1. Introduction

1.1 Background

Change is a part of life. As noted by Charles Darwin (1859),

‘It is not the strongest of species that survive, nor the most intelligent, but the ones most responsive to change’.

The complexity of construction works means that it is hardly possible to complete a project without changes to the plans or the construction process itself. The Project Management Body of Knowledge (PMBOK) defines a project as,

‘a temporary endeavour undertaken to create a unique product or service. Temporary means that every project has a definite end. Unique means that the product or service is different in some distinguishing way from all similar products or services’.

Every project is liable to variations ranging from changes of mind on the part of the clients, their consultants, to unforeseen problems raised by the main contractor or sub-contractor. Variation refers to any changes to the original contract between parties (Hibberd, 1985).

Variations can be in the form of additions, omissions or substitutions. They occur for a number of reasons ranging from finance, design, aesthetic, geotechnical, geological, weather conditions to feasibility of construction.

Variations cause undue uneasiness to the stakeholders because of their effect on the successful delivery of projects in terms of cost, time and quality. On the other hand, variations to a project are necessary because no project is impeccable and changes are required to meet unforeseen circumstances or changed requirements. Variations in projects are inevitable. The construction industry should avoid a situation whereby the client accepts an inferior product because of his inability to change what he now wants, albeit in return for greater certainty with regard to price and time.

Most standard forms of contract include a clause under which the employer or his representative is able to issue an instruction to the contractor to vary the works which are described in the contract. Austin et al (2007) describe construction contracts as,

‘the means of controlling relationships between the project participants’ (Austin et al, 2007).

A change in shape or scheme, revised timing and sequence are all usually provided for by the variation clause. The clause will include a mechanism for evaluating the financial effect of the
variation, the process of authorisation and provision for adjusting the completion date, if necessary. Calculation of the price for the extra work could involve payment in excess of the contract rates. This is where disputes occur. Hi Quo et al (2008) observed that if changes are not resolved through a formal change management process, they are most likely to cause a dispute. Disputes are a severe risk to the project and are the major source of project failure.

Disputes often cause disruption to the smooth running of projects. When not resolved in a timely manner, disputes become very expensive in terms of finances, personnel, time and opportunity cost. As early as 1979, as noted by Abrahamson (1979) most of the employment obtained by the legal profession through engineering work involved disputes about variations.

This clearly illustrates that variations, if not managed effectively, result to litigation and constitute major problem(s) to the smooth progression of operation in the construction industry.

### 1.1.1 Globalisation and Collaborative Relationships

Globalisation is relevant to construction in developing countries. First, at the level of the broad economy, as the World Bank (2004) advises, these countries should improve their investment environments in order to position themselves to benefit from globalisation. Secondly, many of the constructed items which such nations need for the socio-economic development are beyond the capacity and capability of local industries to undertake, owing to size, novelty and complexity of those projects. Therefore foreign firms play a significant role in developing countries. It is estimated that foreign contractors and consultants have about 70% of the construction market in Southern Africa (Ofori, 2001). Muhegi and Malongo (2004) estimate that foreign contractors, which constitute 4% of registered contracting firms in Tanzania undertake more than 80% (by value) of projects in that country.

Hitachi Power Europe was appointed by Eskom Holdings Limited under two contracts (“Main Contract”) as the main contractor for the design, engineering, procurement, fabrication, and erection of a fleet of twelve boilers, six at Medupi and six at Kusile.

According to the Hitachi website (accessed 21 January 2012),

> ‘Hitachi Power Europe GmbH (HPE), a subsidiary of Hitachi, Ltd., designs and constructs fossil-fired power plants. The plant constructor also supplies key components such as utility steam generators, environmental engineering equipment, turbines and pulverizers.

> As a market and technology leader - in utility steam generators, HPE relies on modern, ecologically sound and economic plants. In this way, the company - with its head offices in Duisburg - plays a prime role in securing the supply of electricity on the markets in question.
As an energy plant constructor, Hitachi Power Europe GmbH benefits both from the growing demand for electricity and the boom in power plant construction across the world. HPE is playing a major role here in the modernization of the European power generation system.

Within the Hitachi Group, which has revenues of approx. US$ 112.2 billion and a 360,000 workforce, HPE is responsible for the markets in Europe, the CIS states, Africa and India.

Hitachi Power Europe in turn contracted Murray & Roberts as the subcontractor for the connection design, detail engineering, fabrication and erection of steelwork and erection of equipment to be delivered by Hitachi, under two inter-related subcontracts. Hitachi contracted to provide the design, engineering and procurement information necessary for Murray & Roberts to carry out its contractual obligations, in accordance with agreed programmes.

According to their website (last accessed 25 January 2012), Murray & Roberts is,

‘South Africa’s leading engineering, contracting and construction services company. It has created employment, developed skills, installed infrastructure, delivered services, applied technology and built capacity throughout South and Southern Africa for 109 years, making a significant contribution to sustainable socio-economic development in the region.

Murray & Roberts operates in Southern Africa, Middle East, Southeast Asia, Australasia and North and South America from its home-base in Johannesburg South Africa, where it has a public listing on the Johannesburg Stock Exchange (JSE) Limited. It has an international coordinating office in the United Kingdom and principle offices in Australia, Botswana, Canada, Namibia, United Arab Emirates and Zimbabwe.

Murray & Roberts is primarily focused on resources driven construction markets in industry & mining, oil & gas and power & energy and offers civil, mechanical, electrical, mining and process engineering; general building and construction; materials supply and services to the construction industry; and management of concession operations.

The Group aspires to world class fulfilment in everything it does, through its core competence in industrial design, delivering major projects and services primarily to the development of emerging economies and nations.’

Global Construction project teams are unique entities, created through a complex interaction of factors, with inter-disciplinary players from many countries, varying roles, responsibilities, goals and objectives (Goodman and Chinowsky, 1996). Collaboration and teamwork are therefore crucial since sharing up-to-date information between participants leads to minimisation of errors, reduction of time delays and breaking the widespread rework cycle, and the formalisation of these issues through partnering mechanisms allows a sustainable relationship between
participants to evolve. Benefits of collaborative, rather than adversarial, working relationships within construction organizations are well documented (Walker and Hampson, 2003). All of this is taking place within an increasingly global construction industry which is dominated at the top end by a dozen, large, mainly European contractors but is implemented at a project level by local people and companies.

Globalization refers to everything from the inter-connectedness of experience to the rise in international ventures. For the design and construction industry, however, globalization is a trend that means increased opportunity and competition.

‘Successful sustainable relationships rely on rational forms of exchange characterised by high levels of trust but it is generally accepted that the construction industry has a stronger preference for distrust rather than the full benefits of cooperation’ (Wood and McDermott, 1999).

Due to time differences, Hitachi Power Europe and Murray & Roberts experienced communication problems. There was no timeous response to emails, depending on when the email was sent. Video conferencing was a tool which was viewed as the most convenient. This however, proved to be a costly means of communication, and was not sustainable as a daily means of communication. Previous research has shown that face to face collaborations are better in terms of delivery of projects. According to Steven Rowlinson (2005),

‘A major advantage was identified operating on a face to face basis. When the ‘protective barrier’ of ‘paper warfare’ is broken down by a collaborative approach, the need to formally document every discussion or event disappears and the traditional, contract specified for resolution of discrepancies is circumvented. Direct discussion between decision makers is legitimised, as is rapid decision making. The consequence is that the participants are more comfortable at devolving decision making to appropriate levels within the organization and greater job satisfaction ensues.’(Steve Rowlinson, 2005)

More harmonious working relationships allow both parties to focus on work issues rather than contractual issues. Successful sustainable relationships rely on relational forms of exchange with high levels of trust and open and frank communication.

An important aspect of globalization is the participation of the private sector in public projects. The World Bank (2004) data show an increasing trend of such participation in infrastructure projects in developing countries. Many countries see this as an opportunity to meet their construction needs for budgetary and other reasons.

Thus globalization and its consequences offer advantages for construction industries in developing countries to develop their capacities, capabilities and prospects for the future. Table 1.1 below shows the advantages and disadvantages of globalization.
Table 1.1: Advantages and Disadvantages of Globalisation Considering Construction Industries in Developing Countries

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involvement of international finance makes possible the implementation of several projects, such</td>
<td>Local construction firms have no funds or expertise to participate in the sponsorship of privatised</td>
</tr>
<tr>
<td>as those of major infrastructure.</td>
<td>projects</td>
</tr>
<tr>
<td>Direct foreign investment in projects leads to increase in construction demand, creating work</td>
<td>Local construction companies lack the technical and managerial capacity to undertake most of the</td>
</tr>
<tr>
<td>opportunities for local firms.</td>
<td>foreign-funded projects.</td>
</tr>
<tr>
<td>Competition among foreign firms lowers the costs of projects to developing countries.</td>
<td>It is possible the local firms will be deprived of the opportunity to grow.</td>
</tr>
<tr>
<td>Presence of large number of international firms offers scope for technology transfer and the</td>
<td>Foreign construction firms may pay lip service to technology transfer or take measures to avoid it.</td>
</tr>
<tr>
<td>development of local firms and upgrading of the industry. The larger number of such firms also</td>
<td>Moreover, local companies may not be in a position to benefit from technology transfer, or to</td>
</tr>
<tr>
<td>means that technology transfer can be a tool for competition.</td>
<td>subsequently utilise the acquired expertise.</td>
</tr>
</tbody>
</table>

Source: Challenges of Construction Industries in Developing Countries: Lessons from various Countries (Ofori, 2001)

Globalization also poses problems and challenges. There is a perception that globalization is a one-way flow of exports from the industrialised countries to developing countries. International projects involve a more wider range of issues than domestic projects and in effect, moving outside one’s usual business jurisdiction interjects many unknowns. These projects differ from domestic projects in terms of legal requirements, construction systems, technology and management techniques.

International projects that fail to meet scope, budget, and schedule can result in a host of impacts with serious economic, social and political ramifications.
1.1.2 Major Capital Projects and Design Changes

According to Nicole Rego (2011),

‘Murray & Roberts announced it expected to report a first-half diluted headline loss due to an impairment charge, sending its shares sharply lower. Shares in the company were trading 6.51% lower at R37.07 on Friday (29/01/2011) midday trade, compared with a 1.28% fall in Johannesburg’s top 40 blue-chip index. The Murray & Roberts Group Chief Executive at the time, Brain Bruce, stated that “trading conditions in both of the Middle East and South African markets had become rougher in recent months and cash collection relative to costs incurred on public sector projects remained a concern.”

Excluding the impairment charge, diluted headline earnings per share for continuing operations for the six months to end-December were expected to be 35% to 45% lower, compared with the same period the previous year (2010).’

From Murray & Roberts perspective, the construction of the Dubai Airport, Gautrain, Medupi and Kusile Power Stations were public sector projects that had all suffered significant increases in the scope of works, over and above what had originally been designed and contracted. This has resulted in significant delay and disruption, with additional costs against which the company’s clients had certified only limited payments to date. According to Bruce (2011),

“the resolution of these matters with our clients has been made more complex than necessary, especially as the cause is no fault of Murray & Roberts or its partners. It is taking too long to finalise claims for changes and extensions to contract.”

A cursory investigation carried out by Rego (2010b) on the company’s problem indicates the following issues;

(i) Murray & Roberts has been receiving its monthly payments for work specified in the original contract, but the additional work had been subject to another slow process. Meanwhile Murray & Roberts had to go ahead with construction, leading to an outflow of funds while inflows were restricted. The situation at Medupi, delays at Eskom’s other power station Kusile and claims related to the Gautrain Project and outstanding payments for work on Dubai Airport are the main reasons for the revenue reversal.

(ii) On Monday the 31st of January 2011, Eskom Financial Director Paul O’Flaherty strongly denied that there was a shortage of money for this contract or for the contract as a whole, that payments were dragged out, or that Murray & Roberts should in effect finance Eskom’s capital expenditure.

(iii) Murray & Robert’s financial is on a downward spiral. A lot of people have been retrenched by the company, partly due to the losses on these capital development projects. The company faces further losses through the dispute resolution processes it will have to go through. This will prove a very costly exercise, because the amounts the company intends to
claim is in the billions of Rands. There is no guarantee that they will successfully claim all they feel is due to them.

Notwithstanding the complexity and magnitude of each of the three capital development projects (i.e. Medupi, Kusile and the Gautrain), the worst impact of design changes occurred on the construction of Medupi Power Station. Hence this research was focused on a case study of the Medupi Power Station construction, specifically on the steelwork component.

### 1.1.3 The Medupi Power Station

As noted in the Murray & Roberts website, cited 28 November 2011,

> ‘The Medupi Power Station is South Africa’s biggest construction project to date. It is a dry-cooled coal fired station being built near Lephalele in Limpopo Province. When complete, the power station will have six boilers each powering an 800 Mw Turbine, producing 4800 Mw of power. This will be the largest dry-cooled coal fired power station in the world. The first 800 Mw unit is expected to be commissioned in early 2012, while the other units will be commissioned within the period of 9 month interval. The Medupi project is estimated to cost over R100 billion. Each Boiler Unit will consist of the following steel structures; Boiler Main Frame, Boiler House, Air Pre-Heater, Bunker Structure, Buckstays, Auxiliary Bay, Transverse Coarse Ash Conveyor, Coarse Ash Conveyor, Coal Transfer Conveyor and Inclined Coal Conveyor. An estimated 105 000 tons of steel will be fabricated.’

The main contract for Medupi was signed by Eskom and Hitachi on the 30th of October 2007. The subcontract was signed by Hitachi and Murray & Roberts on the 6th of December 2007. Murray & Roberts had limited recent experience in the construction of power stations, which resulted in a Cooperation Agreement being executed by which all dealings between Hitachi and Murray & Roberts were to be conducted in utmost good faith and Hitachi undertook to bring the necessary expertise to Murray & Roberts to fulfil its role in the partnership.

According to Murray & Roberts, the biggest challenge in this project is the management and implementation of revisions from Hitachi. Hitachi has provided continuously changing Basic Engineering Designs, which have led to:

a. Significant delay and disruption to Murray & Roberts.
b. No recovery of the learning curve savings and little prospect of future recovery.
c. Inefficient connection design, detail engineering and fabrication process leading to Murray & Roberts incurring significant additional costs and losses.
d. An inability to achieve the fabrication rates allowed in the prices as discussed and agreed with Hitachi as part of the collaborative process.
e. The re-incorporation of seismic considerations within the Hitachi design.

Depending on how far the process is, a change from Hitachi would require a corresponding change in the connection design, a change in detailing and re-fabrication of the relevant members. It is therefore imperative that there be an effective design management system in place to facilitate the implementation of the changes with the least disruption in production.

The scope of work for Hitachi and Medupi is a critical issue in the development of this study. The main contractor, Hitachi Power Europe, was responsible for “overall engineering”. Engineering covers all the design for the structure, excluding the subcontractors design, and specifically includes, but is not limited to (Murray & Roberts, 2011):

- Structural Analysis of the structure, modelling of the structure using beams, columns, foundations, ties, plates and shells as necessary.
- Determining the static system (including determining the character of the connections in terms of simple connections, semi continuous connections and continuous connections, which can be interpreted as hinged connections, semi rigid and/or partial connections and fully rigid connections respectively).
- Determining the loadings and load combinations which can act on the structure, following from natural causes like wind, snow (if appropriate), earthquake (if appropriate) and following from the use of the structure. Determining and provision of the effects, per load combination, of the actions (load combinations) in terms of the moments, shear forces, and normal forces per member end or node point including the force direction.
- Determining the size of all the members such that all limit states that can occur are considered, taking into account the choices made for the connections. These limit states are Strength, Stability (e.g. column stability and lateral torsional stability) and deformations of structure as a whole and the composing members.
- Deciding on effective lengths of all members and ensure the stability and buckling resistance of individual members and the provision and positioning of member restraints. If restraints or other specific details are required to effect (implement) these, they must be shown clearly on drawings.
- The Basic Engineering sets out members and therefore any forces arising from the eccentricity of members are to be designed for within Basic Engineering.
- The overall stability of the structure and transmission of such forces to the foundations.
- The sizing and material grade of all members (with an allowance for connections).
- Take cognisance of the physical size and shape of members and other elements and assess the interaction of stresses beyond the point analysed in a simple wire frame model (e.g. haunches and deep members)
• Any movement joints and any articulation of the structure that is required. If it is required, this should be clearly indicated on the documentation, normally on the drawings.
• General arrangement drawings, layout drawings showing all relevant dimensions, levels, members sizes and any other relevant information such as corrosion coatings, etc.
• Any members restraints, erection sequences, aids, lifting points or other such requirements that impact upon the Basic Engineering, and, which must be incorporated into the connection design and detail engineering.
• Ensuring that all members are of a size capable of resisting the forces and, where they are specifically designed to not be, and then the requirement for haunches, stiffeners or other strengthening procedures must be given (i.e. a stiffener in a beam under a point load).
• Basic overall strength and stability, and local stress capacity of members. Stability and buckling of a member (i.e. beam) is outside the scope of detailed engineering and connection design and is part of basic engineering.
• Undertake a review of the connection design and fabrication drawings to ensure that it complies with the principles of basic engineering design intent.
• Where specifically provided for in a contract agreement, the party responsible for the basic engineering shall also provide examples of typical connection designs to be used and to ensure that basic design intent is met.
• Where the nature of a connection, in conforming to the requirements of Basic Engineering, affects the dimensions of a member, the basic engineering designer must satisfy themselves that the proposed connection does not compromise the basic engineering. Should connection complexity become unreasonably excessive then consideration should be given to modification of the basic engineering design.

In order for Murray & Roberts to carry out the connection design the following minimum information should have been supplied by the basic engineering designer (HPE), in a clear unambiguous format:

• Direction and magnitude of all Loads/Forces to be used, not only Maximum/Minimum envelope forces but all load combinations.
• Balance all forces (To ensure against joint rotation)
• Type of connection required i.e. pin, fully rigid, flexible end plate, etc and examples.
• Type of restraint that the connection must impart to the beam member.
• Position of any movement joints indicating direction and distance of movement required.
Chapter 1: Introduction

- Examples of specific connections required if these are not normal, for example, connections which are connected to one side of a member only.

All information was to be clearly communicated to Murray & Roberts in unambiguous format with comprehensive annotated drawings.

The responsibility of the subcontractor, Murray & Roberts, for the structural steelwork comprises and is not limited to the following:

- Detailed Engineering is defined in the contract as: covering all documentation necessary for procurement, manufacture and installation and includes:

  - Preparation of detailed and final concepts.
  - Layouts final dimensions of components and calculations.
  - Lists of purchasing specifications.
  - Quality control procedures.
  - Incorporation of other sub-suppliers information.
  - Planning and completion of the arrangement drawings.
  - Issue of detailed drawings (arrangement and sectional) as well as assembly and/or erection drawings.
  - Issue of manufacturing and/or workshop drawings including parts lists.
  - All Quality Assurance requirements for the manufacture of respective components or system ready for installation.
  - Issue of corrosive protection requirements.
  - Execution of as-built drawings for respective component.

- Connection design is concerned with:

  - The design of the layout of the connections (if not prescribed by the Basic Engineering) followed up by determining the dimensions of the connecting parts like end plates, cleats, bolts, stiffeners, etc, such that the character of the connections in terms of simple connections, semi continuous connections and continuous connections, which can be interpreted as hinged connections, semi rigid and/or partial connections and fully rigid connections respectively, where specified by the basic engineering designer, is met.
  - Transferring of the forces acting at the end of a member into its supporting member, i.e. the transfer of forces at the position under consideration; it does not consider the transfer of forces along the length of a member.
Medupi is the most complex construction project ever undertaken in South Africa to date. The uniqueness of Medupi has also increased the complexity of the project. Gardiner (1994) reinforces this assertion by defining project complexity as,

> ‘the number of subsystems of a product and their interrelationships (where an interrelationship can mean that changes in the design to one subsystem produces cross-impacts and affects the design of other systems)’ (Gardiner, 1994, p. 115).

The uniqueness of Medupi has also increased the complexity of the project. As stated by Williams (1999),

> ‘uncertainty adds to the complexity of the project. A project where a body of knowledge exist is less complex than a State-of-the-Art project where there is no experience’ (Williams, 1999).

South Africa is in urgent need of a reliable power supply. Since early 2008, the country has experienced many power blackouts. This had a very negative impact on the economy of the country. A reliable power supply is imperative for a developing country like South Africa. Due to the fast tracking of Medupi, a number of decisions had to be made, often based on incomplete information, assumptions and personal experience, or rather inexperience, of the construction professionals. Design changes were inevitable. Lu and Issa (2005) suggest that the most frequent and costly changes are related to design (design changes and design errors).

Holt (1990) describes design as,

> ‘the process of seeking to optimise satisfaction and company profitability through the creative use of major design elements (performance, quality, durability, appearance and cost) in connection with products, environments, information and corporate identity’ (Holt, 1990).

According to Murray & Roberts reports, there are currently over 30 000 design changes on the Medupi steelwork. Critical changes have caused consecutive delays in project schedule and rework. Some questions that would deserve in-depth consideration include:

a. Could such a large number of design changes have been anticipated and allowed for in the contracts?

b. Were management methods for handling design changes in place for this project?

For every revision that was issued by Hitachi, Murray & Roberts would prepare a claim document called an Impact Assessment Form. This Impact Assessment is a record of the type of
Chapter 1: Introduction

revision, whether General Arrangement revision or Structural Analysis revision. The document provides specifics as to the time and cost implications of the revision. Due to the magnitude of the changes in the project, keeping track with an Impact Assessment for every single change became a near impossible exercise. Therefore, the need of an effective design management tool or method became clear as the project was developing.

Case studies and previous research indicate that management of the design process is poorly carried out in most projects, as observed by Austin et al (2007). It was noted that design remains an area where the process is not well managed or understood (Austin et al, 2007).

These design changes have led to big disputes over claims for rework and contract extensions; resulting in mediation of an arbitrator and if this is not resolved it may lead to litigation. This will lead to further losses for parties involved.

‘This highlights the need for improved design management as a means to improve the construction industry’s ability to respond to the needs of its customers. However, the development of design management in construction (and other industries) has been hindered by the intuitive and iterative nature of the act of design. This makes it difficult to model, plan, and manage design in the same way as more sequential processes such as those concerned with the physical movement of goods or materials’ (Austin et al, 2007).

This research has comprehensively analysed design management methods applicable on complex projects and then recommended the most appropriate method for Medupi and other similar global collaborative projects.

1.1.4 Managing Design Change.

The system of managing design changes by Murray & Roberts was a manual and cumbersome process. A spreadsheet tracking all revised drawings and structural analysis received was created. It provided a breakdown as to the type of revision, and all associated impacts of the change. For each revision, an Impact Assessment (see Appendix A) had to be created. This was a breakdown of the time and cost impacts of the revision. It provided a description of the change, and how it has negatively hindered the progress of Murray & Roberts. This system for managing design changes on the Medupi project proved to be ineffective. The magnitude of changes became too large. As previously stated, there are more than 30000 design changes. Manually tracking all revisions became a near impossible exercise. The need for an effective design management tool was evident.

There is very limited research work addressing design change management specifically within the construction project management context. Qi Hao et al (2008) observed that change
management is a pure-application-oriented issue. A solution to the problem requires engineering innovation (Qi Hao et al, 2008). This is further reinforced by Austin et al (2007),

‘There has been a growing understanding of the importance of effective design management to ensure that a coordinated building design is developed within budget and to ensure the smooth running of projects’ (Austin et al, 2007).

The South African construction industry has lagged behind in the development and implementation of new management methods. Innovative design management methods were perhaps not needed, due to the fact that South Africa had never before undertaken a project of the magnitude and complexity of Medupi.

Williams (1999) argues that several approaches have been made at managing design changes in modern and complex projects. However, it is difficult to generalise the application of such approaches due to lack of effective synthesis.

The theoretical foundation of design change management established in previous researches was assessed and synthesis of best practices is presented for adaptation in the case study.

1.2 Problem Statement

The effects of frequent changes in design include difficulties in settling variation claims, disruption in the flow of production, dispute resolution and regrettably litigation which have their negative effects on the project’s completion time and cost. To ameliorate these negative effects on the execution of the Medupi project, there is the need to implement a functional and effective design change management system.

1.3 Research Questions

- What were the root causes of the design changes?
- What tools have previously been developed for managing design changes?
- Which tool would be appropriate for a complex project such as Medupi?
- Would tool effectively manage design changes on Medupi?
- Would tool limit claims and disputes?
- What are all the characteristics for the global collaborative projects?
- Would tool be implementable on other similar projects?
- Would tool be accepted in the South African construction industry?
1.4 Research Statement

A systematic approach for managing design changes will significantly reduce risk on global collaborative projects.

1.5 Objective of Study

The objectives of this study are;

- To establish the root cause of the design changes on the case study.
- To intensively analyse Design Management techniques.
- To select the most appropriate for Global Collaborative projects.

This will increase the success of collaborative projects for owners and contractors with project success defined as budget and schedule achievement and meeting technical and operational objectives. Principal beneficiaries will be to the industrial, building and infrastructure sectors, including both private and public organizations that conduct international operations and activities.

1.6 Contribution to Knowledge

This research has determined the appropriate technique for managing design changes on global collaborative projects.

1.7 Scope and Delineation

The study was focused on the Medupi structural steel design. The effects of design changes on structural steel connection design, detailing and fabrication was conducted. Concrete works and other works are outside of the scope of this study.

The main limitation in the study was the lack of recently updated design management tools/methods. The available design management tools/methods are discussed in Chapter 2 in the literature review. Design management tools/methods are constantly being updated but not always available for inclusion in the literature review. This has limited the applicability of some tools on the research project.
1.8 Research Ethics

Permission was obtained from all the participants involved in the study. The names of the participants have not been published without their written consent. The information obtained has not been misused in any way. It was thoroughly explained to the respondents as to what the survey results will be used for. A moral responsibility towards the participants has been maintained.

This study has adhered to the framework and policies of the School of Construction Economics & Management, University of the Witwatersrand Research Ethics Committee.

The participants confirmed that they were not below the age of 16 and also acknowledged their right to discontinue participation in this research at any time without reason. The rights of the participants as well as their privacy and sensitivity have been protected. This research has been conducted with the utmost honesty and integrity.

No participant has been compromised in the conducting and publishing of the study. The data emerging from the study will be made available to all participants on request.

1.9 Validity and Integrity of the Data

A rigorous mathematical analysis of the data was conducted on the information collected from the questionnaires. This was done in order to assess the level of agreement between the respondents, considering that data was collected from respondents of the same company. A mathematical tool was used for analysis of the results. This analysis was done to determine the level of agreement of the respondents. This improved the reliability, validity and integrity of the results.

1.10 Structure of the Report

Chapter 1: Introduction

This chapter entailed a background of the study. It further led to the Problem Statement, Research questions, Research Statement, Objective of Study, Contribution to knowledge, Methodology, Scope and Delineation and Research Ethics.

Chapter 2: Literature Review
Chapter 1: Introduction

The literature review provided a theoretical base for the study and helped determine the nature of the research. Design management techniques and tools were analysed and compared.

Chapter 3: Methodology

This chapter described the method for collecting data which was used in the study. The method for the analysing the data was presented. Qualitative research was conducted.

Chapter 4: Analysis and Discussion

The collected data was analysed in this chapter, identifying all consistencies and differences.

Chapter 5: Conclusion and Recommendation

The study was summarised in this chapter and all findings presented. A recommendation as to design management techniques for global collaborative projects is made.