3. Methodology

3.1 Introduction

The biggest challenge on the Medupi Power Station structural steel component has been the implementation and management of design revisions from Hitachi Power Europe (Prego, 2010a). The lack of an effective design management tool contributed to the inefficient management of design on this project. A comprehensive review of design management literature has been done in Chapter 2. This comprised of an analysis of the design management tools and methods, detailing the advantages and disadvantages of each tool. The objectives of the study have been achieved through the use of appropriate research methodology.

Lehaney & Vinten (1994) defined the term methodology as the techniques and methods implemented to realize the objectives of a particular study. The choice of technique and method depends on the paradigm or context of the research (Fellows & Lui, 2005).

In addition, there are also variants to research methods depending on the description of the research. Malanga (1987) defined research methodology as the study of the reasoning through which research is conducted.

The way in which research is conducted may be conceived in terms of the research philosophy subscribed to, the research strategy employed and so the research instruments utilized (and perhaps developed) in the pursuit of a goal- the research objectives- and the quest for the solution of a problem- the research question. The research questions and research objectives have been outlined in Chapter 1. The purpose of this chapter is to:

- To discuss the research philosophy of this study in relation to other philosophies;
- To expound the research strategy, including the research methodologies adopted;
- To discuss the methods of data analysis.

3.2 Research Philosophy

Below is a definition of research philosophy,

'A research philosophy is a belief about the way in which data about a phenomenon should be gathered, analyzed and used. The term epistemology (what is known to be true) as opposed to doxology (what is believed to be true) encompasses the various philosophies of research approach. The purpose of science, then, is the process of transforming things believed into things known: doxa to episteme. Two major research philosophies have been identified in the Western tradition of science, namely positivist (sometimes called scientific) and interpretivist (also known as anti-positivist)’ (Lehaney & Vinten, 1994)
Chapter 3: Methodology

The research philosophy is imperative in the success of this study. The means of collecting data and analysis are described in detail in the following sections. The two major research philosophies are Positivism and Interpretivism.

3.2.1 Positivism

Positivists believe that reality is stable and can be observed and described from an objective viewpoint (Leedy, 2005), i.e. without interfering with the phenomena being studied. They contend that phenomena should be isolated and that observations should be repeatable. This often involves manipulation of reality with variations in only a single independent variable so as to identify regularities in, and to form relationships between, some of the constituent elements of the social world.

Predictions can be made on the basis of the previously observed and explained realities and their inter-relationships.

"Positivism has a long and rich historical tradition. It is so embedded in our society that knowledge claims not grounded in positivist thought are simply dismissed as scientific and therefore invalid" (Clover & Balsley, 1984).

This view is indirectly supported by Al-Jibouri (2003) who, in a review of 902 Information Systems research articles, found that all the empirical studies were positivist in approach. Positivism has also had a particularly successful association with the physical and natural sciences.

3.2.2 Interpretivism

Below is the definition of Interpretivism,

‘Interpretivists contend that only through the subjective interpretation of and intervention in reality can that be fully understood. The study of phenomena in their natural environment is key to interpretivist philosophy, together with the acknowledgement that scientists cannot avoid affecting those phenomena they study. They admit that there may be interpretations of reality, but maintain that these interpretations are in themselves a part of the scientific knowledge they are pursuing. Interpretivism has a tradition that is no less glorious than that of positivism, nor is it shorter.’ (Lehaney & Vinten, 1994)

3.2.3 Discussion and Rationale for Choice of Approach

‘Both research traditions in Classical Greek times with Plato and Aristotle (positivists) on the one hand, and the Sophists (anti-positivists) on the other. After long, dark periods in European scientific thought, the renaissance of the discipline came in the sixteenth and seventeenth centuries. Since that time, well known positivists have included Bacon, Descartes, Mill, Durkheim, Russell and Popper. On the opposing side we have Kant, Hegel, Marx, Freud, Polanyi and Kuhn’ (Clover & Balsley, 1984).
'It has often been observed (e.g. Lehaney & Vinten, 1994) very accurately that no single research methodology is intrinsically better than any other methodology, many authors calling for a combination of research methods in order to improve the quality of research’ (Leedy, 2005).

'Equally some institutions have tended to adopt a certain “house style” methodology (Leedy, 2005); this seems to be almost in defiance of the fact that, given the richness and complexity of the real world, a methodology best suited to the problem under consideration, as well as the objectives of the researcher, should be chosen’ (Collis & Hussey, 2003).

The research philosophy adopted was relevant to the research questions, as set out in Chapter 1. Therefore, this study utilized a combination of the two research philosophies.

3.3 Research Strategy

3.3.1 Research Description

Description of research will assist in establishing direction of the study and the method which will be used. Research description can be described depending upon the purpose, outcome, time horizon or the process. Each of these descriptions is described in brief in the following sections.

3.3.1.1 Purpose

Research is described depending upon the reason for doing the research which can be either exploratory or descriptive. Each of these descriptions is described next;

(i) Exploratory study: This approach is used to understand and gain insight into the problem which very little is known about and so at the end of the study becomes familiar (Churchill, 2001). This method is used for various other reasons including the following;

- Breaking down a problem into a more detailed sub-problem for a more precise investigation.
- Establishing research questions.
- Establishing research objectives.
- Collecting information on the problems.

Some of the common techniques used in exploratory research include case studies, observation and historical research.

3.3.1.2 Outcome

The research is described depending on the objective whether it is intended to solve a problem (applied) or to add to knowledge (pure). Each of these are described next;
(i) Applied research; is that research designed such that the findings are used to solve a specific existing problem.

(ii) Pure research; the research is designed to make a contribution to knowledge and not to solve a specific problem on the organization or entity.

Therefore, it is apparent that this research study is an applied research since its objective is to select and recommend the most appropriate design management tool or method, to solve an existing problem on the Medupi Power Station or similar global collaborative projects.

3.3.1.3 Time Horizon

Research is described depending upon whether data collected is historical (retrospective case) or is from existing phenomenon (longitudinal case).

(i) Longitudinal cases involve observations and collection of data on current cases.

(ii) Retrospective case studies involve collection of historical data on the phenomenon being studies and the researcher has more control in the selection of a case. The researcher can decide to choose between cases that reflect failure (Voss, Tsikriktsis & Frohlic, 2002).

This research involves collection of data from an ongoing project, thus a longitudinal case study is used.

3.3.1.4 Process

The research is described based on the way data was collected and analyzed. Data can be collected and analyzed either qualitatively or quantitatively. Each of these is described below;

(i) Qualitative research: this research is ‘subjective’ in nature. It emphasizes meanings, experiences and description. It provides complex textual description of how people experience a given research issue. It seeks to understand a given research problem or topic from the perspective of the population or sample size it involves.

(ii) Quantitative research: this research is ‘objective’ in nature. It is defined as an enquiry into a social or human problem, based on a hypothesis or a theory composed of variables, measured with numbers, and analyzed with statistical procedures, in order to determine whether the hypothesis or the theory hold true (Hill & McGowan, 1999). The data is therefore, not abstract, they are hard and reliable; they are measurements of tangible, countable, sensate features of the world (Leedy, 2005).

This research involves collection of data from project managers, engineers, detailers and draftsmen involved in the design of the structural steel component of Medupi Power Station, therefore qualitative research was undertaken. The qualitative method consisted of a literature review and questionnaire.
Relevant literature was reviewed in order to explore existing design management tools/methods. Literature in the form the form of journals and the internet, were used since there is limited research within the design management area of study.

The research methodologies have been established, the section below will describe in detail the methods for collecting data.

3.3.2 Case Study Research

As previously mentioned in Chapter 1, the study was undertaken on a case study. The design of the structural component of the Medupi Power Station was the focus point of the study. A case study is considered viable by Lehaney & Vinten (1994) for the following three reasons:

- It is necessary to study the phenomenon in its natural setting,
- The researcher can ask “how” and “why” questions, so as to understand the nature and complexity of the processes taking place.
- Research is being conducted in an area where few, if any, previous studies have been undertaken.

Case studies are defined in various ways and a standard does not exist. However a definition compiled from a number of sources (Stone, 1978; Benbasat, 1984; Yin, 1984; Bonoma, 1985 & Kaplan, 1985) in Lehaney & Vinten (1994), runs as follows,

'A case study examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups or organizations). The boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used.'

When deciding whether to use the case study approach or not, there are a number of factors to consider. If there is a need to focus on contemporary events or phenomena in a natural setting, the case study is advantageous. The same is also true if there is no strong theoretical base for the research, i.e. if it is a theory building research project.

“A rich and natural setting can be fertile ground for generating theories” (Leedy, 2005).

However, if there is a need for control or manipulation of variables, then the case study would not be appropriate. It is important to clarify that need should relate to the nature of the problem rather than the (in) ability of the researcher(s) to undertake research with a particular methodology. Within the case study approach there are a number of variations.

A key feature of the design of case study research is the number of cases included in a project. Generally speaking it is better, i.e. more valid and generalisable, to include multiple cases, though there are instances where a single case is instructive (Lee, 2005). Exploratory studies are generally better served by single cases, i.e. where there is no previous theory. A single case can also be used to test an existing, well-informed theory. Multiple cases are preferable when the purpose of the research is to describe phenomena, develop and test
Chapter 3: Methodology

Theories. Multiple cases also permit cross-case analysis, a necessary feature for widespread generalization of theories.

The sites or locations where cases are to be conducted should be chosen with great care. It is not appropriate to use an opportunistic approach, using whichever site is available purely on the grounds that it is available. In this study, Medupi was specifically chosen due to the magnitude and impacts of the problem on South Africa.

Case studies require multiple data collection methods, whose results hopefully converge, in order to establish construct validity. Yin (2003) identifies these methods as including:

- Direct observation of activities and phenomena and their environment;
- Indirect observation or measurement of process related phenomena;
- Focus group
- Interviews- structured or unstructured;
- Documentation, such as written, printed or electronic information about the company and its operations; also newspaper cuttings;
- Spreadsheets used by the company to record design changes.

A single case study was chosen to establish which of the well informed design management tools or methods could be used on global collaborative projects. The interview questionnaire was established as the main method of collecting information on the case study, it is described below.

3.3.3 Objectivity, Reliability and Validity

The value of the research largely depends on the willingness and capability of the respondents and subject participants to provide information. In addition, validity and reliability depends on the correctness of the information collected and its analysis, interpretation, and generalization as appropriate (Adams & Schvaneveldt, 1985).

Perry (1998) suggests requirements of good interviews such as objectivity, reliability, and validity. He suggests that to promote objectivity, or ‘avoidance of the bias of the interviewer and the client (or research team)’, the moderator should refrain from contributing to the discussion as much as possible and monitor his or her actions carefully. As the goal of focus group research is to ask ‘why’ rather than ‘how many’, to generate hypotheses rather than assert their representativeness, the question of reliability becomes less important.

Picard (2004) states that,

‘a source of continual concern to the researcher is the validity problem’.

Focus groups tend to suffer from inhibiting factors just as do other methods of qualitative research. Goldman, through his experiences with focus groups, concludes that discrepancies between attitude expression and actual behavior are relatively small in a well conducted focus group, implying reasonable validity of the method.
3.3.4 Sampling in Qualitative Research

In qualitative research, only a sample (a subset) of a population is selected for a given study. The three common methods for sampling in qualitative research are discussed below;

3.3.4.1 Purposive Sampling

‘Purposive sampling, one of the most common sampling strategies, groups participants according to preselected criteria relevant to a particular research question. Sample sizes, which may or may not be fixed prior to data collection, depend on the resources and time available, as well as the study’s objectives. Purposive sample sizes are often determined on the basis of theoretical saturation (the point in data collection when new data no longer bring additional insights to the research questions). Purposive sampling is therefore most successful when data review and analysis are done in conjunction with data collection.’ (Lehaney & Vinten, 1994)

3.3.4.2 Snowball Sampling

‘This method is also known as chain referral sampling, and is also considered a type of purposive sampling. In this method, participants or informants with who contact has already been made use their social networks to refer the researcher to other people who could potentially participate in or contribute in to the study. Snowball sampling is often used to find and recruit ‘hidden populations’, that is, groups not easily accessible to researchers through other sampling techniques.’ (Lehaney & Vinten, 1994)

3.3.4.3 Quota Sampling

‘Quota sampling, sometimes considered a type of purposive sampling, is also common. In quota sampling, we decide while designing the study how many people with which characteristics to include as participants. The criteria chosen allows the researcher to focus on people who are most likely to have experience, know about, or have insights into the research topic.’ (Lehaney & Vinten, 1994)

The study’s research objectives and characteristics of the study population determined which and how many people to select. The population size for this study was 42. This included Project Managers, Engineers, Detailers and Drafters. These are people who worked on the design of the Medupi structural steel. Therefore, the Quota sampling method was chosen.
3.4 Research Design

3.4.1 Introduction

This section describes the design of the research that was used to guide the data collection process from the single selected case study which is the personnel that were responsible for the design and management of the structural steel component of the Medupi Power Station.

The first part of the design gives an overview of the case including the description of the project, the project organization structure and scope definition using work breakdown structure (WBS).

The following sections describe in detail the process used by the researcher in collecting data. Such processes include description of the questionnaire used to establish the root causes of the design changes and ranking of design tools/systems.

3.4.2 Overview of the Case Study Project

- Project Information

The information for the selected project case is given in Table 3.1. The parties involved in the Medupi project are widely known and are disclosed which does not have any impact on research ethics.

Table 3.1 Project Description

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Title</td>
<td>Medupi Power Station</td>
</tr>
<tr>
<td>Contract No.</td>
<td>October 2007-October 2015 (Estimated)</td>
</tr>
<tr>
<td>Location</td>
<td>Lephalele, Limpopo Province, South Africa</td>
</tr>
<tr>
<td>Contract Amount</td>
<td>R100 billion (Estimated)</td>
</tr>
<tr>
<td>Quantity</td>
<td>105 000 tonnes</td>
</tr>
<tr>
<td>Duration</td>
<td>8 years</td>
</tr>
<tr>
<td>Client</td>
<td>Eskom</td>
</tr>
<tr>
<td>Main Contractor</td>
<td>Hitachi Power Europe</td>
</tr>
<tr>
<td>Sub-Contractor</td>
<td>Murray &amp; Roberts</td>
</tr>
</tbody>
</table>
• **Project Scope**

The objective of the project is to construct the biggest coal fired power station in the world. The study is based on the structural steel components of the work, which includes design, fabrication and erection of the following structures;

- Boiler Main Frame
- Boiler House
- Auxiliary Bay
- Bunker Structure
- Buckstay
- Air Pre-Heater
- Transverse Coarse Ash Conveyor
- Transverse Ash Conveyor
- Coal Transfer Conveyor
- Inclined Coal Conveyor

Figure 3.1 depicts scope of works of the project defined using the Work Breakdown Structure (WBS) indicating the major project work elements.

![Figure 3.1: Project Scope](image-url)
**Project Organization**

Figure 3.2 indicates the roles and responsibilities of the various parties that formed the project team responsible for successful delivery of the project.

![Project Organization Chart](image)

**Figure 3.2: Project Organization Chart**

Successful collection of research data involved general procedures and data collection methods consisting of literature review and project documents review. These procedures are discussed briefly:

i. **Literature Review**

The literature review section (Chapter 2) established the theoretical framework which the study followed in conducting research, data collection, analysis and discussion, interpretation and drawing up conclusions. Chapter 2 of this study thoroughly describes the literature reviewed. The process involved collection of data from published books, internet and journals. It also involved collection of unpublished project information. These published books are available in the Architecture library at Wits University. The unpublished project information was obtained with permission from Murray & Roberts.
ii. **Project Documents**

These constituted data from unpublished records including information collected from records kept by Murray & Roberts. For example documents and spreadsheets that were used for logging some of the design changes as well as Impact Assessment Documents.

### 3.4.3 Questionnaire

#### 3.4.3.1 Introduction

The preferred method of data collection was the focus group, but due to logistical constraints, this method could not be realized. Questionnaires were used in the study. The goal of the questionnaire survey was to establish which design management tool was more likely to work on a global collaborative project such as Medupi and similar projects. It also attempted to capture an overview of the current level of understanding of design management methods.

The questionnaire was emailed to all potential respondents. The postal questionnaire was suitable for this study because the purpose of the study was clear enough to be explained in a few paragraphs of print, and the scheme of questions was not over-elaborated. This questionnaire was used to find out facts, opinions and views on design management tools and methods, specifically suited to global collaborative projects. The current Engineering Manager at Murray & Roberts suggested the author spend 10 minutes with each respondent in order to explain the design management tools/methods and attend to any other enquiries the respondents could have.

The questionnaire was mostly ‘closed-ended’ questions requiring a specific response of ‘yes’ or ‘no’ or ranking the importance of factors. This questionnaire provided highly validity of results because of the experience and designation of the respondents. A mass of information was able to be assembled at minimum expense in terms of finance, human and other resources.

The questionnaire also was a quick method of collecting data. It was sent using email, therefore the rate of response was reasonably good. Approximately 10 – 15 minutes was spent with each respondent in order to assist with any enquiries. 42 respondents participated in the study.
3.4.3.2 Questionnaire Design

One questionnaire was designed for the study. It consisted of 3 sections;

- Section A: Personal information i.e. age, designation, experience.
- Section B: Root causes of design changes on Medupi.
- Section C: Design management tools breakdown. Applicability on Medupi and similar projects. Usability in South African industry and reduction of disputes.

The questionnaire was directed at the following personnel;

- Engineering Director/Manager (Current and former)
- Chief Engineer
- Project Engineers
- Section Leaders
- Project Managers
- Senior Design Engineers
- Design Engineers
- Junior Engineers
- Senior Detailers
- Detailers
- Junior Detailers

The questionnaires comprised close-ended questions and were constructed using the Likert scale. This mode of preference indication was deemed most preferable as compared to other modes of attitude scales, such as the Thurstone scale or the Semantic-differential scale. The Likert scale was easy to construct and could be easily understood by the respondents. It allowed the respondents a wider range of choices as compared to the Thurstone scale, thus enabling the collection of more information. Moreover, it is easier to contemplate than the Semantic-differential scale when answering the questions (Berdie et al., 1986).

For the purpose of statistical analysis, numbers were assigned to each anchor. The anchors used in Sections B were: Not relevant at all (=1); Not so relevant (=2); Neutral (=3); Relevant (=4); Very relevant (=5).

Based on information contained in the project documents as well as literature review, a criterion for comparing the different design management tools/systems was developed. The criteria, shown below, were developed based on the problems experienced on the Medupi project;
### Table 3.2: Design Tool/system criterion

<table>
<thead>
<tr>
<th>Design Tool/ system criterion</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detects Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicts Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plans Preventative Measure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-ordinates changes across project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides Impact Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides Post Change Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provides Change Traceability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plans Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedules Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable on Complex Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enhances performance (Time, Cost &amp; Quality)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactivity Enhancing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limits Impacts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requires Physical Interaction of Teams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web-Based System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software Based</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The anchors used in Section C to rate each tool/system were: Not likely at all (=1); Not likely (=2); Neutral (=3); Likely (=4); Most Likely (=5).

The questionnaires were self-administered. Detailed instructions on how to fill up the questionnaires were given at the beginning. A survey of this nature suffers from the possibility that the respondents would not think seriously through the questions before answering them and the possibility of bias (Nkado, 1995). Before sending out the questionnaires, enquiries were made with Engineering Managers as to the likelihood of getting accurate responses. The Engineering Manager suggested spending time with the respondents, which would help in acquiring accurate responses.

### 3.4.3.3 Survey Package

Each of the questionnaires was accompanied by a cover letter (see Appendix B), introducing the theme and objectives of the study. The complete survey package comprised the cover letter and questionnaire. It was addressed to the Engineering director of the firm indicating the objectives of the study. The letter provided an option for the respondent to have a copy of the results. The respondents were asked to return the completed questionnaire as early as possible, but no deadline was specified.
Chapter 3: Methodology

Oppenheim (1983) expresses the opinion that,

‘data obtained by means of interviews and questionnaires should always be regarded as confidential.’

The cover letter that accompanied the questionnaire assured confidentiality and all of the informal contacts over the phone with potential respondents confirmed this.

3.5 Data Processing and Analysis

3.5.1 Introduction

After the answered questionnaire forms were returned to the author, the responses were edited to ensure completeness, consistency and readability. The raw data was established into categories according to designation of the respondents. This was done in order to enable the author to determine the responses according to management levels.

The target response rate for the study was between 70-80%. The actual response was 100%. The analytical process is to take the raw data at the beginning and convert it, using a step-by-step process, into a final narrative (Farrel, 2011). The narrative summarizes, in a prosaic form, the literature and the raw data in preparation for conclusions and recommendations.

Once the data had been checked, they were arranged in a form that enabled it to be analyzed. Quantifiable data from the questionnaires was tabled. Tabulation is a part of the technical procedure wherein the classified data are put in the form of tables (Yin, 2003). Statistical techniques were then employed to analyze the data collected from the survey.

The collected data from the questionnaire was organized and documented. The goal was to facilitate easy retrieval of raw data that could not be included in the report by any other researcher, investigators or evaluator who may wish to review them instead of being limited by case study report therefore help increase reliability of the entire study (Yin, 2003).

The data was tabulated with the use of Microsoft Excel. This allowed the author to be able to plot graphs. This also allowed the author to be able to determine percentages. Tabulation allowed the author to determine with what validity the data can be used to draw up conclusions. The findings were interpreted and explained through theory in Chapter 5.

A brief discussion on the statistical techniques chosen for this research and the rationale behind them is presented below.

3.5.2 Frequency Calculation

Frequency is the measure of how often a particular answer was given. For this study, the author initially tallied the answers by hand before input into Microsoft Excel.

The frequency calculation enabled the author to analyse the data quicker and easier.
3.5.3 Percent Distribution

A percent distribution (percentages) informed the author what proportion of the respondents selected a particular answer.

To calculate percent distribution, the total number of responses was added. The frequency of each answer was then divided by the total number of responses. The total percentage would then add up to 100%.

This percent distribution enabled the data to be put in perspective. Further to this, it allowed for easier interpretation and drawing up of conclusions.

3.5.4 Kendall’s Coefficient of Concordance Analysis

A mathematical tool for analysis of the data collected through the questionnaire was required in order to increase the validity and integrity of the data. This tool allowed for an analysis into the level of agreement or concordance between the respondents due to the fact that they were all from the same organization. This further scientifically ascertained the reliability of the respondents.

Previous research suggests that the quality of the collected data is imperative in order to accurately measure the level of concordance. It is often found that the collected data is questionable (Verbic & Kuzmin, 2009). Kendall’s coefficient of concordance provides a reliable tool for measuring agreement or concordance between ranks in a rank structure.

Kendall and Smith (1939) gave a precise measure of agreement or concordance for data made up of M sets of ranks, where M>2. In cases where there are two variables, X and Y, variable X consists of values $x_i$, $i=1,\ldots,N$ with N being the number of ranks in each set of ranks. Variable Y consists of values $y_j$, $j=1,\ldots,M$ with M being the number of sets of ranks. Each value of variable X, $x_i$, has a rank $r_{ji}$ assigned by the value of the ranking variable Y, $y_j$. $R_i$ is the rank total for value $x_i$ of the variable X.

In cases where perfect agreement is observed between the $j$ values of the ranking variable, one value of the variable X will be assigned a 1 by all $j$ values of the ranking variable, and the rank total will be M. Another value of the variable X would be assigned a 2 by all $j$ values of the ranking variable and the rank total would be 2M. Therefore, when perfect agreement exists among the ranks assigned by M values of the ranking variable, the rank totals are M, 2M, 3M, \ldots, NM. The total sum of ranks for M values of the ranking variables is MN $(N+1)/2$, and the mean rank sum is M $(N+1)/2$.

The degree of agreement between the values of the ranking variable reflects itself in the variation in the rank totals. When all the values of the ranking variable are in agreement, this variation is at an optimum. Disagreements between the values of the ranking variable reflects itself in a reduction in the variation of rank totals. For optimum disagreement the rank totals tend to be the same.
As noted above, $R_i$ is the rank total for value $x_i$ of the variable $X$, the sum of squared deviations of rank totals from the average rank total for $N$ values of variable $X$ is:

$$\sum_{j=1}^{M}(R_j - R)^2,$$

Where $R = \frac{1}{N} \sum_{j=1}^{M} R_j$ is the average rank total. The maximum value of this expression occurs when perfect agreement exists between the values of the ranking variable. It can easily be shown that this value is equal to:

$$\frac{1}{12} M^2 N(N^2 - 1).$$

The coefficient of concordance, $\theta$, is defined as the ratio of sum of squared deviations of rank tools from the average rank total to the maximum possible value of the sum of squared deviations of rank totals from the average rank total (Kendall and Smith, 1939).

$$\theta = \frac{12 \sum_{j=1}^{M}(R_j - R)^2}{M^2 N(N^2 - 1)} \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cd \n
\[ W = \frac{12 \sum_{i=1}^{N} R_i^2 - 3N(N+1)^2}{N(N^2-1) - (\sum T_j)/k} \]

Where;

\( W \) = Kendall’s Coefficient of Concordance
\( R_i \) = the average rank for the \( i \)th column
\( R_s \) = sum of the ranks for the \( i \)th column
\( N \) = number of samples
\( T_j \) = calculation for the \( j \)th row

\[ T_j = \sum_{i=1}^{g_j} (t^3 - ti) \]

\( j = 1, 2 \ldots \ldots k \)

\( k \) = number of trails
\( g_j \) = number of groups of matches in a row \( j \)

### 3.5.4 Validity of data received

The data received is expected to be accurate as the questionnaires were answered by personnel who are currently or previously been involved in the design of the Medupi structural steel.

It is expected that if the same questionnaire was to be sent to the same engineering personnel, the same results would be gathered. The method of analysis used in the study (Kendall’s coefficient of concordance) ensured validity and reliability of the responses.
3.5.5 Limitations

Due to logistical reasons, the focus group research method could not be utilised for collecting the data. This research method was recognized as the ideal method as it would have allowed the respondents to debate the various design management tools/methods in order to establish the best tool/method for managing design changes on Medupi. Several requests were sent to the Engineering Manager concerning a time allocation for the focus group. Regrettably, due to the time constraints, this could not be achieved.

The issue of design management is still sensitive to Murray & Roberts due to the dispute that emerged. Any criticism of the system currently in place for managing design changes was not well received by senior management. It was observed that this issue could potentially impact the results of the study.

The unavailability of the latest developed design management tools/systems was a major limitation of the study. Deficiencies of some of the design management tools/systems have potentially been amended. Due to their unavailability, they were not considered in the study.
3.6 Key Findings & Their Implications

This chapter has discussed the research philosophy of the study in relation to other research philosophies. The research strategy has also been expounded, including the research methodologies adopted. The method of data analysis was discussed as well as the limitations of the research methodology adopted.

The study of design management particularly for global collaborative projects in South Africa is a new phenomenon; therefore there was no established and tested methodology that existed in gathering data. Due to this, a qualitative approach was adopted. The qualitative approach consisted of a literature review and questionnaire. A qualitative approach was utilised as it was the best method suitable for the required results. The personnel involved in the design of Medupi structural steel were the ideal respondents to give insight to the challenges experienced.

A comprehensive literature review into design management was conducted in Chapter 2. The literature review formed the basis of the study therefore were instrumental in formulating the questionnaire (See Appendix B).

A questionnaire was drawn up and emailed to the sample market, with the primary objective of collecting information. The Murray & Roberts Engineering Manager suggested I spend 10 minutes with each respondent in order to explain the design management tools/methods as well as attend to any other enquiries they would have. 42 respondents were used in the study and all participated.

The results of the questionnaire were tabulated and formed using a structural medium, namely Microsoft Excel. Once all the information was correlated, the relevant conclusions were drawn.

Due to logistical constraints, the focus group method could not be utilised as a means of collecting data. The focus group was identified as the ideal method for conducting this kind of research, but regrettably, could not be realised.