have very little effect on cost overruns in this category (design complexity) were: (a) lack of prioritizing re-use in designs and specifications; (b) poor monitoring of design process; and (c) improper plan for waste management in design. This is probably because, most of the respondents believe that these causes are very weak in causing design complexity, hence; they could have little effect in causing cost overruns.

6.4.6 Effects of material-waste control measures on project-cost overrun (Design complexity)

The material-waste control measures that have very high effects in controlling cost overruns in this category (design complexity) were: (i) engaging an experienced designer; (ii) designing readable dimensions and specifications; and (iii) standardising designs and units. An experienced designer should be able to produce a design that is readable by the site workers and a design that would enhance standardisation in material sizes.

However, the material-waste causes that have very little effect on cost overrun were: (a) proper monitoring and supervision of work (b) improving on previous design mistakes/errors, and (iii) the use of specialised technology and consultants. Some of these results corroborate the findings of Abdul-Azis *et al.* (2013); and Brunes and Lind, (2014) on the control measures for cost overruns.

6.5 Quality of Estimating

This section summarises and discusses the issues relating to material waste and cost overrun related to the quality of estimating of a project.

6.5.1 Contributions of quality of estimating to material-waste generation and cost overruns

Poor-quality estimation (under/over) for a project is linked with material-waste generation and cost overruns. Poor quality estimation results in poor unit rates and wrong procurement. In the case of over estimation, more materials would be procured onsite which would be over and above the required quantity and the remaining materials would result in waste, and thereby contribute to cost overruns.

Also, under-estimation would require the additional cost of transportation, loading and unloading of materials for supplementary procurement, resulting in the waste of resources and contributing to cost overrun. Therefore, an experienced estimator is required to achieve an accurate and precise estimate for a project.

These results support the findings of Ameh and Osebe (2006: 253), Jenpanistub (2011: 24), Aziz (2013: 51) and Subramanan, Sruthi, and Kavitha (2014:1) who highlighted poor cost estimation/estimation techniques as a major cause of project-cost overruns. The results also validate the findings of Nguyen, Gupta and Faniran (nd) on the major causes of material waste at the pre-contract stage of a project as stated in section 2 of this study.

6.5.2 Contributions of quantity take-off/cost estimating to material waste generation and cost overruns

Wrong quantity take-off/cost estimation would result in over/under estimation and contribute to waste generation and cost overruns. For instance, a sharp sand/aggregate has a shrinkage allowance of thirty (30) percent and the absence of this allowance in taking-off/cost estimation process would result in under estimation for this material.

These results corroborate the findings of Lee-Hoai, Lee (2008: 367) who established "inaccurate quantity take-off as one of the top five (5) most important causes of cost overrun in large projects in Vietnam. The results are also in line with Aziz (2013: 51), who examined the causes of cost overruns in the Egyptian construction industry.

Others are: Baloyi and Bekker (2011: 61), Allahaim and Liu (2012: 2), Ogunsemi and Jagboro (2006: 253), Azhar, Farouki, and Ahmed (2008: 503), Omoregie and Radford (2006:5).

Additionally, the results support the findings of Nagapan *et al.* (2012) who concluded that inaccurate quantity take-off contributes to material waste generation.

6.5.3 Insufficient time for estimate as a factor that contributes to waste and cost overruns (Quality of estimating)

Insufficient time for estimates contributes to material waste and cost overruns to a very large extent; because pressure on an estimator to produce an estimate earlier than when due could lead to making incorrect assumptions, and could not afford the estimator the time to engage in other estimating activities. Thus project estimators need sufficient time to conduct market surveys/intelligence, in order to have an idea on the current prices of materials; study project particulars, such as the designs/drawings and specifications; engage in risks evaluation and analyses to determine the project risk factors; and ample time for checking and cross checking the prepared estimate, in case of errors and omissions.

Also, a design might sometimes specify foreign materials that might not be locally obtainable, thus, sufficient time must be allowed to avoid assuming the estimation figures.

Consequently, these results corroborate the findings of Kasimu (2012: 775) and Allahaim ad Liu (2013) who identified the problems of insufficient time as one of the major causes of cost overruns in construction projects. The results also validate the findings of Nagapan *et al.* (2012) who identified insufficient time for estimate as one of the major causes of material waste for projects.

6.5.4 Effects of material waste sources and causes on project cost overruns (Quality of estimating)

The material-waste sources and causes that have 'very high effects' on project-cost overruns at the quality of estimating stage of a project were: (i) inaccurate quantity take-off; (ii) insufficient time for estimate; and (iii) lack of detailed (readable and interpretable) drawings and specifications for estimating. Moreover, (1) inadequate project risks evaluation, analysis, and estimation; and (2) inadequate knowledge of site conditions have high effect on cost overruns at the quality of estimating stage of a project.

However, the material-waste causes that have very little effect on cost overruns at the quality of estimating stage were: (a) improper monitoring and improvement on previous mistakes; (b) design requiring frequent changes; and (c) late engagement of estimators.

These findings confirm most of the results stated in section 6.5.1, 6.5.2 and 6.5.3 of the study.

Also, Ameh and Osegbe (2011: 24) believe that most of the problems relating to cost overruns occur at the planning and the estimating stage of a project. Ogunsemi and Jagboro (2006: 253) attributed the problems of cost overruns to erroneous quantity take-off, at an early stage of a building project. Additionally, Jenpanitsub (2011: 24) reported that the Rely Statistics Minister of India (RSMI) noted that under-estimation of original project cost was the major reason for cost overruns.

6.5.5 Effects of material waste control measures on project-cost-overruns (Quality of estimating)

The material waste control measures that have very high effects in controlling cost overruns at the quality of estimating stage of a project were: (i) sufficient time for estimate; (ii) accurate quantity take-off; (iii) engaging an experienced estimator; and (iv) the availability of detailed drawings, dimensions, and specifications. These results are in line with the findings of Jackson (2003: 4) who concluded that drawings must be detailed before achieving a better estimate. The results also support the findings of Peeters and Madauss (2008: 81) who higlighted the fact that a realistic cost estimation is the best way to avoid cost overruns for projects.

Nonetheless, material waste control measures that have little effect on control of cost overrun were: (a) monitoring and improving on previous estimating mistakes; and (b) a thorough design check and estimate. These results corroborate the findings of Abdul-Azis *et al.* (2013) who stated that improving on past mistakes would help in reducing project-cost overruns.

6.6 Quality of Procurement Management

This section summarises and discusses the issues relating to material waste and cost overruns at the quality-of-procurement management stage of a project.

6.6.1 The quality of procurement management in the respondents' organisation

The respondents disclosed that their organisation/firm procures materials strictly, in accordance with project specifications; they have a very efficient and a well organised procurement management; they have the know-how of what to procure, what quantity to procure, at what cost to procure, and where to procure.

Furthermore, some companies disclosed that they have the knowledge of current material prices, both locally and internationally. Some disclosed that they have a network of procurement departments, both locally and internationally, in case a project is designed and is requiring foreign materials.

6.6.2 Contribution of materials procurement to waste-generation and cost overruns

Procuring the appropriate materials, at the right time, in accordance with the specifications; and proper material handling and good product knowledge would reduce material waste and cost overruns.

6.6.3 Contributions of quality of firms' procurement management to material-waste generation and cost overruns

A good quality-procurement management team should envisage better transportation of materials, ordering the appropriate quantity of materials, and the provision of an easy access road. Where these cannot be envisaged, then waste would inevitably occur which would contribute to the cost overrun.

Also, in the absence of a competent and experienced procurement management, a job would probably be given to an incompetent contractor, who might end up wasting materials, and thereby leading to cost overruns.

These results confirm the findings of Brunes and Lind (2014: 10); and Abdul-Azis *et al.* (2013: 2625) that inexperienced personnel are a major cause of cost overruns in the construction industry.

Moreover, lack of quality control in procurement and adequate estimation for procurement as stated in project specifications may result in wastage of materials, thereby contributing to cost overrun. This finding also supports Magnussen and Olsson (2006: 286) who established the impact of quality control on cost overruns and the result revealed a significant reduction in cost overruns.

6.6.4 Effects of material waste sources and causes on project cost-overrun (Quality of procurement management)

The material-waste sources and causes that have 'very high effects' on project-cost overruns at the quality of procurement stage were: (i) procuring items not in compliance with the specifications; and (ii) engaging inexperienced personnel in estimation and procurement. These results confirm the findings of Kasimu (2012: 775) and Jackson (2002: 5) as stated in section 2 of this study.

Consequently, the same results also corroborate the findings of Adewumi and Otali (2013); Osmani, Glass and Price (2008) on the causes of material waste for projects.

Moreover, the material waste causes that have high effects on cost overruns were: (1) procuring wrong quantity of materials at the wrong time; and (2) delivery of substandard materials.

Nevertheless, the waste sources and causes that have very little effects on cost overruns were: (a) errors in shipping; (b) damage of material during transportation; (c) market conditions; and (d) lack of awareness.

6.6.5 Effects of material-waste control measures on project cost overruns (Quality of procurement management)

The material waste control measures that have a very high effect on controlling cost overrun with respect to quality of procurement management of a project are: (i) procuring in accordance with the specifications; and (ii) experienced personnel in estimation and procurement.

These results confirm the findings of Abdul-Azis *et al.* (2013: 2625) who recommended the engagement of experienced personnel as a major control measure for project-cost overruns.

The only material waste cause that has a high effect on cost overrun is: procuring the right quantity of materials at the right time.

However, the material waste control measures that have a very little effect on cost overrun with respect to quality of procurement are: (a) better delivery of materials on-site; (b) adopting good materials abstracting; (c) provision of easy access road for vehicles delivery; and (d) knowledge of the product to be manufactured.

These results support by the findings of Osmani (2008: 1149) as stated in section 2 of this study.

6.7 Quality of Construction Management

This section summarises and discusses the issues relating to material waste and cost overrun with respect to quality-of-construction management of a project.

6.7.1 Quality of construction management based on the respondent's experience

Quality of construction management entails managing the entire construction process from inception to completion with all the necessary management tools; it is the practical way of achieving design reality through proper co-ordinating, controlling, organising, communicating, scheduling, motivating, proper building techniques, and good workmanship; it is the pillar of every construction work, which has to do with the management of people, plant, materials, equipment, money, time, and the entire construction process.

6.7.2 Relationship between interviewee firms' construction management, material-waste generation, and cost overruns

The respondents were not fully satisfied with their organisations' construction management. Some disclosed that, their firm/organisation was operating far below the average level, some at the average level, while some noted that, they still have a very long way to go; because there are situations where projects are not delivered on time, and sometimes within the required cost. These mostly happen, because of inadequate planning.

However, very few respondents disclosed that their firm/organisation was above average, or doing well. This category of respondents explained that, they are experienced and always plan ahead; hence, they generate less waste.

6.7.3 Contribution of sub-contractors and suppliers to material-waste generation and cost overruns (Quality of construction management)

Most of the respondents disclosed that both the sub-contractors and suppliers contribute to material-waste generation and cost overruns. Moreover, the respondents also explained that sub-contractors are profit-oriented individuals and the waste they generate directly affects their profits. They noted that most of the contract agreements require sub-contractors to generate waste at their own risk, which makes them more careful about the amount of waste they generate.

For the suppliers, the quality control department evaluates the supplied product to ensure that they are in conformity with the project's specification.

6.7.4 Impact of rework and mistake/error on material-waste generation and cost overruns

Inexperienced professionals/personnel or working contrary to project specification/contract, lead to rework and mistakes/errors. Therefore, an abortive work is already a waste; and it would require the same type of materials, the same labour, and the same costs to re-build. This result corroborates the findings of Aziz (2013: 51) who concluded that abortive and additional work contributes to cost overruns.

6.7.5 Effects of material-waste sources and causes on project-cost overruns (Quality of construction management)

The material-waste sources and causes that have 'very high effects' on project-cost overrun at the quality of construction management stage were: (i) engaging an incompetent worker; and (ii) rework (contractors' source). These results confirm the findings of Shamugapriya and Subramanian (2013: 734) who found rework as a major cause of cost overrun. Aziz (2013: 51), Kasimu (2012: 775) and Jackson (2002: 5) identified the problem of incompetency and inexperience as a major cause of cost overruns.

Consequently, the material waste causes that have high effects on cost overrun are: (a) incorrect scheduling and planning (contractors' source); (b) shortage of skilled workers (workers' source); (c) lack of experience; and (d) poor financial controls on site.

However, the material waste causes and sources that have very little effect on cost-overrun are: (1) poor staff workers relationship; (2) lack of awareness on waste management; (3) lack of incentive; and (4) use of unskilled labour to replace skilled ones.

6.7.6 Effects of material waste control measures on project-cost overruns (Quality of construction management)

The material waste control measures that have high effects in controlling cost overruns at the quality of construction management stage of a project were: (i) proper scheduling and planning; and (ii) engaging competent workers. These results corroborate the findings of Abdul-Azis *et al.* (2013: 2625) who identified proper scheduling and planning and competent workers as the major control measure for project cost overruns.

The material waste control measures that have moderate effects on cost overruns were: (a) better storage facilities and environment/area; (b) staff vocational training and development; (c) establishing systems of rewards and punishments for material saving; (d) improve contractors' onsite construction management; (e) adequate site control supervision; and (f) ensuring the achievement of good quality workmanship on site.

On the other hand, the material waste control measures that have very little effect on controlling the cost overruns with respect to quality of construction management are: (1) process improvement techniques/improving on previous mistakes; (2) improved material handling methods (3) error-free construction process; (4) proper management support for workers; and (5) holding regular site meetings. These findings are in line with Abdul-Azis *et al.* (2013: 2625) as stated in the section 3 of this study.

6.8 Quality of Site Management

This section summarises and discusses the issues relating to material waste and cost overruns at the quality of site management stage of a project.

6.8.1 Definition of site management by the respondents

Site management is an aspect of construction management that deals with the planning, controlling, co-ordinating, communicating, motivating, scheduling, and organising of the entire activities on the site including the 5Ms (men, machines, money, materials, and management) to achieve the desired project objectives; it involves site security, access road, minimisation of wasteful time, timely provision of materials, and site safety; it has to do with the management of the routine activities on site; and it includes certain group of people that administer the day-to-day running of a site from the inception to completion of a project.

6.8.2 Contributions of site management to material waste and cost overruns

Site management contributes to material waste and cost overruns when the management of the site is poor or when the issues stated in table 5.16 and 5.17 are not properly managed or addressed.

6.8.3 Contributions of site security, site accident, and site dispute to material-waste generation and cost overruns

Inadequate site security would lead to pilfering/thefts and damage/sabotage of materials on site; when the site is not properly organised and disciplined, accidents are bound to occur; and these might affect the workers, the structure, or even both.

6.8.4 Effects of material waste sources and causes on project-cost overruns (Quality of site management)

The material-waste sources and causes that have 'very high effects' on project-cost overruns at the quality of site management stage were: (i) rework; (ii) site accident; (iii) inadequate site security/fencing; (iv) poor site organisation and discipline; and (v) construction site dispute.

Furthermore, (a) lack of experience; (b) poor construction planning and control; (c) theft; and (d) lack of co-ordination among parties were deemed to have high effects on cost overruns. These results support the findings of Azhar, Farouki and Ahmed (2008: 503); Malumfashi and Shuaibu (2012:19); Shamugapriya and Subramanian (2013: 734); and Jackson (2002: 5) as highlighted in section 2 of this study.

The material waste causes that have very little effect on cost overruns are: (1) difficulties in accessing construction site; (2) long storage distance from application point; (3) late delivery of materials; and (4) late information flow among parties.

6.8.5 Effects of material waste control measures on project-cost overrun (Quality of site management)

The material waste control measures that have a high effect on controlling cost-overruns with respect to the quality of site management of a project are: (i) tight security on site (security source); (ii) adequate site organisation and discipline (operation source); and (iii) on-site and off-site re-use of waste materials (site conditions and management source).

Consequently, the material waste control measures that have high effect on cost overrun with respect to the 'operation source' are: (i) waste management throughout the entire lifecycle of a project; (ii) the use of experienced personnel; (iii) promotion of construction waste re-use on-site; and (iv) adequate site planning and control.

On the other hand, the material waste control measures that have very little effect on controlling cost overruns are: (a) issuing procedures for managing hazardous waste (operation source); (b) reduction of off-cut of materials and re-using (residual source); and (d) implementation of onsite material waste sorting (site conditions and management source).

Most of these findings are in line with previous research studies which highlight that improving site management is very important in reducing cost overruns, as it significantly affects onsite productivity (Chan and Kumaraswamy, 1997; Fong, Wong, and Wong, 2006; Osmani, 2008: 1149; Ibrahim, Roy, Ahmed, and Imtiaz, 2010; Abdul-Azis *et al.,* 2013). Koushki *et al*. (2005) also stated that contractor related factors are the main contributors of cost overruns.

6.9 Material-Waste Minimisation and Management

This section summarises and discusses the results of the issues relating to material waste minimisation and management; and cost overruns.

6.9.1 Material waste recovery system adopted in the respondents' organisation

Only one construction organisation/company practiced both re-use and recycling of material waste. This is probably because the company is a strong multinational company working in Nigeria.

On the other hand, other respondents disclosed that their firms only re-use waste materials that have minimal damage, but lack the capacity to recycle.

6.9.2 The influence of material waste (re-use and recycling) on project-cost overruns

Material waste recovery system (re-use and recycling) helps in minimising the amount of waste materials on site, as well as project-cost overruns. The profit made from re-using and recycling waste materials goes back into the project. This could contribute significantly to minimising the amount of project cost overruns.

6.9.3 The training and education programmes for employees on how to minimise material waste and cost overruns

Some respondents disclosed that their staff only learn on the job, and not through any formal training.

While some companies engage their staff on an in-house training on material-waste management; some only engage their staff in attending external training, such as: conferences, workshops, and seminars. However, very few engage their staff in both the in-house and the external training (workshops, seminars, and conferences) on how to manage material waste and cost overruns.

6.9.4 Benefits of recovering (re-use and recycling) material waste and their effects on cost overruns

This section presents the summary and discussion of the economic, the environmental, and the social benefits of recovering material waste and their effects on project-cost overruns.

6.9.4.1 Economic benefits of recovering material waste and their effects on cost overruns

The economic benefits of the material waste recovery system that have very high effect on cost overruns are: (i) profit making on salvaged materials; (ii) project-cost saving through avoided disposal costs; (iii) reduced project-cost overruns; and (iv) saving costs on new materials. The respondents explained that the profit made goes back into the project and thereby reducing the cost overrun.

Furthermore, the economic benefits of material waste recovery system that have a high effect on controlling cost overruns are: (a) cuts down/reduces disposal costs; (b) reduces demand for new materials; and (c) realizing the value of recovered materials.

However, the economic benefits that have little effect on cost overrun are: (1) conserving resources, by diversion from landfill; and (2) reduces energy costs. These findings corroborate the results of Mueller (2012), Tam and Tam (2006), Winkler (2010) and USEPA (2000) on the benefits of recycling material waste in the construction industry.

6.9.4.2 Environmental benefits of recovering material waste and their effects on project cost overruns

The only environmental benefits of material waste recovery system that has high effect on cost overruns is re-using material which could be lost to landfill

Moreover, the environmental benefits that have ‘moderate effects’ on cost overruns are: (i) reducing environmental pollution; and (ii) preserving space in existing landfills and environmental conservation.

This is probably because the respondents think that in all cases, the wasted materials have to be recovered back into the project, and they thereby minimise the amount of cost overruns.

The environmental benefits that have little effects on cost overrun are: (a) curtailing of the negative environmental impact; and (b) minimising the environmental impact, such as contamination of ground water. These findings support the conclusion of Winkler

(2010) and USEPA (2000) on the benefits of re-use and recycling of material waste in the construction industry.

6.9.4.3 Social benefits of recovering material waste and their effects on cost overruns

The social benefits of material waste recovery system that have very high effect on cost overruns are: (i) waste materials are sold to developers of small-sized projects. This is probably because the respondents think that, as waste materials are recovered and sold, the profit goes back into the project.

Moreover, the benefits that have high effect on cost overrun are: (a) waste is used as a benefit to community by helping in disposal; (b) waste from timber formwork is used as firewood by the local community. This is probably because the respondents think that removing the timber waste formwork from the site would save the project, the cost of transportation and disposal to landfill.

However, the social benefits of material waste that have very little effect on cost overrun are: (1) creation of job opportunity; (2) compliance with State and local regulations; and (3) raising the public image of a company**.** These findings support the conclusion of Winkler (2010) and USEPA (2000) on the benefits of re-use and recycling of material waste in the construction industry.

6.9.4.4 Benefits of the re-use of material waste and their effects on cost overruns

The benefits of material waste re-use that have high effect on cost overrun are: (i) re-use is the most profitable means of recovery for the contractors; and (ii) re-use does not require hauling and transportation.

Nonetheless, the moderately effective benefits of re-use are: (a) re-use does not require energy; and (b) re-use does not require reprocessing. These findings are in line with the conclusions of Winkler (2010) on the advantages of re-use in the construction industry.

The benefit of recycling was not captured because 96.7 percent of the respondents explained that they were not into recycling of material waste. However, the only international contractor (3.3 percent) that recycles material waste explained that: (i) recycling reduces project cost through avoided disposal cost; and (ii) recycling cuts down transportation cost and reduces demand for new materials. These findings also corroborate the results of Winkler (2010) and that of USEPA (2000) on the benefits of recycling material waste in the construction industry.

6.10 General Comments on Waste Minimisation and Cost Overrun on Construction Projects

Some respondents had no comments and some commented as follows:

Waste is inevitable in any construction work; but it should be minimised as much as possible, to achieve good sustainability and value for money by the client.

On site material waste generation has a significant impact on the total project cost; hence, proper attention must be given to waste management in order to keep the project cost within the budgeted limit. This comment corroborates the findings of Ameh and Itodo (2013: 748). It is also supported by Teo, Abdelnaser and Abdul (2009: 262) referring to section 1 of this study.

Waste is inevitable on any construction site. If only designs could fit the market sizes of materials. Therefore, the possible waste management principles should be encouraged to achieve the best value for money.

6.11 Comparative views of the respondents on the material-waste sources, causes, control measures, and 'the benefits of recovering material waste and their effect on project cost overruns'

The comparative analyses of the respondent views on the effects of material waste sources, causes, and control measures of various aspects of a project (quality of planning, quality of estimating, quality of design management, design complexity, quality of procurement management, quality of construction management, and quality of site management) considered for this study were proven not statistically significant.

This implies that all the respondents were of the same view on their responses from pre-contract to post-contract stage of a project. They have similar ideas on issues relating to material waste and cost overruns.

Furthermore, there was no difference in the respondents view on the economic, environmental, and social benefits, as well as the benefits of re-use of materials on construction sites.

6.12 Contributions of Material Waste to Project Cost overruns

The results of the correlation analysis between the generated volume of on-site material waste and the amount of cost overruns revealed a strong and statistically significant relationship.

The result implies that, increase in on-site wastage of materials would lead to a corresponding increase in the amount of cost overrun for a project.

This result corroborates the findings of the studies conducted in the UK, Hong Kong, Netherlands, and Nigeria; that wastage of construction materials contributes to additional project cost by reasonable percentages (Ameh and Itodo, 2013: 748). The result also supports the findings of Teo, Abdelnaser and Abdul (2009: 262).

Furthermore, the descriptive analysis also revealed a significant contribution to cost overruns, ranging from a minimum of ₦31,220,528.06 (1.96 percent) to a maximum of ₦39,933,360.29 (8.01 percent), with an average contribution of approximately four (4) percent to the project-cost overruns.

This implies that the average contribution of material waste to project cost overruns was four (4) percent.

Moreover, this percentage (4 percent) is different from the five (5) percent allowed for waste in the process of bill of quantities production.

This result (4 percent contribution) did not support the following findings:

Memon (2013: 10) concluded that construction waste accounts for about 30-35 percent of a project's construction cost, and construction materials wasted on the site account for about 9 percent by weight of the procured materials.

Also, the study refutes the findings reported by Ameh and Itodo (2013: 748) that in the UK, material waste accounts for an additional cost of 15 percent to construction projects-cost overruns; accounts for about 11 percent to construction cost overruns in Hong Kong; and accounts for 20-30 percent in the Netherlands. This is probably because, the methodology adopted for most of these studies were a survey research design, which relies on the professionals' perception of material wastage and cost overrun during construction operation, which is considered a subjective assessment. For instance, the respondents are required to tick a questionnaire with the following options: from 10-15%, 15-20%, 20-30%, and so forth, from which conclusions were drawn.

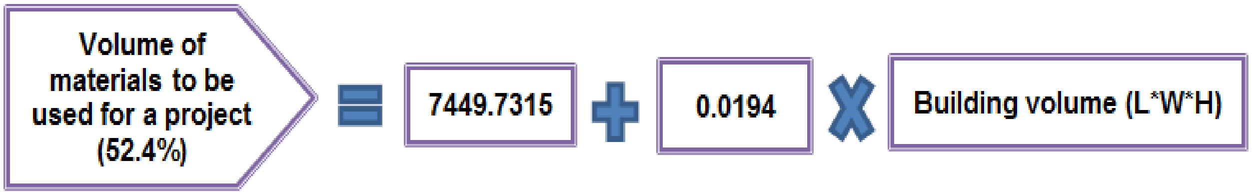
6.13 Mathematical Models for Quantifying the Amount of Materials and Material-Waste for a Proposed Building Project

In an attempt to achieve the objective and sub problem number 5 as stated in section 1.5 and1.6 of this study, this section presents the mathematical models from the results of the linear-regression analyses performed in section 5.12 of this study. The models/equations are further represented in figures.

6.13.1 A model for predicting the volume of materials for a proposed project using building volume (L*W*H), (52.4% project completion)

Figure 6.1 shows a mathematical model for predicting the volume of materials used for a project at 52.4 percent completion. This is because; the collected data for the research was averaged at 52.4 percent completion.

Therefore, the volume of materials used for a proposed project is determined, by adding the constant value (7449.7315) to the coefficient value of the building volume (0.0194), multiplied by the building volume in size (L*W*H) as shown in Figure 6.1.

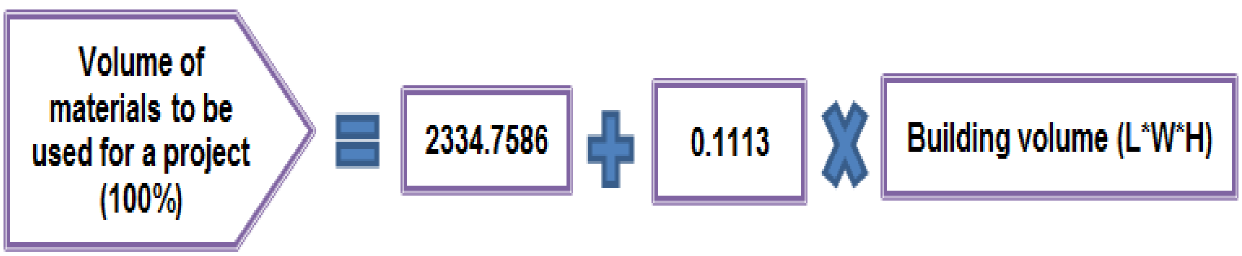


$$Volume\ of\ materials\ to\ be\ used\ for\ a\ project\ (52.4\%\ completion) = 7449.7315 + 0.0194 * (x)$$

Figure 6.1: Mathematical model for predicting the volume of materials to be used for a proposed building project (52.4 percent completion)

6.13.2 A model for predicting the total volume of materials for a proposed project using building volume (L*W*H), (100% completion)

Figure 6.2 shows that the total volume of materials for a proposed project is determined by adding the constant value (2334.7586) to the coefficient value of the building volume (0.1113), and multiplied by the building volume (L*W*H).

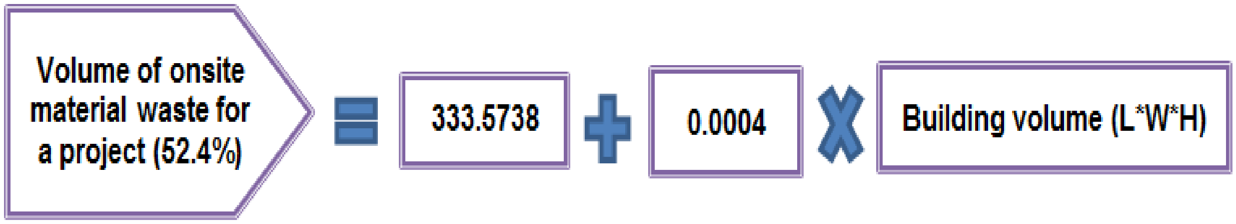


$$Volume\ of\ materials\ to\ be\ used\ for\ a\ project\ (100\%\ completion) = 2334.7586 + 0.1113 * (x)$$

Figure 6.2: Mathematical model for predicting 100% volume of materials to be used for a proposed building project

6.13.3 A model for predicting the volume of material waste for a proposed project using building volume (L*W*H), (52.4% completion)

This model shows how to determine the volume of material waste to be generated at 52.4 percent completion of a proposed building project. This is determined by adding the constant value (333.5738) to the coefficient value of building volume (0.0004), and multiplied by the building volume (L*W*H), as shown in Figure 6.3.

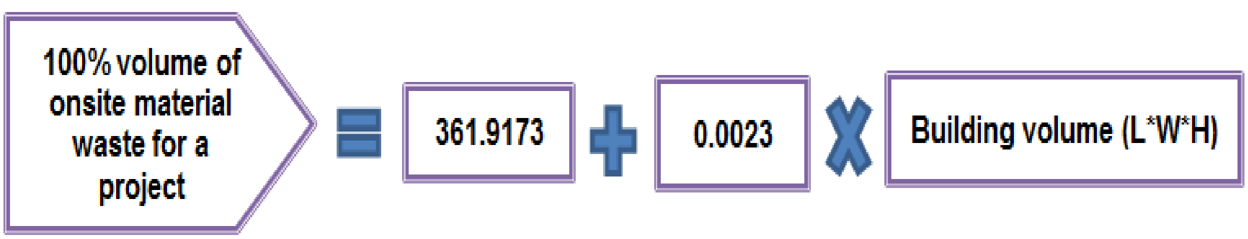


$$\textit{Volume of onsite material waste for a project}\ (52.4\%) = 333.5738 + 0.0004 * (x)$$

Figure 6.3: Mathematical model for predicting the volume of material waste for a proposed project

6.13.4 A model for predicting the total volume of material waste for a proposed building project using building volume (L*W*H), (100 % completion)

This model shows how to determine the total volume (100 percent) of material waste for a proposed building project. This is determined by adding the constant value (361.9173) to the coefficient value of building volume (0.0023), and multiplying the result by the building volume (L*W*H), as shown in Figure 6.4.



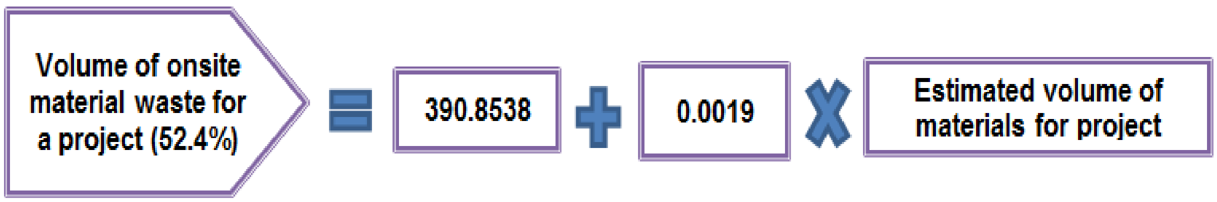
$$100\%\ \textit{volume of onsite material waste for a project} = 361.9173 + 0.0023 * (x)$$

Figure 6.4: Mathematical model for predicting the total volume (100 percent) of on-site material waste for a proposed building project

6.13.5 A model for predicting the volume of on-site materials waste for a proposed building project, using the estimated volume of materials (52.4% completion)

This model shows how to predict the volume of material waste for a proposed project, if the volume of materials is known.

This is determined by adding the constant value (390.8538) to the coefficient value of the volume of materials for the proposed project (0.0019), and multiplied by the volume of materials for the proposed project as shown in Figure 6.5.

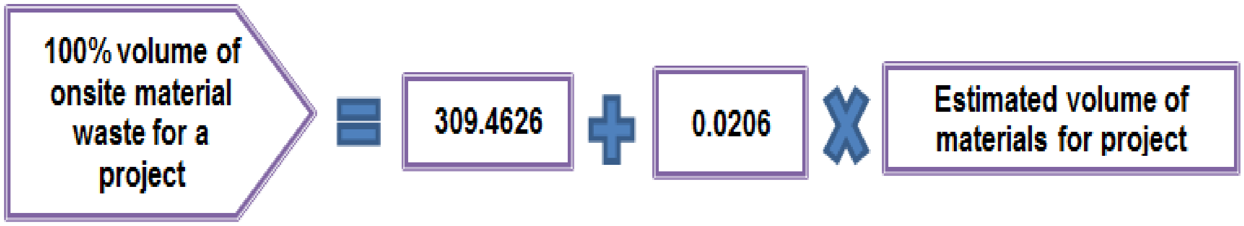


$$52.4\%\ volume\ of\ onsite\ material\ waste\ \ for\ a\ project = 390.8538 + 0.0019 * (x)$$

Figure 6.5: Mathematical model for predicting the volume of on-site material waste for a proposed project (52.4 percent completion)

6.13.6 A model for predicting the total volume of onsite materials waste for a proposed project using the estimated volume of materials

This model shows that the total volume of material waste for a proposed project is determined by adding the constant value (309.4626) to the coefficient value of the volume of materials for a proposed project (0.0206), and multiplied by the volume of materials for the proposed project as shown in Figure 6.6.



$$100\%\ volume\ of\ onsite\ material\ waste\ for\ a\ project = 309.4626 + 0.0206 * (x)$$

Figure 6.6: Mathematical model for predicting 100 percent volume of on-site material waste for a proposed project

To gain a general overview into the mathematical models for quantifying the total volume of materials and material waste for a proposed project, Figure 6.7 presents the general summary.

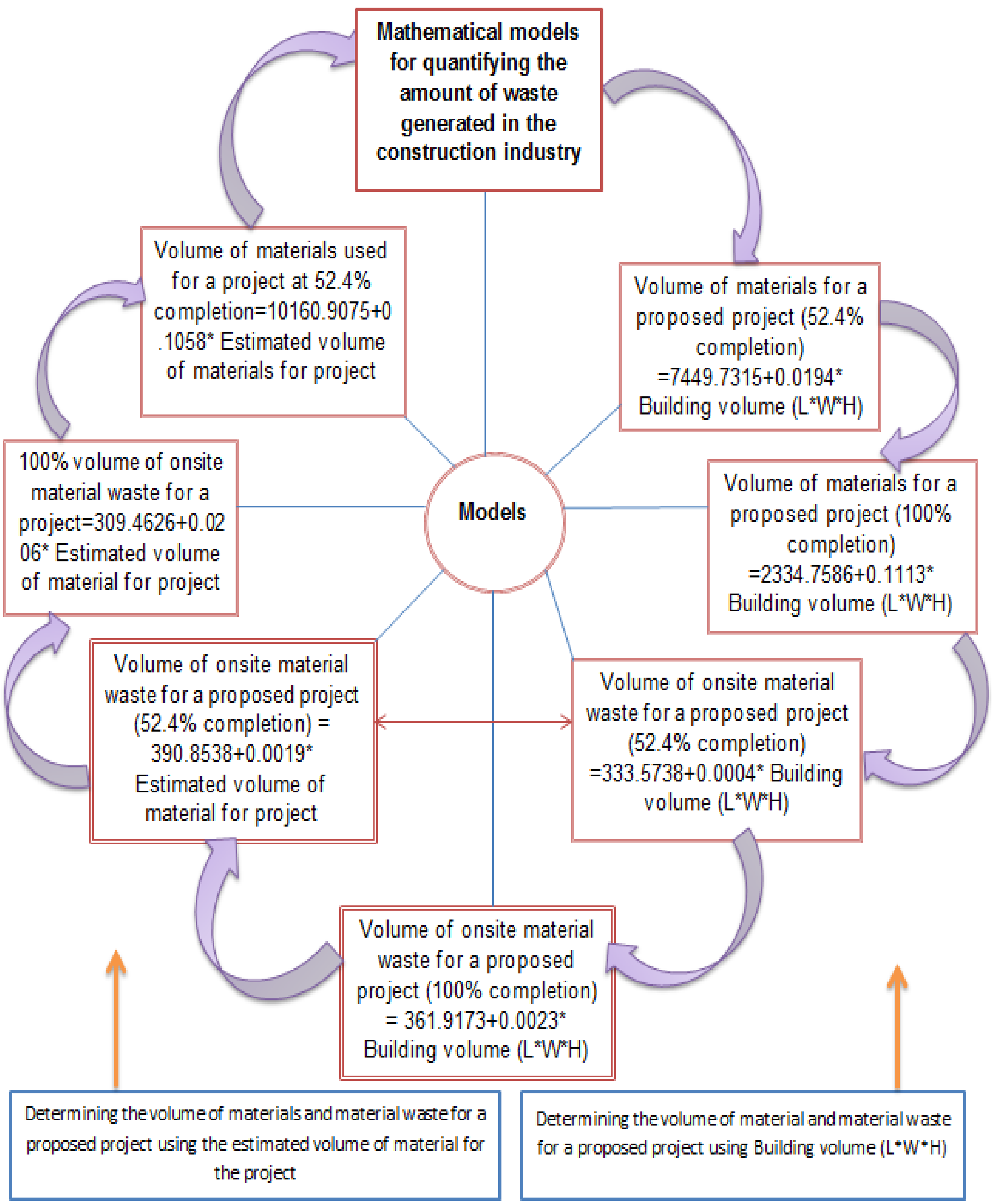


Figure 6.7: Summary of mathematical models for quantifying the amount of material waste on construction site

Source: Researcher's construct, 2015.

6.14 Concluding Remarks

This chapter summarised and discussed the findings of the research in relation to all the research problems (section 1.3), sub-problems (section 1.4) and objectives (section 1.6) of the study. The chapter also discussed the mathematical models for the quantification of material waste in the Nigerian construction industry.

The next chapter presents summary of the research, conclusions, contributions to the body of knowledge and recommendations.

Chapter 7: Summary, Conclusions, and Recommendations

7.1 Introduction

This chapter presents a summary of the research processes, the research findings with respect to the study objectives, the recommendations to the construction stakeholders, and discusses the contributions of the research to knowledge. The chapter also highlights the limitations of the study, and offers suggestions on areas for further research.

7.2 Summary of the Research

Wastage of construction materials has become a serious problem requiring urgent attention in the Nigerian construction industry. Despite the studies that have highlighted the future benefits of reducing construction waste, there has been little progress in implementing the waste management options available to ensure that construction waste is minimised. This is, however, attributed to poor understanding among the Nigerian construction professionals of the causes and sources of material waste generation at various stages of a project (Dania, Kehinde and Bala, 2007:121).

Cost overrun is a problem, which affects 90 percent of the completed projects in the world. The argument on how to eliminate cost overruns has been on-going for the past 70 years. Therefore, studies from different parts of the world have shown that construction material waste represents a relatively large percentage of the production cost. Consequently, as a result of low level of awareness, the Nigerian construction industry pays little attention to the effects of generated material waste on cost overruns.
Thus, this research aimed to investigate the relationship and contributions of material waste to project cost overruns.

7.2.1 Research problem, and sub-problems

As a result of low level of awareness, the Nigerian construction industry pays little attention to the effects of generated material waste on cost overruns.

From the above stated problem, the following sub-problems were formulated:

- S-p $_1$: There is poor understanding of the sources, causes and control measures for construction material waste generation at the pre-contract and post-contract stages of a project (Dania, Kehinde and Bala, 2007: 121; Begum *et al.,* 2007: 191; Wahab and Lawal, 2011: 247)
- S-p $_2$: There is little understanding of the effects of material waste generated from S-p $_1$ on project cost overruns (Ameh and Itodo, 2013: 748)
- S-p $_3$: There is little experience of the benefits of recovering construction-waste material (re-use and recycling) and its effects on cost overruns (Begum *et al.,* 2006: 88)
- S-p $_4$: There is little understanding of the percentage of additional cost contributed by material wastage to construction-cost overruns.
- S-p $_5$: Data on the quantities of material waste have not been well documented (Yuan and Shen, 2011: 670; Babatunde, 2012: 328).

7.2.2 Research aim, objectives, and hypotheses

The aim of the research was to investigate the relationship between material wastage and construction-cost overruns. To achieve the aim, the following objectives were formulated:

- Identify the sources, causes and control measures for construction material waste generation at the pre-contract and at the post-contract stages of a project
- Examine the effects of the material waste generated from Objective 1 above on project-cost overruns.
- Examine the benefits of recovering construction-waste materials (re-use and recycling) and their effects on cost overruns.
- Investigate the percentage of additional cost contributed by material wastage to project-cost overruns.
- Develop a statistical model for quantifying the amount of material waste generated in the Nigerian construction industry.

In order to address the sub-problems listed in section 7.2.1, the following hypotheses were developed to provide necessary explanations:

- Hypothesis H_1: Knowledge of the sources, causes and control measures of construction-waste generation at the pre-contract and post-contract stages of a project is sub-optimal.
- Hypothesis H_2: Knowledge of the effects of waste generated on construction-cost overruns is minimal.
- Hypothesis H_3: Experience with the benefits of recovering construction-waste material (re-use and recycling) is sub-optimal.
- Hypothesis H_4: Knowledge of the additional cost contributed by material wastage is minimal.
- Hypothesis H_5: Statistics on the waste generated are minimal.
- Hypothesis H_{i6}: There is a statistically significant difference between the views of various professionals on the effects of material waste sources, causes, control measure, as well as the benefits of material waste recovery systems on project-cost overruns.
- Hypothesis H_{o6}: There is no statistically significant difference between the views of professionals on the effects of material waste sources, causes, control measure, as well as the benefits of material waste recovery systems on project-cost overruns.

7.2.2 Relationship between material waste and cost overruns

The review of the related literature revealed that, at the pre-contract stage of a project, the causes of cost overruns also cause material waste. This means that all the causes of material waste also cause the anticipated cost overruns at the pre-contract stage of a project. But only 96.88 percent of the causes of cost overrun cause material waste at the pre-contract stage. The remaining 3.12 percent are not related. This implies that managing material waste at this stage denotes managing 96.88 percent of cost overruns.

Furthermore, the relationship between the causes of cost overruns and material waste at the post-contract stage of a project shows that, out of the causes of cost overruns considered, 81.81 percent also cause material waste, showing an 81.81 percent relationship at the post-contract stage of a project.

Consequently, at the post-contract stage of a project, all the material waste causes are also responsible for cost overruns. But on the other hand, when causes of cost overruns were considered, there was an 81.81 percent relationship with the causes of material waste. The remaining 18.19 percent are not related. This implies that, managing material waste at this stage denotes managing 81.81 percent of cost overruns.

In conclusion, there was an 86.74 percent relationship between material waste and cost overruns at both the pre-contract and the post-contract stages of a project.

7.2.3 Theoretical and conceptual framework

The literature review provided the required understanding of the theory surrounding material waste management and cost overruns in the construction industry. Based on the concepts that emanated from the theoretical framework of effective material waste management, which was central to the study, a conceptual framework was created to guide the method of research for the management of material waste and cost overruns in the Nigerian construction industry. The conceptual framework was also utilised in the development of a mathematical equation for managing material waste and cost overruns in the construction industry.

7.2.4 Research methodology and techniques

The appraisal of the problems identified in chapter one of this research pointed to a mixed method (quantitative and qualitative) approach as the most appropriate method for the study. Therefore, a positivist approach utilising the mixed method was adopted in this study to collect data, treat problems and test hypotheses.

In line with the positivist approach adopted for this study, a semi-structured but an in-depth interview was designed in connection with a tick box of questions marked/ticked by the researcher in the course of the interviews. The interviews, the tick box of questions, the field investigation of on-site material waste, and archival records were the instruments through which the primary data for this research were collected.

The respondents in this study were selected based on a purposive sampling decision, which was adopted to select the construction projects within the range of one-hundred million rand (R100M)/ 1.6 billion Naira, and above.

The research problem, sub-problems, and hypotheses formulated in section 1.3, 1.4 and 1.5 were achieved by the findings that originate from the analysed data.

7.2.5 Summary of major research findings

This section presents the summary of the major findings of the research.

7.2.5.1 Identify the sources, causes and control measures for construction material waste generation at the pre-contract and post-contract stages of a project

This objective was achieved from the review of related literature. The identified material waste sources and causes presented in sections 2 and 3, as well as control measures at stages of a project were used in determining the next objective.

7.2.5.2 Examine the effects of material waste sources, causes, and control measures on project-cost overruns at the pre-contract and post-contract stages of a project

The findings of this objective are summarised and presented in two stages of a project namely: the pre-contract and the post-contact stage.

- ***Pre-contract stage of project:***

This section presents the summary of the research findings at the pre-contract stage of a project.

1. Quality of planning

i. Effects of material waste sources and causes on project-cost overruns

The material waste sources and causes that have 'very high effects' on project-cost overruns at the planning stage of a project were: (i) inadequate site investigation; (ii) poor communication flow among members; (iii) inadequate waste management unit; and (iv) lack of regular site meetings at the planning stage.

However, the material waste causes that have very little effects on cost overruns were: (1) improper plan for the establishment of a quality-control unit; (2) improper programme of work; and (3) improper planning and understanding of the method statement.

ii. Effects of material waste control measures on project-cost overruns

The material waste control measures that have very high effects in controlling cost overrun at the planning stage of a project were: (i) plan for early sub-soil investigations; and (ii) proper co-ordination and communication among members at planning stage. The material waste control measures that have high effects on cost overruns were: (a) establishment of a good waste management unit; (b) regular site meetings; (c) setting a target for material waste reduction; and (d) engaging experienced personnel in planning.

On the other hand, the material waste control measures that have very little effect on cost overruns were: (1) proper insurance of work; (2) plan for inclusion of waste management in bidding and tendering process; and (3) re-improving process (learning from previous mistakes).

2. Quality of design management

i. Effects of material waste sources and causes on project-cost overruns (Quality of design management)

The material waste causes that have 'very high effects' on project-cost overruns at the quality of design management stage were: (i) error in design and detailing; (ii) lack of design information; (iii) design complexity/complication; and (iv) inexperienced designer or design team.

The material waste sources and causes that have very little effect on cost overruns were: (a) designing dead spaces; (b) poor knowledge of the changing design requirements; and (c) aesthetic considerations.

ii. Effects of material waste control measures on project cost-overrun (Quality of design management)

The material waste control measures that have very high effects in controlling cost overruns with respect to quality of design management of a project were (i) explicit detailing in design; (ii) interpretable designs and specifications; (iii) engaging experienced designer; (iv) error-free design; and (v) proper design information and consultation.

The material waste control measures that have very little effect in controlling cost overruns at the quality of design management were: (a) design for materials optimization; (b) design for off-site construction; and (c) improving on previous design mistakes.

3. Design Complexity

i. Effects of material waste sources and causes on project-cost overruns (Design complexity)

The material waste sources and causes that have ‘very high effects’ on project cost-overrun at this stage were: (i) inexperienced designer; and (ii) difficulties in interpreting specifications.

The causes with high effect were: (a) designing unstandardised dimensions allowing for cutting and chiseling; (b) designing uneconomical shapes and outlines; and (c) inadequate design information.

The material waste sources and causes that have very little effect on cost overruns with respect to design complexity were: (a) lack of prioritizing re-use in designs and specifications; (b) poor monitoring of design process; and (c) improper planning for waste management.

ii. Effects of material waste control measures on project cost overrun (Design complexity)

The material waste control measures that have very high effects on cost overruns with respect to design complexity in a project were: (i) engaging experienced designer; (ii) designing readable dimensions and specifications; and (iii) standardizing designs and units.

The causes that have very little effects on cost overruns in this category were: (a) proper monitoring and supervision of work; (b) improving on previous design mistakes/errors; and (iii) use of specialised technology and consultants.

4. Quality of estimating

i. Effects of material waste sources and causes on project-cost overruns (Quality of estimating)

The material waste sources and causes that have ‘very high effects’ on project-cost overrun with respect to quality of estimating were: (i) inaccurate quantity take-off; (ii) insufficient time for estimate; and (iii) lack of detailed (readable and interpretable) drawings and specifications for estimating.

Furthermore, (1) inadequate project risks evaluation, analysis, and estimation; and (2) inadequate knowledge of site conditions, have high effects on cost overruns at the quality of estimating stage of a project.

However, the material waste causes that have very little effect on cost overruns with respect to quality of estimating were: (a) improper monitoring and improvement on previous mistakes; (b) a design requiring frequent change; and (c) late engagement of estimators.

ii. Effects of material waste control measures on project-cost overruns (Quality of estimating)

The material waste control measures that have very high effects in controlling cost overruns with respect to quality of estimating of a project were: (i) sufficient time for estimate; (ii) accurate quantity take-off; (iii) engaging experienced estimator; and (iv) availability of detailed drawings, dimensions, and specifications.

Nonetheless, the material waste control measures that have high effects in controlling cost overruns were: (a) monitoring and improving on previous estimating mistakes; and (b) thorough design check and estimate.

- **Post-contract stage of project:**

This section presents the summary of the research findings at the post-contract stage of a project.

5. Quality of Procurement Management

i. Effects of material waste sources and causes on project cost-overrun (Quality of Procurement management)

The material waste sources and causes that have very high effects on project-cost overruns with respect to quality of procurement management were: (i) procuring items not in compliance with specification; and (ii) engaging inexperienced personnel in estimation and procurement.

Moreover, the material waste causes that have high effects on cost overruns were: (1) procuring wrong quantity of materials at the wrong time; and (2) delivery of substandard materials. However, (a) errors in shipping; (b) damage of material during transportation; (c) market conditions; and (d) lack of awareness; were considered to have a very little effect on cost overruns.

ii. Effects of material waste control measures on project-cost overruns (Quality of procurement management)

The material waste control measures that have very high effects in controlling cost overruns with respect to quality of procurement management of a project were: (i) procuring in accordance with specification; and (ii) experienced personnel in estimation and procurement. Therefore, procuring the right quantity of materials at the right time was considered to have high effect in controlling cost overruns.

However, the material waste control measures that have very little effect on cost overruns with respect to quality of procurement management were: (a) better delivery of materials on site; (b) adopting good materials abstracting; and (c) provision of easy access road for delivery vehicles; and (d) knowledge of product to be manufactured.

6. Quality of construction management

i. Effects of material waste sources and causes on project cost-overrun (Quality of construction management)

The material waste sources and causes that have ‘very high effects’ on project-cost overruns with respect to quality of construction management of a project were: (i) engaging incompetent workers; and (ii) rework (contractors’ source). Consequently, (a) incorrect scheduling and planning (contractors’ source); (b) shortage of skilled workers (workers’ source); (c) lack of experience; and (d) poor financial controls on site; were considered to have high effect on cost overrun.

However, the material waste causes and sources that have ‘very little effects’ on cost-overruns with respect to quality of construction management were: (1) poor staff workers relationship; (2) lack of awareness on waste management; (3) lack of incentive; and (4) use of unskilled labour to replace skilled ones.

ii. Effects of material waste control measures on project-cost overruns (Quality of construction management)

The material waste control measures that have high effects in controlling cost overruns with respect to quality of construction management of a project were: (i) proper scheduling and planning; and (ii) engaging competent workers. The moderate effects measures were: (a) better storage facilities and environment/area; (b) staff vocational training and development; (c) establishing systems of rewards and punishments for material saving; (d) improving contractors’ onsite construction management; (e) adequate site control supervision; and (f) ensuring the achievement of good quality workmanship on site.

On the other hand, control measures such as: (1) process improvement techniques/improving on previous mistakes; (2) improved material handling method; (3) error-free construction process; (4) proper management support for workers; (5) holding regular site meetings; were considered to have very little effect' in controlling cost overrun with respect to quality of construction management.

7. Quality of site management

i. Effects of material waste sources and causes on project-cost overruns (Quality of site management)

The material waste sources and causes that have 'very high effects' on project-cost overruns with respect to quality of site management were: (i) rework; (ii) site accident (iii) inadequate site security/fencing; (iv) poor site organisation and discipline; and (v) construction site dispute. However, (a) lack of experience; (b) poor construction planning and control; (c) theft; and (d) lack of co-ordination among parties were deemed to have high effects on cost overruns.

The material waste sources and causes that have 'very little effects' on cost overruns were: (1) difficulties in accessing construction sites; (2) long storage distance from application point; (3) late delivery of materials; and (4) late information flow among members.

ii. Effects of material waste control measures on project-cost overruns (Quality of site management)

The material waste control measures that have 'high effects' in controlling cost overruns with respect to quality of site management of a project were: (i) tight security on site; (ii) adequate site organisation and discipline; (iii) on-site and off-site re-use of waste material; (iv) waste management throughout the entire lifecycle of a project; (v) use of experienced personnel; (vi) promotion of construction waste reuse on site; (vii) adequate site planning and control; and (v) proper administration of 5Ms on site.

The material waste control measures that have ‘very little effect’ in controlling cost overruns were: (a) issuing procedures for managing hazardous waste; (b) reducing off-cut of materials and reuse; and (d) implementation of onsite material waste sorting.

7.2.5.3 Examine the benefits of recovering construction waste materials (re-use and recycling) and their effects on cost overruns

This section presents the summary of the benefits of recovering construction waste materials and their effects on cost overruns.

i. The economic benefits of recovering material waste and their effects on cost overruns

The economic benefits of material waste recovery systems that have ‘very high effect’ on cost overruns were: (i) profit making on salvaged materials; (ii) project-cost savings through avoided disposal costs; (iii) reducing project cost overruns; and (iv) saving cost on new materials.

Furthermore the economic benefits that have ‘high effects’ in controlling cost overruns were: (a) reducing disposal costs; (b) reducing demand for new materials; and (c) realizing value from recovered materials. However, (1) conserving resources by diversion from landfill; and (2) reducing energy costs; were deemed to have little effects on cost overruns.

ii. The environmental benefits of recovering material waste and their effects on project cost overruns

The only environmental benefit of material waste recovery systems that has high effect on cost overruns was that, the materials which could be lost to landfill are re-used. The profit goes back to the project; no transportation cost, disposal cost as well as environment cost is sustained.

Moreover, the environmental benefits that have ‘moderate effects’ on cost overruns were: (i) reducing environmental pollution; and (ii) preserving space in existing landfills and environmental conservation. However, (a) curtailing the negative environmental impact; and (b) minimising environmental impact such contamination of ground water; were deemed to have very little effect on cost overruns.

iii. The social benefits of recovering-material waste and their effects on cost overruns

The social benefits of material waste recovery system that have 'very high effects' on cost overruns were: (i) waste materials are sold to developers of smaller-sized projects. Moreover, (a) waste is used as a benefit to community by helping in disposal, which reduces disposal costs; (b) timber formwork is used as firewood by the local community; were considered to have high effects on cost overruns.

The social benefits of material waste recovery that have 'very little effect' on cost overruns were: (1) creation of job opportunity; (2) compliance with state and local regulations; and (3) raising the public image of a company**.**

iv. The benefits of re-use of material waste, and their effects on cost overruns

The benefits of material waste re-use that have high effect on cost overruns were: (i) re-use is the most profitable means of recovery for contractor (ii) re-use does not require hauling and transportation; (a) re-use does not require energy (b) re-use does not require reprocessing; were deemed to have moderate effects on cost overruns.

7.2.5.4 Investigate the percentage of additional cost contributed by material wastage to project-cost overruns

The results of correlation analysis between the generated volume of on-site material waste and the amounts of cost overruns revealed a statistically significant relationship; implying that, increase in the volume of on-site material waste leads to a corresponding increase in the amount of project-cost overruns.

Furthermore, the descriptive analysis also revealed a significant contribution of material waste to project-cost overruns ranging from a minimum ₦31,220,528.06 (1.96 percent), to a maximum of ₦39,933,360.29 (8.01 percent), with an average contribution of approximately four (4) percent to project-cost overruns.

This implies that the average percentage contribution of material waste to project cost-overrun was four (4) percent.

7.2.5.5 Develop a mathematical model for quantifying the amount of material waste generated in the Nigerian construction industry

The empirical findings from the study (regression analyses) provided the parameters for developing mathematical models for quantifying the amount of materials and material waste generated in the construction industry (see section 5.12).

7.3 Conclusion

Both the literature and the empirical findings from the study have established that a relationship exists between material waste and cost overruns at the pre-contract and post-contract stages of a project. This implies that an increase in material wastage on site leads to an appreciable increase in cost overruns, regardless of the percentage allowed for material waste in the process of bill preparation.

The study concludes from the literature that 100 percent of the causes of material waste also cause cost overruns at the pre-contract and the post-contract stages of a project, while 96.88 percent and 81.81 percent of the causes of cost overruns cause material waste at the pre-contract and at the post-contract stages respectively (see Figure 2.9)

It is also concluded from the empirical analysis that the significant percentage contribution of material waste to project cost overrun ranges from 1.96 percent to 8.01 percent, with an average contribution of four (4) percent.

Therefore, the average percentage contribution of material waste to cost overrun for a project is four (4) percent, which is different from the percentage allowed for material waste in the process of preparation of a bill of quantities.

The study also concludes that material waste sources, causes, and control measures were found to have a significant effect (very high, high, medium, low, and very low) in causing/controlling cost overruns at both pre-contract (quality of planning, quality design management, design complexity, and quality of estimating) and at the post- contract (quality of procurement management, quality of construction management, and quality of site management) of a project.

The study also concludes that there is no significant difference in the perception of the respondents on the effects of material waste causes, sources and control measures on project cost overruns at both the pre-contract and the post-contract stages of a project.

It is concluded that profit-making on salvaged materials; project-cost saving through avoided disposal costs; and cost savings on new materials are the major economic benefits of a material-waste recovery system that have a very high effect on cost overrun. The social benefit of a material-waste recovery system that has a very high effect on cost overruns is that “waste materials are sold to developers of small-sized projects”. The social benefits of material waste-recovery are: “waste is used as a benefit to communities by helping in the disposal thereof”; and “timber formwork is used as firewood by the local community”. The major environmental benefits of material-waste recovery is the “re-use of materials which could be lost to landfills.”

7.4 The Research’s Contribution to Knowledge

The research has contributed to the body of knowledge in the area of construction-material waste and cost overruns considering that, as a result of low levels of awareness, the Nigerian construction industry pays little attention to the effects of generated material waste on cost overruns. In this regard, the following contributions are suggested:

1. The research has developed a clear theoretical understanding of the concept of effective construction waste management and its relationship with cost overrun in the construction industry (see Figure 3.6, page 100).
2. The research has increased the understanding of construction-material waste planning and design, estimating and purchasing, operational, storage, and transporting and delivery at the pre-contract and the post-contract stages of a project (referring to Figure 2.10, page 77).

3. The research has also increased the understanding of construction-material waste planning and design, estimating and purchasing, operational, storage and transporting and delivery and their effects on project cost overruns.
4. The research has increased the understanding of the social, environmental, and economic benefits of recovering construction-material waste and its effects on cost overruns in the construction industry.
5. The research has developed a bespoke methodology for investigating the relationship between material waste and construction-cost overruns in the Nigerian construction industry.
6. The research has provided a detailed understanding of the mathematical relationship between material waste and cost overruns (see Table 5.32, page 234).
7. The research has developed a mathematical equation for managing material waste and cost overruns in the construction industry (see page 107).
8. The research has developed the predictive mathematical models for quantifying the volume of construction materials and material waste in the Nigerian construction industry (see Figure 6.7, page 272).

7.5 Limitations of the Research

The researcher was denied access to some construction projects within the study area, despite the assurance of anonymity and confidentiality. It was explained to him that access to all information in their organisation is confidential; and thus, research students are not allowed in. In some cases, where access was allowed, tracking the targeted respondent for the interviews and other related information were major challenges for the study.

7.6 Critical Evaluation of the Research Approach

Given the philosophical underpinnings of this research, the approach adopted was both qualitative and quantitative or mixed method. The principal means of data collection was reviews, interviews, tick-box questionnaires, archival records (drawings, bills of quantities, project progress reports, and specifications), and field investigation of onsite volume of material waste. The purpose of the tick-box questionnaires was to corroborate the information provided in the literature as well as provide the quantitative data for hypotheses testing. The qualitative approach enabled the researcher to acquire a better understanding of the experiences and perceptions of respondents in the study area regarding the issues leading to material waste and cost overrun in the Nigerian construction industry.

The study covered building construction projects within Abuja, the Federal Capital Territory of Nigeria. The sampling strategy adopted was the purposive sampling (33 projects with a value of ₦1.6 billion/R100 million and above). The need for informative subjects who can contribute and expand the phenomenon under investigation, as well as the need for building construction projects that are likely to generate large quantities of material waste and huge amount of cost overruns informed the choice of purposive sampling. This approach helped to capture the views of the various professionals involved in the investigation. The use of mixed method provided clarity and further enhanced the validity of the research.

The researcher made a statistical presentation of data in form of graphs, tables, and figures and then presented a narrative interpretation of the findings.

The limitation of the research was discussed in section 7.5. However, there is need for a brief recapitulation of the limitations in this section.

The geographical area of this research is Abuja, Nigeria; more representation could have been obtained if other geographical areas of Nigeria had been included. Nevertheless, the uniqueness of this area, as discussed in section 1.8 of this study minimised the influence of the limited scope on the reliability of the study findings.

Another limitation relates to the nature of the topic and the tactical responses. Obtaining honest responses on the issues relating to material waste and cost overrun was not easy. This is because some respondents may not provide the researcher with the true reflection of events, due to their lack of understanding. To minimise this influence, indirect questioning was adopted during the interviews.

The last limitation is of the external validity: What if the research findings/results could be generalised to other construction projects? The interviews were conducted with the experienced professionals of the Nigerian construction industry; although it is not through a random sample. However, the adoption of a mixed method involving both quantitative and qualitative data, as well as contacting the experienced professionals addresses the issue of generalisability in the research.

7.7 Recommendations

Based on the findings and conclusions of this study, the following recommendations are made as effective means of managing material waste and cost overruns in the Nigerian construction industry.

7.7.1 Recommendations for the Nigerian Government

- The management of material waste and cost overruns should be revised, based on the findings of this research and included, as part of the procurement process. This would enable the design and construction teams to investigate or evaluate the extent to which completed buildings comply with the required cost savings and waste-management objectives.
- The federal government should create an enabling environment, by formulating a policy that would encourage the existence of a recycling market, in order to reduce the demand for new materials, reduce cost overruns and the burden on the existing landfills.
- The federal government should formulate a regulation mandating all construction project stakeholders to attend a compulsory workshop on the issues leading to material waste and cost overruns, as well as their management principles.
- The Federal Government of Nigeria should produce realistic policies that would encourage material-waste management and project cost overruns, such as:
  i. Revise the landfill charges to improve environmental sustainability;
  ii. Encourage material waste re-use and recycling;

iii. Develop funding and collaboration opportunities to support research and development in the field of material-waste management and cost overruns; and

iv. Explore options for improving the awareness of the benefits of material-waste management and cost overruns in the broader construction industry.

7.7.2 Recommendations for the Nigerian construction industry

- The Nigerian construction industry should diversify its awareness by establishing a special link with their foreign counterparts in creating the best ways of handling waste management and cost overruns internationally.
- Engage in an inter-industry seminar relationship on the issues relating to material waste, cost overruns, as well as their management.
- Establish a workable waste-management unit; the engagement of competent employees; and the provision of sufficient tools and equipment for the department;
- In order to minimise material waste and costs overruns, it is important that careful consideration be given to issues in the preliminary project stages, such as site and environmental conditions, design specifications and methods of construction;
- The mathematical model for the quantification of onsite-material waste and the mathematical equation for managing material waste and cost overruns developed in the study are recommended to the Nigerian construction industry. This should enable the construction professionals to have some idea of what amount of waste is generated, and to evaluate the extent to which it could be minimised, in order to meet the required waste-management and cost overruns objectives.

7.7.3 Recommendations for construction stakeholders/professionals

- Construction professionals should be well informed of the consequences of material waste contributions to project cost overrun at an early stage of a project, in order to enable them (professionals) to evaluate the extent to which these consequences could be minimised.

- There should be continuous professional training programmes for employees to update their technical knowledge on the issues relating to material waste and cost overruns, as well as the possible ways of managing their detrimental effects on projects.
- Contractors, clients and consultants should work as a team, and hold appropriate meetings on a regular basis, to ensure that the issues leading to material waste and cost overruns are adequately addressed.
- Construction professionals should be informed on the benefits of recovering material waste and their effects in minimising cost overruns.
- In order to minimise material waste that may lead to cost overruns, project clients must ensure:
    i. Early engagement of experienced professionals to curtail the problems leading to material waste and cost overruns;
    ii. Pre-construction information (project brief) is well-communicated and work with the design team, in order to reduce the problems of design change, variation, rework, and cost overruns.
- Sufficient time should be allowed for project estimators to engage in project-risk evaluation and analysis; conduct market surveys/analysis, or market intelligence to have some idea of the current prices of materials; and to prepare accurate bills of quantities. This should reduce the risk of assumptions that might contribute to waste generation and cost overruns.
- Project designers should ensure that the primary source of estimation (drawings, dimensions, and specifications) is well detailed; and that material sizes and units are standardised, in order to reduce the rate of material cutting and chiselling.
- In order to properly manage material waste and cost overruns, project managers and contractors must ensure:

i. Plant and equipment are properly positioned to avoid accidents;

ii. Site organisation and discipline, adequate site security, and better storage facilities are enforced;

iii. Procuring materials, in accordance with the specifications, and the engagement of experienced personnel in procurement and estimation.

7.8 Recommendations for Further Research

- Further research should be conducted to investigate the relationship between construction waste and time overruns in the construction industry.
- Evaluate the percentage contributions of material waste-recovery systems (re-use and recycling) in minimising cost overruns.
- A research project should be conducted to develop a mathematical model for predicting the amount of cost overruns for projects.
- This research has largely focused on construction projects within Abuja, Nigeria. Consequently, there is a need for research into the application of the concept in other parts of the country, in order to increase the generalisability of the findings.

7.9 Caution

The recommendations in this study should be adopted with caution; as the findings at this stage are only hypotheses based on a small sample frame. The identified percentage contribution of material waste to project cost overruns, as well as the developed mathematical models, were based on 52.4 percent project completions.

7.10 Concluding Remarks

This chapter has presented the summary, conclusions, and recommendations for this research. The next section looks at the references used in the research, as well as the appendices.

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9.0 Appendix A: Survey Instrument

Nelson Mandela Metropolitan University

for tomorrow

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01st December, 2014

Dear Respondent,

PhD Research Thesis: Mr. SAIDU, Ibrahim

I wish to confirm that the bearer of this letter Mr. SAIDU, Ibrahim is a bonafide PhD candidate in the Department of Construction Management within the School of the Built Environment at the Nelson Mandela Metropolitan University in Port Elizabeth, South Africa. His thesis project is titled: ***"Management of Material Waste and Cost Overrun in the Nigerian Construction Industry".***

Mr. SAIDU is now conducting field studies and requires input from the Nigerian construction industry/organizations. The purpose of this letter is to request you to provide Mr. SAIDU, Ibrahim with any possible assistance by providing necessary information including the granting of interview (s).

Thank you for the opportunity to introduce Mr. SAIDU. Should you require any further information, please do not hesitate to contact me on the details provided below.
Yours sincerely,

Winston M.W. Shakantu
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Professor of Construction Management (Materials and Methods)
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AN INTERVIEW GUIDE

On
"Management of Material waste and cost overrun in the Nigerian Construction industry"

Preliminary questions
Name of the person being interviewed____
Position____
Name of the Firm/Organization____
Name of the project____
Project location ____
Project value (₦) ____
Years of experience in the industry: ____
Highest educational qualification ____
Please describe your role in the organization

SECTION ONE: PRE CONTRACT STAGE OF PROJECT

1.0 Quality of Planning

1.1 Describe the components & quality of construction planning and waste management at the pre contract stage of a project in your organization?
1.2 How does your firm/organization plan for material waste and cost overrun?
1.3 In your own opinion, is there any relationship between "quality of planning" and "material waste generation" on site? What about cost overrun?
1.4 What strategies does your firm use to improve "quality of planning" to minimize material wastage and cost overrun for a project?

2.0 Quality of Design Management

2.1 Describe the constituents of and the quality of design on your project?
2.2 Is there any relationship between quality of design management and material waste generation?
2.3 Does the quality of design affect project cost overrun? Please elaborate?
2.4 Does the quality of design management contribute to design complexity?
2.5 How can design minimize material waste generation on site and cost overrun?

3.0 Design Complexity

3.1 Define, design complexity
3.2 Does complexity in design contribute to onsite material waste generation?
3.3 What about cost overrun?
3.4 Is there a relationship between design complexity and the occurrence of variations in a project?
3.5 Does design complexity contribute to materials waste generation and cost overrun?

3.6 What are the strategies put in place by your organization/ industry in controlling material waste that may arise as a result of design complexity?

4.0 Quality of Estimating

4.1 Does the quality of estimating contribute to material waste generation on construction sites?
4.2 Does quantity take-off/cost estimating contribute to waste generation and cost overrun?
4.3 Does estimating or allowance for waste have anything to do with material waste generation and cost overrun?
4.4 To what degree would you consider 'insufficient time for estimate' to be a factor that contributes to material waste and cost overrun?
4.5 What is your suggestion as to the best strategies in achieving best quality of estimating for a project?

SECTION TWO: POST CONTRACT STAGE OF PROJECT

5.0 Quality of Procurement Management

5.1 Can you tell me about the quality of procurement management in your organization/industry?
5.2 Does the quality of procurement management contribute to material wastage? What about cost overrun?
5.3 How would you describe procuring or allowances for waste with respect to material waste and cost overrun?
5.4 How would you relate the procurement of materials to material waste generation and cost overrun?
5.5 What strategies does your firm use in minimizing material waste through procurement for a project?

6.0 Quality of Construction Management

6.1 Based on your experience, what is the quality of construction management?
6.2 How can you relate the quality of your firm/organization's construction management to material waste generation and cost overrun?
6.3 Do sub-contractors and suppliers in any way have an effect on the material waste generation and cost overrun?
6.4 Does rework have any impact on the material waste generation and cost overrun? What about Mistakes/errors?
6.5 What are the strategies required to achieve the best quality construction management?

7.0 Quality of Site Management

7.1 Define site management?
7.2 How does site management contribute to material waste and cost overrun?
7.3 How do the site security, site accident and site dispute affect material waste generation and cost overrun?
7.4 How can a quality site management be achieved?
7.5 Would quality site management affect material waste generation and cost overrun?

8.0 Material Waste Minimization/Management

8.1 Can you tell me about material waste recovery system (reuse and recycling) in your firm/organization?
8.2 Does material waste recovery system (reuse and recycling) have any influence on the material waste generation and project cost overrun?
8.3 What are the economic, social and environmental benefits of recovering (reuse and recycling) material waste?
8.4 Do these benefits have effects on cost overrun?
8.5 What available training does your organization/industry have in educating its employees on how to minimize material waste and cost overrun?

……………………………………………………………………………………………...

Do you have any general comment on how to minimize material waste and cost overrun in a construction project?

……………………………………………………………………………………………...

The interview guide above was for objectives 1, 2 & 3

Objective 4 & 5:

Investigate the effect of additional cost contributed by material wastage to project cost-overrun

Develop a statistical model for quantifying the amount of material waste generated in the Nigeria's construction industry.

The required details for objective 4 & 5 are captured in the table below (Project details required)

PROJECT DETAILS REQUIRED

SN	Estimated Project Cost (EC)	Estimated Project Time (ET)	Cost Now (CN)	Time Now (TN)	% of work Completed	Estimated Cost of work Completed (₦)	Actual Cost of work Completed (Cost Now) (₦)	Building Volume (L x W x H) (M3)	Estimated volume of materials for Project (M3)	Volume of material used (M3)	Volume of material waste recorded (M^3)
1											
2											
3											
4											
5											

10.0 Appendix B: Collected Data

Data on project information

P/N	Name of Company/ Firm	Name of Project	Estimated Cost of Project (EC) (₦)	% of work Completed	Estimated Cost of work Completed (₦)	Actual Cost of work Completed (Cost Now) (₦)	Cost Overrun (₦)	Estimated Time for the Project (Month)	Time Now (Month)	Building Volume (L x W x H) (M^3)	Estimated volume of materials for Project (M^3)	Volume of material used(M^3)	Volume of waste recorded (M^3)	100% Volume of waste
1	**Blank columns for the purpose of anonymity**		3, 200, 000, 000.00	17%	544, 000, 000. 00	800, 000, 000. 00	256, 000, 000. 00	24	11	26, 262. 94	8, 925	1,517.25	65.24	383.7647059
2			14, 000, 000, 000. 00	47%	6, 580, 000, 000.00	8, 540, 000, 000.00	1, 960, 000, 000.00	24	15	186, 860.00	35, 503. 40	16, 686.60	634.09	1349.12766
3			1, 650, 000, 000.00	59%	973, 500, 000.00	1, 155, 000, 000.00	181, 500, 000. 00	20	36	17, 486.60	5,126. 84	3, 024. 84	124.02	210.2033898
4			6, 000, 000, 000.00	35%	2, 100, 000, 000. 00	2, 400, 000, 000.00	300, 000, 000.00	24	12	56, 532. 00	10, 741. 08	3,759. 38	155.49	444.2571429
5			5, 880, 000, 000.00	43%	2, 528, 400, 000.00	3, 609, 400, 000.00	1, 081, 000, 000	22.5	54	29, 964. 00	7, 191. 36	3, 092. 29	196.23	456.3488372

6			1, 800, 000, 000.00	63%	1, 134, 000, 000.00	1, 632, 321, 000.00	498, 321, 000.00	16	11	102,320. 00	19, 082.68	12, 022.09	963.40	1529.206349
7			15, 900, 782, 412. 82	30%	4,770, 234, 724. 00	5, 678, 313, 444. 00	908, 078, 720. 00	36	13	635, 737. 20	75, 033.66	22, 510. 10	891. 85	2972.8333
8			7, 300, 000, 000. 00	30%	2, 190, 000, 000. 00	3, 285, 000, 000. 00	1, 095, 000, 000.00	24	32	93, 440. 00	14, 651.39	4, 395.42	128.04	426.8
9			1, 800, 000, 000. 00	68%	1, 224, 000, 000. 00	1, 681, 100, 000.00	457, 100, 000. 00	24	21	18,170. 00	5, 566.77	3, 785.40	232.14	341.3823529
10			6, 000, 000, 000.00	23%	1, 380, 000, 000.00	1, 800, 000, 000. 00	420, 000, 000. 00	24	16	105, 658. 00	14, 010. 25	3, 222. 36	136.34	592.7826087
11			1, 650, 000, 000.00	65%	1, 072, 500, 000. 00	1, 451, 300, 000. 00	378, 800, 000. 00	24	23	130, 311. 60	17, 201.13	11, 180.74	572.45	880.6923077
12			1, 900, 000, 000. 00	25%	475, 000, 000. 00	600, 000, 000	125, 000, 000	18	9	82, 080. 00	13, 953. 60	3, 488. 40	108.14	432.56
13			2, 580, 333, 000. 00	15%	387, 049, 950. 00	580, 574, 925. 00	193, 524, 975	18	7	81, 622. 41	14, 633. 00	2, 194. 95	57.72	384.8
14			40, 000, 000, 000. 00	5%	2, 000, 000, 000. 00	6, 321, 562, 000. 00	4, 321, 562, 000. 00	36	3	5, 181, 480. 00	673, 592.40	33, 679.62	707.27	14145.4
15			20, 940, 557, 219.20	17%	3, 559, 894, 727.00	5, 152, 849, 814	1, 592, 955, 087.00	48	19	102, 550.00	17, 320.70	2,944.51 9	57.71	339.4705882
16			3, 450, 000, 000. 00	23%	793, 500, 000.00	1, 293, 512, 000. 00	500, 012, 000. 00	24	11	26, 223.37	4, 982. 44	1, 145. 96	36.01	156.5652174
17			1, 666, 345, 702. 48	31%	516, 567, 168. 00	833, 732, 165. 00	317, 164, 997.00	18	8	127, 615.319	20, 791.48	6, 445. 36	223.01	719.3870968
18			2, 300, 000, 000. 00	25%	575, 000, 000. 00	805, 000, 000. 00	230, 000, 000. 00	24	10	104, 286. 00	17, 207. 19	4, 301.80	141.96	567.84
19			2, 300, 000, 000. 00	90%	2, 070, 000, 000. 00	2, 185, 000, 000. 00	115, 000, 000. 00	24	21	130, 000. 00	19, 019. 15	17, 117. 24	701.81	779.7888889
20														

			15, 031, 447, 866. 04	11%	1, 653, 459, 265. 00	1, 935, 632, 165. 00	282, 172, 900. 00	40	5	622, 021. 36	67, 385.61	7, 412. 42	158.85	1444.090909
21			1, 880, 000, 000. 00	48%	902, 400, 000. 00	1, 534, 000, 000. 00	631, 600, 000. 00	20	14	148, 500	19, 305. 56	9, 266. 67	398.47	830.1458333
22			1, 686, 920, 734.40	100%	1, 686, 920, 734.40	3, 100, 000, 000. 00	1, 413, 079, 266. 00	17	39	42, 700. 00	9, 522. 10	9, 522. 10	400.88	400.88
23			1, 635, 000, 000. 00	56%	944, 692, 619. 00	1, 265, 323, 555. 00	320, 630, 936.00	24	18	43, 747.20	7, 231.41	4, 049. 59	247.03	441.125
24			1, 800, 000, 000. 00	68%	1, 224, 000, 000. 00	1, 364, 562, 110.00	140, 562, 110.00	26	16	84, 240.00	10, 951.20	7, 446. 82	156.38	229.9705882
25			1, 686, 951, 106. 00	100%	1, 686, 951, 106. 00	2, 700, 000,000. 00	1, 013, 048, 894. 00	24	54	29, 568. 00	5, 322.35	5, 322.35	NR	NR
26			1, 700, 000, 000. 00	60%	1, 020, 000, 000. 00	1, 360, 000, 000. 00	340, 000, 000. 00	68	92	84, 000. 00	15, 414.00	9, 248. 40	322.74	537.9
27			2, 860, 000, 000. 00	88%	2, 516, 800, 000	3, 162, 831, 000. 00	646, 031, 000. 00	24	36	136,000. 00	16, 728. 00	14, 720.64	529.94	602.2045455
28			7, 621, 687, 168. 00	100%	7, 621, 687, 168. 00	15, 184, 000, 000. 00	7, 562, 312, 832. 00	20	54	89, 060.00	15, 585. 50	15, 585. 50	568.87	568.87
29			2, 635, 001, 302. 00	95%	2, 503, 251, 237. 00	2, 985, 333, 000. 00	482, 081, 763. 00	18	21	118, 263. 00	19, 158.61	18, 200. 68	893.65	940.6842105
30			1, 931, 621, 700. 00	98%	1, 892, 989, 266. 00	2, 161, 313, 000. 00	268, 323, 734. 00	24	24	126, 615	16, 459. 95	16, 130. 751	645.23	658.3979592
31			63, 000, 000, 000. 00	90%	56, 000, 000, 000. 00	62, 333, 222, 000	5, 333, 222, 000. 00	60	96	3, 252, 311. 00	211, 914. 50	190, 723. 05	4, 005. 18	4450.2

Result of tick box used by the interviewer in connection with interview guide

SECTION A: SOURCES AND CAUSES OF MATERIAL WASTE GENERATION AND THEIR EFFCTS ON COST OVERRUN AT PRE-CONTRACT STAGE OF A PROJECT

S/no	Sources and causes of material waste related to cost overrun	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Score	Percentage
1	**Quality of Planning**	QS	QS	PM	QS	PM	PM	PM	SE	QS	QS	PM	PM	PM	QS	PM	PM	SE	QS	PM	PM	PM	SE	PM	PM	SE	QS	QS	SE	STO	PM	PM=50% QS=30% ,	SE=16.67%, STO=3.33%
1.1	Improper planning	1	1	1	1	1	1	1			1	1	1	1	1		1	1	1	1		1	1		1	1		1			1	**22**	**73**
1.2	Over estimation to accommodate variations													1							1											**2**	**6.7**
1.3	Lack of legislative enforcement		1	1	1		1		1			1		1			1			1		1			1	1	1	1			1	**15**	**50**
1.4	Inadequate site investigation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
1.5	Inadequate scheduling	1			1		1	1			1						1			1	1	1			1	1		1		1	1	**14**	**47**
1.6	Poor communication flow among members	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**29**	**97**
1.7	Improper coordination of the entire project and professionals	1	1	1			1	1		1	1			1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	**24**	**80**
1.8	Unsatisfactory budget for waste management	1		1		1	1		1	1	1		1		1	1	1		1	1	1	1		1		1	1		1	1	1	**21**	**70**
1.9	Insurance problem	1	1		1			1	1	1		1				1	1	1		1	1	1		1	1	1		1	1	1	1	**20**	**67**
1.10	*Poor plan for material standardization	1		1								1													1							**4**	**13**
1.11	*Inadequate waste management unit	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	**28**	**93**
1.12	*Improper plan for material waste management (reuse, reduce and disposal)		1		1	1	1		1			1		1						1			1		1						1	**11**	**37**
1.13	*Improper program of work			1										1						1												**3**	**10**
1.14	*Improper plan for site organization and layout			1	1			1			1	1	1	1															1			**8**	**27**
1.15	*Lack of regular site meeting	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	**27**	**90**
1.16	*Liaise/ compliance with local authority in case of local laws		1	1		1	1	1	1	1	1		1		1	1		1	1	1	1		1	1		1		1	1	1		**21**	**70**
1.17	*Improper planning and understanding of method statement			1																		1				1					1	**4**	**13**
1.18	*Improper planning of project risks		1			1	1	1		1	1		1		1		1		1	1		1		1		1	1		1			**16**	**53**
1.19	Lack of inclusion of waste management in the bidding process																	1														**1**	**3.3**

1.20	*Improper plan for the establishment of a quality control unit															1	1					1		1							1	**5**	**17**
1.21	*Inexperienced personnel/professionals in planning and waste management					1	1	1	1	1	1	1	1	1	1			1	1	1	1		1	1	1	1	1	1	1	1		**22**	**73**
1.22	*Lack of re-improving process (learning from previous mistakes)					1														1									1			**3**	**10**
1.23	*Poor harmonization of brief										1							1						1	1	1						**5**	**17**
1.24	*Poor knowledge of site conditions										1													1			1					**3**	**10**
1.25	*Cost related problems										1								1					1			1					**4**	**13**
1.26	*improper plan for adequate staff training and development								1			1					1		1			1				1					1	**7**	**23**
1.27	*Poor material estimation													1	1	1					1											**4**	**13**
1.28	*Lack of feasibility and viability studies												1	1	1	1					1								1	1		**7**	**23**
1.29	*Inadequate identification of construction techniques	1																														**1**	**3.3**
1.30	*Plan for adequate site organization	1	1	1	1	1	1	1	1																							**8**	**27**
1.31	*Improper plan for record of material inventory	1																														**1**	**3.3**
1.32	*Improper plan for adequate site exploration	1																														**1**	**3.3**
1.33	*Excess material delivery	1																														**1**	**3.3**
1b	***Client***																																**0**
1.34	Communication error between client and designer	1	1	1		1		1	1	1	1		1	1	1		1		1	1		1	1	1	1	1	1		1		1	**22**	**73**
1.35	Frequent demand for design change	1		1										1		1	1															**5**	**17**
1.36	Lack of awareness				1			1	1																							**3**	**10**
2.0	**Quality of Design management**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
2.1	Frequent design changes and material specification	1	1	1			1	1			1		1	1		1				1		1			1							**12**	**40**
2.2	Error in design and detailing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
2.3	Lack of design information	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**28**	**93**
2.4	Design complexity/complication	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1			**27**	**90**
2.5	Poor communication flow among design team		1	1							1			1												1	1	1			1	**8**	**27**
2.6	Designing dead spaces						1								1										1							**3**	**10**
2.7	Poor knowledge of the changing design requirements								1									1	1									1				**4**	**13**
2.8	Poor management of design process	1		1			1		1	1		1		1				1		1	1		1		1	1	1		1		1	**16**	**53**

29	Inexperience designer or design team	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1		1	1	**27**	**90**
2.10	Interaction between various specialists						1	1			1	1	1											1	1	1	1	1				**10**	**33**
2.11	*Designing uneconomical shapes and outlines	1	1	1	1			1			1	1	1	1		1	1			1		1		1	1		1	1		1	1	**19**	**63**
2.12	*Lack of standardization in design/ sizes and units	1	1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	**26**	**87**
2.13	*Lack of build ability analysis			1																												**1**	**3.3**
2.14	*Difficulty in interpreting material specifications		1		1	1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	**26**	**87**
2.15	*Readability, constructability and maintainability	1	1	1	1	1	1	1	1	1	1		1	1		1	1			1	1		1	1	1	1	1		1	1	1	**24**	**80**
2.16	*Insufficient time for design					1	1			1	1							1					1	1		1			1			**9**	**30**
2.17	*Poor harmonization of clients brief						1	1	1	1	1																					**5**	**17**
2.18	*Over or under designing				1	1	1	1	1	1	1	1																				**8**	**27**
2.19	*Poor structural arrangement of a design	1	1	1	1	1																										**5**	**17**
2.20	*Aesthetic considerations	1	1																													**2**	**6.7**
2.21	*Poor planning of design process	1	1	1																												**3**	**10**
2.22	*Poor functionality of a design	1	1																													**2**	**6.7**
2.23	*Designing unavailable technology			1	1	1		1	1			1				1					1		1				1					**10**	**33**
2.24	*Lack of geo-physical survey		1																													**1**	**3.3**
3.0	**Design Complexity**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage**
3.1	Designing uneconomical shapes and outlines	1	1	1	1			1		1	1	1	1		1	1	1		1	1		1	1		1	1	1	1	1	1	1	**23**	**77**
3.2	Sophisticated systems and components		1										1		1					1		1		1			1	1	1	1		**10**	**33**
3.3	Difficulties in interpreting specification	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	**28**	**93**
3.4	Designing irregular shapes and forms	1	1	1		1		1	1	1		1	1	1	1	1		1		1	1	1				1			1	1	1	**20**	**67**
3.5	Designing substandard dimensions, allowing cutting and chiseling	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1			1	1		1		1	1	**24**	**80**
3.6	*Error in design						1	1		1		1	1	1		1			1		1		1	1					1	1	1	**14**	**47**
3.7	*Inexperienced designer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
3.8	*Designing materials that are not readily available/locally obtainable		1		1		1	1	1	1	1				1									1	1				1			**11**	**37**
3.9	*Use of specialized technology and consultant	1		1			1																	1								**4**	**13**
3.10	*Lack of build ability analysis			1														1	1			1			1							**5**	**17**
3.11	*Lack of monitoring and Improving on				1					1		1									1											**4**	**13**

	previous mistakes																																
3.12	*Inadequate design information	1				1	1	1	1	1	1	1	1	1		1			1	1	1	1	1	1	1		1		1	1	1	**22**	**73**
3.13	*Lack of prioritizing reuse in designs and specifications	1																														**1**	**3.3**
3.14	*Improper planning for waste management		1																													**1**	**3.3**
3.15	*Lack of thorough understanding of design before construction	1																														**1**	**3.3**
3.16	*Prefabrication and pre-casting of concrete panels		1		1																											**2**	**6.7**
3.17	*Poor communication among designers (Architect and Engineers	1																														**1**	**3.3**
3.18	*Poor monitoring of design process			1																												**1**	**3.3**
4.0	**Quality of Estimating**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**35**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage**
4.1	Over/under estimating and allowance		1	1	1	1	1	1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1		1		1	1	**24**	**80**
4.2	Inaccurate quantity take-off	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
4.3	Insufficient time for estimate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
4.4	Different methods used in estimation	1		1					1	1			1	1	1	1	1	1			1		1		1	1			1	1		**16**	**53**
4.5	*Inexperienced estimator	1	1	1	1											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**20**	**67**
4.6	*Lack of detailed drawing and specifications (readable and interpretable)	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	**28**	**93**
4.7	*Inadequate project risks evaluation, analysis, and estimation	1	1		1	1	1		1	1	1	1	1		1	1	1			1	1	1	1	1	1	1		1		1	1	**23**	**77**
4.8	*Inadequate knowledge of site conditions	1	1		1	1			1	1														1	1	1		1	1	1	1	**13**	**43**
4.9	*Lack of estimating information	1	1		1	1		1	1									1			1		1	1	1		1		1	1	1	**15**	**50**
4.10	*Poor knowledge of fluctuating market conditions/prices		1	1			1	1			1	1	1						1	1					1	1	1	1	1	1	1	**16**	**53**
4.11	*Improper monitoring and improvement on previous mistakes		1			1	1	1								1							1			1						**7**	**23**
4.12	*Design requiring frequent change	1																														**1**	**3.3**
4.13	*Late engagement of estimator				1																											**1**	**3.3**

5.0	**Quality of Procurement management**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage**

5a	***Procurement and Transportation***	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**STO**	**PM**		
5.1	Errors/mistakes in material ordering/procurement		1	1									1	1			1				1				1							**7**	**23**
5.2	Procuring items not in compliance with specification	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
5.3	Errors in shipping								1									1			1				1	1						**5**	**17**
5.4	Mistakes in quantity surveys: Poor estimate for procurement (Over procuring)	1	1			1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1		1		**23**	**77**
5.5	Wrong material delivery procedures	1	1	1		1	1	1			1		1	1			1	1	1	1	1		1		1		1	1				**18**	**60**
5.6	Delivery of substandard materials	1	1		1	1	1	1	1			1	1	1		1		1			1		1	1	1	1	1	1	1	1	1	**22**	**73**
5.7	Damage of material during transportation	1	1	1	1	1	1	1	1	1		1	1	1		1	1			1	1											**16**	**53**
5.8	Late delivery /Inadequate delivery schedule	1	1		1	1		1					1				1			1						1	1		1			**11**	**37**
5.9	Market conditions																				1								1		1	**3**	**10**
5.10	Poor material handling	1	1	1							1	1	1	1			1	1	1				1		1		1	1	1		1	**16**	**53**
5.11	Waiting for replacement																															**0**	**0**
5.12	Poor protection of materials and damage during transportation												1					1			1		1									**4**	**13**
5.13	Over allowance (difficulties in ordering less)	1						1			1		1						1		1						1					**7**	**23**
5.14	Frequent variation orders																															**0**	**0**
5.15	Poor product knowledge	1	1	1				1	1		1		1	1				1			1				1	1		1	1		1	**15**	**50**
5.16	Difficulties of vehicles in accessing site							1					1											1				1				**4**	**13**
5.17	*Procuring substandard materials			1																	1	1										**3**	**10**
5.18	*Inexperienced personnel in estimation and procurement	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
5.19	*Procuring the wrong quantity of materials		1		1	1	1	1	1			1	1		1	1	1	1	1	1			1	1	1	1	1		1	1	1	**22**	**73**
5.20	*Poor quality control for evaluation of procured product				1	1	1	1			1				1	1			1	1	1	1	1	1		1	1		1		1	**17**	**57**
5.21	*lack of competent procurement management					1	1		1	1					1			1					1	1					1			**9**	**30**
5.22	*Lack of professionalism and transparency in procurement											1	1			1								1			1					**5**	**17**
5.23	*Lack of early preparation of materials requisition before time																					1										**1**	**3.3**
5b	***Manufacturers***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
5.24	Poor quality of materials	1	1	1			1				1						1															**6**	**20**

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
5.25	Sub-standard sizes of materials				1	1	1				1		1	1		1		1	1	1		1	1	1	1							**14**	**47**
5.26	Poor product information	1	1								1		1																			**4**	**13**
5.27	Lack of awareness																															**0**	**0**
5.28	Poor projection for materials																															**0**	**0**
5c	***Suppliers***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
5.29	Poor supply chain management		1			1			1			1		1			1		1				1		1		1			1		**11**	**37**
5.30	Poor packaging			1						1					1																	**3**	**10**
5.31	Supplier errors					1					1																					**2**	**6.7**
5.32	Poor product incentive																															**0**	**0**
5.33	Poor handling of supplied materials	1	1		1	1	1	1	1		1		1		1		1	1		1	1	1				1						**16**	**53**
5.34	Poor methods of unloading materials supplied in loose form	1	1	1																												**3**	**10**

6.0	**Quality of Construction Management**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
6a	***Contractors***	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**STO**	**PM**		
6.1	Incorrect scheduling and planning	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1			1	1	1		1	1	1	1		**25**	**83**
6.2	Inappropriate contractor's policies																								1							**1**	**3.3**
6.3	Lack of awareness		1																													**1**	**3.3**
6.4	Lack of experience	1	1		1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1				1	1	1		1		**22**	**73**
6.5	Laziness																							1								**1**	**3.3**
6.6	Poor site management and supervision	1	1			1		1		1		1				1	1			1	1	1			1	1		1		1	1	**16**	**53**
6.7	Poor building techniques	1	1			1	1	1	1	1	1		1		1			1	1			1	1	1	1		1	1				**18**	**60**
6.8	Incompetent subcontractor/supplier	1	1	1	1	1	1							1	1						1	1										**10**	**33**
6.9	Poor financial controls on site		1		1	1			1	1		1		1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	**22**	**73**
6.10	Use of unskilled labour to replace skilled ones														1																	**1**	**3.3**
6.11	*Improper management of plant and materials														1																	**1**	**3.3**
6.12	*Rework	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
6.13	*Poor communication and coordination	1	1	1	1	1					1	1		1		1		1	1	1		1	1	1	1	1	1	1	1			**20**	**67**
6.14	*Lack of proper organization and control	1		1	1	1				1	1	1		1	1			1	1	1		1	1		1	1	1	1	1	1	1	**21**	**70**

6.15	*Lack of a quality control unit						1								1				1						1				1			5	17
6.16	*improper management of the 5ms,			1				1				1		1	1			1											1		1	8	27
6.17	*Poor motivation				1	1						1		1					1	1	1		1		1		1	1	1			12	40
6.18	*Improper monitoring of the construction process																													1	1	2	6.7
6.19	*Lack of regular site meetings										1	1					1			1		1				1		1		1	1	9	30
6b	***Culture***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
6.20	Lack of incentive	1	1	1		1	1	1	1	1	1	1					1		1		1					1			1	1	1	17	57
6.21	Lack of training and development	1	1	1		1	1	1		1		1			1	1	1				1		1	1					1	1	1	17	57
6.22	Lack of support from senior management		1																											1	1	3	10
6.23	Lack of awareness among practitioners on waste management			1				1				1	1						1						1							6	20
6c	***Workers***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
6.24	Workers mistake or error during construction	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30	100
6.25	Incompetent worker	1			1	1	1	1	1	1												1								1		9	30
6.26	Poor workers' attitude																										1					1	3.3
6.27	Lack of experience workers	1	1			1	1	1	1	1	1	1	1			1		1	1	1	1		1	1	1	1	1	1		1	1	23	77
6.28	Shortage of skilled workers													1											1							2	6.7
6.29	Too much over time for workers																															0	0
6.30	Inappropriate use of materials and Equipment	1	1				1		1		1							1	1			1	1	1		1	1	1		1	1	15	50
6.31	Poor workmanship	1	1	1		1	1	1	1	1	1					1						1			1		1		1	1		15	50
6.32	Damage caused by workers											1																				1	3.3
6.33	Worker's lack of enthusiasm																	1														1	3.3
6.34	*Inappropriate adoption of re-use of materials					1																										1	3.3
6.35	*Poor staff workers relationship	1																														1	3.3
6.36	*Poor adherence to specifications		1																													1	3.3

7.0	**Quality of Site Management**	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**STO**	**PM**		
7a	***Storage***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**

7.1	Wrong material/equipment storage/stacking	1	1	1		1	1	1		1			1							1			1						1			**11**	**37**
7.2	Transfer of materials from storage to application																															**0**	**0**
7.3	Damage by other trades																															**0**	**0**
7.4	Poor site storage area	1	1	1	1	1	1		1		1	1			1	1	1		1			1	1	1		1		1	1	1		**20**	**67**
7.5	Long storage distance from application point.														1																	**1**	**3.3**
7.6	Damage by weather	1	1			1	1																						1			**5**	**17**
7b	***Security***																																
7.7	Inadequate site security/Fencing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
7.8	Theft	1	1			1	1		1	1			1	1	1	1	1	1	1		1		1	1		1	1	1		1	1	**21**	**70**
7.9	Vandalism, sabotage pilferage, and material damage	1	1	1		1	1	1			1	1	1	1	1			1	1		1		1	1		1	1	1	1	1	1	**22**	**73**
7.10	Power and lighting problems on site	1	1					1				1	1							1		1							1	1		**9**	**30**
7c	***Site conditions***																																
7.11	Poor site management and the 5ms	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1			1	1	1	1	1		1	1	1	**26**	**87**
7.12	Poor site and unforeseen ground conditions						1	1	1		1			1	1																	**6**	**20**
7.13	Leftover materials on site																															**0**	**0**
7.14	Waste resulting from packaging																															**0**	**0**
7.15	Lack of environmental awareness	1		1	1		1	1			1		1	1	1															1		**10**	**33**
7.16	Difficulties in accessing construction site			1	1										1															1		**4**	**13**
7.17	Problems relating to on-site health and safety	1		1	1		1	1	1		1			1		1				1	1	1								1		**13**	**43**
7.18	Site congestion and Interference of other crews																															**0**	**0**
7.19	Inadequate site investigation	1		1								1																		1		**4**	**13**
7.20	Disputes on site	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	**27**	**90**
7.21	Extra materials ordered are discarded instead of carrying over to next site																1					1								1		**3**	**10**
7.22	Equipment failure on site		1		1		1	1	1		1			1																		**7**	**23**
7.23	Concurrent execution of numerous activities													1			1															**2**	**6.7**
7.24	*Poor site organization and disciplined	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	**29**	**97**
7.25	*Wrong location of cranes on site	1	1			1	1		1	1	1	1			1			1	1				1	1								**13**	**43**
7.26	*Wrong placement of equipment on site				1																	1	1									**3**	**10**
7.27	Site accident	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	**29**	**97**
7.28	*Site meetings											1	1							1								1			1	**5**	**17**
7.29	*Lack of adherence to program of work					1																										**1**	**3.3**

7.30	*Late delivery of materials																				1											**1**	**3.3**
7d	***Operation***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.31	Nature of construction process				1																											**1**	**3.3**
7.32	Tools not suitably used																						1									**1**	**3.3**
7.33	Damages caused by third parties																																
7.34	Lack of waste management plans	1		1	1		1	1	1		1	1	1		1	1	1	1			1	1	1			1	1		1		1	**20**	**67**
7.35	Communication problem	1	1	1	1		1	1		1	1	1	1	1			1			1		1	1	1	1		1	1				**19**	**63**
7.36	Non availability of appropriate equipment																				1		1				1				1	**4**	**13**
7.37	Lack construction knowledge and methods	1			1			1	1		1			1				1	1				1				1		1			**11**	**37**
7.38	Scarcity of equipment	1		1			1	1	1		1		1	1									1						1			**10**	**33**
7.39	Late information flow among parties	1							1				1									1				1					1	**6**	**20**
7.40	Lack of coordination among parties	1		1	1		1	1	1	1	1	1	1	1		1	1			1	1	1	1		1		1			1	1	**21**	**70**
7.41	Poor construction planning and control	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1			1		1			1		**22**	**73**
7.42	Poor site supervision	1	1		1			1	1	1	1		1	1			1	1		1	1	1	1				1		1		1	**18**	**60**
7.43	Rework	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
7.44	Inappropriate records of materials	1	1				1	1				1	1				1	1		1			1					1	1	1		**13**	**43**
7.45	*Lack of adherence to material waste regulations																											1	1			**2**	**6.7**
7.46	*Inappropriate delegation of responsibilities	1	1			1	1		1						1								1	1								**8**	**27**
7.47	*Lack of experience	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1		1	1			1		1	**24**	**80**
7.48	*Lack of learning from previous mistakes		1			1	1				1												1						1			**6**	**20**
7.49	Lack of quality control						1					1									1		1	1				1		1		**7**	**23**
7e	***Residual waste***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.50	excess mixture of mortar	1	1			1		1			1		1	1														1	1			**9**	**30**
7.51	wrong cutting of materials to length		1	1	1																											**3**	**10**
7.52	cutting uneconomical shaped materials	1	1		1												1			1												**5**	**17**
7.53	packaging waste																															**0**	**0**
7f	***Other Sources***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.54	Unpredictable local conditions	1					1														1											**3**	**10**
7.55	Festival celebration/ public holidays		1			1							1						1							1						**5**	**17**
7.5	Effect of weather or damage by weather				1			1			1						1															**4**	**13**

	Control measures for material waste and cost overruns at the Pre-Contract Stage of a project	QS	QS	PM	QS	PM	PM	PM	SE	QS	QS	PM	PM	PM	QS	PM	PM	SE	QS	PM	PM	PM	SE	PM	PM	SE	QS	QS	SE	STO	PM		
1.0	**Quality of Planning**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
1.1	Plan for early sub-soil investigations	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
1.2	Proper investment into waste reduction		1		1	1	1	1			1			1		1						1				1			1			**11**	**37**
1.3	proper planning of construction projects layout	1	1		1	1	1	1	1		1	1	1	1	1																	**12**	**40**
1.4	Plan for inclusion of waste management in bidding and tendering process	1		1	1	1			1									1														**6**	**20**
1.5	Enhance regulation execution of related government departments		1					1		1			1	1									1				1			1		**8**	**27**
1.6	Improved planning and scheduling	1	1		1	1		1	1		1	1	1	1	1		1	1	1	1		1	1		1	1		1	1		1	**22**	**73**
1.7	Proper coordination and communication	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**29**	**97**
1.8	Proper insurance	1	1		1			1	1	1		1																				**7**	**23**
1.9	Set a target for material waste reduction		1		1	1		1	1			1	1	1		1	1	1		1	1	1		1	1	1		1	1	1	1	**21**	**70**
1.10	Improve major project stakeholders' awareness about resource saving and environmental protection				1			1	1				1																			**4**	**13**
1.11	*Plan that will reduce frequent design Change	1		1				1	1					1	1	1	1															**8**	**27**
1.12	*Plan for material standardization	1		1								1			1										1							**5**	**17**
1.13	*Carrying design team along	1				1		1																								**3**	**10**
1.14	*Regular site meetings	1	1	1	1	1		1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	**26**	**87**
1.15	*Establishment of good waste management unit	1	1		1	1		1	1	1	1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	**26**	**87**
1.16	*Re-improving process (Learning from previous mistakes)		1			1														1									1			**4**	**13**
1.17	*Legislative enforcement		1	1	1	1		1	1		1	1	1	1			1			1		1			1	1	1	1			1	**18**	**60**
1.18	*Adequate material waste estimation			1											1	1	1					1										**5**	**17**
1.19	*Planning of project risks					1	1	1		1		1	1				1		1	1		1		1		1	1		1			**14**	**47**
1.20	*Proper harmonization of brief						1		1									1						1	1	1						**6**	**20**
1.21	*Experienced personnel					1	1	1	1	1	1	1	1	1	1	1			1	1	1		1	1	1	1	1	1	1	1		**22**	**73**

1.22	*Identification of construction technique															1																**1**	**3.3**
1.23	*Feasibility and Viability studies												1	1	1	1					1								1	1		**7**	**23**
1.24	*Build ability Analysis			1				1																	1							**3**	**10**
1.25	*Consideration of available technology, resources and materials		1	1					1	1		1	1																			**6**	**20**
1.26	*Geophysical surveys		1																													**1**	**3.3**
1.27	*interaction between different designers (Architect and Engineer)							1																								**1**	**3.3**
2.0	**Quality of Design Management**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
2.1	Design for materials optimization		1																		1			1								**3**	**10**
2.2	Design for reuse and recovery	1					1	1		1																						**4**	**13**
2.3	Design for offsite construction					1															1			1								**3**	**10**
2.4	Designing for deconstruction							1												1												**2**	**6.7**
3.5	Use of prefabricated units and standard materials	1	1			1									1									1			1			1		**7**	**23**
2.6	*Communication and Coordination of design process		1	1							1			1											1	1	1	1			1	**9**	**30**
2.7	*Designing economic shapes and outlines	1	1	1	1			1			1	1	1	1		1	1			1		1		1	1		1	1		1	1	**19**	**63**
2.8	Incorporation of large-panel metal formworks																															**0**	**0**
2.9	Reduction in the rate of design change	1	1	1			1	1			1		1	1		1				1		1			1							**12**	**40**
2.10	Utilization modular designs															1									1							**2**	**6.7**
2.11	Reduced design complexity	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1			**26**	**87**
2.12	*Explicit detailing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
2.13	*Interpretable design and specifications	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	**28**	**93**
2.14	*Experienced Designer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
2.15	*Proper management of design process	1			1	1	1	1	1	1						1		1		1	1		1		1	1	1		1		1	**17**	**57**
2.16	*Error-free Design	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**28**	**93**
2.17	*Standardization in Design	1		1		1	1			1	1	1					1	1	1	1	1		1	1	1	1		1	1	1	1	**20**	**67**
2.18	*Readability, constructability and maintainability	1	1	1	1	1	1	1	1	1	1		1	1					1	1	1		1	1	1	1	1		1	1	1	**23**	**77**
2.19	*Proper design Information and consultation	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**28**	**93**
2.20	*Adherence to Clients brief						1	1	1	1	1																					**5**	**17**
2.21	*Sufficient time for design					1	1			1	1							1					1	1		1			1			**9**	**30**
2.22	*Early engagement of designer				1																												
2.23	*Improving on previous design mistakes			1																												**1**	**3.33**

3.0	**Design Complexity**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
3.1	*Experienced designer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
3.2	*Standardization in design and units	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	**27**	**90**
3.3	*Interpretable designs	1	1																1	1	1	1		1	1	1	1	1	1			**12**	**40**
3.4	*Readable dimensions and specifications	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**29**	**97**
3.5	*Designing economic shapes and outlines	1	1	1	1			1		1	1	1	1		1	1	1		1	1		1	1		1	1	1	1	1	1	1	**23**	**77**
3.6	*A design recommending available human resources and local materials		1		1		1	1	1	1	1										1			1		1						**10**	**33**
3.7	*Use of specialized technology and consultants	1		1		1																		1								**4**	**13**
3.8	*Proper monitoring and supervision of work			1															1			1			1							**4**	**13**
3.9	*Improving on previous design mistakes				1				1		1										1												
3.10	*Engaging in build ability analysis at the planning stage			1														1	1			1			1							**5**	**17**
4.0	**Quality of Estimation**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
4.1	Ensure a good knowledge of material estimation (Unified method of estimating)	1		1					1	1			1	1	1	1						1				1		1				**11**	**37**
4.2	Error free estimation	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1		1	1	1	1	**26**	**87**
4.3	Knowledge of fluctuating market prices of materials		1	1				1	1			1	1	1					1	1					1	1	1	1	1	1	1	**16**	**53**
4.4	*Thorough checking of design and the prepared estimate											1			1						1		1									**4**	**13**
4.5	*Experienced estimator	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**29**	**97**
4.6	*Detailed drawings, dimensions and specifications	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	**29**	**97**
4.7	*Proper risks estimation	1	1		1	1	1		1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	**25**	**83**
4.8	*Knowledge of site conditions	1	1		1	1			1	1														1	1	1		1	1	1	1	**13**	**43**
4.9	*Sufficient time for estimate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
4.10	*Availability of estimating information	1	1		1	1			1	1								1			1		1	1	1		1		1	1	1	**15**	**50**
4.11	*Accurate quantity take-off	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
4.12	*Monitoring and improving on previous estimating mistakes		1			1	1	1								1							1			1						**7**	**23**

POST CONTRACT STAGE

5.0	**Quality of Procurement Management**	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**STO**	**PM**		
5a	***Procurement and transportation source***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
5.1	Better transportation of materials			1					1			1	1																			**4**	**13**
5.2	Enhanced construction material handling by workers	1	1	1							1	1	1	1			1	1	1				1		1		1	1	1		1	**16**	**53**
5.3	Adopting good materials abstracting		1																			1					1		1			**4**	**13**
5.4	Provision of easy access road for vehicles delivery							1					1												1			1				**4**	**13**
5.5	Adopt a unified method of estimating for procurement	1	1			1	1	1	1		1	1					1	1	1		1	1	1	1			1	1	1			**18**	**60**
5.6	Ordering of appropriate quantity of materials	1	1		1	1		1					1				1			1						1	1		1			**11**	**37**
5.7	Timely delivery of materials	1	1		1	1		1				1					1			1		1				1	1			1		**12**	**40**
5.8	*Standard evaluation and comparing with specification					1	1	1	1			1				1	1	1	1	1	1	1	1	1	1	1	1		1		1	**19**	**63**
5.9	*Procuring in accordance with specification	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
5.10	*Experienced personnel in estimation and procurement	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**29**	**97**
5.11	*Insurance of the procured materials		1															1							1							**3**	**10**
5.12	*Procuring the right quantity of materials at the right time		1		1	1	1	1	1			1	1		1	1	1	1	1	1			1	1	1	1	1		1	1	1	**22**	**73**
5.13	*Quality control assurance for evaluation of procured product				1	1	1	1			1				1	1			1	1	1	1	1	1		1	1		1		1	**17**	**57**
5.14	*Competent procurement management					1	1		1	1					1			1					1	1					1			**9**	**30**
5.15	*Professionalism and transparency in procurement											1	1			1								1			1					**5**	**17**
5b	***Manufacturers source***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
5.16	Improved quality of materials	1	1	1			1				1						1															**6**	**20**
5.17	Materials should manufactured in standard units				1	1	1				1		1	1		1		1	1	1		1	1	1	1							**14**	**47**
5.18	Knowledge of product to be manufactured	1	1								1		1																			**4**	**13**
																																0	**0**

5c	***Supplier source***	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
5.19	Better and improved supply chain management	1				1	1	1		1		1	1	1	1			1		1	1			1		1		1			1	**16**	**53**
5.20	Efficient methods of unloading materials supplied in loose form		1	1	1	1	1	1	1	1		1		1		1	1	1	1	1	1	1	1				1					**19**	**63**
5.21	*Better delivery of materials on site	1	1	1																												**3**	**10**

6.0	**Quality of Construction Management**	QS	QS	PM	QS	PM	PM	PM	SE	QS	QS	PM	PM	PM	QS	PM	PM	SE	QS	PM	PM	PM	SE	PM	PM	SE	QS	QS	SE	ST O	PM		
6a	***Contractors source***	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
6.1	Competent contractor	1	1	1	1	1	1							1	1						1	1										**10**	**33**
6.2	Proper scheduling and planning of project	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1			1	1	1		1	1	1	1		**25**	**83**
6.3	Use of skilled and experienced labour	1	1												1																	**3**	**10**
6.4	Adequate site control and supervision	1	1			1		1		1		1				1	1			1	1	1			1	1		1		1	1	**16**	**53**
6.5	Integrate waste management into the assessment of construction contractor										1							1						1								**3**	**10**
6.6	Improve contractors' onsite construction management	1	1			1		1		1		1		1				1	1		1	1	1			1	1		1	1	1	**17**	**57**
6.7	*Competent supplier	1	1	1	1	1	1							1	1							1	1									**10**	**33**
6.8	*Proper communication and coordination	1	1		1	1	1				1	1		1		1		1	1	1	1	1	1	1	1	1	1	1	1			**21**	**70**
6.9	*Error-free construction process		1					1				1						1					1			1						**6**	**20**
6.10	*Process improvement techniques		1			1				1	1				1	1							1	1								**8**	**27**
6.11	*Adequate building technique		1																													**1**	**3.3**
6b	***Culture source***	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
6.12	Establish systems of rewards and punishments to encourage material saving	1	1	1	1	1	1	1	1	1	1	1					1		1		1					1				1	1	**17**	**57**
6.13	Proper management support for workers			1																										1	1	**3**	**10**
6.14	Awareness among practitioners on managing waste		1					1				1	1						1						1				1			**7**	**23**
6.15	Staff vocational training and development	1	1	1	1	1	1	1		1		1			1	1	1				1		1	1					1	1	1	**18**	**60**
6c	***Workers source***	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Scores	Percentage (%)
6.16	Ensuring that good quality workmanship is achieved	1	1	1		1	1	1	1	1	1					1						1			1		1		1		1	**15**	**50**

6.17	Appropriate material utilization		1							1			1		1			1			1		1	1		1		1				10	33
6.18	Availability of good work-life balance		1												1							1					1					4	13
6.19	Engaging competent workers	1	1			1	1	1	1	1	1	1	1			1		1	1	1	1		1	1	1	1	1	1		1	1	23	77
6.20	*Adoption of re-use of materials					1																										1	3.3
6.21	*Adherence to specifications		1																													1	3.3
6.22	*Regular site meetings	1																														1	3.3
6d	***Storage source***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
6.23	Better storage facilities and environment/area	1	1	1	1	1	1		1		1	1			1	1	1		1			1	1	1		1		1	1	1		**20**	**0**
6.24	Improved method of material usage				1	1			1			1				1					1		1									**7**	**0**
6.25	Appropriate material storage	1	1					1				1			1				1													**6**	**0**
6.26	Proper material protection against weather	1	1																													**2**	**0**
6.27	Improved method of material handling	1	1					1				1				1			1													**6**	**0**

7.0	**Quality of Site Management**	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**STO**	**PM**		
7a	***Site condition and Management source***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.1	Proper materials inspections on delivery to site						1					1									1		1	1				1		1		**7**	**23**
7.2	Proper records and documentation of materials	1	1				1	1				1	1	1			1	1	1	1			1	1				1				**14**	**47**
7.3	Daily record taking	1	1				1	1				1	1				1	1		1			1	1								**11**	**37**
7.4	Usage of materials request booklets																															**0**	**0**
7.5	Regular site meetings on materials issues	1	1									1	1							1								1				**6**	**20**
7.6	On site material quality evaluation						1					1									1		1	1				1		1	1	**8**	**27**
7.7	On-site and offsite re-use of waste material		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		**27**	**90**
7.8	Separation of hazardous waste from others																															**0**	**0**
7.9	Adherence to design and specification	1	1								1	1					1	1						1				1				**8**	**27**
7.10	Good communications flow on site	1	1	1	1		1	1		1	1	1	1	1			1			1		1	1	1	1		1	1				**19**	**63**
7.11	Implement onsite material waste sorting									1								1														**2**	**6.7**
7.12	Recycle generated waste materials																															**0**	**0**
7.13	*Proper management of 5ms on site	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1			1	1	1	1	1		1			**24**	**80**

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
7b	**Security Source**																															**0**	**0**
7.14	Tight security on site	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
7.15	Availability of a workable security lighting on site	1	1					1				1	1							1		1							1	1		**9**	**30**
7.16	*Adequate site temporary fencing	1	1								1			1	1				1				1	1			1					**9**	**30**
7b	***Operation source***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.17	Issuing procedures for managing hazardous waste															1					1											**2**	**6.7**
7.18	Prepare a list and record of salvageable waste										1								1					1								**3**	**10**
7.19	Site meetings on material waste management	1										1	1							1								1			1	**6**	**20**
7.20	Adherence to waste management regulations	1														1		1		1			1		1		1					**7**	**23**
7.21	Encourage management of the environment																															**0**	**0**
7.22	Waste management throughout the entire lifecycle of a project										1		1																			**2**	**6.7**
7.23	Promote construction waste reuse on construction sites	1	1	1	1	1	1	1	1			1	1		1	1	1	1	1	1		1	1	1	1	1	1	1				**23**	**77**
7.24	Research and development in the discipline of waste management																															**0**	**0**
7.25	*Use of experienced personnel	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1		1	1			1		1	**24**	**80**
7.26	*Adequate site organization and discipline	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1		1	1	1	1	1	1	1	1	**27**	**90**
7.27	Adequate site supervision	1	1		1				1	1	1	1		1	1			1	1		1	1	1	1				1		1		**17**	**57**
7.28	*Learning from previous mistakes		1			1	1				1									1	1		1	1				1		1		**10**	**33**
7.29	*Proper site planning and control	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1		1	1	1			1		1			1			
7c	***Residual***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
7.30	Reduce off-cut of materials and reuse		1		1																							1	1			**4**	**13**
7.31	Mixture of appropriate quantity of mortar	1	1					1			1		1	1																		**6**	**20**

8.0	**Benefits of recovering (reuse and recycling) material waste**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
8a	***Economic benefits***	**QS**	**QS**	**PM**	**QS**	**PM**	**PM**	**PM**	**SE**	**QS**	**QS**	**PM**	**PM**	**PM**	**QS**	**PM**	**PM**	**SE**	**QS**	**PM**	**PM**	**PM**	**SE**	**PM**	**PM**	**SE**	**QS**	**QS**	**SE**	**ST C**	**PM**		

8.1	Profit making on salvaged materials	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
8.2	Reduces demand for new materials		1			1	1		1	1	1			1		1		1					1	1	1		1		1	1		**15**	**50**
8.3	Realize value of recovered materials		1																													**1**	**3.3**
8.4	Cut down transportation cost	1		1	1	1	1			1		1	1		1		1	1			1		1	1	1				1	1	1	**18**	**60**
8.5	Reduced energy cost																															**0**	**0**
8.6	Cut down/reduce disposal cost	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1			1		1		1		1		1	1	1	**22**	**73**
8.7	Conserving resources by diversion from landfill																											1				**1**	**3.3**
8.8	Encourage creation of recycle market																															**0**	**0**
8.9	New source of revenue for waste generators																															**0**	**0**
8.10	Tax break gained for donation																															**0**	**0**
8.11	Cheaper exercise as a result of landfill tax																															**0**	**0**
8.12	Project cost saving through avoided disposal cost	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1	**28**	**93**
8.13	*Generate values by producing financial returns		1			1	1			1	1				1	1		1	1		1		1	1			1		1	1		**15**	**50**
8.14	*Saves cost on new materials										1				1	1			1		1	1	1	1			1	1	1			**11**	**37**
8.15	*Reduces project Cost overrun									1								1														**2**	**6.7**
8b	***Environmental benefits***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
8.1	Preserve space in existing landfills	1		1										1											1							**4**	**13**
8.2	Minimize environmental impact such contamination of ground water	1	1	1	1									1											1	1		1			1	**9**	**30**
8.3	Re using material which could be lost to landfill	1	1		1	1	1	1		1	1	1	1	1	1		1		1	1	1		1	1	1	1			1		1	**22**	**73**
8.4	*Reduces environmental pollution	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
8.5	*Reduction in carbon emission		1			1	1		1	1	1				1			1	1		1		1	1			1		1	1		**15**	**50**
8.6	*Conservation of the environment		1			1	1		1	1	1				1			1	1		1		1	1			1		1	1		**15**	**50**
8.7	*Curtail the negative environmental Impact		1			1	1		1	1	1				1	1					1									1		**10**	**33**
8c	***Social benefits***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
8.1	Creation of job opportunity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**30**	**100**
8.2	Raises the public image of the company		1																							1					1	**3**	**10**
8.3	Compliance with state and local regulations																								1	1		1			1	**4**	**13**
8.4	*Timber formwork is used as fire wood by the local community	1	1		1	1	1	1	1				1	1	1		1	1			1	1	1	1	1	1		1	1	1	1	**22**	**73**
8.5	*waste is used as a benefit to community by															1					1									1		**3**	

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
	helping in disposal.																																

8d	***Reuse***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Total Scores**	**Percentage (%)**
8.1	Reuse does not require reprocessing	1	1	1		1			1	1			1	1		1	1		1	1			1		1		1	1	1	1		**18**	**60**
8.2	Reuse does not require hauling and transportation	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1				1	1			1	1	1	1	1		**22**	**73**
8.3	Reuse is the most profitable means of recovery for contractor		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1		1	1	1		1	1		1	1	**24**	**80**
8.4	Reuse does not require energy		1	1	1	1	1	1	1	1	1	1	1			1	1			1	1	1	1		1		1			1		**20**	**67**

11.0 Appendix C: Results of Statistical Analyses

Results of ANOVA analyses

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
A1_Total	PM	15	14.00	1.60	0.41	13.11	14.89	11.00	16.00
	QS	9	12.89	2.26	0.75	11.15	14.63	10.00	17.00
	SE	5	13.00	2.74	1.22	9.60	16.40	10.00	17.00
	Total	29	13.48	2.03	0.38	12.71	14.25	10.00	17.00
A2_Total	PM	15	10.20	2.14	0.55	9.01	11.39	7.00	14.00
	QS	9	10.67	3.20	1.07	8.21	13.13	5.00	15.00
	SE	5	10.00	1.58	0.71	8.04	11.96	8.00	12.00
	Total	29	10.31	2.38	0.44	9.41	11.21	5.00	15.00
A3_Total	PM	15	6.80	1.47	0.38	5.98	7.62	3.00	8.00
	QS	9	7.11	1.90	0.63	5.65	8.57	5.00	10.00
	SE	5	5.60	0.89	0.40	4.49	6.71	5.00	7.00
	Total	29	6.69	1.58	0.29	6.09	7.29	3.00	10.00
A4_Total	PM	15	7.33	1.23	0.32	6.65	8.02	5.00	10.00
	QS	9	7.00	2.06	0.69	5.42	8.58	5.00	10.00
	SE	5	8.20	1.48	0.66	6.36	10.04	6.00	10.00
	Total	29	7.38	1.57	0.29	6.78	7.98	5.00	10.00
A5_Total	PM	15	10.67	2.72	0.70	9.16	12.17	7.00	18.00
	QS	9	9.89	3.37	1.12	7.30	12.48	4.00	14.00
	SE	5	10.60	0.89	0.40	9.49	11.71	10.00	12.00
	Total	29	10.41	2.68	0.50	9.39	11.43	4.00	18.00
A6_Total	PM	15	26.80	8.06	2.08	22.34	31.26	14.00	43.00
	QS	9	25.33	9.64	3.21	17.92	32.75	14.00	40.00
	SE	5	31.20	7.98	3.57	21.29	41.11	19.00	40.00
	Total	29	27.10	8.50	1.58	23.87	30.33	14.00	43.00
A7_Total	PM	15	17.93	4.51	1.16	15.44	20.43	10.00	27.00
	QS	9	19.44	6.04	2.01	14.80	24.09	13.00	30.00
	SE	5	18.20	4.66	2.08	12.42	23.98	13.00	24.00
	Total	29	18.45	4.92	0.91	16.58	20.32	10.00	30.00
B1_Total	PM	15	10.80	3.21	0.83	9.02	12.58	6.00	18.00
	QS	9	9.44	2.07	0.69	7.85	11.03	7.00	13.00
	SE	5	9.60	1.95	0.87	7.18	12.02	7.00	11.00
	Total	29	10.17	2.71	0.50	9.14	11.20	6.00	18.00
B2_Total	PM	15	10.40	2.23	0.58	9.17	11.63	7.00	13.00
	QS	9	10.44	2.24	0.75	8.72	12.17	7.00	13.00

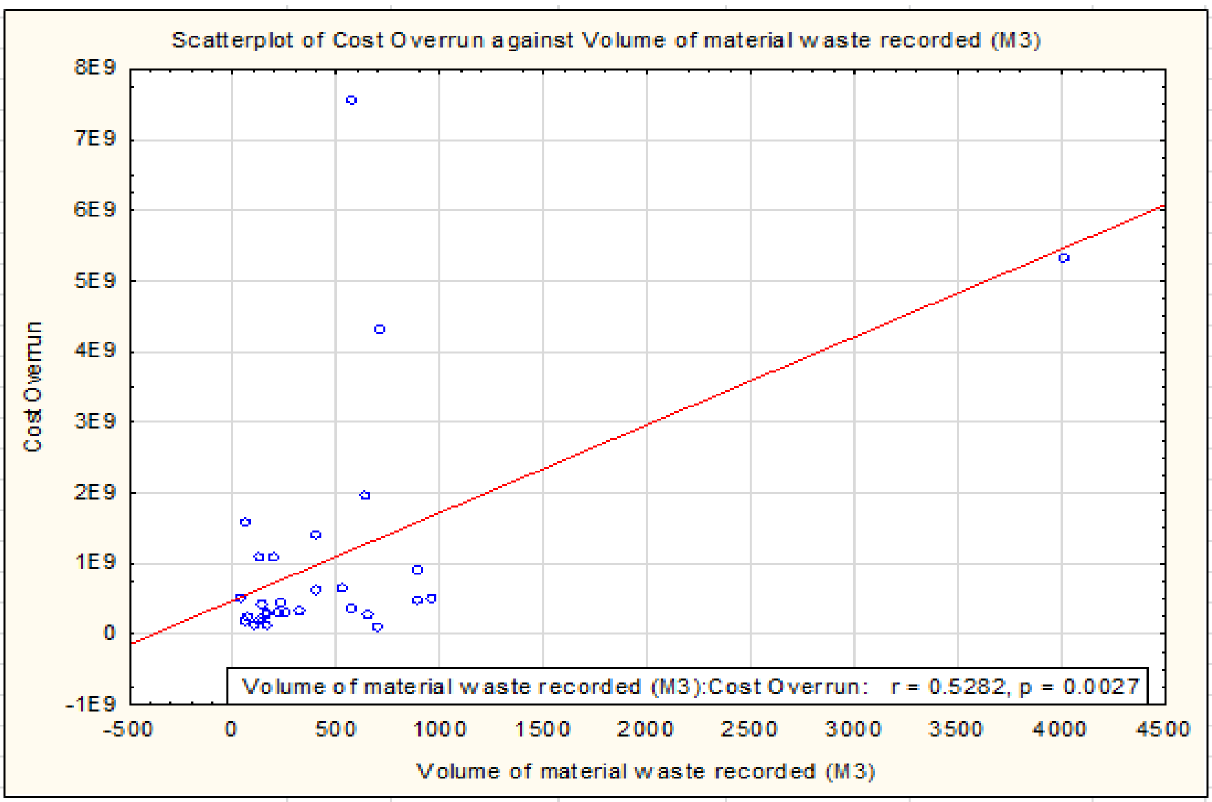
	SE	5	9.60	0.89	0.40	8.49	10.71	9.00	11.00
	Total	29	10.28	2.03	0.38	9.50	11.05	7.00	13.00
B3_Total	PM	15	4.80	1.42	0.37	4.01	5.59	3.00	7.00
	QS	9	5.44	0.88	0.29	4.77	6.12	4.00	7.00
	SE	5	4.60	1.14	0.51	3.18	6.02	3.00	6.00
	Total	29	4.97	1.24	0.23	4.49	5.44	3.00	7.00
B4_Total	PM	15	7.67	0.90	0.23	7.17	8.16	6.00	9.00
	QS	9	7.56	1.88	0.63	6.11	9.00	5.00	10.00
	SE	5	8.60	2.07	0.93	6.03	11.17	5.00	10.00
	Total	29	7.79	1.47	0.27	7.23	8.35	5.00	10.00
B5_Total	PM	15	8.80	2.08	0.54	7.65	9.95	4.00	11.00
	QS	9	8.56	2.74	0.91	6.45	10.66	5.00	13.00
	SE	5	9.40	1.34	0.60	7.73	11.07	8.00	11.00
	Total	29	8.83	2.16	0.40	8.01	9.65	4.00	13.00
B6_Total	PM	15	8.07	3.06	0.79	6.37	9.76	4.00	14.00
	QS	9	10.33	5.32	1.77	6.25	14.42	6.00	22.00
	SE	5	7.80	1.92	0.86	5.41	10.19	6.00	11.00
	Total	29	8.72	3.81	0.71	7.28	10.17	4.00	22.00
B7_Total	PM	15	10.80	3.28	0.85	8.98	12.62	5.00	17.00
	QS	9	12.11	3.55	1.18	9.38	14.84	9.00	18.00
	SE	5	9.20	3.27	1.46	5.14	13.26	6.00	14.00
	Total	29	10.93	3.39	0.63	9.64	12.22	5.00	18.00
C1_Total	PM	15	4.33	1.18	0.30	3.68	4.98	2.00	6.00
	QS	9	5.11	1.17	0.39	4.21	6.01	4.00	7.00
	SE	5	5.20	2.17	0.97	2.51	7.89	2.00	7.00
	Total	29	4.72	1.39	0.26	4.20	5.25	2.00	7.00
C2_Total	PM	15	2.27	1.22	0.32	1.59	2.94	1.00	4.00
	QS	9	3.33	1.00	0.33	2.56	4.10	2.00	5.00
	SE	5	3.00	0.71	0.32	2.12	3.88	2.00	4.00
	Total	29	2.72	1.16	0.22	2.28	3.17	1.00	5.00
C3_Total	PM	15	2.07	0.80	0.21	1.62	2.51	1.00	4.00
	QS	9	1.78	0.83	0.28	1.14	2.42	1.00	3.00
	SE	5	2.40	0.89	0.40	1.29	3.51	2.00	4.00
	Total	29	2.03	0.82	0.15	1.72	2.35	1.00	4.00
D1_Total	PM	15	2.93	1.03	0.27	2.36	3.51	1.00	4.00
	QS	9	2.67	1.12	0.37	1.81	3.53	1.00	4.00
	SE	5	2.40	1.52	0.68	0.52	4.28	1.00	4.00
	Total	29	2.76	1.12	0.21	2.33	3.19	1.00	4.00

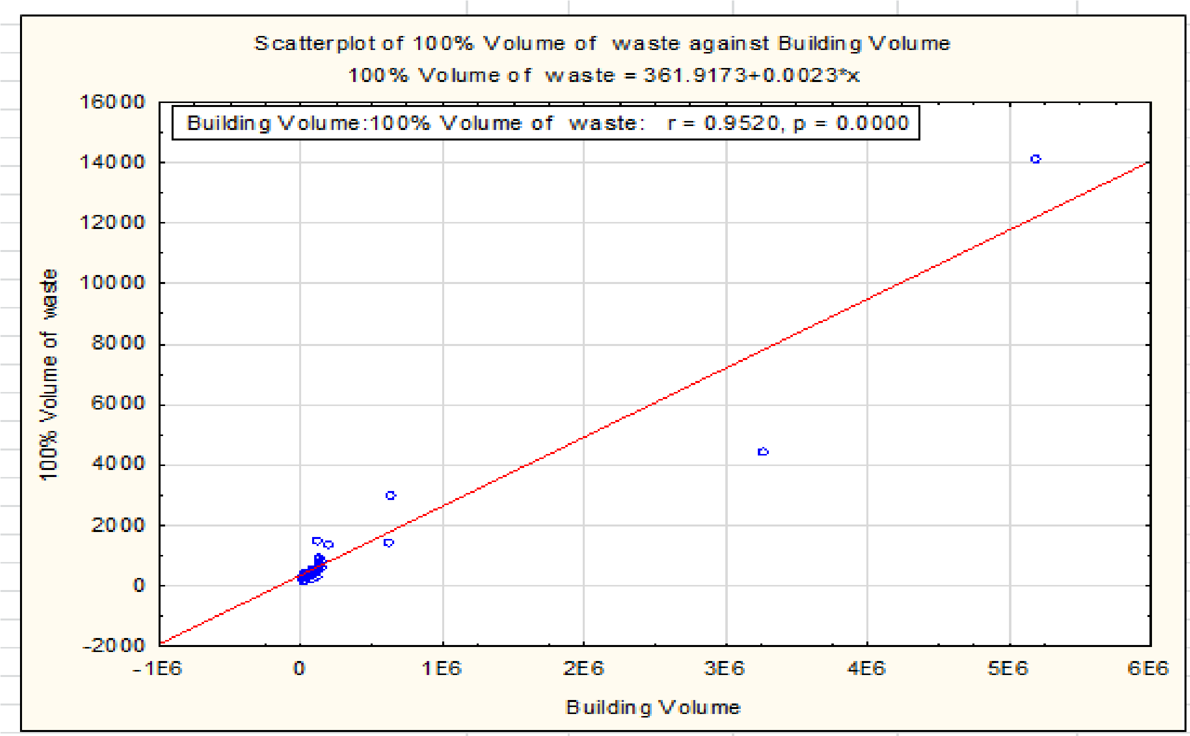
ANOVA

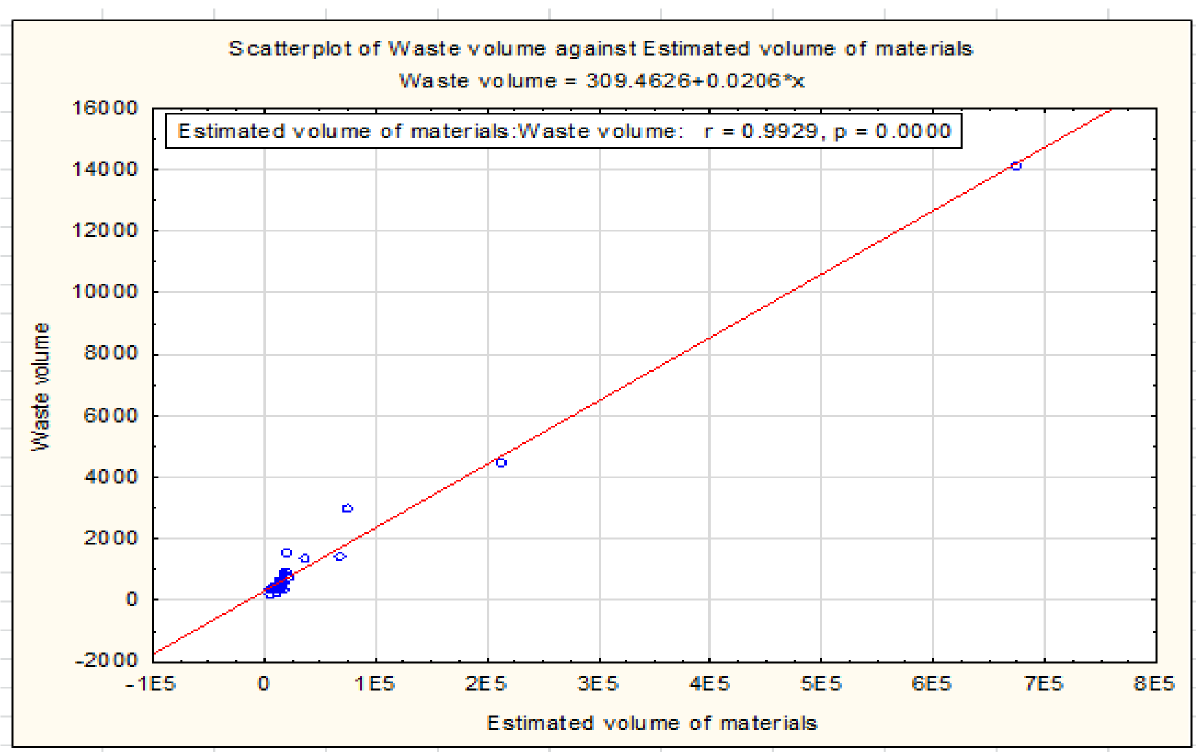
		Sum of Squares	df	Mean Square	F	Sig.
A1_Total	Between Groups	8.35	2	4.18	1.016	.376
	Within Groups	106.89	26	4.11		
	Total	115.24	28			
A2_Total	Between Groups	1.81	2	0.90	.150	.861
	Within Groups	156.40	26	6.02		
	Total	158.21	28			
A3_Total	Between Groups	7.72	2	3.86	1.606	.220
	Within Groups	62.49	26	2.40		
	Total	70.21	28			
A4_Total	Between Groups	4.69	2	2.35	.952	.399
	Within Groups	64.13	26	2.47		
	Total	68.83	28			
A5_Total	Between Groups	3.61	2	1.81	.238	.790
	Within Groups	197.42	26	7.59		
	Total	201.03	28			
A6_Total	Between Groups	113.49	2	56.74	.774	.472
	Within Groups	1907.20	26	73.35		
	Total	2020.69	28			
A7_Total	Between Groups	13.22	2	6.61	.259	.774
	Within Groups	663.96	26	25.54		
	Total	677.17	28			
B1_Total	Between Groups	12.32	2	6.16	.826	.449
	Within Groups	193.82	26	7.45		
	Total	206.14	28			
B2_Total	Between Groups	2.77	2	1.39	.319	.730
	Within Groups	113.02	26	4.35		
	Total	115.79	28			
B3_Total	Between Groups	3.14	2	1.57	1.026	.372
	Within Groups	39.82	26	1.53		
	Total	42.97	28			
B4_Total	Between Groups	4.00	2	2.00	.917	.412
	Within Groups	56.76	26	2.18		
	Total	60.76	28			
B5_Total	Between Groups	2.32	2	1.16	.236	.792
	Within Groups	127.82	26	4.92		
	Total	130.14	28			
B6_Total	Between Groups	34.06	2	17.03	1.191	.320

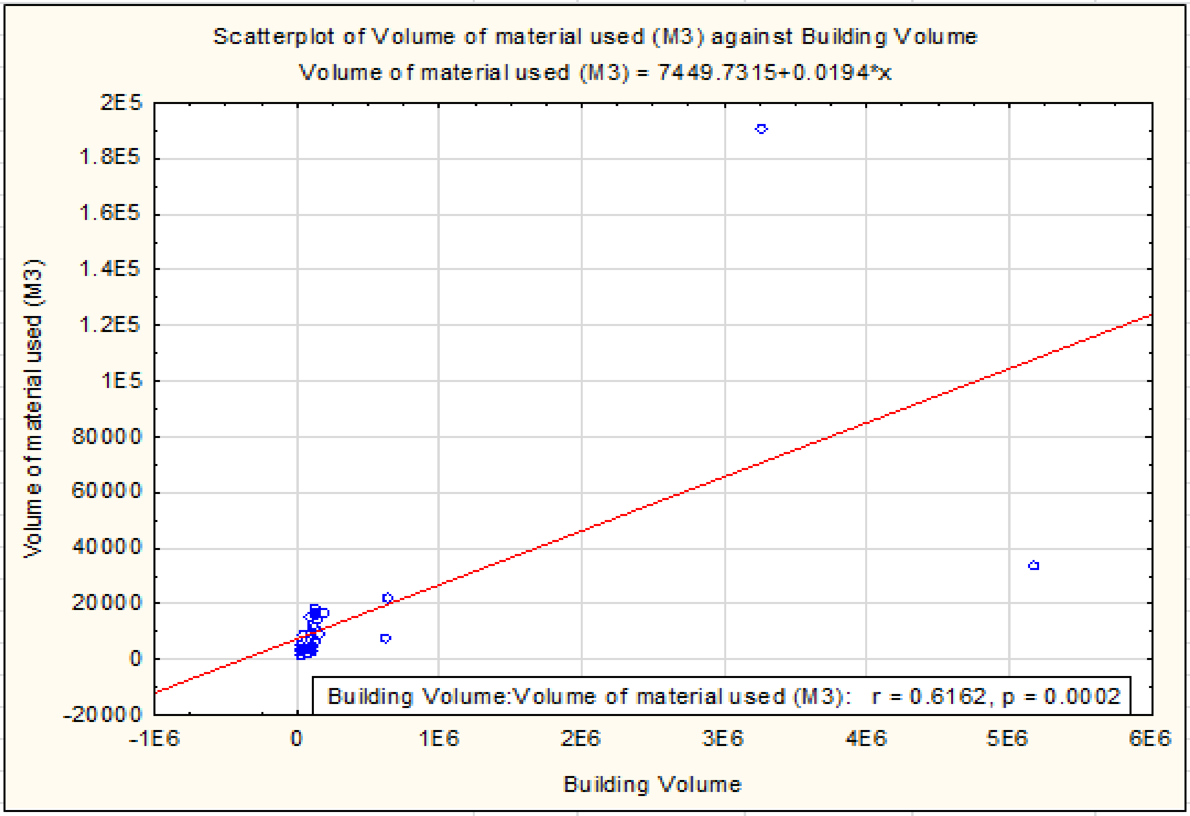
	Within Groups	371.73	26	14.30		
	Total	405.79	28			
B7_Total	Between Groups	27.77	2	13.89	1.228	.309
	Within Groups	294.09	26	11.31		
	Total	321.86	28			
C1_Total	Between Groups	4.77	2	2.39	1.265	.299
	Within Groups	49.02	26	1.89		
	Total	53.79	28			
C2_Total	Between Groups	6.86	2	3.43	2.883	.074
	Within Groups	30.93	26	1.19		
	Total	37.79	28			
C3_Total	Between Groups	1.28	2	0.64	.938	.404
	Within Groups	17.69	26	0.68		
	Total	18.97	28			
D1_Total	Between Groups	1.18	2	0.59	.448	.644
	Within Groups	34.13	26	1.31		
	Total	35.31	28			

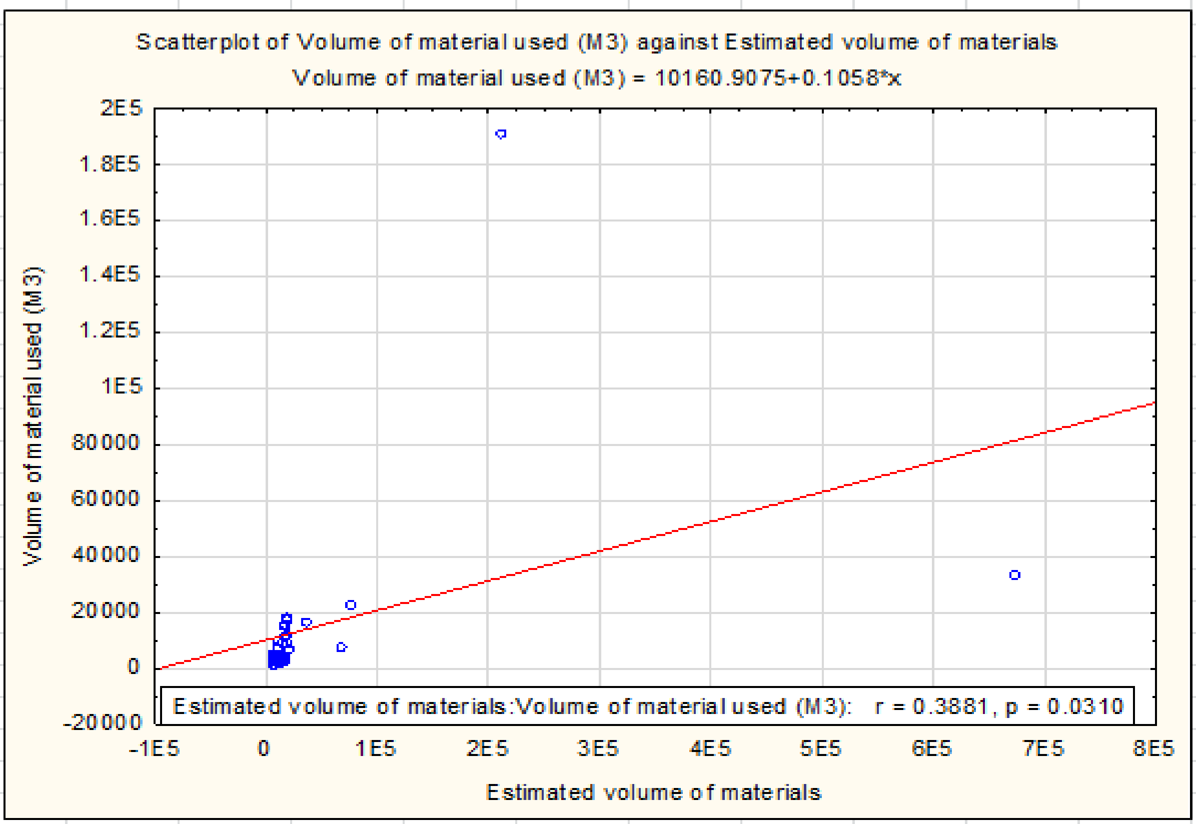
Results of Regression and Correlation Analyses

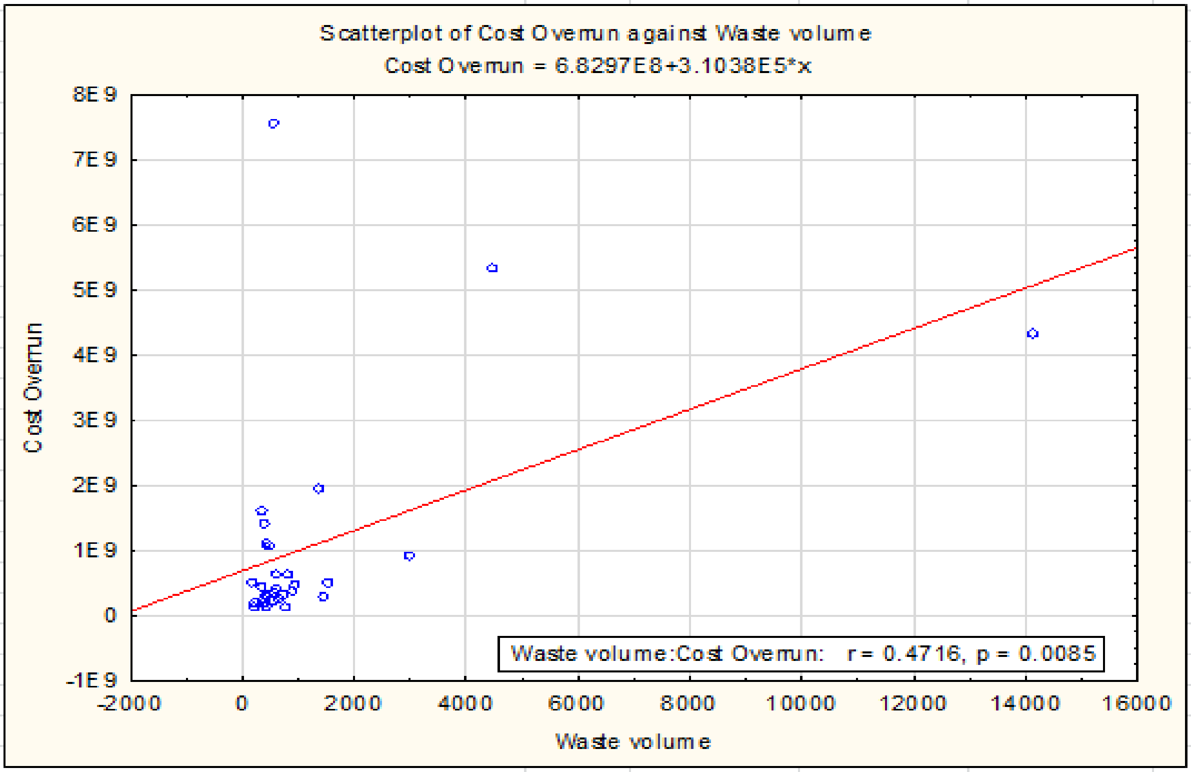


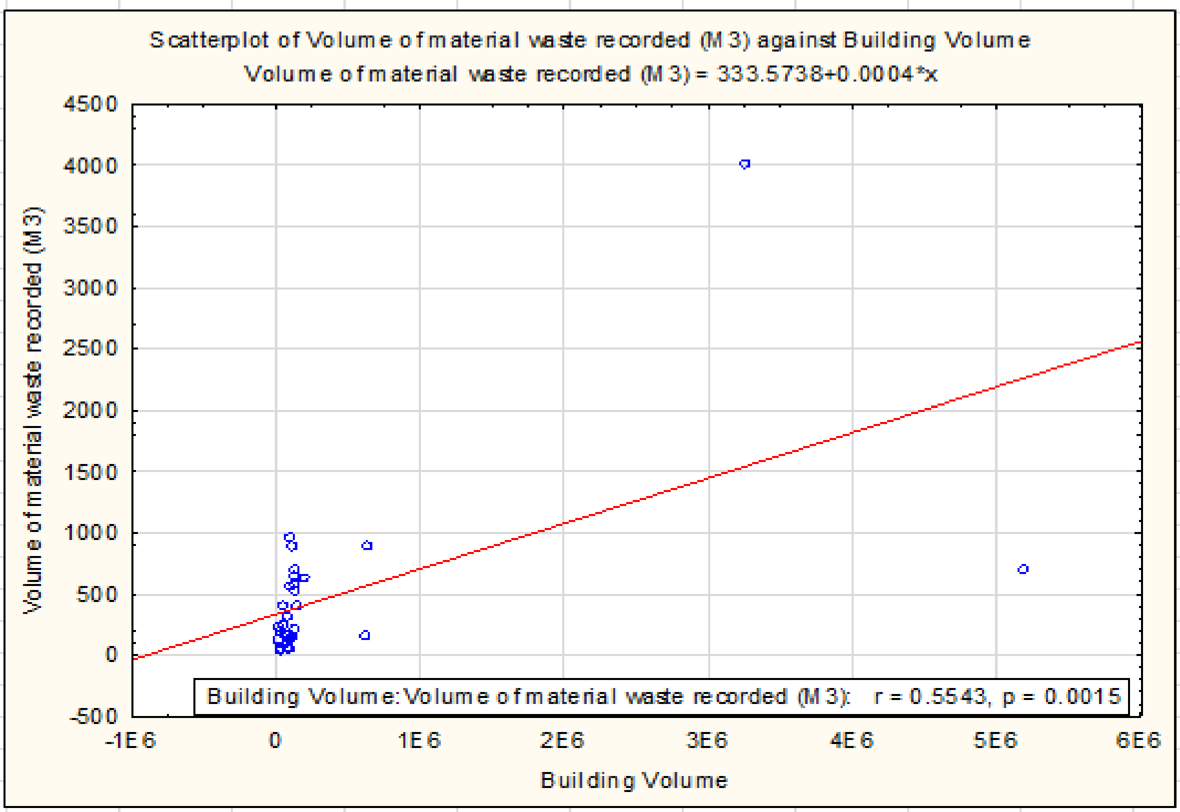

Scatterplot of 100% Volume of waste against Building Volume
100% Volume of waste = 361.9173+0.0023*x
Building Volume:100% Volume of waste: r = 0.9520, p = 0.0000
100% Volume of waste
Building Volume
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-1E6
0
1E6
2E6
3E6
4E6
5E6
6E6

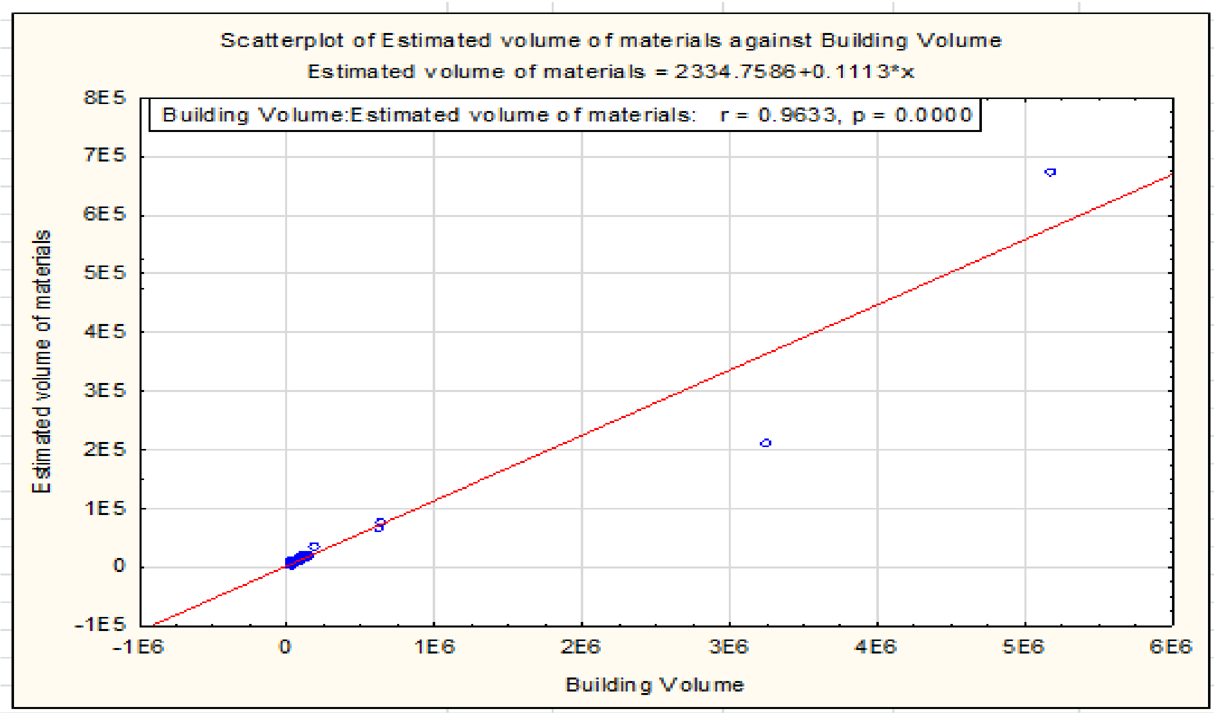

Scatterplot of Waste volume against Estimated volume of materials
Waste volume = 309.4626+0.0206*x
Estimated volume of materials:Waste volume: r = 0.9929, p = 0.0000
Waste volume
Estimated volume of materials
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
-1E5
0
1E5
2E5
3E5
4E5
5E5
6E5
7E5
8E5


Scatterplot of Volume of material used (M3) against Building Volume
Volume of material used (M3) = 7449.7315+0.0194*x
Building Volume:Volume of material used (M3): r = 0.6162, p = 0.0002
Volume of material used (M3)
Building Volume
2E5
1.8E5
1.6E5
1.4E5
1.2E5
1E5
80000
60000
40000
20000
0
-20000
-1E6
0
1E6
2E6
3E6
4E6
5E6
6E6


Scatterplot of Volume of material used (M3) against Estimated volume of materials
Volume of material used (M3) = 10160.9075+0.1058*x
Estimated volume of materials:Volume of material used (M3): r = 0.3881, p = 0.0310
Volume of material used (M3)
Estimated volume of materials
2E5
1.8E5
1.6E5
1.4E5
1.2E5
1E5
80000
60000
40000
20000
0
-20000
-1E5
0
1E5
2E5
3E5
4E5
5E5
6E5
7E5
8E5


Scatterplot of Cost Overrun against Waste volume
Cost Overrun = 6.8297E8+3.1038E5*x
8E9
7E9
6E9
5E9
4E9
3E9
2E9
1E9
0
-1E9
Cost Overrun
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
Waste volume
Waste volume:Cost Overrun: r = 0.4716, p = 0.0085


Scatterplot of Volume of material waste recorded (M3) against Building Volume
Volume of material waste recorded (M3) = 333.5738+0.0004*x
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Volume of material waste recorded (M3)
-1E6
0
1E6
2E6
3E6
4E6
5E6
6E6
Building Volume
Building Volume:Volume of material waste recorded (M3): r = 0.5543, p = 0.0015



Scatterplot of Estimated volume of materials against Building Volume
Estimated volume of materials = 2334.7586+0.1113*x
Building Volume:Estimated volume of materials: r = 0.9633, p = 0.0000
Estimated volume of materials
8E5
7E5
6E5
5E5
4E5
3E5
2E5
1E5
0
-1E5
-1E6
0
1E6
2E6
3E6
4E6
5E6
6E6
Building Volume