AN IDENTIFICATION OF FACTORS INFLUENCING DELAY, REVISION AND REWORK IN MULTIDISCIPLINARY INFRASTRUCTURE DESIGN PROJECTS IN SOUTH AFRICA

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A research report submitted to the Faculty of Engineering and Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2014.

Declaration

I, Ohikhateme Adeoye declare that this research report is my unaided work. It is being submitted in partial fulfillment of the degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other university.

....

(Signature of Candidate)

....5th..............day of ....August..........................2014

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DEDICATION

To God, Most High I dedicate this work and to the loving memory of my mother, Patience Osomoaghe Adeoye, I love you Mum.

ABSTRACT

For many years now delays, reworks and revisions have weighed down the construction industry in South Africa. There have been several attempts to minimize this problem, but none has managed to comprehensively manage this scourge and it looks as though the situation has come to stay. This study takes a look at some of the supposed causes of delay, rework and revision found in the literature in the light of their characteristics and influence. The data is drawn from a questionnaire survey of forty three construction industry professionals practicing in South Africa. Using a step multiple regression analysis, T-Test analysis and relative importance index to determine the major causes of delay, rework and revision. It was found that change related issues and approval related issues were amongst the foremost factors causing delay, rework and revisions. The study also found problems of inadequate design coordination tools, poor information technology, inadequate change management structures and systems, and poor scope definition to be significant problems facing the industry.

Keywords: Scope definition, Change management, Approval, delay, rework, revision

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List of Acronyms

AEC: Architecture Engineering and Construction

BIM: Building Information Technology

CPM: Critical Path Method

DSM: Dependency Structure Matrix

GERT: Graphical Evaluation and Review Technique

HVAC: Heating, Ventilation and Air Conditioning

M&E: Mechanical and Electrical

PERT: Project Evaluation and Review Technique

QFD: Quality Function Deployment

SPSS: Statistical Package for the Social Sciences

CHAPTER ONE: INTRODUCTION

1. Introduction

Multidisciplinary design is a series of problem solving activities performed by various groups of design experts to meet client's requirements and specifications within a specified time and budget. Multidisciplinary designs are provided to help handle our progressively complex and developing structures. The present day approach to multidisciplinary design work is iterative and time consuming, leading to poor and expensive designs. There are problematic issues inherent in any design project, especially in the multidisciplinary design project settings where experts from different fields and level of experience have to work together. An important aspect of multidisciplinary design is how the issues arising are identified, aligned, managed and resolved in order to reduce revision, rework and delay. Many factors can hamper the progress of a multidisciplinary design process and cause delay, revisions and rework. So it is important to understand the workings around the design process. Yang and Wei (2010) identified some factors responsible for delays, rework and revision in the design process to include some design changes, poor labor productivity, inadequate planning, owners error, designer errors, an external body, by an act of God. Most of the disputes and claims arising during and after projects are as a result of time and cost overruns which are a fall out from delays, reworks and revision. Further Yang and Wei (2010) also suggested that delay, rework and revisions seem to be part of all projects, so that identifying the factors influencing them and preventing them from occurring, are better than resolving subsequent delay-related disputes. This is a proactive approach to managing delays, revisions and reworks in multidisciplinary designs. This phenomenon of continuous influence warrants the study, the identification of the factors causing delay, rework and revision on the design processes in Architecture, Engineering and Construction (AEC) projects. Identifying delay liabilities also helps to improve delay and dispute resolution.

Though, there is a better awareness of the importance of an operational design management system in order to achieve better coordinated drawings within the agreed time and cost (Choo *et al.*, 2004). Still, not much has been achieved in terms of the actual identification and management of the design related issues, as more time and focus has been given to identification and management of issues surrounding the construction phase. It is clear that a scientific examination of the causes of delays, reworks and revisions is the first step to developing effective prevention strategy (Love *et al.*, 2008). Hence, the main objective of this study is to identify the common factors that are responsible for delay, revisions and rework in South African multidisciplinary design projects and to propose an effective mitigation plan.

1.1 Generic design process and characteristic

Generic design process can be described as a conventional group of activities used for executing a design. A design team is a transitory organization, having a unique generic process, purpose and composition, comprising diverse people and cultures from different disciplines and business firms appointed to carry out diverse kinds of specialist work on a project. The generic design process concerns itself with the end product of the design, the behavior and the performance of individuals concerned, and the organization and interaction of design groups engaged in the generic design process. A generic design process model can be divided into phases, which aids the designer to communicate the tasks, solutions and processes and improve management control in an engineering process. The generic design process can be used as a standard base line for the development of specific design processes. Tasks and deliverables can be defined using generic design process levels and phases. Shared generic design process models can be used to synchronize processes of multiple stakeholders. Terms in the generic design process model act as defined reference terms used to communicate process progress or stages. Stanland (1974) stated that the generic design process has three aspects, the organization, the task and the solutions. More recent research (Senthilkumar, 2010) stated that the generic design process has three domains; people, product and process which work together by several dependencies. A generic design process may not be useful in all design situations, as each design has its own specific characteristics. Nevertheless, a generic design process model provides guidance, in basic management processes in the improvement of the conventional design and construction process in the construction industry. The main dimensions of the design situation will dictate the form of design process to be initiated. There are significant similarities and crucial differences between design activities implemented in different situations that are influenced by the characteristics of the design situation such as the task, the designers and the organization. To get a design process that is most suitable we augment the classical generic-design process with other different forms of designing. The modified generic-design process connects three different positions (people, product and process) with respect to design activities that is been used (Smith and Eppinger, 1995).

The connection between the domains of the design process and their dependencies ordinarily creates a generic design process that is iterative, high in rework, revisions and delays. The process often contains a set of complex relationships in the middle of a grandiose number of interconnected problems. It is the interconnected that leads to iteration among the various engineering task in a large project (Smith and Eppinger, 1995). The generic design process is an act which has its methods, thinking and its processes. The activities are influenced largely by scientific factors and the interactions among various stakeholders with different perspectives (Lu and Cai, 2001). These interactions often have dependency relationships which characterize the design process, which if they are not managed properly can lead to waste in terms of rework, revisions and delay. The concept of waste is difficult to appreciate in design and hence it easily goes unnoticed. Information management has been established to be vital to the success of the design process. Traditional design process makes use of Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) to manage design projects since they measure delay impact. These techniques fall short for more complex designs and are not proactive methods. These techniques are also inadequate for managing the iterative and information intensive requirements of current design processes. The need to understand and develop the science behind the generic design process is important and is one of the rationales behind this study, since one method cannot be used universally for all situations. In order to broaden our understanding and horizon on this issue, an exploratory study into real world design problems is required.

1.2 State of the South African industry

In South Africa, as in many developing countries, the design practice used for solving difficulties in multidisciplinary designs involves ad-hoc strategies obtained through multiple opinions brought to the design process. Instead of linking the different opinions, the design practice accepts the strongest opinion. This method is not a holistic problem solving approach to multidisciplinary problems (Shakeri and Brown, n.d.). Another practice for solving complexities in South Africa is the use of sequential design, this method encourages the different disciplines in the design process to take part in the design process sequentially and information sharing is done only at interfaces. This method does not allow conflicts between disciplines to be identified timeously, but rather encourages late identification of conflicts leading to larger amounts of rework and delays (Shakeri and Brown, n.d.). The project practices adopted can affect the way participants perform their task in a multidisciplinary team. This can also influence the nature of the design firms in a place.

In South Africa, technical staff losses have continued to rise in the engineering field due to the existence of these adverse practices (Lawless, 2007). Civil engineering professionals per 100,000 people have dropped to two. Electrical engineering profession is no better. As a result of this inadequate capacity, infrastructure targets are not being met, proper planning is not being done, infrastructure is deteriorating, and rework, revisions and delays are widespread (Lawless, 2007). The fact that South Africa lacks the adequate number of professionals it requires in her construction industry makes the study of the factors triggering delays, rework and revisions more relevant. For South Africa to be able to compete with the rest of the world in the business of construction, she should be striving towards eliminating or minimizing delays, rework and revisions in her industry. One of the first step towards eliminating these delays, reworks and revisions is by identifying the factors causing them, which is what this study is seeking to achieve.

A typical multidisciplinary design process in South Africa will usually be executed by a team of design experts selected from diverse fields inside the same company or from another company. The team is formed to execute a specific project over a period of time and within a specified budget. Many times this team is formed without any methodical development of the requirements and no evaluation of design goals with respect to the requirements. This type of arrangement usually causes delays, reworks and revisions to thrive.

The traditional planning tools generally employed in design and construction projects in South Africa include the Graphical Evaluation and Review Technique (GERT), Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM). These are not holistic enough for managing multidisciplinary projects. These planning tools are limited in managing the iterative nature of concurrent and fast track multidisciplinary projects in South Africa, thus leading to inept and expensive designs with many delays, reworks and revisions. Sometimes, design teams may operate from different geographical locations, this further exacerbates the already problematic situation. Marquardt and Nagl's (2004) study of current design procedure reveals that the creative design process is not yet well understood in South Africa because the design process and its results are not well documented. This therefore does not encourage systematic reengineering, continuous improvement and reuse of previous solution and experience.

1.3 Purpose of the study

Over the years design revisions, rework and delays have adversely impaired project performance in South Africa and have continued to contribute to time and cost overruns (Baloyi and Bekker *, 2011). Today's assessment of many construction firms have shown that knowledge and expertise required in multidisciplinary designs are limited and the pressure for shorter time for design and construction is increasing (Wang *et al.*, 2002). This situation compounded with inadequate facilities and human capacity has invigorated the current level of delays, revisions and reworks we find in South Africa. Although, there has been a considerable amount of research into this area, the factors that cause revisions, delays and rework are not fully established.

Baloyi and Bekker , (2011) investigation of the factors causing delays during the construction of the 2010 fifa world cup stadia, revealed incomplete drawings, design changes, clients slow decision making, inadequate planning and scheduling as the main causes of delays. The study revealed that nearly all the projects (upgrading and construction of new stadia) experienced time delays and cost overruns.

In this competitive business environment of the 21st century, the need for constant improvement in the design and construction methods cannot be overemphasized. Any industry that is to attain and keep any competitive advantage in terms performance and lucrativeness should always be striving to get better and better. This report is in line with improving design and construction methods in South Africa and giving the industry a competitive advantage.

The presence of design delays, revisions and reworks and their resultant cumulative negative effects on project performance in South Africa cannot be denied and thus a solution is required. The actual cost incurred from these delays and rework may not be known, because they are usually not measured or documented by companies. In dealing with this issue, this study seeks expert understanding regarding delays, rework and revision issues from projects which they have been directly involved with. By performing this in-depth study into delays, reworks and revisions in multidisciplinary designs project, this study tries to unfold and unpack the industry-wide discernment of factors influencing or causing delays, rework and revisions.

The importance of this study is gaining importance internationally, and there are serious dangers for countries that ignore it. South Africa runs the risk of continuously making uninformed decision that may lead to major delays, rework and revisions if the industry continues to ignore this study. It is hoped that the findings from this study would help to improve the standard of design and construction practices in South Africa. It is also hoped that the outcome of this study will help to save time and cost, and reduce conflict amongst practitioners in the industry. This study is also used to show the influence of project characteristics, clients, designers and contractors have on design outcomes. A quick evaluation of the literature suggests that delays, reworks and revisions are caused by a cluster of issues which work collectively together. It is hoped that the findings from this study can contribute to the existing body of knowledge in terms providing more knowledge for better management of design and construction projects in South Africa.

1.4 Problem statement

Many researchers have described delay, revision and rework as a global problem in the design and construction industries. The inability to deliver infrastructure projects on time and within budget has been the downfall of many designers and contractors in South Africa. Delays, revisions and rework are still found in the work of most of the typical design and construction companies in South Africa, causing the complications of time and cost overruns on projects.

Multidisciplinary design method has emerged as a more effective form of designing, which can easily accommodate larger and more complex projects arising from man's evolving and increasing needs. It involves a combining of experts from different fields of knowledge. The current planning methods in engineering design and construction give little attention to the iterative nature of the multidisciplinary design process, thus leading to series of rework with its resultant time and cost overruns in the design and construction phases. (Josephson and Hammerlund 1999 cited in (Li and Taylor, (n.d.) found that rework, revisions and delays can increase construction cost significantly by up to 10% - 15% of the contract price. Li and Taylor (n.d.) suggests that in large infrastructure projects, undetected and unresolved rework in the design phase could lead to even larger amounts of rework, delays and revisions in the construction phase. Rework and revisions are normally associated with addressing errors or changes. Fixing rework near the point of rework creation usually increases efficiency and reduces rework losses. When an error or a change is discovered late in the project development process, the impact of the rework on the overall project performance is always more. Essentially, both the design and construction phases will benefit from eliminating the causes of rework early or nearer the point of creation.

It was also observed that current procedure in planning, management and control of multidisciplinary design projects in the United States of America is similar to that of

South Africa. It is not a holistic process as it mainly focuses on the delivering the design deliverables, enumerated at the beginning of every stage of the design or construction phase, rather than planning, managing, and controlling the entire process, the flow of information throughout the processes (Choo *et al.*, 2004). Information is a key factor, in the success of any multidisciplinary project because of the different aspects and fields involved. It is evident that more research needs to be carried out, in the field of multidisciplinary design projects, in order to get a better understanding and a holistic view of the underlying factors causing failures during the multidisciplinary design process.

Infrastructure projects are usually complex multidisciplinary projects and they usually require professional support in various areas of the project. The ability to create a pool of knowledge, solutions and to develop a multidisciplinary approach to problem for the client is needed. This is achieved by team work. Structural engineers, civil engineers, mechanical engineers, architect, draught men, electrical engineers, builders, geologist and planners form part of infrastructure projects that provide technical and professional support. These different groups are usually supposed to come together to form multidisciplinary teams that implement the design and construction of the project. These groups before coming together usually have well-entrenched institutions which can be a huge problem to manage during the design process.

Also, a significant factor to be managed in infrastructure project is the government. The government may be present as the client, licensor, regulator or grantor etc. Usually these different institutions that come together have their own set operating philosophies and culture which is a challenge for setting up a team that fits the intended purpose. A design environment and which can manage the different institutions is also required. Team work and information flow are therefore necessary ingredients in any successful multidisciplinary project.

The design tools used by the South African industry cannot model the iterative nature of the developmental design process, and this leads to delay, rework and revisions which have a knock on effect on time and cost of the project. Hence, identifying the key factors influencing the delay, revision and rework in the design process is a key step in coming up with robust and profitable solution for overcoming these problems.

1.5 Aims and objectives

The objective of this research is to determine the factors influencing design delays, revisions and rework in South African multidisciplinary design projects.

Some other objectives of this study include;

1. To comprehend the characteristic of multidisciplinary infrastructure design projects in South Africa.
2. To identify the factors influencing revision, rework and delay in South African multidisciplinary design projects.
3. To identify the relationships between the causes of delays and the design performance indicators

1.6 Hypotheses

The following four hypotheses were tested by this study

- There is no relationship between the top 10 causes of delays, reworks and revisions and drawing (design) rework
- Information related issues have no significant effect on design delay
- Changes have no significant effect on Drawing (Design) Rework
- Scope change and poor information flow combined will have no significant effect on site rework due to design

1.7 Research questions

- What are the characteristics of multidisciplinary designs projects?

- What are the possible root causes of revision, delay and rework in South African multidisciplinary design and construction projects?

1.8 Scope of study

This present work is focused on the delay, rework and revisions during the design process and also the delay rework and revisions during the construction phase but are due to the design related factors.

1.9 Limitations of study

The study is limited to Gauteng province, South Africa. However, a large population of design and construction firms in South Africa has their head offices located in Gauteng- possible about 70%.

1.10 Assumptions

- This study assumes that there exist factors that influence delay, revision and rework in South African multidisciplinary design projects.
- The study assumes that the design firms interviewed are representative of the population under study.

1.11Research design and methods

The term "quantitative" means to quantify two concepts using mathematics and inferential statistics. Golafshani (2003) stated that quantitative research permits the researcher to become acquainted with the issues of the study and produce a hypothesis that would be tested. This is in line with this study. He further noted that quantitative research supports a scientific or positivist paradigm in which facts are observed and measured (variables can be identified and relationships can be measured).

A quantitative research method is adopted for this study because it provides a process that is capable of fulfilling the purpose of this research and answering the research questions. There are different approaches and strategies that may be used for a quantitative research design. The current study adopted the following strategies:

Epistemology is the philosophical knowledge inherent in the theoretical perspective and also in the methodology (Crotty, 2009). This research chooses 'objectivism' as its epistemological perspective, since it is in line with the aims and purpose of the study. One of the aims of this research and of choosing this research design is to generalize the information gathered from the sample to the population, so that some inferences can be drawn about the characteristics of the population.

Positivism is one of the four theoretical perspectives listed by Creswell, (2009) and it has been adopted for this study. It is a deterministic philosophical approach in which causes or factors determine outcomes (Creswell,2009).The study is aimed at determining the factors influencing delay, rework and revisions in multidisciplinary infrastructure design projects in South Africa, and aims to propose an effective mitigation plan to avoid design revisions, rework and delay. This research study adopts an inductive approach which is a method of building theory. This is consistent with achieving the aims and objectives set out for this research. The inductive approach enables a closer understanding of the research context and the meanings social actors attach to the design process. These are consistent with the emphasis of induction listed in Saunders *et al.*, (2002).

A questionnaire survey is proposed for data collection in this study. According to Saunders *et al.*, (2002), a questionnaire is a data gathering tool used to inquire a set of questions in a predetermined order. Structured and semi structured interviews may also be used to gather information and to clarify some of the questionnaire related issues. Statistical analysis was proposed for this research.

The methodology involved

- An investigation and analysis of the literature to ascertain possible parameters that influence delay, rework and revision
- Using questionnaire surveys to collect data
- Statistical analysis of the data to identify critical factors influencing delay, rework and revision.

Some factors influencing researcher approaches, strategies and methods chosen include:

- Settings
- Researcher's skill
- Research paradigm
- Ethics
- Participant's concerns
- Accessibility

1.12 Ethical standard

Ethics is moral correctness of a specified conduct. Privacy is the corner stone of the ethical issues that confront those who undertake research. It is important that research which involves gathering data meets ethical standard in terms of consent, confidentiality, participant reactions and the effect of the way in which data is used, analyzed and reported. This research has taken proactive steps in meeting the requirements set out by the Human Research Ethics Committee set up by the University of the Witwatersrand. In order to satisfy ethical considerations in this study, the following guidelines were observed:

- Participation in the research is strictly voluntary and unwillingness to participate will not carry any penalty or loss of benefit to respondents.

- The names of participants in this study will not be revealed unless permission is given, and specific details that may be used to identify particular projects, clients, or individuals will be omitted.

Some of the ethical issues related to this study include privacy, consent, and confidentiality. The way and manner, in which the data collected is used, analyzed and reported is also an issue of ethics related to this study.

In this study an assurance to protect the privacy, interest, confidentiality and right of each and every participant is written out at the onset, stating that the above ethical guideline is adhered to by the researcher. This assurance is written as part of the consent form given to each intending participant, see appendix c. The agreement to keep the confidentiality is specified to each prospective participant at the time when the participants permission to be part of the survey is being sought. The aim of this is to assure the prospective participant that their confidentiality is safe guarded throughout the study. This helps to ensure that the respondent privacy is preserved and the respondent will not suffer any loss of benefit as a result of the information they have provided to this study.

1.13 Structure of the report

This research report is divided into five chapters.

Chapter One: introduces the research project, presents a general overview of the design process, highlighting multidisciplinary designs process, its achievements and inadequacies. The chapter presents an overview of design process in the South African industry. The chapter also presents the research problems, the aims and objectives of the report, as well as the scope and limitations.

Chapter Two reviews significant primary, secondary and tertiary literature of earlier work done in areas relevant to the field of study in order to get a better understanding of the research problem.

Chapter Three discusses the methodology espoused for this study, the rationale behind the selection, the study procedure, the different stages, the tools employed, and the steps taken. The chapter also discusses the data gathering methods.

Chapter Four presents the findings of the research, the analysis of the data and interpretation made. The chapter also touches on the significance of the findings.

Chapter Five presents the research conclusions and recommendations of the research report. The chapter also highlights the contribution of this study to the existing body of knowledge. Possible direction for further study is also discussed.

CHAPTER TWO: REVIEW OF LITERATURE

2.0 Introduction

This chapter presents an introduction to the area of research and a review of some of the related literature. The multidisciplinary design process is discussed in the second section. The third section reviews the characteristics of the design process. The fourth section discusses the design process in the construction or infrastructure sector. The fifth section discusses integration and information flow in multidisciplinary design and construction. The sixth section looks at interface management in design and construction. The seventh reviews delays in multidisciplinary design and construction projects. Section eight discusses rework in the design process. The ninth section reviews design errors and omissions. The tenth section looks at the importance of communication management in the design process. The eleventh section discusses design changes and change management.

2.1 Challenges in multi-disciplinary design process

Multidisciplinary design is a complex engineering activity that comprises of professionals from different disciplines with different perspectives working together as a team to produce a shared goal. Multidisciplinary design project presents enormous complexities. It deals with the ethos and paradigms from different domains and is usually faced with complicated multiple-objective decision making processes under uncertain environments (Marquardt and Nagl, 2004).

It is not usual in design to have an immediately clear problem given as a task. This ill-defined nature of design problems easily allow designers to form their own idiosyncratic understanding of the design problem and to propose different design concepts favored by different members of the design team (Cross and Clayburn, 1995). This type of situation can be chaotic, giving rise to a lot of rework, revisions and delays. The multidisciplinary design process has to do with initiating tough compromises and concessions in order to strike a balance between competing objectives such as performance, cost, safety, and efficiency. Design is an iterative process where different concepts and solutions are considered. The outcome of any design phase development is usually a set of design calculations, drawings, documents and specifications which define the project to be constructed. Design calculations are used in reinforcing the plans already prepared by the architect, depending on the type of project. Drawings are a graphical representation of the works to be constructed. Drawings help to relate a clearer picture of the instructions to the recipient. Drawings should be prepared in line with construction drawing practice. Specifications are documents stipulating specific standard requirement to be constructed and to what level of quality (Halpin and Woodhead, 1980).

A typical multidisciplinary construction/ infrastructure project involves a broad range of fields and specialists such as the structural engineer, land surveyors, quantity surveyors, architects, electrical engineer, and HVAC (Heating Ventilation and Air Conditioning) engineer working together for a brief period of time to achieve a shared goal (Ren et al., 2011). Usually, on a large multidisciplinary design project, there is a project leader whose job is to oversee, manage and coordinate all the project activities. Mostly each discipline involved in the overall project design come up with their own set of drawing plans and documents illustrating what they want to do. In most cases these drawings have overlaps, and in such cases the design decisions may be mutually dependent and thus collaboration and coordination is necessary for the successful execution and completion of design projects.

Multidisciplinary design process is an iterative, information-intensive process. During design, the exchange of information, thoughts and opinions is critical to the development of ideas. Solving design problems involves specifying, organizing and combining a wide range of elements together. A key element in achieving success in the design process is the quality of information available throughout the design process. Another key factor is the capacity to plan and manage the design process successfully, considering the repetitive form of the design process and the ever changing needs of the client (Choo *et al.,* 2004). Managing the iterative nature of designs is paramount for success and it requires some certain skills.

Lloyd and Scott (1994) suggested as a way of management that some design sessions are recorded and designers be made to verbalize their thoughts throughout the session. This method is time consuming and is not suitable in some cases of multidisciplinary designs where there is a language barrier. Time may be wasted considering thoughts that have not been well thought through.

To achieve right designs and drawings the first time, it is important to define the task clearly. The anticipated outcome should also be spelt out clearly during the design brief. However, the amount of preliminary work done determines the completeness of the brief. Depending on the project, some projects may require a site investigation, feasibility study or even a land survey to be completed before the brief. This may help to prevent delays that would have occurred due to differing site conditions.

In all the design organizations involved, management must endeavor to pass across accurate information as was received from the client, to all staff involved in the project design. It is vital that everyone is on the same page in terms of understanding the project and its requirements. There should be no room for errors, omissions and misunderstandings in apprising and interpreting the design. All misunderstandings, errors and omissions must be clarified immediately.

It is also critical to make allowance for inflation and wage increments by using historical costing (Rutter and Martin,1990). Inflation, which is a fall in the purchasing value of money, causes prices of goods and services to go up and wages to increase by the year. It is important to make allowance for yearly inflation when costing a project that will span over a period of years.

Design firms, should also avoid quoting lesser fees in order to get jobs. It is vital that the design fee quoted should match the quality of the design expected by the client, so that the design firms can afford the right caliber of staff to do the designs (Rutter and Martin, 1990).

It is also recommended to monitor and control the number of man hours spent on each project and at all the stages of work. This type of information is useful when estimating man hours for future projects. Also to save cost and time, it is suggested to remove staff from projects when the program is delayed or there is a protracted strike.

Rutter and Martin (1990) suggested that all design drawings and calculations should be checked by a more senior independent designer or engineer who was not originally part of the design process. However, the way that the checking is performed is important in order to avoid unnecessary repetition of the work already done. Using a selective method for checking design documents is helpful and is one way of avoiding a repetition of work done. Also it is recommended that drawing and checking are carried out together to avoid undue delays as a result of multiplication of errors. When errors are detected on time, it easier and faster to resolve them than when the error has caused more errors.

Choo, *et al* (2004) stated that the current planning and management trend is often focused on design deliverables. The tendency is to have a master plan that is circulated, showing participants when deliverables are expected, without proper plan for information transfer and coordination. Experience from past design projects have shown that is often an unproductive exercise.

Puddicombe (1997) stated that a large portion of failures occurring in multidisciplinary infrastructure project were as a result of adversarial relationship existing among the different parties involved. An adversarial relationship can be caused by the different immediate goals of the various organizations participating in the overall design and construction project. He also suggested the use of information technology to solve this problem, but was quick to add that information technology alone could not resolve all the effects of adversarial relationships in the industry.

2.2 Characteristics of the design process

Prins and Kruijne (2011) defined the design process as an information generation and specifying process, starting from the brief to the detailed design and construction stage. Managing the design process involves the careful supervision, planning, delegating, directing, coordination and controlling of design activities across the number of phases, disciplines and people involved. Lu and Cai (2001) defined the design process as managing the product data in different abstraction levels.

Designs can be performed in sequence so that a phase is completed before the next phase begins (Lloyd and Scott, 1994), or concurrently, in which case the designs are carried out simultaneously. In order to meet deadlines, most designs today are done concurrently. Concurrent engineering design aims to achieve parallel development of the design product toward the goal of increased design performance.

The three major phases in the design process include: the theoretical design phase, the preliminary design phase and the detailed design phase. Shiau and Li (2007) described the theoretical or conceptual design phase as the early initial phase where engineering art, applied knowledge, construction methods, environmental issues and commercial aspects are coupled together and considered. Once the concept has been approved a preliminary design is developed. It is suggested that the preliminary design should be reviewed after completion, whilst the detailed design should be reviewed and checked as the design process is ongoing (Halpin and Woodhead, 1980). The end product of the design phase is a set of drawing plans and specifications that set out the project to be constructed. Prins and Kruijne (2011) found that while the actual expenditure during the design phase is relatively small, the consequences of the decisions taken have far reaching effect.

Earlier research (Austin et al., 1999) demonstrates the importance of using design management practices in administering the design process, in order to better manage the risk issues, ensure smooth running of the project and to achieve coordinated drawings within the stipulated time and cost. A large portion of the interdependent design activities requires serious management effort and a review plan, because for an average specialist, the issues of self-preservation, profit making and expansion of work still control their decision making processes. The specialists have to play their appropriate roles, and early commitment is required, appropriate incentives are important in order to manage the shared risk or reward (Farooqui and Ahmed, 2008). It is also noteworthy to note that the management of a project changes to suit the integration needs at the different stages of that project, and also to suit the way the team members behave and interact. Design management also highlights when the concurrent and collaborative working strategy is appropriate (Austin *et al.*, 2002).

Managing a design project properly requires:

(1) **Organizing information and communication**: The importance of information and communication in managing a design project cannot be overemphasized, as the manner in which the designer approaches the problem depends on the amount of information available to him or her. The aptitude to request information that is needed as the design solution is developed, is important to effective performance. Effective organization of information and communication requires careful application of tools and techniques which can account for the iterative and complex nature of the design process (Austin *et al.*, 2002).

Conventionally, the critical path method was used in planning the design process, but it was found to be inappropriate due to the advent of more complex design projects. Usually, the first stage of managing a building design process should be to create a model showing design activities, activity relationships and linkages, dependencies and information requirements. The activities in the model should be linked through a dependency table, forming a dependency structure matrix (DSM) analysis tool (Austin et al., 1999). This DSM tool is used in finding the information flow and communication requirement via the dependencies at the early stages of the design process. Once the DSM is formulated, the iterations can then be better understood. Organizing information flow and communication is also better achieved via the DSM matrix. Also the DSM analysis identifies the best sequence of activities based on the availability of design information. Other techniques for organizing information include design documentation, and coordination meetings. From time to time these techniques should be reviewed and improved to avoid common pitfalls and time-wasters (Mel, 1981).

(2) Motivating and controlling participants: Rutter and Martin (1990) defined design as mainly an iterative, interactive and creative process in which different ideas and solutions are considered with diplomacy and tact to avoid conflict. Effective communication is essential for managing the different ideas and solutions brought forward by participants of a multidisciplinary design project. Earlier research by (Mel, 1981) discovered that people accept and respond positively to messages that are adult and/or assertive than any other kind of message. Mel (1981) defined an adult and/or assertive more communication as one that is clear about intention, beliefs and opinion while respecting those of others. When dealing with other participants and professionals from different fields as in the case of most multidisciplinary designs, it is important to choose the adult way of communication in order to get participants to accept and respond positively to messages. This method helps in motivating and controlling other participants without conflict.

(3) Understanding future needs of the project: This requires engineering knowledge and experience to comprehend the design and construction needs and to foresee future problems before they occur. It involves planning ahead. The ability to understand the future needs of a project, helps to maximize resources and save cost and improve profit.

To achieve effective design management, effective planning, scheduling, controlling and the coordination of the design process is required. Mel (1981) revealed that most project managers spend very little time on actual planning, delegating, directing and controlling of project activities. However, they spend more time in coaching, negotiating, disagreeing, soliciting and receiving data. So if we examine the design process we see that only a minor quota of the total design time is used in the actual design process, a lot of time is wasted on soliciting for information, disagreeing and redoing previous work. Successful design management is achieved by the attainment of the client's requirements and needs. Design management can be carried out through different actions such as:

- Careful analysis of the client's needs and requirements at the onset. The project brief that describes the clients' needs and requirement should be reproduced for the groups involved to study carefully.
- The use of Quality Function Deployment (QFD) – Akao (1990) as cited by (Brief, n.d.) stated that QFD is a system for evolving design quality to satisfy the client and then transform the clients' needs into design objectives, technical characteristics and specifications. QFD is achieved by deploying methods for achieving quality into the component parts and elements of the design process.
- Introducing continuous review and improvement methods into the design process Bessant et al., (1994), as cited by Bhuiyan and Baghel (2005) defined continuous improvement as a practice of dedicated and continued incremental improvement. As a client's requirements become more demanding, and his expectation become higher a continuous developmental appraisal and improvement to project performance is required. Bhuiyan and Baghel (2005) are of the opinion that continuous improvement can be achieved at three different levels: individual, group and management levels. At individual level continuous improvement deals with improvement of the day to day task. The group level deals with the improvement of problem solving at a general level, while at management level it involves the improvement of organizational strategy.
- Integrating contractors into the design process – is a process also referred to as designing for constructability. It involves a thorough evaluation of the design drawings, specifications, standards and construction methods by experienced

engineers or contractors. This procedure is used to check for obstacles in construction before the actual construction begins (Othman and Ahmed, 2011). This helps prevent or reduce rework, delays and revisions.

- The improvement and optimization of the design process through quick iterations and free flow of information across the different specialist which issue design and construction information.

Choo, *et al* (2004) defined the following methodology and actions for improving design quality:

- Standardization – deals with the generation of design information, work specification and processes amongst projects of similar characteristics, in order to establish a uniform design requirement for different designers. This helps to improve the efficiency of designers.
- **Planning** – is taking the long term viewpoint. It involves ascertaining the required activities to be carried out to meet the design criteria. It also requires understanding the different activities, their relationships and sequence.
- **Coordination** – involves integrating the different specialties during the design phase through a logical sequence of information transfer so as to avoid making incorrect assumptions
- **Control** – deals with how the designs are being executed, evaluating the pace and status of execution. It also involves estimating and procuring resources and materials needed.
- **Supervision** – checking the quality of the design with regard to the design requirement, owners requirements and constructability
- **Scheduling** – Involves defining the start time, duration and completion time for all the activities.

2.3 Design process in the construction sector

Designs are undertaken in many different areas and fields but construction design is unique and is undertaken specifically for construction purposes. The construction design process is usually a once-off project, and usually executed in a hostile environment. While most other design projects are executed in a controlled environment. Like other designs, construction design is undertaken to transform ideas into reality. The construction design process is unique and different from other design processes in so many ways, and these ways have been grouped into three: 1.Project distinctiveness, 2. Resource needed and 3. Environmental factors (Austin et al., 2001). Construction design is also defined in terms of its hierarchy of sub processes and problems. The sub processes are the designs within the scope of responsibility of its five major design disciplines which are Architecture, Civil, Structural, Mechanical, Electrical and Instrumentation (Austin *et al.*, 1999). The construction design process involves a lot of decision making, often over a period of time, with several interdependencies, under extremely uncertain conditions. Unlike the production design process, quality is achieved in the construction design process by carefully identifying the customers' needs and requirements and subsequently translating those needs into specifications (Tzortzopoulos and Formoso, 1999). Given the large capital amount usually budgeted for construction projects, it is important to monitor and measure project performance in terms of meeting schedule and budgetary commitments. While some projects are not completed because of time and cost overruns others are eventually completed with huge losses.

2.4 Integration and information flow in design and construction

Integration is the process of ensuring that all the various elements of a project are properly coordinated (PMI, 2008). Integration in design is the ability to plan, manage and coordinate information flow in a design process. A design/construction project team is a temporary organization, having unique generic process and composition, comprising of diverse people, with diverse cultures from different disciplines and backgrounds integrated together to undergo a project with one or more kind of specialist work on that project.

The complexity of many design and construction projects has underlined specialization and proficiency in design. Integration involves making tradeoffs and breaking complex functions into fields and areas for quicker and better tackling. However, a constant flow of information, analyses of requirements across the different areas or fields of specialization, is required for better value generation.

Austin et al., (2001) conducted an investigation involving three design teams comprising a number of design experts from several different organizations, and found that interaction accounted for only about 10% of the design time. Puddicombe (1997) found that a large number of failures experienced in the industry were as a result of dissimilar objectives existing among the teams and organizations participating on a project. Harmonization of goals and objectives is essential and continuous interaction is a tool for achieving the same.

Puddicombe (1997) described two major tools for achieving integration - contractual and social psychological. The social psychological aspect involves partnering and harmonization of goals and objectives, while the contractual aspect involves matching project characteristics with the contract. He argues that the universal nature and use of contracts has resulted in a diverse set of ideas with little agreement.

An adversarial relationship is one of the negative effects of using the specialization and professionalism system for designing. Adversarial relationships are often caused by incongruent goals of the various professions involved and their consequent divergent behaviors. The divergent goals of the different professionals involved causes a lack of cooperation, and can also cause unnecessary misunderstanding and disputes (Nam and Tatum, 1992). Other reasons for adversarial relationships include the pursuit of self-success and control. It has been observed that the adversarial relationship between the designer and contractor is much deeper than that between functional departments. Hence, there is little or no integration between the design and the construction phase. Puddicombe (1997) refers to this condition as disintegration. It has been suggested that a lack of understanding of the underlying dynamics that cause enmity can hinder progress of finding an effective model of integration.

Integration is highly recommended during the design process. Integration during design allows all the parties involved to collaborate during the entire design process. This helps to reduce the existing adversarial relationship to a far lesser degree. It is useful to add that there are some projects where early integration or extended integration is not necessary. In this sort of project, the cost of achieving integration is much more than its benefits (Puddicombe, 1997).

Integration in design involves coordinating jobs assigned to the parties as well as integrating the various requirements, needs and constraints of all parties involved (Prins and Kruijne, 2011). Collaboration, trust and mutual understanding are necessary for successful integration. The theoretical foundations of the integration process are components of management and organizational theories (Mintzberg, 1991, as cited by Prins and Kruijne, 2011). This means that integration should be carried out as part of management activities.

Integration allows the free flow of information across discrete phases of a project. It has been suggested that the free flow of information through the discrete phases at the different stages of a project, could help enhance the performance of the highly fragmented members. Information flow is essential for multidisciplinary design projects to succeed. For information flow to succeed in an organization, integration must first be in place. As part of understanding the importance of information flow, it is imperative to understand how human beings work best in teams, and the impacts of emerging information technologies on team work, as these will influence how team members communicate with each other in the course of a project.

The quality of all the project team decisions made throughout the project depends on the accessibility and reliability of the information that is available. At the different stages of the development process, participants need to interact with one another, exchange ideas amongst themselves, share data and technical information with each other, comment on information shared in order to solve issues and make decisions, and sometimes negotiate and make compromises until an agreement is reached by all the parties involved (Lavanya and Sugumaran, 2013). They also stated that the traditional approach to procuring and building, does not allow for effective integration of all the participants involved in the project at the different stages of the project development process. It is important to understand the usage of traditional and other procurement processes for construction projects before choosing a contract as this will influence how team members behave towards each other on projects. The contract is not just a legal document as it also lays the foundation by which parties operate. The problem of adversarial relationship is identified to be incumbent in some traditional procurement method where there is a separation of responsibilities in the design and construction phases.

2.5 Interface management during design and construction

Usually, there is a relationship between the design and construction phase that can be better seen as an integrated system (PMI, 2008). Wideman (2002) as cited in Chen, Reichard and Beliveau, (2007) defines interface management as the management of communication across boundaries of organizations that are interdependent. Interface management involves managing the problems that occur across people, departments, and disciplines involved in the design and construction of a project.

In the design phase, interface management helps in the improvement of the quality of connections between various designs components, through close coordination. Less time is spent conducting audits and verifications if the design documentations are coordinated methodically between design consultants (Love *et al.*, 2012). Interface management also helps to reduce project conflicts amongst project participants and it also provides a better organization to the work place environment. It is important to give cognizance to the design and construction interface because the quality of the construction work eventually produced, depends on the quality information gathered and analyzed during the design and planning phase, and also the level of construction input into the design process. Prins and Kruijne, (2011) are of the opinion that value is produced when knowledge flows. It is therefore necessary to take cognizance of and to manage the various interface issues properly so as to allow for continued free flow of information between participants, departments and the various disciplines involved in a project.

Some of the problems that affect the interface between owner and designer listed by Al-Hammad and Al-Hammad (1996) include:

- Additional cost of design fee for design changes
- Incomplete drafted contract documents and agreement between owner and designer,
- Inaccurate specifications and working drawings,
- Owner's meager estimation for design services relative to his demands,
- Incorrect estimation of project budget by designer,
- Owner's unawareness of issues to be considered by designers when designing
- Owners insufficient knowledge of municipality requirements

Some of the problems that affect the design and construction interface include:

- Designer's inexperience,
- Inadequate design communication supports between designer and owner,
- Inadequate detailing of designs,
- Lack of design standards with consequent loss of efficiency in the construction phase and
- Lack of constructability.

Al-Hammad and Al-Hammad (1996) are of the opinion that a better level of integration can be achieved by doing the following:

- Early involvement of the different professionals, disciplines, contractors and participants,
- Creation and implementation of an information transmitting plan,
- Regular face to face meetings, and

- Appointment of a domain- bound specialist as the project leader.

2.6 Delays in multidisciplinary design and construction projects

A delay is the non-completion of a project inside the stipulated time frame as specified by the contract (Gündüz *et al.*, 2012). A delay can be defined as a situation emanating from an action or a group of actions or inactions, created by the client, contractor, consultant or external forces causing an extension in the amount of time stipulated to finish a project. The design process can be a complicated process because of the combination of endeavors and trades involved at different stages of the design. Therefore effective coordination and integration is important to successful design process. A multidisciplinary design project is considered a success if it is completed within the time and budget stipulated, and in agreement with the specification and to the stakeholder's satisfaction as set out at the on-set of the project in the contract document (Majid, 2006). Conversely, a multidisciplinary design project is also considered to be a failure if it is not finished within the time and budget set out, and in accordance with the specification and to stakeholder's satisfaction as set out at the on-set of the project in the contract document.

In the design phase, a delay means the non-completion of a design task as per schedule. A delay is a major problem in construction because a delay in one area can affect other areas. An elongation of the project duration is one of the common effects of delays and it usually has negative effects on the parties involved. To achieve project deadlines, it is important to identify the likely factors influencing delays and consequently the successful completion of projects, and to estimate their impact at the bidding stage of the project (Gündüz *et al.*, 2012). Today, most design and construction projects are unable to meet project scheduled deadlines for various reasons; One common reason is that delay analysis is ignored at the onset. It is also necessary to define the prevalent delay causes in design works. Majid (2006) found that delays can be reduced by identifying their causes and resolving them. Delays caused during the design phase have a significant impact on the construction schedule and project completion time if the project completion date is already fixed.

Yang and Wei (2010) examined delay causes in the design and planning phases. The causes they identified include: Calculation and drawing errors, the inability of the owners to review designs on time, late integration of emerging technologies into designs, ineffective coordination and integration of other designers involved, poor monitoring and control of the project schedule. Others include design changes initiated by financial constraints, frequent changes in design information, design changes initiated by vendor, clashes in drawings, contractor-initiated design changes, owners and end users initiated design changes, inexperienced consultants, incomplete drawings, late response to contractor's queries, late supply of design information, Not enough data gathered about the site and survey before design, slow approval of key changes in the scope, delay in gaining necessary permits from the municipality, late submission of design documents, and late approval of design drawings.

Design defects are often detected during the execution phase, sometimes just before starting construction of the specific task and in other cases when the task is ongoing. The resulting losses are of different kinds and magnitude. Venkatachalam and Varghese (2010) suggested that some of the causes of design delays could be resolved by preventive steps and better design management processes. Venkatachalam and Varghese (2010) listed the causes of delay/revision in designs into five different categories

Table 2.1 Cause and effect of drawing delays and revisions Venkatachalam and Varghese (2010)

S/ no	Category	Causes
1	**Designers Error and Omissions**	Inappropriate Assumptions
2		Poor Information Flow
3		Lack of Human Resources
4		Inappropriate Sequence of Work Performed
5		Less Productivity
6		Ripple out Effects

7		Optimistic Design Duration Estimation
8		Design Error
9	**Vendors Error and Omissions**	Inefficient Vendor Data
10		Superseded Vendor Data
11		Insufficient Information in Vendor Data
12		Missing Data in Vendor Documents
13		Uncertain Vendor Data
14		Incorrect Vendor Data
15	**Differing Site Conditions**	Changes of Construction Method
16		Change of Soil Properties
17		Changes in Loads
18		Other Unanticipated Reasons
19	**Owner Initiated Changes**	Suspension of Work
20		Ambiguous Specification
21		Change of Scope
22		Change Orders
23	**Changes in Local Bylaws**	
24	**Law of Regulatory Authorities**	Disapproval of Work
25		Other Reasons

According to Love, *et al* (2012) the organization and project related procedures used by a firm can influence the effectiveness and efficiency of people involved in the design task. Lopez, *et al* (2010) suggested the following issues that can contribute to design delays in projects.

- Poor staff training.
- Inexperienced designers.
- Deficient knowledge on certain aspects of the design.

- Unrealistic time estimate given to design task and the use of time boxing.
- Miscalculation of resources needed for design task.

Yang and Wei (2010) found client requirement to be the major cause of delay in design and construction projects. The client and the project team members should maintain a cordial working relationship for effective communication if project is to be completed on schedule

The common effects of delay include:

a) Time overrun (b) Cost overrun (c) Customer dissatisfaction/decline

(d) Disputes (e) Arbitration (f) Litigation (g) Third party claims

(h) Total abandonment (i) Staff turnover

Delays can also lead to a loss in revenue owing to the inability to handle other projects.

Over the years, the accountability and responsibility for factors causing delays on construction projects has been denied. This usually leads to disputes and protracted litigations (Yates and Epstein, 2006). To help check this trend Rubin, *et al*(1983) as sited by Yates and Epstein (2006) categorized delay factors causing delays into four main types:

1. **Non compensable excusable delays**

These delays are usually caused by a natural phenomenon and are usually called an "Act of God". They could also be caused by an unforeseen circumstance but they are never caused by any of the parties involved. These delays are usually with time extensions but without financial compensation unless stated in the contract document.

2. **Compensable excusable delays**

These delay factors are usually caused by the owner or client. Time extension and cost compensation are usually given to the contractor when they occur.

3. **Non-excusable delays**

These are delays that are caused by the contractor. Time extension and cost compensation are usually not given to the contractor for such delays when they occur.

4. **Concurrent delays**

They have noted that some delays fall outside these 3 categories mentioned above. Sometimes a number of factors combine to cause delays. When more than one factor combines to cause delay it is called a concurrent delay.

Love *et al* (2012) claim that involving clients in the design process may reduce the amount of design related change orders in the form of rework during the construction. However, they quickly added that this can be said for only clients who have the requisite knowledge of design.

2.7 Reworks in the multidisciplinary design process

Love and Li (2000) defined rework in construction as "the unnecessary effort spent in redoing a process or an activity that was incorrectly implemented the first time". On the other hand, the construction industry institute (CII) defines rework as "activities that have been done more than once"(CII, 2002). The definition by CII(2002) may not be more appropriate, because there are cases where the work was carried out right the first time but the client now wants something different. This is termed as a change order by the client rather than rework. Rework in construction projects has serious negative impacts in terms of time and cost performance. Rework leads to customer dissatisfaction, delays, and losses, and in some cases, litigation. The direct cost of rework has been found to be between 3% to 23% (Love, 2002). The indirect cost may not be quantifiable but rework can have a negative impact on the moral of the workers and the reputation of the firm. Palaneeswaran (2006) stated that in construction projects, many factors can influence rework. Some of the factors mentioned include errors, omissions, changes, damages.

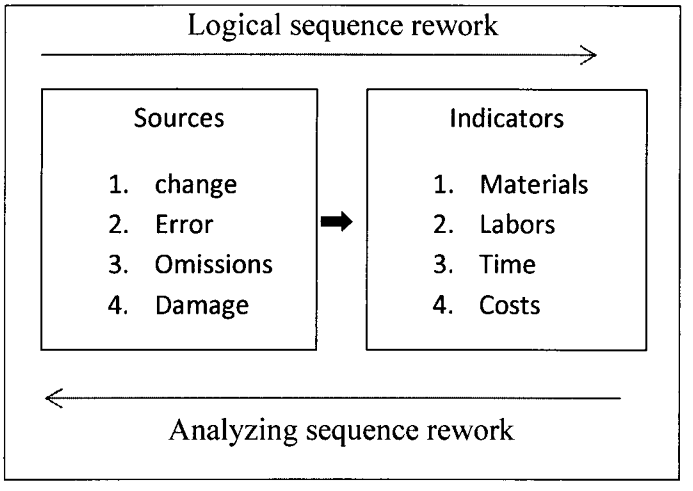

Fig 2.1 Rework sequence (Mastenbroek, 2010)

Further research by Yang and Wei (2010) shows the influences such as poor communication, poor coordination, inadequate planning and scheduling, clients financial problems, incomplete design drawings and specifications, misinterpretation of design, and poor quality of contract documentation, are some of the factors causing rework. Many of these factors are interconnected, while others stand alone. Most of these factors could be categorized under poor management practices. Love, *et al* (2004) stated other factors that cause rework, delay and revision in construction to include:

- Staff turnover,
- Setting out inaccuracies,
- Error in survey controls,
- Poor material use,
- Failure to provide protection to the works,
- Inadequate construction supervision,
- Unforeseen physical conditions (Site Data),
- An Act of God such as flooding,
- Use of inappropriate materials and equipment,
- Differing site conditions, and

- Damage to other trades due to carelessness.

Love, *et al* (2004) refer to some specific rework activities that increase cost and time. These include redesign due to an insufficient brief, revisions from unverified drawings issued, and changes due to incorrect drawing scales. It is difficult to find solutions for all design related rework problems but trying to find the factors that influence rework, revision and delays is doable. Unlike in the construction process, the design process involves activities that are highly interrelated and finding the right sequence for carrying out these activities without wasteful rework is a challenge (Choo *et al.*, 2004). An ample amount of time and effort is spent on identifying errors and redoing rework in a bid to ensure conformity (Dale, 1999). The time spent on identifying errors and doing reworks could be better used if we understand the factors causing delay, rework and revision and we avoid them. Research by (Love et al., 2004) suggested the use of constructability analysis to reduce the rework in design and construction. This strategy can only be achieved by using the wisdom and skills of key team members to improve team work, improve planning and scheduling of site operations, and to oversee the quality of contract documentation produced. It was reported that savings of up to 6% to 10% were made on projects where this strategy was adopted. However, it is not a comprehensive solution to the entire situations that cause rework. It is important to demonstrate that rework is aroused by a number of issues which plague design and construction projects. These issues need to be addressed holistically in order to reduce rework and achieve maximal benefits from design and construction projects embarked upon. As part of solving the problem of rework, design firms need to check their management practices from time to time in order to find gaps which allow rework to occur, and make changes accordingly in order to improve service delivery and save cost.

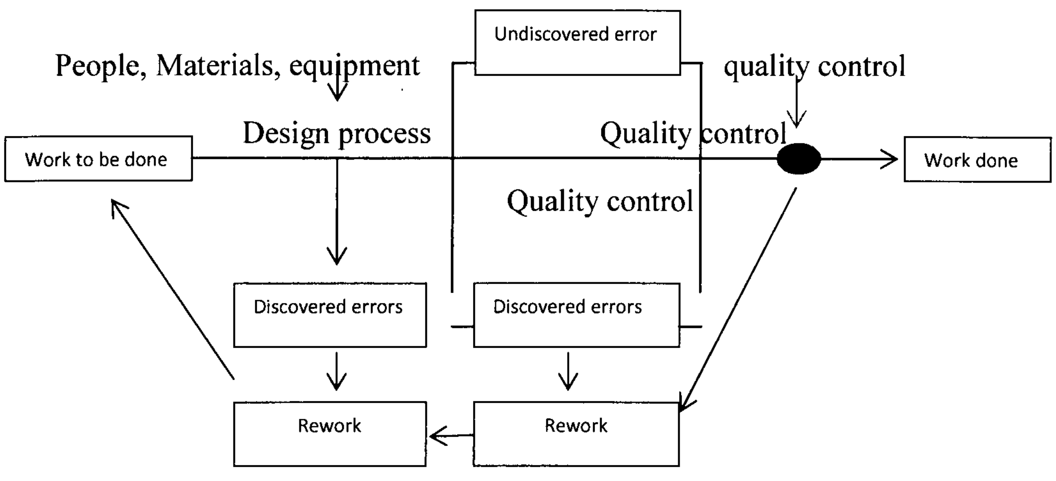

Fig 2.2 Rework process (Mastenbroek, 2010)

Fig 2.2 shows the rework cycle in the design process. The figure shows that an undiscovered error remains in the process until it is found and redone.

2.8 Design errors and omissions

An error is a deviation of some sort from a planned course of actions supposedly leading to a desired goal. (Reason and Hobbs, 2003). Love, *et al* (2009) showed that design errors in construction mostly occur from cognitive mistakes and omissions made when doing designs. Love *et al.*, (2012) in their recent paper stated that even the most qualified and competent persons can make mistakes. Furthermore, a team can make mistakes. Generally, there are many factors that can cause errors to occur. Love *et al* (2004) are of the opinion that most of the causes of errors are not independent. Some of the causes of errors in design mentioned in the literature include, intentional violations/ non-compliances, insufficient training of design consultants, ineffective operation of computer-aided automation, inadequate quality control system, unreasonable client and end user expectation and inadequate coordination and integration of the design teams (Lopez *et al.*, 2010). However, most design errors occur directly or indirectly from human failures. Lopez, *et al* (2010) suggests that people have the greatest potential to reduce errors through learning and knowing. When design errors occur in multidisciplinary project without detection, Love, *et al* (2012a) describe it as a latent error waiting to happen. Organization and project related practices can affect the ability of people to identify errors. Since multidisciplinary projects are closely coupled systems, design errors made in any part of the system often generate more errors in other parts down the supply chain. The errors eventually become built in problems which are by far more expensive to rectify. There is no single strategy for solving the problem of errors but rather a congruence of strategies may be adopted to reduce design errors. Against this background, this research tries to establish the influence of design errors on rework, revisions and delays in multidisciplinary design project.

The occurrence of design errors and the negative resultant impact it has on social infrastructure is no longer a hidden issue (Lopez *et al.*, 2010). We have seen collapses of buildings and bridges all around the world caused by gross design errors. Research in the late seventies (Matousek and Schneider, 1976) revealed that the main cause of collapse and accidents is gross error. This leads to about 80-90 percent of failures occurring in bridges, buildings and other social infrastructure. Earlier research by Love, *et al* (2012b) state that the cost of design errors will be much higher where there is a design failure that leads to a loss of life. If negligence is proven in a wrongful death lawsuit, offenders may be stripped of their license to practice and be made to pay large sums of money as compensation to people who may have been damaged from the death of the victim. Love, *et al* (2012b) noted that design errors committed within contract documentation could lead to consequential rework that can arise during the construction process.

To get the best out of any multidisciplinary design project in terms of time and cost, it is important to implement ways of eliminating design errors right from start. To eliminate or reduce design errors, it is important to ascertain their root causes. Love, *et al* (2012) suggests that error prevention is not a once off thing but a continuous process. Setting up an error prevention system also helps in mapping dependencies and interface project requirements.

Just like individuals, a team or group can also commit errors. In spite of all the research that has been done to resolve the issue of design errors, very little progress has actually been achieved in terms of eliminating design errors practically. This is as a result of several interdependent issues. One issue is that design firms remain unresponsive to make changes in their organizational and project management practices. Some practices that would help resolve these issues are consciously omitted to satisfy immediate needs (Love *et al.*, 2009). Love, *et al* (2000) stated that when a design firm offers or accepts a low design fee for a project they usually 'time box' tasks. What this means is that a fixed amount of time is given to complete each task, regardless of whether or not the task has been completed. Other issues include the lack of human resources (experienced designers), poor scope definition and an unrealistic project time estimate allocated to most projects. Depending on the type of contract, often times clients may have to take loans from banks to finance projects. Due to the high interest rates on loans, clients are always in a hurry to get the project up and running and thus request unrealistic project times. It has been discovered that using cheaper tendering to obtain the services of design firms may also have deemphasized the amount of design checks, reviews and verifications done on design documentation (Love *et al.*, 2012). This means that right from the beginning of the project errors and omissions are prone to occur. Fatigue, time boxing and unresponsive organizational practices are among other reasons why design checks and reviews are not carried out before design documentations are issued out. Cusack (1992) stated that the cost of remedying errors can increase the value of a project by up to 5%. This is besides some of the latent effects that cannot be quantified. More recently Palaneeswaran, (2013) identified design audits as an effective way for reducing design errors and its consequent rework and revisions. Generally design audits can be grouped as either internal from within or external audits from outside. Despite the effectiveness of design audits, errors are still prevalent as a result of ineffective audit protocols, systems and implementation (Palaneeswaran, 2013). Most often, design firms do not practice thorough audits because of time, cost and lack of human resources involved. Hence the problem of design errors and associated failures is still occurring.

2.9 Importance of communication management in the design process

The repetitive and information intensive pattern of the design process makes effective communication a necessary tool for achieving success in any design process. Effective communication is a tool that needs to be developed and used properly to improve the effectiveness of design projects especially with regards to delays, rework and revisions. It is important to note that until communication has produced a desired behavioral change, no effective communication has taken place. In design management, it is important to pay attention to informal communication (Mel, 1981). For an organization to work effectively, most of its peer-to-peer communication should be informal, as over-reliance on formal communication creates delays and rework instead of speeding up work (Mel, 1981). At the commencement of a design process, it is critical to draw up an effective communication plan. There are different levels of communication which need to be understood and highlighted in the plan when undertaking designs:

- Peer to peer communication such as occurs between designers and engineers.
- Manager and staff communication such as occurs between a boss and subordinate.
- Staff and work meetings such as occur for coordination, technical or informational purposes.

A regular staff meeting is one method of communication that has continuously been used in design management. However, it is still not effectively used. Most staff still believes that staff meetings are too long, unproductive, too recurrent and not properly planned and managed. A survey carried out on an engineering organizations revealed that participants view their work meeting as more than a 60% waste of time (Mel, 1981). Mel (1981) focus is on meetings and he outlines some ways of making meetings more useful, productive and effective which in turns saves time and cost on a project. They include:

- Holding meetings only when it is important, after maximizing other options of providing information.
- Restricting attendance to those who are needed.
- Explaining the purpose of the meeting at commencement.
- Circulating an agenda prior to the meeting and following the agenda.
- Asking for input but avoiding repetition.
- All responsibilities assigned and agreements must be minuted and followed up
- Regular appraisal of meetings should to be carried out.

Managing meetings effectively is an important aspect of design management. When meeting are managed properly, delays, rework and revisions are reduced. Profit margins are increased, staff turnover is reduced, office systems are improved and the working environment is better. The quality of management achieved on any complex and uncertain project is dependent on how well the people work together. The implementation of tools and techniques for managing projects are only as good as the people that manage them (Hedley and Stephen, 2008). They discuss four major approaches of management but focuses on the relationship approach to managing projects.

Relationship approach: is described as a means of improving project performance through relationships. These can be between people and organizations or between organizations as project actors that can be actively managed socially. A relationship approach to management recognizes the situations and context that can disrupt a reasonable application and create unwanted outcomes. This approach helps to reduce adversarial behavior from top to bottom because of the established relationship already existing. They believe that a relationship approach is interdependent with other approaches. This approach is usually recommended for multidisciplinary projects.

Senthilkumar (2010) noted two key factors identified by researchers to be influencing the design process as (1) dependency relationship and (2) design information flow. He also noted that in an attempt to solve the problem of design information flow, extensive research was carried out, which resulted in the formulation of graphical based tools such as GERT and Petri-Nets. However these tools have serious limitations.

Functional management approach: This approach looks at a range of people issue beyond the direct task focused thinking. It has a better appreciation of human and organizational behavior. It has a strategic front end focus combined with project execution and integration. It takes into account the internal and external factors from the start of the project to the completion of the project. This kind of approach suitable for multidisciplinary projects

Information processing approach: This paradigm tends to insert a more integrated approach into the linear task focused thinking. This approach is execution-based coupled with a wide consideration of stakeholders inside the project. It is a cause and effect paradigm which takes into account additional information to plan its project strategy and implementation. This kind of approach is suitable for multidisciplinary projects.

Traditional project management approach: An execution oriented approach that puts into use tools and techniques to foster rational order and efficiency. This approach places importance on control and is task orientated. This type approach may create conflicts in multidisciplinary projects

Wood (2005) as cited by Mason (2008) stated that partnering represents one of the most significant means of refining project performance whilst offering benefits to both clients and contractors. Partnering can be defined as a strategic alliance formed between two entities. Partnering was introduced to overcome perceived performance problems that may occur as a result of adversarial relationships. Earlier research by Matthews, *et al* (2000) as sited by Mason (2008) shows that partnering is based on trust, commitment to a common goal and an understanding of the expectations and values of the different entities involved. However, partnering has experienced a slow take off in the construction industry because

- The construction industry does not have an agreed expressed definition and philosophy for partnering.
- Competitive tendering still remains the principal method for selecting subcontractors. Mason (2008) believes that competitive tendering is a process with uneasiness and conflict because the actors are driven in different trajectory due to the predisposition of the competitive environment whilst partnering is the direct opposite of competitive tendering. In his submission, he was quick to add that not everything about competitive tendering is negative and not everything about partnering is positive.
- The construction industry has not fully adopted it. The construction industry is known for adapting slowly to change.

However, the view held by most specialists is that partnering has not improved the relationship or the amount of disputes experienced by the industry (Mason, 2008).

2.10 Design changes and change management

A change in design and construction term can be described as the deviation in the contract requirements from that which was originally agreed between the parties at the time of tender and the subsequent requirement enforced to this agreement during the actual design or construction period (Oracle, 2009). A change in general terms can be defined as a modification, deviation or an alteration to something that existed. Some reasons for design changes listed by (Rounce, 1998) include:

- To correct technical inaccuracies
- Design development
- Improving build ability in design
- To suit subcontractors design
- To obtain planning approval
- To make the contractors life easier
- To add missing information

Change management is a significant aspect of project management. Change management in design is the management of changes and development within the design process. Design and construction changes are usually referred to as a change request and it involves an alteration or a modification to the design or construction. A change request often happens while work is being done, and it could either be in oral or written form. Changes are common in the design process and they can occur from different sources, through different causes, and at different phases of the design process.

The influence of changes to designs varies from little or no impact to a considerably high impact. However, the impact of some changes cannot be directly measured. Changes include, but are not limited to, the revision of specification and drawings, addition and deletion of work, change to contract documentation, errors, omissions and conflict clarification (Oracle, 2009). Major changes constitute a breach of contract and are unacceptable, and the designer or contractor is under no obligation to perform them. Changes have different attributes; they may be compulsory or optional, internal or external, proactive or reactive, preferential or regulatory, beneficial or disruptive.

Oracle (2009) is of the opinion that change management is really concerned with manipulating the factors which create changes, so that changes are advantageous, proactive, optional and preferential. The management of changes is important to what changes can do or to the effects of changes. Inadequate management of changes and the process of changing could have disruptive effects. Having a change control system is always necessary on any project and more especially on design or construction projects. A change control system is a plan as to the procedure by which an official document may be changed. A change control system has to be agreed on before it can be used. It stipulates the procedures for handling changes, it manages approval or rejection of change requests, it captures and documents changes made, it coordinates changes made across the relevant knowledge areas, and it maintains the integrity of the performance measurement baseline set out at the onset of the project. Some essential steps of change management listed by Oracle (2009) include:

- Identify the initial contract requirements,
- Identify changes and create a change order file,
- Determine new requirements,
- Communicate the new requirements to relevant areas,
- Measure the effects of the change and new requirements and determine entitlements,
- Negotiate and agree on change entitlements,
- Execute change order, and
- Document complete record of executed change.

2.11 Review of factors influencing delays, rework and revisions (adapted from Odeh and Battaineh, 2002)

The results from related literature are summarized and concluded in the following table. The most dominant and important factors are identified and listed on the table. Odeh and Battaineh (2002) categorization of delay factors was adapted to provide a structure for summarizing the various factors causing delay, rework or/and revision on this table.

Table 2.2 Analysis of factors influencing delays, rework and revisions

References	Client	Consultant	Contractors	External	Main Methods involved	Main findings/outcomes
(Odeh and Battaineh, 2002)	Slow payment procedure adopted by client	Shortage of technical personnel	Insufficient contractor cash flow	Shortage of foreign currency for importation of materials	Interviews and questionnaire surveys	
(Toor and Ogunlana, 2008)	Lack of resources Client change order. lack of finance	Ineffective communication Incompetent and less experienced companies	Poor contractor management Shortage of equipment Shortage of labor	Underdeveloped business environment Bureaucracy, corruption	Case study	Procurement reforms Reduction of bureaucracy
(Palaneeswaran, 2006)	Changes made by client	Design Errors Omissions Poor communication	Poor coordination	Failures	Interviews and questionnaire surveys	Reducing non-value adding transactions
(Love et al.,1999)	Poor decision making Sequential procurement process	Absence of quality focus	Poor communication flow	Fixed power structure	Case study	The main cause of rework attributed to the sequential nature of the supply chain. Findings show interconnectedness of the supply chain. TQM culture to reduce rework
(Rounce, 1998)	Unreasonable design changes requested by client Redesign due to inadequate definition of brief	Extended design due to lack of coordination Lack of motivation of design team Changes arising from unchecked drawings	Time dealing with queries on drawings Insufficient program time for construction process. Use of incorrect or out of date information. Adversarial relationship between contractors and design team	Suppliers technical design problem. Wasted time due to changed meeting dates		Application of quality management techniques to the design process to improve quality in the design process.
(Ramanathan et al., 2012)	Insufficient communication between the client and designer in the design phase.	Design changes by designer. Mistake in soil investigation. Late approval of	Unavailability of professional construction management. Accidents during construction.	Unforeseen ground conditions. Waiting for permits from government. Price fluctuation	Questionnaire surveys	Collective comparison revealed that the ranking given to causes of delay by all researchers is not the same

	Inadequate early planning of project	shop drawings	Waiting for sample material approval			
(Love et al., 2010)	Excessive client involvement in the project Changes made at the request of the client	Lack of clearly defined working procedures	Insufficient changes initiated by the contractor to improve quality	Ineffective use of information technology	Questionnaire surveys	Mean total rework costs was 10% of the contract value for the sample
(Ogunlana et al.,1996)	Client frequent changes creating design and coordination problems	Problems caused by consultants incompetence Technical staff overstretched.	Problems caused by contractors inadequacies Low technical and managerial skill of contractors	Problem of shortages Inadequacies in industry infrastructure	Interviews	Formulation and execution of participatory program for the development of the construction industry through a national agency dedicated to the industry
(Taher and Pandey, 2013)	Changes in clients requirement Slow decision making Income issues	Planning errors Incompetent technical employees Improper electrical and mechanical design coordination	Subcontractors slow progress Broken equipment Miscommunication between contractors Material management	Differing site conditions Unforeseen weather Strikes Acts of nature	Questionnaire surveys	Changes in clients specification is one of the main cause of delay in both design and construction phases.
(Andi et al.,2010)	Material change Slow drawing approval Scope changes Owner interferences	Design changes Design errors Poor communication between consultant and contractor	Labor shortages Material shortage Equipment shortage Slow contractor payment Poor supervision	Bad weather Slow delivery of material Local regulation Accidents	Questionnaire surveys	The most frequent factors causing delays expressed by the contractor are associated with design information
(Yang and Wei, 2010)	Change orders by client Unrealistic initial plan Complicated administration process of client Poor scope definition	Unclear authority among designers Project complexity Inadequate experience of designers Poor communication between designers	Inadequate planning Poor labor productivity Inadequate planning and scheduling Change orders by deficiency design Incomplete design drawings and specifications	Weather Infectious disease	Questionnaire surveys	Changes in client requirement is the main cause of delay in both the planning and design phases
(Abd El-Razek et al.,2008)	Owners initiated changes Excessive	Design error made by designer Mistakes in soil	Equipment shortage Delay in contractor progress payment	Foundations conditions encountered in the	Questionnaire surveys	The major significant delay factors was lateness in approving shop drawings, cash shortage and

	bureaucracy in project owner operations Cash problems Slowness of owners decision making process	investigation Shop drawing approval delay Poor organization	Shortage of labor Waiting for sample material approval Damage of material Inadequate early planning	field. High water table levels discovered on site Accidents during construction		slow owner's decision making exercise, design errors, excessive bureaucracy, labor shortages and inadequate labor skills.
(Gündüz et al., 2012)	Client change orders Conflict between joint ownership Slowness in decision making Poor communication and coordination with other parties Delay in approving design documents	Inaccurate site investigation Lack of experience of consultant in construction projects Poor communication and coordination with other parties	Frequent change of subcontractors Inadequate contractor experience Poor site management and supervision Inappropriate construction methods	Price fluctuations Unfavorable site conditions Natural disaster (flood, hurricane) Change in government regulations. Conflicts, wars. Delay in obtaining permits	Interviews	Inadequate experience of contractors has the most importance on delay
(Majid and McCaffer, 1998)	Changes in scope Financial delays	Shortage of qualified personnel Poor planning And Inefficient communication	Equipment, labor and material shortage. Contractor financial difficulty Poor coordination Inadequate supervision	Unreliable supplier Late delivery Subcontractors delay An act of God	Interviews	Late delivery of materials and slow mobilization are the major factors that leads to contractors poor performance
(Baloyi and Bekker *, 2011)	Design changes Clients slow decision making Change orders by client during construction	Incomplete drawings Late issue of instructions	Shortage of skilled labors Poor planning and scheduling Shortage of manpower Inaccurate material estimates	Labor disputes and strikes Late delivery of materials Project complexity	Questionnaires	Design changes, Incomplete drawings, Late issue of instructions, Poor planning and scheduling and Clients slow decision making were the major causes of delay

From the above analysis in table 2.1, the following were found to be significant causes of delay, rework and revisions:

- Design change
- Scope changes
- Unrealistic project time estimate
- Project complexity
- Insufficient design details
- Clashes in drawings
- Lack of coordination
- Lack of experienced designers/companies
- Poor information flow
- Lack of input information
- Inappropriate assumptions
- Inadequate planning and scheduling
- Owners initiated changes
- Approval delays
- Vendors errors and omissions
- Design errors and omissions
- Differing site conditions
- Changes in laws of regulatory agencies
- Design errors and omissions, approval delays
- Resources

These foremost factors listed above were chosen from the literature for further analyses using questionnaire surveys. From the literature it was also found that majority of the researchers distributed questionnaires to clients, consultants and contractors in order to obtain the interpretation of respondents concerning the factors causing delays, reworks and revisions. For consistency and reliability, questionnaire survey was also used in this study.

2.12 Summary

The literature review seeks to identify major delays, reworks and revisions causal factors. Baloyi and Bekker , (2011) investigation of the factors that caused delays during the construction of the 2010 fifa world cup stadia, revealed incomplete drawings, design changes, clients slow decision making, inadequate planning and scheduling as the main causes of delays. The study revealed that nearly all the projects (upgrading and construction of new stadia) experienced time delays and cost overruns.

From the analysis of the literature in table 2.1, it was observed that changes related issues were the foremost significant causes of delays, reworks and revisions, followed by issues of communication, planning, scheduling, and coordination.

A number of previous studies agree that a large percentage of delays, reworks and revisions experienced are as result of changes but this can be prevented by better management skills. It is important to determine if this is also true in South Africa, as timely completion of projects is important for the economic well-being of any nation.

The outcome of this study will also help to provide useful and useable information to the existing construction management body of knowledge in South Africa.

The finding largely presented in this literature was done internationally and thus can be used to validate the findings made from this research. Hence the need to pursue further studies in this area earnestly.

This study is relevant to the South African environment because recent studies from (Baloyi and Bekker *, 2011) shows that delays, reworks and revisions affect the South African construction industry negatively.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter explains the adopted research methodology in the study. Chapter starts discussing the research design adopted for this study. It is stated that the study tended to be more quantitative than qualitative. Therefore the researcher adopted a quantitative research design. The rationale behind the selection of the quantitative method of research work is also been discussed in the following section. The four stages of social research: epistemology, theoretical perspective, methodology and methods of this study were outlined in the sixth section. Sampling and accessibility for this study was discussed in section 3.7, Data analysis is discussed in section 3.8, Scaling in section 3.9, followed by voluntary response and bias in section 3.10, the analysis method is discussed in section 3.11, a discussion of validity and reliability issues are in section 3.12, ethics is in 3.13, whilst generalizability in section 3.14

3.1 Quantitative research design

A research design is a plan used to conduct research, it involves the intersection of philosophies, strategies of inquiry and specific methods (Creswell, 2009). There are many explanations given to quantitative research design. However, (Creswell, 2009) explains it as a method for testing objective theories by studying the relationships among variables. The variables are measured on instruments such as a questionnaire by assigning a numerical scale or position or attributes to the variables and the numbered data is analyzed using statistical procedures (Creswell, 2009).

Rather than being polar opposites, studies tend to be more quantitative than qualitative or vice versa (Creswell, 2009). This study tends to be more of quantitative than qualitative because the data is in numerical form and qualitative data is not in numerical form (Trochim, 2001). However, it has some of the features of a qualitative research. Like in the qualitative research, assumptions have been made; protection against bias has also been built in.

There are differences between a qualitative and quantitative research design which many authors have tried to highlight. However, (Creswell, 2009) argues that they are not discrete as they appear, that they represent different ends on a continuum. The key thing about the quantitative research approach is that it involves the analysis of quantitative data to solve research problems.

However, (Saunders *et al.*, 2002) divides quantitative data into two clusters: actual data and quantifiable data. They described actual data as data whose values could not be quantified numerically and ranked but whose values could be described, categorized or classified into sets. However, most research will usually have some numeric data which can be quantified. They also described quantifiable data as data whose values could be measured numerically as quantities by assigning a numerical scale or positions. They argued that since a numerical scale or a position or a rank could be assigned to each data value, a quantifiable data is more precise than categorical data. Hence, for this study collecting a quantifiable data is adopted.

Usually in a quantitative design the theory precedes the observation. In this study, the literature (theory) precedes the observation (survey). The nature of the data collected for a quantitative design approach is usually more objective, concrete and standardized. The nature of data required for this study needed to be objective and concrete in order to meet the researcher's goals and objectives. Being objective is an important part of a complete inquiry; researchers must check methods and conclusions for bias. The objectivity of the information gathered is necessary to identify current factors influencing delay, revisions and rework in multidisciplinary infrastructure design projects in South Africa.

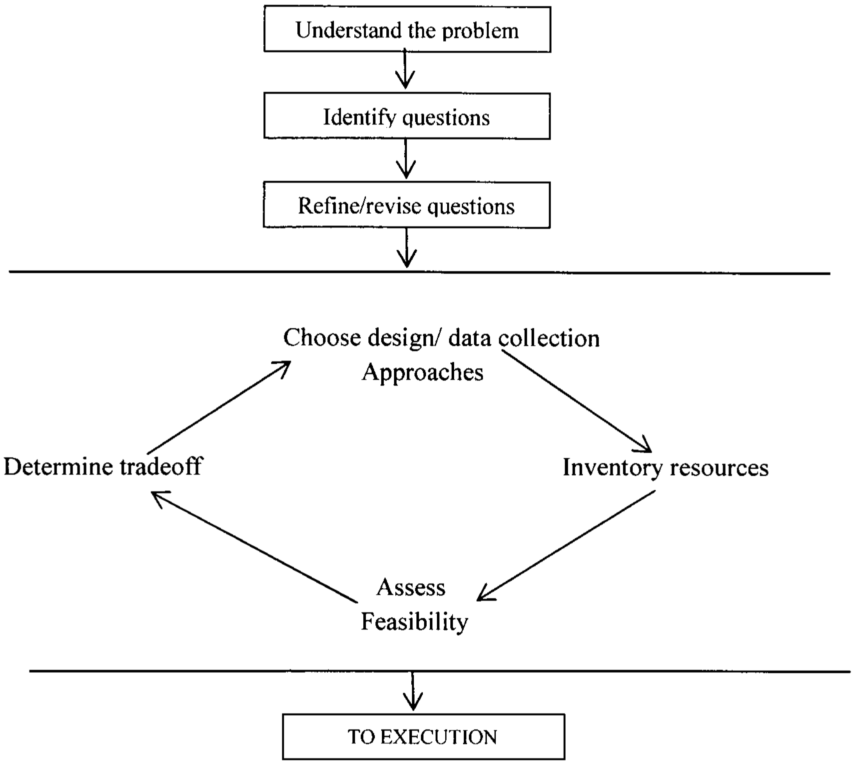

Fig 3.1 Research design process source: (Bickman and Rog, 1998)

The study aimed to identify the factors influencing rework and delay in South African multidisciplinary infrastructure design projects. The study goals were achieved by undertaking the following:

1. Conducting a review of relevant literature on multidisciplinary infrastructure design projects to determine some of the accepted causes of delay, rework and revision
2. Conducting questionnaire surveys with qualified respondents to gather their views on the accepted causes of delay, rework and revision
3. Conducting questionnaire surveys with qualified respondents to discern the characteristics of multidisciplinary infrastructure design projects.

4. Conducting questionnaire surveys with qualified respondents to study the characteristics of some design performance indicators in relation to the causes of delay, revisions and rework.
5. Finding the correlation between the design performance indicators and the prevalent causes of delays, reworks and revisions.

Different parts of a design make up an integrated and interacting whole. In this study, the research questions are at the center of that whole research. (Maxwell, 2005) suggest that research questions are the heart of any research and that they connect to all the other elements that make up the design. (Maxwell, 2005) interactive model of research design listed four immediate component elements which are connected to the research questions to include: goals; methods; validity; conceptual framework. These four interact immediately with the research questions. Also listed was the environmental factors that also influence the design method (including: personal goals; participants concern; funding; ethics; research settings; researcher dexterity, researchers accustomed method of research; research paradigm; perceived problems; personal experience; existing theory; data and conclusion; prior and pilot research). The factors listed influenced the research design approach chosen for this study.

Of the contextual factors listed in Maxwell's (2005) model influencing research design approaches, funding and accessibility had the most significant impact on this particular study. This research was self-sponsored and accessibility was restricted. During the course of data collection accessing the required respondents proved to be a major problem as the researcher had to go two or three times in some cases before having access to the respondent. Time also affected the research methodology in that the researcher is given a short time to complete the study.

Ethical standard was maintained in this research, this was done by not revealing respondents names, details or the companies they work for. Maintaining ethical standard constrained the 'aims', 'objectives' and 'methods' for this study since all unethical practices were avoided completely.

Some of the perceived problems of design rework and delay in multidisciplinary infrastructure design projects in South Africa further informed this study. Many multidisciplinary infrastructure design projects in South Africa suffer from delay and rework setbacks. This study presents an opportunity to examine the likely factors that influence or contribute to delays and rework.

Maxwell (2005) model ignored accessibility issues, which was a serious issue in this study. Accessibility swayed the method that was favored for collecting data at the start of the research design. Accessibility also affected who the researcher was able contact and how much time was spent on collecting the data from contacts. In the preliminary stages of selecting the research design method, the researcher planned to retrieve documents from different companies to add to the analysis. These documents were restricted and the researcher encountered universal refusal on request to obtain these documents. The ethics committee of the university also restricted the researcher in terms of this.

However, the inquiry was done in two stages. The first stage includes a literature review. From the literature review, 20 causes of delay were drawn out. In the second stage the researcher evolved a self-administered questionnaire using the delay causes found in the first stage. This was distributed instead of holding a series of unstructured and structured interviews with respondents. An analysis was done to measure the relative importance of each of the factors found in the first phase to influence delays and rework and to probe for other factors which were not mentioned.

3.2 Research stages

Saunders, *et al* (2002) model 'the research onion' classified research design into six phases which include: techniques and procedures; time horizons; choices; strategies; approaches; philosophies. Crotty, (2009) model classified the research design into four stages which include: epistemology; theoretical perspective; methodology and methods. Crotty, (2009) model was adopted for this research because it was able to justify this research.

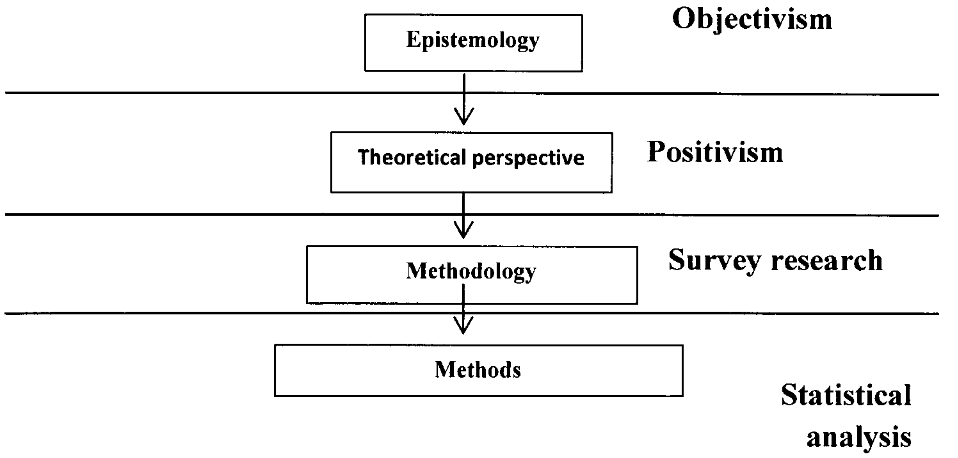

Fig 3.2 Research main stages adopted from Crotty (2009)

3.3 Thesis epistemology

Epistemology is the philosophical knowledge found within the theoretical perspective chosen and thus in the methodology (Crotty, 2009).This study selects 'objectivism' as its epistemological perspective as it adapts with this studies main aims and objectives. One of the aims of this research and of choosing this research design is to be able to generalize the information gathered from the sample to the population so that some inferences can be drawn about some the characteristics of the population. An effective mitigation plan to avoid design revisions, rework and delay can also be developed from the inferences made. Objectivism is a scientific research approach which believes that careful scientific research can obtain an objective truth and meaning (Crotty, 2009) . The objectivist view describes what it means to know. This research did not just create something out of nothing as would be consistent with subjectivism and did not just build on the literature alone as is done in constructionism approach (Crotty, 2009). The first phase of this research was built on literature search and unstructured interviews to identify causes of delays and rework. The second phase involved creating a questionnaire based on the literature findings. This was followed by the statistical analysis and findings. In this study there is an objective truth which is that there are factors that influence delays and reworks in South African multidisciplinary infrastructure design projects that need to be identified and can identified with precision and certitude.

3.4 Thesis theoretical perspective

Social research is theoretical but it is also empirical, because part of it is based on developing, exploring or testing theories, while the other part is built on observations and measurement (Trochim, 2001). The theoretical perspective is the philosophical position that lies behind the adopted methodology (Crotty, 2009). Positivism is one of the four theoretical perspectives listed by (Creswell, 2009) and it has been adopted for this study. It is a deterministic philosophical approach in which causes or factors determine outcomes (Creswell, 2009). This research aimed at identifying the factors influencing delay, rework and revisions in multidisciplinary infrastructure design projects in South Africa and to propose an effective mitigation plan to avoid design revisions, rework and delay. The research aim is consistent with the positivist philosophy in that it brings out the need to identify the factors that influences delays, reworks and revisions (Crotty, 2009). It is a measurement of the reality perceived around the researcher. Determinism advocates that investigating the relationships amid variables through surveys is fundamental to addressing research questions and hypothesis (Creswell, 2009). The variables in this study are the detected factors listed which influence delays, rework and revisions.

3.5 Thesis methodology

The methodology explains the precise technique and procedures used. It also describes the activities engaged in to gather and analyze the data. A literature search and survey research methods were used in this research (Creswell, 2009). Statistical analysis was used in this research. The literature search was used to identify the causes of delays, rework and revisions in the first phase of the research. A questionnaire survey was carried out to establish the validity of the causes of delays and rework identified from the literature review. The questions were developed based on the findings from the literature review. The questionnaire dealt with questions relating to the viewpoints of the respondents. The intention of the questions was to measure the importance the respondents gave to the causes of delays, reworks and revisions listed.

The actual survey research molded the second phase of this research. Liang, *et al* (2011) defined a survey as a method of exploring facts in a study with the purpose of collecting data and its scientific properties. Creswell (2009) describes a survey research approach as a way of studying the trends, standpoints or opinions of a population of people by studying a sample of the larger population. One rational for using a survey design in this study is the economy of the design, the ease sending questionnaire across through emails and also of receiving responses during data collection and the ability to meet the intended goals of the research. The findings are also generalizable and inferences can be drawn from the results.

3.6 Thesis method

To develop the survey research, questionnaires and statistical analysis were used. Self-administered questionnaires were used in this survey. The target respondents for the study were the clients, contractors and consultants which are comprised of civil engineers, project managers, architects, planners, structural engineers, draft men, directors of design firms and construction companies. These were targeted to investigate the factors causing delay, rework and revisions in multidisciplinary infrastructure design projects in South Africa. The questionnaire was designed in May 2013 and was sent out in June, July and August of 2013.

The main purpose of the survey was to collect scientific data which can be quantified. The data collected helped the scientific knowledge in terms of substantiating or not substantiating the literature, bringing new ideas and finding, integration and modification of policies and regulations in South Africa.

By means of a five-point Likert scale, the causes of delays, rework and revision were examined in the first phase of the research, the respondents were asked to evaluate the causes of delays, reworks and revisions listed in the questionnaire by indicating their appropriate level of frequency on a typical project the respondent was involved in. The questionnaire composed of forty nine variables in all, twenty perceived causes of delays, reworks and revisions, eleven typical project characteristics, and eight typical design performance indicators, each variable having five attributes assigned to it.

The respondent is asked to tick one attribute out of the five attributes listed against each variable listed. The twenty variables listed as the perceived causes of delays, reworks and revisions were identified in the first phase of the study from the literature. The respondents were also given a place at the end of each section to provide additional information that they think may be useful but has not been mentioned by the researcher. The questionnaire was designed in both word format and in Acrobat reader format for easy downloading and printing from any computer. It was done in word format for the benefit of respondents who wanted to fill it out electronically and return electronically. It was designed in just two pages to reduce printing papers for participant who preferred to print it, fill it and scan it back to the researcher or post it back to the researcher.

Statistical analysis was embarked upon only after all the questionnaires were received. Statistical analysis was first used to ascertain the validity and reliability of the findings. Creswell (2009) informs that validity and reliability of figures on instruments lead to meaningful interpretation of data. Creswell further added that objective data comes from scientific observation and measures.

Creswell (2009) stated that a study using questionnaires or interviews for data collection can either be cross-sectional or longitudinal in nature. However, this study can be classified as a longitudinal study because the data and results were compiled and achieved over time.

Accessibility was also considered when the researcher chose the survey method adopted, the researcher noted that potential participants were unwilling to be involved in structured interviews because of the perceived fears that it may take their time, disrupt their working hours and also because of the formalities involved. Most of the participants preferred the option of using self-administered questionnaire because it took away the formalities and it gives them an option of filling it during their free time and convenience. With this method subjectivity is reduced, the researcher cannot interfere with the answers the participants provided. In order words this method reduces bias.

According to Creswell (2009) the procedure for the achieving the research findings is completed in seven stages:

1. Ascertain the issues to investigate – Plan the research
2. Investigate and explore the literature to ascertain possible parameters which influence delay, rework and revision
3. Organize the research and examine issues in details
4. Design the research process and investigational tools required

5. Carry out actual survey
6. Clean the data to remove inconsistencies, uncompleted data and duplicate reading
7. Evaluate, process and interpret the data

A research design is methodical plan employed to study a scientific problem. Each design presents its own procedures; and methods but a good research design should be able to achieve the aims, goals and objectives of a planned research. The reasons why this research design is adopted include:

- This research design is chosen because it can accommodate the sequence of flow of this study, the sequence of this study dictates that the theory of the study precedes the observations, the factors measured in the questionnaire are factors observed from the literature (theory).
- This research design was adopted because it is able to accomplish the planned research goals, aims and objectives.
- This research design was chosen because it reduces the threat to the validity of the findings.
- This research design was adopted because it is able to deal with of some of the constraints facing the study, constraints like availability of professional respondents, participant's schedules and what the participants will consent to.
- This research design was adopted also because it can screen out external influences thereby eliminating subjectivity, reducing bias and giving more accurate findings.
- This research design was adopted considering the nature of the research. The time allowed, funding and resources available. The research is time limited and this adopted research designs fits into the schedule.

- This research design was also adopted because it is less intrusive as many participants feel that face to face interviews threaten their privacy.

3.7 Sampling and accessibility

Trochim (2001) defined sampling as the process of selecting entities such as people from a large population of interest with the intention of studying the sample and generalizing the results back to the population the sample was selected from. For this research to exhaustively investigate the factors responsible for delays, rework and revisions on multidisciplinary infrastructure design projects in South Africa, the population from which the researcher would select a sample is practitioners from all of South Africa. Clearly in this research it is impossible to survey and analyze all the practitioners available in the entire population in one single survey owing to the constraints of time, funding, resources and accessibility (Saunders *et al.*, 2002). So the researcher elected to reduce survey sample size and the amount of data by opting to do the survey only in Gauteng. In this study, South Africa serves as the main population from which a sample Gauteng is taken from. The rationale for doing this study in Gauteng is that about 70-75 percent of most the companies head offices in South Africa reside in Gauteng. The concentration of companies and practitioners in Gauteng help the researcher reach more people and save time, it also reduces cost of data collection and the data was more manageable as fewer people were involved. Henry (1990) as site by Saunders, *et al* (2002) argues that smaller population makes for higher accuracy since more time can be spent on checking and testing the data for accuracy before the analysis.

3.7.1 Selecting sampling method

Self-selection sampling was adopted in this study. Self-selected sampling relates to where the respondents opt into a sample. Saunders, *et al* (2002) stated that "self-selection sampling occurs when you allow an individual to identify their desire or to volunteer to take part in a survey". Trochim (2006) stated that since it is difficult to reach all the participants in the parent population of a study, the researcher is obligated to choose an applicable and reasonable number of respondents from the parent population. This process is referred to as sampling.

In this study, the ethics of the university mandates the researcher to solicit for volunteers to participate in the survey. This nature of this study does not allow for random sampling. Only a few volunteered to participate and all those that volunteered were sent the questionnaire. There were some amongst those who volunteered and were sent the questionnaires, who never returned the completed questionnaire even after several reminders.

Using random sampling would have meant that some of those who volunteered to participate would not be qualified or eligible. And some amongst those who are eligible and qualified would not have been selected, and some amongst those who were selected would be unwilling to participate.

The researcher sent out participant information sheet or a request sheet to the potential respondent in which the researcher kindly sought the respondent consent to take part in the survey. The participant information sheet was sent out with a consent form which the participant had to sign upon acceptance to participate in the survey before data collection can be taken. This practice is in compliance with the university's ethical standard.

The survey is administered in this manner to ensure that the respondent understands what the research entails before committing themselves to it. This is because the opinions and feelings of the respondents are often revealed from the questions. The researcher also administered some of the questionnaires using the internet but with the participant information sheet and consent form sent out first to get the participants consent. The researcher publicized the survey on a range of bulletin boards for engineers, architects and project managers requesting for volunteers to fill the questionnaire. Those who responded and agreed to participate were sent the questionnaire immediately by email or in person.

3.7.2 Location of study

Gauteng is one of the nine provinces of South Africa. It is home to most of the administrative and regional offices of design and construction firms in South Africa and usually their operations extend from Gauteng to other parts of South Africa. Johannesburg is the provincial capital of Gauteng and it is the one of the most industrialized city in South Africa and hence it was chosen for this study.

Gauteng province in South Africa was chosen for this study for the reason that about 70% of the eligible firms and companies for this survey have their head offices located in Gauteng. The number of eligible design firms and construction companies tend to reduce yearly, so a conscious attempt was made to reach as many companies as possible. The sites available to publicize the survey were small with enrollment of about 100 eligible civil engineering companies. One respondent was asked to volunteer from an establishment in order to reduce repetition of information. For this study, the targeted respondents were those who had experience in design and construction sector. The questionnaires were given to clients, consultants and contractors. The respondents were from different construction affiliations. The respondents include: interface managers, design coordinators, structural engineers, design managers, electrical engineers, civil engineers, mechanical engineers, contractors, architects, design leaders and project managers.

3.8 Data analysis

Quantitative data includes numerical data or data that can be quantified to answer research question(s) and the study aims and objective (Saunders, *et al* 2002). Trochim (2001) stated that quantitative data is usually in numerical form. Data collection is usually an outcome of the research process. The study data was based on 43 returned valid responses. For any data gathered to be useful it has to be analyzed and interpreted.

From the literature review it was gathered that there were revisions and reworks on design and construction projects that consequently led to substantial delays in the completion time. It was also found that there were factors responsible for directly and indirectly responsible for these delays. So a delay, revision and rework causes analysis was performed to identify some of the major contributing its factors on multidisciplinary design and infrastructure projects.

The first step of the analysis was done by asking questions from professionals in the industry. In these prior dialogues, questions were not prearranged or drafted, allowing for spontaneity in answering the questions on the influences of design delays, revisions and rework. The feedback received include: inexperienced vendors, non – conformance to client specific needs and the needs of regulatory agencies, social uprising, poor communication, not having correct input information at the correct time due to poor planning and understanding of the engineering process of all disciplines, lack of skills required and strikes.

The second step was a literature review to further analyze and corroborate the factors listed during the dialogues. The factors identified during the literature search were matched with those listed during the dialogues to develop the questions for the survey. Taking into consideration the latest studies, twenty most significant critical factors causing delays were chosen for evaluation. Eleven noteworthy project characteristic were also chosen and eight key design performance indicators were chosen for evaluation. The questions were designed to evaluate the factors causing delay, rework and revision and their frequency of occurrence, the adequacy of project characteristics, and the frequency of occurrence of design performance indicators. The questionnaire consists of five sections. The first section asked for demographic information such as the types of projects familiar with the respondent, the current and previous job titles of the respondent, respondent's years of experience and typical value range of the projects that the respondent had been involved in. The second sections sought to establish other engineering disciplines involved on the same project. The third section tried to ascertain the role played by the respondent on that project. The fourth section sought to evaluate the respondent's assessment of the causes of delays, rework and revision on familiar projects. The fifth section sought to establish the rate of recurrence of some key design performance indicators on the same project

3.9 Scaling

This was used to attach weights to the questions for computation. The study adopted the Likert scaling method as it helps to improve quantitative measurement by making them more specific for computation. A Likert scale rating of 1-5 was used in the design of the questionnaire to evaluate the factors causing delay, rework and revision and their corresponding frequencies and to estimate the frequency of the design performance indicators in the projects the respondent was reporting. A five point Likert rating was also used to quantify the level of adequacy of the project characteristics of the project the respondent was reporting. Space for the provision of additional information was also provided in each section.

The scales were interpreted as follows:

1 =Never

2=Sometimes

3=Average

4=Often

5= very often

And

1= Not Adequate

2=Somewhat Adequate

3= Adequate

4= Very Adequate

5= Most Adequate

3.10 Voluntary response and bias

Biases in survey sampling talks about the predisposition of a sample measurement to methodologically over estimate or under estimate (Creswell, 2009). Biases can occur when using an unrepresentative sample. Biases can also occur when the respondent is put under undue pressure when filling the questionnaire. This is why the researcher decided to give the respondent freedom to fill the questionnaire in their own time without any assistance from the researcher. The questionnaire was designed to be easy to comprehend so that every respondent could complete it easily without needing aid, help or assistance. The design, nature and ethics of this study does not allow for using random sampling. But only one respondent is administered in each firm. In order to get a representative sample all volunteers were accepted. Random sampling could not be used in this survey also because of the high number of respondents that declined to participate. On receiving the consent form and the participant information sheet requesting for voluntary participation, many potential participants initially randomly selected declined to participate in the survey without reason. Others who accepted to participate never actually returned the completed questionnaire even after several reminders. Random sampling would have made the sample size smaller and data collected inadequate. As earlier discussed self-selection sampling was adopted in this research. In this study, the survey was voluntary, participation was solicited for as required by the universities ethics. The effects of voluntary response bias of random sampling may be found in this study. Creswell (2009) stated that if the non-respondent had responded, their responses may have changed the overall result.

3.11 Analysis method

The data collected was analyzed statistically by calculating the mean, the relative importance index, the Pearson correlation and the significance level and the Cronbach's alpha level for the project characteristics and design performance indicators in order to find the relative importance, the frequency of occurrence and the correlation values for all the factors listed causing delays, rework and revision.

Each question was designed using a Likert scale rating from 1 to 5, which represents the frequency of occurrence and the level of adequacy. Where r is the rating value attached to each factor (r = 5,4,3,2, and 1 for very often, often, average, sometimes and never for finding the frequency of the causes of delay, rework and revision and r =5, 4,3,2,1 for most adequate, very adequate, adequate, somewhat adequate and not adequate for finding the level of adequacy of the project characteristics).
The relative importance index equation was used to calculate the rank for each cause of delay, rework and revision listed in the questionnaire.

The relative importance index (RII) value is calculated using the formula

$$RII = \frac{Er}{A\,x\,N} \quad (0 \leq \text{RII} \leq 1)$$

Where

E = response category index for 5 (very often), 4 (often), 3 (average), 2 (sometimes), and 1(never) for finding the frequency of the causes of delay, rework and revision and 5 (most adequate), 4 (very adequate), 3 (adequate), 2 (somewhat adequate) and 1(not adequate) for finding the level of adequacy of the project characteristics.
R= is the rating attached to the response = 5, 4,3,2,1 respectively.
A = highest weight (5 in this case) and N is the total number of respondents (Chan and Kumaraswamy, 1997).
Before performing any further analysis, the reliability for each of the research construct was ascertained by using Cronbach's coefficient alpha. When the Cronbach's coefficient alpha value is more than 0.7 the study construct is deemed to be a reliable measure (Cronbach, 1951). The Cronbach's coefficient alpha value reached for each construct used in the survey is shown in Table 1. From Table 1the Cronbach's coefficient alpha level obtained for all the constructs used in this study demonstrates a high level of internal consistency. A condition for construct validity is that the measures are linked to the same construct (Love et al., 2004). The constructs for which the data is collected are delay, rework and revision causes, project characteristics and key design performance indicators. Seeing the limited

study on the aforementioned issues in South Africa, the attained alpha levels shows that questionnaire survey is a reliable research instrument(Love et al., 2004).

Table 3.1 Cronbach's alpha level

Constructs	No of Items	Mean	SD	Cronbach's alpha
Causes of delay, rework and revisions	20	57.9762	11.28670	0.869
Project Characteristics	11	31.9048	6.89224	0.885
Key design performance indicators	8	26.5116	6.61662	0.9

(Cronbach, 1951) describes the alpha (α) values for internal consistencies.

- $\alpha < 0.5$ indicate a poor reliability
- $0.5 < \alpha \leq 0.7$indicate a sufficient reliability
- $\alpha > 0.7$ indicate a good reliability

Cronbach's α formula can be defined thus

$$\alpha = \frac{K\bar{c}}{(\bar{v} + (K-1)\bar{c})}$$

Where $K$is the number of variables, $\bar{v}$ is the average variance of each component (item), and $\bar{c}$ is the average of all covariance's between the components across the current sample of persons (that is, without including the variances of each component) (http://en.wikipedia.org/wiki/Cronbach%27s_alpha...).

Mean is a favorite method used for finding the average of a set of two or more numbers. The mean equation was also used to calculate the average value for each cause of delay, rework and revision listed in the questionnaire. The relationship between the rankings of the variables is confirmed by the mean.

Formula for calculating the mean = $(x) = \frac{\Sigma(Frequency \times data\ value)}{number\ of\ data\ value}$

Pearson correlation coefficient for sample data is denoted by "r". The formula for Pearson correlation coefficient r is given by:

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

Where,

r = Pearson correlation coefficient

x = Values in first set of data

y = Values in second set of data

n = Total number of values.

The value of Pearson correlation coefficient varies between -1 and +1. Where -1 implies a perfect negative correlation, while +1 is a perfectly positive correlation. On the other hand, there is no correlation if the coefficient of correlation is zero (Assaf et al., 1995).

A one sample t test was done using SPSS (statistical package for the social sciences) to compare means of respondent's estimate of delay, rework and revision causes and to ascertain if there are any considerable difference between the means. This test was carried out since the variables have a continuous distribution and are measured using ordinance scale of measurement.

Two hypothesis were created

1. Ho: the factors causing delays, reworks and revision had no effect on the key performance indicators. To examine the relationship between the causes of delay, rework and revision and the key design performance indicators correlation analysis was done using SPSS.
2. Ho: the project characteristics had no effect on the design performance indicators. To examine the relationship between the project characteristics and the design performance indicators correlation analysis using SPSS was used

3.12 Validity and reliability

Reliability refers to the dependability and constancy of the findings. While validity involves the accuracy of the conclusions made from the outcomes of the measurement. Cronbach's coefficient alpha (Cronbach, 1951) is a popular method used for checking consistency. In this study the Cronbach's alpha value was used to check the internal consistency and reliability of the constructs used. The high Cronbach's alpha levels attained for the constructs as presented in Table 1 shows that questionnaire survey used for measurement in this study is a reliable.

Love, *et al* (2012) also state that a measurement has content validity if there is a consensus agreement amid researchers that the instrument used for measuring fulfills all the measurement criteria and covers all the aspect of the measured variable. In this study the selection of measurement criteria was developed and derived from the literature. The construct for measurement used therefore has content validity. Love, *et al* (2006) stated that the reliability of data is closely associated with the data source and consequently linked to the years of experience of the respondent. From the findings in section 4.2.1, the average or mean respondent's years of experience in this survey was 14 years, while the median years of respondent experience was 12 years. We can infer that the data is reliable.

3.13 Ethics

Prior to administering a questionnaire survey, an application is submitted to a committee that reviews your questionnaire to ensure that the questionnaire those not violate the ethics policy observed by the school. The University of the Witwatersrand has an ethics policy guiding all research conducted by the school according to two categories, human and non-human categories. The provision for each category must be met prior to the issuance of an ethic clearance certificate which guides the researcher in carrying the survey. This is in accordance with best practice observed worldwide

3.14 Generalizability

Generalizability is concerned with the size of the relationship among variables and the probability that the same relationship is found in the larger population that the study sample is representing. How your sample population reflects the true state of the larger population depends on the size of your population (Field and Hole, 2003).They further added that the larger the sample the more reliable the correlation will be. Ghasemi and Zahediasl (2012) stated that with a large enough sample size (>30 or 40 or more) parametric procedures can be used albeit the data is not normally distributed. The large sample (>30 or 40 or more) used for this study makes it possible to have a representative sample for factors influencing delay, rework and revision. In view of this it can be concluded that the data is generalizable to the parent population in this case the South African design and construction industry.

CHAPTER FOUR: ANALYSIS AND PRESENTATION OF FINDINGS

4.0 Introduction

This chapter begins by discussing the method of data analysis followed by a presentation of the findings. The findings are discussed in the light of the research questions and the objectives of the study. The study involved conducting a quantitative, descriptive research to investigate factors influencing revision, rework, and delays in multidisciplinary infrastructure design projects in South Africa. A structured data analysis was done and it was aimed at establishing

- Factors which influence revision, rework and delays on multidisciplinary infrastructure design projects in South Africa
- Measuring factors and observing for patterns and regularities.
- Normality test to ascertain the normality distribution of the data obtained
- A one sample t test was done to analyze the importance of the factor causing delay, the adequacy of the project characteristics and the frequency of the design performance indicators.
- Testing for correlation between the different factors influencing delay/rework
- The data was analyzed to determine the relationships amidst the causes and effects delays, reworks and revisions have on the design performance indicators.
- Formulation of tentative hypothesis for further investigation.

Chapter three sections 3.8 and 3.9 present the method of collecting data and data analysis. This chapter discusses the research findings. The findings were used to formulate recommendations that will optimize multidisciplinary infrastructure design projects in South Africa. Data was obtained from self-administered questionnaires, completed by a total of 43 respondents (n=43), which was a 71.66% response rate. 60 questionnaires were handed out in total. The respondents were made up of 14 Civil Engineers, 6 Structural Engineers, 5 Mechanical Engineers, 16 Project Managers, 1 Electrical Engineer and 1 Architect.

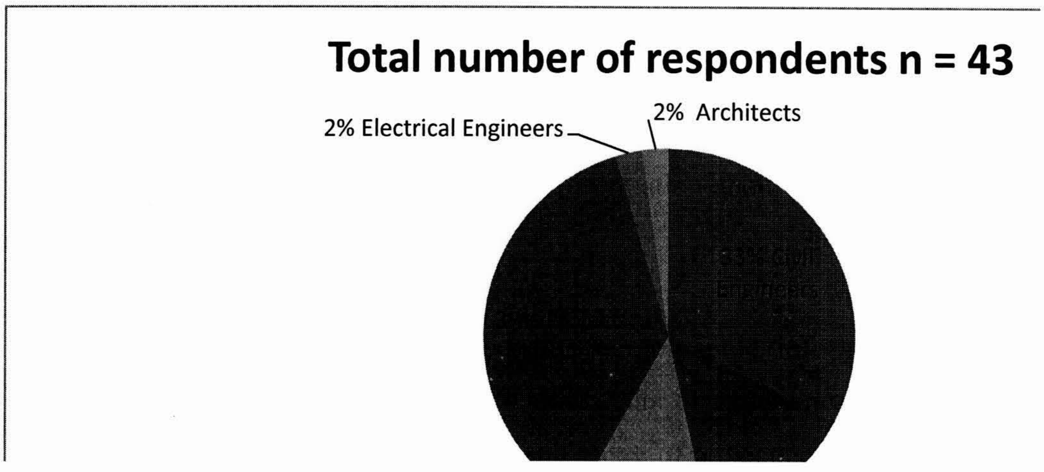

Fig 4.1 Demography of the respondents based on their disciplines

Fig 4.1 gives a graphic summary of respondents by discipline.

A total of 50 questionnaires were received out of 70 handed out, however, only 43 were properly filled and usable for this study. A targeted response was rather applied for this study due to the specifics required in terms of the profile of the respondents. An additional reason for targeting respondents was that most respondents contacted at the onset were wary and unwilling to reveal information about their jobs to unknown individuals.

The questionnaire comprised of five sections:

- The first section sought to ascertain demographic information about the respondent such as discipline, job title, years of experience, type of projects done, value range of projects done and sector of projects done
- The second section sought to further establish the characteristics of the projects the respondent was involved in
- The third section sought to ascertain the role played by the respondent over the last five years
- The fourth section captured of data evaluating the causes of delay, rework or/and revisions and measuring the adequacy of the project characteristics as experienced by the respondent.

- The fifth section captured of data evaluating the frequencies of the project performance indicators existing

4.1 Methods of data analysis and presentation

A descriptive analysis was carried out first to test for data skewness and normality, and to measure the frequencies of all the collected data variables. A correlation analysis was also carried out using the Pearson correlation and the significance level between the factors causing delays and the key performance indicators was determined. The significance level was set at 0.05. This implies that correlation is significant for values less than 0.05.

4.2 Discussion of discoveries

4.2.1 Demographic Information

While this is not part of the objective of this study, nonetheless it is vital information for understanding the background of each respondent. The purpose in obtaining this data is to describe the demographic variables of the sample. The demographic data include discipline, job title, years of experience, type of projects done, value range of projects done, and the sector of projects done.

Table 4.1: Descriptive statistics for years of experience of the respondents

Statistics

Years of experience

N	Valid	43
	Missing	0
Mean		14.0000
Median		12.0000
Mode		10.00
Std. Deviation		9.78093
Skewness		.982
Std. Error of Skewness		.361
Range		40.00
Minimum		1.00
Maximum		41.00

Valid respondents for this survey were16 Project managers, 14 Civil engineers, 6 Structural engineers, 5 Mechanical engineers, 1 Architect and 1 Electrical engineer.

Table 4.2: Frequency of years of experience of the respondents

Years of experience

Years of experience		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	1	2.3	2.3	2.3
	3.00	2	4.7	4.7	7.0
	4.00	4	9.3	9.3	16.3
	5.00	4	9.3	9.3	25.6
	6.00	1	2.3	2.3	27.9
	7.00	1	2.3	2.3	30.2
	9.00	2	4.7	4.7	34.9
	10.00	5	11.6	11.6	46.5
	12.00	2	4.7	4.7	51.2
	13.00	3	7.0	7.0	58.1
	14.00	2	4.7	4.7	62.8
	15.00	3	7.0	7.0	69.8
	17.00	2	4.7	4.7	74.4
	19.00	1	2.3	2.3	76.7
	20.00	2	4.7	4.7	81.4
	25.00	1	2.3	2.3	83.7
	28.00	1	2.3	2.3	86.0
	30.00	4	9.3	9.3	95.3
	35.00	1	2.3	2.3	97.7
	41.00	1	2.3	2.3	100.0
	Total	43	100.0	100.0	

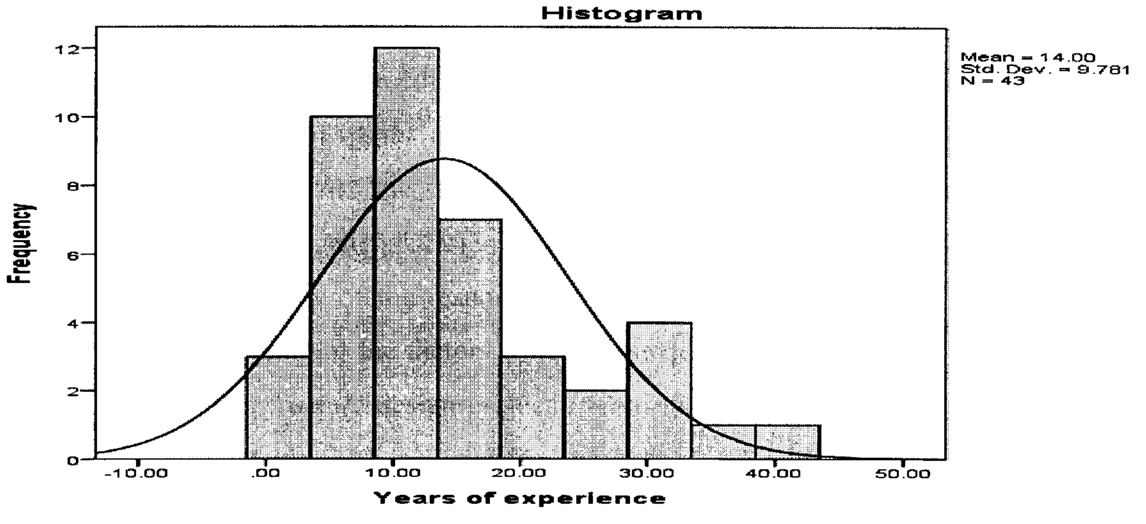

Figure 4.2 Bar chart showing years of experience

From this particular sample, the histogram is positively skewed which suggest that there are a greater number of respondents with more years of experience than the mean in this survey. The average or mean respondents years of experience in this survey was 14 years, while the median years of respondent experience was 12 years. The highest percentage of years of working experience was 10 years (11.6%) followed by 30 years (9.3%). The standard deviation was 9.78093, which indicates that the sample was heterogeneous in terms of years of experience. This suggests an indication that the majority of the respondents who took part in the survey should have a good understanding of the factors which cause delays, rework and revision in multidisciplinary infrastructure design projects. From the findings it is apparent that most of the respondents had experiences more than one project. Of the 43 respondents, 88% had experience in civil design and construction, 76% structural designs, 62% architecture, 69% electrical designs and construction, 41% geotechnical engineering, 48% piping, 41% mechanical engineering, 25% roads etc. However, the majority of the respondents had experiences in multidisciplinary project. From the percentages, it is believed that the study can be used to develop a better understanding of the factors influencing delays in multidisciplinary design and infrastructure projects in South Africa.

4.2.2 Consistency of the result

Table 4.3 Descriptive statistics for research constructs

Constructs	No of Items	Mean	SD	Cronbach's alpha	Reliability Assessment
Causes of delay, rework and revisions	20	57.9762	11.28670	0.869	Good
Project Characteristics	11	31.9048	6.89224	0.885	Good
Key design performance indicators	8	26.5116	6.61662	0.9	Good

Before doing any detailed enquiry on any of the research construct their reliability was first ascertained by using Cronbach's coefficient alpha. When Cronbach's coefficient alpha value is more than 0.7 the study construct is deemed to be a consistent measure (Cronbach, 1951). The Cronbach's coefficient alpha value, the quantity of items used in each scale for every construct used in the questionnaire, is shown in Table 4.3. The Cronbach's coefficient alpha level for the constructs in this study indicates a good level of internal reliability. The constructs for which the data is collected are delay, rework and revision causes, project characteristics and key design performance indicators. The alpha coefficient for the 20 factors causing delay is 0.869. The Cronbach's alpha value for the eleven project characteristic under investigation is 0.885. The Cronbach's alpha value for the eight design performance indicators is 0.9. In all three cases the values suggest that the composition have a high internal consistency. Cronbach, (1951) describes the alpha (α) values for internal consistencies as follows:

- $\alpha < 0.5$ indicate a poor reliability
- $0.5 < \alpha \leq 0.7$indicate a sufficient reliability
- $\alpha > 0.7$ indicate a good reliability

Seeing the limited studies on the aforementioned issues in South Africa, the attained alpha levels shows that questionnaire survey is a reliable research instrument(Love et al., 2004).

Table 4.4 Shows the Relative Importance Index values for the top ten factors causing delay, rework and revision

Factors that cause delay, rework and revision	RII	Rank	Group
Scope Change	0.7116	1	Change related
Approval Delay	0.7023	2	Approval related
Design Change	0.6790	3	Change related
Owners Initiated changes	0.6790	4	Change related
Poor Scope Definition	0.6790	5	Scope related
Resources	0.6279	6	Resource related
Poor Information Flow	0.6279	7	Information related
Lack of input Information	0.6046	8	Information related
Unrealistic Project Time Estimate	0.6186	9	Time related
Insufficient Design Details	0.6046	10	Design related

The relative importance index equation was used to calculate the rank for each cause of delay, rework and revision listed in the questionnaire.

The relative importance index (RII) value is calculated using the formula

$$RII = \frac{Er}{A\,x\,N}\ (0 \leq \text{RII} \leq 1)$$

Where

E = response category index for 5 (very often), 4 (often), 3 (average), 2 (sometimes), and 1(never) for finding the frequency of the causes of delay, rework and revision and 5 (most adequate), 4 (very adequate), 3 (adequate), 2 (somewhat adequate) and 1(not adequate) for finding the level of adequacy of the project characteristics.

R= is the rating attached to the response = 5, 4,3,2,1 respectively.

A = highest weight (5 in this case) and N is the total number of respondents (Chan and Kumaraswamy, 1997).

$$RII \text{ for Scope Change} = \frac{(1x1)+(10x2)+(5x3)+(18x4)+(9x5)}{5 \times 43} = 0.7116$$

RII for Scope Change = 0.7116

Similar computations were carried out for the other factors.

Table 4.4 shows the top ten causes of delay, rework and revision. From Table 4.5, we can see that all changes related issues are among the top 5.

4.2.3 Frequency scores for causes of delay, rework and revisions

Table 4.5: Shows mean and frequency scores for causes of delay, rework and revisions

causes of delays, rework & revision	**RII**	**Frequency of scores**					**Mean score**	**Total**
Frequency		1	2	3	4	5		
Scope Change	1	1	10	5	18	9	3.5581	43
Approval Delay	2	nil	8	9	22	4	3.5116	43
Design Change	3	nil	11	9	18	5	3.3953	43
Owners Initiated changes	4	3	6	9	21	4	3.3953	43
Poor Scope Definition	5	2	9	12	10	10	3.3953	43
Resources	6	3	9	16	9	6	3.1395	43
Poor Information Flow	7	2	9	17	11	4	3.1395	43
Lack of input Information	8	3	8	17	10	4	3.0952	42
Unrealistic Project Time Estimate	9	2	15	5	19	2	3.0930	43
Insufficient Design Details	10	1	18	8	11	5	3.0233	43
Lack of Coordination between Designers	11	2	15	12	6	7	2.9535	43
Inadequate Planning & Scheduling	12	3	19	10	6	5	2.7907	43
Design errors and Omissions	13	1	21	8	11	1	2.6977	43

Lack of Experienced Designers	14	6	16	7	9	4	2.6744	43
Clashes in Drawings	15	3	19	9	9	2	2.6512	43
Project Complexity	16	1	22	16	3	1	2.5581	43
Differing Site Conditions	17	3	19	18	2	nil	2.3953	43
Vendors Error and Omissions	18	2	28	9	4	nil	2.3488	43
Inappropriate Assumptions	19	8	21	7	6	1	2.3256	43
Changes in Laws of Regulatory Agencies	20	17	19	5	1	nil	1.7209	43

Mean is a favorite method used for finding the average of a set of two or more numbers. The mean equation was also used to calculate the average value for each cause of delay, rework and revision listed in the questionnaire.

Calculation of Mean Scores : From table 4.5 Scope change had one (1) respondent scored 1, ten (10) respondent's scored 2, five (5) respondents scored 3, eighteen (18) respondents scored 4 and nine (9) respondents scored 5. Total responses (N) = 43

$$\text{Formula for calculating the mean} = (x) = \frac{\sum(\textit{Frequency} \times \textit{data value})}{\textit{number of data value}}$$

$$\text{Mean score } \textit{for} \text{ Scope Change} = \frac{(1x1) + (10x2) + (5x3) + (18x4) + (9x5)}{43} = 3.5581$$

Mean Score for scope change = **3.5581**

Similar computations were carried out for the other factors.

The mean score for Approval Delay= **3.5116,**

The mean score for Design Change=**3.3953,**

The mean score for Owners Initiated Changes=**3.3953,**

The mean score for Poor Scope Definition=**3.3953,**

The mean score for Resources=**3.1395,**

The mean score for Poor Information Flow=**3.1395,**

The mean score for Lack of input Information=**3.0952,**

The mean score for Unrealistic Project Time Estimate=**3.0930,** The mean score for Insufficient Design Details=**3.0233.**

The mean score for Lack of Coordination between Designers = **2.9535**

The mean score for Inadequate Planning & Scheduling = **2.7907**

The mean score for Design errors and Omissions = **2.6977**

The mean score for Lack of Experienced Designers = **2.6744**

The mean score for Clashes in Drawings = **2.6512**

The mean score for Project Complexity = **2.5581**

The mean score for Differing Site Conditions = **2.3953**

The mean score for Vendors Error and Omissions = **2.3488**

The mean score for Inappropriate Assumptions = **2.3256**

The mean score for Changes in Laws of Regulatory Agencies = **1.7209**

These values are shown in table 4.5

4.2.4 Normality Test

Recent research on the normal distribution (Kalla, 2011) stated that a better comprehension of the normal distribution assumptions helps researchers to be acquainted with their study and where it has discontinuities. Before conducting a one sample t-test analysis, it is necessary to ascertain that the dependent variable follows a normal distribution.

Ghasemi and Zahediasl (2012) stated that with a large enough sample size (>30) parametric procedures can be used albeit the data is not normally distributed. They further alluded to the central limit theory, stating that the sampling distribution in a large sample (>30) tend to be normal irrespective of the shape of the data. Therefore, since this study sample collected is large (>30 or 40) the data is assumed to be normally distributed.

4.2.5 One sample t-tests analysis result for causes of delay, rework and revision

Table 4.6: One sample t-test analysis for the causes of delay, rework, or /and revision

Test Value = 3						
S/no	**Causes of delay, rework, or /and revision**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Unrealistic Project Time Estimate	3.0930	.578	H0-accepted	0.6186	9
2	Poor Scope Definition	3.3953	.036	H0- rejected	0.6790	5
3	Scope Change	3.5581	.003	H0- rejected	0.7116	1
4	Project Complexity	2.5581	.000	H0- rejected	0.5116	16
5	Insufficient Design Details	3.0233	.893	H0-accepted	0.6046	10
6	Design Change	3.3953	.013	H0- rejected	0.6790	3
7	Clashes in Drawings	2.6512	.046	H0- rejected	0.5302	15
8	Lack of Coordination between Designers	2.9535	.809	H0-accepted	0.5906	11
9	Lack of Experienced Designers	2.6744	.104	H0-accepted	0.5348	14
10	Poor Information Flow	3.1395	.372	H0-accepted	0.6279	7
11	Lack of input Information	3.0952	.562	H0-accepted	0.6046	8
12	Inappropriate Assumptions	2.3256	.000	H0- rejected	0.4651	19
13	Inadequate Planning & Scheduling	2.7907	.238	H0-accepted	0.5581	12
14	Owners Initiated changes	3.3953	.020	H0- rejected	0.6790	4
15	Differing Site Conditions	2.3953	.000	H0- rejected	0.4790	17
16	Changes in Laws of Regulatory Agencies	1.7209	.000	H0- rejected	0.3441	20
17	Design Errors and Omissions	2.6977	.062	H0-accepted	0.5395	13

18	Vendors Error and Omissions	2.3488	.000	H0- rejected	0.4697	18
19	Approval Delay	3.5116	.001	H0- rejected	0.7023	2
20	Resources	3.1395	.421	H0-accepted	0.6279	6

**. Correlation is significant at the 0.05 level (2-tailed).

Note: Null Hypothesis = Ho: $\mu = 3$

Alternate Hypothesis = Ha: $\mu \neq 3$

If $p < 0.05$, reject H0

If $p > 0.05$, accept the null hypothesis or fail to reject null hypothesis

A one sample t-test analysis was performed to know whether the sample mean is different from the hypothesized population mean of 3.

The first row of Table 4.6 presents the value of the hypothesized population mean the researcher is comparing the sample mean to.

("Sig. (2-tailed)") < 0.05 is the level of significance typically used for the t test.

If $p < 0.05$ it means that there is a statistically significant difference between the sample-estimated population mean and the hypothesized population mean and thus the null hypothesis is rejected and the alternative hypothesis is accepted. If $p > .05$, it means that the difference between the sample-estimated population mean and the hypothesized population mean is not statistically significantly different. In this case, the researcher accepts or fails to reject the null hypothesis

A hypothesized test value of 3 was run through a one sample t-test analysis, as 3 correspond to a rating of "average" in the 5-point Likert scale administered in the survey. From Table 4.6, it can be inferred that the researcher is at least 95% confident that the results did not come by chance.

From Table 4.6 according to the relative importance index values calculated we see the top ten factors causing delay, rework and revision as: "scope change", "approval delays", "design change", "owners initiated changes", "poor scope definition", "resources", "poor information flow", "lack of input information", "unrealistic project time estimate" and "insufficient design details". All these variables have mean values greater than the hypothesized mean level of 3 (average). The factors that are greater than the hypothesized mean have greater influences on delay, rework and revision while those that are below have less influence on delay, rework and revisions.

From table 4.6 it is evident that all the variables influence delay, rework and revisions in South African design projects. From the relative importance index values, the top three influencers were the "scope changes", "approval delay" and "design changes". Among the least three "changes in laws of regulatory agencies", "inappropriate assumptions" and "vendor's error and omissions". Since the South African industry is weak in the the modern information technology applications. Scope and design changes also have a knock on effect with the design process in terms of delay and rework.

Notice that the mean of "lack of input information" is greater than the mean of "unrealistic project time estimate" because the variable "lack of input information" has one missing value. However, "lack of input information" has a lower Relative Importance Index value than "unrealistic project time estimate".

Table 4.7: Shows the mean and the frequency scores for the project characteristics

S/No	Project characteristics	RII	Frequency of scores					Mean score	Total
	Frequency		1	2	3	4	5		
1	Scope Definition	5	3	11	19	7	3	2.9070	43
2	Project Organization	3	1	9	22	9	2	3.0465	43
3	Design Coordination	4	2	9	24	6	2	2.9302	43
4	Interface Management	8	3	11	18	9	1	2.8571	43
5	Design Planning	2	2	10	19	8	4	3.0465	43
6	Design Documentation	1	1	8	23	8	3	3.0930	43
7	Change Management	7	3	9	23	7	1	2.8605	43
8	Resources	11	1	18	17	6	1	2.7209	43
9	Coordination Tools	9	2	12	23	5	1	2.7907	43
10	Design Verification	6	2	14	17	8	2	2.8605	43

11	Design Approval	10	5	14	14	7	3	2.7442	43

Calculation of Mean Scores : From table 4.7 Scope definition had three (3) respondent score 1, Eleven (11) respondent's score 2, Nineteen (19) respondents scored 3, Seven (7) respondents scored 4 and three (3) respondents scored 5. Total responses (N) = 43

$$\text{Formula for calculating the mean} = (x) = \frac{\Sigma(Frequency \times data\ value)}{number\ of\ data\ value}$$

$$\text{Mean score for scope definition} = \frac{(3x1) + (11x2) + (19x3) + (7x4) + (3x5)}{43} = 2.9070$$

Mean Score for scope definition = **2.9070**

Similar computations were carried out for the other factors.

These values are shown in table 4.7

Table 4.8 Shows the Relative Importance Index values and the ranks of the project characteristic

Rank	Project Characteristic	RII	Group
1	Design Documentation	0.6186	Documentation related (Adequate)
2	Design Planning	0.6093	Planning related (Inadequate)
3	Project Organization	0.6093	Organization related (Inadequate)
4	Design Coordination	0.5860	Coordination related (Inadequate)
5	Scope Definition	0.5813	Scope related (Inadequate)
6	Design Verification	0.5720	Design related (Inadequate)
7	Change Management	0.5720	Change related (Inadequate)
8	Interface Management	0.5581	Interface related (Inadequate)
9	Coordination Tools	0.5581	Interface related (Inadequate)
10	Design Approval	0.5488	Approval related (Inadequate)

11	Resources	0.5441	Resource related (Inadequate)

The relative importance index equation was used to calculate the rank for the project characteristics listed in the questionnaire.

The relative importance index (RII) value is calculated using the formula

$$RII = \frac{Er}{A \times N} \, (0 \leq \text{RII} \leq 1)$$

Where

E = response category index for 5 (very often), 4 (often), 3 (average), 2 (sometimes), and 1(never) for finding the frequency of the causes of delay, rework and revision and 5 (most adequate), 4 (very adequate), 3 (adequate), 2 (somewhat adequate) and 1(not adequate) for finding the level of adequacy of the project characteristics.

R= is the rating attached to the response = 5, 4,3,2,1 respectively.

A = highest weight (5 in this case) and N is the total number of respondents (Chan and Kumaraswamy, 1997).

RII for Design Documentation = $\frac{(1x1) + (8x2) + (23x3) + (8x4) + (3x5)}{5 \times 43}$ = 0.6186

RII for Design Documentation = 0.6186

Similar computations were carried out for the other factors

From Table 4.8 we can see that only design documentation is adequate in terms of the project characteristics. From the study the others are inadequate. This has a knock on effect on the design process in terms of delay and rework.

4.2.6 One sample t-test analysis for project characteristics

Table 4.9: Shows the one sample t-test analysis result and the rank of the project characteristics according to the Relative Importance Index values

Test Value = 3						
S/no	**Project Characteristics**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Scope Definition	2.9070	.543	H0-accepted	0.5813	5
2	Project Organization	3.0465	.720	H0-accepted	0.6093	3
3	Design Coordination	2.9302	.596	H0-accepted	0.5860	4
4	Interface Management	2.8571	.323	H0-accepted	0.5581	8
5	Design Planning	3.0465	.762	H0-accepted	0.6093	2
6	Design Documentation	3.0930	.486	H0-accepted	0.6186	1
7	Change Management	2.8605	.294	H0-accepted	0.5720	7
8	Resources	2.7209	.032	H0- rejected	0.5441	11
9	Coordination Tools	2.7907	.095	H0-accepted	0.5581	9
10	Design Verification	2.8605	.336	H0-accepted	0.5720	6
11	Design Approval	2.7442	.132	H0-accepted	0.5488	10

**. Correlation is significant at the 0.05 level (2-tailed).

Note: Null Hypothesis = Ho: $\mu = 3$

Alternate Hypothesis = Ha: $\mu \neq 3$

If $p < 0.05$, reject Ho

If $p > 0.05$, accept the null hypothesis or fail to reject null hypothesis

A t-test analysis was performed to know whether the sample mean is different from the hypothesized population mean of 3.

The first row of Table 4.9 presents the value of the hypothesized population mean the researcher is comparing the sample mean to. A hypothesized population mean of 3 was administered through a one sample t-test as 3 correspond to a rating of "average" in the 5-point Likert scale administered in the survey.

("Sig. (2-tailed)") < 0.05 the level of significance typically used for the t test

If $p < 0.05$ it means that there is a statistically significant difference between the sample-estimated population mean and the hypothesized population mean and thus the null hypothesis is rejected and the alternative hypothesis is accepted. If $p > 0.05$, it means that the difference between the sample-estimated population mean and the hypothesized population mean is not statistically significantly different. In this case, the researcher accepts or fails to reject the null hypothesis.

From Table 4.9, it can be inferred that: The researcher is at least 95% confidence level that the results did not come by chance

The difference between the sample projected population mean and the hypothesized population mean is not statistically significantly different for all variables except for resources.

From Table 4.9 we see that the actual mean of most of the project characteristics is less than or equal to the hypothesized level of 3 for all the variables. When variables are less than or equal to the hypothesized mean it indicates that the variable are inadequate or somewhat. The variables that have their mean values greater than the hypothesized mean are inferred to be adequate.

From Table 4.9 it can be inferred that almost all the project characteristic are inadequate except for design documentation and design planning which are adequate in the South African design projects. Table 4.9 indicates that the top three in terms of adequacy are "design documentation", "design planning" and "project organization". "Coordination tools", "design approval" and "resources" are among the most inadequate project characteristics on South African design projects. Again, since the South African industry is lacking in human resources (engineers) and modern coordination tools (Lawless, 2007) . The industry is not able to provide the required coordination tools, quick approval of documents and resources. These too have a knock on effect on the design process in terms of delay, revisions and rework.

Table 4.10: Frequency scores for key design performance indicators

S/N	Key Design Performance indicators	Rank	Frequency of scores					Mean score	Total
	Frequency		1	2	3	4	5		
1	Drawing Revisions	1	1	11	4	17	10	3.5581	43
2	Drawing (Design)Rework	4	nil	14	8	13	8	3.3488	43
3	Site Rework due to Design	7	2	12	14	9	6	3.1163	43
4	Design Delay	6	1	11	12	14	5	3.2558	43
5	Submission Delay	8	1	13	14	12	3	3.0698	43
6	Approval Delay	2	nil	8	12	15	8	3.5349	43
7	Design Changes	5	nil	12	11	16	4	3.2791	43
8	Scope Changes	3	2	9	12	12	8	3.3488	43

Calculation of Mean Scores : From table 4.10 Drawing revision had one (1) respondent score 1, eleven (11) respondent's score 2, four (4) respondents scored 3, seventeen (17) respondents scored 4 and ten (10) respondents scored 5. Total responses (N) = 43

Formula for calculating the mean = $(x) = \frac{\sum(Frequency \times data\ value)}{number\ of\ data\ value}$

Mean score for Drawing revision = $\frac{(1x1) + (11x2) + (4x3) + (17x4) + (10x5)}{43} = 3.5581$

Mean Score for Drawing Revision = **3.5581**

Similar computations were carried out for the other factors.

These values are shown in table 4.10

Table 4.11 Shows the Relative Importance Index values for the Key Design Performance indicators

S/No	Key Design Performance indicator	RII	Group
1	Drawing Revisions	0.6186	Drawing related
2	Drawing (Design)Rework	0.6093	Drawing related
3	Site Rework due to Design	0.6093	Design related
4	Design Delay	0.5860	Design related
5	Submission Delay	0.5813	Time related
6	Approval Delay	0.5720	Time related
7	Design Changes	0.5720	Design related
8	Scope Changes	0.5581	Scope related

The relative importance index equation was used to calculate the rank for the project characteristics listed in the questionnaire.

The relative importance index (RII) value is calculated using the formula

$$RII = \frac{Er}{A\,x\,N}\ (0 \leq \text{RII} \leq 1)$$

Where

E = response category index for 5 (very often), 4 (often), 3 (average), 2 (sometimes), and 1(never) for finding the frequency of the causes of delay, rework and revision and 5 (most adequate), 4 (very adequate), 3 (adequate), 2 (somewhat adequate) and 1(not adequate) for finding the level of adequacy of the project characteristics.

R= is the rating attached to the response = 5, 4,3,2,1 respectively.

A = highest weight (5 in this case) and N is the total number of respondents (Chan and Kumaraswamy, 1997).

RII for Drawing revision = $\frac{(1x1) + (11x2) + (4x3) + (17x4) + (10x5)}{5 \times 43} = 0.7116$

RII for Drawing Revision = **0.7116**

Similar computations were carried out for the other factors.

These values are shown in table 4.11

4.2.7 T-test analysis of key design performance indicators

Table 4.12 T-test analysis of key design performance indicators and ranks

Test Value = 3						
no	**Key Design Performance indicators**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Drawing Revisions	3.5581	0.003	H0- rejected	0.7116	1
2	Drawing (Design)Rework	3.3488	0.050	H0- accepted	0.6697	4
3	Site Rework due to Design	3.1163	0.499	H0- accepted	0.6232	7
4	Design Delay	3.2558	0.117	H0- accepted	0.6511	6
5	Submission Delay	3.0698	0.645	H0- accepted	0.6139	8
6	Approval Delay	3.5349	0.001	H0- rejected	0.7069	2
7	Design Changes	3.2791	0.070	H0- accepted	0.6558	5
8	Scope Changes	3.3488	0.054	H0- accepted	0.6697	3

**. Correlation is significant at the 0.05 level (2-tailed).

Note: Null Hypothesis = Ho: $\mu = 3$

Alternate Hypothesis = Ha: $\mu \neq 3$

If $p < 0.05$, reject Ho

If $p > 0.05$, accept the null hypothesis or fail to reject null hypothesis

A t-test analysis was performed to know whether the sample mean is different from the hypothesized population mean of 3.

The first row of Table 4.12 presents the value of the hypothesized population mean the researcher is comparing the sample mean to. A hypothesized population mean of 3 was administered through a one sample t-test as 3 correspond to a rating of "average" in the 5-point Likert scale administered in the survey.

("Sig. (2-tailed)") < 0.05 the level of significance typically used for the t test

If $p < 0.05$ it means that there is a statistically significant difference between the sample-estimated population mean and the hypothesized population mean and thus the null hypothesis is rejected and the alternative hypothesis is accepted. If $p > 0.05$, it means that the difference between the sample-estimated population mean and the hypothesized population mean is not statistically significantly different. In this case, the researcher accepts or fails to reject the null hypothesis.

From Table 4.12, it can be inferred that:

The researcher is at least 95% confident that the results did not come by chance

The difference between the sample projected population mean and the hypothesized population mean is not statistically significantly different for all variables except for drawing revisions and approval delay.

From Table 4.12 we see that that the actual mean of almost all the key design performance indicators are greater than the hypothesized level of 3 When the variable mean is greater than the hypothesized mean it indicates that the design performance indicators occur often or very often.

From Table 4.12 we see that almost all the design performance indicators occur often or very often except for "submission delay" and "site rework due to design" in the South African design projects. We can infer from Table 4.12 that "drawing revisions", "approval delays" and "scope changes" are among the first three most occurring indicators in South African design projects. While "submission delay", "site rework due to design" and "design delay" are less occurring in South African design projects. Again we see that the South African industry is not performing well. The industry is unable to manage drawing revisions, approvals and scope changes as effectively as it should and these too have a knock on effect on the entire design process in terms of delays revisions and rework.

4.2.8 Descriptive statistics

Table 4.13 Descriptive statistics and ranking results for revision, rework and delay factors

Revision Rework and Delay Factors	Range	Minimum	Maximum		Mean value from survey		Std. Deviation
	Statistic	Statistic	Statistic	Mean	RII	Rank	Statistic
Changes in Laws of Regulatory Agencies	4.00	1.00	4.00	1.7209	0.3441	20	.79659
Inappropriate Assumptions	4.00	1.00	5.00	2.3256	0.4651	19	1.01702
Vendors Error and Omissions	3.00	1.00	4.00	2.3488	0.4697	18	.71991
Differing Site Conditions	4.00	1.00	4.00	2.3953	0.4790	17	.79101
Project Complexity	4.00	1.00	5.00	2.5581	0.5116	16	.76539
Clashes in Drawings	5.00	1.00	5.00	2.6512	0.5302	15	1.11021
Lack of Experienced Designers	5.00	1.00	5.00	2.6744	0.5348	14	1.28584
Design Errors and Omissions	5.00	1.00	5.00	2.6977	0.5395	13	1.03590
Inadequate Planning and Scheduling	4.00	1.00	5.00	2.7907	0.5581	12	1.14555
Lack of Coordination between Designers	5.00	1.00	5.00	2.9535	0.5906	11	1.25268
Insufficient Design Details	4.00	1.00	5.00	3.0233	0.6046	10	1.12310
unrealistic project time estimate	4.00	1.00	5.00	3.0930	0.6186	9	1.08702
Lack of input Information	4.00	1.00	5.00	3.0952	0.6046	8	1.05483
Poor Information Flow	4.00	1.00	5.00	3.1395	0.6279	7	1.01375
Resources	4.00	1.00	5.00	3.1395	0.6279	6	1.12507
Poor Scope Definition	4.00	1.00	5.00	3.3953	0.6790	5	1.19800
Owners Initiated changes	4.00	1.00	5.00	3.3953	0.6790	4	1.07215
Design Change	3.00	1.00	5.00	3.3953	0.6790	3	1.00332
Approval Delay	3.00	1.00	5.00	3.5116	0.7023	2	.90953
Scope Change	4.00	1.00	5.00	3.5581	0.7116	1	1.14022
Valid N (list wise)							

Table 4.13 shows the ranking of the factors influencing delays, rework or/and revision in an ascending order of RII.

Notice that the mean of lack of input information is greater than the mean of unrealistic project time estimate because the variable "lack of input information" has a missing value, however "lack of input information" has a lower relative importance index value than "unrealistic project time estimate".

Notice also that the variables resources and poor information flow have the same mean and RII values even though they are ranked as 6 and 7 respectively.

Notice that the variables design change, "owner initiated changes" and "poor scope definition" have the same mean and RII values even though they are ranked as 3, 4 and 5 respectively.

Table 4.14 shows the various index and ranking results for the project characteristics

Project characteristics	Range	Minimum	Maximum	RII	Mean value form survey		Std. Deviation
	Statistic	Statistic	Statistic	RII	Mean	Rank	Statistic
Design Documentation	4.00	1.00	5.00	0.6186	3.0930	1	.86778
Project organization	4.00	1.00	5.00	0.6093	3.0465	2	.84384
Design Planning	4.00	1.00	5.00	0.6093	3.0465	3	.99889
Design Coordination	4.00	1.00	5.00	0.5860	2.9302	4	.85622
Scope Definition	4.00	1.00	5.00	0.5813	2.9070	5	.99556
Design Verification	4.00	1.00	5.00	0.5720	2.8605	6	.94065
Change Management	4.00	1.00	5.00	0.5720	2.8605	7	.86138
Interface Management	4.00	1.00	5.00	0.5581	2.8571	8	.92582
Coordination Tools	4.00	1.00	5.00	0.5581	2.7907	9	.80351
Design Approval	4.00	1.00	5.00	0.5488	2.7442	10	1.09312
Resources	4.00	1.00	5.00	0.5441	2.7209	11	.82594

Table 4.14 shows the ranking of the project characteristics in descending order of RII values, from the greatest to the smallest.

Notice that the variables "project organization" and "change management" have the same mean and RII values even though they are ranked as 2 and 3 respectively.

Notice that the variables "design verification" and "design planning" have the same mean and RII values even though they are ranked as 6 and 7 respectively.

Table 4.15: Various index and ranking results for design performance Indicators

Key design performance indicators	Range	Minimum	Maximum	RII	Mean value from survey		Std. Deviation
	Statistic	Statistic	Statistic	RII	Mean	Rank	Statistic
Drawing Revisions	4.00	1.00	5.00	0.7116	3.5581	1	1.18125
Approval Delay	3.00	2.00	5.00	0.7069	3.5349	2	1.00827
Scope Changes	4.00	1.00	5.00	0.6697	3.3488	3	1.15230
Drawing (Design) Rework	3.00	1.00	5.00	0.6697	3.3488	4	1.13145
Design Changes	3.00	1.00	5.00	0.6558	3.2791	5	.98381
Design Delay	4.00	1.00	5.00	0.6511	3.2558	6	1.04865
Site Rework due to Design	4.00	1.00	5.00	0.6232	3.1163	7	1.11717
Submission Delay	4.00	1.00	5.00	0.6139	3.0698	8	.98550
Valid N (list wise)							

Table 4.15 shows the ranking of the design performance indicators in descending order of RII value.

Notice that the variables "scope changes" and "drawing (design) rework" have the same mean and RII values even though they are ranked as 3 and 4 respectively.

4.2.9 Hypothesis 1:

Ho: There is no relationship between the top 10 causes of delay, rework and revisions and drawing (design) rework

Table 4.16 Correlation analysis between top ten causes of delay, rework and revisions and drawing (design) rework

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.125	10	2.213	2.198	.046[b]
	Residual	31.208	31	1.007		
	Total	53.333	43			

a. Dependent Variable: "drawing (design) rework"

b. Predictors: (Constant), "insufficient design details", "resources", "scope change", "owner initiated changes", "design change", "poor scope definition", "unrealistic project time estimate", "lack of input information", "approval delay", "poor information flow"

The data obtained from the survey administered was analyzed by using the Pearson's correlation test and three important findings are shown in Table 4.6.

The findings show that there is a relationship between the Top ten causes of delay, rework and revisions and drawing (design) rework because the significance level ($p = 0.046$) is less than 0.05 which is our level of test for 95% confidence level. This means that there is only 4.6% likelihood of getting this result by random chance. The null hypothesis is rejected in this case. This result indicates that all the variables are jointly significant to influence the dependent variable "drawing (design) rework". This confirms that these factors are responsible for causing delays, rework and revisions on South African multidisciplinary projects.

4.3.0 Hypothesis 2:

Ho: Information related issues have no significant effect on design delay

Table 4.17; Correlation analysis between information issues and design delay

Information issues and design delay Parameters

Information related issues versus design delay	**Pearson Correlation Sig. (2-tailed)**	**Correlation significance level**
Poor Information Flow versus Design Delay	0.414** 0.006	**. Correlation is significant at the 0.01 level (2-tailed).
Lack of input Information versus Design Delay	0.370* 0.016	*. Correlation is significant at the 0.05 level (2-tailed).
Inappropriate Assumptions versus Design Delay	0.411** 0.006	**. Correlation is significant at the 0.01 level (2-tailed).

The data obtained from the administered survey was analyzed using the Pearson's correlation test and three significant results are shown in Table 4.17.

From Table 4.17, it can be inferred that there is a noteworthy relationship between "poor information flow" and "design delay" (correlation coefficient =0.414, p= 0.006). This is less than 0.05 which is our level of test for 95% confidence level. This means that there is 0.6% chance of getting result by random chance. There is also noteworthy relationship between "lack of input information" and "design delay" (correlation coefficient =0.370, p= 0.016). This is less than 0.05 which is our level of test for 95% confidence level. This means that there is 1.6% chance of getting this result by random chance.

There is also a noteworthy relationship between "inappropriate assumption" and "design delay" (correlation coefficient = 0.411, p= 0.006). This is less than 0.05 which is our level of test for 95% confidence level. The correlation coefficient value is positive and it is strong .This means that there is 0.6% chance of getting this result by random chance. This implies that issues around information will increase the likelihood of design delays on South African design projects. The null hypothesis is rejected in this case.

4.3.4 Hypothesis 3:

Ho: Changes have no significant effect on Drawing (Design) Rework

Table 4.18; Correlation between issues of changes and drawing (design) rework

Change issues and drawing (design) rework Parameters

Changes issues versus Drawing (Design) Rework	**Pearson Correlation Sig. (2-tailed)**	**Correlation significance level**
Scope Change versus Drawing (Design) Rework	0.418** 0.005	**. Correlation is significant at the 0.01 level (2-tailed).
Design Change versus Drawing (Design) Rework	0.337* 0.027	*. Correlation is significant at the 0.05 level (2-tailed).
Owners Initiated change versus Drawing (Design) Rework	0.414** 0.006	**. Correlation is significant at the 0.01 level (2-tailed).

The data obtained from the survey administered was analyzed using the Pearson's correlation test and three significant results are shown in Table 4.18.
There is a noteworthy relationship between "scope change" and "drawing (design) rework" (correlation coefficient =0.418, p= 0.005). The correlation coefficient value is positive and it is strong. This suggests that there is a good positive correlation between "scope change" and "drawing (design) rework". P is < 0.01 which is our level of test for 95% confidence level. This means that there is a 0.5% chance of getting this result by random chance.

There is a noteworthy relationship between "design change" and "drawing (design) rework" (correlation coefficient =0.337, p= 0.027). The correlation coefficient value is positive and it is strong. This suggests that there is a good positive correlation between "design change" and "drawing (design) rework". P is < 0.05 which is our level of test for 95% confidence level. This means that there is a 2.7% chance of getting this result by random chance. There is also a noteworthy relationship between "owner initiated changes" and "drawing (design) rework" (correlation coefficient = 0.414, p= 0.006). The correlation coefficient value is positive and it is strong. We can infer that there is a good positive correlation between "owner initiated changes" and "drawing (design) rework". P is < 0.01 which is our level of test for 95% confidence level. This means that there is a 0.6% chance of getting this result by random chance
This implies that issues related to changes are likely to increase the amount of drawing (design) rework in South African design projects. The null hypothesis is rejected in this case

4.3.2 Hypothesis 4:

Ho: "Scope change" will have no significant effect on site rework due to design

Table 4.19: Tests of between-subjects effects

Dependent Variable: Site Rework due to Design

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.485[a]	14	2.106	2.571	.016
Intercept	193.499	1	193.499	236.248	.000
Scope change	9.399	4	2.350	2.869	.041
Poor information flow	14.027	4	3.507	4.282	.008
Scope change * Poor information flow	9.275	6	1.546	1.887	.118
Error	22.933	28	.819		
Total	470.000	43			
Corrected Total	52.419	42			

a. R Squared =0.562 (Adjusted R Squared = .344)

**. Correlation is significant at the 0.05 level (2-tailed).

Ho: "Poor information flow" will have no significant effect on site rework due to design

Ho: "Scope change" and "poor information flow" interaction will have no significant effect on "site rework due to design"

The data obtained from the survey administered was analyzed by using the Pearson's correlation test and three significant results are shown in Table 4.19.

There is a significant relationship between "scope change" and "site rework due to design" because the significance level (p = 0.041) is less than 0.05, which is our level of test for 95% confidence level. This means that there is a 4.1% chance of getting this result by random chance. The null hypothesis is rejected in this case.

There is a significant relationship between "poor information flow" and "site rework due to design" because the significance level (p= 0.008) is less than 0.05 which is our level of test for 95% confidence level. This means that there is a 0.8% chance of this getting result by random chance. The null hypothesis is rejected.

We can infer that "scope change" and "poor information flow" interaction have no significant effect on "site rework due to design" because the significance level ($p= 0.118$) is greater than 0.05, which is our level of test for 95% confidence level. We fail to reject the null hypothesis

4.3.3 Correlation analysis

Table 4.20: Correlation between factors causing delays, rework /revision and design performance indicators

		Drawing Revision	Drawing (Design) Rework	Site Rework due to Design	Design Delay	Submission Delay	Approval Delay	Design Changes	Scope Changes
unrealistic project time estimate	Pearson Correlation	.478	.341	.226	.313	.149	.323	.265	.392
	Sig. (2tailed)	.001	.025	.145	.041	.339	.035	.086	.009
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho-accepted	Ho-rejected	Ho-accepted	Ho-rejected	Ho-accepted	Ho-rejected
Poor Scope Definition	Pearson Correlation	.126	.107	.232	.183	.016	.116	.046	.243
	Sig. (2tailed)	.419	.496	.135	.240	.917	.457	.772	.117
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Scope Change	Pearson Correlation	.435	.418	.303	.276	.155	.128	.346	.501
	Sig. (2-tailed)	.004	.005	.048	.073	.320	.415	.023	.001
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho- rejected	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-rejected
Project Complexity	Pearson Correlation	.279	.045	.006	.263	.168	.252	.073	.125
	Sig. (2-tailed)	.070	.776	.970	.089	.281	.103	.643	.425
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Insufficient Design Details	Pearson Correlation	.259	.275	.282	.359	.321	.178	.166	.086
	Sig. (2-tailed)	.093	.075	.066	.018	.036	.253	.286	.585
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho- rejected	Ho-accepted	Ho-accepted	Ho-accepted
Design Change	Pearson Correlation	.392	.337	.319	.286	.260	.092	.561	.352
	Sig. (2tailed)	.009	.027	.037	.063	.092	.558	.000	.021
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho- rejected	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-rejected
Clashes in Drawings	Pearson Correlation	.206	.421	.283	.160	.153	.128	.309	.284
	Sig. (2tailed)	.184	.005	.066	.305	.326	.413	.044	.065
	Hypothesis Result	Ho-accepted	Ho- rejected	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted
Lack of Coordination between Designers	Pearson Correlation	.291	.381	.242	.154	.157	.190	.359	.275
	Sig. (2-tailed)	.058	.012	.118	.323	.315	.223	.018	.074
	Hypothesis Result	Ho-accepted	Ho- rejected	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted
Lack of Experienced Designers	Pearson Correlation	.217	.211	.126	.222	.187	.266	.281	.127
	Sig (2-tailed)	.163	.175	.419	.152	.229	.085	.068	.418
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Poor Information	Pearson Correlation	.232	.330	.406	.414	.157	.181	.366	.263

Flow	Sig. (2-tailed)	.135	.031	.007	.006	.315	.244	.016	.088
	Hypothesis Result	Ho-accepted	Ho- rejected	Ho- rejected	Ho-rejected	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted
Lack of input Information	Pearson Correlation	.326	.520	.502	.370	.089	.111	.229	.388
	Sig. (2-tailed)	.035	.000	.001	.016	.574	.482	.144	.011
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho- rejected	Ho-rejected	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected
Inappropriate Assumptions	Pearson Correlation	.400	.396	.490	.411	.167	.151	.383	.266
	Sig. (2-tailed)	.008	.009	.001	.006	.285	.333	.011	.084
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho- rejected	Ho-rejected	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted
Inadequate Planning and Scheduling	Pearson Correlation	.317	.278	.261	.383	.203	.305	.349	.381
	Sig. (2-tailed)	.038	.071	.091	.011	.192	.046	.022	.012
	Hypothesis Result	Ho-rejected	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted	Ho-rejected	Ho-rejected	Ho-rejected
Owners Initiated changes	Pearson Correlation	.404	.414	.418	.331	.199	.328	.254	.406
	Sig. (2-tailed)	.007	.006	.005	.030	.202	.032	.100	.007
	Hypothesis Result	Ho-rejected	Ho- rejected	Ho- rejected	Ho-rejected	Ho-accepted	Ho-rejected	Ho-accepted	Ho-rejected
Differing Site Conditions	Pearson Correlation	.217	.294	.270	-.039	.086	.176	.038	.106
	Sig. (2-tailed)	.162	.055	.080	.805	.584	.258	.807	.497
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Changes in Laws of Regulatory Agencies	Pearson Correlation	.043	.163	.198	-.112	-.096	.131	-.081	-.021
	Sig. (2-tailed)	.784	.295	.203	.474	.541	.402	.608	.893
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Design Errors and Omissions	Pearson Correlation	.238	.234	.093	.182	.208	.318	.272	.190
	Sig. (2-tailed)	.124	.130	.554	.242	.181	.038	.078	.222
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted	Ho-accepted
Vendors Error and Omissions	Pearson Correlation	.018	.110	.126	.005	-.169	.098	-.208	.051
	Sig. (2-tailed)	.911	.482	.421	.974	.278	.533	.181	.747
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted
Approval	Pearson	.193	.216	-.037	.184	.225	.395	.129	.280

Delay	Correlation								
	Sig. (2-tailed)	.214	.165	.816	.237	.147	.009	.408	.069
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-rejected	Ho-accepted	Ho-accepted
Resources	Pearson Correlation	-.024	-.095	.063	.191	.012	.185	-.101	-.038
	Sig. (2-tailed)	.878	.543	.690	.220	.937	.236	.521	.807
	Hypothesis Result	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted	Ho-accepted

**. Correlation is significant at the 0.05 level (2-tailed).

Note: Null Hypothesis = Ho – the mean is 2.5

Alternate Hypothesis = H1- the mean is not 2.5

"Sig" is the significance for the test (aka the p-value) If $p < 0.05$, reject the Ho

Table 4.21 Descriptive analysis

	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Scope Change	4.00	1.00	5.00	153.00	3.5581	.17388	1.14022	1.300
Drawing Revisions	4.00	1.00	5.00	153.00	3.5581	.18014	1.18125	1.395
Approval Delay	3.00	2.00	5.00	152.00	3.5349	.15376	1.00827	1.017
Approval Delay	3.00	2.00	5.00	151.00	3.5116	.13870	.90953	.827
Design Change	3.00	2.00	5.00	146.00	3.3953	.15300	1.00332	1.007
Owners Initiated changes	4.00	1.00	5.00	146.00	3.3953	.16350	1.07215	1.150
Poor Scope Definition	4.00	1.00	5.00	146.00	3.3953	.18269	1.19800	1.435
Scope Changes	4.00	1.00	5.00	144.00	3.3488	.17572	1.15230	1.328
Drawing (Design) Rework	3.00	2.00	5.00	144.00	3.3488	.17254	1.13145	1.280
Design Changes	3.00	2.00	5.00	141.00	3.2791	.15003	.98381	.968
Design Delay	4.00	1.00	5.00	140.00	3.2558	.15992	1.04865	1.100
Resources	4.00	1.00	5.00	135.00	3.1395	.17157	1.12507	1.266
Poor Information Flow	4.00	1.00	5.00	135.00	3.1395	.15460	1.01375	1.028
Site Rework due to Design	4.00	1.00	5.00	134.00	3.1163	.17037	1.11717	1.248
Lack of input Information	4.00	1.00	5.00	130.00	3.0952	.16276	1.05483	1.113
Design Documentation	4.00	1.00	5.00	133.00	3.0930	.13234	.86778	.753
unrealistic project time estimate	4.00	1.00	5.00	133.00	3.0930	.16577	1.08702	1.182
Submission Delay	4.00	1.00	5.00	132.00	3.0698	.15029	.98550	.971
Project Organization	4.00	1.00	5.00	131.00	3.0465	.12868	.84384	.712
Design Planning	4.00	1.00	5.00	131.00	3.0465	.15233	.99889	.998
Insufficient Design Details	4.00	1.00	5.00	130.00	3.0233	.17127	1.12310	1.261
Lack of Coordination between Designers	5.00	.00	5.00	127.00	2.9535	.19103	1.25268	1.569
Design Coordination	4.00	1.00	5.00	126.00	2.9302	.13057	.85622	.733
Scope Definition	4.00	1.00	5.00	125.00	2.9070	.15182	.99556	.991
Design Verification	4.00	1.00	5.00	123.00	2.8605	.14345	.94065	.885
Change Management	4.00	1.00	5.00	123.00	2.8605	.13136	.86138	.742
Interface Management	4.00	1.00	5.00	120.00	2.8571	.14286	.92582	.857
Coordination Tools	4.00	1.00	5.00	120.00	2.7907	.12253	.80351	.646
Inadequate Planning and Scheduling	4.00	1.00	5.00	120.00	2.7907	.17470	1.14555	1.312
Design Approval	4.00	1.00	5.00	118.00	2.7442	.16670	1.09312	1.195
Resources	4.00	1.00	5.00	117.00	2.7209	.12595	.82594	.682
Design Errors and Omissions	5.00	.00	5.00	116.00	2.6977	.15797	1.03590	1.073
Lack of Experienced Designers	5.00	.00	5.00	115.00	2.6744	.19609	1.28584	1.653
Clashes in Drawings	5.00	.00	5.00	114.00	2.6512	.16930	1.11021	1.233
Project Complexity	4.00	1.00	5.00	110.00	2.5581	.11672	.76539	.586
Differing Site Conditions	4.00	.00	4.00	103.00	2.3953	.12063	.79101	.626
Vendors Error and Omissions	3.00	1.00	4.00	101.00	2.3488	.10979	.71991	.518
Inappropriate Assumptions	4.00	1.00	5.00	100.00	2.3256	.15509	1.01702	1.034
Changes in Laws of Regulatory Agencies	4.00	.00	4.00	74.00	1.7209	.12148	.79659	.635

4.3.4 Summary of key findings

From the findings, it is safe to infer that the average number of years of experience held by the professionals who engaged in this survey was 14 years. It is safe to conclude that majority of the professionals in South Africa have about 14 years' experience.

From the analysis carried out, it was found that scope changes, approval delays and design changes are the foremost causes of delays, reworks and revisions. It is safe to conclude that there are delays, reworks and revisions existing in the multidisciplinary infrastructure design projects undertaken in South Africa. It is also safe to conclude that the above mentioned factors are responsible for causing these delays, reworks and revisions present in multidisciplinary infrastructure projects in South Africa. This supports what the literature said. From this we can conclude that the status quo internationally is also the status quo in South Africa.

From the analysis of the project characteristics carried out, it can be seen that from the eleven project characteristic analyzed, only design documentation and design planning are adequate in the industry. The other nine which include: project organization, design coordination, scope definition, design verification, resources, coordination tools, design approval are all at an inadequate level. This goes to show why the industry is experiencing a high volume of delays, reworks and revisions.

From further analysis in chapter four, it can be seen that drawing revisions, approval delays and scope changes are frequently occurring on multidisciplinary infrastructure projects in South Africa. This is not a good development for the South African industry. As these are performance indicators and it implies that the industry is not performing well. This corroborates the literature and hence the status quo is the same internationally.

The findings also show that the hypothesis "There is no relationship between the top 10 causes of delays, reworks and revisions and drawing (design) rework" is false. On the contrary, it was found that there is a relationship between the top ten causes of delay, rework and revisions and drawing (design) rework. This finding does support the literature and it can be concluded that what is happening internationally is also happening in South Africa.

It was also observed from the analysis, that the second hypothesis "information related issues have no significant effect on design delay" is false. On the contrary, it was found that there is a relationship between information related issues and design delay. Therefore we can conclude that as information related issues increase, the design delays, reworks and revisions will also increase in multidisciplinary infrastructure projects in South Africa. This agrees with what is in the literature. It is safe to say that the status quo internationally is also the status quo in South Africa.

From the analysis, it can be concluded that the hypothesis 3 "changes have no significant effects on drawing rework" is false. There is a strong positive correlation between design changes and drawing rework. This means that as design changes increase in the industry, drawing rework will also increase. This means that design changes do not favor the industry, so as much as possible it should be discouraged. It is advised that fewer design changes are made in order to reduce the number of delays, reworks and revisions.

From the analysis also, it can be concluded that the hypothesis "scope change and poor information flow interactions will have no significant effect on site rework due to design" is true. But there is a significant relationship between scope change and site rework due to design. There is also a significant relationship between poor information flow and site rework due to design. What this implies is that when scope change and poor information flow correlate individually with site rework due to design there is correlation. But combined together, there is no correlation with site rework due to design.

Table 4.22 Summary of significant correlations between the factors influencing delay, rework and revisions and the design performance indicators

	Drawing Revisions	Drawing (Design) Rework	Site Rework due to Design	Design Delay	Submission Delay	Approval Delay	Design Changes	Scope changes
Unrealistic project time estimate	.001 Significant	0.025 Significant	0.041 Significant	0.035 Significant			0.035 Significant	
Scope change	0.004 Significant	0.005 Significant	0.048 Significant					
Insufficient design details				0.018 Significant	0.036 Significant			
Design change	0.009 Significant	0.027 Significant	0.037 Significant				0.000 Significant	0.02 Significant
Clashes in drawing		0.005 Significant					0.044 Significant	
Lack of coordination between designers		0.012 Significant					0.018 Significant	
Poor information flow		0.031 Significant	0.007 Significant	0.006 Significant			0.016 Significant	
Lack of input information	0.035 Significant	0.000 Significant	0.001 Significant	0.016 Significant				0.011 Significant
Inappropriate assumptions	0.008 Significant	0.009 Significant	0.001 Significant	0.006 Significant			0.011 Significant	
Inadequate planning and scheduling	0.038 Significant			0.011 Significant		0.046 Significant	0.022 Significant	0.012 Significant
Owners initiated changes	0.007 Significant	0.006 Significant	0.005 Significant	0.030 Significant		0.032 Significant		0.007 Significant
Design errors and omissions							0.038 Significant	
Approval delay							0.009 Significant	

Table 4.19 gives a summary of the values that correlate between the factors causing delay, rework and revisions and the design performance indicators. Form the table, the correlations between all the information related issues (Poor information flow,

Lack of input information, inappropriate assumptions) and the design performance indicators can be seen. Information related issues were earlier identified among the top ten factors causing delay, rework and revision. From this, it can be inferred that the level of team work in the industry comes short. This also confirms earlier findings showing a lack of coordination tools for transferring information. From table 4.19, the correlations between changes related issues and design performance indicators can be seen. Change related issues were identified as the top major causes of delay, rework and revisions. It can therefore be inferred from both finding that managing changes are a problem in the South African industry.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter ties the main findings of the study to the study aims and objectives. The aim of the study has been formulated as: To identify the factors influencing revision, rework and delay in South African multidisciplinary projects, to understand the characteristic of multidisciplinary infrastructure design projects in South Africa, and to suggest effective mitigation plans to avoid these design revisions, rework and delay. This first section presents an introduction. The findings of the causes of delays rework and revision are presented in the second section. The third section discusses the findings from the interpretation of the project characteristics. The fourth section looks at the results from the evaluation of the design performance indicators. The fifth section looks at the contributions of this study to the existing literature. The sixth section discusses some recommendations and solutions. The seventh section, suggests recommendations for further studies.

5.1 Causes of delay, rework and revisions

An analysis of the internal consistency of the construct used in this research was measured by Cronbach's coefficient alpha value and the outcome of the analysis was discussed in sections 3.11 and 4.2.3. The findings revealed a high internal consistency level.

A collective analysis of the factors influencing delays, rework and revisions show changes related issues (scope changes, design changes and owners initiated changes), approval related issues, information related issues, resource related issue, design issue and time issue as the top ten causes of delay, rework and revisions. The top ten causes are:

1. Scope Change
2. Approval Delay
3. Design Change
4. Owners Initiated changes

5. Poor Scope Definition
6. Resources
7. Poor Information Flow
8. Lack of input Information
9. Unrealistic Project Time Estimate
10. Insufficient Design Details

From the analysis therefore, we see that change related issues are the prevalent cause of delay, rework and revisions. From this, we can infer that changes are a regular feature in the industry, and the ability to manage them so that they do not cause a delay, rework or revision is lacking. It was observed that there were no designer's experience related issues, government regulatory issues, or omissions issues among the top ten causes of delay, reworks and revision.

The study shows change related issues as the foremost major cause of rework, revision and delay in the South African industry. It can be therefore be inferred that the South African industry falls short in terms of managing changes. Changes have a knock on effect on the entire design process in terms of delay and rework as they tend to push back the start dates for electrical and mechanical contractors. It was also concluded that the industry deals with high rework cost and disputes due to a high volume of changes. Changes also usually increase the likelihood of contractual disputes at the end or even during a project (Lavanya and Sugumaran, 2013). Changes can originate from issuing late instructions, errors, mismanagement, omissions, clients changing their mind, or damages.

The study presented approval delays as the second major factor causing delay, rework and revision. Approval is typically required for things like designs, drawings, materials, testing company, insurance policy, subcontractor, suppliers, and payment. A delay in approving any or all of these items has a knock on effect on the entire design and construction process in terms of time and cost overruns.

5.2 Effects of project delays

The study identified the main direct negative effects of delay, rework and revision to include:

1. Time overrun
2. Cost overrun

Mastenbroek (2010) identified indirect negative effects to include:

1. Stress
2. Loss of future business
3. Lack of motivation

This finding implies that many client organizations have slow, or cumbersome approval processes and are unable to handle the large number of items coming for approval in a timely fashion. Since a substantial amount of changes emanate from the client, and the issue of approval delay also starts with the client, what this study is highlighting then is the importance of client's role. Large client organizations exist with sophisticated project management capabilities, but some clients are less well resourced, and this can lend in time to clients changes and approval delay.

5.3 Evaluation of project characteristics

Eleven theorized project characteristic were evaluated for their adequacy on projects, and how they affect the design performance indicators. The analyses indicate that the top three characteristics in terms of adequacy are design documentation, design planning and project organization. Coordination tools, design approval and resources are considered the bottom three most inadequate project characteristics of South African design projects. It was observed that only design documentation was adequate among all the project characteristics which are:

1. Design Documentation
2. Design Planning
3. Project Organization
4. Design Coordination

5. Scope Definition
6. Design Verification
7. Change Management
8. Interface Management
9. Coordination Tools
10. Design Approval
11. Resources

From the study, it can be seen that coordination issues such as change management, interface management and coordination tools are inadequate on projects. It can be concluded that the South African industry is at an inadequate level in terms of coordination and interface management tools. Information flow during the design and construction phases are usually cyclical as information is being updated and changed continuously. Tracking and updating with real time coordination tools such as the BIM (Building Information modeling) is possibly a more effective way than using printed documentation and static information. The design approval process can be streamlined where design organizations automation tools for drawing document control, so that engineers and design managers can track drawing progress and are informed timeously of the design documents requiring approval. Inadequate resources for design will be linked to the strength of the design organizations estimating, and the adoption of the practices such as time boxing. It is important that design firms resist the pressure to undercharge during competitive tendering, since they would then be made to adequately resource the project or would have to resort to inexperienced and junior resources.

5.4 Review of the design performance indicators

Eight design performance indicators were chosen on the basis of a relevant literature review, and were collectively analyzed for their frequency of occurrence and their correlation to the factors causing delay, rework and revisions. The analysis showed "drawing revisions", "approval delay" and "changes issues" being the foremost design performance indicators and showed "design delay", "site rework due to design" and "submission delay" being the most unlikely design performance indicators to occur. The eight performance indicators are:

1. Drawing Revisions (highest occurring)
2. Approval Delay
3. Scope Changes
4. Drawing (Design) Rework
5. Design Changes
6. Design Delay
7. Site Rework due to Design
8. Submission Delay (least occurring)

The prominence of "approval delays" and "scope change" substantiates the earlier findings discussed in the previous section. So, these are important causes of revision, rework and delays and they are also likely to occur. From this we can conclude that "scope changes" and "approval delays" are a major problem in the South African construction industry.

From the study, it can be inferred that better change management practices and more effective information technology throughout the design process may help to reduce the amounts of delay, rework and revisions currently experienced. Furthermore, the study sets out a foundation for further research in the areas of approval, interface management, change management, coordination and information technology.

5.5 A review of the Pearson's correlation findings

From the correlation analysis carried out, the top ten causes of delay, rework and revision have a significant relationship with drawing (design) rework. There is also an important relationship between information related issues and design delay. There is also a noteworthy relationship between changes related issues and drawing design rework. It can be inferred that the interaction of scope change and poor information does not give a correlation to site rework due to design.

5.6 Conclusion

The study focused on finding the factors influencing delay, rework and revision and understanding the characteristics of multidisciplinary infrastructure projects in South Africa. The study adopted a questionnaire survey with twenty theorized factors causing delays, reworks and revisions to evaluate the factors influencing delay, rework and revision, as well as eleven projects characteristic and eight design performance indicators to understand the characteristics of multidisciplinary infrastructure design projects in South Africa. The survey was designed on the basis of a relevant literature review.

All the respondents surveyed agreed with the theorized factors listed. The questionnaire was sent to clients, consultants and contractors and the data collected was analyzed using Cronbach's coefficient alpha level, statistical t-test, relative importance index and Pearson's correlation test. Based on the findings from the literature and the survey, the following conclusions were drawn:

- The South African design and construction industry is not performing well because it is witnessing delays, reworks and revision.
- That delays, reworks and revision do not just happen but there are factors in control of them.
- The South African design and construction industry can perform better by amending its policies and incorporating the right practices.

All the study aims and objectives of this study were achieved. The objectives of this study include;

- To comprehend the characteristic of multidisciplinary infrastructure design projects in South Africa.
- To identify the factors influencing revision, rework and delay in South African multidisciplinary design projects.
- To identify the relationships between the causes of delays and the design performance indicators

All the research questions were also answered. The research questions include

- What are the characteristics of multidisciplinary designs projects?
- What are the possible root causes of revision, delay and rework in South African multidisciplinary design and construction projects?

The study tested the following four hypotheses and these were the outcomes

- There is no relationship between the top 10 causes of delays, reworks and revisions and drawing (design) rework was proven false
- Information related issues have no significant effect on design delay was proven false
- Changes have no significant effect on Drawing (Design) Rework was proven false
- Scope change and poor information flow combined will have no significant effect on site rework due to design was proven true

From the finding in the literature and from the analysis carried out it can be concluded that the South African construction industry is facing similar challenges as with other countries. The practitioners are similar in their perceptions of the causes of delays, reworks and revisions.

5.7 Limitations of the study

- The study was carried out in Gauteng province only.
- Literature reviews and questionnaire survey were the only mode of data collection

5.8 Contributions to the body of knowledge

The following are the contributions of this study to the body of knowledge:

- The study helped to consolidate the perceived factors causing delays, reworks and revisions in multidisciplinary infrastructure design projects in South Africa.
- The study helped in identifying the foremost rework, revision and delay causes

- The study facilitated in the determination of key design performance indicators factors
- The study helped to determine the relationships between the causes of delay, rework and revision and the performance of design
- The study helped to identify some of the adequate and inadequate project characteristic of multidisciplinary infrastructure design projects in South Africa.
- The study provides a questionnaire that could be adopted for collecting data.

5.9 Recommendations:

The recommendations emanating from this study are in three forms:

- To reduce the amount of delays, reworks and revisions experienced in multidisciplinary infrastructure design projects in South Africa by recommending effective mitigation plans and procedures
- To improve the level of adequacy of some of the applicable project characteristics listed
- To propose further studies, given that the study has identified the following as a key problem

Recommendations for scope change:

- Ensure regular workshops on change and transition management
- Undertaking periodic change initiative assessment
- Provide up to date information as soon as changes are made
- Ensure adequate change management and control system
- Design scope freezing and fixing deadlines managed by experienced designers
- Ensure that the client is aware of the responsibility of the changes and the knock on effect and then get it in writing - clients have selective memories

Recommendations for approval delays

- Ensure early submission of documents for approval
- Submission and approval dates should be put in writing

- Ensure that the client is aware of the delay caused by slowness in approval of documentation and the knock on effect- clients have selective memories
- Proper planning must to maximize waiting period
- Allow for sufficient lead time
- Avoid late submission of drawings
- Implement a proactive approval process that makes subcontractors to submit their drawings early

Recommendations for design changes

- Ensure adequate design reviews and verifications
- Ensure professional design management
- Early design commitment
- Change limitation (loose in the initial stages of the design and tighter with increasing design information)
- Provide incentives such as shared rewards and risks
- Design scope freezing managed by experienced designers
- Develop a systematic and structured change control program
- Observe the work done by initial contractors and ensure that delays outside your control are documented
- Design Auditing
- Give early warning of changes to "M&E" contractors
- Documentation of changes
- Checks and cross referencing with other involved design consultants
- Better design coordination
- Understanding and compliance to clients brief

Recommendations for owners initiated changes

- Design coordination
- Change limitation should be set (loose in the initial stages of the design and tighter with increasing design information)

- Scope freezing
- Ensure that the client is aware of the responsibility of the changes and the knock on effect and then get it in writing - clients have selective memories
- Give early warning of changes to "M & E" contractors to avoid large volumes of rework and revision.

Recommendations for poor scope definition

- Love, *et al* (2006) stated that the designer and the owner should inform the contractor of the exact design status and the potential for change when time has not allowed the whole project to be defined completely. This information is helpful to the contractor in drawing up a more realistic tender making provision for mechanism and procedures for administering changes.
- Ensure professional design management
- Allow end user involvement in the development of the scope
- Resolve all project scope issues at meetings before actual commencement (Love *et al.*, 2004)

Recommendations for poor information flow

- Developing an agreed information plan at the onset of the project
- Ensure satisfactory coordination meetings
- Ensure correct coordination tools
- Ensure proper and timely collaboration and integration of all parties
- Give early warning of changes to "M & E" contractors to avoid large volumes of rework and revision.
- Restructuring functional teams and defining joint goals and responsibilities helps to break down communication barriers.

Recommendations for lack of input information

- Development of an acceptable information plan at the onset of the project
- Ensure regular coordination meetings

- Ensure adequate coordination tools
- Ensure timely collaboration and integration of all parties
- Have a domain bound specialist as the project leader

Recommendations for unrealistic project time estimate

- Avoid taking risk on projects overruns in terms of time and cost
- Negotiations should be done on realistic project time estimate
- Ensure professional design management

Recommendations for insufficient design details

- Love, *et al* (2006) stated that the designer and the owner should provide the contractor with an assessment of design status and the potential for change when time has not allowed the whole to be defined correctly. This information will help the contractor to draw up a more realistic tender making provision for mechanism and procedures for administering changes.
- Ensure professional design management
- Prior to commencement of project work, clarification meetings should be held to clarify all misunderstandings and insufficient details.

Whatever the cause maybe it is crucial to reduce the impact of delays, revisions and rework by reestablishing the critical path and fast-tracking the work by using the initial allocated floats.

5.10 Suggestions for further studies

Further studies should be carried out:

- On how to fast track delayed projects
- How to reestablish critical paths for a delayed project
- How to effectively use information technology and coordination tools to mitigate the amount revisions, reworks and delays
- How to measure the impact of delay, rework and revision on projects in other terms different from time and cost.

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Appendix A: Questionnaire

This research will adhere to the framework and policies of the School of Civil and Environmental Engineering, University of the Witwatersrand Research Ethics Committee. Any data for research publication purposes will be treated with anonymity unless permission is granted for it to be used otherwise. In addition, the data obtained will not be used for either commercial purposes or made available to third parties without express consent to use the data for research stated. You have a right to discontinue participation in this research at any time without reason. The findings emerge from the study will be made available to all project participants on request.
The questionnaire seeks to gather information about the factors influencing delays, rework and revisions in multidisciplinary design projects in South Africa. (Please fill/tick/circle as appropriate – the unanswered questions are considered as the Not Applicable questions). Kindly reply personally or via email to ohisadeoye@yahoo.com or by post to: O.S Adeoye, P.O. Box 3589 Pinegowrie 2123 South Africa.

Section 1

This section aims at establishing the types of projects you are familiar with and are most comfortable describing

Please indicate the type of project you are/have been involved with in the last 5 years (Please tick as appropriate)

Mining		Factories	
Telecommunication		Schools	
Power		Airport	
Hospitals		Other (please specify):	
Roads			

Please indicate your current job title/position

Design Manager		Designer	
Design Coordinator		Interface Manager	
Design Leader		Other (please specify):	

Please indicate your years of experience (Please tick as appropriate)

(A) 1 year ☐ **(B)** 2 years ☐ **(C)** 3 years ☐ **(D)** 4 years ☐ **(E)** Other (please specify)……….

Please indicate how long this firm has been involved in multidisciplinary engineering projects

(A) 1 year ☐ **(B)** 2 years ☐ **(C)** 3 years ☐ **(D)** 4 years ☐ **(E)** Other (please specify)……….

What is the typical value range for the projects you are/ have been involved with in the last 5 years?

(A)<R10M☐ **(B)** R10M – R50M **(C)** R50 – R250M ☐ **(D)** R250 – R750M ☐ **(E)**☐ Other (please specify)…..

Which sector are the projects you have worked on?

Public ☐ **Private** ☐ Other (please specify)……….

Which engineering or other disciplines were in the design phase? In the construction phase

Architecture		FITOUT	
Structural		Façade	
Electrical		Vendors	
HVAC		Acoustics	
PHE		Geotechnical	
Fire		Road and Runways	
Systems		Fuel	
BHS		AGL	
Civil		Other (please specify):	
Piping			

3. Which of these best describes your role on projects in the last 5 years (Please tick as appropriate)

Detailed Design		Design Control	
Design Coordination		Engineering design management across multiple disciplines	
Overall project management		Other (please specify):	
Engineering design of infrastructure			

<u>4. The following questions evaluate the causes of delay, rework, or/and revision</u>

a) Please tick the appropriate frequency of the following causes of delay, rework and revision you encountered on a typical project you have worked on

	Never	Sometimes	Average	Often	Very often
Unrealistic Project Time Estimate					
Poor Scope Definition					
Scope Change					
Project Complexity					
Insufficient Design Details					
Design Change					
Clashes in Drawings					
Lack of Coordination between Designers					
Lack of Experienced Designers					
Poor Information Flow					

Lack of Input Information					
Inappropriate Assumption					
Inadequate Planning and Scheduling					
Owner Initiated Changes					
Differing Site Conditions					
Changes in Laws of Regulatory Agencies					
Design Errors and Omissions					
Vendors Error and Omissions					
Approval Delay					
Resources					
Others (please specify):					

b) In your typical project, please describe the adequacy of the following items

Project Characteristic	**Adequacy**				
	Not Adequate	**Somewhat Adequate**	**Adequate**	**Very Adequate**	**Most Adequate**
Scope Definition					
Project Organisation					
Design Coordination					
Interface management					
Design Planning					
Design Documentation					
Change Management					
Resources					
Coordination Tools					
Design Verification					
Design Approval					

5. In your opinion what frequency of the following design performance indicators exists?

Design Interface	**Evaluation Frequency**				
	Never	**Sometimes**	**Average**	**Often**	**Very Often**
Drawing Revisions					
Drawing (Design) Rework					
Site Rework due to Design					
Design Delay					
Submission Delay					
Approval Delay					
Design Changes					
Scope Changes					

What design management or interface method/tool do you use currently?

1. **No specific tool,**
2. **BIM (Building Information Modelling)**
3. **Other design management tool (Please Specify)..**

What process do you use for Design Interface Management?

1. **Regular project meeting**
2. **Coordination meeting**
3. **Design Interface Meeting dedicated to only interface management issues**
4. **Ad hoc meeting**
5. **Others please specify**

Thank you very much for taking your time to participate in this survey. Please feel free to leave any other suggestions in the space provided below:

Appendix B: Participant Information Sheet

Adeoye Ohikhateme
P.O. Box 3589
Pinegowrie
2123 Johannesburg
26th April 2013
Participant Information Sheet

Dr I.O. Adegoke Pr.Eng. Ph.D.
Managing Member
AES Civil & Structural Consulting Engineers
Suite 303A, MISA Park, 15 Catherine Ave.
North cliff Ext 9, 0114762155

Dear Sir/Madam

An Identification of Factors Influencing Delay, Rework, and Revision in Multidisciplinary Infrastructure Design Projects in South Africa – A Masters Research Report

My name is Ohikhateme Adeoye, a master student of the University of Witwatersrand, Johannesburg.

I am conducting a research entitled above as part of the fulfillment of my Master's degree in Civil Engineering.

The aim of this study is to identify factors influencing rework, revision, and delay in South African multidisciplinary design project.

I wish to ask that you kindly assist us in this study by granting me permission to interview you for about 20minutes at your work place and by completing our questionnaires. There is no financial obligation on your part.

Participation in this research is voluntary and refusal to participate will not bring any penalty or loss of benefit to you. The names of participants in this study will not be revealed unless permission is given, and specific details that may be used to identify particular projects, clients, or individuals will be omitted.

If you have any queries or concerns about this study, please contact me or my supervisors directly through the contact details given below.

Thank you for your assistance.

Kind Regards

Adeoye Ohikhateme

Supervisor Details

Dr. Senthilkumar Venkatachalam,
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School of Construction Economics and Management
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Appendix C: Consent Form

Consent Form

To: Adeoye Ohikhateme
P.O.BOX 3589
PINEGOWRIE 2123

Consent to participate in the research report entitled "An Identification of Factors Influencing Delay, Rework, and Revision in Multidisciplinary Infrastructure Design Projects in South Africa" – A Masters Research Report

I .... (the Participant) agree to the following:

- That the research report has been explained to me and I understand about the research.
- The research involves identifying factors influencing rework, revision, and delay in South African multidisciplinary design projects.
- The researcher requires information regarding the workings of design projects in South Africa.
- I have agreed to participate in this research report and as such agreed to be interviewed and/or to complete a questionnaire.
- I accept that the interviewer may take notes during the interview, which may be used in the report.
- I understand that participation in this research is voluntary, if I wish I need not answer questions. Refusal to participate will not bring any penalty or loss of benefit to me. Names of participants in this study will not be revealed unless permission is given, and specific details that may be used to identify particular projects, clients, or individuals will be omitted.
- I accept that all my rights have been conveyed to me and I am aware of them.

I hereby give my consent to participate in this study.

Participant's signature .... Date......................................

Appendix D: Clearance letter

Assessment of Ethics of Research Protocols in which humans are involved

Researcher: Adeoye O S **Student No.** 554693

All research in which humans are involved either as informants or subjects (carried out in the University by undergraduates, postgraduates, staff or affiliated staff in the name of the University) need to respect the rights of individuals and that:

- the informant or subject has consented to the research without coercion;
- the questions posed are not insulting or embarrassing;
- confidential matters that could place the informant in an embarrassing, false or compromising position vis-à-vis authorities, are handled circumspectly;
- the privacy and wishes of informants are respected, i.e. anonymity of the informant is maintained if required;
- the informant is informed as fully as possible as to the aims and possible implications of the research.

The Assistant Dean for Post Graduate Affairs has informed that for MSc researchers on a half coursework half research (50/50) program, the assessment can be carried out by a Committee within the respective School.

The MSc research proposal by Adeoye O S includes the acquisition of information by the use of questionnaires and a School Committee composed of Prof James, Prof Ilemobade and Dr Ndiritu assessed the proposed research protocols on 30 July 2013.

The committee found the research proposal to meet all the requirements set by the HREC (Non-Medical) of the University of the Witwatersrand.

John Ndiritu

Post Graduate Coordinator
School of Civil and Environmental Engineering