UNIVERSITY OF THE WITWATERSRAND

WASTE MANAGEMENT STRATEGIES EMPLOYED ON CONSTRUCTION SITES IN GAUTENG

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A research report submitted to the Faculty of Engineering and the Built Environment, of the University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the MSc. (Building) in Construction Project Management

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SCHOOL OF CONSTRUCTION ECONOMICS & MANAGEMENT

DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the MSc. (Building) in Construction Project Management to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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ABSTRACT

There is a problem of construction waste on construction sites. However, there are various strategies that can be employed; not only on construction sites, but generally on construction projects from the inception of the project to manage construction waste more effectively. Construction waste management can loosely be defined as a function of controlling waste on construction projects to limit its generation and disposal but enhance reduce and recycling. Construction waste mainly arises from design changes, poor choice of construction materials, improper material specifications, inappropriate strategies employed or wrong strategies implemented; leading to poor management of waste on construction projects. Construction waste can be 'physical' or 'non-physical'.

Physical construction waste refers to tangible solid waste of materials emanating from construction activities. Non-physical waste pertains to waste of time and project funds in the form of unnecessary expenditure. The aim of this study is to identify waste management strategies utilized on construction sites in Gauteng. Pertinent literature provided a basis of the study. A cross-sectional survey using three construction sites in Gauteng: an office building project, a road project and a civil works project was adopted. The most common strategies were found to be –proper selection of construction materials, proper planning and logical sequencing of construction work activities on a project. There is a variety of branded materials hence the need for proper selection of materials. Further, there are a lot of factors that influence the flow of work activities hence the requirement to keep track and plan activities accordingly to counter distortions. It is acknowledged that strategies found to be common in Gauteng are basic techniques in controlling construction waste generation and the results tied back to the literature.

It was established that technological tools like Building Information Modeling are not yet common in Gauteng. Improvements on usage of prefabricated components and offsite manufacturing of components is recommended to stakeholders of the construction industry. It is also logical to conclude that waste management strategies employed on construction sites in Gauteng are anchored on factors of economic viability and government policies. In their quest to make projects profitable and in their efforts to make construction projects compliant to regulations, as a result, construction contractors achieve reductions in waste generation on construction projects. Therefore what the study found out are mainly practices that could, in addition to achieving primary aim, contribute to waste reduction. These strategies identified are

implemented primarily to achieve time, cost and quality objectives and thus indirectly waste reduction.

DEDICATION

I dedicate this dissertation to the School of Construction Economics and Management of the University of Witwatersrand.

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Undertaking this research work has been a truly memorable experience for me and it would not have been possible to do without the support and guidance that I received from others.

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LIST OF ACRONYMS

AIA	American Institute of Architects
BIM	Building Information Modelling
CEM	Construction Economics and Management
CIDB	Construction Industry Development Board
CSIR	Council for Scientific and Industrial Research
CWM	Construction Waste Management
EMS	Environmental Management Systems
EPA	Environmental Protection Agency (USA)
MBO	Management by Objectives
MSW	Municipal Solid Waste
RSA	Republic of South Africa
UK	United Kingdom
UNEP	United Nations Environment Programme
UNITAR	United Nations Institute for Training and Research
USA	United States of America
WMH	Waste Management Hierarchy
WMP	Waste Management Plan
WP	Waste Management

LIST OF ABBREVIATIONS

Dr.	Doctor
ed.	Edition
et al.	et alia (and others)
Fig.	Figure
No.	Number
n.d.	No date
Pg.	Page
Prof.	Professor
3Rs	Reduce, Reuse, Recycle

TABLE OF DEFINITIONS

Construction waste: The Environment Protection Department - Government of the Hong Kong Special Administrative Region (2015) define Construction Waste as any matter which is generated as a result of construction work and abandoned. Quite often, this matter is a mixture of surplus materials arising from site clearance, excavation, construction, refurbishment, renovation, demolition and road works. Such waste as scrap, spoiled materials, temporary and false work materials that are not included in the finished project, packaging materials and waste generated by the workforce also constitute construction waste.

Disposal: Disposal is the final stage of waste management. It involves activities aimed at the systematic disposal of waste materials in locations such as landfills or waste-to-energy facilities (LeBlanc, 2017). Therefore, disposal refers to final deposition of waste in a solid waste disposal facility.

MBO: Management by Objectives (MBO) is a personnel management technique where managers and employees work together to set, record and monitor goals for a specific period of time. (Grimsley, 2015)

Recycle: Construction Waste Recycling (2017) define recycling as the separation and recycling of recoverable waste materials generated during construction and remodeling them to usable products. Material packaging, material scraps, old materials and debris all constitute potentially recoverable materials. According to Napier (2016), the term "Recycle" refers to the introduction of waste materials into some process of remanufacture into a new product. These new products can be the same, similar or completely different from the original product. Waste is managed in order to get materials out of it!

Reduce: In this context, waste reduction refers to the minimisation of the generation of waste. Some construction-related waste can be minimized. For example, Napier (2016) stated that construction materials can be selected on the basis of being designed and manufactured to be transported with minimal packaging.

Reuse: Napier (2016) stated that reuse refers to the subsequent use of a material, product or component upon salvage: some materials can be reused. Reuse is therefore the recovery of components, products or materials and reusing them for the same or similar purposes as their original use. For example, old doors and windows frames from demolished buildings can be donated or sold for beneficial reuse on other projects.

Waste Management: LeBlanc (2017) define Waste Management as the discipline associated with the control of generation, storage, collection, processing or disposal of waste in a way that best addresses the range of public health, conservation, economics, aesthetics, engineering and other environmental considerations. Waste Management therefore involves elimination of waste, minimizing waste, recycling waste, reusing materials and/or disposal of waste. Objectives for construction waste management are to reduce the generation and disposal of construction waste, to maximize reuse and recycling and to avoid and minimize construction waste through better design and construction methods.

Waste Management Hierarchy: Waste Management Hierarchy is a concept in recognition that no single waste management approach is suitable for managing all materials and waste streams in all circumstances (Environmental Protection Agency, 2017). The hierarchy ranks various waste management strategies from most to least environmentally desirable - reducing, reusing, and recycling. Effective and responsible solid waste management practices are heavily aligned with the reduction, recycling, and reuse of wastes as essential for sustainable management of resources.

Waste Elimination: Some waste generated in the process of construction can be eliminated. According to Napier (2016) durable modular metal form systems and false work materials used in construction can be selected on the basis of being readily demountable and reusable on other projects, thus eliminating waste associated with formwork materials.

Waste Minimization (Reduce): Some building-related waste can be minimized for example by selecting standard materials and components that will not require cutting on site and by adopting construction methods that will minimize generation of waste (Napier, 2016).

1 INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

Ismam and Ismail (2014) posit that waste management involves integrated, comprehensive and systematic approaches aimed at rational achievement and maintenance of acceptable environmental quality and support of sustainable development. Therefore, to achieve effective waste management programmes in the construction industry, strategies as means to this end, need to be developed.

Behm (2008) stated that construction is a large, dynamic, and complex industry sector that transforms various resources into built physical, social and economic infrastructure that plays an important role in any country's socio-economic development. The same author stated that construction workers and employers build roads, houses, office blocks, hotels, malls and repair and maintain physical infrastructure. Thus, construction work can involve such activities as land clearing and preparation of sites for new construction, building of new structures, rehabilitation, renovations, additions, alterations, maintenance, repair of buildings or engineering projects like highways and utility systems.

Zutshi and Creed (2015) stated that virtually all other sectors of the economy largely depend on the construction industry through both backward and forward linkages. Individuals and organizations require products of the construction industry, that is, the built environment, for a full range of social and industrial activities but there is still a need for the natural environment to support and sustain the built environment.

Gauteng is one of the nine provinces of the Republic of South Africa. It is where the greater Johannesburg, the economic hub of the country; and Pretoria, the capital city are located. The province is the economic epicenter of the country and there is always some construction work going on within the province at any given time. For this reason, additional to proximity and ease of access to construction sites within this area, Gauteng was chosen for this study. The province has been selected for a cross-sectional survey research to determine waste management strategies that are employed on construction sites and how appropriate they are so as to establish possible improvements that can be implemented to better address the problem.

1.2 BACKGROUND

Construction activities in Gauteng; as is the case generally throughout the whole country and the developing world at large, lead to a problem of creation of construction waste through demolition, land-clearing and disposal of excess materials which quite often end up in landfills. However, specific strategies can be employed on construction projects to better address or harness waste creation and the allied effects. Integrating and embracing construction waste management in the construction process yields a win-win situation to the project and the environment by simultaneously reducing waste generation and attainment of sustainable goals.

Chandrappa and Das (2012) define waste as unwanted material at the point of generation, which does not have immediate use. Numerous waste generation activities - including construction operations - on one hand and poor waste management methodologies on the other, lead to much waste being disposed of in authorized and unauthorized public spaces causing harm to the environment and the inhabitants as a result.

Waste occurs within the lifecycle of buildings and infrastructural units, during construction, modification and demolition phases (Esin and Cosgun, 2007). Pires et al. (2011) stated that sustainable management of solid waste has become necessary at all phases from planning to design through operation and decommissioning. As a consequence, the spectrum of new and existing waste management strategies and treatment technologies has also spanned from maintaining environmental quality at present to meet sustainability goals in the future. According to the same source, such an orderly evolution promotes the need to seek more socially acceptable options of waste control in waste generating industries like the construction industry.

Lost production time, unnecessary expenditure and wasted materials on projects are all considered to be construction waste (Nagapan et al., 2012). The same authors refer to the first two as non-physical waste. Material waste is referred to as physical waste, which is what this study intends to investigate. Turan et al. (2009) contend that problems associated with solid waste are difficult to address, but efforts towards more effective and efficient waste management continue in many countries and cities around the world.

Udawattaa et al. (2015) in their study to determine effective approaches to eliminate and/or minimize waste generation in construction projects state that construction waste generation has been identified as one of the major issues in the construction industry due to its direct impact upon the environment as well as on the efficiency of the construction industry. The authors further argue that as the industry cannot continue to practice if the environmental resources on which it depends are depleted, it is therefore of paramount importance for waste management to be understood in order to encourage stakeholders to achieve related goals. In their study, the authors call for the need to address technical and human aspects in construction waste management strategies so as to improve performance and success of these activities.

Several factors collectively combine to influence selection of appropriate waste management strategies for a particular scenario, all of which have an influence on the waste handling and disposal options. These factors include, among others; affordability in terms of capital and operational costs; accessibility with respect to road infrastructure and conditions; availability of sustainable on-site storage facilities and a plethora of legal, technical and economic considerations. Further, these factors largely vary with the type of waste. Construction waste predominantly consists of inert material such as rubble and other bulky debris. This waste is often considered to be more of an aesthetic and environmental issue than a public health problem (CSIR Building and Construction Technology, 2005).

There are various strategies for dealing with construction waste. Scientific studies have established that these strategies could lead to roughly between twenty-five and forty percent reduction in solid waste on construction sites (Nagapan et al., 2012). The most economically acceptable approaches being minimizing and converting construction waste like demolition debris and land-clearing debris from disposal and redirecting recyclable material back into the construction process. This practice is commonly called construction waste management (AIA, 2008).

Huge volumes of solid waste are produced every year from construction and demolition activities making construction a leading source of solid waste in many countries and cities (Tam et al., 2006). The same authors stated that increasing generation of these wastes has led to a significant impact on the environment and has since escalated to be a major public concern. As such, minimization of construction waste has become a pressing issue. Tam et al. (2006) identified six major reasons for excessive construction waste - cutting components on site; over-ordering; damage to material and components during transportation; loss during installation; poor workmanship and design or specification changes.

The construction industry in South Africa, including Gauteng, is characterized by a considerable component of labour content and labour subcontracting in line with empowerment, employment creation and poverty alleviation policies. According to Tam et al. (2006), labour-intensive practices are generally criticized for poor safety records, delays and unacceptable levels of quality failures. According to the same author, factory production, that is prefabrication; can reduce waste and encourage recycling of construction waste, ultimately leading to a reduction of environmental contamination and sustainability of the construction industry.

Wang et al. (2015) in their study to identify the best design strategies for construction waste minimization found that the use of prefabricated components exerts the largest influence on waste reduction, followed by few design modifications during construction and investments on waste reduction. This sentiment was previously highlighted by Baldwin et al. (2008). Specifying usage of prefabricated components in the design reduces waste generation during the construction stage. Zutshi and Creed (2015) emphasized that there is a need to incorporate sensitivity in design and wise utilization of materials during construction to prevent unnecessary degradation. However, Baldwin et al. (2009) and Poon and Jaillon (2009) argue that standardization is a pre-requisite for usage of prefabricated components otherwise prefabricating alone cannot win the battle against waste generation on construction projects.

A design that fully considers ahead of time every detail of the actual construction process efficiently prevents unnecessary material waste (Wang et al., 2015). The same authors further stated that it is important to keep design changes during construction to a minimum while at the same time investing in waste reduction methods like implementing training programmes to improve workforce awareness in order to reduce waste on construction sites. It would be interesting to know the extent of any such programmes in Gauteng.

Ding et al. (2016) stated that effective construction waste management is of prime significance for future sustainable development. Waste generated from construction activities can have many negative impacts on the environment if not properly managed. These authors found source reduction to be an effective waste reduction strategy and sorting construction waste to be vital in construction waste recycling and reuse. It has been mentioned that attention should be paid to source reduction methods such as low waste technologies and on-site management in order to achieve better environmental performance of the construction waste reduction strategies. It would be interesting to identify the extent of waste sorting on construction sites in Gauteng and what happens to this waste.

Ding et al. (2016) also stated that the most common and traditional solution for construction waste in a lot of places worldwide is landfilling. However, the authors acknowledge based on prior studies, that the strategy of landfilling consumes a lot of land resources and it has been difficult to meet the demands for landfilling in many countries and cities. Waste on landfills causes harmful effects on the environment especially if not properly managed, thus, waste management has become an urgent issue for the industry and the government. It has also been noted that a larger component of construction waste is solid matter therefore if landfilling is the sole strategy employed to deal with waste, a huge amount of land will be occupied and soil will be polluted.

A study by Peng et al. (1997) to examine the strategies of diverting from landfilling to recycling found that it is still a challenge, around the world, to establish a successful construction waste recycling operation because markets for secondary materials have not yet matured. Implementing robust ways of construction waste minimization by design has a significant contribution in avoiding construction waste at source (Lia et al., 2015). Commercial recycling operations require excessive capital investments; resultant products are deemed to be of poor quality hence low demand leading to collapse of recycling operations in most cases (Peng et al., 1997).

Construction and demolition waste is unavoidable and zero waste is unlikely (Ghiani et al., 2014). According to Shen and Yuan (2010) research pursuing solutions to minimize the generation of such waste has been conducted in the past few decades to find solutions to avoid loss of resources and to protect the environment. In line with these developments, a waste management method hierarchy has been well established, comprising strategies for dealing with waste.

Peng et al. (1997) developed a hierarchy of construction and demolition waste disposal. These possibilities for disposing of waste from construction and demolition activities are: Reduce, Reuse, Recycle, Compost, Incinerate and Landfill. The hierarchy is based on minimization of both resource consumption and environmental damage. The waste management strategies in the hierarchy are arranged in ascending order of their adverse impacts to the environment from low to high (Lu and Yuan, 2011). Reducing waste yields the greatest environmental benefits (Abdelhamib, 2014). Reduction is considered the most effective and efficient method for minimizing the generation of waste and eliminating waste disposal problems followed by reuse (Lu and Yuan, 2011). Landfilling is the most undesirable strategy because of its high adverse impacts to the environment.

Lu and Yuan (2011) noted various solutions for reducing waste. These included reducing waste through government legislation; reducing waste by design; developing an effective waste management system; use of low waste technologies. It would be interesting to know to what extent improving practitioners' attitudes towards waste reduction could be an effective strategy in Gauteng. These factors form the subtlest strategies towards which construction waste management has been driven forward in recent years. Further, the construction industry seems to be taking measures towards reducing waste generation at source by embedding and re-emphasizing the thought right from the design stage of construction projects.

Among some of their findings, Udawattaa et al. (2015) established that reinforcing legislation and regulation relating to construction waste management could help enhance waste management performance on construction projects. Implementation of monitoring methods to reinforce legislative tools to check and embed compliance to effective waste management practices were found to be very relevant. However, collaborative effort should be encouraged so that reduction, reuse and recycling methods are embraced in the industry. Legislative and punitive measures seem to make more sense but landfill processes still seem to be more prevalent.

Construction waste presents a significant challenge to the sustainable development in the context of rapid urbanization. This calls for construction waste management to be implemented at different levels of project development right from the design phase (Lia et al., 2015). The same author found that the designers' attitude and perceived behavioral control have a positive and significant effect on their attitude towards waste minimization. This therefore requires policy changes to facilitate waste minimization in the design process.

Chikezirim and Mwanaumo (2013) in their study to evaluate waste management strategies adopted in Tshwane building industry found that minimization and disposal of construction wastes has become one of the most pressing construction and environmental issues in recent years. It has been found, on a local scene, that the disposal of waste can have a significant negative impact on the environment as total volume of available landfill sites is decreasing and costs associated with waste handling are increasing.

The release of the international standard for environmental management ISO 14001 in 1996, and its subsequent amendments (ISO 14001, 2004; BSI, 2013 and Briggs, 2012), have resulted in wider acceptance of Environmental Management Systems (EMS) across various industrial sectors (Zutshi and Creed, 2015). Many municipal authorities in Sub-Saharan Africa due to inadequate revenue from their local tax base fail to implement waste management techniques that are compatible with their environmental, social and economic contexts. As such, rigorous evaluation of all waste management options and strategies need to be implemented (Oteng-Ababio et al., 2013). Further, Turan et al. (2009) mentioned that there is a requirement for strengthened environmental mechanisms, efforts and cooperation between both public and private to achieve environmental reform.

Construction waste management is vital for sustainable development in order to help address issues related to the environment, social and economic problems for the benefit of the world for a better future (Nagapan et al., 2012). Saez et al. (2013) postulated that construction industry stakeholders have a wide range of best practices in construction waste management that can be implemented. These aforementioned strategies, like for example, reducing waste by design; reducing waste by prefabrication; reuse and recycling materials should be enforced and reassessed for effectiveness and continuous improvement to protect the environment. Wagner and Arnold (2008) emphasized that the traditional method of landfilling has short term economic advantages and landfills contains recoverable materials that are lost.

Landfilling normally goes unchecked when there is substantially more undeveloped land available which can make land disposal less expensive (Wagner and Arnold, 2008). Often though, undeveloped land is scarce hence landfilling is not a favorable option in most cities, including the area under study – Gauteng. There are some landfill sites within Gauteng for example Marie Louise Landfill in Roodepoort and Robinson Deep Landfill in Turffontein where building contractors can dump building rubble and soil for free. Cities have become important drivers in promoting strategies for sustainable development since the evolution of infrastructure (Guerra et al., 2016). It has been noted that currently cities are responsible for major environmental offences: air pollution, water contamination, degradation of natural resources, and excessive consumption of fossil fuels and devastation of forests (Guerra et al., 2016).

The construction industry has always been a major producer of material waste (Baldwin et al., 2009; Poon 2007). Construction waste generation is dynamic; therefore, predicting waste levels in advance is not easy. The most effective method of reducing environmental impact of construction waste is by primarily preventing its generation or reducing it as much as possible. If waste generation could not be prevented or only prevented to a certain degree, the next step should be to ensure that construction waste is reused and recycled as much as possible (Esin and Cosgun, 2007; Poon 2005).

Solid waste is a valuable resource offering several social, economic, environmental and technological benefits (Potdar et al., 2015). The growing stream of waste requires a sustainable waste management strategy (Jamasb and Nepal, 2010). Yet, by reviewing the waste management experience of some cities for the past few decades, it is perceived that radical changes are needed to render the waste management system more sustainable (Chung and Poon, 1998). It has been noted that proper waste management generally yield some economic, social and environmental benefits – valuable resources are recovered, health risks lessened and environmental degradation avoided.

1.3 PROBLEM FORMULATION OR PROBLEM IDENTIFICATION

Nagapan et al. (2012) pointed out that construction waste is a problem in many developing countries considering adverse effects on environment, economy and social aspects. This assertion has been echoed by various authors as stated in the literature review. Other problems of waste management failures like increasing project costs and loss of valuable materials were also pointed out in the literature review. It has been observed that it is common on construction projects that non-physical waste like cost and time overruns are not properly addressed among the construction players but still these two parameters (time and cost) together with safety in recent years are given more attention ahead of waste management. It is against this background that it is found imperative to emphasize waste management practices on construction projects and construction sites. Waste is a loss. It has to be managed!

1.4 PROBLEM STATEMENT

The construction industry draws its resources from the natural environment. As such, wastage of materials on construction sites has to be controlled to achieve sustainability goals. Construction waste means that valuable resources are lost leading to economic losses and unwarranted additional demand from the natural bodies. Funders of construction projects, constructors, clients and other relevant stakeholders need effective and efficient construction waste management strategies so that no unnecessary resources and finances are lost. There is a need to promote profitability of construction projects, sustainable development and environmental protection in Gauteng and the world over through dealing with and controlling waste effectively on construction sites. It is very needy to emphasize on waste management practices so that this is not merely imbedded in time, cost, quality, and safety objectives; but as a standalone goal.

1.5 RESEARCH QUESTIONS

The study focuses on identifying construction waste management strategies employed on construction sites in Gauteng given quite a plethora of these strategies in use the world over.

Further, the effectiveness of these strategies employed will be investigated so as to identify appropriate strategies that should be implemented in order to curb the problem of construction waste in a better way. Specific questions are:

a) What construction waste management strategies are employed on construction sites in Gauteng?

b) How effective are waste management strategies employed on construction sites in Gauteng?

1.6 HYPOTHESIS

Prefabrication and off-site manufacturing of construction components is believed to be the most common waste management strategy employed on three construction sites in Gauteng that are used in this study.

1.7 RESEARCH AIM AND OBJECTIVES

1.7.1 AIM

The aim of this study is to identify waste management strategies common on construction sites in Gauteng in light of sustainable and preferred methods world-wide that effectively reduces waste generation and/or disposal from construction activities.

1.7.2 OBJECTIVES

(a) Identify waste management strategies used in Gauteng;

(b) Highlight the pros and cons of various construction waste management strategies employed on construction sites in Gauteng;

(c) Recommend favorable waste management strategies that can be implemented in the context of construction sites in Gauteng.

1.8 SIGNIFICANCE OF THE STUDY

The findings of this study will contribute to the benefit of the construction industry in light of the fact that waste management on construction is not given the same level of attention given to time, cost and quality and safety objectives. Construction stakeholders in Gauteng and beyond are enlightened on what construction waste management strategies to employ on construction sites so as to better address the problem of construction waste. As mentioned in the literature, construction waste on construction sites leads to socio-economic and environmental issues, for example, additional funding that could have been avoided, depletion of natural resources and environmental degradation. Establishing strategies that could address such problems effectively is imperative. This study also helped the researcher to understand the underlying issues with respect to waste management on construction sites. Construction management is quite often imbedded in time, cost, quality and safety objectives and not dealt with as a separate goal.

1.9 SCOPE AND LIMITATIONS

This study is based on identifying waste management strategies employed on construction sites in Gauteng. It follows that the study is anchored on management of construction waste specifically on construction sites in Gauteng. Data was collected from three construction sites from different disciples of building, roads and civil works in a snapshot survey.

Limitations are influences that the researcher cannot control. They are the constraints or shortcomings, conditions or influences that cannot be controlled by the researcher that place restrictions on research design, research methods and subsequently research findings and conclusions (Bhattacherjee, 2012).

Limitations to this study have been split to three groups, that is, relating to the study, the researcher and to the participants. Pertaining to the study itself, there has been an inevitable problem of verifying data. Data supplied by subjects cannot be independently verified. The researcher has to take what respondents mentioned in completed questionnaires at face value. It is believed though that the implications of this limitation were not major looking at the targeted sample of participants who are actually expected to be experienced and knowledgeable on the subject matter. Further, generalizability of findings from three construction sites to the entire province of Gauteng or the whole construction industry may not be appropriate. However, an in-depth insight regarding waste management strategies employed on construction sites in Gauteng has been developed.

The researcher also had a problem of response rate. Returned completed questionnaires were fewer than what was expected. However, this research was not based on the quantity of questionnaires returned or number of respondents involved but rather the quality of data collected. For this reason, though, it is believed that collected data is valid.

1.10 KEY ASSUMPTIONS

Key assumptions that the researcher adopted in putting together this research report are mentioned below;

- Minimization of the generation of waste on construction sites – Reduction – is the most preferred method of waste management;
- There is reluctance in utilization of recycled materials by construction stakeholders, right from the client, designers and the constructors, and;
- Findings from three constructions sites used for the study can be generalized for the whole of Gauteng.

1.11 OUTLINE OF THE METHODOLOGY

This study adopted an interpretive philosophy aimed at theory building or contributing to the body of knowledge. A cross-sectional survey strategy has been utilized for this explanatory study. Three construction sites formed the broader population of the study and questionnaires were sent to specific management personnel of these sites; that is, project managers, contract managers, site agents, production supervisors, for data collection. Participant observation data collection method was utilized in one of the sites to enrich data collected. Data was analyzed qualitatively and open coding techniques used to help with the analysis and referencing of items.

1.12 OUTLINE OF THE REPORT

The structure of this research report comprises of separate sections, namely – the preliminary material, body of the report and the supplementary section. The first part of the preliminary material includes the title of the report, a declaration, abstract, dedication and acknowledgments. The second part of the preliminary material includes a table of contents, list of figures, list of tables, list of graphs, list of symbols, list of acronyms, list of abbreviations; where lists of descriptions of components of the report and corresponding page numbers are given. The body of the report consists of six chapters, which are briefly described below. The last section of the report comprise of supplementary materials - list of references and the appendices.

Chapter 1 is the introduction of the report. The purpose of the chapter is to familiarize the reader with the topic under study. Broad background information concerning the problem of waste on construction sites and projects is discussed in this chapter. Aspects of problem formulation, problem statement, research questions, hypothesis, aims and objectives of the study, significance of the study, scope and limitations of the study, key assumptions, brief outline of the methodology and this outline of the full report also form part of Chapter 1.

The second chapter of the report covers the literature review. Elaborate literature around the topic of construction waste management and strategies that are employed to curb the problem is critically reviewed. It is acknowledged that not all the literature was covered but quite a number of journals and other sources have been utilized. The introduction and purpose of the literature review, waste management method hierarchy, factors affecting construction waste generation, construction waste management strategies, advantages and disadvantages of construction waste management as well as barriers to implementation of effective waste management comprise *Chapter 2* of the report.

Chapter 3 focuses on the research design and methods adopted in this study. A brief discussion on research philosophies and approaches is included in this chapter. A research design including a research strategy employed, research choice and time horizon are briefly outlined. Data collection techniques and procedures used in the study are explained. Further, issues of sampling techniques, credibility of research findings and ethical considerations form part of this chapter.

Research findings are presented in *Chapter 4.* Findings here refers to data collected through collection techniques and procedures employed in the field before analysis and interpretation of such data. Findings are not interpreted in this chapter but in the subsequent chapter. Chapter 5 is the discussion and analysis part of the report. A discussion on relevance of research results and how findings fits into existing research; analysis, explanations and implications of such findings in line with the research aim, objectives, subsequent answers to research questions and acceptance or rejection of the hypothesis are elaborated in *Chapter 5*.

The last chapter, *Chapter 6*, is the close of the body of the report. Key findings in brief and the general overview of the report are given in the last chapter. Conclusions, recommendations and areas of further research flowing form the study also form part of the last chapter.

1.13 CONCLUDING REMARKS

In light of the adverse consequences of increased construction waste in the last couple of decades, studies have been conducted to examine how to progressively and effectively minimize the generation of waste during construction and thus reduce associated adverse effects to the environment and increased costs on projects. Hence this study was meant to determine strategies employed in dealing with construction waste in Gauteng to check relevance of the same in line with modern systems and methods employed around the world in recent years. This particular study would add to the growing body of literature by presenting a review of waste management strategies employed on construction sites in Gauteng and recommend some options that can be utilized in the future.

2 CONSTRUCTION WASTE MANAGEMENT PRINCIPLES AND PRACTICES

2.1 INTRODUCTION AND PURPOSE OF LITERATURE REVIEW

This literature review investigates the issue of construction waste on construction projects from the perspective of strategies employed on sites to address the problem. Pertinent research findings from a plethora of sources relevant to waste management methods, strategies and techniques on the greater world outlook provided insights into trends and patterns through which attempts to deal with this problem have evolved. As a result, major concepts around the topic will be established.

This literature review provides an overview of the construction industry and its linkages to the economy, environment and the society. Factors leading to the generation of waste from construction activities, construction waste management strategies and advantages of effective waste management are critically reviewed so as to cover the important aspects of construction waste management as a basis for this particular study.

From the body of literature covering construction and demolition waste management, insights into strategies employed the world over prior to and during construction were established. Further, assessments of the effectiveness of various waste management strategies as presented by different authors from varying localities are important in identifying the advantages and drawbacks of each of the strategies.

Literature related to construction waste management is critically reviewed in order to develop a list of strategies adopted in managing construction waste on construction projects. As such, this literature review is also meant to shape and form the basis of a questionnaire design and structured questions that will be utilized in the data collection process of this study.

Construction is an important activity in any economy (Babatunde, 2012). Individuals and organizations require a built environment for the full range of social and industrial activities (Zutshi and Creed, 2015). The construction industry plays a significant role both in the infrastructure development and the economy of any country yet the construction industry is one of the major contributors of negative impacts to the environment. A comprehensive understanding of construction waste generation and management is required to reduce these negative impacts (Nagapan et al., 2012). Thus, this literature review will also showcase linkages between the construction industry and other sectors of the economy.

2.2 DESCRIPTION OF CONSTRUCTION WASTE

Construction activities are environmentally unfriendly (Behm, 2008; Lu et al., 2016; Yuan et al., 2012). Such activities as excavation operations, site clearance, site preparation, demolitions, road works, building renovations and alterations generate tremendous volumes of construction and demolition waste (Lu and Yuan, 2010; Tchobanoglous and Kreith, 2002). Whilst the construction industry significantly contributes to the economy of any country, construction activities have a negative impact on the natural environment. A huge amount of construction waste is generated during construction, which has huge negative impacts on the environment if not properly managed. Therefore, effective construction waste management is of primary importance for sustainable development (Ding et al., 2016; Guerra et al., 2016; Ismam and Ismail, 2014).

One of the major features of the construction process is the production of substantial volumes of waste (Zutshi and Creed, 2015). As mentioned, waste on construction projects leads to additional material costs leading to financial losses. However, effective management of construction waste provides an example of how material costs can be saved (UNEP; UNITAR, 2013). Construction waste or construction and demolition waste generally refers to solid waste generated in the construction sector. More specifically, the term is defined as that waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation (Shen and Yuan, 2010).

As a result of waste generation on construction sites, contractors often have to bear the loss of profit due to additional overhead costs, delays and drop in productivity levels because of additional time required for cleaning and waste disposal (Udawattaa et al., 2015). The same authors further posit that the construction industry cannot continue to practice if the environmental resources on which it depends are depleted, hence the need to harness loss of valuable materials on construction sites. Waste management practices can be implemented on construction projects and sites during the design, planning and construction phases to reduce this loss of valuable resources (Gangolells et al., 2014).

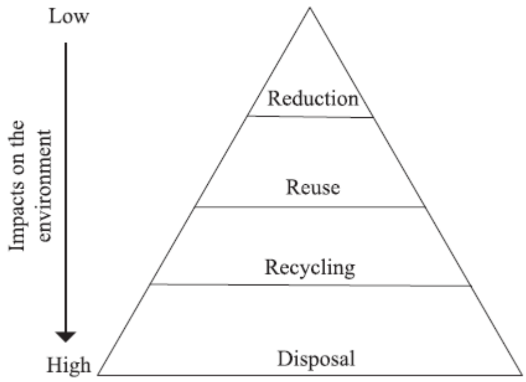
It is well known that construction activities improve the public facilities and the overall living environment in a number of ways. However, the construction industry has long been criticized as a main culprit in causing environmental degradation and associated environmental concerns worldwide through land depletion and deterioration, energy consumption, solid waste generation, dust and gas emission, noise pollution, and consumption of natural resources (Shen and Yuan, 2010; Duan et al., 2015; Yuan, 2013; Shen and Yuan, 2010; Poon and Jaillon, 2009).

Construction waste is now a serious problem in many countries and cities due to the amount of construction activities on one hand and poor waste management processes on the other. Construction activities not only consume a large amount of natural resources, materials and energy, but also generate unacceptable levels of solid waste (Yuan et al., 2012). Waste management strategies have to simultaneously achieve environmental, social and economic objectives. These are the three spheres of effective construction and demolition waste management (Yuan, 2013). Waste reduction; the most preferred effective and efficient method of dealing with waste, refers to the activities carried out in the phases of project design, planning and/or construction phases aimed at preventing the generation of waste (Yuan et al., 2012; Peng et al., 1997).

2.3 WASTE MANAGEMENT METHOD HIERARCHY

According to Peng et al. (1997), in line with these research developments, a waste management method hierarchy has been well established, comprising of four strategies (Fig. 2.1), namely, waste reduction, reuse, recycling, and disposal. The impacts from using the four strategies on the environment are in ascending order from low to high. The primary principles of the hierarchy are minimizing resource consumption and preventing environmental pollution; the two pillars of sustainability in construction. Peng et al. (1997) mentioned that the first three strategies (reduce, reuse, and recycle) in the waste management method hierarchy are well known as 3Rs of construction waste management, which has been used as basic principles for conducting waste management approaches.

Figure 2.1: Waste Management (WM) methods hierarchy



Source: Yuan and Shen, 2011:671.

Ding et al. (2016) stated that broadly construction waste reduction management is divided into two stages: measures such as on-site material management, personnel management and low-waste technologies should be adopted to reduce waste generation from initial planning stage. These measures are classified into source reduction, which actually involves minimizing waste generation before it is generated; and measures such as on-site sorting are adopted to reduce waste emissions after waste has been generated. Waste reduction should be the top priority in any waste management approach (Potdar et al., 2015; Abdelhamib, 2014; Jamasb and Nepal, 2010; Esin and Cosgun, 2007).

Table 2.1 below list waste management strategies regardless of the stage of project development. However, this study will focus mostly on strategies employed during the construction stage on construction sites.

Table 2.1: Waste management strategies

Item	Waste Management Strategies	Reference
(i)	Proper selection of materials	Poon and Jaillon, 2009
(ii)	Offsite manufacturing	Udawattaa et al., 2015 Gangolells et al., 2014
(iii)	Use information communication technologies packages like BIM for accurate quantity surveys	Udawattaa et al., 2015
(iv)	Implement proper onsite management systems e.g. proper stacking of materials, housekeeping etc.	Gangolells et al., 2014; Saez et al., 2013; Wang et al., 2015; Yuan, 2013;
(v)	Implementation and enforcement of policies and regulations	Wang et al., 2015; Lu and Yuan, 2010; Osmani et al., 2008;

Item	Waste Management Strategies	Reference
(vi)	Proper planning of construction activities (sequencing of activities)	Poon, 2007; Chung and Poon, 1998
(vii)	Drawing up and implementing Waste Management Plans	Wang et al., 2015; Lu and Yuan, 2010;
(viii)	Assign implementation responsibility for waste management to designated people	Wang et al., 2015; Lu and Yuan, 2010;
(ix)	Adequate supervision of waste management activities with clear instructions	Udawattaa et al., 2015; Osmani et al., 2008; Ghiani et al., 2014;
(x)	Training and education of stakeholders e.g. operators and laborers	Wang et al., 2015; Lu and Yuan, 2010; Osmani et al., 2008
(xi)	Financial rewards and incentives	Ghiani et al., 2014; Osmani et al., 2008;
(xii)	Enhance effective communication amongst project teams	Wang et al., 2015; Poon and Jaillon, 2009;
(xiii)	Organize regular meetings to check conformance and lessons learnt	Poon, 2007
(xvi)	Transparency in reporting so that corrective action can be taken when necessary	Udawattaa et al., 2015; Poon and Jaillon, 2009
(xvii)	Instill sense of collective responsibility and teamwork	Udawattaa et al., 2015; Gangolells et al., 2014
(xviii)	High level of collaboration and risk sharing	Udawattaa, et al., 2015; Osmani et al.,2008
(xix)	Relationship building among stakeholders	Udawattaa, et al., 2015; Yuan, 2012
(xx)	Low waste construction technologies to minimize waste generation	Chikezirim and Mwanaumo, 2013; Yuan, 2012;
(xxi)	Consider environmental aspects in design and tendering stages	Wang et al., 2015
(xxii)	Design for adaptability (design to suit environment or materials readily available)	Udawattaa et al., 2015; Poon and Jaillon, 2009;
(xxiii)	Proper design and construction documentation e.g. specifications	Udawattaa et al., 2015; Baldwin et al., 2008;
(xxiv)	Simplification of design	Ajayi, et al., 2017; Udawattaa et al., 2015; Wang et al., 2015
(xxv)	Standardize the design to suit available sizes of materials and components (i.e. dimensional coordination)	Li et al., 2015; Baldwin et al., 2008
(xxvi)	Incorporate waste management plans into design from beginning of project	Udawattaa et al., 2015
(xxvii)	Promoting prefabrication methods	Saez et al., 2013; Jaillon and Poon, 2009; Tam, et al., 2006
(xxviii)	Apply lean principles	Zhang et al., 2012
(xxix)	Reinforce legislation and regulation related construction waste management	Udawattaa et al., 2015; Baldwin et al., 2008;
(xxx)	Increase landfill charges	Jaillon and Poon, 2009
(xxxi)	Adoption of transparent environmental reporting	Udawattaa et al., 2015
(xxxii)	Enforce prequalification of contractors based on waste management generation	Udawattaa et al., 2015; Zhang et al., 2012
(xxxiii)	Develop markets for recycled products	Wang et al., 2015; Yuan, 2013
(xxxiv)	Understand attitudes and behaviors towards waste management	Osmani et al., 2008

Item	Waste Management Strategies	Reference
(xxxv)	Change attitudes and industry behaviors towards waste minimization	Osmani, et al., 2008
(xxxvi)	Encourage industry to promote suitable waste management practices	Lu and Yuan, 2011; Lu and Yuan, 2010
(xxxvii)	Whole lifecycle costing approaches in construction	Ajayi, et al., 2017; Udawattaa et al., 2015; Osmani et al., 2008;
(xxxviii)	Adequate knowledge of design interpretation by site management and personnel	Ajayi, et al., 2017
(xxxix)	Adequate knowledge of construction operation and sequence by designers in order to design out waste.	Ajayi, et al., 2017
(xl)	Contractual provisions in contract documents stating waste minimization as part of key project success factors	Ajayi, et al., 2017
(xli)	Strict adherence to project drawings,	Ajayi, et al., 2017
(xlii)	Engagement of all stakeholders in construction waste management (promote awareness)	Udawattaa et al., 2015; Poon, 2007;

2.4 FACTORS AFFECTING CONSTRUCTION WASTE GENERATION

There are a number of major factors that lead to construction waste generation. Nagapan et al. (2012) stated that wrong material storage, poor materials handling, poor quality of materials, ordering errors, mistakes in quantity surveys, poor attitudes of workers, poor supervision and lack of waste management plans influence the generation of waste on construction sites.

Yuan (2013) stated that these indicators encompass design changes, consideration of construction waste reduction in design, investment in construction waste management, formulation and implementation of waste management regulations, site space available for performing waste management, adoption of low-waste construction technologies, impacts of waste reduction cost, and waste management culture within an organization. Low waste construction technologies here refer to strategies pertaining to lean construction and balancing cut and fill in earthworks activities. Each of these indicators is expanded briefly.

2.4.1 DESIGN CHANGES

There is a general consensus amongst studies that design changes form one of the most significant sources of construction waste (Ekanayake and Ofori, 2004). According to Yuan (2013), changes to original designs normally cause waste in two ways. Firstly, if construction materials have already been purchased in line with the original design and cannot be resold or returned to the supplier. Secondly, if a structure has been constructed, any change in the design might result in part of the structure being demolished and such materials cannot be salvaged. The process of waste generation through project design is complex due to the usage of diverse of materials and the involvement of other stakeholders besides designers, such as clients and contractors (Osmani et al., 2008). Such complexity consequently results in that very few attempts are being made to minimize waste in design; this is probably the underlying barrier to effective operation of waste minimization in project design (Yuan, 2013).

2.4.2 CONSIDERATION OF CONSTRUCTION WASTE REDUCTION IN DESIGN

Consideration of construction waste reduction in design can largely affect waste generation in the construction stage. For instance, a study by Osmani et al. (2008) estimated that approximately more than a third of on-site waste is related directly or indirectly to project design. Further, there are some findings that construction and demolition waste generation in the construction stage would be minimized if proper waste reduction strategies and practices are taken into account in design, such as design for standard-sized building supplies (masonry blocks or dimension lumber length, windows, etc.), and adopting modular or prefabricated materials (Jaillon and Poon, 2009). Nevertheless, construction waste management is mostly not put to a priority in project design (Osmani et al., 2008). Thus, considering the potential of construction waste reduction in design is critical to the total amounts of waste generation in construction projects (Yuan, 2013; Li et al., 2015).

2.4.3 INVESTMENT IN CONSTRUCTION WASTE MANAGEMENT

Investment in construction waste management can help promote construction waste management practices in various ways, typically including purchasing equipment for waste management, developing and implementing waste management plans, motivating practitioners to minimize construction waste and continuously improving operatives’ skills on waste handling through vocational training (Yuan, 2013). This is backed by Osmani et al. (2008), who stated that financial reward was perceived to be a key incentive driving waste reduction during the project construction. Furthermore, significant amount of waste caused in various construction activities through poor workmanship, deformation during transportation and delivering could be largely reduced if operatives’ skills were improved through training. However, many industry practitioners are somehow reluctant to minimize construction and demolition waste simply because it meant higher investments. This indicates evidently how investment is a significant indicator affecting the effectiveness of construction and demolition waste management (Yuan, 2013).

2.4.4 CONSTRUCTION WASTE MANAGEMENT REGULATIONS

The importance of exhaustive governmental regulations for supporting construction waste management has been extensively investigated. For example; Karavezyris et al. (2002) confirmed that the government plays a crucial role in promoting construction waste management practices by enforcing regulations for the whole industry. The governmental regulation is identified as the most important factor for conducting construction waste management in most cities (Lu and Yuan, 2010). It was found by Tam et al. (2006) that the mandatory system for operating a waste management plan in construction projects significantly reduces the productivity of companies.

2.4.5 SITE SPACE AVAILABLE FOR PERFORMING WASTE MANAGEMENT

Site space refers to the space used for on-site waste collection, sorting and handling. Since construction waste is often the mixture of inert and organic materials; mixed and contaminated waste is not suitable for reuse or recycling but generally disposed of at landfills directly (Shen and Yuan, 2010). On-site sorting is widely perceived as effective in achieving a higher rate of waste reuse and recycling. Without a space layout pre-planned for waste collection and sorting, the temporary placement of sorting facilities and implementation of waste collection and sorting activities might disarrange other construction activities (Wang et al., 2015). Further, Shen and Yuan (2010) stated that pollution resulting from construction waste to the site surroundings would be greatly lessened through effective on-site sorting. Therefore, sufficient on-site space for waste sorting is important in maximizing construction waste reuse and recycling (Yuan, 2013).

2.4.6 ADOPTION OF LOW-WASTE CONSTRUCTION TECHNOLOGIES

Low-waste construction technologies help reduce, reuse or recycle construction waste. Such technologies include prefabrication, innovative formwork and false work, and low-waste structures (Udawattaa et al., 2015). Research studies have identified potentials of low-waste construction technologies, such as prefabrication and modular structure in buildings, for minimizing construction waste. Jaillon and Poon (2009); Esin and Cosgun (2007); Baldwin et al. (2008), suggested that for high-rise residential buildings, the main opportunities for waste minimization are related to the adoption of pre-casting and pre-fabricated techniques. A study by Jaillon and Poon (2009), revealed that waste reduction is one of the major benefits when using prefabrication compared with conventional construction. An investigation by Tam et al. (2006) also showed that the average level of waste generation of the conventional construction method is much higher than that of prefabrication in the trades of concreting, rebar fixing, plastering and tiling. These facts imply that a wider use of low-waste construction technologies would reduce construction waste generation considerably (Yuan, 2013).

2.4.7 WASTE MANAGEMENT CULTURE WITHIN AN ORGANIZATION

Waste management culture within a construction organization is largely related to the influence of human factors on construction waste minimization, such as the awareness on practitioners on waste management. Previous studies have pointed out that practitioners' awareness of resource saving and environment protection is of vital importance to construction waste minimization (Yuan and Shen, 2011). Since contractors ranked time as the top priority, their effort mostly focused on completing the project in the shortest time, rather than the environment (Poon, 2007). Therefore, improving practitioners' awareness of construction waste management can make a significant contribution to effective construction waste management and thus ameliorate waste management culture within the organization (Yuan, 2013).

Causative factors of construction waste are summarized below in Table 2.2. The table is derived from the causative factors of construction waste fishbone diagram designed by Nagapan et al. (2012)

Table 2.2: Causative Factors of Construction Waste

Causative Factors of Construction Waste			
Design: • Design changes • Design errors • Lack of design information • Poor design quality • Slow drawing distribution • Complicated design • Poor coordination of parties during design	**Handling:** • Wrong methods of loading and unloading • Wrong material storage • Poor material handling • Damage during transportation • Poor quality of materials	**Workers:** • Poor workmanship • Workers' mistakes • Incompetency • Damage caused by workers • Insufficient training of workers • Lack of awareness among workers • Material inventory not well documented	**External Factor:** • Pilferage • Effects of weather • Festival celebration • Accidents • Unpredictable local conditions • Lack of legislative enforcement • Vandalism • Damage caused by third parties
Management: • Poor site management • Bad construction methods • Lack of coordination between parties	**Procurement:** • Ordering errors • Waiting for replacement • Variation orders • Over allowances • Wrong material	**Site Condition:** • Unforeseen ground conditions • Problems of site access • Waste because of packaging	

• Late information flow between parties • Lack of waste management • Waiting periods • Long project duration • Lack of environmental management	delivery • Items out of specification • Mistakes in quantity surveys • Supplier errors	• Poor site conditions • Congestion of the site • Interference of others' crews on site	

Source: Nagapan et al., 2012:331.

Pilferage or stealing of materials form site is not necessarily a waste causation factor. Pilferage of materials from a construction site necessitates procurement of additional materials to replace. Such a loss on stolen materials is therefore loosely regarded as waste.

2.5 CONSTRUCTION WASTE MANAGEMENT STRATEGIES

For a very long time, landfilling was the sole waste disposal solution. Nowadays, the solution to construction waste is not only disposal. Studies have shown that landfilling is inefficient because it is not only a waste of resources but also creates significant negative impacts on the environment. The primary component of construction waste is solid waste hence if landfilling is the sole solution, a huge amount of land will be occupied and soil will be polluted. Therefore, landfilling as a passive and last-resort treatment cannot satisfy the requirements of sustainable development. Improvements to construction waste management have thus shifted attention to waste reduction strategies (Ding et al., 2016).

Ding et al. (2016) stated that in order to achieve better environmental performance of the construction waste management through waste reduction methods, attention should be paid to source reduction by employing methods such as low waste technologies and on-site performance management. In the meantime, encouragement of sorting behaviors such as improving stakeholders' waste awareness, refining regulations, strengthening government supervision and controlling illegal dumping should be emphasized. Other construction waste management strategies are discussed below.

2.5.1 WASTE MANAGEMENT PLAN (WMP)

According to Nagapan et al. (2012) a Waste Management Plan (WMP) is the basis for successful waste management practices in construction projects. It is a comprehensive plan needed on site to understand and to achieve waste management goals for the project. Having a WMP and assigning implementation responsibility to designated people helps to manage construction waste effectively in construction projects (Poon, 2007). Gangolells et al. (2014)

stated that it is imperative that the contents of a waste management plan are disseminated to all workers, to help them meet its requirements (Gangolells et al., 2014). However, it is still necessary to conduct regular site inspections and review waste management performance periodically to identify additional waste reduction requirements (Udawattaa et al., 2015).

2.5.2 INVESTMENTS ON WASTE MANAGEMENT MEASURES

Incorporation of waste management plans into the design and the importance of effective planning during project execution has been emphasized in order to harness wastages on construction sites. It has been pointed out that issues with fragmentation of design and construction phases and the importance of involving builders in the design process to minimize waste generation proved to be very effective (Udawattaa et al., 2015).

Yuan (2012) stated that investment in construction waste management through purchasing equipment and machines that promote waste minimization and improving workers' skills on waste management is a useful strategy for reducing waste on construction projects and construction sites. However, it can be noted though that such investments could not yield immediate or even tangible returns that could be significant in a single project especially for small projects. Source reduction methods are most effective ways of minimizing generation of construction waste and have the potential of bringing huge benefits to the environment and reducing project costs (Ding et al., 2016). However, effective construction waste reduction management depend upon policies and regulations that promote the implementation of reduction measures. For instance, increasing landfill charges have been identified as having led to the evolution of ways of reducing waste generation in the first place (Pires et al., 2011).

2.5.3 "MANAGEMENT BY OBJECTIVES" (MBO)

A study by Udawattaa et al. (2015) using the exploratory factor analysis revealed success factors that could be adopted in the construction waste management processes. It was pointed out to be imperative to organize team building sessions to instill awareness within the project teams regarding waste management. Equipping project teams with strategic guidelines in waste management and making sure of proper design and documentation were also realized to be very important. Other factors stated were innovation in waste management decisions and carrying out lifecycle assessments and management. The evidence from this study suggested that both technological and attitudinal or behavioral approaches require improvement to eliminate or minimize waste generation in construction projects.

2.5.4 USE OF PREFABRICATED MATERIALS

Tam et al. (2007) suggested that construction waste generation can also be reduced by using prefabrication technologies. It has been estimated that the average waste generation from the use of prefabricated material is halved. Prefabrication construction methods help to create a tidier and safer working environment as well as reducing the time and onsite labour requirements. These methods have been criticized though because still they cannot fully avoid the generation of construction waste. Ding et al. (2016) noted the short comings associated with prefabrication to include less flexibility when using prefabricated components and transportation of such offsite fabricated or manufactured components to site and to their final position.

2.5.5 SITE COMMUNICATION AND COORDINATION

Udawattaa et al. (2015) argued that construction waste can also be reduced by having clear communication between the main contractor and subcontractors. It has been pointed out that it is particularly necessary to concisely communicate waste management policies at both the company and site level through clear communication channels. Further, construction workers can be more engaged in waste management issues by having regular meetings where environmental benefits of effective waste management can be communicated. Through such measures, the awareness of project participants about waste management objectives can be enhanced.

High levels of collaboration and risk sharing were identified as a solution for waste generation. It has been stressed that main contractors have to make sure that subcontractors comply with specifications, and construction workers have to know why they are practicing waste management and what the benefits are. It has been pointed out that common interests only prevail when the requirements for waste management are explained to people who are actually involved in waste management and when they are placed in contract specification (Udawattaa et al., 2015).

2.5.6 CONTINUOUS TRAINING AND DEVELOPMENT OF EMPLOYEES

Training and education is another effective way of minimizing waste generation (Wang et al., 2015). The effectiveness of waste management strategies can be improved by educating supervisors and estimating staff about waste minimization strategies, highlighting the advantages of profit maximization, and conveying to all staff that waste management is as important as the time, cost, quality and safety issues in construction projects.

Udawattaa et al. (2015) noted that it is necessary to conduct training and education activities to enhance the performance of waste management practices. It was highlighted in the study that designers need evidence-based methods to demonstrate the benefits of waste management to clients. Clients can be motivated to implement waste management practices in their projects by demonstrating the advantages of implementing good waste management strategies such as, for example, less construction accidents and a speedier construction process.

2.5.7 PROMOTING AWARENESS

Yuan (2013) highlighted the critical role of enhancing major project stakeholders' awareness about saving resources and environmental protection in order to improve waste management performance in construction projects. Equally important, Udawattaa et al. (2015) stated that the implementation of relevant policies and regulations also helps to enhance the awareness and willingness of contractors and other project participants to address waste issues.

2.5.8 LEGISLATION AND BY-LAWS

Osmani et al. (2008) demonstrated that legislation is one of the key incentives for the implementation of waste management in the design process, for instance. Reinforcing legislation and regulation related to construction waste management and having monitoring methods in place to check compliance helps to enhance waste management performance. The same authors argued that legislation can be used as a tool to initiate and market the benefits of waste management. Relevant waste management policies could encourage architects, for example, to design out waste in construction projects. In order to promote zero waste culture, the construction industry and authorities have to improve legislation with a solid enforcement plan and methods of systematic tracking of proposed measures.

Researchers have argued that it is necessary to increase landfill charges to discourage dumping and landfilling of construction and demolition waste, as most of the time waste is disposed of with little or no attempts of material recovery (Jaillon and Poon, 2009). As a result, such procedures and policies should also address behavioral changes at a construction site level. However, Bakshan et al. (2016) noted that examining such attributes requires context-specific measures in order to arrive at fair judgements. The role of human factors in construction waste has gained more attention from researchers in the last decade or so (Yuan and Shen, 2011). However, studies have found that even though project rewards can be used to motivate the workers, the reward is not as influential as culture. It has been suggested that financial rewards and incentives can be used to minimize waste generation in construction projects. However, acknowledging the competitive nature of the construction industry, waste management should not be a cost burden for contractors and it is necessary to encourage contractors to implement better waste management practices by using incentives (Udawattaa et al. 2015).

2.5.9 CHANGING ATTITUDES

Research studies have also pointed out that the most common causes of construction waste generation can be prevented by changing worker's attitudes (Osmani et al., 2008). Udawattaa et al. (2015) stated that in general, the attitudes of construction professionals do not support the implementation of proper waste management practices in construction projects. Therefore, it is imperative to consider human factors when managing construction waste. Similarly, researchers have found that understanding attitudes and behaviors towards waste management plays a crucial role in the effective management of construction. It has been argued that construction waste can be effectively managed by changing attitudes rather than changing technologies. Different researchers came to this conclusion by different approaches (Udawattaa et al., 2015).

2.5.10 PROMOTING REUSE AND RECYCLING

According to Poon (2007), other strategies for improving waste management include ensuring reuse or recycling opportunities through careful handling and storage of recyclable materials and good housekeeping on construction sites. Yuan (2013) emphasized the importance of developing recycling markets for construction products in order to encourage recycling in construction projects. Further, a study by Jaillon et al. (2009) have shown that reduction measures on construction sites are unsatisfactory because of inadequate regulations and lack of necessary market-driven benefits.

2.5.11 SOCIAL MEDIA PLATFORMS

A study by Udawattaa et al. (2015) revealed that some stakeholders in the construction industry highlighted some practical ways of implementing solutions for construction waste management in construction projects such as using social media and educational programmes and some notices in lunch rooms to enhance knowledge on waste management. Additionally, using monitoring programmes to ensure compliance of waste management practices with legislation and involving contractors in the preparation of design documentation were found to be beneficial. Communicating short-term and long-term benefits of waste management through social media and company newsletters helps to improve waste management practices in construction projects.

2.5.12 INTEGRATING DESIGN AND PROCUREMENT

Some researchers have highlighted the importance of incorporating waste management processes in the design and procurement phase and then extending this to onsite technologies. On the other hand, some researchers preferred attitudinal approaches rather than changing technologies. It has been established that some project managers perceive construction waste management should take technical and attitudinal issues into consideration by equipping workers with basic technical know-how relating to waste control as well as instilling behavioral reforms. However, it is interesting to note that some other project managers prefer technologies over attitudinal approaches for waste minimization (Udawattaa et al., 2015).

Furthermore, it has been realized in some studies that construction waste management transaction costs are not high enough to incentivize contractors to manage waste conscientiously. Thus, other institutional arrangements, such as promoting the value of environment protection leadership, are critical for achieving superior construction waste management performance (Lu et al., 2016). During the design stage, a great potential for waste avoidance exists through decisions about processes and materials specification (Duan et al., 2015).

2.5.13 HOUSEKEEPING

Most commonly implemented practices to control waste on construction sites were found to be on-site cleanliness and order, correct storage of raw materials, and prioritization of the nearest authorized waste management sites. The dissemination of contents of waste management plans to all workers, to help them meet its requirements was also found to be very common. Further, it was generally noted not to be uncommon for waste management practices to be implemented in construction projects and sites during the design, planning and construction phases. Many of the improvements suggested by construction firms were found to be related to the establishment of environmental awareness and training programmes for all the stakeholders (Gangolells et al., 2014).

2.5.14 PROJECTS LIFE CYCLE ANALYSIS

Gangolells et al. (2014) also pointed out that implementing construction waste management throughout the life cycle of construction projects is also vital. The same authors noted that only construction materials that can be directly used in subsequent construction processes (such as metal and timber) are reused and recycled on-site, whilst other construction waste is sent to landfill or disposed of illegally. To improve the situation, waste management on construction sites should embrace the idea of implementing waste management strategies throughout the life cycle of construction projects, ranging from the project design stage, construction stage, to the final demolition stage. Each of the stages would contribute to construction waste generation, either directly or indirectly.

2.6 ADVANTAGES OF EFFECTIVE CONSTRUCTION WASTE MANAGEMENT

Construction waste generation has been identified as one of the major issues in the construction industry due to its direct impacts on the environment as well as the efficiency of the construction industry. As the industry cannot continue to practice if the environmental resources on which it depends are depleted, the significance of waste management needs to be understood in order to encourage stakeholders to achieve related goals (Udawattaa et al., 2015).

Yuan (2013) stated that the main advantages of implementing waste management planning are that the image of the organization is improved, while saving raw materials and increasing the awareness of the staff. According to Wu et al. (2016); the contractor plays a huge role in minimising construction waste on construction sites. An image of contructing organizations that better manage constrution waste is improved. Udawattaa et al. (2015) on the other hand have argued that the main advantage of effective waste management to contractors is that the cost of construction is reduced. Many practitioners within the industry and beyond will attest to this benefit of implementing effective waste management on construction sites.

According to Udawattaa et al. (2015), it is well recognized that construction waste has economic residual value and it is possible for its generation to be avoided. This means that construction waste can be converted back to usable materials through recycling. The same authors contend that effective waste management also has social and environmental benefits as it reduces the area needed for landfill along with the health risks related to waste disposal. Similarly, managing construction waste can be seen as a way of achieving better productivity and safety on construction sites.

2.7 DISADVANTAGES OF EFFECTIVE CONSTRUCTION WASTE MANAGEMENT

A major problem of too much emphasis on construction waste management on construction projects is that of increase in red tape. Extra paperwork; that is, filing in control forms, and inspection reports (Yuan, 2013) maybe frustrating to some. This is perceived to be affecting productivity and smooth flow of work activities. However, there are no many disadvantages of construction waste management; only benefits.

2.8 BARRIERS TO IMPLEMENTATION OF EFFECTIVE CONSTRUCTION WASTE MANAGEMENT

Osmani et al. (2008) explored the major barriers faced by architects in implementing construction waste management and found that poorly defined individual responsibilities, clients' lack of interest, and lack of training are the main obstacles to the effective implementation of waste minimization design.

Ding et al. (2016) noted that recycling as a waste management approach has some major limitations. The implementation of on-site sorting, low value of recycled waste, high sorting cost, limited space and site constraints, limited waste separability and lack of recycling markets all combine to make recycling construction waste not very worthy.

Zhang et al. (2012) noted that lack of skilled and qualified workers is one of most significant barriers to the adoption of related technologies and methods that could be fruitful in waste minimization. It has also been argued that at the same time, the adoption of related technologies and methods also increases construction time (Yuan and Shen, 2011).

Implementing waste management processes increases costs and reduces productivity on construction sites; for example, an individualized waste management plan for each construction site and on-site waste sorting, especially in demolition works, involve a significant extra cost (Gangolells et al., 2014). The same authors also stated barriers related to subcontracting works in the construction sector. It has been noted that there are some reported difficulties in tracking, controlling and managing waste generated on-site by subcontractors and the environmental awareness of small subcontractor's workers (Gangolells et al., 2014).

Most cities around the world have not conducted regular statistics on amounts of construction waste generation. This has been a major barrier for stakeholders to understand the actual status quo of construction waste generation and consequently preventing the proposal of effective management measures to improve the situation (Yuan, 2013).

2.9 CONCLUDING REMARKS

The above literature review indicates that waste management policies and regulations, stakeholders' construction waste reduction behaviors, on-site construction waste management and environmental impacts are closely related to each other. Construction waste reduction management at the construction phase is a complex system involving a lot of factors. Faced with the large amount of construction waste in the last decades, continuous research efforts have been devoted to establish ways of minimizing generation of construction and demolition waste in order to reduce associated adverse impacts during construction and demolition of infrastructure components. A probable explanation is that construction waste reduction is the highest preferred strategy of waste management.

It is well recognized that construction waste has residual or economic value and its generation can be avoided. It is there important to determine potential ways to eliminate and/or to minimize waste generation in construction projects in order to protect the environment and/or recoup economic value of waste. To avoid or reduce construction waste, it is necessary to be mindful of the environmental effects of waste generation and to prevent waste generation as early as possible in construction projects phases.

The importance of addressing both the technical and human aspects of waste management to improve the performance of waste management practices in construction projects and construction sites have been emphasized. It has been realized that in some circles, construction waste management practices or strategies fail because of over-emphasis on technical solutions alone.

The governments through its relevant organs and senior management of organizations in the construction industry have a responsibility to develop strategic guidelines for construction waste management and to facilitate effective onsite waste management plans by enhancing company policies and regulations relating to construction waste management. Proper design and documentation needs to be facilitated by consultants while all stakeholders need to be innovative by incorporating lifecycle management to enhance the performance of waste management practices. Indeed, all stakeholders need to be engaged in the waste management process through taking a holistic approach. A proper Waste Management Plan helps serve this purpose as highlighted in the review of literature.

Particularly, design changes occurring during construction are perceived to be the most significant cause of construction waste. On the other hand, however, a wide range of materials and elements included in construction projects, together with their nature, on its own makes the implementation of waste management strategies difficult especially on sites. It is still possible though, as pointed by researchers, to manage construction waste. Thus, field work was done for this study to collect data by means of a questionnaire to determine waste management strategies that are employed on construction sites in Gauteng.

3 RESEARCH DESIGN AND METHODS

3.1 INTRODUCTION

Saunders et al. (2009) refers to research design as a stage in the research process that is concerned with the overall plan for research work. Research design therefore is the general plan of how the process of answering research questions will go about. Another author on social science research principles, methods and practices, Bhattacherjee (2012) refers to research design as a comprehensive plan for data collection in an empirical research aimed at answering specific research questions or testing specific hypotheses. It is emphasized by the same author that research design specifies the processes of data collection, instrument development and the sampling process. As pointed out by Kelly (2011) research is a practical activity aimed at answering a research question by means of a research design and methods of data collection and analysis.

Research design in this study will follow the concept of the research onion composed by Saunders et al. (2009). Key issues underlying the choice of data collection methods; research philosophies and research approaches adopted for this study will be briefly discussed. Layers that explicitly define and focus on the process of research design, that is, research strategies, research choices and time horizons are broken down while taking note that the research design is sufficient for the objectives derived from the research question of this study. Further, the research methods portion includes a discussion on ways of collecting data from the target population and data analysis techniques. Ethical issues and constraints that were expected, for example, access to data, time, location and financial resources are also discussed to describe how this research design has been tailored to suit this study.

3.2 RESEARCH PHILOSOPHY

Saunders et al. (2009) stated that research philosophy relates to the development of knowledge and the nature of that knowledge. The same author discussed four research philosophies – positivism, realism, interpretivism and pragmatism. These philosophies are differentiated depending on their ultimate goals in scientific research. An important feature of positivism is that of adoption of the stance of the natural scientists, that is, working with an observable social reality and that the results of such research can be law-like generalizations. Bhattacherjee (2012) stated that positivist studies are those that are used for theory or hypotheses testing whilst interpretive studies on the other end are those that are used for theory building. The author further states that positivist designs seek generalized patterns based on an objective view of reality. However, interpretive designs seek subjective interpretations of phenomena based on perspectives of the subjects involved. A feature also supported by (Greener, 2008)

The philosophy of pragmatism as defined by Saunders et al. (2009) refers to a position that argues that the most important determinant of the research philosophy adopted is the research question. In this philosophy, it is argued that it is possible to work within both positivist and interpretivism positions; applying a practical approach, which integrates different perspectives to help collect and interpret data.

The fourth research philosophy is realism. In realism it is believed that what the senses show us as reality is the truth: that objects have an existence independent of the human mind. Realism is similar to positivism in that it assumes a scientific approach to the development of knowledge. The philosophy of realism is divided into types. Direct realism says that what you see is what you get; implying that what we experience through our senses portrays the world accurately. Critical realists argue that what we experience are sensations, the images of the things in the real world, not the things directly; implying that often our senses deceive us (Saunders et al., 2009).

This particular research adopted an interpretivist philosophy since an observable reality of construction waste on construction sites is to be studied looking at the strategies adopted to harness this problem.

3.3 RESEARCH APPROACH

Saunders et al. (2009) contend that there are two research approaches: deductive approach and inductive approach. A deductive approach is employed when a theory or hypothesis is tested. An inductive approach on the other hand is when collected data is analyzed and as a result, a theory developed. Deduction is more aligned to positivism while induction to interpretivism philosophy although such labelling is of no real practical value.

According to Bhattacherjee (2012), the goal of the researcher in inductive research is to infer or to identify theoretical concepts and patterns from observed data whereas in deductive research, the goal is to test concepts and known patterns from theory using new empirical data. Therefore, inductive research is often loosely called theory-building research, while deductive research is theory-testing research. However, the goal of theory-testing is not just to test a theory, but also to refine, improve, and possibly extend it meaning that these two approaches take place in a cyclical process.

The most important characteristic of a deductive approach is that it involves a search to explain causal relationships between variables. The approach works well with structured data collection instruments and it requires a control on variables that are being investigated so that a theory or a hypothesis can be successfully tested (Saunders et al., 2009). The same author further emphasized that in order to uphold the principles of scientific rigor; deduction dictates that the researcher should be independent of what is being observed or under study.

Further, Saunders et al. (2009) pointed out an additional important characteristic of deduction to be that concepts need to be defined and simplified in a way that enables facts to be measured quantitatively. Such reductionism will mean that problems are better understood in their simplest possible elements. It is also stated that under a deductive approach, samples need to be of a sufficient numerical size in order to be able to generalize statistically about relationships between variables.

With the inductive approach, theory would follow data rather than vice versa as with deduction (Saunders et al., 2009). With inductive methods, a small sample of subjects might be more appropriate than a large number as with the deductive approach. Further, it is stated that other features of an inductive approach are its alignment to usage of qualitative data and flexibility to use a variety of methods to collect data in order to establish different views around the area of study.

It is particularly important in research to choose an approach in that it promotes a more informed decision about research design. Research design refers to the techniques by which data are collected, procedures by which data are analyzed and the overall configuration of a research process in terms of the kind of evidence to be gathered and how such evidence is interpreted in order to provide good answers to a research question. Secondly, as stated by Saunders et al. (2009), a thought about research approaches help to establish which research strategies and choices will work or that will not work in a particular study.

In this particular study therefore, an inductive approach mapped on an interpretivist philosophy was adopted. An inductive approach is believed to be appropriate looking at the fact that there is a wealth of literature around the topic of construction waste management strategies employed on construction. Additionally, an inductive approach was preferred in this research work because it is quicker to complete and low-risk especially since the study is cross-sectional (Saunders et al., 2009). In the context of this study particular study, cross-sectional research means a study or data collection is done at a certain point or snapshot during the course of the project. Thus, this study was carried out at a certain time during the course of the case projects. Furthermore, according to Bhattacherjee (2012) deductive conclusions are stronger than inductive conclusions.

3.4 RESEARCH STRATEGY

It is important that a research design identifies research strategies that will be employed in the research. Each of the strategies can be employed for exploratory, descriptive or explanatory research. Exploratory studies are those studies that are conducted in order to understand what is happening so as to establish new insights; descriptive studies seek to portray or to paint an accurate picture of events or situations. Explanatory studies establish causal relationships between variables (Saunders et al., 2009). This particular study will be more descriptive in nature.

Saunders et al. (2009) stated that theoretically some research strategies belong to the deductive approach, others to the inductive approach. Therefore, what is most important is whether the strategy is appropriate for answering a particular research question and to meet objectives of the research. There are a couple of strategies by which research can be executed namely; experimental studies, surveys, case studies, action research, grounded theory and ethnography. A cross-sectional survey strategy is preferred for this research as expanded and justified hereunder.

3.4.1 CROSS-SECTIONAL SURVEY

MacDonald & Headlam (1986) stated that surveys are questionnaire-based method of research that can yield both qualitative and quantitative information. Questionnaires can be used in a wide range of settings, for example to gather information on a small sample population at a single point in time. Further, surveys can be carried out by phone, post, email, website or face to face. This makes this strategy very flexible and easy to use.

According to Saunders et al. (2009), a survey is the most popular research strategy that is most often used to answer “who, what, where, how much and how many” research questions. Popularity of a survey strategy owes to its nature of being flexible in collecting large amounts of data in a highly economical way. Notable problem of this strategy though is that data collected could not be wide-ranging as those collected by other methods is based on the questions on the data collection instrument. This has been partially addressed by incorporating open-ended questions in the survey though.

Based on the about features and advantages, a cross-sectional survey has been employed for this study using a questionnaire survey.

3.5 RESEARCH CHOICE

Research choice refers to the way in which a preference is made regarding adopting a quantitative or qualitative technique and procedures or both (Saunders et al. 2009). It is mentioned in the same source that individual quantitative and qualitative techniques and procedures do not exist in isolation. Three available research choices as described by the same author are: the mono method, mixed methods and the multiple methods.

In the mono method, a single data collection technique and a corresponding analysis procedure is used. For example, data can be collected using a questionnaire, analyzed using a quantitative procedure. This method is very simple and can be relatively less time consuming. On the other hand, Saunders et al. (2009) described mixed methods as referring to those combinations where more than one data collection technique is used with associated analysis techniques but sticking to either a quantitative or qualitative procedure. Mixed methods, just like multiple methods facilitates deeper understanding, analysis and interpretation making it possible to draw solid conclusions but these methods could have made this study to be complex, costly and time consuming.

The third research choice - multiple methods - uses more than one data collection technique and analysis procedures to answer a research question. This choice is increasingly advocated within business and management research where a single research study may use both quantitative and qualitative techniques and procedures in combination (Saunders et al., 2009).

In this particular research therefore, a mono method based on questionnaire data collection technique and qualitative analysis procedure will be adopted. A non-statistical understanding of construction waste management strategies employed on construction sides is sort after.

3.6 TIME HORIZON

In planning a research, it is advisable to decide whether a research will be a snapshot, that is, taken at a particular time or to follow a diary basis or a series of snapshots in order to represent events over a given period (Saunders et al., 2009). The snapshot time horizon is what is referred to as cross-sectional while the diary perspective called longitudinal. It is emphasized by the same authors that these time horizons to research design are independent of which research strategy is being pursued or choice of method. Cross-sectional studies are quite advantageous in that they save time; a series or lengthy observations are required for a longitudinal type of research. Cross-sectional researches often employ a survey strategy and are often qualitative rather than quantitative. Longitudinal research on the other hand has the capacity to study change and development by studying behaviors or trends over time.

In this particular research, a cross-sectional horizon will be adopted. This is meant to save time. This stance is also preferred because of the temporary nature of construction projects.

3.7 DATA COLLECTION TECHNIQUES AND PROCEDURES

As mentioned, a cross-sectional survey was adopted for this study. Authors on research design and methods - Bhattacherjee (2012), Saunders et al. (2009) stated that in adopting a case research, it is advisable to use and triangulate multiple sources of data. Triangulation refers to the use of different data collection techniques within one study in order to confirm findings obtained through another method of data collection. For example, qualitative data collected using semi-structured interviews may be a valuable way of triangulating data collected by use of a questionnaire.

A questionnaire has been utilized in this particular research for data collection. This instrument was sent to correspondents by email or a web-based questionnaire will be used. To achieve some form of triangulation, three different sites were used, with the same questionnaire being circulated. As pointed out by various authors; (Bhattacherjee, 2012; Saunders et al., 2009), observations are another technique of collecting data in research. This method was used to complement the questionnaire method in one of the three sites.

3.7.1 QUESTIONNAIRES

Invented by Sir Francis Galton, a questionnaire is a research instrument consisting of a set of questions intended to capture responses from respondents in a standardized manner. Questions may be unstructured or structured. Unstructured questions ask respondents to provide a response in their own words, while structured questions ask respondents to select an answer from a given set of choices (Bhattacherjee, 2012). In most types of research, the greatest use of questionnaires is made within the survey strategy; however, both experiment and case study research strategies can make use of these techniques (Saunders et al., 2009).

Normally a questionnaire as a general term include all techniques of data collection in which each person is asked to respond to the same set of questions in a predetermined order (Saunders et al., 2009). It therefore includes both structured interviews, telephone questionnaires as well as those in which the questions are answered without an interviewer being present, such as the online questionnaire (Bhattacherjee, 2012; Saunders et al., 2009; Greener, 2008). In this study, questionnaires were sent to respondents by email, embedded as an attachment which was completed and returned the same way.

The design of a questionnaire affects the response rate and the reliability and validity of the data collected (Saunders et al., 2009). To limit these threats, questions were designed such that respondents are able to read, understand, and respond to them in a meaningful way. Further, both structured and unstructured questions were incorporated in the questionnaire to allow the respondents to express themselves while at the same time retaining some standard of the responses through structured items. As stressed by Pallant (2005), data collected are only as good as the instrument that is used to collect them and the research framework that guided their collection. As such, a questionnaire for this research has been designed so as to obtain sufficient data to answer research questions.

A questionnaire instrument is very convenient and inexpensive to administer. Respondents can complete the questionnaire at their own time and the researcher would not normally spend a lot of money in sending the questionnaire, reminding respondents to complete the questionnaire and in receiving the completed questionnaire from respondents (Bhattacherjee, 2012). Hence the choice made.

Bhattacherjee (2012) argued that because each respondent is asked to respond to the same set of questions, therefore a questionnaire provides an efficient way of collecting responses and comparing responses in data analysis. In order to maximize response rates, validity and reliability, individual questions were carefully designed to make sure that they are clear and straight forward. Further, a clear and pleasing layout of the questionnaire and lucid explanation of the purpose of the questionnaire were ensured.

After a questionnaire was prepared, it was shared with colleagues for some comments so as to have an insight unto its performance and to make sure that instructions, questions and structured responses are clear (Pallant, 2005). This was done to make sure the questionnaire is clear and that the wording and instructions to respondents are not vague.

Although the questionnaire may not be appropriate or practical for certain demographic groups for example the illiterate and some potential respondents who do not have access to computers and emails, it is still believed that a desirable response rate will be achieved, considering the nature of the target sample. As expressed by MacDonald and Headlam (1986), a questionnaire has a greater focus on collecting rich and detailed qualitative data.

It is interesting to note that a lot of successful research around the topic of construction waste management has been done using a questionnaire in different contexts like in the United Kingdom (UK), Malaysia, Turkey, China to name a few (Esin and Cosgun (2007), Osmani et al. (2008), Lu and Yuan (2010), Yuan (2013) and Saez et al. (2013)). It is therefore believed that the same will work in the particular context of the study – Gauteng province of RSA.

3.7.2 PARTICIPANT OBSERVATION

Participant observation was used as a supplementary data collection method where data collected by a questionnaire was considered not rich enough. As pointed out by Saunders et al. (2009), observation involves systematic observation and recording data followed by analysis and interpretation. The same author contends that it is rewarding and enlightening to pursue participant observation to add to the richness of research data. Since the aim and objectives of this study is to know what waste management strategies are employed on construction sites; it was deemed vital to observe or watch actions on the ground.

The researcher made use of participant observation method by visiting sites and observing what is being done in relation to the line of study. Immersion of the researcher in a research setting with the objective of observing what is done to manage waste on construction sites was very vital in adding to the data collected by means of a questionnaire. Waste management strategies employed on site where then recorded. The recording process was guided by a questionnaire and all information gathered and recorded was useful for the study. The only problem encountered with using participant observation method was time. Participant observation method is very time consuming.

3.8 TARGET POPULATION AND SAMPLING APPROACH

MacDonald and Headlam (1986) define a sample as a section of the wider population that will be engaged in the survey. Detailed consideration of sampling still need to be made even when not striving for statistical significance or quantitative data analysis. The same authors emphasized that it is still important to understand the make-up of respondents and the sampling frame to be adopted.

Three construction projects were chosen from different sectors - buildings (commercial), roads and civil projects within Gauteng. The reasoning behind the selected type of projects was mainly to enrich the study and to have different types of materials used, work breakdown structures, location of projects and functionality of the finished product. Gauteng has been chosen because of proximity to the researcher and ease of travelling to sites. Sites were chosen on the basis of size of the project in terms of visual appeal and the size of main contractor where grade seven contractors in terms of Construction Industry Development Board (CIDB) grading system were preferred. Further, construction sites that involve various trades and a variety of materials were considered. For example, sites where only concrete and steel are the only major materials were considered not suitable. Professionals from these projects either from the contractors, consultants or client personnel were considered for the study. Generally, professionals sort after included architects, engineers, environmental management professionals, project managers, quantity surveyors and some senior technical staff. There was no specific number or make-up of the respondents list. Everyone from the chosen sites who can provide succinct information based on experience or expertise had been welcome to participate.

Initially six construction sites; two sites per each sector, that is, building project, civil works project and road works project. These sites were chosen randomly having seen some visually appealing construction work going on. Project managers on each of the sites were contacted telephonically and the briefing given regarding description and purpose of the study. Further on, selection of the final three sites that were used in this case study research were selected on the basis of issues of access and then, quality of responses received in a completed questionnaire. Four project managers consented to the request and questionnaires were then sent out. However data from the three construction sites was used, leaving the second site of the road- works sector. This decision was based on the quality of responses received.

3.9 CREDIBILITY OF RESEARCH FINDINGS

This basically refers to the validity and reliability of research findings. Validity is concerned with whether the findings are really about what they appear to be about (Saunders et al., 2009). It is advised that lack of validity in the conclusions of research work is minimized by adopting an appropriate research design that built in the opportunity to gather valid data.

A notable threat to validity is the history around the topic or concept under study; for example, respondents can answer questions based on what happened in the past rather than from actual experiences. Another problem relates to the nature of the study - if the results of the study could disadvantage the respondent or respondent organization then it is mostly likely that collected information may not be valid. For example, if it is believed that this research will expose some poor waste control on a particular site and such information end up reaching top management of that particular site team; then respondents may not be willing to open up on some real issues prevalent on site. Further, Saunders et al. (2009) stated that it is advisable to make sure that a method of collecting data used or questions asked do not hamper fair responses from respondents. An attempt has been made in this research to make questions as unambiguous as possible in order to obtain valid findings.

On the other hand, reliability refers to the extent to which data collection techniques or analysis procedures will yield consistent findings (Saunders et al., 2009). It is asserted that there may be four threats to reliability. The first of these is subject or participant error; that is, an error emanating from the participants or respondents involved in the study. This has been thought of to be controlled by choosing more neutral times when participants are neither on high mood nor on low mood. For example, mid-month when respondents perhaps have cleared their end of the month tasks and preferably mid-week when people are not from a weekend or approaching a weekend. There was no strict mechanism of identifying the right times in this study since an instrument had to be sent to respondents whereupon they can complete it whenever is convenient to them.

Another threat relating to subjects or participants is that of subject or participant bias. For instance, it is common that interviewees or respondents may answer or respond to questions in a way that their bosses or peers would expect. This problem should be well thought of during the design of the research (Saunders et al., 2009).

Threats relating to the researcher or the observer are observer error and observer bias. This often refers to the way by which questions are asked and answers interpreted by the researcher. Since some structured questions will be included in the questionnaire, it is believed that this will reduce this threat to reliability.

3.10 METHOD OF DATA ANALYSIS

In research, data can be analyzed either quantitatively or qualitatively. Quantitative data in a raw form before being processed and analyzed convey very little meaning. These data, therefore, need to be processed to turn them into information and make them useful. Quantitative analysis techniques such as graphs, charts and statistics allows this; making it possible to explore, present, describe and examine relationships and trends within our data (Saunders et al., 2009).

Qualitative data on the other hand refers to all non-numeric data or data that have not been quantified such as data from responses to open-ended questions in a questionnaire or data from transcripts of in-depth interviews. These data need to be analyzed and the meanings understood qualitatively. Qualitative data analysis procedures assist this, allowing theory development from raw data in deductive and inductive approaches (Saunders et al., 2009).

Unlike quantitative analysis, which is statistics-driven and largely independent of the researcher, qualitative analysis involves making sense or understanding of the concepts and subjects under study, rather than predicting or explaining (Bhattacherjee, 2012). Furthermore, it is imperative to note that qualitative data analysis attempts to understand reasons and motivations for actions and establish how people interpret their experiences and the world around them (MacDonald and Headlam, 1986). According to the same authors, qualitative analysis aims to generate ideas and to provide a complete and detailed description of what is observed in order to develop insights into the setting of a problem.

As outlined by MacDonald and Headlam (1986), the purpose of using qualitative research is to contextualize, interpret and understand perspectives, from ideas of respondents usually selected on experience or exposure to the area under study. Consequently, qualitative methods provide results that are usually rich and detailed offering in-depth ideas and concepts.

The review of literature provided theoretical concepts and framework on which the subject of construction waste management is understood. Collected data will be analyzed in a way that will establish links to the existing body of knowledge in the study area using qualitative methods of data analysis based on the rationale outlined. Further, the choice of qualitative methods is also driven by the personal knowledge of the researcher about the context from which data was collected.

Bhattacherjee (2012) described three coding techniques for analyzing qualitative data: open, axial, and selective. Open coding is a technique that involves the identifying, uncovering and naming of concepts that are hidden in qualitative data. Open coding technique was be used in this study to analyze empirical data that was be collected from three sites using a questionnaire instrument. In this technique, the researcher examined collected data (unstructured part of the questionnaire) line by line and identified discrete perceptions and interactions of relevance that were summarized and coded as concepts. These concepts were then used to explain the broader concept of waste management strategies employed on construction sites. Responses to structured items of the questionnaire were analyzed by collating the frequency of responses to each of the questions.

Other coding techniques mentioned; axial and selective coding, were not employed in this particular study. According to Bhattacherjee, axial and selective coding methods are more suitable when there is a need to put data into themes or categories. Selective coding is involves the process of choosing one category to be the code category and then relating all other categories to that category. This coding system therefore works when there is such a core concept or a code category. In this study, there was no need to categorize concepts hence none adoption of these coding variants.

3.11 ETHICAL CONSIDERATIONS

Bhattacherjee (2012) refers to a dictionary meaning of ethics as the conformance to the standards of conduct of a given profession or group. The same author also refers to ethics as the moral distinction between right and wrong; however, what is unethical may not necessarily be illegal. Therefore, as expanded by Greener (2008), ethics relate to moral choices affecting decisions, standards and behavior.

This particular study was executed in a way that uphold the principles of ethical research stated as by MacDonald and Headlam (1986):

- This research has been designed, reviewed and undertaken to ensure integrity and quality;
- Research subjects or participants were informed fully about the purpose, methods and intended possible uses of the research, what their participation in the research entails;
- Confidentiality of information supplied by research subjects and the anonymity of respondents was guaranteed;
- Efforts were made to make sure that research subjects participate in a voluntary way, free from any unnecessary coercion;
- Any form of harm to research participants that could emanate from their participation was avoided, and;
- The independence of research process was ensured. No conflicts of interest or partiality on the part of the researcher.

In order to achieve the aforementioned principles; the following framework as adopted from Bhattacherjee (2012), Greener (2008) and MacDonald and Headlam (1986) was central to this study.

Voluntary participation and harmlessness - research participants in this research were made aware that their participation in the study is voluntary and that they have the freedom to withdraw from the study at any time without any unfavorable consequences and that they will not be harmed as a result of their participation or non-participation in the research.

Informed consent form - efforts were made in this research to make sure that all participants receive and sign an informed consent form that clearly describes their right to not participate and right to withdraw, before their responses in the study can be recorded, for example before being asked to complete a questionnaire. Further, minor persons were not requested to participate in this research.

Anonymity and confidentiality - the identity of participants was not disclosed in order to protect their interests and future well-being. Anonymity implies that neither the researcher nor readers of the final research report will be able to identify a given response with a specific respondent. Further, anonymity assures that subjects are insulated from law enforcement or other authorities who may have an interest in identifying and tracking such subjects in the future. Respondents were also be guaranteed confidentiality, meaning the researcher did not divulge collected data to any third parties but used such data solely for this research. Therefore, guaranteeing anonymity and confidentiality to respondents will also help in obtaining truthful responses from participants.

Disclosure – the researcher provided information about the purpose of the study and possible uses of the research to potential before data collection to help them decide whether or not they wish to participate in the study. This was important in establishing whether enough subjects have been found or there is still need to contact some more prior to sending consent forms and data collection instrument.

Analysis and reporting - ethical obligations relating to data analysis and reporting was embraced in this study. Unexpected findings or outcomes of the research were honestly and fully disclosed even if they cast some doubt on the research design or findings.

3.12 JUSTIFICATION OF RESEARCH METHODS ADOPTED FOR THE STUDY

As discussed above, interpretivist favors humanistic qualitative methods rather scientific qualitative methods. Interpretivist research philosophy has been adopted for this study following the aforementioned distinct feature. This study is grounded on the reality and understanding of behaviors without predictions of the phenomenon. Thus, this approach has been favored as it allows focus to a specific, unique area of research interest rather than a generalized statistical study. Further, since this study seeks to identify strategies employed on construction sites in a qualitative rather than quantitative study, interpretivism philosophy was found suitable.

According to Sanders et al. (2009) adoption of interpretivism allows for in-depth study based on facts rather than a general kind of statistical study. Further, primary data generated via interpretivism studies is associated with a high level of validity because data in such studies is often factual, trustworthy and honest. Though there is a notable limitation of bias on the part of the researcher associated with this philosophy, the above stated strengths has necessitated adoption of this interpretivism for this particular study.

As inductive research approach has been preferred for this particular study, aligned to the philosophy chosen. This particular study focuses mainly on testing theory based a reality. This design matches the features of an inductive approach. As stated by Saunders et al. (2009), with inductive approaches, a small sample of subjects can be more appropriate than a large sample. Further, induction is preferred in many theory-testing studies because of its alignment to usage of qualitative data and its flexibility to use a variety of data collection methods to establish different views around the area of study.

A cross-sectional research strategy has been employed for this study. According to Bhattacherjee (2012), a survey has advantages of being inexpensive, flexible, extensive and dependable. The cost of administering surveys was very minimal, especially in this study where a survey instrument was emailed to subjects. Other methods, cannot be this inexpensive and flexible. Even though follow up calls were inevitable, cost of gathering data was not excessive. Further, the anonymity of surveys allowed respondents to answer with more open and valid answers.

A qualitative approach has been adopted for this study. This is because the goal of the study is to understand than to explain the reality. Consequently, an in-depth, rich data was sought in this study. Data was collected by means of a questionnaire that was emailed to three sites at a single point in time or snapshot while projects were in progress. Questionnaires where preferred because of anonymity and the flexibility they give subjects to complete at their own time and not being influenced by any pressure like in the case of face-to-face interviews. Collected data was analyzed qualitatively utilizing open coding techniques to identify most common construction waste management strategies employed on construction sites in Gauteng.

3.13 CONCLUDING REMARKS

This study has been designed from a positivist standpoint, based on a deductive approach to test existing theory. A cross-sectional or on-point case study strategy will be employed. Data had been set to be collected from participants by an emailed questionnaire. Research participants targeted were basically construction professionals like engineers, architects, construction managers, environmental practitioners, to name just a few, from selected construction sites. Data collection focused on strategies that are employed on sites to manage waste, factors leading to waste on construction sites, types of construction materials that leads to the creation of waste and those that cause less waste on construction projects. Collected data was analyzed qualitatively so as to derive a rich and detailed understanding of how construction waste is managed on construction sites in Gauteng and this is presented in the next chapter.

4 PRESENTATION OF RESEARCH FINDINGS

4.1 INTRODUCTION

The previous chapter outlined the research design and data collection methods of this study. A data collection instrument was discussed and an indication of subsequent data analysis tools given. This chapter focuses on and presents the findings of the case study research that was based on three construction sites. Findings are presented in accordance with the research questions that guided the study. The focus of the study is to identify waste management strategies employed on construction sites in Gauteng. In order to understand strategies employed in managing construction waste; it is vital to understand the waste causation factors as well. Thus, data collection for this study centered on;

a) Strategies for managing construction waste and,
b) Waste causation factors.

Table 4.1 below provide a summary of each site, type of construction project and number of responses received from each site.

Table 4.1: Summary of construction sites used

Name of Construction Site	Type of Construction Project	Size of contractor	Number of responses received
Site A	Civil Works Project (bridges and road works)	Grade 9	3
Site B	Road works Project (road layer-works and block paving)	Grade 9	3
Site C	Commercial Building Project (office block)	Grade 8	1 Plus Participant Observation

Qualitative data were collected by means of questionnaires that were emailed to respondents to complete and returned the same way. Follow up telephonic discussions were conducted in order to have a clear understanding especially on some responses given to open ended items of the questionnaire. Personal observations were conducted on Site C and some informal discussions carried out with some senior personnel on site in order to gather more data and to improve the quality of data collected.

This chapter presents responses, views, ideas and opinions obtained from research respondents. As such, analysis, judgments, opinions, thoughts or feelings of the researcher regarding the findings will not be found in this chapter but on subsequent chapters that focuses on the discussion of the report and the conclusion. As this research report adopted a qualitative approach; findings or results of the research are presented in qualitative form. Quantitative or statistical presentations of data are irrelevant. Finer details pertaining to construction sites or projects from which data were collected will not be revealed in line with ethical pledges of this research.

4.2 FINDINGS FROM SITE A

The first case-study site is a civil works project involving the construction of bridges and associated surfaced roads in Gauteng's Johannesburg metropolitan area. The project is carried out by a large construction company with grade 9CE in terms of CIDB construction companies grading. The company has a track record in infrastructure projects and this project in particular has a lot of visual appeal in terms of its location, size and nature of the works. The estimated value of the project was not asked so that respondents are not scared away that confidential information is been sort after. These traits meet the criterion that has been set regarding the nature of the sites to be selected for this study. Data were collected almost mid-way through the twenty-four months' construction period of the project.

A total of three completed questionnaires were received from management of the site; that is, from the project director, site manager and production manager. The caliber of respondents matched the target population. As stated by respondents, key materials used on the project include ready-mix concrete, reinforcing steel, crushed stone materials, precast concrete kerbs, paving blocks, prefabricated pipes and culverts.

4.2.1 WASTE CAUSATION FACTORS IN SITE A

A respondent from Site A pointed out that efforts are being made to control waste generation through such means as enforcing disciplinary measures on wasteful operators and workers and through staff training. However, the respondent perceives the most effective strategy in controlling waste in the construction industry to be recycling construction waste back into useful construction components and materials. Further to the assertion, it was mentioned that government sponsorships on recycling plants and promotion of recycled products could be effective in improving utilization of recycled materials in construction projects.

Waste management strategies employed on Site A were identified by respondents. Waste causation factors prevalent on this site were also stated in the in responses to the questionnaire.. Respondents mentioned that waste causation factors aligned to the design of the project mainly relate to design changes and design errors. Material handling factors that were said to be common on site included wrong methods of loading and unloading of materials and damage to materials during delivery to site. Poor workmanship, incompetency of the workforce and lack of training were mentioned to be leading workforce related waste causation factors.

A full list of waste causation factors that were considered to be common in Site A are shown in Table 4.2 below. Waste causation factors prevalent on each site have been included so as to evaluate effectiveness of waste management strategies employed on that particular site based on the causation factors. Items in this table and other tables that follows in this chapter are coded in line with questions and structured responses in the research instrument. This will facilitate comparison of responses from different case-study sites.

Table 4.2: Waste causation factors in Construction Site A.

Item	Criterion of Waste Causation Factors	Site A Waste Causation Factors
Q8	Waste causation **design factors**	8.1 Design changes 8.2 Design errors
Q9	Waste causation **material handling factors**	9.1 Wrong methods of loading and unloading 9.4 Damage during delivery to site
Q10	Waste causation **work force factors**	10.1 Poor workmanship 10.2 Incompetency 10.3 Lack of training
Q11	Waste causation **external factors**	11.1 Pilferage/stealing 11.2 Bad weather
Q12	Waste causation **management factors**	12.2 Wrong construction methods
Q13	Waste causation **procurement factors**	13.1 Ordering errors 13.2 Variation orders 13.4 Subcontractors
Q14	Waste causation **site condition factors**	14.4 Too many separate contractors and/or subcontractors on site
Q15	**Other** waste causation factors identified on Site A	15.1 Engineers changing bending schedules 15.2 Incorrect concrete orders 15.3 Unnecessary printing of toolbox talks

		15.4 Design changes 15.5 Weather damage to layer-works

4.2.2 WASTE MANAGEMENT STRATEGIES EMPLOYED IN SITE A

Proper selection of materials and offsite manufacturing of materials and components were stated as strategies employed to manage construction waste in Site A. These are the strategies that were picked by respondents from the structured responses that were given in a questionnaire. Implementation and enforcement of site specific policies and regulations; proper planning of construction activities (sequencing of activities); assigning implementation responsibility for waste management to designated people as well as ensuring adequate supervision of waste management activities with clear instructions to designated people are other strategies employed to manage waste on this particular site.

A full list of strategies employed on Site A as detailed by the respondents are as tabulated in Table 4.3 below.

Table 4.3: Waste management strategies employed in Construction Site A.

Item	Criterion of Waste Management Strategies	Waste Management Strategies employed
Q16	Waste management strategies employed on Site A	16.1 Proper selection of materials 16.2 Offsite manufacturing 16.5 Implementation and enforcement of policies and regulations 16.6 Proper planning of construction activities (sequencing of activities) 16.8 Assign implementation responsibility for waste management to designated people 16.9 Adequate supervision of waste management activities with clear instructions
Q17	Other waste management strategies employed on Site A to reduce waste generation	17.1 Ordering correct measured quantities and not from drawings 17.2 Ordering materials timeously and not way in advance 17.3 Materials on site checks 17.4 Charging sub-contractors for damage to materials 17.5 Doing it right the first time

As postulated by CIRIA (1995); it is initially through design that waste minimization, reuse and recycling of construction materials can be encouraged and promoted. Experts in the construction industry were asked what measures can be taken at design stage to ensure minimum waste generation on site during the subsequent construction stage. From Site A, it was established that some important aspects, namely: design checks, bill of quantities checks to make sure quantities and schedules tie up with drawings, use of recycled materials (for example cut to fill) and reduction in over designing could be effective in controlling construction waste by design.

4.3 FINDINGS FROM SITE B

Site B is a bus route road-works project in Gauteng. The nature of the construction site and the contractor executing the project meet the desired criterion set for this study. The project has a contractual construction period of over eighteen months. The project has a visual appeal deriving from the location of the site and from the nature of the service to be rendered when the project in completed. It is interesting to learn how construction waste is managed on such a site that is not localized but stretching some distance at the same time.

A total of three useable completed questionnaires were received from Site B. Questionnaires were received from the Site Agent, Construction Safety Officer and Student Engineer.

Major materials used on the project were stated to be ready-mix concrete, reinforcing steel, cement for stabilization of road layers, timber, plastic sheets. Diesel though not one of the construction materials was stated to be a key consumable on the project. It was pointed out that one of the strategies used on Site B to manage waste generation is the use of prefabricated components or offsite manufacturing of components and materials.

4.3.1 WASTE CAUSATION FACTORS IN SITE B

Respondents from Site B concurred that effective methods that could better address construction waste and resultant problems are recycling and reuse. In addition, acceptance of recycled materials by clients or funders, legislative measures, government sponsorships for recycling plants and promotion of recycled products in whatever mode deemed suitable were stated as possible drivers towards effective usage of recycled materials in construction projects. Responses given even to unstructured questionnaire items were very clear, hence follow up interviews were not conducted. Data was deemed sufficient for this study.

In Site B, design changes were mentioned to be the leading waste causation factor directly related to the design element of the project. Pilferage of construction materials was identified by the respondents to be one of the leading external waste causation factors on site. Furthermore, lack of environmental management was also mentioned to be a waste causation factor attributable to management or administration of Site B.

A complete list of waste causation factors identified by the respondents in Site B are as listed below in Table 4.4. Items in the table have been coded in line with a questionnaire that was used for collecting data.

Table 4.4: Waste causation factors in Construction Site B.

Item	Criterion of Waste Causation Factors	Site B Waste Causation Factors
Q8	Waste causation **design factors**	8.1 Design changes
Q9	Waste causation **material handling factors**	9.4 Damage during delivery to site 9.5 Too much handling of materials from site storages to work areas
Q10	Waste causation **work force factors**	10.4 Damage to materials by workers
Q11	Waste causation **external factors**	11.1 Pilferage/stealing 11.4 Unpredictable site conditions
Q12	Waste causation **management factors**	12.3 Lack of environmental management 12.5 Lack of coordination and information flow between parties
Q13	Waste causation **procurement factors**	13.2 Variation orders 13.3 Supplier errors 13.4 Subcontractors 13.6 Over allowances
Q14	Waste causation **site condition factors**	14.2 Problems of site access 14.3 Congestion of site
Q15	**Other** waste causation factors identified on Site B	15.6 Disposing of consumables 15.7 Topographical drainage condition

4.3.2 WASTE MANAGEMENT STRATEGIES EMPLOYED IN SITE B

Quite a number of strategies are in place in Site B to manage construction waste on site. Proper onsite management system, for example, proper stacking of materials and good housekeeping, proper planning of construction activities (sequencing of activities) and training of machine operators and laborers are some of the strategies mentioned.

It is interesting to note that method statements, waste management plans, environmental management plans have been stated as some of the strategies in managing waste as it is a requirement lately in most projects for such documentation. Further, some form of construction waste is because of components that are not specifically incorporated into the works, for example, pallets. It was stated that it is important that these are returned to suppliers to rid the site of such waste.

A full list of these strategies employed on Site B as detailed by the respondents is provided in Table 4.5 below.

Table 4.5: Waste management strategies employed in Construction Site B.

Item	Criterion of waste Management Strategies	Waste Management Strategies employed
Q16	Waste management strategies employed on Site B	16.1 Proper selection of materials 16.4 Proper onsite management systems e.g. proper stacking of materials, housekeeping etc. 16.5 Implementation and enforcement of policies and regulations 16.6 Proper planning of construction activities (sequencing of activities) 16.7 Drawing up and implementing Waste Management Plans 16.9 Adequate supervision of waste management activities with clear instructions 16.10 Training and education of machine operators and laborers 16.13 Transparency in reporting so that corrective action can be taken when necessary 16.14 Instilling sense of collective responsibility and teamwork
Q17	**Other** waste management strategies employed on Site B to reduce waste generation	17.6 Method Statements dealing with Site Establishment, Waste Management and rehabilitation 17.7 Environmental Management Plan 17.8 Give certain waste generated (e.g. Wood / Timber) to the local community 17.9 Ensure delivery packaging is returned back to suppliers where possible (e.g. Cement Pallets)

Respondents from Site B also provided an opinion as to what could be done to better manage waste causation in the construction industry through the design process of construction projects.

It has been mentioned that designs and specifications should specify recyclable materials. Further, it was stated that standard sizes of materials and components to be incorporated into the works should be thought of during the design stage. Designers also need to be proactive at design stage to accommodate reuse of waste materials produced by the project, for reuse within the project or other projects.

4.4 FINDINGS FROM SITE C

Site C is a commercial building project that includes a three-storey office block. The site is next to one of the national roads in the east rand area of Johannesburg. The features of the site, the size of the project and the size of the main contractor of the project meet the set criteria for this research. Major materials used on the project include bricks, ready-mix concrete, reinforcing steel, cement and various aggregates.

One questionnaire was received from Site C. This completed questionnaire was a consolidated effort of the Project Manager, General Foreman and a Quantity Surveyor. To further enrich the study, further data were collected by direct observation on site by the researcher. Some important aspects that were not mentioned in a completed questionnaire were identified. Materials were properly staked and housekeeping was very proper. Further, it was noted that the coordination of the whole project is well organized. Some debris that came off construction activities was utilized for fill on access roads. Concrete was not batched on site, instead ready-mix concrete was used. It was also gathered from informal discussions no large stock of material is stored on site. Bricks, cement for mortar, aggregates and other materials were ordered and delivered to site on a “just in time” fashion.

4.4.1 WASTE CAUSATION FACTORS IN SITE C

Respondents from Site C stated that generally effective methods in addressing construction waste and resultant problems from disposal of construction waste to be reuse and reduction. Acceptance of recycled materials by clients was stated as one of the ways that could improve usage of recycled construction products and materials. On the other hand, waste management plans on site were stated as a preferred tool of ensuring less waste generation on construction activities on site.

Design changes and slow distribution of drawings were mentioned to be the leading waste causation factors directly related to the design element of the project. Damage to materials by workers and mistakes by workers were identified by the respondents to be one of the leading material handling waste causation factors on site. Additionally, unpredictable site conditions were mentioned to be an evident external waste causation factor on Site C.

Table 4.6 below is a list of waste causation factors that were identified by the respondents on Site C. Items in the table have been coded in line with a questionnaire that was used for collecting data.

Table 4.6: Waste causation factors in Construction Site C.

Item	Criterion of Waste Causation Factors	Site C Waste Causation Factors
Q8	Waste causation **design factors**	8.1 Design changes 8.3 Slow distribution of drawings
Q9	Waste causation **material handling factors**	9.1 Wrong methods of loading and unloading 9.4 Damage during delivery to site
Q10	Waste causation **work force factors**	10.4 Damage to materials by workers 10.5 Mistakes by workers
Q11	Waste causation **external factors**	11.4 Unpredictable site conditions
Q12	Waste causation **management factors**	12.5 Lack of coordination and information flow between parties
Q13	Waste causation **procurement factors**	13.2 Variation orders 13.4 Subcontractors
Q14	Waste causation **site condition factors**	14.4 Too many separate contractors and/or subcontractors
Q15	Other waste causation factors identified on Site C	15.4 Changes in design 15.9 Over design of projects

4.4.2 WASTE MANAGEMENT STRATEGIES EMPLOYED IN SITE C

Several waste management strategies are in place in Site C to manage construction waste on site. Proper selection of materials and employing low waste construction technologies to minimize waste generation were some of the strategies mentioned.

A full list of strategies employed on Site C as detailed by the respondents and some personal observations is provided in Table 4.7 below.

Table 4.7: Waste management strategies employed in Construction Site C.

Item	Criterion of waste Management Strategies	Waste Management Strategies employed
Q16	Waste management strategies employed on Site C	16.1 Proper selection of materials 16.4 Proper onsite management systems e.g. proper stacking of materials, housekeeping etc. 16.6 Proper planning of construction activities (sequencing of activities) 16.15 Low waste construction technologies to minimize waste generation
Q17	**Other** waste management strategies employed on Site C to reduce waste generation	17.10 Calculations done to minimize wastage **Observed strategies:** 17.11 Offsite manufacturing i.e. use of ready-mix concrete instead of batching onsite 17.12 Reuse of demolition debris for access roads layer-works 17.13 Less material stock on site. “Just in time” deliveries of materials

A respondent from Site C mentioned that, regarding managing waste causation in the construction industry through the design process of construction projects – this should be driven by engineers and architects in the design phase to ensure that designs do not mean over handling of materials. It was also reiterated that proper inspection of sites at the design stage is required to ensure that the initial design does not differ too much from the final as-built project. Design changes during construction and possible demolition and reconstruction during the construction leads to waste that could have been avoided.

4.5 CONSOLIDATION OF RESULTS – SITE A, B AND C

A total of thirteen strategies were stated by respondents in answering open ended questions. Fifteen out of a possible seventeen were stated as common on the three sites brought together. In Table 4.8 below, strategies on the left (“Series 16”) were structured responses in a questionnaire. Strategies on the right side (“Series 17”) are other strategies mentioned by respondents in answering unstructured items of a questionnaire.

Table 4.8: Consolidated results from the three sites

Waste Management Strategies employed on construction sites in Gauteng: Consolidated results from three sites	
16.1 Proper selection of materials 16.2 Offsite manufacturing 16.4 Proper onsite management systems e.g. proper stacking of materials, housekeeping etc. 16.5 Implementation and enforcement of policies and regulations 16.6 Proper planning of construction activities (sequencing of activities) 16.7 Drawing up and implementing Waste Management Plans 16.8 Assign implementation responsibility for waste management to designated people 16.9 Adequate supervision of waste management activities with clear instructions 16.10 Training and education of machine operators and laborers 16.13 Transparency in reporting so that corrective action can be taken when necessary 16.14 Instilling sense of collective responsibility and teamwork 16.15 Low waste construction technologies to minimize waste generation	17.1 Ordering correct measured quantities and not from drawings 17.2 Ordering materials timeously and not way in advance 17.3 Materials on site checks 17.4 Charging sub-contractors for damage to materials 17.5 Doing it right the first time 17.7 Environmental Management Plan 17.8 Give certain waste generated (e.g. Wood / Timber) to the local community 17.9 Ensure delivery packaging is returned back to suppliers where possible (e.g. Cement Pallets) 17.10 Calculations done to minimize wastage 17.11 Offsite manufacturing i.e. use of ready-mix concrete instead of batching onsite 17.12 Reuse of demolition debris for access roads layer-works 17.13 Less material stock on site. “Just in time” deliveries of materials

4.6 CONCLUDING REMARKS

Data were collected by means of questionnaires that were emailed to respondents and returned the same way. Not so many completed questionnaires were received but data collected is believed to be reliable for this particular type of research. Data were also collected through participant observation on Site C in order to get some more data from the site.

5 DISCUSSION AND ANALYSIS

5.1 INTRODUCTION

This chapter focuses on the interpretation of the results that were presented in the previous chapter. Therefore, this chapter contains a discussion and analysis of the findings in relation to the aims and objectives of the study. Further, this chapter indicates implications and linkages between findings and the literature. Strengths, weaknesses and limitations of the study are also be highlighted.

Construction projects are undertaken for different socio-economic benefits to stakeholders. For example, funders develop to benefit from a facility or to provide a service or infrastructure; contractors and construction consultants undertake construction projects for a financial gain. Construction waste involves a loss of economic materials, financial losses in construction projects, environmental hazards just to name a few problems as a result of construction waste. Hence the need for construction wastes to be managed.

Central to this study is to establish construction waste management strategies that are employed on construction sites in Gauteng and how effective they are looking at other strategies and construction waste management techniques employed in other places around the world. Effectiveness of strategies employed on construction sites in Gauteng are evaluated looking at their pros and cons.

Data collected from three sites as shown in the previous chapter shows that there are quite a number of waste management strategies or waste control measures employed on construction sites in Gauteng. These waste management strategies that have been identified link back to literature that formed the basis of the study.

5.2 STRATEGIES COMMON IN CONSTRUCTION SITES IN GAUTENG

Numerous waste management strategies have been found to be employed on construction sites in Gauteng as shown in a simplified indication of these strategies in Table 5.1 below. Strategies highlighted have been mentioned to be in use in at least two sites.

Table 5.1: Most common Waste Management Strategies in Gauteng – a comparison of three sites

Item	Criteria	Waste Management Strategies employed in Gauteng: Results from three construction sites
Q16	Waste management strategies employed on Site A	16.1 Proper selection of materials
		16.2 Offsite manufacturing
		16.5 Implementation and enforcement of policies and regulations
		16.6 Proper planning of construction activities (sequencing of activities)
		16.8 Assign implementation responsibility for waste management to designated people
		16.9 Adequate supervision of waste management activities with clear instructions
Q17	Other waste management strategies employed on Site A to reduce waste generation	17.1 Ordering correct measured quantities and not from drawings
		17.2 Ordering materials timeously and not way in advance
		17.3 Materials on site checks
		17.4 Charging sub-contractors for damage to materials
		17.5 Doing it right the first time
Q16	Waste management strategies employed on Site B	16.1 Proper selection of materials
		16.4 Proper onsite management systems e.g. proper stacking of materials, housekeeping etc.
		16.5 Implementation and enforcement of policies and regulations
		16.6 Proper planning of construction activities (sequencing of activities)
		16.7 Drawing up and implementing Waste Management Plans
		16.9 Adequate supervision of waste management activities with clear instructions
		16.10 Training and education of machine operators and labourers
		16.13 Transparency in reporting so that corrective action can be taken when necessary
		16.14 Instilling sense of collective responsibility and teamwork
Q17	Other waste management strategies employed on Site B to reduce waste generation	17.6 Method Statements dealing with Site Establishment, Waste Management and rehabilitation
		17.7 Environmental Management Plan
		17.8 Give certain waste generated (e.g. Wood / Timber) to the local community
		17.9 Ensure delivery packaging is returned back to suppliers where possible (e.g. Cement Pallets)
Q16	Waste management strategies employed on Site C	16.1 Proper selection of materials
		16.4 Proper onsite management systems e.g. proper stacking of materials, housekeeping etc.
		16.6 Proper planning of construction activities (sequencing of activities)
		16.15 Low waste construction technologies to minimize waste generation
Q17	Other waste management strategies employed on Site C to reduce waste generation	17.10 Calculations done to minimize wastage
		17.11 Offsite manufacturing i.e. use of ready-mix concrete instead of batching onsite
		17.12 Reuse of demolition debris for access roads layerworks
		17.13 Less material stock on site. "Just in time" deliveries of materials

Twelve out of seventeen strategies that were listed in structured items in a questionnaire were ticked as being employed on construction projects in Gauteng to manage construction waste. These are shown as "Series 16" in Table 5.1 above. Additional twelve strategies that were not included in structured responses were stated by respondents to be used to manage construction waste in Gauteng. These are shown as "Series 17" in Table 5.1 above.

Five strategies were selected by respondents in at least one site. These were strategies coded 16.1, 16.4, 16.5, 16.6 and 16.9. Two of these five were selected in all the three sites. These were strategies coded 16.1 and 16.6: proper selection of materials and proper sequencing of construction activities.

It makes sense that strategies of proper selection of materials and proper sequencing of construction activities were found to be the most common. Proper selection of materials to be used in a project means translates to less quality related rejections by the client or agents of the client. Material rejections on site after material has been delivered lead to waste generation when materials have to be returned back to the supplier. Too much material handling and transportation as pointed out in the literature review is one of the causes of construction waste. Additionally, if material of poor quality is used on a project; rework, repair and maintenance in not uncommon. Both these factors lead to additional material requirements and material waste.

Proper selection of materials is not relevant solely on site operations. Selection of materials need to be correct right from the design process. Specifications often come with descriptions of materials to be used on a project. Hence it is imperative that proper materials are specified with the designs, for example, specifying prefabricated culverts instead of cast in situ culverts. At the same time, prefabrication helps avoid other waste causation factors such as poor workmanship and mistakes by operatives.

Proper planning and sequencing of construction activities in the construction process cannot be re-emphasized. Poor planning and sequencing of construction activities lead to a lot of rework. A simple example of poorly sequenced activities could be putting in plumbing pipes or electrical conduits after plastering. Executing these work activities in such a manner will mean that some plastering will have to be chiseled out and replaced after pipes or conduits have been put in place. Sometimes construction activities are not executed as initially planned depending on such factors as the budget, availability of materials, availability of personnel and equipment thus leading to some activities being delayed and others brought forward. This is common in construction projects to avoid paying standing labour and plant and to avoid time overruns.

Proper planning also relates to making sure that resources in the form of materials, labour, plant and equipment are available and sufficient for all work activities. Inadequate resources inherently lead to slow productions, poor quality of work and other productivity related bottlenecks. Resultantly, reworks and other productivity related problems become common on construction sites; eventually leading to construction waste that could have been avoid by proper planning, resource allocation and leveling.

Leading possible strategies to managing construction waste are successful or relevant to a certain extent. There is a problematic waste causation factor of design changes that is common on most construction projects. Design changes are often inevitable in construction projects as site conditions may differ from what was anticipated. However, it is fair to state that design changes during construction is the leading waste causation factor and it is difficult to get a strategy that could wholly address this factor since some design changes cannot be avoided.

5.3 EFFECTIVENESS OF WASTE MANAGEMENT STRATEGIES EMPLOYED

As shown in the literature review chapter, effectiveness of waste management strategies is gauged on scale of the waste management method hierarchy. The most preferred methods are aligned to waste reduction (minimization and prevention) followed by reuse and then recycling. Waste disposal methods are the least preferred.

Adequate supervision of waste management activities is one of the strategies that has been identified as being common in Gauteng. This strategy is more linked to all the methods of the hierarchy. It is perceived that this strategy is very relatively effective and more important. Supervision could enhance awareness, improve knowledge and experience in all the categories of the hierarchy. Adequate supervision aimed at reducing waste generation, reuse of waste materials, recycling of waste and even disposal of waste is imperative in effective waste management.

Proper selection of materials can also be classified as an effective method since it is more linked to minimization of waste generation that could emanate, for example, from quality failures and rework. Proper selection of materials includes making sure that only materials that meet minimum project specifications are procured. The design function also has a role in the selection of materials for the project. As pointed out in literature, waste reduction should be factored into the design process. This strategy is therefore considered effective because it is a strategy that involves even the design process where important decisions are made.

Implementation and enforcement of policies and regulations is also a waste management strategy that is aimed at minimization of waste generation. It also follows that proper sequencing of work activities also promotes a smooth flow of work thereby reducing reworks. These strategies are therefore also effective when employed for waste management.

Waste management strategies that have been identified to be employed on construction sites in Gauteng, based on the three sites, are considered generally effective especially looking at the causation factors stated as prevalent on each site. Strategies employed to manage counter the effects causation factors are deemed relevant.

5.4 PHASES OF CONSTRUCTION WASTE MANAGEMENT IN GAUTENG

From an analysis of results of a study of waste management strategies employed on construction sites in Gauteng, it has been established that traditional or basic strategies and techniques are more common. Technologies and workforce training; for instance, are not common strategies.

Workforce training as pointed out in the literature review is one of the powerful strategies in achieving better waste control on construction sites. There are a few reasons why this strategy is not so common. The temporary nature of construction projects is one of the reasons. It often does not make an economic sense to send people for training and lose productivity yet the project is under tight construction time frames. Further, a huge proportion of each construction project team is made up of temporarily employed personnel. As such, it is always perceived not to be immediately beneficial to send workforce for such training sessions.

Technological advancement like the Building Information Modelling (BIM) has not been found to be used in Gauteng. However, this is still a new developing tool. The researcher believes that BIM will be adopted gradually across the globe and make such parameters that have a huge impact on controlling waste like planning of construction activities, quantity surveys and information flow between project teams to be better managed and resultantly contribute towards effective waste management and minimization of waste creation.

5.5 CONCLUDING REMARKS

The aim of this study is to identify waste management strategies common on construction sites in Gauteng. Proper selection of construction materials and proper planning of construction activities have been identified as the most common waste management strategies employed on construction sites in Gauteng. These strategies also help contractors on construction projects to meet some project control objectives like for instance cost reduction, smooth flow of work, procurement and resource planning. Though project specific and dependent on client needs and other project specifications, use of prefabricated materials is also regarded to be a common strategy in managing waste on construction sites in Gauteng.

Strategies stated above, that were found to be employed on construction sites in Gauteng, have some pros and cons against other strategies identified in the literature. For instance, proper selection of materials could be effective in avoiding re-works and quality issues on site. Proper sequencing of works promotes smooth flow and tracking of works activities and helps in procurement planning of resources. However these strategies also have limitations with regards to their effectiveness in controlling waste. Proper selection of materials and proper scheduling of work activities does not in any way address construction waste caused, for instance, by design changes. Design changes have been identified as the leading waste causation factor. It is imperative therefore to encourage stakeholders to ensure that the design is fine-tuned to satisfaction prior to construction or during initial stages of construction to avoid generation of waste as a result of changes in designs. This is unusual though because of some unforeseen factors, design errors, changes in client needs and other factors.

Some recommendations regarding waste management strategies and their implementation on construction sites are presented in the following chapter in the context of construction sites in Gauteng and beyond. Generally though, it has been established that several strategies need to be employed on a single project and different phases of the project and on different activities. No single strategy can be totally effectively as a method of controlling or managing construction waste.

6 CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

Problems emanating from poor waste management and associated environmental impacts have become a pressing issue. There is a need to reduce generation of waste, reuse waste materials and recycle waste to useable products to avoid or minimize disposal into landfill areas; to achieve sustainability goals and to keep the environment clean. As pointed out in the literature in different areas across the world; the construction industry contributes a huge amount of solid waste that end up in landfills and other pieces of land unauthorized for landfill purposes. Effective construction waste management strategies aligned to 3R principle helps mitigate such a problem.

This particular study was carried out to identify strategies used on construction sites in Gauteng to manage construction waste. The objectives therefore being to highlight the pros and cons of such strategies employed and to recommend some strategies that have been used successfully in some urban areas. Gauteng is a largely developed urban center in South Africa; landfill is not favorable hence the need to continuously seek to establish and develop strategies that can better address the issue of construction waste.

Though it is well recognized that there are barriers in implementation and application of construction waste management strategies on construction sites; it is still important to keep on agenda the importance of effective waste management on construction sites. Notable barriers to waste management on construction projects mainly relate to time, cost, safety and quality objectives that are normally prioritized ahead of waste management. However, it is also recognized that construction waste has residual value and its generation can be reduced thus contributing towards the achievement of time, cost, safety and quality requirements on any construction project.

6.2 OVERVIEW OF THE STUDY

This study was carried out to identify waste management strategies employed on construction sites in Gauteng. Three sites were chosen to form part of the broader population base for the study that was conducted on a survey strategy using an emailed questionnaire. Specific targeted respondents included project managers, site agents, engineers, quantity surveyors, general foreman from the three sites.

Extensive literature was critically reviewed and formed a foundation to the study. The function of construction waste management was defined and elaborated from the literature. Major concepts of waste management, waste management hierarchy; practices and principles of construction waste management defined and explained.

The research onion (Saunders et al., 2009) formed the main source upon which the research design was derived and formulated. In short, a questionnaire was used on a snapshot survey of three construction sides in Gauteng. The study was qualitative rather than quantitative and as such focused on understanding facts rather than explanation of phenomena on an interpretivist philosophy.

Collected data was analyzed qualitatively using open coding techniques to breakdown data. Findings tied back to literature but the hypothesis that prefabrication and off-site testing is a common construction waste management strategy in Gauteng was rejected. Common strategies amongst the three sites were as mentioned in the in the conclusion below. It is further noted that awareness has to be improved in the industry at large to prioritize waste management at the same par as cost, time, quality and safety.

6.3 CONCLUSIONS

Findings from three on-going construction sites through a cross-sectional survey that made use of a questionnaire data collection method with structured and semi-structured items identified strategies employed on construction sites to manage construction waste. These research results can help understand the current situation regarding construction waste management in Gauteng and can therefore help towards improving construction waste management.

There are several strategies that have been found to be employed on construction sites in Gauteng to manage construction waste – as shown in the previous chapters. The following strategies were found to be the most common amongst the three construction sites in Gauteng;

a) Proper selection of materials;
b) Proper planning of construction activities (sequencing of activities);
c) Implementation and enforcement of policies and regulations;
d) Adequate supervision of waste management activities with clear instructions, and;
e) Proper onsite management systems for example, proper stacking of materials, housekeeping

Findings from this study show that proper selection of materials and proper planning of construction activities has been identified as the most common strategies employed to manage construction waste in Gauteng. It is recognized that these strategies are not strictly context-specific but the notion makes logical sense on any construction project world-wide. Selection of quality materials helps to meet project specifications and/or quality requirements in any project.

Some researchers (Wu et al., 2016) have mentioned that economic viability and governmental supervision are the two significant factors influencing the contractor to make construction waste minimization decisions. It is noted that this notion concurs with the strategies listed above of adequate supervision, proper management systems and enforcement of policies. However, it is noted that governmental laws and regulations are often very broad. Contractors play a part as well on construction sites in developing some internal policies to make sure that set regulations are met. Further, contractors logically plan and execute work activities in order to produce a final product that meet requirements. In this particular study, proper sequencing of construction activities has been identified as one of the leading strategies favorable in controlling the generation of waste on construction sites. Proper planning and sequencing of working activities determine the timing and type resource requirements as the project progress. Therefore, it is noted that there are some significant factors influencing the contractor to make construction waste minimization decisions additional to or supplementary to economic and legal objectives.

Contractors have a major role to play on construction sites to minimize the generation of construction waste. Various waste management strategies and measures have been reported in the existing literature. The implementation of these waste minimization strategies, however, still has to be improved in Gauteng. Technological measures such as lean construction and such measures and training and education could be useful.

6.4 RECOMMENDATIONS

Sentiments made by Wu et al. (2016) that economic viability and governmental supervision are the two significant factors influencing contractors to make construction waste minimization decisions have been proved true in this study. This particular study has established that construction waste management strategies employed on construction sites in Gauteng are mostly aimed towards financial gains (economic viability) and compliance to legislation and by-laws. Therefore, as concluded by the same author, it is recommended in this particular study that enhancing legislation could be one of the effective measures in order to push contractors to minimize waste generation on construction sites.

It is very unlikely to have zero waste from construction activities. New construction projects in Gauteng urban expansion and urban renewal through demolition of existing buildings cause a lot of construction waste. This waste can be converted back into usable materials by recycling processes. Still, waste management strategies of proper selection of materials for construction, proper planning of construction activities and other methods as stated in the previous chapter should be employed to reduce generation of waste and for management of waste on construction sides. For example, demolition waste or rubble can be reused on site as base of access roads instead of importation of other materials (proper selection of materials).

It was mentioned in the literature review that BIM can be utilized as a less expensive, virtual, and computational environment to enable designers to ponder different design options, or contractors to evaluate different construction methods, both leading to construction waste generation minimization. It is therefore recommended to embrace this technology in the near future to help manage construction waste - from designing out waste right in the design process through to minimization of waste generation on construction sites.

6.5 AREAS FOR FURTHER RESEARCH FLOWING FROM THE RESULTS

This study has been successful in identifying waste management strategies employed on construction sites in Gauteng to meet the objectives of the study. Strategies identified concur to the existing literature. As pointed out above, the most common strategies have been identified as proper selection of materials and proper planning of work activities on site. However, there are some important strategies that can still be implemented and address the problem of construction waste generation more effectively, for example, BIM, lean construction technologies, training and education among other measures.

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APPENDICES

APPENDIX A: QUESTIONNAIRE

APPENDIX A

RESEARCH QUESTIONNAIRE

Title of study: Waste management strategies employed on construction sites in Gauteng

Could you please complete the following questionnaire by ticking the relevant box or boxes or by typing in your answer in the text box provided underneath each question. Email completed questionnaire to 554575@students.wits.ac.za. For clarification and enquiries in connection with this questionnaire, feel free to e-mail or call +27 71 868 0452. Thank you for participating.

1. What type of a construction project are you working on?

(i)	Building project (Commercial)	√
(ii)	Building Project (Residential)	
(iii)	Building Project (Other)	
(iv)	Road Works Project	
(v)	Civil Works Project	

2. What is the expected duration of the project?

Start Date	mm-yyyy
Completion Date	mm-yyyy

3. Where is the project located?

East Rand	
West Rand	
Johannesburg North	
Johannesburg South	
Johannesburg Central	
Pretoria East	
Pretoria West	
Pretoria North	
Centurion	
Pretoria Central	
Other Gauteng areas (specify:)	

4. Which of the following waste control methods is best effective in managing waste?

(i)	Waste disposal	
(ii)	Recycling	
(iii)	Reuse	
(iv)	Reduction	

5. It is advisable to recycle and reuse construction waste. Which of the following options do you think would encourage the construction industry to recycle and reuse more?

(i)	Acceptance of recycled materials by clients	
(ii)	Legislation	

(iii)	Government sponsorships for recycling plants	
(iv)	Promotion of recycled products	
(v)	Other: (specify:)	

6. Which of the following do you think would enable your site to reduce waste generation?

(i)	Staff training	
(ii)	Use of prefabricated components	
(iii)	Waste Management Plans	
(iv)	Disciplinary action on wasteful operators and workers.	
(v)	Other: (specify:)	

7. List major materials that are used in your project.

(i)	(iv)
(ii)	(v)
(iii)	(vi)

8. Which of the following waste causation **design factors** lead to a lot of waste on your site?

(i)	Design Changes	
(ii)	Design errors	
(iii)	Slow distribution of drawings	
(iv)	Complicated design	

9. Which of the following waste causation **material handling factors** lead to a lot of waste on your site?

(i)	Wrong methods of loading and unloading	
(ii)	Wrong material storage	
(iii)	Poor quality of materials	
(iv)	Damage during delivery to site	
(v)	Too much handling of materials from site storages to work areas	

10. Which of the following waste causation **work force factors** lead to a lot of waste on your site?

(i)	Poor workmanship	
(ii)	Incompetency	
(iii)	Lack of training	
(iv)	Damage to materials by workers	

(v)	Mistakes by workers	

11. Which of the following waste causation **external factors** lead to a lot of waste on your site?

(i)	Pilferage/stealing	
(ii)	Bad weather	
(iii)	Accidents	
(iv)	Unpredictable site conditions	
(v)	Holidays e.g. December shut down	

12. Which of the following waste causation **management factors** lead to a lot of waste on your site?

(i)	Insufficient site management	
(ii)	Wrong construction methods	
(iii)	Lack of environmental management	
(iv)	Long project durations	
(v)	Lack of coordination and information flow between parties	

13. Which of the following waste causation **procurement** factors lead to a lot of waste on your site?

(i)	Ordering errors	
(ii)	Variation orders (change orders)	
(iii)	Supplier errors	
(iv)	Subcontractors	
(v)	Mistakes in quantity surveys	
(vi)	Over allowances	
(vii)	Items out of specification	

14. Which of the following waste causation **site condition** factors lead to a lot of waste on your site?

(i)	Unforeseen ground conditions	
(ii)	Problems of site access	
(iii)	Congestion of site	
(iv)	Too many separate contractors and/or subcontractors	
(v)	Poor site conditions	

15. What **other** waste causation factors have you identified on your site?

(i)
(ii)
(iii)
(iv)
(v)

16. Which of the following strategies are employed on your site to manage construction waste?

(i)	Proper selection of materials	
(ii)	Offsite manufacturing	
(iii)	Use ICT packages like BIM for accurate quantity surveys	
(iv)	Proper onsite management systems e.g. proper stacking of materials, housekeeping etc.	
(v)	Implementation and enforcement of policies and regulations	
(vi)	Proper planning of construction activities (sequencing of activities)	
(vii)	Drawing up and implementing Waste Management Plans	
(viii)	Assign implementation responsibility for waste management to designated people	
(ix)	Adequate supervision of waste management activities with clear instructions	
(x)	Training and education of machine operators and labourers	
(xi)	Financial rewards and incentives for machine operators and labourers	
(xii)	Organizing regular meetings to check conformance and lessons learnt	
(xiii)	Transparency in reporting so that corrective action can be taken when necessary	
(xiv)	Instilling sense of collective responsibility and teamwork	
(xv)	Low waste construction technologies to minimize waste generation	
(xvi)	Increasing landfill charges	
(xvii)	Prequalification of contractors and subcontractors based on waste management generation	

17. What other waste management strategies are employed on your site to reduce waste generation?

(i)
(ii)
(iii)
(iv)
(v)

18. What measures can be taken at design stage to ensure minimum waste generation on site during construction stage?

(i)	e.g. Standardizing the design to suit available sizes of components and materials
(iii)	
(iii)	
(iv)	
(v)	

The End…. Thank you ☺