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IMPROVING INTERFACE MANAGEMENT ON A MEGA CONSTRUCTION PROJECT

A Research Report submitted to the Faculty of Engineering and Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science (Building)

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MAY 2018

DECLARATION

I hereby declare that this research report is my own original unaided work except where I have explicitly indicated otherwise. I declare that this work has been undertaken and written by me in its entirety.

I have followed all the necessary methods in referencing the thoughts and concepts of others.

This research report has also not been submitted by any other person in my University previously.

_____

Candidate

On this _____ day of _____ 2018

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I wish to sincerely thank and acknowledge the contributions of:

1. My Supervisor, Dr. Oluwayomi Babatunde for his supervision and support which has led me to complete this research

2. The Project Director for granting me permission to utilise the selected site as a case study for the research

3. All the participants who took the time to answer the questionnaires and give more insight on the topic

4. Friends and family for the support awarded to me during the duration of my studies.

ABSTRACT

Interface management has in recent years become a key area of focus within the construction sector as the industry undertakes more complex projects. These mega projects are characterised by their complexity, huge scale, high cost and longer duration. This study was conducted in an attempt to understand interface management in its entirety and its role within mega construction projects with the aim of developing a workflow to be used for the management of interfaces on mega projects.

To address the objectives of this study a case study method was adopted and questionnaires were utilized to gather data. A total of 50 questionnaires were sent out to ten specialist contractors on the selected mega project and only 36 questionnaires were returned. Through the process of content analysis the results were as follows: Firstly, a number of different types of interfaces were found to exist within the project environment including design interface, design-construction interface, systems interface, contractual interface, organizational interface and construction interface. Secondly, a number of issues exist within the project environment which influence interface challenges. These root causes were found to be just to name a few, poor scope definition, different contracting strategies, poor co-ordination, scope gaps, access delays, poor planning, lack of communication, lack of interface management strategies and so forth. These issues can therefore be referred to as a catalyst in causing interface problems to occur within the project environment.

To meet the third objective a number of improvements to the current interface management strategies were noted. These improvements included using software's such as the building information model, efficient scheduling methods, interface management team, interface management procedure, contractually identified interfaces, proper communication, better resource planning, better stakeholder management and so forth. Through the study of these improvements this study proposed a stage gate workflow process for the management of interfaces on a mega construction project so as to eliminate possible interface risks. Each stage gate introduces an interface management workflow and the items to evaluate at that particular stage gate to ensure that interfaces are addressed collectively throughout the project.

Keywords: Mega construction project, Project complexity, Interfaces, Interface management.

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ACRONYMS

BIM	Building Information Modelling
DIMS	Design Interface Management System
IMS	Interface Management System
IM	Interface Management
RASCI	Responsibility Assignment Matrix System
WBS	Work Breakdown Structure

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CHAPTER 1: INTRODUCTION

1.1 Background of the study

A mega construction project can be defined as a large infrastructure project which is complex in nature and requires an intense workforce to execute. Grun (2004) and Flyvberg et al. (2013) have labelled these projects as giants or beasts while Hassan et al. (1999) noted these projects as having high capital cost, program urgency, technological advancements and multi-disciplinary. Mega construction projects have brought about unprecedented challenges to the traditional methods and techniques associated with project delivery (Chen et al., 2007). These projects have in recent years experienced exponential growth triggered by cultural, economic and technological globalisation (Fiori and Kovaka, 2005). Mega construction projects are complicated in that they entail bringing together a number of independent multi-disciplinary teams, inter dependant systems, budgets, schedules and materials together for a certain period of time (Daniel et al., 2014). These projects are characterised by high cost, high complexity, and longer duration and usually involve several work packages comprising of several projects occurring in parallel to each other (Mortaheb et al., 2010). This nature has thus brought forth complex interfaces between the different project elements. It is evident that the contractors and subcontractors require close collaboration throughout the project lifecycle, resulting in the origin of interfaces between different project stakeholders (Shokri et al., 2012).

The initial definition of an interface was introduced by Wren (1967:69) who defined an interface “as point of contact between relatively autonomous organizations which are interdependent and interacting as they seek to cooperate to achieve some larger system objectives”. However, this definition is system based and suggests that different independent organisations must collaborate through interfaces to achieve the goals associated with their system. There exist a number of interface layers between the project itself and between entities outside of the project both locally and internationally. Shokri et al. (2012) has defined an interface as a link that exists within the project environment between alternative elements, project scope and stakeholders while Okebugwu and Omejah (2015) defined an interface as a point of connect or collaboration between parties or constituents in a project environment. However, an interface can be generally considered as a shared boundary point where different independent but interacting components of the project come together thus creating conflict

within that point. These interfaces originate during the decomposition of contracting strategies, contracts, designs, systems, scope, stakeholders, project phases, construction elements (Shokri, 2014).

Shokri et al. (2015: 197) has construed that “understanding the project complexity is crucial for determining or designing the tools, methods and skills required to effectively deal with interface issues in a construction project”. However, understanding project complexity is not an easy task because the concept of project complexity is composed of many interrelated sub concepts, and, thus, is complex in itself (Ahn et al., 2015).

Khadimally (2014) and Staats (2014) agreed that interfaces can be categorised into:

- External Interfaces: Occur between the contractor and the client and their external entities or between systems or the surrounding environment ; and
- Internal Interfaces: Occur within the work areas of the contractors responsibilities and also occur between disciplines or in a system between components.

Over the past decade, Africa has seen rapid increase in infrastructure development with mega projects streaming to total of a hundred and nineteen which has been increased by investments in sectors such as power, energy and transport (Deloitte, 2014:8). Southern Africa has been at the front of the pack with 36% of African projects of which 28% are under South Africa’s project count (Deloitte, 2015:17). South Africa has undertaken projects such as the Gautrain, Bus Rapid System, Power stations, Solar Power plants and Stadiums in the last decade to name a few. These projects have experienced time and cost overruns as a result of their complex nature. Shokri et al. (2014) concurred that methods of handling interfaces have become insufficient especially for handling complex projects. A need therefore arises to shift away from the traditional method of managing mega projects to a more concerted effort in the implementation of project management practices (Daniel et al., 2014). Interface management has in recent years therefore been introduced as a mechanism for combating interface challenges on complex projects globally. Daniels et al. (2014) stated that one problem facing the implementation of interface management on mega projects is simply lack of knowledge on how it must be implemented.

1.2 Statement of the problem

Joham et al. (2009) expressed that complex mega projects must be tackled in a different manner than routine projects. While, Piantanida et al. (2014) declared that the key to successful mega projects is the efficient management of all interfaces across boundaries. Noteboom (2004) articulated that interface management issues contribute up to 20% of the total project cost. A need therefore arises to shift away from the traditional method of managing mega projects to a more concerted effort in the implementation of project management practices (Daniel et al., 2014).

Mega construction projects are complex in that they consist of many subsystems all connecting to one big system and being executed by a number of multi-disciplinary teams which are all geographically dispersed. These characteristics give rise to multiple points of contacts between the different systems and different project teams. If these interfaces are not properly planned for interface issues might arise impacting performance of the project. Poor management of these interfaces may as a result cause design errors, mismatched parts, system performance failures, co-ordination problems, and construction conflicts (Chen et al., 2007). Moreover, these interfaces can result in arbitration, contract termination, time and cost overruns, claims, quality issues and legal actions (Chen et al., 2008; Morris, 1983; Mortaheb & Rahimi, 2010).

Therefore, the lack of interface management on large projects serves as a catalyst for cost and schedule overruns resulting in delays in commissioning and excessive rework (Piantanida et al. 2014). Without an interface management strategy to manage interfaces on mega projects, co-ordination issues occur between the different project components causing delays and additional cost to the project.

1.3 Research aim

The aim of this research is to address interface challenges through developing a workflow for interface management on a mega construction project.

1.4 Primary Research Question

How can interface management be improved on a mega construction project in order to reduce interface challenges?

1.5 Objectives of the research

The objectives of the study are:

- To identify the main types of interfaces that exist within the project environment;
- To identify the main sources of interface challenges on mega projects; and
- To evaluate how interface management can be improved on a mega construction project.

1.6 Scope of the study

This study explores mega construction projects and the challenges prevalent within these projects as a result of interfaces. It further evaluates the different interfaces that exist within projects, how these interfaces have been dealt with and the arising importance of interface management within the construction industry. This study ultimately focuses on interface management on a single mega construction project in South Africa. It seeks to establish the challenges that this project is facing in terms of interfaces, the main source of these interface issues and the strategies currently being used by different contractors within the project to deal with interfaces. Finally, the study evaluated how interface management can be improved within the project environment.

1.7 Research Methodology

The research methodology selected for this study was a quantitative case study method. The descriptive survey design was adopted for purposes of this study and a structured questionnaire was designed to suit the objectives of this study. The utilised case study for the research is a single mega construction project in South Africa as it meets all the qualities of a being a mega project. The site consists of a (+-50) work packages, each being executed by different specialist contractors together with their sub-contractors. For purposes of this study

the main contractors will be termed specialist contractors. Ten specialist contractors were therefore selected within the project site in accordance to the highest rand value and within these contractors the targeted group was contract managers, project managers, engineers, planners and construction managers. To achieve the objectives of this study, literature was firstly reviewed for better understanding the objectives in line with the global industry. A questionnaire was therefore designed including both open and closed ended questions and sent to the selected participants for the study. Survey method has within literature been preferred in quantifying observations and providing greater confidence in result's obtained.

1.8 Research significance

Interface management is a growing area of focus within the construction industry as projects become more and more complex (Shokri et al. 2015). Flyvberg (2014) expressed that on time and on budget delivery of construction projects has become even more crucial as mega projects cost billions of dollars to execute. A major cause of the cost and schedule overruns on these projects has been attributed to inadequate management of communication and interfaces between stakeholders (Han et al. 2007; Nikander and Eloranta 2001; Nitithamyong and Skibniewski, 2004; Wong and Zhang, 2013 and Jergeas and Ruwanpura, 2009). This study seeks to provide an in-depth probe into interface management and its role within mega projects as a mechanism for combating interface challenges. This study reviews the current strategies being used within the industry for dealing with interfaces and identifies the challenges and gaps thereof. This study sets forth an interface management workflow which provides a mechanism for dealing with interfaces on a mega project to improve project performance and to reduce or eliminate interface risks.

Research has been defined as the systematic and objective identification, collection, analysis, distribution and utilisation of information with the aim of assisting management in making decisions (Malhotra, 2004). Therefore, the results of this research are expected to assist mega construction projects in better understating interface management and its challenges and how it can be implemented to better manage interfaces within the project.

1.9 Limitations of the study

- The scope of this research is limited to a single case study of a mega construction project in South Africa. The project was considered a critical case study and as a result used for the research due to South Africa's biggest construction companies being involved in this project.
- Using a single case study has an impact on the data results obtained as other mega projects might have different challenges with regard to interface management. The results obtained from the case study might not be directly usable on other mega projects as projects differ in terms of scope, complexity and scale but might provide a guideline.

1.10 Ethical considerations

Ethics is a very critical component of any research undertaking. Saunders et al. (2009) described ethics as the manner in which research is conducted in relation to those that are affected by the research being conducted. Cooper and Schindler (2008) indicated that for research to be ethical it must be designed and executed in a manner that does not inflict physical harm, pain, and discomfort to the respondent. Ethical concerns arise from the planning stage of the research all through to collection, analysis and reporting of data (Saunders et al. 2009). Oliver (2010) expressed that it is important to treat those involved in the research in accordance to the values and standards that assert their humanity. Ethical considerations were upheld in undertaking this research and participants were not forced into partaking in the research. The confidentiality of the participants was maintained throughout the collection and reporting of data. To further comply with ethical considerations, the respondents were informed regarding the aim of the study within the body of the designed questionnaire. Prior to sending out the questionnaires approval was obtained to conduct research from the project director within the selected site. Further approval was obtained from the directors within the construction companies selected to participate in the study within the selected site. Quality assurance was also practised with respect to competency of respondents, correctness and completeness of the utilised questionnaires (Saunders, 2012). An ethical clearance certificate was obtained from the School of Construction and Economics ethics committee (Annexure B). The information gathered for the research was not be utilised for anything either than the execution of this research.

1.11 Structure of the report

The structure of the dissertation is described below:

Chapter 1 provides an overview of the research background. The chapter presents the research problem, research aim, objectives and research questions for the study.

Chapter 2 provides a review of the current literature on Mega construction projects, project complexity, project risks, project integration and interface management. It also provides an overview of the current strategies used for managing interfaces on mega construction projects.

Chapter 3 evaluates research methods utilised to gather data to meet the objectives set for the study. Data collection methods are identified in accordance to the objectives set and to provide an answer to the main research question. This chapter justifies the selection of research methods and designs and the sampling technique undertaken for the study.

Chapter 4 discusses the results obtained through the use of questionnaire survey. It summarises the most important findings from the survey.

Chapter 5 presents the conclusions and recommendations for the study. The chapter suggests topics for future research.

1.12 Summary

This chapter provided a brief background of the research area, the problem statement, objectives, aim, research significance and the research structure. The chapter highlighted on mega construction projects and provided a brief introduction to interface management. The next chapter presents the literature review in relation to the research area of the study.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Chapter Overview

This chapter provides description, summary and evaluation of the existing literature. It seeks to provide a critical analysis of the existing knowledge on the subject area of the research. Firstly, literature will be reviewed regarding mega projects and their complexity and the challenges they face; secondly, a review will be conducted into the different project interfaces that exist within the project environment space. Lastly, an in-depth review into interface management is conducted regarding the current strategies being used for interface management.

2.2 MEGA CONSTRUCTION PROJECT

2.2.1 What is a Mega Construction Project?

Mega construction projects are growing at an accelerated rate across the globe as a result of combating the challenges brought forth by weakened infrastructure due to population growth. These projects have been defined in a number of ways within the industry. Flyvberg (2014) has defined mega projects as large scale, complex ventures that might cost a billion dollars or more, may take a number of years to develop and build, and run into a million man hours. Meanwhile, Charret and Loots (2015) defined mega projects as large scale projects which comprise of significant expenditure and cash flow, large design, procurement and construction workforce which needs to be appropriately managed throughout the project lifecycle. These projects can vary from oil and gas extraction, processing plants, highways, tunnels, bridges, railways and conventional, nuclear or renewable power plant (Brookes and Locatelli, 2014). They are also united by their extreme complexity, both technical and human terms and by long record of poor delivery (Brookes and Locatelli, 2014) and are designed and constructed by a number of local and international companies with suppliers and vendors from different countries.

Flyvberg (2014) reported that nine out of ten projects exceed the planned time and cost and such projects yield lower revenues and as such hindering growth of the economy as opposed to progressing it. Li and Guo (2011) commented that mega projects do not produce favourable results and this can be seen through occurrence of time and cost overruns resulting in stakeholder disappointment. Meanwhile, a study by PriceWaterCoopers (2013) concluded

that mega projects usually exceed their budgets by 50%. The risk is mainly that these projects encompass many moving parts, resources and contractors (PriceWaterCoopers, 2013). The failure rate of mega projects increases the importance of understanding the characteristics as shown in Table 2.1 associated with these projects for better planning and control.

Table 2.1: Characteristics of Mega Projects

National Research Council (2010)	Zidane et al. (2013)	Hassen et al. (1999)	Haynes (2002)
• Time (+5yrs) • Cost < than £100M • Colossal use of resources • Large size • Risk and uncertainty • Technological Innovation • Social, economic, and environmental impacts • Multiple owners • Complexity • Poor performance • Change of priorities • Indirect benefits to non-user	• Large scale project • Technologically demanding • Over 1 billion dollars • Time (+5yrs) • Program urgency • Different objectives • Fails to meet cost estimates, time schedules& outcomes • Poor performance • Cost overruns • Management of complex activities • Technological innovation	• High capital cost • Long duration but program urgency • Technologically and logistically demanding • Requiring multi-disciplinary inputs from many organisations and, • Leading to a virtual enterprise for project execution	• Multiple owners • Mega size • Social, economic, political and environmental impacts • Time (+5yrs) • Destabilises markets • Unique risks • Financial difficulties • Complex undertakings

Ahn et al. (2015) further expressed that project complexity is multi-faceted. The challenges impacting mega projects are a result of lack of understanding of what project complexity in itself means. Project complexity is one of the ultimate factors of difficulty in project management (Ahn et al. 2015).

Heng and Guo (2011) described project complexity as falling into three categories namely,

- Technical: Design and technologies employed in design and construction process
- Social: Impact of mega project on environment and social systems
- Managerial: Business and governance aspects of projects inclusive of financial management, scheduling, and resource deployment and decision management.

The complexity associated with mega projects requires proper coordination and control in relation to technical and social resources (Mancini et al., 2014). Daniels et al. (2014) further reinforced that complex projects require increased efforts in project management processes throughout the project life cycle while Maylor et al. (2008) expressed that project complexity is multi layered and with many dimensions.

2.2.2 Understanding Mega Project Complexity

Understanding project complexity is one of the vital components of addressing possible challenges that might occur on construction projects. Complexity is thus one of the constructs of mega projects.

Table 2.2 illustrates the level of differences in the execution of traditional and complex projects. It must be noted that a different approach must be adopted in the execution of mega projects as a result of the complexity associated.

Table 2.2: Comparison of traditional versus complex project characteristics

Traditional Projects	Complex Projects
• Standard practices can be used - Design, Funding & Contracting • Static interactions • High level of similarity to prior projects creates certainty	• Standard practises cannot be used - Design, Funding and Contracting • Dynamic interactions • High level of uncertainty regarding objective and or/objectives

Source: Transportation Research Board (2012)

Remington et al. (2009) defined complexity as the features which challenge the project and make it hard to foresee project outcomes and even to manage or control the project. Ochieng et al. (2013) stated that the major challenge with complexity is that it varies this being due to client's vision, interests and goals associated with the particular project. These projects are difficult to control and understanding them is even more difficult (Vidal et al, 2011). Ahn et al. (2015) remarked that complexity seems to be centred on managerial complexity and thus requires more refined managerial expertise and systems.

The level of complexity in mega projects creates inefficiencies in the conventional tools and methods of project management used in dealing with interfaces (Vidal and Marle, 2008). Remington and Pollack (2008) emphasised the need to move away from the traditional practises of managing projects which date back to the construction of the pyramids. Additionally, old construction theories cannot be utilised to manage current projects as there has been substantial growth in construction from since then and this is the reason why most current projects are failing. A gap thus exists for new project management methods to cap the challenges being presented by current mega construction projects. Moreover, there is a need to provide more effort towards integration, co-ordination, communication and control in order to tame these projects.

2.2.3 Challenges facing Mega Construction Projects

It is crucial for any project team to understand the challenges associated with mega construction projects in order to come up with strategies that aid project success. Mega projects face a great deal of challenges during the project life cycle and if not mitigated, can negatively impact the project. Table 2.3 summarises the challenges facing mega projects into different categories.

Table 2.3: Challenges facing Mega Projects

Flyvberg (2014)	Charret and Loot (2015)	Egbu (2011)
• Inexperience of teams • Multiple stakeholders • Technology misalignment with complexity • Complex interfaces • Change of project scope • Inadequate cost • Inadequate schedule	• Shortage of skilled resources; • Inadequate scoping; and • Poor risk allocation • Multiple stakeholders • Aggressive project schedule • Scope inadequacies • Inadequate cost estimates	• Role definition • Interface Management • People issues • Culture and political influences • Risk Management • Resource Management • Project methodology

It can be reasoned that the challenges associated with mega projects tend to impact projects negatively causing time and cost overruns to occur. Further, these projects require advanced practices which shift away from the traditional manner of running projects to a more in depth practice into understanding mega projects, their components, complexities and efficient methodologies. Interfaces have been regarded within literature as one of the challenges facing mega projects, as a result of the increase in the need for complex projects. Project complexity causes several interfaces as a result of bringing multi-disciplinary teams and materials together temporarily (Daniels et al., 2014). The level of project complexity therefore drives the number of interfaces that exist within the project. Davis (2013) expressed that mega projects require more than a ‘one size fits all approach’ as they possess unique needs in terms of complexity, technology, time, and novelty.

2.3 PROJECT INTERFACES

2.3.1 Interface Definition

There exist many interfaces within projects in general and an even large number of interfaces on mega construction projects. Interfaces between systems or units must be identified at all stages of the project so as to effectively manage them (Lin and Siao, 2011). Interfaces can defined in a number of ways as summarised in Table 2.4

Table 2.4 Interface definitions

Source	**Definition**
Wren (1967)	Interfaces are defined as the contact point between relatively autonomous organisations which are inter dependant and interacting to achieve some larger system objectives.
Healy (1997)	Boundary across which interdependency exists and responsibility for interdependency can change.
Huang et al. (2008)	The elements in a project that need to be physically and functionally organised or cooperated within elements.
Khadimally (2011)	Interface is the place at which independent systems meet or communicate with each other.
Shokri et al. (2012)	Interfaces are links between different components in a project such as scope, project participants and construction elements.

Although a number of definitions exist within industry regarding interfaces Pavitt and Gibb (2003) have categorised interfaces into three, as presented in Figure 2.2 and explained subsequently:

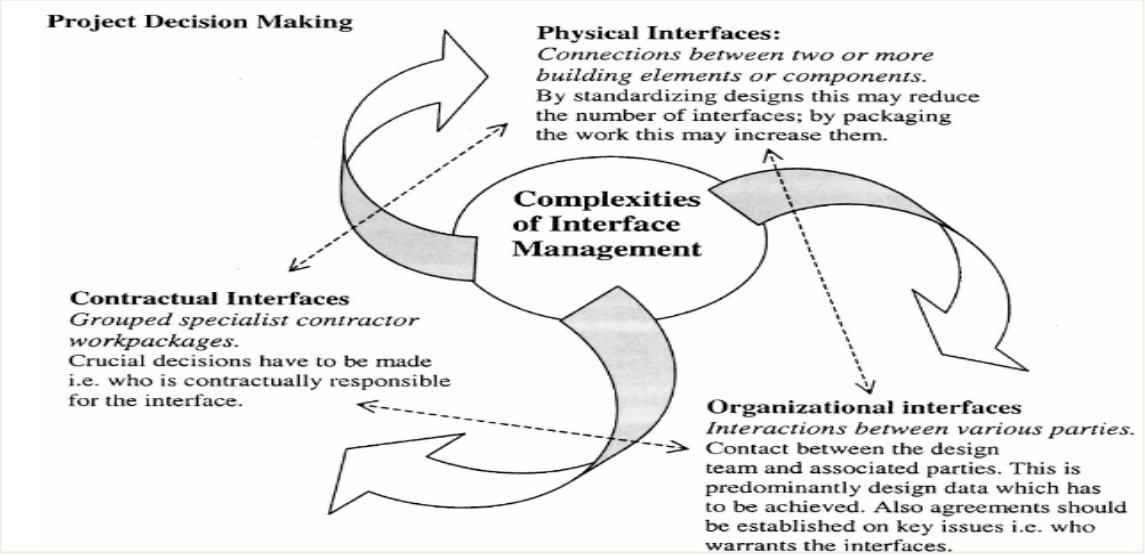


Figure 2.1: Complexities of interface management

Source: Pavitt & Gibb (2003)

Physical: Describes the physical connections that exist between building elements. Such an interface is dependent on the level of the design and can thus present challenges during the construction period.

Contractual: Describes work elements that are that are grouped into distinct work packages by contract. These interfaces can be attributed to the work packages associated with the project for both contractors and subcontractors.

Organisational: Describes interfaces that take place between different people associated with construction project. Having a number of divisions within an organisation can cause interface issues due to lack of proper structure to convey all information between divisions.

Collins et al. (2010) further distinguishes all types of interfaces as falling into:

Inter-project Interface: Interfaces between different parties directly involved in project planning and execution.

Intra-project Interface: Interfaces within the organization of each independent party, involved in a project.

Extra-project Interface: Interfaces between the project parties and other parties/organizations which are not directly involved in project execution. (e.g. permits from government or environmental organizations).

The physical, contractual, inter project and intra project can be characterised as internal interfaces relating to the project environment itself while organisational and extra project interfaces relate external interfaces providing a link between the project and the external environment not related to the project. Qian (2007) stated that internal interfaces are easier to handle as the responsibility matrix should be clear on ownership of interfaces. Further, Qian (2007) reiterated that external interfaces need to be clarified and defined prior to ensure that all interfaces are identified and acknowledged.

2.3.2 Main causes of Interface Problems on Mega Projects

Mega projects involve multiple stakeholders (internal and external), multiple systems running in parallel, large amounts of design and data, multiple contracting strategies and so on. The nature of these projects involves a complexity that needs thorough alignment between all associated characteristics. The main issue with the current management of interfaces is that interfaces of the whole project are not addressed but focus is mainly on managing the interfaces between a couple of internal departments of a project (Shokri et al., 2012).

A study conducted by Weshah (2015) identified common interface problems within mega projects. The identified problems included:

- Insufficient communication and co ordination
- Financial difficulties
- Poor decision making
- Limited skills for labour and engineering
- Issues in materials procurement
- Issues in construction processes
- Issues in engineering process
- Project site issues
- Information challenges
- Lack of project management
- Lack of interface management
- Planning and scheduling problems
- Wrong project cost estimate
- Inexperienced project teams
- Technological advances

- Improper work packaging and design
- Unclear contract details
- Geotechnical challenges

Al-Hammad (2002) & Shokri et al. (2012) further identified the following:

- Long lead items
- Permits
- Contract obligations & poor contracting strategy
- Government laws
- Wrong specifications
- Change orders
- Environmental problems
- Poor quality of works

Venkatachalam (2012) also identified inappropriate assumptions, poor flow of information and lack of proper sequencing as the factors for interface issues on a project. Meanwhile, Fritschi (2003) also noted factors such as unclear scope definition, poor information, and lack of communication and Alarcon and Mardones (1998) noted issues such as lack of integration among specialists, defects of specialists, inconsistent changes by owner, improper drawings and specifications, designer's lack of knowledge and non-technical specification. These challenges therefore need to be addressed on all projects as possible risk prior to commencement of any project in order to combat them arising during the execution phase of the project. Shokri (2015) discussed the importance of front end planning in ensuring that the project is properly planned from the inception stages. This early planning will assist project teams to be able to identify and mitigate risks during the early stages of the project. Front end planning must therefore be used as a mechanism to eliminate potential interface project risks.

Chen (2007) narrows down interface issues as arising from people/participants, methods/processes, resources, documentation, project management and the environment. These form the major components in any project execution and are vital factors to take into consideration during planning of any project in order to eliminate any interface issues as the project progresses. Chen et al. (2008) noted that interface issues have an impact on productivity, quality, delays, claims and cost overruns. Meanwhile, Sundgren (1999) mentioned that failure

in managing interfaces during the construction phase leads to additional cost and time. Additionally, Noteboom (2004) further expressed that more than 75000 task related interfaces exist within project environment, and the confusion related to interface challenges is regarded the greatest risk factor to cost and time.

2.3.3 Interfaces as risks on Mega Projects

Construction projects are plagued with various types of risks at all stages of the project life cycle (Zhao et al., 2010) and the management of this risk should be a continuous process which spans all the phases of the life cycle (Smith, 1999). Smith (1999) further noted the importance of identifying all possible risks which may have a significant impact on the project during initial stages so as to prepare a response for them. Meanwhile, Chillot (2010) has defined a risk as an uncertain event which has the probability of impacting the project (positively or negatively) in relation to cost, time and performance; thus, limiting intended achievements. A general view of research has noted early identification of risk as a crucial element to combating any impacts which can potentially arise as a result of the identified risk. Risks vary at different stages of the project and thus require continuous monitoring from inception till completion. Chillot (2010) further categorised risks into two as presented in the ensuing Table 2.5,

Table 2.5: Risks

External Risks	Internal Risks
Natural Hazards	Management problems
Government Regulations	Schedule delays
Market conditions	Technical and quality information
Contractor/ vendor performance	Late deliveries of materials
Financial	Lack of access
Legal and technical	Labour shortages.

Source: Chillot, 2010

Shokri (2014) defined the external risk as those factors that affect the project from the outside environment while internal risk impact a specific work package. Risks and their effects should be observed throughout the project and by all the participants involved in the decision-making process (Ceric, 2003). It cannot be concluded that there exists a project which carries no risk, it is, thus, important to note that a risk needs to be managed, minimised, shared, transferred or accepted (Renuka et al, 2014).

Risk management can be defined as the process of identifying, assessing and prioritizing risks with the goal of monitoring, controlling and reducing the negative aspects associated with that risk (Shokri, 2014). Banaitiene and Banaitis (2012) have defined risk management as a comprehensive and systematic manner of identifying, analysing and responding to risks to ensure that the project objectives are achieved. Construction Excellence (2015) identified risk management as a process which enables identification of issues that might possibly have an impact on a project with the onus of minimising those potential risks. The management of risk on construction projects is widely recognised as a crucial process to achieving project objectives in terms of time, cost, quality, safety and environmental sustainability (Osei-Fusu, 2014). Further, this management serves to combat all possible risks. According to Edmead (2007), the risk management process objectives should be to eliminate negative risks, reduce risks to an 'acceptable' level and or to transfer risks.

The management of interfaces is both internal and external risk for mega construction projects as a result of the stakeholders and components involved within it. Interface management ensures that all interface challenges are addressed early to improve the efficiency of construction projects (Daniels et al, 2014). Failure to properly manage the interface risks may have an impact on the cost, scope control, quality, schedule, safety and resources (Crumrine et al., 2005; Mortaheb & Rahimi, 2010; Pavitt & Gibb, 2003). Ultimately poor definition of interfaces within the project environment has a potential of leading to problems within the organisation, imprecise definitions of responsibility and poor reporting of data (Morris, 1979).

2.4 INTEGRATION

2.4.1 Project Integration Management

The Project Management Institute (2013) defined integration management as the process and activity utilised to identify, define, unify, coordinate and combine the various processes and project management activities within the process groups. Further, it was stated that integration management evaluates the interdepencies among the knowledge areas and also reviews and concludes on resource allocation, objectives and ensures that stakeholder expectations and requirements are met. According to PMI (2013), integration management deals with integrating processes within the different knowledge areas and also ensures management of all project documentation to ensure that they are consistent with the project management plan. Project integration coordinates all the processes adopted for all the knowledge areas to the project management plan and thereafter documents how a change to one area impacts the other areas as well. Integration management ultimately focuses on pulling all the knowledge areas together to achieve project success through project lifecycle.

Integration management follows the following process,

- Develop project charter – Authorises existence of project;
- Develop Project Management Plan -integrating all plans;
- Direct and Manage Project Work - Performing work in plan;
- Monitor and Control Project Work - Reporting project progress;
- Perform Integrated Change Control – reviewing and approving change requests; and
- Close Project or Phase - Finalising all activities across process groups (PMI, 2013).

Integrated change control is performed as a reviewer of all changes exposed to the project whether it is from the project documents, deliverables, baseline, or project management plan. This control serves to analyse and approve or reject these changes. PMI (2013) stated that “the key benefit of this process is that it allows for documented changes within the project to be considered in an integrated fashion while reducing project risk, which often arises from changes made without consideration to the overall project objectives or plans”.

It can be noted that interface management is part of project integration management. While integration management evaluates the processes required to ensure proper coordination of various project elements, interface management seeks to identify all points of interaction between the various project elements. Interface management and integration management are

often used interchangeably within the construction industry even though interface management is a subset of integration management and seeks to identify points of contact between stakeholders as opposed to the integration of processes.

2.5 INTERFACE MANAGEMENT

2.5.1 Defining Interface Management

Interface management has its origins rooted back in the systems engineering area which has been treated as pertinent to most projects. This is due to a project being referred to as a system consisting of a number of interrelated and interconnected elements which need to work together achieve a defined goal (Struckenberg, 2008). Morris (1983) stated that a system is a grouping of information, things, people and/or other attributes in accordance to a particular system. Meanwhile, having advancements in technology might challenge companies in that they may not have the necessary skills to execute the work which therefore causes international companies to be given the work. Haas et al. (2016) noted that having geographically dispersed stakeholders poses significant interface risks within the project. The project manager therefore needs to ensure collaboration between the components, parts, sub systems, organizational units and people to produce an integrated whole.

Interface management, has in recent years, been noted as a developing project management practise (Keerthana and Shanmugapriya, 2017). This can be due to the increasing complexity of construction projects which requires collaborative effort between project stakeholders who may be geographically distributed (Shokri et al., 2012). “Interface management is the process of creating or identifying interfaces, maintaining transparency over their definition, defining and enforcing the rules of their functioning, optimizing system efficiency to trigger their full coordination, and resolving interface issues, so as to guarantee the system’s overall functional unity” (Godinot, 2003:15). Chen el al. (2007) defined interface management as the improvement of quality of physical connections between construction components, the reduction of project conflicts among project parties through planning and coordination, and optimization of the design in terms of quality, compatibility, constructability, cost and risk. Meanwhile, Wideman (2002:3) has further defined interface management as “the management of communication, coordination and responsibility across a common boundary

between two organizations, phases, or physical entities which are interdependent;" and also "managing the problems that often occur among people, departments, and disciplines rather than within the project team itself."

Interface management is an ongoing process and should be considered dynamic throughout the life of a project with the goal of maintaining the balance between scope, time, cost, quality, and resources (Crumrine et al., 2005). In building construction, physical interfaces, joints, and connections between different elements or sections tend to cause problems for building design, manufacture, construction, and operation throughout the life of the buildings (Chen, 2007). Morris (1983) stated that interface management also identifies the following:

- The subsystems to be managed on a project;
- The principal subsystem interfaces requiring management attention; and
- The ways in which these interactions should be managed successfully.

Pavitt and Gibb (2003) further stated that interface management is of importance in a number of areas including design, procurement, logistics, programming, contracting, management, external influences and human relationships. In addition, Kossiakoff et al. (2011) noted that interface management identifies and describes interfaces as part of system concept definition and coordinates and controls those interfaces to maintain system integrity during development, construction and consequent system enhancements. Figure 2.4 represents a typical interface diagram between the project stakeholders. The success of this relationship matrix remains part of project integration – which can be described as the process which ensures that all project elements such as tasks, subsystems, components, parts, organisations, organizational units and people fit together as integrated whole which functions according to the plan (Struckenbruck, 2008).

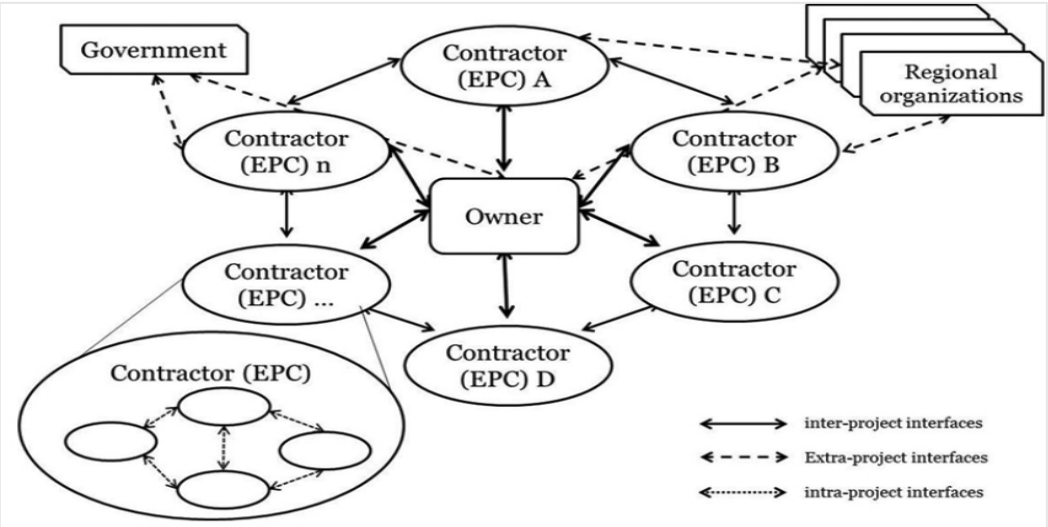


Figure 2.2 Interface levels
Source: Shokri et al, 2012

Ahn et al. (2015) highlighted the need to understand project complexity as the first key element to developing a comprehensive interface management system. Further, understanding of project complexity is not an easy undertaking as this complexity is embedded with a number of interrelated sub concepts, which are also complicated increasing associated risk. It can be construed that gaining an insight into the complex nature of projects can shed light on the interface management practises which can assist in preventing or alleviating the adverse impacts which rise as a result of poor interface management (Ahn et al., 2015). It can be argued that the challenge is that the complexity in projects is influenced by a number of factors which makes projects different in the nature but Morris (1983) further argued that projects follow a common pattern of interfaces resulting from common pattern of sub system interaction.

Morris (1983) expressed that interface management identifies the following:

- The subsystems to be managed on a project;
- The principal subsystem interfaces requiring management attention; and
- The ways in which these interactions should be managed successfully.

The objective of interface management is to provide a balance regarding all aspects of the projects in relation to resource, scope, time, quality and resources (Crumrine et al., 2005). Keerthana and Shanmugapriya (2017) commented that lack of an efficient management practise gives rise to issues such as design errors, mismatched parts, systems failures,

coordination difficulties, and construction conflicts. Therefore, the challenge facing mega projects seems to be lack of awareness on how to deal with the complexity of interfaces without having to result to the traditional methods used on small or medium size projects.

2.5.2 Awareness of Interface Management

Many construction projects are becoming more complex and larger in scale because of significant improvements in technology and operations. These projects involve various stakeholders, with different geographical locations and working cultures having to collaborate with one another throughout the project life cycle (Shokri et al., 2012). It is essential that the project stakeholders evaluate the amount of interfaces within projects and the manner in which to deal with those associated with interfaces. On many projects, the benefits of interface management are not reaped due to the lack of awareness on implementation of formal rather than informal interface management strategies. The detachment of the project stakeholders makes it difficult to close the gap in between project interfaces. The current complexity of projects is challenging the practises being adopted on these projects providing more awareness on the issues that need more attention such as the complexity of interfaces in a complex project. The lessons learnt on these projects will provide better basis for firm strategies to be adopted for the management of project interfaces.

2.5.3 Benefits of Interface Management

Interface management provides a solution to effectively managing interfaces during the project life cycle. Daniel et al. (2014) articulated that the benefits of utilising interface management on large construction projects include:

- Builds an understanding of project complexity;
- Optimises design in terms of quality, compatibility, constructability, cost, risk, and function to meet customer needs;
- Improved planning through avoiding, minimising or eliminating potential for interface issues;
- Builds and maintains desirable relationships and communication channels among project participants;

- Standardises the handling process and work flows for various types of interfaces in construction projects;
- Enables construction delivery to be dynamic; and
- Identifies and records good practises in dealing with project complexity.

Shanischara (2014) further noted the following benefits:

- Efficient communication between project stakeholders;
- Transparency across boundaries;
- Provides auditable trail to project decisions;
- Enhances awareness of critical issues; and
- Ultimately promotes clear, accurate, timely and consistent communication for exchange of project information.

Meanwhile Chen et al. (2007) described the benefits to be that of:

- Enabling classifying and reporting the best IM practices that can be use and applied even for other projects;
- Assisting in improving design in terms of risk, cost and quality;
- Providing a well-developed construction project delivery system;
- Minimising uncertainties within projects and regulates workflow;
- Improving work packaging;
- Allowing for early identification of interfaces to decrease interface issues during project phase; and
- Assisting stakeholders to understand project difficulty.

As noted through literature a number of benefits exist with regards to adoption of interface management on projects. Mega projects face a number of challenges and that is why strategies such as interface management need to be implemented in order to reap the benefits associated with it ensuring that cost and time impacts are minimised with regard to interfaces.

2.5.4 Current Applications of Interface Management Strategies

2.5.4.1 Interface Management Strategy (IMS)

A number of strategies have been identified within literature for the management of interfaces. Lin (2009) put forth a five phase process including identification, interface communication, interface recording and interface closing. A process based interface management strategy is said to involve the 5 steps as depicted in the above figure.

a) Identification : Identification of interface points through review of design drawing, specifications, contract, work breakdown structure (Chua and Godinot, 2006)
b) Documentation: Records all information regarding the interface points including characteristics, stakeholders roles and responsibilities, deliverables and need dates
c) Transfer: Owner transfers information regarding identified interfaces to the awarded contractor. The contractor will have full information on the interfaces to be dealt with, the parties involved and deadlines.
d) Communication: During this step the parties involved in an interface need to validate and approve the interface. The parties can thereafter start using interface agreements as a medium of communication through the presence of Interface Manager
e) Closure: The interface is closed when all stakeholders reach agreement on the efficiency, accuracy and completion of all information and tasks related to a particular interface (Shokri et al., 2012). This step will be dependent on whether the interface is through the whole life cycle or not.

This interface management workflow represents basic workflow which is used within the industry for management of interfaces. The workflow is not fully defined and integrated but gives a generic idea of how to deal with interfaces within the project. Each project team is therefore expected to build up from this process to suit the particular project at hand.

2.5.4.2 Work Breakdown Structure Approach (WBS)

The WBS or simply put the 'work breakdown' is a technique for breaking down the project into smaller chunks while representing activities associated with achieving the end goal of the project (Jha, 2011). Globerson (1994) stated that the work breakdown structure decomposes the projects into smaller size units for project management and planning purposes. Meanwhile Tiner (1985) stated that the advantage of the work breakdown structure is that it allows major elements to be identified while breaking them down into tasks for construction purposes. All in all the work breakdown structure breaks down the project and defines how the data to the project will be summarised in line with the various levels of management; it further seeks to identify all the preceding information of an activity which serves as basis for detailed planning (Godinot, 2003). This approach enables the project stakeholders to evaluate the validity and alignment of project information with project goals and enables identification of unclear information or scope of works.

WBS Matrix

Another approach to utilising the work breakdown structure is noted in research paper conducted by Bachi and Hameri (1997). The researchers introduced the concept of aligning the product breakdown structure with the activity breakdown structure to form the WBS matrix. This WBS matrix divides the project into work packages and details the work to be completed under each work package. Within each work package all low level tasks are identified, the objectives associated with each as well as the resources required to complete each task (Lanford and McCann, 1983). The WBS structure approach utilises the work packages associated with the project to identify interfaces using Work Package Sheets at conception of the project. A work package report, schedule sheet and budget sheets are prepared on regular basis. The WBS is required to be kept at an intermediate level which might cause problems regarding the identification of interfaces at the lowest level that occur during implementation (Godinot, 2003). Another noted disadvantage is that not all project related documents are aligned to the work breakdown structure (management plan and schedule, bills of quantities e.t.c) which tends to be a problem.

In terms of interface management the work breakdown structure matrix identifies all the activities required on the project and then all interfaces are identified. Firstly, Godinot (2003) stated that all activities and products are cross referenced against the work breakdown

structure to ensure that all items are included. When alignment is achieved then all interfaces are identified using work package sheets which created include scope, interface description, schedule, budget and deliverable description. The work packages are then checked if they have clearly identified all interfaces and the responsible interface holders and if so, then the work package report is created which includes interface issues and any risks associated. Godinot (2003) proposes this method for management of interfaces instead of the tree like work breakdown structure which at times fails to breakdown the entire scope of the project. The major disadvantage to this proposed method can be that on mega projects although the work packages are identified on a high level scale, the scope associated with some of the work packages might not be defined in detail as projects chase the urgency associated with these projects. Some of the work packages get clearly defined as the project is underway due to the urgency of commencing work especially on the major work packages.

2.5.4.3 Responsibility Assignment Matrix System (RASCI)

The RASCI chart is also used as one of the tools for the management of interfaces on construction projects. The role of the Rasci chart is to clarify the roles and responsibilities of stakeholders involved within the project and also eliminate unnecessary activities (Racichart, n.d). Shokri (2015) stated that the chart is known as “Participants Involved Tool” as it points out the interfaces which exist between project functions (progress, forecasts, estimates, schedules, cost control, change management) and the phases of the project. Crumrine et al, 2005) construes that these matrices are crucial for defining, allocating and handling the responsibilities for those organisational roles dealing with project interfaces.

The Rasci chart seeks to identify all the project activities and the roles in the organisation for each activity. Under interface management the matrix designates roles of responsibility between tasks, activities and milestones and assists in keeping track of delegated responsibilities between boundaries of interfaces thus eliminating confusion. Disadvantages of RASCI matrix include,

- No proper alignment exists between project participants with overlapping responsibilities;
- Decisions take too long; and

- If there scope is not properly defined then the responsible people cannot be identified timeously.

2.5.4.4 Workflow driven IM System

In a study conducted by Shokri (2015) a workflow driven interface management system is introduced for curbing interface issues on mega projects. This workflow is adopted from the interface management system presented earlier but it is further developed or extended to provide a more in-depth vision of what each phase consists of.

Shokri (2015) stated that an Interface Management framework must be carried it in six steps.

Step 1: Interface identification – This is the initial phase of the workflow where all the project related information is identified, studied and analysed to ensure efficient identification of all interfaces within the project environment. This phase, reviews all designs, contracts, specifications and so forth to identify possible overlapping areas between all areas of the project and submitted for approval by the interface manager.

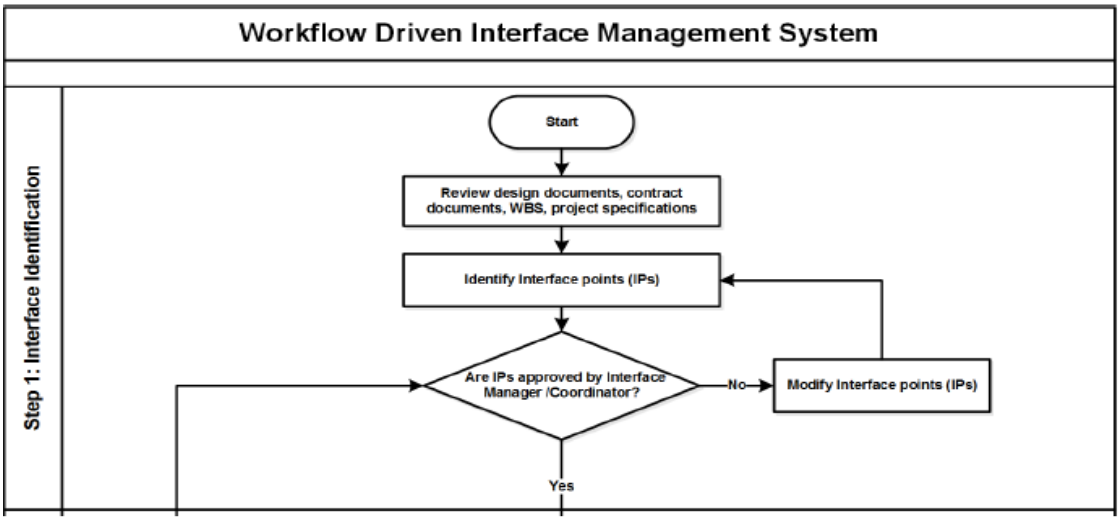


Figure 2.3: Interface identification
Source: Shokri (2015)

Step 2: Interface Documentation – After all interface points are identified, these are documented so that all responsible people are identified. This information is therefore send forth to the interface manager and team for approval.

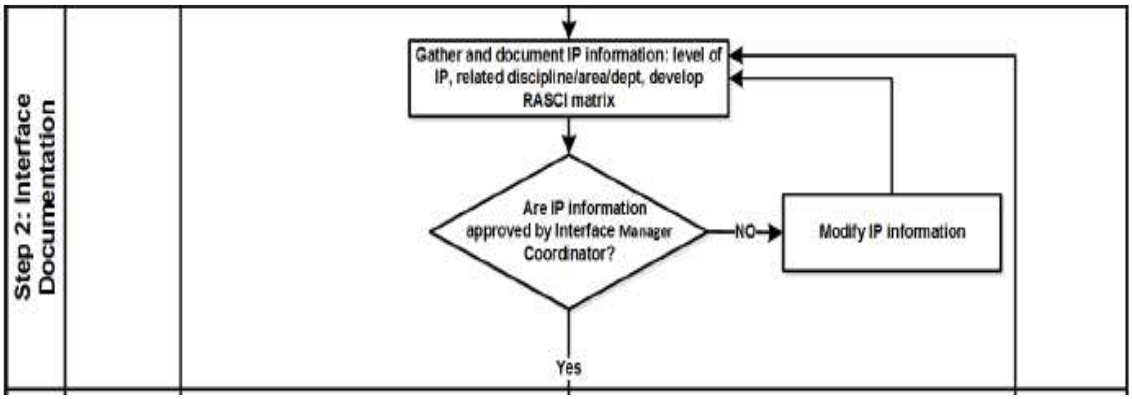


Figure 2.4: Interface documentation
Source: Shokri (2015)

Step 3: Interface Transferring – Once the contract for a particular package is awarded all the relevant information with regard to interfaces is tracked and transferred to the awarded contractor. The contractor can then start interfacing with all the relevant parties who are responsible for the interface. This enables the awarded party to review and check if they agree with all interfaces.

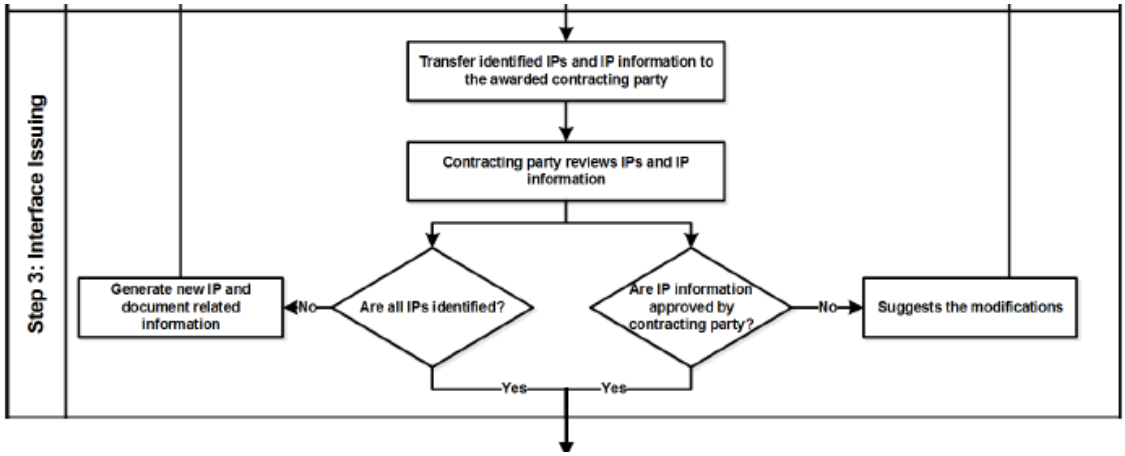


Figure 2.5: Interface issuing
Source: Shokri (2015)

Step 4: Interface Communication – This step ensures that the awarded contractor communicated all the information pertaining to an interface including description of interface, responsible people and need dated for the interface. An interface agreement is further developed when both parties owning an interface agree to the interface. This avoids any delays as all parties know the interfaces they are responsible for.

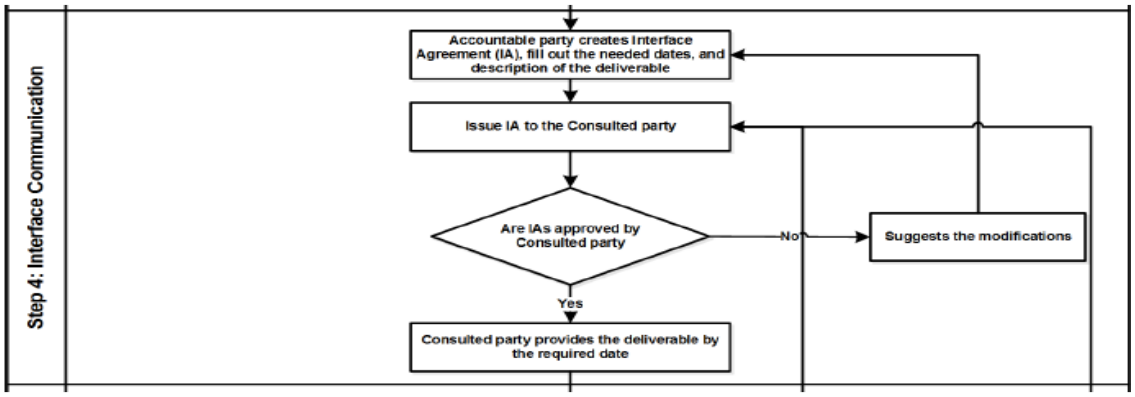


Figure 2.6: Interface communication
Source: Shokri (2015)

Step 5: Interface monitoring and control – This step ensures that the interface management team monitors all interfaces through noting all the deadlines that are underway, progress of interfaces and the durations attached to each interface. The interface manager of each work package needs to keep track of all interfaces and ensure that all the relevant dates are met so as to not delay the project.

Step 6: Interface closing – Parties involved must agree on accuracy, efficiency and completion of communicated deliverables.

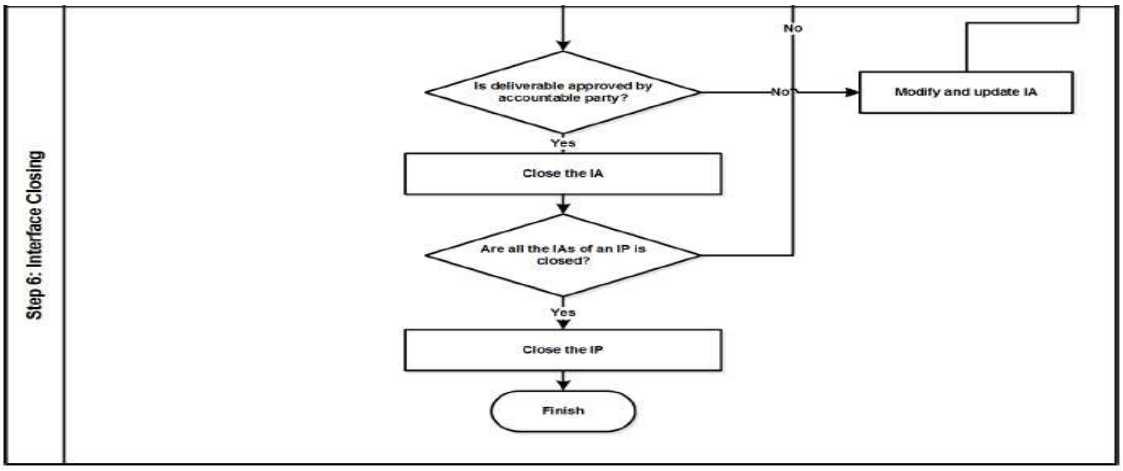


Figure 2.7: Interface Closing
Source: Shokri (2015)

2.5.4.5 Design Interface Management System

The design interface management system is a structured methodology forming the drawing design structure matrix. It identifies the design interfaces that are existent within a project. The Dims process commences with the identification of elements such as systems, main components and sub components and it further identifies the construction dates associated with these components together with the design durations. The second step of the process identifies both the physical and the design interfaces; these interfaces are identified in with involvement of parties involved. The physical interfaces between components are captured using the physical interface matrix and from then the design interfaces are identified through the design interface matrix. “The DIM captures the design information interfaces between the physically interfaced components and the design disciplines involved” (Venkatachalam and Varghese, 2008:171). These design interfaces are identified through workshops with the entire project team to ensure that all interfaces are accounted for. Lastly, all interface related issues are captured in the Design Interface Agreement.

2.5.4.6 3D Models

3D models have in recent years been a major attraction in the construction industry as they assist all stakeholders to better understand how the building functions prior to it being constructed. 3D models have been recognised as being easy to understand, providing design optimization, allowing collaboration, allowing for clash detection between elements, better control over methods of construction and so forth. 3D models have been favoured for their ability to improve the design process of the project and in being able to assist the clashes that are in existence by bringing together designs from other systems. The most recent tool within the industry is the building information modelling. Building information modelling is based on traditional CAD, geometry based CAD and parametric modelling techniques. (Chen, 2014).This tool has the ability to eliminate clashes between the different structural components.

2.6 Summary

The management of interfaces on mega projects is becoming an interesting area of study within the construction industry as the boom of mega construction projects continues. Noteboom (2014) noted that interface management related risks amount to about 20% of project cost while Han et al. (2007) stated that major projects are experiencing overruns as a result of the inadequate management of communication and interfaces between stakeholders in a project. The traditional projects do not possess quiet a large number of interfaces and can thus be managed through the use of traditional project methods such as work breakdown structure, rasci method, high level interface management system and 3d models. These strategies have not been rendered efficient for the management of large scale interfaces within mega projects. The stakeholders within these projects all have to conduct work in parallel with each other in order to complete a portion of the entire system. Shokri (2015) has emphasized interfacing between stakeholders to be addressed at an earlier stage within the project in order to reduce any interface risk that might arise later.

Mega construction projects have been characterised as having multiple stakeholders both local and international, different procurement strategies, different contracts, complex scope of work, complex engineering function and so forth. These characteristics give rise to thousands of interfaces between the project and organisations. The complexity of mega construction projects creates many points of interaction between the different project components as multiple parties are involved in the implementation. Therefore, the higher the complexity in terms of scope and technology associated with the project the greater the number of interacting points arising from contracts, engineering, scope and so forth. The complexity of the project needs to be clearly dissected and understood so as to identify all interfaces.

A number of gaps exist within literature regarding the management of interfaces. These gaps include lack of understanding of mega project complexity and its influence on project interfaces, lack of understanding of different interfaces that exist within project, root causes of those interfaces and the lack of unified interface management strategies. Project complexity has been labelled as a vital component of preparing for the management of interfaces (Ahn et al. 2015). Within this research the types of interfaces that exist within mega projects are identified through gathering data through the research case study. This

enables the researcher to gain more knowledge on this issue in order to assist projects especially in the South African context to define and understand the different interfaces that might possibly exist within a mega project.

Furthermore, the main sources of interfaces on mega projects are further unpacked as these will enable projects to be weary of the possible sources that give rise to interface challenges. Literature does not provide comprehensive information regarding these root causes. Different stakeholders within projects tend to deal with interfaces in a non-collaborative effort thus neglecting to execute efficient pre planning for the interfaces and the possible sources that might give rise to them. Thousands of interfaces exist within a mega project but the important part is in deciding where these interfaces can possibly stem from during the different intervals of the project. Moreover this study aims to expand on the limited factors that have been identified within literature. Lastly, the workflows that have been identified within literature present a single workflow while the study introduces a stage gate workflow emphasising the importance of fully developing the workflow as the project goes through the different stage gates of the project.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter served to unpack the research designs, approaches and methodologies employed in the analysis of the data collected for the research. Further the relevant design, methodology and form of data analysis were selected in relation to the research study with the stance of answering the research objectives.

The study ultimately sought to address the challenges faced on a mega construction project in South Africa in relation to management of interfaces. The survey method was adopted for the research as it allowed for gathering of data from different individuals within a multi-faceted environment.

3.2 Research Design

3.2.1 Defining Research

Welman and Kruger (1999) defined research as the application of various techniques and methods with the aspiration of producing scientifically obtained knowledge through the use of objective method and procedures. Saunders et al. (2009) stated that research is a tool that is used to find out things in a systematic way with the purpose of increasing knowledge. Literature has suggested that research follows the criteria of defining and redefining problems, devising hypothesis or solutions, collecting data, organising that data, evaluating the results and reaching conclusions to ensure that the solutions fit the objectives of the research. Furthermore Saunders, Lewis and Thornhill (2009) further categorises research into the following classification namely:

3.2.1.1 Exploratory research: This research is conducted where there is a problem which has not been clearly defined, it occurs before much is known (Van Dyk, 2012 and Saunders et al. 2009). Saunders et al. (2009) stated that the main advantage of this exploratory research is its flexibility and adaptability to change. Literature has stated that exploratory research seeks to study a certain field with the premise of explaining the relationship between variables. Hair et al. (2003) stated that exploratory research is utilised to develop a better understanding of what is happening, to seek new insight and to assess occurrences. Contrary to that, Welman

and Kruger (1999) stated that exploratory research determines whether or not a particular phenomenon exists in order to gain familiarity with such a phenomena. Saunders et al. (2009) stated that there are three methods through which exploratory research can be conducted. These methods included search of literature, interviews with field experts and also through conducting focus groups. Babbie (2001) stated that the shortcomings of exploratory studies have been attributed to the seldom nature of providing satisfactory answers to research questions though they can hint at the answers and can also propose which research methods could provide absolute answers.

3.2.1.2 Descriptive research: Descriptive research observes and describes the manner in which a subject behaves without being influenced. Saunders et al. (2003) stated that the objective of descriptive research is portraying an accurate profile of persons, events and of situations, it is crucial for the researcher to have a precise depiction of the phenomena on which the researcher wishes to collect data prior to commencement. Through this form of research, the researcher observes and then describes what was observed examining the existing patterns and what they imply (Babbie, 2001). Descriptive studies answer questions of where, what, how and when.

3.2.1.3 Explanatory research: Explanatory research seeks to identify key relationships and key variables within a study to assess their cause and effect relationship (Van Dyk, 2012). This type of research seeks to elucidate why and how a relationship exists between two or more variables.

Zikmund et al. (2012) summarises the main characteristics of different types of research as presented in Table 3.1,

Table 3.1 Types of research

	Explanatory research	Exploratory research	Descriptive research
Amount of uncertainty characterising decision situation	Clearly defined	Highly ambiguous	Partially defined
Key research statement	Research hypotheses	Research question	Research question
When conducted?	Later stages of decision making	Early stage of decision making	Later stages of decision making
Usual research approach	Highly structured	Unstructured	Structured
Examples	'Will consumers buy more products in a blue package?'	'Our sales are declining for no apparent reason' 'What kinds of new products are fast-food consumers interested in?'	'What kind of people patronize our stores compared to our primary competitor?' 'What product features are the most important to our customers?'

Rubbin and Babbie (2008) and Yegidis and Weinbach (2002) noted that exploratory research must first set out the variables of interest within a research area. Secondly, descriptive research must occur to allow understanding of the characteristics and relationship between the identified variables. Lastly, explanatory research must occur to identify trends on how the variables impact one another. Exploratory research looks into the ideas and patterns relating to a certain research area while descriptive research goes further into examining a problem and explanatory research goes further than descriptive through explaining why something is happening.

This research started by adopting exploratory research approach through obtaining better understating of the area of research using existing literature which assisted in identifying the problem and scope of research. Secondly, descriptive research method was adopted through extracting and sourcing more information regarding the focused research area to increase the researcher's knowledge and, lastly, the explanatory research method was utilised to fully dissect the research topic.

3.3 Elements of the Research Process

An important aspect of any research undertaking lies in the strategic planning of the research which sets out the process used in answering the objectives and aim of the study. Research design is concerned with the careful planning of a successful investigation for conducting and analysing data with the option of enhancing the validity of the study (Polit-O'Hara & Hungler, 1993). Khothari (2004) indicated that research design is concerned with the collection of data and techniques. The selection of a research design can be attributed to the nature of the research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study (Creswell, 2014). Saunders et al. (2012) have pointed out that it is important that the researcher selects between two main research approaches including deductive and inductive as presented in Table 3.2,

Table 3.2 Adopted from Research Onion

Philosophies	**Approach**	**Strategies**	**Choices**	**Time Horizons**	**Techniques**
-Positivism -Realism -Interprevitism -Pragmatism	-Deductive -Inductive	-Experiment -Case study -Action research -Grounded theory -Ethnography -Archival	-Mono method -Mixed method -Multi method	-Cross sectional -Longitudinal	-Data Collection and -Data analysis

Source: Saunders, Lewis and Thornhill, 2012

3.3.1 Research Philosophy

Bryman (2012) indicated that the research philosophy deals with the beliefs attached to the nature of the reality being investigated. The assumptions stemming from the research philosophy provide headway for how the research will be embarked on. Saunders et al. (2012) expressed that the research philosophy should be influenced by the research questions to be addressed by the study. Goddard and Melville (2004) further articulated that research philosophies differ due to different goals associated with the research and the methods to be used in achieving those set of goals.

3.3.1.1 Philosophical Stances

a. Positivism

Saunders et al. (2009) expressed that the research philosophy chosen for the study gives forth assumptions regarding the view of the researcher in the world. These assumptions further reinforce the research strategy and research methods. Positivism is of the notion that you can only rely on research if it is scientific deeply rooted in science and mathematics (observable, measurable and empirical). Welman et al. (2006) also indicated that positivisms can be linked directly to scientific methods which strive to introduce laws applicable to populations. O'Leary (2004) further reinforced that the positivists believe there is nothing in the world without an explanation, nothing beyond human understanding.

In summary, the positivist expressed that it is possible to be detached from the research in order to remain objective (Morris, 2006). Secondly, positivist also believe that valid knowledge is created through direct observation of senses and this entails being able to measure what should be seen as knowledge (Vosloo, 2014). Thirdly, the positivist is of the premise that scientific theories give forth a hypothesis which gets submitted for empirical testing. Scott & Usher (2011:13) summed up positivism as "equating legitimacy with science and scientific methods". For purposes of the research the positivist approach is not applicable as this study does not focus on the natural sciences.

b. Interprevist/Constructivist

Interprevitism supports the notion that people do not look at the world in the same way but rather understand the world in different ways which influences the way they act. Collis & Hussey (2009:56-57) and Rubin & Babbie (2010:37) commented that "Interprevitism is all about understanding and interpreting daily events, experiences and social structures as well as the value that people attach to these phenomena". Within this method participants provide views on the situation being studied. It is believed that knowledge is not objective and value free but is diffused to us through ideas and individual experiences. Creswell (2003) remarked that constructivists do not commence with a theory but rather theory and patterns are developed throughout the progress of the research process. The constructivist can utilise both qualitative and quantitative research methods. For purposes of the study this method is applicable as the study is reliant upon the views of the participants to unravel information regarding the research subject matter. Deetz (1996) indicated that interpretivist seek to understand the phenomena through the meanings being attached to them by individuals. Data

was collected through use of questionnaires to gain understating of the research area so as to draw inferences between information and abstract pattern.

c. Realism

Realism is of the view that scientific methods are not perfect and, therefore, theory can be revised and theory needs to be an ongoing process to allow new methods of research. Saunders et al. (2012:114) indicated that “realism is independent of the mind”. Livesey (2011) proposed the use of focus groups or in-depth interviews for data collection within the realism paradigm. For purposes of the study this approach is not applicable due to the study involving multiple disciplines where questionnaires will be utilised to gather necessary data and expand on research area.

d. Pragmatism

According to Creswell (2003) pragmatism considers the research problem as central to the study and promotes understanding of the problem through various approaches. Meanwhile, Mackenzie and Sally (2006) stated that making the research question central ensures that methods chosen for data collection and analysis provide insights into the questions and do not conform to any other paradigms. Feilzer (2010:8) noted that pragmatism “side steps the contentious issues of the truth and reality” and “focuses on what works as the truth in accordance to the research question under investigation”.

Table 3.3 provides a summarised version of the different philosophical stances through breaking down the methods and data collection tools that can be used with each paradigm. This study will use an interpretivist/constructivist research paradigm as the study relies upon the views of the participants on the subject matter being investigated due to their vast experience on the research topic. The parties contribution will serve to unravel the problem associated with the study.

Table 3.3 Research Paradigm and Research Methods

Paradigm	Methods	Data Collection tools
Positivist/ Post positivist	Quantitative. Although qualitative methods can be used within this paradigm, quantitative methods tend to be predominant…	Experiments Quasi experiments Tests Scales
Interpretivist/Constructivists	Quantitative methods predominate although quantitative methods may also be utilised	Interviews Observations Document reviews Visual data analysis
Transformative	Qualitative methods with quantitative and mixed methods.	Diverse range of tools- particular need to avoid discrimination e.g: sexism, racism and homophobia.
Pragmatic	Qualitative and/or quantitative methods may be employed. Methods are matched to the specific questions and purpose of research.	May include tools from both positivist and interpretivist paradigms e.g Interviews, observations and testing and experiments

Source: Mackenzie and Sally (2006)

3.4 Research Approaches

3.4.1 Deductive approach

In deductive research the idea is to develop from general to particular through establishing the general theory and knowledge base first and testing the knowledge gained from the research process against it (Kothari, 2004). Crowther and Lancaster (2008) were of the premise that the first step in deductive research is formulation of theories or hypothesis while Collins (2010) expressed that the deductive approach undertakes the following steps:

- Identifying the relationship between two variables;
- Stating how the identified variables can be measured;
- Testing the identified relationships; and
- Analysing the outcome of the test and establishing how the proposition needs to be modified and then continuing with the process again.

Further, the particular study must seek to explain causal relationship between variables, identify patterns and trends, develop hypothesis and test it using qualitative data (Williams, 2007).

3.4.2 Inductive approach

Saunders et al. (2012) argued that the inductive approach, although it supports depth knowledge, it involves a higher rate of uncertainty as a result of the researcher moving from specific observations to broader theories and conclusions. Beiske (2007) indicated that within this approach observations are the starting point for the researcher and patterns are observed within data. Further, there is no framework which supports the data collection and the research focus can be informed after data has been collected (Flick, 2011). Another disadvantage of the inductive method is its more explanatory nature and involves a long process of collecting and analysing data for the formation of theory while deductive approach is more constricted and investigates specific theory or hypothesis (Bryman & Bell, 2007).

Saunders et al. (2012) highlighted the key differences between the two approaches to provide more clarity on what to consider when selecting a research approach as presented in Table 3.4,

Table 3.4 Differences between deductive and inductive approaches

Deduction emphasis	Induction emphasis
• Scientific principles • Moving from theory to data • The need to explain causal relationships between variables • The collection of quantitative data • The application of controls to ensure validity of data • The operationalisation of concepts to ensure clarity of definition • A highly structured approach • Researcher independence of what is being researched • The necessity to select samples of sufficient size in order to generalize conclusions	• Gaining an understanding of the meanings humans attach to events • A close understanding of the research context • A more flexible structure to permit changes of research emphasis as the research progresses • A realisation that the research is part of the research process • Less concern with the need to generalize

Source: Saunders et al. (2012)

For purposes of this study, to fulfil the research objectives and achieve aim of the study the deductive approach was utilised using quantitative research methods through the use of structured questionnaire.

3.5 Research Strategies/Designs

Common widely used research strategies include:

- Experiment: This research strategy examines the results of the experiment against expected results (Saunders et al., 2012) and it examines the relationship between factors. This type of method uses hypothesis instead of research questions to determine whether a relationship exists between variables. For purposes of this study this strategy is not applicable as the study uses research questions to gain data in relation to the study.
- Case Study: Deals with the in depth examination of a certain field which may be due to insufficient theory and knowledge. It studies a single unit and then draws generalisations (Bryman, 2012). Fellows and Liu (2003) stated that a case study method is used to back a study by researching on previous or current topics. For the purposes of the study this strategy is applicable as the study focuses on one mega project. Case study design method is important for areas of research where there is a need for in-depth investigation of a problem.
- Survey: Surveys are mostly used in qualitative research studies and involve sampling a certain portion of the population (Brymann and Bell, 2011). Surveys produce date which allows empirical analysis. Bhattacherjee (2012) further enforced that surveys possess more weight than other methods as a result of being able to measure people's traits, beliefs, preferences, factual information or attitudes.

  For purposes of the study surveys were utilised on the selected mega project to gain more understanding of the research area from different participants. The descriptive survey was utilised to gain data from a set population within the selected mega project to gain more understanding regarding the research problem.

Surveys can be divided into the following types:

- Descriptive Surveys: Leedy and Ormbad (2005) stated that descriptive surveys require the researcher to ask questions and opinions from a set population and tabulate the relevant responses received. This method enables the researcher to make the necessary conclusions. Meanwhile Blumberg et al. (2008) stated that descriptive surveys embark on answering questions through profiling a group of problems, individuals and events.
- Trend Surveys: These surveys may be undertaken at different points with sampling taking place at different intervals using similar respondents.
- Action Research: Commonly used in nursing or teaching (Wiles et al., 2011).
- Grounded Theory: This is a qualitative research method which involves deriving patterns from data. As a result, interviews can be transcribed, coded and then grouped in accordance.
- Ethnography: Within this research, the researcher conducts the research from the perspective of the people being observed and aims to understand these differences. This method is utilised to study cultures and historical societies.

3.5.1 Study Research Strategies /Designs

The research undertook a case study strategy as the research focuses on one mega construction project in South Africa with the intention of understanding the interface challenges faced and how they could be improved. Only one mega project was selected for the study due to the magnitude and complexity associated with the project to give more insight regarding the issues regarding interface challenges on the project. Another reason for the selection is that the project is still underway and is faced with a number of challenges as a result of the integration issues within the project and the number of main contractors that are on site.

3.5.2 Critical case study

Crowe et al. (2011) indicated that a case study is useful to use when there is a need to gain detailed knowledge regarding a certain research area in its real life context. According to Bromley (1990:302) a case study is “systematic inquiry into an event or a set of related events which aims to describe and explain the phenomenon of interest”. The critical case study provides an in-depth investigation and allows for in-depth investigation of data within a

specified context. Tellis (1997) reported that a critical case study method assists in understanding and analysing the procedure and consequence of a phenomenon through complete surveillance, reconstruction and examination of the case study under investigation. Jacobsen (2002) described that these case studies are conducted to provide a holistic picture of a possible event or situation. Meanwhile, Yin (2009) commented that case studies complement the strengths and confinements of other types of research. The use of case studies as a research method has been stated to be a legitimate research method which can cater for both qualitative and quantitative research methods especially in resolving processes that are within wider social context (Cronin, 2014). It has been identified that critical case studies allow for testing of real life situations as they happen in practise (Flyvberg, 2006) and that in-depth investigations provide detailed analysis (Lindvall, 2007) while ensuring that detailed and relevant data gathered while understating difficult situations.

3.5.3 Limitations of critical case study

Flyvberg (2006) argued that the case study method can often give rise to an issue of validity and reliability in terms of the data obtained. Murphy (2014) expressed that the challenge with single case studies is in that the results obtained from the case study can neither be confirmed nor denied when it comes to validity and reliability. Flyvberg (2006) further commented that it is somewhat difficult to generalise from a single case and the data obtained is too narrow to be utilised scientifically. Yin (2009) further commented that the limitations on these studies are in their lack of precision as the investigator tends to not follow systematic processes. Krusenvik (2016) concluded that the critical case study method like any other research method has both its advantages and disadvantages.

3.5.4 Adopted research designs

For purposes of the research a critical case study research method was selected as a result of the selected area of study and as well as the population selected to participate in the study. This study focuses on a mega construction project and as a result access was obtained for conducting research within this project which was mainly why the project was utilised to gather data regarding the research area. In achieving objective one of the research, literature was studied and analysed and the main types of interfaces that exist within mega projects

were identified. The objective was further unpacked through the responses received from the structured questionnaires. For objective three the strategies being utilised within the selected project were identified together with their benefits and challenges. Improvements to these strategies were further identified by the participants, which then led to development of the stage gate workflow for managing interfaces.

3.6 Research Choices

Research choices include the mono method, mixed method and multi method (Saunders et al. 2009).

3.6.1 Qualitative Research

The qualitative approach investigates how the respondents interpret their own reality (Banister et al., 2011). Further, qualitative research examines the meaning of social phenomena rather than seeking a causal relationship between variables (Feilzer, 2010). Marshall (1996) further stated that qualitative research provides an understanding of complex psychological matters that assist in answering explanatory questions such as how and why. Ultimately, qualitative research seeks to collect and analyse data in a variety of methods mostly non numerical.

Hennink et al. (2010) summarised the qualitative research cycle into three distinct phases namely the design phase, the analytical phase and the ethnographic phase as represented in figure 3.1.

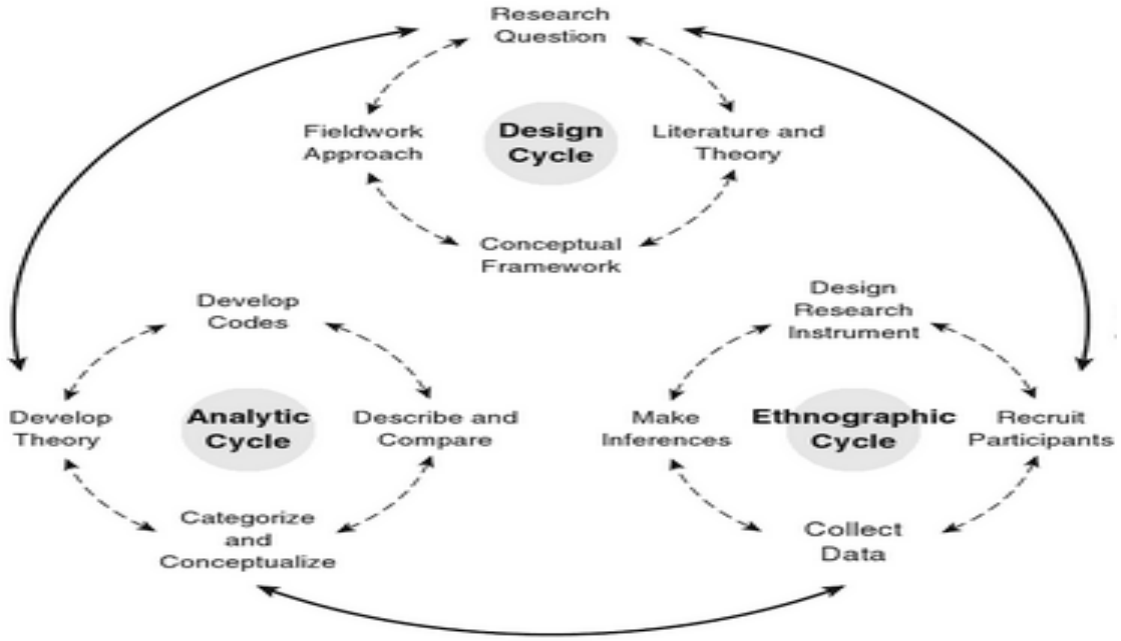


Figure 3.1 Qualitative research cycle
Source: Hennink et al. (2010)

Further, it is noted that qualitative research is beneficial in studying new topics, understating difficult matters, clarifying people's beliefs and their associated behaviour and also for sourcing out and understanding the social and cultural norms of a society. English et al. (2003) stated that qualitative data can be founded on opinions and perceptions. Qualitative research is therefore interpretive as the researcher seeks to analyse and interpret the responses received from the study participants.

3.6.2 Quantitative research

Quantitative research is concerned with quantifying a certain phenomenon through generating numerical data or data that can be converted to statistics (Monfared and Derakshan, 2015). Murray (2003) stated that quantitative research uses numbers and statistical methods as the researcher seeks to test a casual hypothesis. Quantitative research can also be adapted using graphs and charts to provide a clearer view of the results obtained. Denzin (2000) further stated that quantitative research is inflexible but it is this inflexibility that opens room for comparison of results received but one needs to know the suitable questions to ask and the manner in which they should be asked.

Quantitative research can thus be mainly summarised into identifying the research problem, reviewing the literature and the describing the theoretical framework. Qualitative and quantitative research can further be distinguished as summarised in the Table 3.5.

Table 3.5 Differences between qualitative and quantitative research

	Qualitative research	Quantitative research
Objective	To gain an understanding of the underlying reasons, beliefs, motivations	To quantify data and extrapolate results to a broader population
Purpose	To understand why? How? What is the process? What are the influences or contexts?	To measure, count, quantify a problem
Data	Data are words	Data are numbers or numerical data
Study population	Small number of participants or interviewees, selected purposively Referred to as participants or interviewees	Large sample size of representative cases
Data collection	In-depth interviews, observations and group discussions	Referred to as respondents or subjects
Analysis	Analysis is interpretive	Analysis is statistical
Outcome	To develop an initial understanding, to identify and explain behaviour, beliefs or actions	To identify prevalence, averages and patterns in data. To generalise to a broader population.

Source: Hennink et al. (2010)

The research utilised a case study approach using quantitative research method through the use of a structured questionnaire utilising both open and closed ended.

3.7 Data Collection

The collection and analysis of data is dependent on the methodological approach which has been used for the study (Bryman, 2012). Saunders et al. (2009) reiterated that the process used at this stage of the study contributes a great deal to the reliability and validity of the research. Thus the data collected can be classified into primary and secondary data. Mooi and Sarstedt (2011) defined primary data as data being collected by the researcher for a particular purpose while secondary data is data collected which is being derived from another researcher for a different objective.

3.8.1 Secondary Data: For purposes of the study the data was collected through existing literature to help put focus on the study. These sources were observed through existing books and internet digital forms. Existing documentation relating to the particular project was used.

- Secondary data was collected from published publications (textbooks, academic journals, industry reports, and library and internet data).

3.8.2 Primary Data: The primary data in relation to the research was achieved through the use of questionnaires (inclusive of both multiple choice, open and closed ended questions) in order to meet the objectives of the research.

3.8 Study Elements

3.8.1 Population and Sampling

Polit and Hunger (1999) defined a population as the entire objects, subjects or members that follow a specific set of specifications. The population can also be referred to as a complete set of people or objects that embody the same unique characteristics as set out within the sampling frame of the research. Sampling data is favoured as it allows for a more accurate investigation and easily gets rid of unwanted data (Blumberg et al. 2008). It is also vital to ensure that the selected sampling methods for the research are not biased. The selection of a sampling technique is dependent on the research problem. It can either be probabilistic or non-probabilistic. The initial step in probability based sampling is deciding on the population where results will be obtained (Doherty, 1994). Further, within this selection the members of the population to be observed all possess an equal chance of being selected. While non-

probabilistic sampling does not give all members of the population an equal chance to be selected (Alvi, 2016). The population is selected using a certain criteria.

Table 3.6 displays the different methods associated with probability and non-probability sampling.

Table 3.6 Sampling

Probability Sampling	**Non probability sampling**
• Simple Random Sampling • Cluster Sampling • Multiphase sampling • Systematic Sampling • Stratified Random Sampling • Multistage Sampling	• Accidental Sampling • Quota Sampling and • Purposive Sampling

3.8.2 Population and sampling for the study

For purposes of this study a non-probabilistic sampling method was utilised and the sample was selected using purposive sampling. Purposive sampling can be defined as a method of selecting specific individuals from a group of people and using them as a sample (Etikan et al. 2015). The selection of this sampling method can also be influenced by the researcher's knowledge of the population of the study. Polit and Beck (2010) stated that purposive sampling is dependent on the researcher's knowledge about a particular population, which is then used to handpick the sample. Further, the advantage to this is that individuals, who are knowledgeable about the study, can be easily selected.

For meeting the three objectives of the study purposive sampling method was selected. The sample for the study was ten main contractors with the highest rand value (work package cost) on the selected project site. For purposes of this study main contractors are termed specialist contractors. The selected site is of a large scale and has (+-) 50 work packages all being executed by different specialist contractors. All these contractors have direct contracts with the client. The sample for the study was selected from this target project population of (+-) 50 specialist contractors on the site under investigation.

3.9 Data Collection and Analysis

Kothari (2004) stated that the analysis of data requires three steps including: (1) preparation of the data for analysis, (2) analysis of the data, and (3) interpretation of the data (drawing conclusions against objectives of the study).

3.9.1 Data sources

a. Interviews: Interviews use a set of pre-planned questions for gathering information through oral quiz. Interviews provide a way of communicating with respondents which offers more detailed insight into the study and allows for rich and valuable data to be obtained.

b. Unstructured interviews: Interviews provide a platform for the interviewer to put forth open ended questions and allows the person being interviewed to honestly express their thoughts.

c. Structured interviews: The interviewer uses questions which have been prepared beforehand to ask questions. These questions are in most cases closed ended questions which require precise answers.

d. Semi structured interviews: This is a combination of both structured and unstructured interviews and utilises both open and closed ended questions.

e. Focus groups: This interview occurs through interaction with a group of people. Such an interview can be requested after individual interview have been conducted to further explore the gathered information.

f. Questionnaires: The advantage of questionnaires is the ability to reach a wider population group through distribution. This allows for more data to be collected but is restrictive in that the questionnaire cannot be customized to suit different participants partaking within the study.

The data was collected through the use of structured questionnaires inclusive of both multiple choices, open and closed ended questions. This method was chosen due to its anticipated response rate from the selected sample size on the project as the project is under urgency and participants tend to be busy on the project.

3.9.2 Adopted method for data collection

Data collection for the objectives of the study was achieved through the use of structured questionnaires administered through a cross sectional survey. The questionnaires with their cover letters were sent using a survey site to ten specialist contractors on the site. 50 questionnaires were distributed overall, with only five questionnaires being sent to each specialist contractor. The specialist contractors on the project specialise in civil, mechanical, electrical, structural and C&I making their responses vast. The questionnaires were distributed to the sample participants on the selected project on three occasions to try and improve the response rate received each time.

The returned questionnaires (36 out of 50) were analysed through descriptive statistics using frequency distributions in the form of bar, pie charts and frequency tables. Explanations were then employed to provide analysis of data obtained from the field to give meaning to research findings. This method allowed for compression of the huge data obtained into easily analysable results. Results obtained were scanned and stored in a computer with a password for future reference and hard copies were destroyed.

Table 3.7 Summarises the returned questionnaires as per the selected sample,

	Contractors Respondents				
Company	**Project manager**	**Construction manager**	**Engineer**	**Planner**	**Other**
1	2		1	2	
2	1		1	1	
3			1	2	
4	2		1	2	
5	1		1	1	1
6			1	1	
7	1		1	2	
8	1		1	1	
9	1		1	1	
10	2		1	1	
Total	**11**	**0**	**10**	**14**	**1**
	22%	**0%**	**20%**	**28%**	**2%**

3.10 Ethical considerations

The ethical considerations of the research conducted were as follows,

1. Consent was obtained from the project director of the site to conduct the research;
2. Ethics clearance was obtained from the university through the application process and the submitted ethics form was submitted and cleared by the university. A clearance certificate as attached in Annexure B was submitted;
3. There was no financial compensation given to the respondents which could have in anyway influenced their responses;
4. Each questionnaire had an attached consent form indicating the purpose of the study and guidelines associated (Annexure A);
5. Research was planned to maintain an unbiased and neutral approach both in the conduct and reporting of the findings of the study;
6. The research data obtained was kept confidential and stored in a secure computer;
7. The parties names were not revealed without any permission and information obtained was used solely for the research and participants were alerted of this; and
8. All materials were referenced properly to avoid any plagiarism.

3.11 SUMMARY

This chapter set forth the research process undertaken for the study inclusive of research approaches, strategies, data types and adopted collection methods, the population and sampling techniques. This chapter demonstrated how the research questions and issues raised in previous chapters were investigated. The research utilised a case study research method using structured questionnaires as the tool adopted for data collection; the questionnaires were distributed to the different package teams on the selected project.

CHAPTER 4: DATA COLLECTION AND PRESENTATION

4.0 Introduction

The literature reviewed within this study provided an in-depth description together with a theoretical framework for this research. This chapter presents the data analysis and findings of the research conducted as part of the field work. It discusses results obtained from the respondents. The research analysis will start by reviewing the received data. The selected sample has been broadly discussed within research methodology in the preceding chapter. The results present quantitative data results obtained from the distributed questionnaires with respect to the objectives and the first section of the questionnaire explores the general information of the participants taking part in the research. The questionnaires sought out to dissect the research topic with the aim of obtaining the relevant data required to address the objectives of the research.

CASE DESCRIPTION

For this research, a mega construction project in South Africa was selected based on the type of project and having been granted permission to execute the research using the project as case study and for purposes of confidentiality the project will be named Project A. Project A is infrastructure power delivery project which consists of several disciplines namely civil, structural, mechanical, electrical and C&I. The project is being executed by multiple specialist contractors as there are (+-50) work packages on the project and these contractors have been directly contracted by the client. The current cost for the project is R180 billion. The project met all the requirements of a mega construction project having (+-50) specialist contractors on site each undertaking work using either the traditional, design or build, deign bid build route. The project budget was set at above a billion rands and this budget has continued to increase as a result of the challenges that have been realized within the project. Project A was selected for the study as it embodied all the characteristics of a mega construction project including complexity, scale, multiple contractors, program urgency, duration over five years, level of risks and uncertainty and so forth and is part of the current mega projects being constructed within the country.

4.1 Characteristics of respondents

Part 1: Questionnaire

The aim of the questionnaire was to understand the view of the selected project regarding interface management. The challenges arising out of the complexity of the project and its impact on project interfaces and as well as understanding the current status of how interfaces are dealt with within the project. For purposes of the research, 50 questionnaires were distributed to ten contactors on site with each contractor being accountable for 5 questionnaires. Out of the questionnaires sent out only thirty six where received back constituting a response rate of 72%. The questionnaires were sent out on more than one occasion to try and increase the response rate received each time.

Saldivar (2012) developed a table showing the acceptable response rates for varying methods of survey study as presented in table 4.1,

Table 4.1 Prime Response Rate Survey

Survey mode	**Response rate**
In person	80-85%
Phone	80%
Mail	50% -70%
Email	40 – 60%
Online	30%

In accordance to table 4.1, the response rate for online surveys must at least be 30% while Hamilton (1999) also notes that online surveys average a response rate in the range of about 30%. For purposes of the research the questionnaires were sent out using emails to ensure that all individuals had access to the questionnaires and clarity could be easily provided regarding the questions.

Survey Results

4.2 Questionnaire Survey Results

4.2.1 General Information of respondents

Table 4.2 represents the characteristics of the participants from the selected group of specialist contractors on Project A.

Table 4.2 Characteristics of respondents

Profession	**Frequency**	**Response Percent**	**Cum. Percent**
Project Manager	11	31%	31%
Construction Manager	0	0%	31%
Engineer	10	28%	59%
Planner	14	38%	97%
Other (please specify)	1	3%	100%
Age of respondents			
Below 25	0	0%	0%
25-35	17	47%	47%
36-40	11	31%	78%
40 and above	8	22%	100%
Qualifications			
Diploma	7	20%	20%
Bachelors	21	62%	79%
Masters	4	12%	91%
Other (please specify)	2	6%	100%

The respondents were requested to specify their designation, age and qualifications. The highest numbers of responses received were from individuals between the age group of 25-35 (47%) and 36-40 (31%) indicating an experience level on more than 5 years. More than half of the respondents possessed their bachelor's degree (62%) and less than a quarter are working as planners (38%) and project managers (31%) on the project. It was gathered that some of the respondents acquired their qualifications and some experience from abroad while

others acquired them within the country and most of the respondents had studied engineering, construction and project management. Ultimately the professionals involved in the project are qualified and have relevant experience.

4.2.2 What is the estimated cost range of your project?

The first part of Table 4.3 provides breakdown of the respondent's projects in terms of monetary value.

Table 4.3: Project cost ranges and procurement routes

Project cost ranges	Frequency	Response Percent	Cum. Percent
>1BN	22	60%	60%
500M-1BN	9	26%	86%
100M-500M	4	11%	97%
<100M	1	3%	100%
Procurement			
Traditional method	3	9%	9%
EPCM	7	19%	28%
EPC	7	19%	47%
Design &build	13	36%	83%
Design bid build	6	17%	100%

Above 60% of the respondents indicated that their involvement was in packages with a cost of above a billion rand. The exchange rate at the current date is 1ZAR=0.080USD and 1ZAR=0.060GBP. It has been noted within the literature review that projects that are more than a billion dollars are considered to be mega projects, and in this case 60% of the work packages are above a billion rands thus pointing out the level of complexity associated with the individual work packages themselves and thus the project as a whole.

The second part of the table represents the procurement strategies that are utilized within the project which include Engineering, Procurement, Construction and Management, and Engineering, Procurement and Construction, Design and build, Design bid build. Different procurement strategies exist on the project as a result of the complexity of the project and the specialized nature of the scope thus contributing to the difficulty of dealing with interfaces. On Project A the selected contractors are using FIDIC red (construction) or yellow book (design and build) and NEC3 contracts as a result of the different procurement strategies. The project consists of both local and international contractors. Most of the respondents selected design and build (36%) as the strategy used on their projects.

4.3 Project Complexity

Understanding the level of complexity associated with the project is essential in understanding the scale of interfaces that might exist within the project as discussed in earlier chapters. Project complexity is a crucial area that must be evaluated in order to better understand the types of interfaces arising from the project (objective 1) and the sources that might bring about challenges as a result (objective 2).

4.3.1 What is the level of complexity associated with your particular work package?

High: Scope of work is highly complex

Medium: Scope of work is a bit complex

Low: Scope of work is not complex

Figure 4.1 illustrates the level of complexity associated with the work packages within the project site.

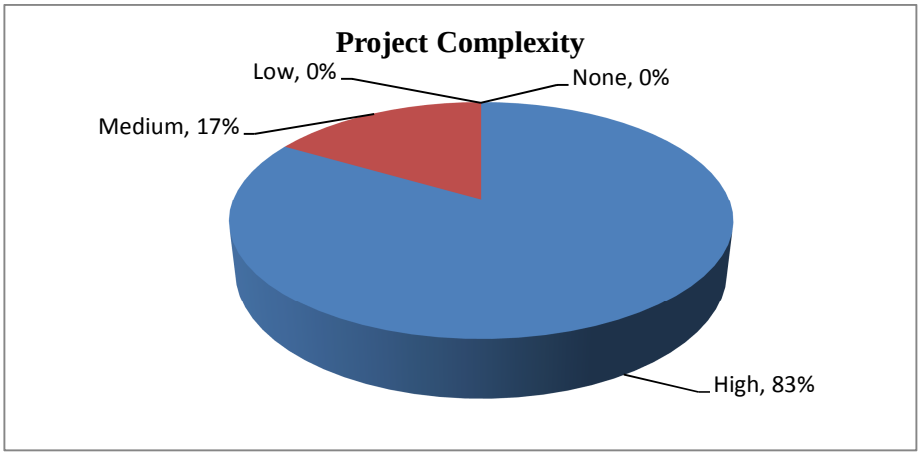


Figure 4.1: Complexity level associated with projects

A high number of the participants (83%) agree that the complexity associated with their work package is high as a result of the nature of the project being executed which includes different work packages such as buildings, boilers, turbines, conveyors, dams and so forth. It was reiterated that this complexity can be linked to the scale of the project, advanced technologies and complexity of the scope of work. It can be seen from figure 4.2 that the cost of the work packages can be somewhat related to the complexity of the project. This can be evaluated through the cost of the projects above 1BN being 50% while the complexity associated with packages on the project is also above 50%. A slightly lower number of respondents (17%) stated that the level of complexity associated with their work packages is medium.

4.3.2 Main challenges faced by your organisation as a result of project complexity?

Figure 4.2 represents the major challenges being faced by mega construction projects globally with the aim of drilling down into the major challenges being faced on the selected project site.

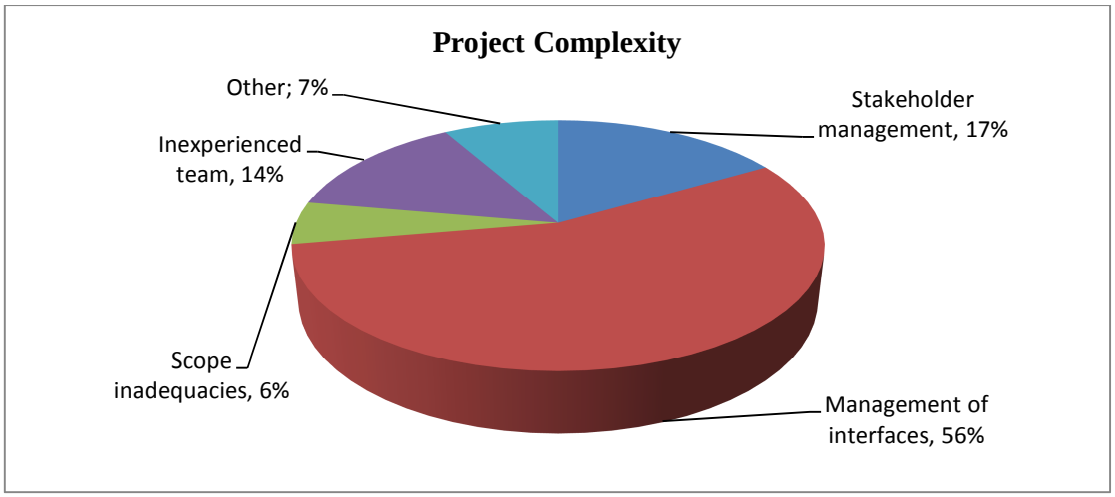


Figure 4.2: Project complexity challenges

When questioned about the challenges faced on the project as a result of the project complexity, majority of the contractors (56%) have selected management of interfaces as a major challenge facing the project. The management of interfaces is a challenge facing mega projects globally resulting from the large number of stakeholders within the project both local and international. Stakeholder management (17%) has been noted as another challenge facing the project together with the inexperience of the different project teams (14%). It has been noted within literature that stakeholder management can be better improved through interface management which identifies all project stakeholders and seeks to formalise communication between them.

4.3.3 Occurrence level of the complexity challenges

(1-Not occurring, 2- least occurring, 3- most occurring, 4- high occurring, 5- very high occurring)

Figure 4.3 represents the level of occurrence of the different major challenges noted for mega construction projects by the respondents.

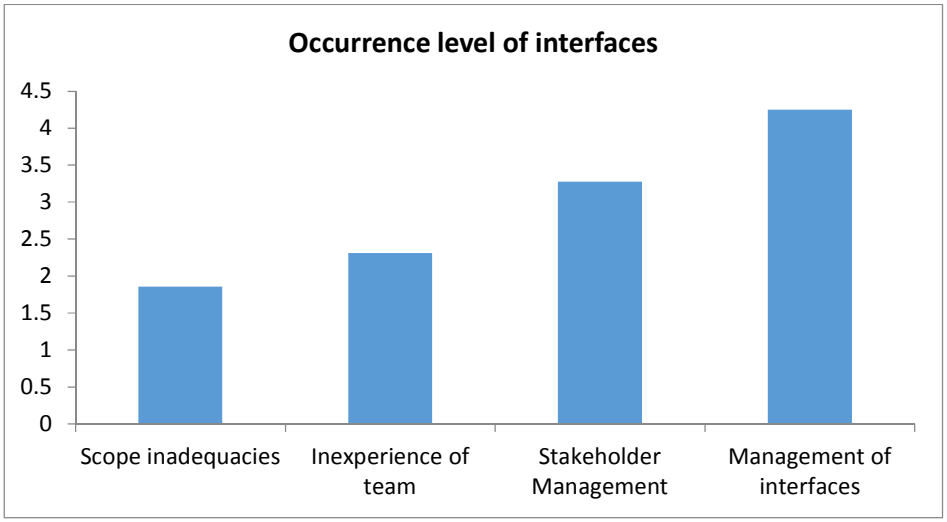


Figure 4.3: Most ranking challenge (Mean)

Herein, the received data indicated a high occurrence level for the management of interfaces on the site represented by a mean of 4.25. The respondents have noted interfaces as being a major challenge on the project and as noted previously this high occurrence could be a result of the project complexity, scope of work packages, local and international stakeholders, different procurement and contracting strategies, different designs and systems, different level of experience and so forth. The participants have also noted stakeholder management (3.28) as a challenge on the project as a result of the number of existent stakeholders both local and international. Olumolaiye and Chinyio (2009) described stakeholder management as the process of identifying stakeholders with interest in a project and identifying a plan to engage those stakeholders to ensure that they are aligned and that all objectives are met. It was highlighted that the major challenge is in ensuring that the objectives of the project are aligned to the objectives of stakeholders and that the urgency of the project is balanced with the views of the stakeholders. In addition the respondents have identified the inexperience of project teams (2.31) as a most occurring challenge on the project. Although it has been noted as least occurring (1.86) it was stated that on project within the contract there are requirements supporting local skills upliftment where contractors need to subcontract a portion of the work or get into joint ventures with less experienced contractors. These

requirements has thus brought forth its own hindrances in that some of the local contractors are inexperienced and take longer in executing task, have no understanding of contract law, cash flow management, scheduling and so forth. Lastly, the respondents have also noted scope inadequacies as least occurring when compared to the other noted challenges on the project. Ultimately it can be concluded from these results that the management of interfaces is a real problem on the project and the other challenges noted also have an impact on the management of interfaces as all challenges on the project indirectly or directly impact the management of interfaces.

4.4 Project Interface

4.4.1 What does the word interface mean to you?

Figure 4.4 sought to evaluate how contractors within the site defined an interface in order to evaluate if the participants understood what an interface is.

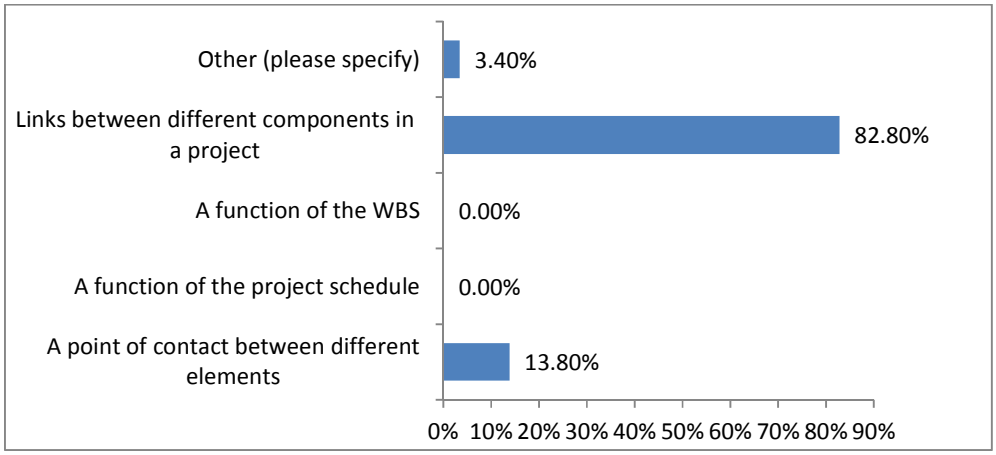


Figure 4.4: Interface definition to respondents

It was found that the word interface is defined differently among different work package. It was found that 83% of the respondents described an interface as a link between different project components in a project. This definition is supported by Shokri et al (2012) and Khadimally (2011) who defined an interface as links between different components in a project communicating with each other. It can be concluded from the results that the respondents understand the meaning of the word interface as also noted by definitions under the literature review.

4.4.2 No. of interface relationships among work packages

Table 4.4 sort out to understand the interfaces being faced on the different work packages through establishing the number of interfaces the work package have.

Table 4.4 Number of contractor interfaces

No of contractor interfaces	Frequency	% Response	% Cum response
=<10	0	0%	0%
=<20	0	0%	0%
=<30	36	100%	100%

On a mega construction project there exists thousands of interfaces between the different project elements (construction, phases, stakeholder, and designs). All the respondents stated that the numbers of interfaces they are involved in are more than 30, reflecting the level of intensity associated with the different work packages. There is a correlation between the complexity of the project and the number of existent interfaces on the project. A high number of interfaces are borne from a complex scope of work as the stakeholders involved in the execution are all geographically dispersed and all systems/components all interface with each other to produce the required project.

4.4.3 What type of interfaces exists within your work packages and between the project at large?

Figure 4.5 illustrated the types of interfaces that exist within the project.

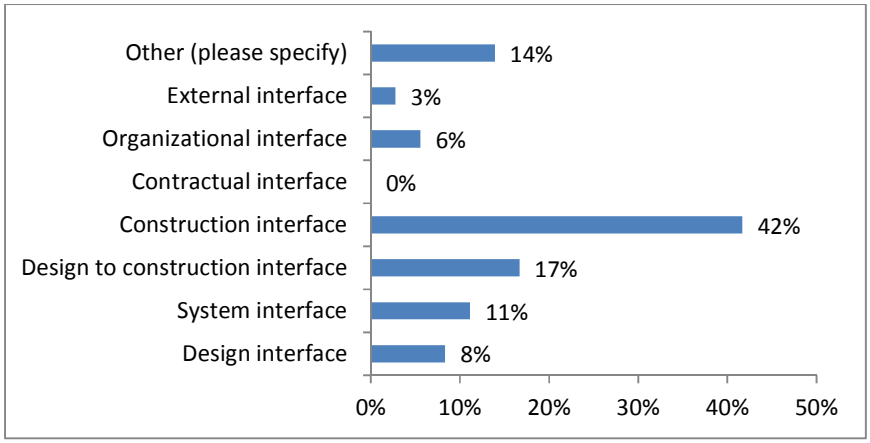


Figure 4.5: Interfaces that exist within the project

Results of the study showed that majority of the respondents indicated the construction interface (42%) as the most occurring interface within the project. The construction interface can be attributed to the scope of work as contractors need to work simultaneously or in

parallel within the same work areas, taking into account the cut off points for different activities. On this project, weekly integration meetings are held which serve as a platform for requesting and discussing incoming and outgoing interfaces. This opportunity does not provide a thorough solution as contractors do not have access to the complete view of the project to enable them to plan ahead for their interfaces. The second highly ranked interface (17%) is the design to construction interface which is a major cause of scope inadequacies if not aligned which creates time wastage in having to revise designs prior to construction. Mardones and Alarcon (1988) identified the main problem as the lack of interaction between the design and construction team during the pre-planning phase. These interfaces are mainly discussed informally between the engineers, the construction managers, planners and superintendents.

The forth ranked interface by the respondents (11%) is the interface between different systems that exist within the project as each work package consists of a number of systems which from part of the bigger project systems. The two lowest ranking types of interfaces are the organisational (6%) and external interfaces (3%).

4.4.4 Identification of the main sources of interface challenges on the work packages

Table 4.5 summarises the responses of all the respondents, a number of issues were found with regard to the selected project. The sources identified included,

Table 4.5 Sources of interface challenges

Sources	**Respondents**
Poor scope identification from tender	3
Different contracts and procurement strategies	4
Constructability	2
Scope gaps and access issues	5
Work packaging and scheduling	5
Poor coordination and lack of planning	6
Lack of Master schedule of Client to contractor	4
Wrong information and groups working in silo`s	5
Ineffective package interface management	7
Communication and Coordination issues	7
Design challenges between the different Contractors for	6

different systems	
Integration work interface between the systems, electrical, control and instrumentation and the process system	1
Interface to an environment and the permit issues from Government	1
Site access	3
Construction - Package to Package	10
Misalignment on placing the packages and poor planning	5
Communication and Coordination issues;	5
Lack of project management;	1
Finance;	1
Lack of proactiveness	2
Contractors not meeting interface dates;	10
Poor quality between contractors at the interface;	3
Communication between internal parties;	5
Design team, Construction/ Execution Team and end-user;	3
Contractors not finishing work to implement an agreed interface schedule;	2
Lack of scope integration and system integration in different packages;	6
Lack of skills;	2
Clarifying interfaces with other discipline; and	1
Inadequate resource & time planning, inclement weather, inadequate designs, unforeseen site conditions.	3

4.4.5 Stage of the life cycle when interface management needs to be introduced

Figure 4.6 provided insight into the phase that the respondents rendered suitable for implementation of interface management.

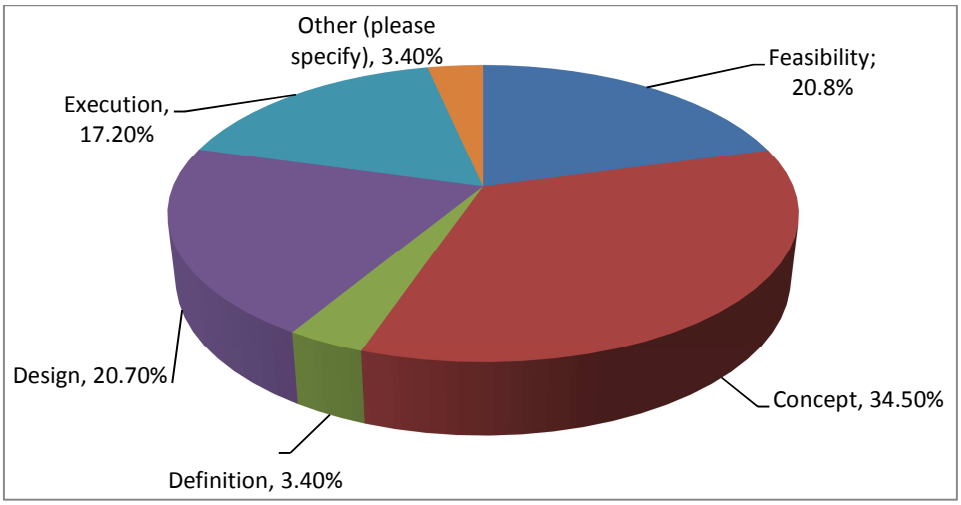


Figure 4.6: Implementation on interface management

The respondents indicated in figure 4.6 that interface management needs to be implemented from the concept phase of the project (34.5%) to avoid any misalignment with regard to interfaces that might possibly occur within the project. Shokri (2015) has identified the importance of front end planning on mega projects in order to ensure alignment of the different elements of the project. The feasibility phase (20.8%) and the design phase (20.7%) have also been found by the respondents as the phases where interface management needs to be implemented while (17.2%) of the respondents noted that interface management needs to be accounted for during the execution phase. This poses a challenge as interfaces cannot be dealt with as work progresses but should be dealt with prior to construction even starting. Interface management sets out the platform for bringing different elements of the project together. Identifying interfaces during execution does not allow for proactive identification and mitigation of any interfaces; thus, providing time wastage during the execution phase. Only few (3.4%) of the respondents indicated that interface management must be introduced during the definition phase while others (3.4%) indicated that interface management must be adopted at all stages of the project life cycle as projects are always changing.

4.5 Strategies used to manage interfaces on the selected project site at organizational and project level

Different projects deal with interfaces in different ways but mainly through the use of schedule, meetings, 3d models and so forth. It is important as the project team to understand the different types of interfaces to be encountered on a project in order to have relevant strategies in place to deal with them. This question sought to identify the mostly widely used strategies for dealing with interfaces within the project on both project and organisational level.

4.5.1 Organisational level interface

Table 4.6: Organisational interface

Strategy	Frequency	Response %	Cum Response%
Work plan	5	14%	14%
Face to face meetings	16	44%	58%
Emails and phone calls	7	19%	78%
Interface Agreements	3	8%	86%
Other (please specify)	5	14%	100%

In accordance to Table 4.6 face to face meetings (44%) were the mostly used method for dealing with interfaces between the stakeholders within the organisations. It was highlighted that this method is preferred as it allows for clarity to be provided at the meetings and for issues to be raised and addressed. The downfall to this method is having to wait for the allocated meeting times and not being able to foresee and address issues at the very instance they occur or even prior to occurring. The second most preferred method for dealing with organisational interface is emails and phone calls (19%). This method is preferred due to the ease of communication which can be done instantly as and when issues occur. These two methods provide a disadvantage in that they do not provide a common database where all the organisational interface issues are logged; thus, allowing each member a chance to address their interfaces on time.

The third most used method for dealing with stakeholder interface is the work plan which sets out the work to be executed by the individual for that particular work package. This method also neglects to bring about integration between the different departments and levels within the organisation which can pose challenges if there are no interfaces. Others (14%) have indicated that they use all the listed methods to deal with organisational interfaces whilst only

8% have listed interface agreements as the methods they use. Caglar et al. (2007) stated that interface agreements monitor the exchange of information produced by one party and is needed by another party. Further Caglar et al. (2007) stated that interface agreements foster integration between project participants and ensure that execution excellence is reached.

4.5.1.1 Benefits and challenges faced by participants with relation to their above selected strategy

a. Work Plan

A total of 14% of the respondents selected work plan as one of their strategies used in managing interfaces at organisational level. The respondents noted that the work plan allows for consideration of interfaces early in the process, allows for efficient planning and communication between parties and also for parties to understand their interfaces with other disciplines.

Secondly, the respondents noted that the challenges of using the work plan is that people do not stick to their schedules and thus commitment dates are not met. Another challenge that was noted is the change of project team from time to time which impacts the performance of the project. Lastly, the respondents indicated that lack of foresight planning causes everyone to kill fires everyday instead of planning ahead.

b. Face to face meetings

A total of 44% of the respondents noted face to face meetings as the strategy used for organisational interfaces. The respondents expressed that face to face meetings are more effective as they allow for documentation of discussions and agreements. Another noted benefit was that issues get resolved quicker within these meetings thus combating any interface delays. Other respondents also noted that these meetings allows for clarity of issues between parties and allows for team collaboration between different disciplines.

The disadvantages noted by the respondents are that these meetings take people away from supervising the works. Secondly, it was indicated that other vital members of the project teams do not attend these meetings which poses a challenge. Lastly, the project participants come to the meetings unprepared and not knowing what is due from their end.

c. Emails and Phone calls

A total of 19% indicated that they deal with organisational interfaces through the use of emails and phone calls. The respondents noted that the benefit of emails and phone calls is that they enable record keeping of agreements between individuals. Secondly, they stated that emails allow for information storage and provide a manner for clarifying issues that are unclear within the project documents.

The disadvantages noted by the respondents for emails and telephone included misinterpretation of information between project participants. Secondly, if emails are not paid attention too for clarity time is wasted awaiting clarity.

d. Interface Agreements

A total of 8% of the respondents selected interface agreements as the strategy they use at organisational level for dealing with interfaces. The benefits noted by the respondents for this strategy was that interface agreements allow for transparency between project participants in terms of identifying the carrier of the interface. Secondly it was noted that this strategy allows for follow up participants should there be a delay in closing interfaces as the agreements serve as a tracker into the responsibilities of project teams.

The disadvantages indicated by the respondents for interface agreements was that the scope of work is huge in mega projects and sometimes there is no time for filling and agreeing of interface agreements as a result of project urgency.

4.6 Strategies used by respondents to manage interfaces at the project level on their work packages

Figure 4.7 sought to understand the strategies utilised for management of interfaces by the respondents at the project level.

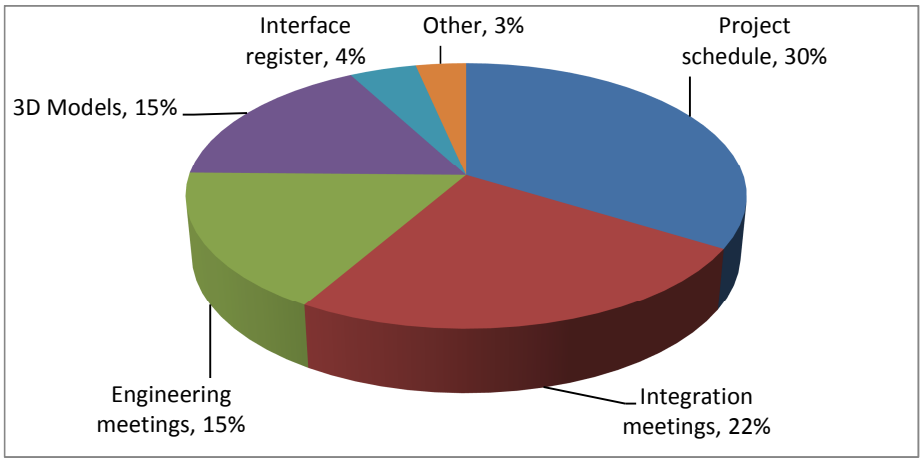


Figure 4.7: Interface management strategies

When asked regarding strategies to manage interfaces at project level, the respondents indicated in figure 4.7 that the project schedule as the highest (30%) ranked strategy for managing interfaces, as the project schedule brings together all the different elements of each work package. Problem with the master schedule of the project it is not a live document where all contractors have access to view the changes and be able to notice changes to any interface or dates. This is due to the client and the contractor chasing different dates and using a resource loaded schedule from contractors side and non-resource loaded schedule from client's side.

Integration meetings (22%) were ranked as second highest form of dealing with interfaces on the project. Interfaces meetings are held on a weekly basis on the project where each of the different contractors' representatives attends (planners and construction team). The meetings take into account all interfaces to be encountered for a certain period and also to note if the contractor that has the interface will be able to handover that interface to the other contractor. Engineering meetings are also held on a weekly basis to deal with all engineering interfaces as well as engineering to construction interfaces. The project schedule on the project is used as the main tracking tool for interfaces and provided information on incoming and outgoing interfaces on the site. 3D models (15%) were also noted as a strategy for managing interfaces. On site models are done using Navisworks programme which incorporates all model designs received from the contractors to identify clashes between various work packages.

Whilst 15% stated that engineering meetings are used for interfaces, this task is handled by the client's team to review all interfaces existing within the designs to avoid any occurrences during execution. Finally other respondents (4%) noted that the keep interface registers, this would highly depend on the scope of the project. Lastly 3% indicated that they use each of the above mentioned methods as strategies for interface management.

4.6.1 Benefits and challenges of the above selected interface management strategies

a. Project Schedule

A total of 30% of the respondents selected the project schedule as a strategy for dealing with project interfaces. The benefits noted by the respondents were that the project schedule allows parties to go through incoming and outgoing interfaces so as to know when to provide an interface and when to exit an interface. It allows for different project teams to know who they are interfacing with and the durations provided for those interfaces.

The challenges indicated by the respondents was that the schedule provides no accountability as interface dates keep on shifting if a contractor is unable to provide the interface. The contractor doesn't always honour their schedule.

b. Integration meetings

A total of 22% of the respondents selected integration meetings as a strategy used to manage project level interfaces. The respondents noted that integration meetings provide a platform where all contractors can discuss their interfaces and the challenges and any delays that might occur as a result. The respondents noted that this allows all contractors to plan ahead.

The challenges noted by the respondents as a result was that integration meetings do not hold the contractors responsible as a contractor can keep on shifting the date thus delaying all other contractors without any accountability. Secondly, the respondents noted that not all key project team members attend these meetings and as a result clarity regarding other issues cannot be obtained immediately.

c. Engineering meetings

A total of 15% of the respondents selected engineering meetings as their strategy of manging with interfaces. The respondents indicated that engineering meetings provide platform for clarifying all engineering issues including interface issues as a result of designs and system and any construction clashes.

The respondents noted that engineering meetings are not open to all project team members and some changes made within these meetings are sometimes not updated within the schedules thus causing delays as a result.

d. 3D models

A total of 15% of the respondents noted 3D models as a strategy being used to manage project level interfaces. The respondents noted that the benefit of using 3D models is that they assist you in detecting any clashes that exist within the work package if all the drawings uploaded are the latest revisions. Secondly, the respondents noted that the 3D models enable project teams to understand the scope of work better in that being able to identify interface issues.

The respondents noted that the challenge of using 3D models is that sometimes the latest drawings are not uploaded in the system which at times creates interface issues in the long run as clashes are not identified in time. The respondents also noted that not all team members are granted access to these models.

e. Interface register

A total of 4% of the respondents noted that they use interface registers for managing interfaces. The respondents noted that interface registers provide a platform for recording all interfaces that exist between the different project teams. This enables project teams to keep track of all interfaces that are incoming and outgoing. The respondents also stated that this mechanism ensures record keeping of all interfaces and usually provides reminders to owners of the interface.

The respondents also expressed that the disadvantage to the interface register is that not everyone pays attention to it and other interfaces are not updated within the register which provides a challenge.

4.7 Ways of improving interface management on a mega construction project

Table 4.7 shows the participants suggestions when asked for ways in which the interface management on the site can be improved to allow for better co-ordination and management of interfaces. All the respondents contributed to the following,

Table 4.7 Improvement methods

Improvement methods	**No of respondents**	**% responses**
Develop a complete interface matrix	5	14%
Regular interface meeting between all packages need to be held	5	14%
Building Information Management (BIM)	5	14%
Proper scheduling with integrated schedule showing all interfaces	6	16%
Comprehensive governance	5	14%
The project need to be detail planned during execution where the packages and the interface must be facilitated. With the project goals and positive action incentivised;	5	14%
There is a need for properly defined interfaces contractually	7	19%
There is a need for an interface department within the site to assist in the management of interfaces	9	25%
More focus must be put on the pre planning stage of the	6	16%

project		
less contracts on the project	3	8%
proper development of the schedule based on WBSs	1	2.7%
alignment between the design and construction phase	6	16%
Interface management needs to be introduced earlier in the project	9	25%
Better stakeholder management	8	20%
Improvement in the level of design work	5	14%
Better resource planning	3	8%
Better procurement strategies	3	8%
Accountability in terms of time, cost and quality	3	8%

In accordance to the responses received as tabulated above a huge majority of the respondents noted that interface management (25%) needs to be introduced from the inception phase of the project. The respondents also noted the need for an interface management department (25%) within the project as a mechanism to improve management of interfaces within the project. There is also a need for better stakeholder management (20%) as noted by the respondents. Other respondents noted that to improve interface management interfaces need to be clearly defined within the contract (19%). The other noted that there is a need for efficient and integrated project schedule (16%) showing all the interfaces that exist within the project. Front end planning (16%) and alignment of design and construction phase have also been noted as mechanism strategies for improving interface management. Further, the research participants indicated that for there to be an improvement in interface management on the project there needs to be better resource planning (8%), better procurement strategies (8%) and fewer contracts (8%) on the project. The respondents have indicated all these strategies as mechanism to assist in improving interface management on a mega construction project.

CHAPTER 5 SUMMARY AND RECOMMENDATIONS

5.0 Introduction

This research sought to address the concept of interface management with the view of gaining an understanding of the concepts, definitions, strategies and challenges of interface management on mega projects. The objectives sought to establish the types of interfaces that exist on mega projects, the main sources of interface challenges and the effectiveness of the methods being utilised to manage interfaces at both project and organisational levels and how they can be improved.

5.1 REVISITING RESEARCH OBJECTIVES

The research objectives were as follows:

5.1.1 The types of interfaces that exist within the project environment

The first objective of the study dealt with understanding the types of interfaces that exist on projects. The theory generated classified interfaces into the following,

Table 5.1 Types of interfaces on projects

Interface Categories	**Source**
Inter-project interface, Intra-project interface, Extra-project interface	Collins et al. (2010)
Systematic, Organisational and Personal	Stuckenbruck (1983)
Perfect match, Partial match, and Total mismatch	Healy (1997)
Actual, functional, extended, temporal, and future interfaces	Korman, Fischer, and Tatum (2003)
Physical, Contractual, and Organizational	Pavitt and Gibb (2003)
Contractual interfaces	Miles and Ballard (2002)

The following interfaces were identified by the questionnaire respondents as existing within project environment,

a. Construction interface: The construction interface was identified as one of the interfaces that exist within the project environment. This is a result of the number of contractors that exist within mega construction projects. These contractors work in parallel with each other and within similar work areas. This, as a result gives rise to interfaces between the different contractors.
b. Design to construction interface: Design to construction interfaces were identified due to the misalignment that occurs during the execution phase of projects. This misalignment is caused by lack of integration between the design and construction phase of the project. The construction team needs to be involved in the project during the design development phase so as to eliminate any discrepancies during execution stage.
c. System interface: It was noted that a number of systems exists within the project environment forming part of the bigger system. The systems are often designed by different professionals, which at times create clashes between the different systems if interfaces are not identified and dealt with.
d. Design Interface: The design interface is brought about by the different types of procurement routes. The design engineers are normally geographically making it hard for communication and with others designers involved in design and build packages.
e. Organisational interface: Often on projects it is important to ensure there is a communication structure in place between the parties working within an organisation to avoid any delays in terms of deliverables. Mostly on the project the organisational interfaces are dealt with using the responsibility matrix for each work package together relying on the work package schedule to give out incoming and outgoing interfaces between the disciplines.
f. External interface: This interface was noted as the interface between the project and the external environment. This includes all the stakeholders directly or indirectly involved on the project. The project also has interests from the community, legal, environmentalists, legal e.t.c which is a challenge if the objectives are not channelled to one route.

It can be concluded that the interfaces existent on the selected Project A are similar to those noted within the literature. This is the first point of departure in understanding the importance of managing all the existent interfaces within mega projects and the importance of treating interface management independently from project management. It is therefore of importance to ensure that all interfaces are categorised and that within those categories all interfaces are identified.

5.1.2 Main sources of interface challenges on mega construction projects

This objective was achieved through analysis of collected field data. The study revealed that there are a number of issues that give rise to interface challenges on mega projects stem from the complexities associated with the projects contractual scope and requirements. Table 5.2 provides a list of the sources based on the generated theory and also takes into account the identified sources from the information collected from the respondents on Project A.

Table 5.2 Sources of interface challenges

Project A (Respondents)	**Literature**
Poor scope identification from tender	Inconsistencies among drawings and specifications (Alarcón and Mardones, 1998) Unclear scope definition (Mortaheb et al., 2010). Changes in requirements or scope (Anumba, et al. 2007). Contract problems (Shokri, 2012). Unclear scope definition (Mortaheb et al., 2010)
Different contracts and procurement strategies	Contract problems (Shokri 2012)
Financial difficulties	Inaccurate project budget information and inconsistency between project requirements and budget (Huang et al., 2008)
Scope gaps and access issues	Changes in requirements or scope (Anumba, et al. 2007); changes introduced by the owner and designers (Alarcón and Mardones, 1998).
Work packaging and scheduling	
Poor coordination and lack of planning	Lack of coordination among specialties

	(Josephson, et al. 1996). Inappropriate sequence of work performed (Varghese and Senthilkumar, 2010). poor ordering of tasks (Anumba, et al. 2007). Lack of communication and coordination between project parties (Huang et al., 2008)
Lack of Master schedule of Client to contractor	Contractors poor planning and scheduling (Mortaheb & Rahimi, 2010)
Wrong information and groups working in silo`s	Poor communication (Fritschi, 2002). Insufficient and inaccurate interface information, as well as inefficiencies in information sharing (Al-Hammad and Al-Hammad, 1996; Al-Hammad, 2000; Miles and Ballard, 2001). Lack of coordination among specialties (Josephson, et al. 1996; Alarcón and Mardones, 1998).
Ineffective package interface management	Problems arise when issues cut across delivery teams, with cross-function issues often not receiving the necessary priority (Nooteboom, 2004). IM is a critical project component that to date has not been fully appreciated, or appropriately addressed (Nooteboom, 2004). Poor definition of project interfaces (Shokri 2012).
Communication and Coordination issues	Poor coordination and communication between project parties (Mortaheb et al. 2010). Poor information flow (Varghese and Senthilkumar, 2010). Poor communication (Fritschi, 2002). Lack of Resource and Personnel to Facilitate Coordination Lack of Information or Outdated Information (Chen 2007) poor communication and coordination Mortaheb & Rahimi, 2010
Design challenges between the different Contractors for different systems	Designers with little knowledge (Alarcón and Mardones, 1998); defects of individual specialists (Alarcón and Mardones, 1998) Inconsistencies among drawings and specifications (Alarcón and Mardones, 1998).

	Unclear details in the drawings (Shokri 2012)
Integration work interface between the systems, electrical, control and instrumentation and the process system	Misunderstanding of integration and fusion between project parties as a system components (Shokri 2012) Lack of Coordination among Specialties (Chen 2007) Lack of Experience in Design and Construction (Chen 2007)
Interface to an environment and the permit issues from Government	Inexperience with local laws and other government regulations and modification in laws and regulations Al-Hammad (2000); R. Huang et al. (2008); Ku et al. (2010). Regulation problems caused by the unfamiliarity of the related parties with local rules, including local laws or regulations as well as the government audit system (Huang et al., 2008)
Site access	-
Construction issues	New technology (Huang et al., 2008) Changes to the project scope (Huang et al., 2008) Unclear & Incomplete scope definition (Mortaheb & Rahimi, 2010) Contractors poor planning and scheduling (Mortaheb & Rahimi, 2010)
Misalignment on placing the packages and poor planning	Inefficiency of the project schedule (Mortaheb & Rahimi, 2010) contractors poor planning and scheduling(Mortaheb & Rahimi, 2010)
Lack of project management	“Lack of key deliverables such as internal and external interface list, and IM plan within FEED package” (Mortaheb & Rahimi, 2010) Inefficient project management team (Mortaheb & Rahimi, 2010) Lack of project management (Chen et al, 2008)
Finance	Financial Problems, Delayed payments, Poor estimates(Chen 2007) Late in progress payment to contractor (Mortaheb & Rahimi, 2010)
Lack of proactiveness	Delay in reviewing and approving key

	deliverables (Mortaheb & Rahimi, 2010) Poor decision making (Al-Hammad (2000); Ayudhya (2011); Chen et al. (2008); R. Huang et al. (2008); Ku et al. (2010)
Contractors not meeting interface dates	-

5.1.3 Improving interface management on a mega construction project

This objective was achieved through the use of a questionnaire and ultimately through the introduction of an interface management strategy. This strategy is as shown below.

5.1.3.1 Interface Management Workflow

The introduction of interface management stage gate workflow stems from information gathered in relation to the project site and as well as the information gathered from the field study. A proposal is thus put forth to assist the project site in improving its management of interfaces. The respondents identified the need for interface management plan/procedure, interface management managers and department and so forth.

The steps below are proposed by this study for improving the management of interfaces on a mega construction project.

Development of interface management plan

a. Just as with any process in the construction cycle interface management needs to start with development of the interface management plan for all project stages which,

b. Defines interface, interface management

c. Establishes the type of interfaces likely to exist within that particular project using historical data from similar projects and expect judgement

d. Identify how the type of interfaces will be dealt with in the project

e. Establishing the level to which interfaces will be dealt with

f. Integrate the interface management plan into the project management plan

Appoint interface management team

a. Appointment of the team should be accomplished during the early stages of the project in order to avoid any discrepancies in the set procedures.

b. The team must be dedicated to solely handling the interfaces on the site and co coordinating between the different work packages.

c. The team must cheer all meetings from the beginning (prior to tender) of the project to flush out all the interfaces that exist within the project, ensure that interface are recorded and agreed upon between both parties on tender award.

d. Each work package must have its own interface coordinator focusing solely on the interface management within that team and co coordinating with the other co coordinators and ultimately the interface manager.

e. The team will monitor and status and give progress constantly

Develop interface management procedure

Proposed stage gate interface management workflow

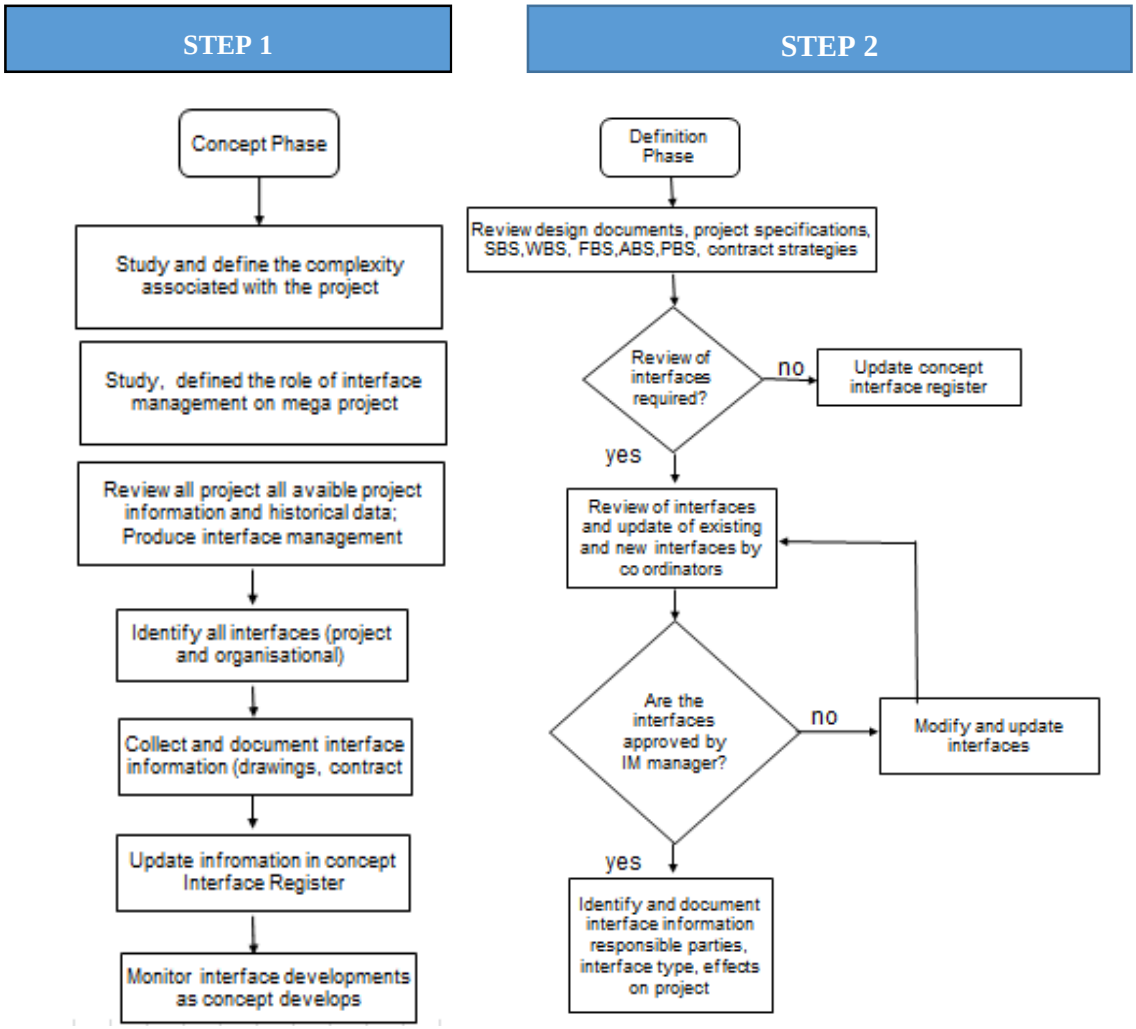
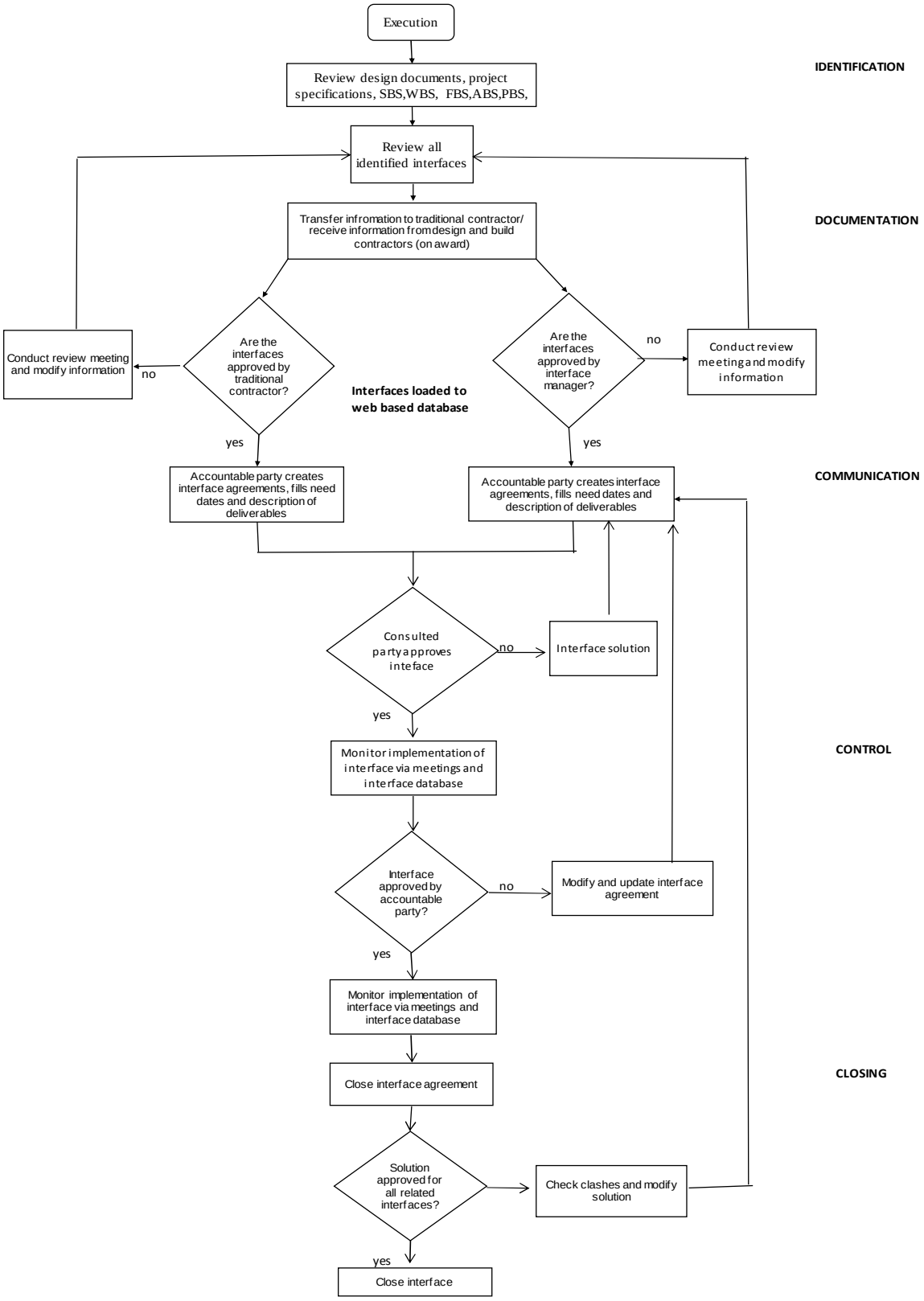


Figure 5.1 Stage gate interface management workflow

STEP 3


Execution
IDENTIFICATION
Review design documents, project specifications, SBS,WBS, FBS,ABS,PBS,
Review all identified interfaces
DOCUMENTATION
Transfer infromation to traditional contractor/ receive information fromdesign and build contractors (on award)
Are the interfaces approved by traditional contractor?
no
Conduct review meeting and modify information
yes
Interfaces loaded to web based database
Are the interfaces approved by interface manager?
no
Conduct review meeting and modify information
yes
COMMUNICATION
Accountable party creates interface agreements, fills need dates and description of deliverables
Accountable party creates interface agreements, fills need dates and description of deliverables
Consulted party approves inteface
no
Interface solution
yes
CONTROL
Monitor implementation of interface via meetings and interface database
Interface approved by accountable party?
no
Modify and update interface agreement
yes
Monitor implementation of interface via meetings and interface database
CLOSING
Close interface agreement
Solution approved for all related interfaces?
Check clashes and modify solution
yes
Close interface

The interface management process should start during the initial stages of the project to ensure sufficient coverage of all interface risk associated with the particular project. The study proposes that interface management be managed through all the phases of the project life cycle and that interval points be created through all phases for the identification of interfaces at that particular phase and more effort should be put to identify and deal with interfaces during concept and definition phase to avoid any impacts during the execution phase.

a. Concept phase

During this phase of the project the idea of the project is studied and explored to determine the feasibility of the project. The project team is also put together to define the objectives, scope, purpose and deliverables of the project. It is crucial that the interface management team is appointed during this time to undergo the task of studying the project and reviewing its concept in order to start establishing the interface management plan, procedures, tools and techniques to be utilised to manage the project interface while integrating will all other areas. At this stage the interface management team can be able to study historical data of similar projects and analysing what interfaces where encountered and how they were dealt with and which strategies where used for this role. This enables the team to create and update an interface register with all the interfaces that have been identified from the concept data, drawings and models. The identification of interfaces at this phase will assist in identifying all possible interfaces and their possible extent on the project and thus enable development of the relevant tools and techniques to tackle the nature of interfaces on that particular project.

b. Definition phase

During this phase the concept is defined in more detail and the project management plan is developed using all other individual plans catering for the nine knowledge areas. For the interface management team review of all identified interfaces from the concept phase becomes an important aspect as more detail is available. The team must ensure communication plans and stakeholder management plans are developed and detailed to ensure proper communication of all interfaces to the relevant parties to avoid occurrence of any risk. The team must also ensure sufficient design management, scope management, schedule management, risk management, construction management, document management, stakeholder management processes and tools are put in place during this stage to support

interface management. Interface management stems from communication of different project elements thus all other processes need to be properly defined to support interface management.

c. Execution phase

i. Interface identification

At the borderline of definition and execution where all the information has been defined to a certain extent, the interface manager and all the co coordinators must review all project information and identify all the interfaces that exist between the different project elements. It is essential to study project scope and specifications, system breakdown structure, work breakdown structure, function breakdown structure, project schedule as this is where the interfaces are likely to be borne out of. The types of interfaces need to be studied and identified including organisational, functional, system, physical and so forth. All information related to the identified interfaces need to be gathered. The sources of information for tracking and managing interfaces can be interface agreements, interface workshops, interface meetings, requirement matrix, design criteria manuals, design specification and development.

An interface management kick off workshop should be held to discuss the interfaces already identified and new interfaces. Interface workshops and meetings must be held regular as a platform to identify and discuss all interfaces involving the interface management team as well as project team members as interfaces stem from a variety of elements as noted within the research. An interface management web based database needs to be developed to assist in handling interfaces and all interfaces need to be logged within the web based database by all the interface managers.

ii. Interface documentation

All information related to identified and approved interfaces needs to be collected and documented within the interface database. This might include parties to the interface, interface problems, interface solutions and deadlines. Interface agreements must also be developed to document agreement between the two parties to the interface. This agreement makes the interface formal. All the information must be logged in the interface register within the interface database identifying the interface ID, interface title, description of the interface,

and type of interface, accountable and consulted parties to the interface, interface agreements and the risk attached to the particular interface. The interface register must be linked to the responsibility matrix identifying all the parties responsible for a certain interface to promote visibility.

It must be realised that types of interfaces carry with them different types of risk thus the risk associated with interfaces must also be determined and documented into the interface database (schedule, financial, performance). It is also crucial to ensure synchronisation of the project schedule within the interface management database to ensure alignment of major interface milestones.

iii. Interface communication

Communication is a key element in resolving any interface issues that exist within a project thus there must be synchronisation between the interface management and communication management within a project. The proposed web based interface management database can be used as the live tool for conveying all interfaces that exist between project participants who are globally dispersed. Communication must be handled within the database as well as interfaces meetings and a plan must be developed for how conflicts will be handled between the parties. Project teams can also communicate via interface meetings where all project team members are available.

iv. Interface control and closure

The interface management team must be responsible for handling all interface related matters including monitoring all upcoming interfaces, interface changes, progress of interface agreements and due dates as noted within the interface register. The database will be used as the central place for synchronising all of the project information that gives rise to interfaces. The database must also account for other tools being used within the project in order to produce comprehensive information. Tool that can be utilised to assist in interface management can include tools like BIM, Dims, Navisworks, Relatics, Primavera, Documentum and so forth. Interface reports must be easily drawn from the database to ensure that the project teams are constantly aware of the interface progress. All the team members should work together to ensure that the interface coordinators have all the current data and are aware of all possible changes which might impact interfaces or even the interface dates

noted within the database. All high risk interfaces must be red flagged within the database so that a solution can be speedily determined by the interface management team. A successful interface management process requires the necessary technical tools to support its implementation and control to ensure that the process is translated sufficiently. All interfaces are to be closed once they have been dealt with.

Investigations into the selected mega project for study (Project A) noted that there is no interface management plan for the project and there is no proper awareness into interface management among the project teams. From the client's management team interfaces on the project are managed independently through every department as there is no platform allowing for synchronization of project interfaces. There is no standard/common system on the project into the management of interfaces.

A number of improvements to the current strategies being used on the project were identified. Findings revealed that to improve interface management on a mega construction project there needs to be an interface management department to deal solely with interface issues, interface management needs to be planned for from the inception of the project, interfaces need to be contractual, there needs to be better stakeholder management, preplanning, better resource planning, interface management matrix, interface management procedure/plan must be introduced and so forth. These improvement gaps have thus led to the proposal of a stage gate interface management workflow.

This study put forth an interface management strategy which is a workflow utilised in managing interfaces from concept, definition and finally execution. The steps noted within the proposed procedure include developing interface management plan, appointing interface management team and developing interface management procedure. The process identified within the procedure includes interface identification, interface documentation, interface documentation interface control and closure.

5.2 Recommendations for future research

Interface management is a growing field within the construction industry as projects are increasing in size and complexity. Therefore, there exist a lot of improvements opportunities within the field itself and the following studies are suggested for future research:

- Factors constraining the development of interface management in South Africa
- Conduct case study research into different projects that adopted interface management from inception and the challenges they faced and similarities within those challenges
- Enhancement of the interface management teams role on mega construction projects
- Impact of project delivery systems on interface management
- Barriers to effective interface management of mega construction projects

5.3 Limitations

The number of participants used for the study could have been increased to provide greater insight into the interface challenges from global view of the project. Nonetheless, the sample size permitted reasonable interpretations to be drawn from the results of the study. Using a single case study has an impact on the data results obtained as other mega projects might have different challenges with regard to interface management. The results obtained from the case study might not be directly usable on other mega projects as projects differ in terms of scope, complexity and scale but might provide a guideline. The results obtained from the study also revealed that majority of the participants are mostly familiar with construction interface instead of the overall interfaces within the project which might be biased.

5.4 Concluding Remarks

Interface management has in recent years been a growing area of practise and has attracted industry professionals globally. Interface management states that the growing nature of projects from the traditional to mega projects has necessitated awareness into the management of boundaries between the different project elements. There is no consensus that has been reached definitions related to interface management within the industry. The major challenge to these mega projects is in understanding the complexity of these projects as they are characterised by scope, size and numerous stakeholders. Interface management thus requires understanding of the complexity associated with a particular project in order to understand the interface challenges as a result. The breakdown of the project strategies and characteristics might help to achieve more clarity on such complexity. There should be acknowledgement on any project of the different types of interfaces that such as physical, organisation, contractual, functional, resource and knowledge or in short internal and external interfaces. Interfaces should be defined, classified, analysed and prioritised. This assists the project team to better plan for interface management on the project.
A number of benefits have been identified within the study regarding interface management including but not limited to improving project performance, enhancing communication between stakeholders and reducing time and cost overruns.

The aim of the study was to improve interface management on a mega construction project in South Africa through studying the interface management within the project and identifying existent challenges. This aim was achieved through questionnaires. The study further proposed a strategy to be followed on the selected mega project, the strategy developing interface management plan and developing interface management procedure which defined the process to be used and the tools to be used in support of this strategy. Most importantly a web based database was proposed as the collaborated platform to manage the interface management strategy.

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APPENDIX A: QUESTIONNAIRE

Letter of introduction

Department of Construction Management and Economics
University of Witwatersrand
Jan Smuts
Johannesburg

JUNE 2017

TO WHOM IT MAY CONCERN

I, Nonkululeko Mhlanga serve to inform you that all information submitted within the questionnaire will be treated as confidential.

Participation in the study might not benefit participants directly but it will benefit the project to ensure improved delivery and it might benefit the industry as a whole to get an in-depth knowledge regarding the importance of interface management on mega project and thus add to existing literature.

The main objective of the study is to improve the management of interfaces on a mega construction project in South Africa. The study looks into the sources of interface challenges to better understand the challenges caused by the complexity associated with these projects. The key deliverable of the research is to provide a solution for the management of interfaces on a mega construction project in South Africa.

All the responses received as part of the study will remain confidential. Personal information may be disclosed if required by law. Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee. The names of participants and organizations are not required within the responses but they may be given.

Should you wish to know the findings of the research, the information will gladly be sent to you in a summary of the results.

With thanks,
Nonkululeko Mhlanga

My details

Nonkululeko Mhlanga
Student no. 0610006e
0610006e@students.wits.ac.za
0734404647

Participant Consent Form

Title of Research Project: Interface Management on a Mega Construction Project in South Africa

Name of Researcher: Nonkululeko Mhlanga
Supervisor's Name: Dr. Oluwayomi Babatunde

	YES	NO
1. I confirm that I have read and understood the information sheet explaining the above research project and I have had the opportunity to ask questions about the project.	☐	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.	☐	☐
3. I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.	☐	☐
4. I agree for the data collected from me to be used in future research	☐	☐
5. I agree to take part in the above research project.	☐	☐

_____ _____ _____

Name of Participant Date Signature

_____ _____ _____

Researcher Date Signature

Contact details
Researcher: *email: 0610006e@students.wits.ac.za cell: 073 440 4647*
Supervisor: *email: Oluwayomi.Babatunde@wits.ac.za phone: 011 717 7658*

UNIVERSITY OF THE WITWATERRAND

SURVEY QUESTIONNAIRE

TITLE OF THE STUDY: Improving Interface Management on a mega construction project

The objectives to be addressed within the questionnaire include:

1. Identification of the main types of interfaces that exist within the project environment
2. Evaluating the main sources of interface challenges on mega construction projects
3. How interface management can be improved on a mega construction project

Student/ Researcher: Ms. Nonkululeko Mhlanga

Supervisor: Dr. Oluwayomi Babatunde

NB: Please note that the research is being carried out for academic purposes only and your assistance in answering the questionnaire will be highly appreciated. All information relating to the research will be handled with maximum confidentiality. Thank you.

GENERAL INFORMATION OF PARTICIPANTS

1. Participant Designation *(tick as applicable)*

A	Project Manager	
B	Construction Manager	
C	Engineer	
D	Planner	
E	Other	

Please specify……..

2. Age group *(tick as applicable)*

A	24 and below	
B	25-35	
C	36-40	
D	40 and above	

3. Highest qualification *(tick as applicable)*

A	Diploma	
B	Bachelors	
C	Masters	
D	Other	

4. Cost range of work package

A	<1bn	
B	500M-1bn	
C	200M-500	
D	>100M	

6. Type of procurement strategy used for your work package

A	Design and build	
B	Design bid build	
C	EPC	
D	EPCM	
E	Other	

Please specify……..

PROJECT COMPLEXITY (Objective 1&2)

Project complexity is one of the key drivers of arising challenges within mega projects and understanding this complexity eliminates or reduces possible risks that might arise.

7. What is the level of complexity associated with your particular project?

High: Scope of work is highly complex
Medium: Scope of work is a bit complex
Low: Scope of work is not complex

A	High	
B	Medium	
C	Low	
D	None	

8. Main challenges faced by the organisation as a result of project complexity?

A	Stakeholder management	
B	Management of interfaces	
C	Scope inadequacies	
D	Inexperience of project team	
E	Other	

Please specify……

9. What is the occurrence level of the above selected complexities, using the scale *(1-Not occurring, 2- least occurring, 3- most occurring, 4- high occurring, 5- very high occurring)*

	1	**2**	**3**	**4**	**5**
	Not occurring	Least occurring	Most occurring	High occurring	Very high occurring
Stakeholder Management					
Management on interfaces					
Scope Inadequacies					
Inexperience of project team					

PROJECT INTERFACES (Objective 1 & 2)

9. What does the word interface mean to you?

A	A point of contact between different project elements	
B	A function of the project schedule	
C	A function of the Work Breakdown Structure	
D	Links between different components in a project (scope, participants, construction)	

10. How many contractors are you in direct interface with on you project?

A	<10	
B	<20	
C	< 30	

11. What type of interfaces exists within your project and between the project at large?

A	Design interface	
B	Systems interface	
C	Design to construction interface	
D	Construction interface	
E	Contractual interface	
F	Organisational interface	
G	External interfaces	
H	Other	

Please specify……...

12. What have been the main sources of interface challenges on your project?
(Sources: The root causes of interface challenges)

……
……
……
……
……
……

13. For objective two of the research, at which stage of the project life cycle should interface management be implemented?

A	Feasibility	
B	Concept	
C	Design	
D	Definition	
E	Execution	
F	Other, specify	

14. What strategies are used within your company to manage interfaces? *(Select applicable)*

Organisational level interface

A	Work plan	
B	Face to face meetings	
C	Emails and phone calls	
D	Interface Agreements	
E	Other	

Please provide explanation on the benefits and challenges of the above selected method

……
……
……
……
……

Project Level Interfaces

A	Work breakdown structure	
B	Project Schedule	
C	Interface management framework	
D	Systems Engineering	
E	Integration meeting	
F	Engineering meetings	
G	Other	

Please specify……

Please explain the benefits and challenges to handling of the above selected method

……
……
……
……
…….

18. Please advise further with your level of experience how interface management can be improved within the project site?

……
……
……
……
……

Thank you for your participation.

APPENDIX B: ETHICS CERTIFICATE

School of Construction Economics & Management

University of the Witwatersrand, Johannesburg -PO Box 20, Wits 2050, South Africa • Tel: +27 (0)11 717 7652/77669 · Fax: +27 (0)11 717 9729 Email:CEM@wits.ac.za

SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE **PROTOCOL NUMBER** CEM/16/08/NM3/MSC

PROJECT TITLE: AN INVESTIGATION INTO AN EFFECTIVE INTERFACE MANAGEMENT STRATEGY ON A MEGA CONSTRUCTION PROJECT IN SOUTH AFRICA

INVESTIGATOR	Nonkululeko Mhlanga 0610006e
SCHOOL/DEPARTMENT	**SCHOOL OF CONSTRUCTION ECONOMICS AND MANAGEMENT**
DATE CONSIDERED	11/10/2016
DECISION OF THE COMMITTEE	Approved conditionally with respect to the declaration and forwarded moderate corrections. Please note these corrections.
EXPIRY DATE	28th October 2017

DATE 12 October 2016

CHAIRPERSON _____
Dr. Kola Ijasan

cc: Supervisor: Dr. Yomi Babatunde

DECLARATION OF INVESTIGATOR (S)

To be completed in duplicate and **ONE COPY** returned to the Secretary Mrs. M. Sithole at the CEM reception desk.

I fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the committee. **I agree to completion of a yearly progress report.**

_____ 03 / 03 / 2017
Signature **Date**