THE CAUSES OF DESIGN CHANGES IN PETROCHEMICAL PROCESS PLANT PROJECTS IN THE MPUMALANGA AND FREE STATE PROVINCES IN SOUTH AFRICA

By

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ABSTRACT

Title of treatise:	The Causes of Design Changes in Petrochemical Process Plant Projects in the Mpumalanga and Free State Provinces in South Africa
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This objective of this study is to determine and analyse the causes of design changes when executing petrochemical process plant projects in the Mpumalanga and Free State Provinces in South Africa. Data for analysis was obtained through a questionnaire survey based on the literature review. Although data is mainly qualitative in nature, the techniques used to analyse the data is quantitative.

The results from the survey indicate that the main causes of the design changes is the unrealistic duration to complete design and insufficient equipment information resulting in assumptions at early stages of the design. The change in scope of work and none attendance of sufficiently experienced personnel and key stakeholders at design reviews later enforcing changes were determined to be the design change factors often experienced in petrochemical process plant projects in the Mpumalanga and Free State Provinces.

DECLARATION

I declare that this research in entirely my own work, unaided work, except where otherwise stated. All sources referred to are adequately acknowledged in the text and listed.

I accept the rules of assessment of the University of Pretoria and the consequences of transgressing them.

This treatise is being submitted in partial fulfilment of the requirements for the degree of MSc (Project Management) at the University of Pretoria.

It has not been submitted before for any other degree or examination at any other university.

…………………………………..
Signature of Student

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LIST OF ACRONYMS

AFC – Approved for Construction

BEDP – Basic Engineering Design Package

BOOT – Build Own Operate Transfer

DCI – Design Change due to Improvement

DCO – Design Change by Owner

DCP – Design Change by Process

EPC – Engineering Procurement and Construction

EPCm – Engineering Procurement and Construction Management

GDP – Gross Domestic Product

P&ID – Piping and Instrumentation Diagram

PMBOK – Project Management Body Of Knowledge

CHAPTER 1: THE PROBLEM AND ITS BACKGROUND

1.1 Introduction

The South African chemical industry is of substantial economic significance to the country, contributing around 5% to GDP and approximately 23% of its manufacturing sales (Chemical Allied Industries Association, 2011). The chemical sector has experienced significant growth over the last few decades and this lead to a high number of capital expansion projects undertaken with the objective to boosting production to match anticipated increase in demand for petrochemicals.

Design changes are experienced during the execution of petrochemical process plant projects resulting in increased contract costs and schedule delays which frequently results in disputes between contracting parties. The cumulative, design changes costing five to ten percent of the original contract price of a process plant project are not unusual. The price tag for such delays and disruption claims can rise to unbelievable magnitudes, especially when a significant number of the changes occur late in the final design stage or during construction. Long (2012) discovered that the cumulative direct cost of the design changes is considerably greater than ten percent of the original contract price.

The process that is employed at a petrochemical process plant normally involves steps known as unit operations in which a chemical process takes place in an equipment unit. The process equipment unit are usually connected to one another by means of pipes in a way that allows materials to be transported to the next equipment unit when each operation is complete. The process is therefore like a manufacturing assembly line with the output of the previous process unit becoming the input or feed to the next unit. (WiseGEEK, January 2012).

Designing and building a petrochemical process plant facility is not as simple as employing people to erect the structure and connect pipes and electricity. Unlike other structures, such as stores or office buildings, there is a lot more consideration that needs to be taken with petrochemical process plants. A design change to one process equipment unit can have a knock-on effect on the design of a successor of the process equipment unit resulting in schedule and cost impact.

The aim of this research is to find out what are the causes of design changes when executing petrochemical process plant projects in the Mpumalanga and Free State provinces in South Africa where the major petrochemical plants in the country are situated.

1.2 Definition of the main problem

The main problem is to identify the factors leading to design changes in the process plant projects. (What are the main causes of design changes?)

1.3 Sub-problems

Sub-problem 1

- Various parties are involved during the design stage of the project, i.e. Client; Design Consultants (EPC Contractors) and process equipment suppliers/vendors. Which of the parties is mainly responsible for design changes resulting in design delays?

Sub-problem 2

- Are sufficiently skilled personal utilised in the design phase of the project to identify changes as they develop and minimise such changes?

Sub-problem 3

- What are the factors/causes of the design changes?

1.4 The Hypotheses

The following hypotheses are set forth:

- Most of the factors leading to design changes could be avoided early on in the project and these are mainly in the Employer's control.
- The Employer is the source of numerous changes encountered during the execution of process plant projects. The changes introduced by the design consultant are minimal compared to those initiated by the Employer.
- Inexperienced personnel are utilised during the design phase and they increase the likelihood of design changes that has a ripple effect on the project resulting in increased cost and schedule delays.
- The study will reveal that the change in scope during design and inadequate design reviews are the major factors/causes of the design changes.

1.5 Delimitation

The study is limited to petrochemical process plant projects undertaken in South Africa, with particular focus on projects in the Secunda and Sasolburg areas located in the Mpumalanga and Free State provinces where major process plants are situated. Projects between R600m and R1bn forms part of this study and this includes capacity increase projects or new plants (both green and brown fields projects); maintenance projects do not form part of the study.

Projects currently in execution and those completed within the past five years will form part of this study. Only two Engineering, Procurement and Construction Management (EPCm) Contracting Companies within South

Africa and the major employer in the petrochemical sector i.e. SASOL (Pty) Ltd will form part of this study. Data will be obtained from the respondent's personal assessment of the projects they participated in (via questionnaire) and will therefore be subjective and directed towards specific projects and not hypothetical situations.

The limitation to the study is that the contracting parties involved in respective projects will try to protect themselves and apportion responsibility of the design changes to other parties.

1.6 Definition of terms

Brown Fields Project - A project which has constraints imposed by prior work, as construction is undertaken in or around existing structures, facilities or plants**.**

Delays - Delays are slippages in the project schedule resulting in the completion of a project been achieved after the practical completion date indicated in the contract documents**.**

EPC Contractor/Consultant – Design/Engineering Consultant, appointed by the Employer to conduct engineering (design), procurement and construction management (EPCm) for and on behalf of the Employer.

Employer – The Employer is the owner of the project and has entered into a contract with the Consultant for rendering of professional engineering services.

Equipment Supplier/Vendor – This refers to designers and fabricators of specialised equipment used in the process plants.

GDP – Gross Domestic Product

Green Field Project – A project that lacks any constraints imposed by prior work, as construction is undertaken on land where there is no need to remodel or demolish an existing structure.

Process Plant Facility – Facility that uses mechanical, chemical or other process equipment to alter the matter or composition of the feedstock material streams (solid, liquid or gaseous phase) to produce different products.

Works – The works are all facilities and the associated plant and material to be fabricated, constructed and installed under the management of the consultant.

1.7 Assumptions

It is assumed that the Consultants have sufficient process plant design experience and are competent to undertake plant design.

1.8 The importance of the study to the petrochemical industry

The chemical sector will continue to grow and the current domestic demand for products is forecasted to increase. The cause of design changes resulting in project delays and the recommended measures identified through this study can be implemented by contracting parties in future projects, thus reducing the number of extension of time disputes in the industry.

The design teams involved in the petrochemical process plant projects will minimise design changes by taking into account factors leading to design changes as determined through this study, this will result in quality designs that enables construction activities to continue with minimal delays.

1.9 Research Methodology

The causes of design changes in projects will be established through existing literature and review of lessons learned from completed projects. These causes of changes will be the basis of the questionnaire. The University of Pretoria Statistics department will be consulted for assistance with the structuring and design of the questionnaire. The questionnaire will be circulated to the respondents via email.

The research methodology will be qualitative in nature and purposive sampling will consist of the consultant's design engineers, which is the process, mechanical, electrical, instrumentation and civil engineers. The Employer's engineers or review team involved in design activities, e.g. reviews and approvals, will form part of the sample. The Project Managers from both the Consultant and Employers will also form part of the study.

The respondents will be asked to complete the questionnaire based on the experience of currently running projects or projects completed within the last five years.

CHAPTER 2- LITERATURE SURVEY

2.1 Overview of South African Petrochemical Industry

The South African chemicals industry was founded in the latter part of the nineteenth century as a result of increased demand for explosives and chemicals to support the mining sector. As the country has no significant upstream oil reserves and until recently little natural gas, the chemical industry has primarily developed around the gasification of coal. The establishment of a petrochemicals industry can be traced back to the 1950's when the first oil from coal plant (Sasol 1 complex) was built at Sasolburg in the Free State province (Chemical Allied Industries Association, 2011).

It was, however, only in the sixties and seventies when the possibility of a chemicals industry based on local raw materials rather than imported feedstocks became possible. This followed the establishment of two large synthetic oil-from-coal process plants (Sasol 2 and 3 complexes) by Sasol at Secunda during the early 1980's to provide strategic self-sufficiency in fuels.

The South African chemical industry is of substantial economic significance to the country, contributing around 5% to GDP and approximately 25% of its manufacturing sales. The industry is the largest of its kind in Africa. It is highly complex and widely diversified, with end products often being composed of a number of chemicals which have been combined in some way to provide the required properties and characteristics. (Chemical Allied Industries Association, 2011).

Despite the impacts of the global financial crisis, including expenditure tightening, a few leading end-user companies within the petrochemicals industry in South Africa are continuing to implement planned capital expenditure projects with the objective of boosting production capacity to match the anticipated increase in demand for chemicals and petrochemicals. The leading chemicals and petrochemicals companies such as SASOL and

PetroSA are going forward with their capital expenditure programmes to increase production capacity, despite the global financial crisis. This includes the construction of new chemical processing plants and refineries with growth expected to continue from 2010 to 2015. (Market Overview, The Research and Market, October 2011).

One of the major problems facing the chemicals sector in executing projects is the large number of design changes occurring leading to increased contract costs and schedule impact which often results in disputes between contracting parties. Williams et al (1995) in their study on the effects of design changes on a large vehicle design and manufacture engineering projects at the United Kingdom discovered that the majority of the claims was for design changes. It was felt that the totality of these changes caused an overspent greater than the sum of the effects that could be assigned to the individual changes. Furthermore, there were thousands of items of design documentation, which contractually had to be approved within a certain time-limit, and it was proved that the project client's average approval time was well in excess of the contractual limits with some instances of documents taking many times the limit to gain approval and these contributing significantly to cost overspend. The study revealed that many comments on the design documents were invalid, serving no valid design purpose but slowing down the design process as the design documents had to be answered and document re-entered into the approval process.

Mohammad et al (2010) states that there are many reasons why design changes occur. The needs of the employer may impose changes to the parameters of the project, and technological developments may alter the design and the choice of the engineer. The architects review of the design may bring about changes to improve or optimise the design and hence the operation of the project. All these factors and many others necessitate changes that are costly and generally unwelcome by all parties.

2.2 Uniqueness of design changes in the Process Plant Projects

2.2.1 Bidding Process

During the bidding stage of the project the employer presents the basic engineering design package (BEDP) for process plants projects as part of the request for quotations to the pre-qualified engineering, procurement and construction (EPC) contractors, commonly referred to as the Consultants. The BEDP will contain the basic process plant layout and process flow selected by the employer in the basic engineering phase of the project. The BEDP will be developed in more detail by the selected consultant in the next phase of project and will form the basis of design in the detailed engineering/design phase of the project. (SASOL Business Development and implementation Model, 2005).

The employer may represent that the BEDP is sufficiently defined to enable the design consultant to prepare a fixed price bid for the final design of the process plant facility. Despite these presentation employers frequently initiate what they believe to be simple design changes to the consultant's scope of work. The cumulative design changes costing five to ten percent of the original contract price of a process plant project are not unusual (Long, 2011).

Results from the study undertaken by Sami et al (2006) focusing on delays on international construction projects with special reference to the Arabian Gulf area, led to the conclusion that contract documents were far from complete at formation of the lump sum contracts in many instances, thus projects were tendered prematurely without the necessary construction documents being sufficiently detailed to reflect the full scope of work. Incomplete bidding documents may result in misinterpretation of the design requirements by the design team, resulting in design changes within the design chain.

Based on the above it can be concluded that it is important for enough time to be allocated by the Employer to ensure sufficient details are included in the bidding documents to minimise design changes due to misinterpretation of the design requirements by the prospective consultant. The scope of work is to be well defined to minimise misunderstanding of the project's scope of work during the bidding process.

2.2.2 Design Flow Process

In process plant projects the starting point of the design is the selection of the process flow layout, from which the process data is developed. The subsequent design steps are based on the process data, a typical Forster Wheeler South Africa (FWSA) design flow is depicted in figure 1 below.

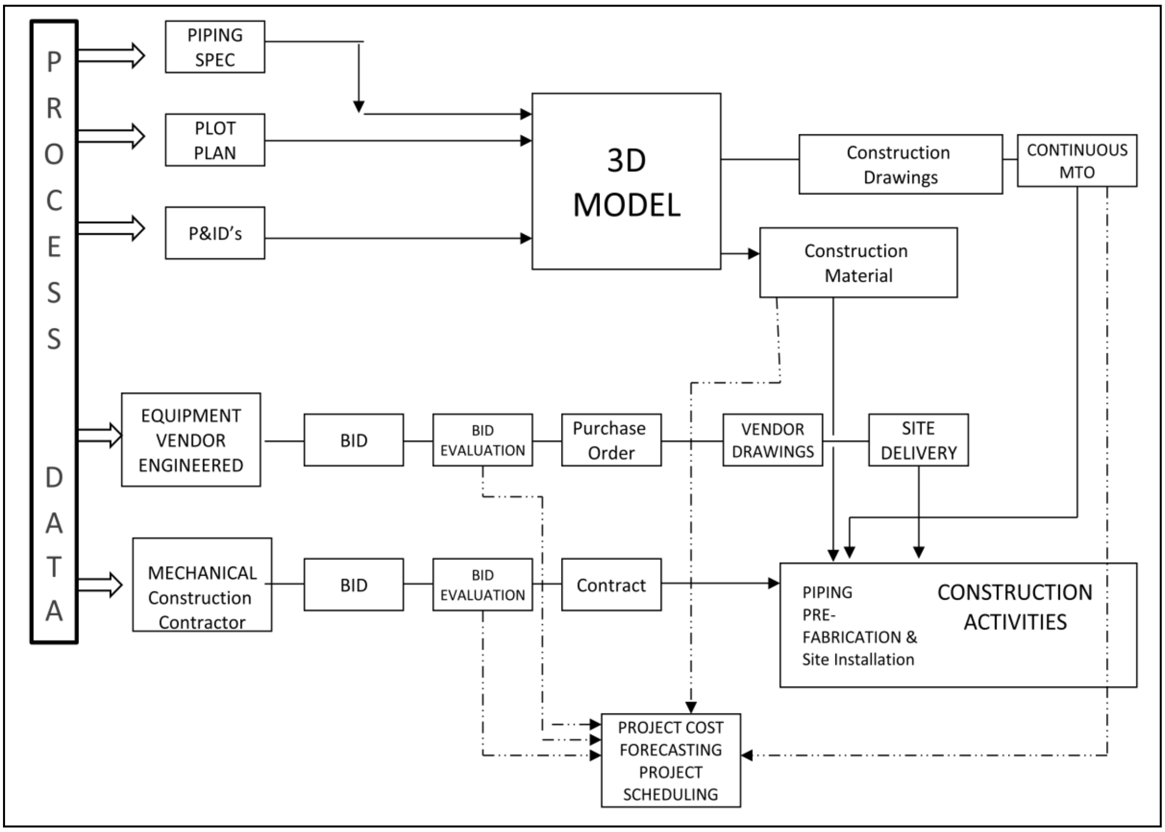


Figure 1: Typical Design Flow, (FWSA Design Model)

Among the most important documents in the design flow are the:

- Plot Plans.
- Equipment List.
- P&IDs (Piping and instruments diagrams)
- 3D Model.

(SASOL, Business Development and Implementation Model: 2005)

The plot plan indicates the plot space required for the proposed process plant equipment layouts. The plot plan provides an indication whether the process plant is to be erected on a new ground (green field) or brown field where the new plant is erected within existing facilities. Plot Plans and Equipment List are generally produced in the early phase of the project, they are very important for their various implications, and used by all disciplines. (Design Guide for Layout and Plot, December 2011).

The development of the three dimensional model is key step in the entire chain of the project. It offers close integration among disciplines – structural, civil, process plant equipment, conveying systems, and piping disciplines. With the model the plant operations and maintenance personnel, for example, have ample time to make process improvement suggestions before completion of final design and construction. Approved for construction drawings (AFC) are developed and extracted from the model (Intergraph, Metals and Mining: January 2012).

The design flow diagram (figure 1) indicates that a change in one of the steps will affect the subsequent and/or preceding design steps. Section 2.2.3 explains the knock-on effect of a change in the process plant design flow.

2.2.3 Knock-on effect of changes in Process Plant Designs

Design of process plant projects differ from other construction projects because the design incorporates mechanical, chemical or other process equipment to alter the matter or composition of the feedstock material streams (solid, liquid or gaseous phase) to produce different products. The process equipment used includes pumps, compressors, reactors, furnaces, and others. The process units are like manufacturing assembly line with the output of the previous process equipment becoming the input or feed to the next equipment. Therefore, a design change to one process operation and its associated equipment can have a knock-on effect on the design of a successor of the process equipment (Long, 2011).

The design change may also affect other disciplines, e.g. influence the civil, structural, mechanical, electrical and instrumentation design. An example can be a change made by a process engineer increasing the size of a process compressor. This results in a heavier compressor to be installed requiring the civil engineer to design a bigger compressor foundation and also increase the structural support of the compressor. The electrical implication is that a bigger drive motor is required to drive the compressor resulting in a higher rated control switch gear and bigger substation to house the electrical equipment.

In this case a single process requirement change has ripple effect, resulting in schedule and cost impact. It is thus important for the project team members to have a holistic picture and appreciation of the impact of the introduced change, no matter how small the change may be deemed to be.

2.2.4 Expectation of shorter payback periods

Loots (1995), cites that in the petrochemical industry it is critically important that the process facility be brought into production in the shortest possible time in order that revenue generated by the sale of products can start to yield returns on the considerable investment. This is in contrast to many infrastructural projects such as highways, bridges, power stations, railroads, dams which can often be financed under terms such that the duration of construction is not nearly as critical as it is in the process industries. This is partly a reflection of the shorter lifetime of the process plant, which may only be in production for a decade or so, whereas infrastructural projects have lives of fifty years or more.

It therefore follows that the design phase of process plant projects are generally undertaken under strict schedule pressures and design teams have shorter times to meet the employer's requirement to have the process plant completed in as short a period as possible in order for the plant to generate revenue. The project team often are forced to explore ways of shortening activity durations or conduct duration compression.

Duration compression is a special case of mathematical analysis that looks for ways to shorten the project schedule without changing the project scope (e.g. to meet imposed dates or other schedule objectives) and includes techniques such as:

- Crushing — in which cost and schedule trade-offs are analyzed to determine how to obtain the greatest amount of compression for the least incremental cost. Crashing does not always produce a viable alternative and often results in increased cost.
- Fast tracking — doing activities in parallel that would normally be done in sequence (e.g. starting to write code on a software project before the design is complete, or starting to build the foundation for a

> petroleum processing plant before the 25 percent of engineering point is reached). Fast tracking often results in rework and usually increase risks.
> (PMBOK, 1996)

A study results from Memon (2011) reveals that poor design and delays in design is ranked as the most significant cause of cost overrun as perceived by experts of Malaysian construction industry. Unrealistic contract duration and requirements imposed is ranked as second most significant factor in Malaysia. If contract duration is not estimated correctly the project might be delayed resulting in cost overrun. Memon's (2011) literature review found that inadequate contract duration was a moderately significant factor causing construction cost overrun in Pakistan. Construction expert in Malaysia are of the opinion that lack of experience is the third most important factor causing cost overrun and delays in construction projects.

It is Loot's (1995) view when discussing Project Risk Management in Process Industries that every project is dogged with uncertainties. The precise scope of work at the time of contracting is generally uncertain as engineering/design is typically not more than 20 percent complete when a decision is taken to proceed with a project. There exist uncertainty regarding the exact configuration of the project, the productivity that the construction work force will be able to achieve; the precise nature of contracts and subcontracts is unknown. The philosophy behind procurement and the duration of testing to ensure compliance with specifications is also unknown. Although these project specific uncertainties will be resolved as the project proceeds, but at the outset, when time and budgetary targets are being formulated, all these uncertainties usually exist.

In their study on key risks management in construction projects by Patrick et al (2001); tight schedule was ranked as the most significant client risk among other risks factors, which infers that formulating an appropriate schedule in the conceptual/feasibility phase is never more constructive to the project delivery. The clients should prepare a practical schedule allowing sufficient but redundant time to accommodate all design and construction activities. As time and cost are always closely correlated, a lengthy schedule will undoubtedly wreck the project cost benefit. Inadequate program scheduling often appears in project with tight schedule when some activities need to be reduced to meet the project timeline. Moreover, uncertainty surrounds most facets of construction projects, which makes it impossible to accurately predict the time required for various activities. Choosing experienced designers can help minimise the difference between the proposed and practical program schedules

Industrial report (2009) based on a three year research project from 2001 to 2004, written by the research team from University of the West of England, University of Salford and University of Loughborough it was found that during construction projects, many decisions have to be made under uncertain conditions. Due to limited time available to complete the design the project team have to make assumptions based on existing available information and their experience. If any assumption is proven wrong, some decisions have to be revised, in other words, changes are often inevitable.

The question can therefore be asked at what stage of design completion percentage should the employer make the decision to proceed with the construction phase in order to minimise design changes which may affect the construction contractor on site. Could it be that due to schedule pressures the employers are willing to take the risk of design changes which may result in schedule and cost overruns? Design teams often have to make assumptions regarding site conditions in order for the design work to continue, what happens if the assumptions are proven to be incorrect late in the design flow?.

2.3 Related Work

Changes in a construction project can be classified according to the causes that forced them. Mohammad et al (2010), cites Burati et all who concluded that changes in construction are caused by design, construction, fabrication, transportation or operability. He reveals that design changes were found to constitute 52.5% of total changes, fall mainly into three categories.

The first category is the design changes caused by improvement through design process (DCI). Examples are changes resulting from design reviews, technological advances or constructability reviews. Design changes originated by Owner (DCO) fall into the second category, scope change indicated as an example. Third is the design changes initiated by Engineer or consultant familiar with the process (DCP). Examples are additions of pumps, valve or instrumentation that affect the operation of the facility.

Mohammad et al (2010) found that the client, consultant, construction contractor and equipment vendors (Sami, 2006) are parties responsible for causing design changes. The factors leading to design changes per party were found to be as follows:

a) Client related changes:

These are the causes of design changes as initiated by the client. In some instances the owner directly initiates changes or the changes are required because the owner fails to fulfil certain requirements for carrying out the project. The changes initiated by the client were found to be as follows:

- <u>Change in scope</u>

Memon (2011) states that frequent design changes with change in the scope of the project have strong positive correlation with each other. PMBOK (1996) under project scope management states that scope change requests may occur in may forms – oral or written, external or internally initiated, and legally mandated or optional. Changes may require expanding the scope or may allow shrinking. Most changes occur as a result of one or more of the following factors. Firstly an external event such as the change in government regulation e.g. the change in regulation regarding petroleum products, in particular cleaner fuels, affecting the petrochemical industry (Government Notice R421 of May 31, 2012). Secondly an error or omission in defining the scope of product, e.g. failure to include a required feature in the design of telecommunications systems, results in scope of work change. Thirdly, an error or omission in defining the scope of the project, for example the use of bill of materials instead of a work breakdown structure. Lastly a value-adding change for example an environmental remediation project is able to reduce costs by taking advantage of technology that was not available when the scope was originally defined.

The Consultants which were part of the research study by Sun all (2009) on managing changes in construction projects indicated that in many projects late changes to the design are made because the client keeps changing their requirements. This result in a waste of staff time as high as 30% in a typical project.

Patrick et al (2001) mentioned that variations by the client can directly result in the changes in the planning, design and construction. Variations possibly result from two reasons, the change in mind by the clients or the misunderstanding/misinterpretation of the client’s needs in the project brief. For the former cause the clients will bear the responsibility, for the latter one, a knowledgeable initial project team should be established as early as possible to define the project scope and functions precisely. High performance/ quality expectations are contained in most client's mind, which may mean the sacrifice of project cost, time and even safety.

- Owner's financial problems

Change in the financial status of the owner may result in the owner instructing the design team to focus on lean design, fit for purpose, in order to reduce the project costs. (The Lean Design Guidebook: 2012).

Tumi et al (2009) cites the work of Rahman et al in which it was determined through a survey that financial problem is confirmed by the survey as the main causes of delay in the Malaysian construction industry

Mezher et al (1998) conducted a survey of the causes of delays in the construction industry in Lebanon from the viewpoint of owners, contractors and architectural/engineering firms. It was found that owners were more concerned regarding financial issues and contractors regarded contractual relationships as the most important, while consultants considered project management issues to be the most important causes of delays.

- Inadequate project objectives

Project objectives should list the quantifiable criteria that must be met for the project to be considered successful. The objectives must include, at least, cost, schedule and quantity measures. Project objectives should have an attribute, e.g. cost, a yardstick (e.g .U.S dollars) and an absolute or relative value (e.g. less than a 1.5 billion).The Project objective should be included in the scope statement which provides a documented basis for making future project decisions and confirmation or developing common understanding of project scope among the stakeholders(PMBOK, 1996). Inadequate project objectives may result in misalignment among the design team, a situation which may result in design changes.

- Replacement of material

Due to financial reasons the employer may deem it necessary to replace material captured in the design with other material type that is cheaper but fulfil the design requirements.

- Interference by the Employer

Interference by the employer on the consultant work flow is one of the contributing factors to design changes (Sami, 2002).

- Change in specifications or defective specifications

Design teams are faced with a situation where they have to properly interpret the specifications called for in the contract documentation. Misinterpretation and presentation of the specifications in the design may result in design changes. Claims Management (2012) mentioned that sometimes the drawing asks for one product but the specification calls for another. This situation is very common on construction projects where the drawings are assigned to different consultants, each one of them acting on their own, without any kind of direction from a team leader. This leaves the contractor with the difficult task of assuming and quoting on one article, but when the installation is going to be made, the owner, requires another article to be installed, instead of the one that you have already quoted.

The term defective specifications is common throughout the industry and generally refers to specifications containing errors and/or omissions. The common types of defective specifications include the following:

- Copied specifications
- Expired specifications;
- Generic specifications;
- Impractical specifications;
- Multiple specification interpretations; and
- Nondisclosure

(Holloway: 2006)

Copied specifications: In many cases, specifications are rarely prepared totally from scratch or solely for a specific project. Principal factors that increase the probability that copied specifications will result in errors in the contract documents include the fact that the engineering, design, and construction drawings are the primary focus of the design team and the client. The technical specifications tend to be a secondary priority and little attention is given to them until the design is complete. Under such circumstances, copying and editing an existing specification is often viewed as the obvious and easiest method of preparing specifications. Copied specifications are not inherently defective or inappropriate, but when used improperly and assembled carelessly, they can lead to changes and problems during construction. (Construction Reporter: 2007).

Expired specifications: In the industry many specification have got a limited shelf life. The age of a specification can become problematic in projects, because the specifications are subject to changes and further development which may alter the design.

Generic specifications: Generic specifications are similar to copied specifications in that they often originate from previously completed projects.

Impractical specifications: The design teams often follow old ways of doing things, sometimes conducting and completing the design without due consideration for construction means and methods, or not properly coordinating an item with adjacent work. Design conflicts sometimes result in specifications that are needlessly difficult, and sometimes impossible to build.

Multiple specification interpretations: If a specification is subject to more than one reasonable interpretation, design team members have the right to choose one of those interpretations. This may result in inconsistencies and change in design.

Nondisclosure refers to the failure to inform a contractor of design or construction information that is or may be significant to the pricing and completion of the work. This may affect the design and result in changes.

b) Consultant related changes

These are the causes of design changes the consultant directly initiates or the changes are required because the consultant fails to fulfil certain requirements for carrying out the project. The changes initiated by the consultant were found to be as follows:

- Change in design
- Errors and omission in design
- Conflicts between contract documents
- Design complexity
- Inadequate shop drawings details
- Lack of consultant’s knowledge of available material and equipment

Patrick (2011) when discussing risk related to designers states that to avoid defective design, the design team need not only to understand fully understand what the clients want as defined in the project brief, but also to establish an efficient communication scheme among the designers.

Sun et al (2009) cites that the construction contractors often have to delay the work on site and even re-do the work because the drawings provided by the designers are either incomplete or inconsistent with the site conditions Their study on managing change in construction projects indicates that it is important to have accurate information to enable the design to continue with a high degree of accuracy (e.g. accurate information regarding underground site conditions will affect the design of the underground civils). Prior to any design scheme, bore hole, soil test and survey with the government agencies and nearby building should be conducted to ascertain the site conditions and reduce unexpected risks.

Patrick et al (2001) states that choosing responsible and experienced designers is critical in minimising wrong decision or assumptions being made at the design stage which may later result in design changes

Abdalla et al (2002) cites the study of Assaf et al in which the causes of delay in large building construction projects in Saudi Arabia are studied. The most important causes included approval of shop drawings, design changes, design errors, labor shortage, slow decision making and inadequate labor skills. Menon (2011) study on factors leading to construction cost overrun found that the delay in preparation and final approval of drawings ranked as the sixth cause of project delays.

Other possible causes of design changes mentioned by Sami (2002) includes the late decision making process which may result in the design team making assumptions due to indecisiveness.

c) Contractor related changes:

In some instances the construction contractor may suggest design changes or the changes may be due to the contractor failure to fulfil certain requirements for carrying out the project. The contractor related changes were found to be as follows:

- Lack of contractor's involvement in design

Many constructability issues occur as a result of a lack of communication between the project owner, architect or designer and the construction company before construction commences. Constructability reviews are easily managed for projects where the contractor is determined beforehand. The preferred contractor is engaged at the first client briefing stage and is involved all the way through the design phases. The contractor is an integral part of all design meetings and reviews all documents, plans, drawings, specifications, tender documents and procurement schedules. For build-own-operate-transfer (BOOT) projects (where the construction company is entirely responsible for all project design and construction), in the absence of an internal constructability review function the company must bring in external constructability expertise to establish a rigorous design review that is fully buildable, without excessive costs or time delays. This requires designers to provide their designs for external review at all levels, something that some architects are unwilling to do. Late involvement of the contractor may result in design changes due to late addressing of design constructability issues. (McDowall: 2008).

The study by Mohammad (2010) reveals that the employer, consultant and the construction contractor's involvement or lack thereof in the design stage of the project may result in factors which may cause design changes. These changes may result in project schedule delays and/or cost overruns. Sami (2002) mentions that lack of involvement of the construction contractor in the design stage may result in difficult to construct design, requiring changes later in construction phase.

d) Equipment Vendor Relates changes

Equipment vendor not meeting design specifications, resulting in the design team changing previously selected process equipment and also the lack of knowledge of available materials and equipment have a negative impact of design.

2.3.1 Other Causes of Design Changes and Delays

Ahmed (2002) identified the following possible causes for delays:

- Lack of coordination or interest by plant owners at design phase and enforcing change during the construction phase
- Inadequate reviews, which may be compounded by late involvement or change of personnel bringing new ideas late during design phase
- Insufficient data collection and survey before design.
- Inexperienced personnel
- Lack of coordination at design phase: The lack of coordination of the project team activities contributes significantly towards design changes.

Other frequently cited reasons for design changes included a change in the employer's requirements, designer's omission in tender documents and new information on existing site conditions (Cox, 2010).

In the study by Sami et (May 2006) on international projects the most important conclusions are as follows:

- Consultants play a very important role in design-related delay because they are in charge of the design process in conjunction with the owner of the project. On the other hand, the government plays the most important role in code-related delay, while the contractor has the major responsibility in construction-related delay.

- Design-related issues, such as changes in drawings and incomplete and faulty specifications and change orders, have a very damaging effect on project completion times and invariably lead to cost escalations as well.

- These issues can be controlled with proper design process management and timely decision-making. Decisions made early in the life of a project have the most profound effect on the project's objectives of delivering a safe, quality project within the time and budget allocated.

Code related design changes are sometimes encountered in construction projects. Loots (1995), states the following case as an example of project design delay due to change in international standard requirements, code related change:

"An offshore gas production platform was designed according to ruling international standards. Its design was such that it would deliver gas continuously to an onshore plant that could not tolerate a loss of supply of longer than 15 minutes. During the construction of the offshore platform the international standards were changed due to a disaster in the offshore gas industry elsewhere. The tighter control standards meant a likelihood that the platform supply would be lost for more than 15 minutes every day, and that at a late stage in the project it became necessary to include additional gas storage in the system."

2.4 Types of Delays

There are two kinds of causes for delays in construction projects: external and internal causes. Internal causes of delays include the causes, originating from parties involved in that project. These parties include the Employer, Designers, Contractors, equipment vendors/suppliers and Consultants. Other delays, which do not come from these four parties, are based on external causes, for instance from the material suppliers or weather. (Sami, 2002).

Delays can be classified in the following broad categories:

- Non-excusable delays
- Excusable non-compensable delays
- Excusable compensable delays
- Concurrent delays

The above is explained as follows:
(Wikipedia; 2012)

2.4.1 Non-excusable Delays

These are type of delays were the construction contractor is not compensated in terms of time and/or costs and may be required to pay liquidated damages.

The construction contractor is responsible for the non excusable delays. These may be due to underestimates of productivity, inadequate scheduling or mismanagement, construction mistakes, equipment breakdowns, staffing problems etc. These delays are within the control of the Contractor or are deemed to be foreseeable; however, it is not necessary that they be both.

2.4.2 Excusable non-compensable delays

This is a delay caused by factors that are not foreseeable, beyond the Contractor's reasonable control and not attributable to the Contractor's fault or negligence. This means that neither party is at fault under the terms of the contract and has agreed to share the risk and consequences when the excusable events occur. The Contractor will not be compensated for the cost of delay, but he will be entitled to additional time to complete his work and is relieved from any contractually imposed liquidated damages for the period of delay.

2.4.3 Excusable compensable delays

The contractor is entitled compensation both in terms of time and cost. In addition to the compensable delays that result from contract changes by change Notice or Employers Instruction, there are compensable delays that can arise in other ways. Such compensable delays are excusable delays, suspensions, or interruptions to all or part of the work caused by an act or failure to act by the Employer resulting from Employer's breach of an obligation, stated or implied, in the contract.

According to the survey conducted Sami (2006) it is concluded that design related delays are considered to be excusable compensable delays. The design related delays are among the five most critical delay categories which include the construction-related, financial/ economic, management/ administrative and code-related.

2.4.4 Concurrent delays

Concurrent delays occur when both the Owner and the Contractor are responsible for the delay. In this instance the owner’s risk event has occurred whilst the contractor is also at fault for a delay in the project. The Employer cannot in this instance force the contractor to accelerate or be held liable for liquidated damages. The Contractor on the other hand cannot recover delay damages from the Employer.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this section is to describe the research methodology employed for this study. The research problem is outlined in chapter 1 and the relevant theory was discussed in chapter 2.

The onion approach (figure 3.1) is adopted in getting to the choice of data collection techniques and analysis.

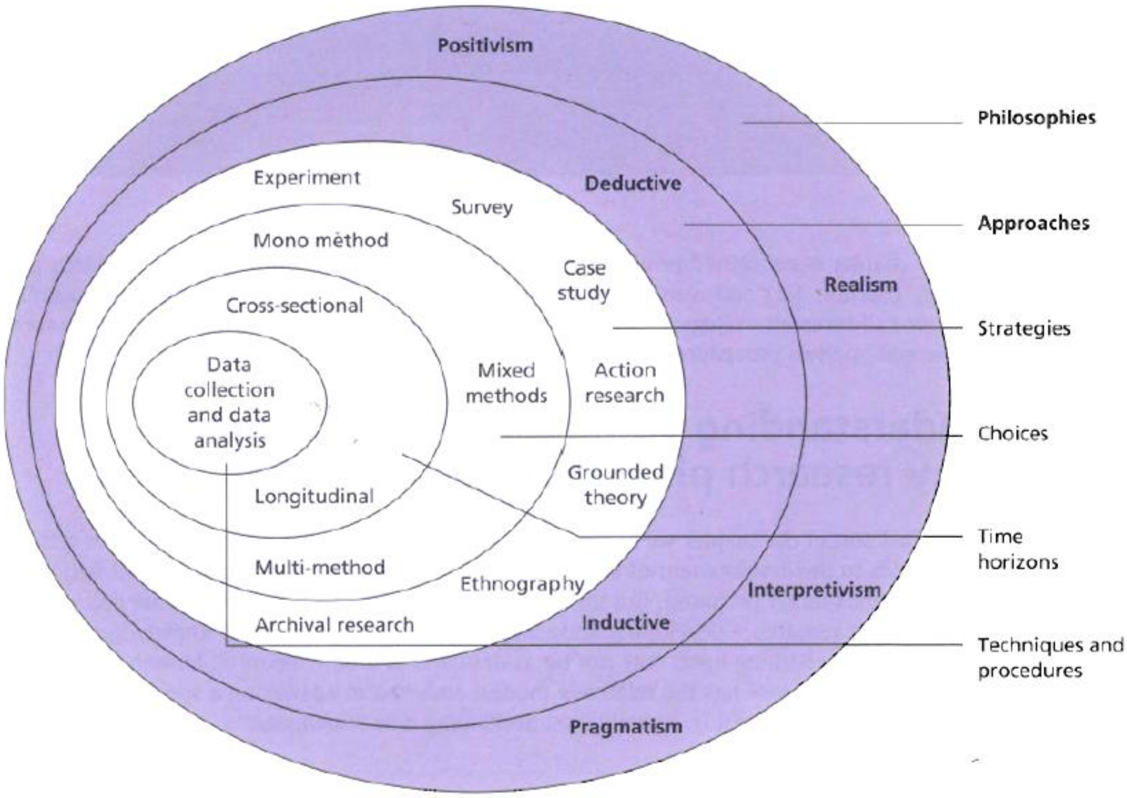


Figure 2: The Research Onion (Saunders 2009)

3.2 Research Philosophy, Approach and Strategy

The theory relating to the causes of design changes during project execution was obtained and a hypothesis relating to the study was formulated as indicted in chapter 1. The study adopts a deductive approach in which the previously formulated hypothesis based on reviewed literature will be tested, when data collected is compared with the expectation created from theory (Saunders 2009). It is thus necessary to select a sample of sufficient size in order to generalise conclusion.

The research strategy is to elicit the individual's assessment or opinion on the cause of design changes in chemical process plant projects based on their experience on chemical process plant projects. According to Zikmund (2003) the survey method is generally used when the researcher wishes to elicit opinion. The research strategy adopted in this study is through survey. Saunders (2009) mentions that the survey strategy is usually associated with the deductive approach. This is a commonly used strategy in business and management research and is most of the times utilised to answer who, what, how much and how many questions.

The research choice refers to the way in which the researcher chooses to combine quantitative and qualitative techniques and procedures in their study (Saunders 2009). In this study a single data collection technique and corresponding data analysis procedure (mono method) as described by Saunders was utilised. The research methodology will be qualitative in nature.

A cross sectional study approach is employed and it will reflect a snapshot time horizon, implying that the study is taken at a particular time as explained by Saunders (2009). The study will be limited to petrochemical process plant projects currently in execution and those completed in the past 5 years with focus on the projects undertaken by the major industry player in the Mpumalanga and Free State provinces.

3.3 Data Collection and Analysis

The specific population for the study is confined to individuals with experience in the chemical process plant execution and will focus on projects executed by SASOL Group of Companies. Purposive sampling will consist of the consultant's design engineers, which is the Process, Mechanical, Electrical, Civil, Instrumentation, Project and Designers. The Employer's engineers or review team involved in design activities will form part of the sample. The Project and Engineering Managers from the Consultant, Employers and Equipment Supplier/Vendors will also form part of the study. The selected method for data collection will be by self administered questionnaires via email. The sample makeup and size is as indicated in table 3.1. below.

Discipline	**Consultant**	**Employer**	**Equipment Supplier/Vendor**	**Total**
Process Engineers	3	3	1	**7**
Mechanical Engineers	3	3	2	**8**
Electrical Engineers	3	2	2	**7**
Instrumentation Engineers	3	2	1	**6**
Project Engineers	3	2		**5**
Project Designers (Drawing Office)	3			**3**
Commissioning Engineers			2	**2**
Project Managers	5	5	3	**13**
Engineering Managers	3	3		**6**
TOTAL	**26**	**20**	**11**	**57**

Table 1: Sample Size

A response rate of 75% is expected and thus the researcher expects to obtain over 40 cases for analysis. According to Saunders (2009) data for analysis can be grouped into three categories namely

- Summarising (condensation) of meaning
- Categorisation (grouping) of meaning
- Structuring (ordering) of meaning using narrative

Categorisation which involves developing categories and subsequently attaching these categories into meaningful chunks of data for analysis will be employed in this study in order to answer the research problem and sub-problems. The University of Pretoria Statistics Department will be consulted for assistance with the structuring and design of the questionnaire and also data analysis. A draft questionnaire was developed and issued via email to the Statistics Department for comments and analysis of the questionnaire in line with main and sub-problems. Upon final approval thereof the questionnaire was issued via email to the respondents.

3.4 Development of a questionnaire

Self-administered questionnaire shall be developed for collection of data on the respondent's opinion on the factors causing design changes. The data will be analysed to answer the main problem and sub-problems of the study. The questionnaire was developed using an excel document to be send electronically via email for completion by the respondents. The respondents were given a period of 5 days to complete the questionnaire.

The questionnaire is developed into 2 sections where section A's aim is to obtain the respondents attributes whilst section B's purpose is to obtain the respondent's opinion on factors leading to design changes. The rating of occurrence frequency of the design change cause and the responsible party or parties deemed to be responsible for causing of the change shall form part of questionnaire. This shall be based on projects the respondent has recently completed.

Each investigative question was targeted at gathering data about the main or sub-problems. The respondents opinion on the investigative question is recorded which is the variable data required for analysis. A check was conducted to ensure inclusion of the relevant questions in the questionnaire.

CHAPTER 4 DATA ANYLYSIS AND INTERPRETATION

4.1 Introduction

The purpose of the data analysis and interpretation chapter is to present the analysis and discussion of data gathered from the respondents. This chapter attempts to answer the research questions asked at the beginning of the study, the main problem and the sub problems (refer to see sections 1.2 and 1.3). Data collection methodology is highlighted in the previous chapter and the questionnaire used is attached as appendix A. The questionnaire is structured in such a way that the first two questions are of numerical data and categorical data applies for the balance of the questions, i.e. questions 1 to 19 of section B. The last three questions, questions 20 to 22 are open-ended questions and seek to obtain other causes of design changes not mentioned elsewhere in the questionnaire.

Before the questions are analysed, a brief outline is given of the sample size and response rate.

4.2 Sample size and Response rate analysis

The sampling frame was compiled focusing on personnel who are currently working on process plant chemical projects and have completed such projects in the past 5 years. A total of 50 questionnaires were issued to be completed by the respondents. A response rate of 75% was originally estimated however 70% was received, equivalent to 35 respondents. A lower than expected response rate may weaken the effectiveness of the questionnaire survey, however the respondents experience in the petrochemical industry, profound knowledge and ample experience can compensate for the aforementioned weakness.

A snap shot of the total response rate was calculated and it yielded the following (Saunders, et al. 2009):

$$total\ response\ rate = \frac{total\ number\ of\ responses}{total\ number\ in\ sample - ineligible}$$

$$total\ response\ rate = \frac{35}{50 - 0}$$

$$total\ response\ rate = 70\%$$

The original target was to issue 58 questionnaires, however 7 prospective respondents could not be reached, 5 had high work load and 3 were off sick and could not complete the questionnaire. Saunders (2009) provides another way of calculating the active response rate as follows:

$$active\ response\ rate = \frac{total\ number\ of\ responses}{total\ number\ in\ sample - (ineligible + unreachable)}$$

$$active\ response\ rate = \frac{35}{57 - (0 + 7)}$$

$$active\ response\ rate = 70\%$$

The active response rate of 70% is regarded as reasonable and satisfactory when compared to a good practice of 35% for academic studies (Saunders, 2009).

4.3 Data Analysis (Attributes)

The first question on the questionnaire related to the experience in terms of number of years the respondents had on petrochemical process plant projects. The respondents experience may be critical when drawing the conclusion in chapter 5. Figure 4.1 below reveals that 12 of the respondents (34%) have between 4 and 6 years relevant experience whereas 4 of the respondents (11%) have over 15 years experience. The analysis revealed that the years experience range was from 2 years minimum with 40 years as the maximum. This is perceived to be an indication of the huge gap regarding experience in the project environment, young professional being introduced into the industry with highly experience personnel reaching retirement age. Knowledge transfer is therefore critical.

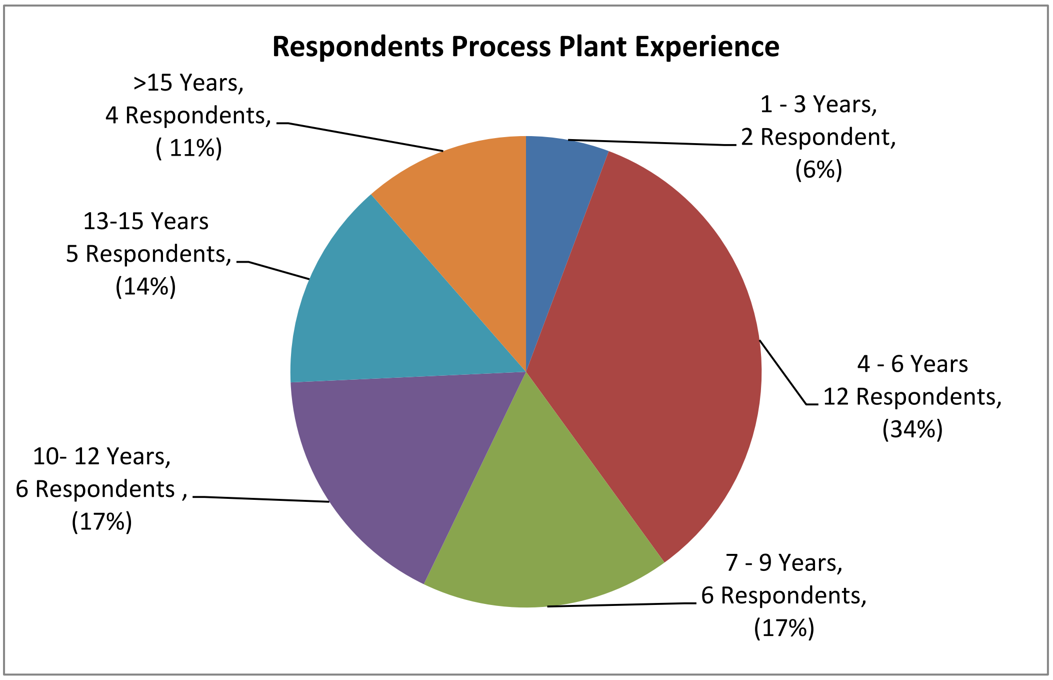


Figure 3: Respondents Process Plant Projects Experience

The second question addressed the number of projects the respondents had worked on in the previous 5 years. Figure 4 below provides the analysis.

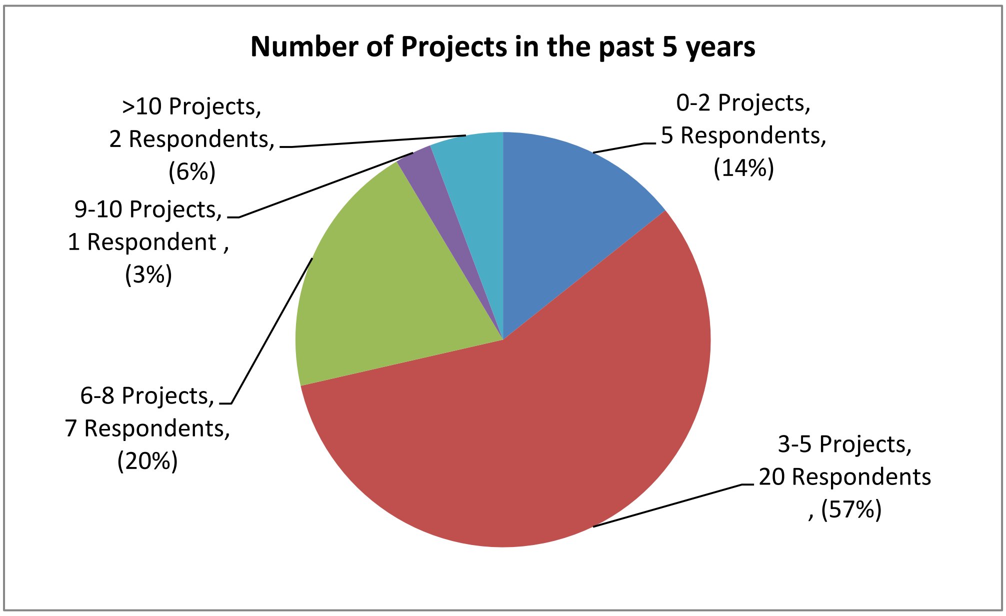


Figure 4: Number of projects work on in the past 5 years

The above shows that the 20 of the respondents, 57%, have worked on 3 to 5 projects in the past 5 years. This was expected due to the size and long duration of the process plant projects. It was discovered that for the respondents that had worked on over 9 projects, this was mainly on sub-projects which were part of a programme, running over a longer duration. They were allocated to work on various programme work packs which had to be completed within a short period of time in support of the bigger project.

Question 3 was aimed at determining the organisation the respondents belong to. The three organisations considered was the employer, also known as the client, the design consultant and lastly the equipment vendor. Figure 5 provides the analysis.

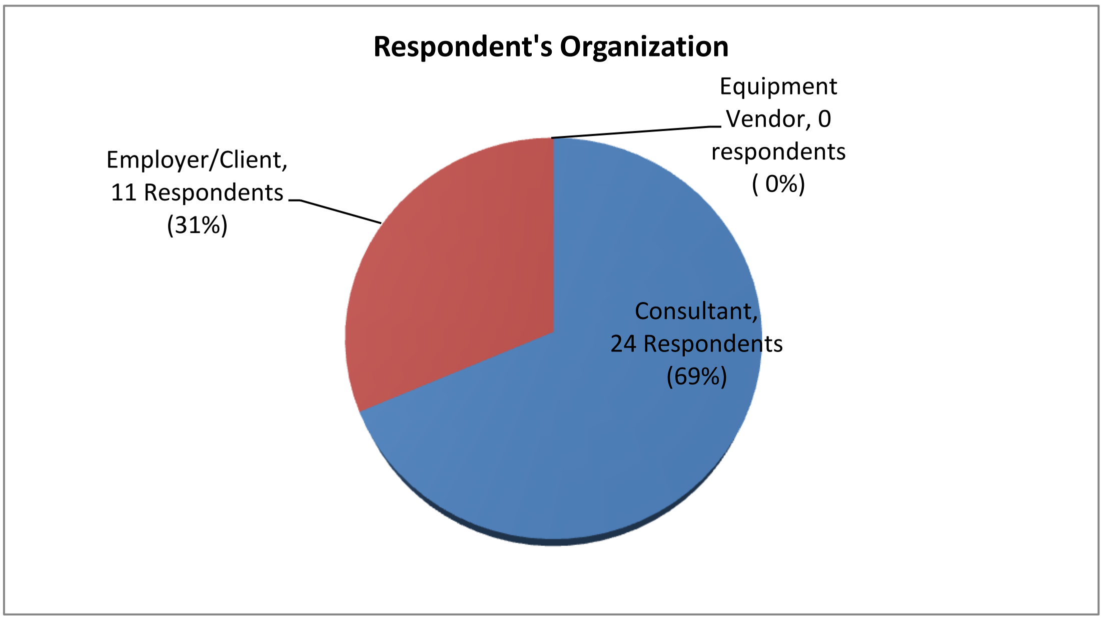


Figure 5: Respondents Organisation

The majority of the respondents were the consultants at 69% equivalent to 24 respondents. Equipment vendors were part of the sample and none of them could be reached at the time of sending out the questionnaires. The implication to the study is that the Consultant and the Employer will present their opinion regarding the vendor's influence on design changes. Unfortunately this will not be tested against the vendor's response.

It should be noted that some of the respondents belonging to the employer's organisation indicated their unwillingness to respond, citing their discomfort in assigning the project delays to their organisation. This has resulted in a low response rate from the Employer's organisation which will result in the outcome of the study results been based on a greater weighting on the Consultant's opinion.

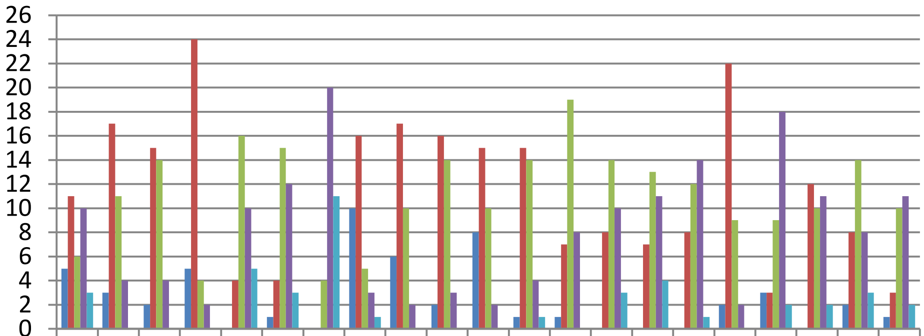
4.4 Analysis of Data (Opinion based)

The aim of section B of the questionnaire was to obtain the respondents opinion on the factors causing design changes as obtained from the literature review. The respondents were to answer the questions based on their opinion on how they feel or perceive the factors causing design changes in the projects they have been involved in. This data type obtained for questions 1 to 19 of part B is descriptive in nature. Descriptive data defines categories numerically and ranks them in order to count the number of occurrences in each category of variables (Saunders, et al. 2009). The respondents had to rate each question based on the five categories, which were:

- Very Often
- Often
- Unsure
- Rarely
- Never

In answering the main problem, i.e. the main causes of design changes, the first category to be analysed will be “very often”. This will be done by counting per question the number of times the respondents have ranked each factor which very often occurs in projects and causing design changes.
This may result in a number of design change factors weighted equally and considered by respondents as the factors causing changes. The first three factors with a high count will be ranked as the factors mainly responsible for design changes in the petrochemical. The other factors of design changes will be obtained from the first two highest count factors under the “often” category.

Each questionnaire was coded with a unique number and a master excel document was developed to collate all the respondents questionnaires. The final count per question based on the five categories is represented in the graph below.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q13a	Q13b	Q14	Q15	Q16	Q17	Q18	Q19
Very Often	5	3	2	5	0	1	0	10	6	2	8	1	1	0	0	0	2	3	0	2	1
Often	11	17	15	24	4	4	0	16	17	16	15	15	7	8	7	8	22	3	12	8	3
Unsure	6	11	14	4	16	15	4	5	10	14	10	14	19	14	13	12	9	9	10	14	10
Rarely	10	4	4	2	10	12	20	3	2	3	2	4	8	10	11	14	2	18	11	8	11
Never	3	0	0	0	5	3	11	1	0	0	0	1	0	3	4	1	0	2	2	3	2

Figure 6: Descriptive Data Analysis (Ranking)

With the above graph it may be difficult to establish the major contributing factor based of the five categories, hence the additional graphs are presented below to make analysis easier.

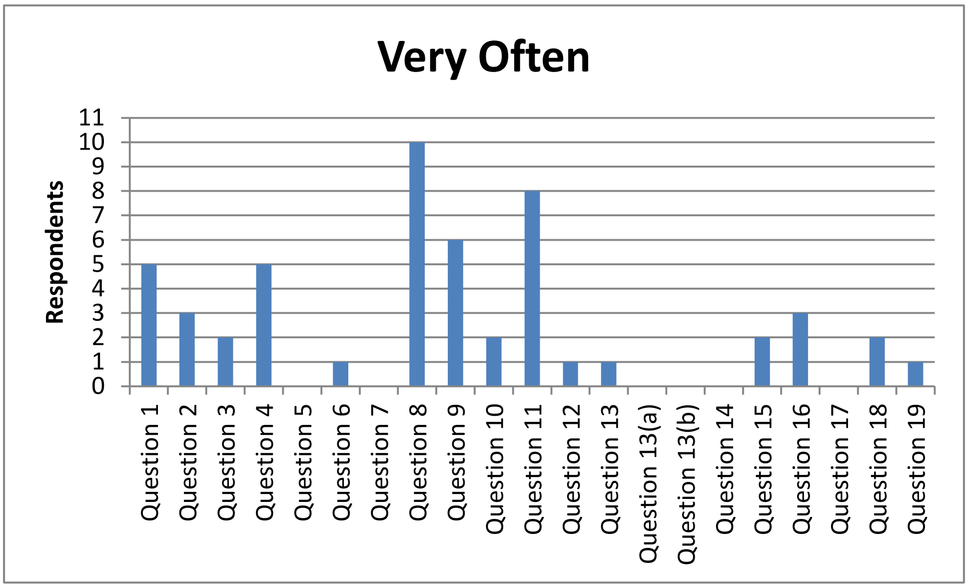


Figure 7: Factor(s) Very Often Causing Design Changes

Question 8 (Unrealistic duration to complete design) was ranked by 10 respondents to be the highest factor that very often causes design changes. Questions 11 (Insufficient equipment information resulting in assumptions at early stages of design) and questions 9 (insufficient/unknown information regarding site conditions during design phase) were ranked to be the second and third factors that very often cause design changes.

The first two factors are related, to obtain sufficient equipment information, the design team need more time to develop the design to a stage where more process information can be made available to the equipment vendor to specify in more details the process equipment to be used.. The process equipment information can then be made available to the design team to continue with the design without making major assumption, e.g. equipment size, weight, electrical requirements etc. However, the schedule pressure does not allow for this process to be followed. Without sufficient process information from the design team the equipment vendor cannot be utilised effectively in the design.

Figure 8 below provides an analysis of a factor(s) which often causes design changes.

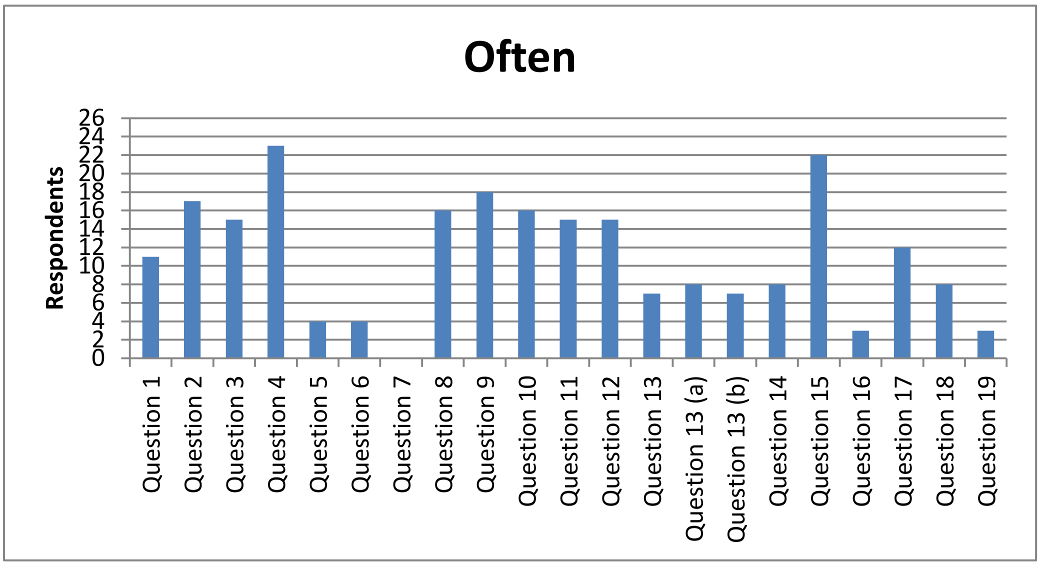


Figure 8: Factor(s) Which Often Causes Design Changes

Question 4 (Change in scope of work) was ranked to be the major factor which often causes the change in design. This was ranked by 23 respondents and was closely followed by question 15 (Sufficiently experienced personnel and critical stakeholders not attending design reviews and later enforcing design change) with 22 respondents agreeing to this factor.

Having sufficiency experienced personnel during the early stages of project may help minimise the change in scope of work later on in the project. In some instances, an unrealistic time frame provided to the design team to complete the design, may result in scope changes, e.g. more information becomes available later which the design team were not given time to explore in the early stages of the project.

The factors which the respondents are unsure about their contribution towards design changes are presented below.

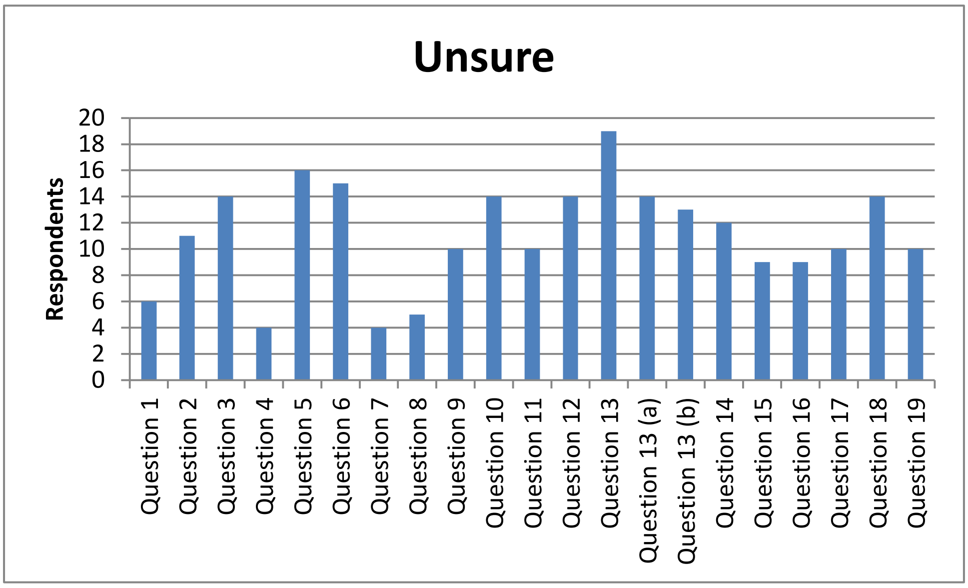


Figure 9: Design Change Factor(s) which the respondents are unsure about

Question 13 (Lack of necessary experience by the design team, inadequate design skills) and question 5 (Change in design specification after contract award) and are ranked to be factors which sometimes cause design changes. The two factors were ranked by 19 and 16 respondents respectively. Question 6 (Ambiguous design specifications resulting in rework) was ranked as the third factor by 15.

A lack of necessary experience by the design team (inadequate design skills) can be linked with figure 4.1 (analysis of years experience). This further emphasised the experience gap between young design team members, who form the majority of the design team complement, compared to the few experienced personnel currently involved in the projects.

The analysis of factors which rarely and never contribute to design changes are presented in the two graphs below.

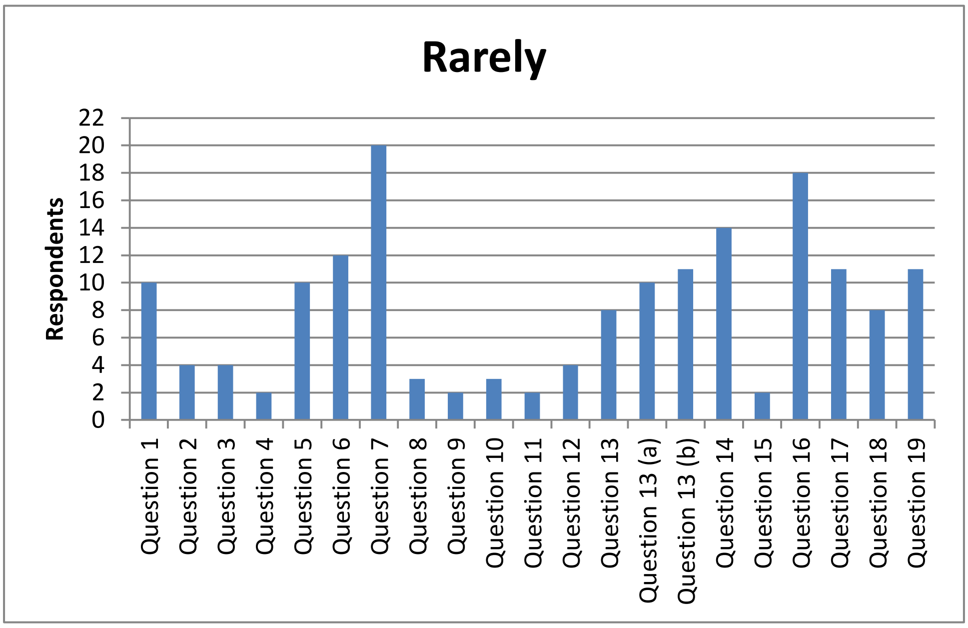


Figure 10: Factor(s) Which Rarely Cause Design Changes

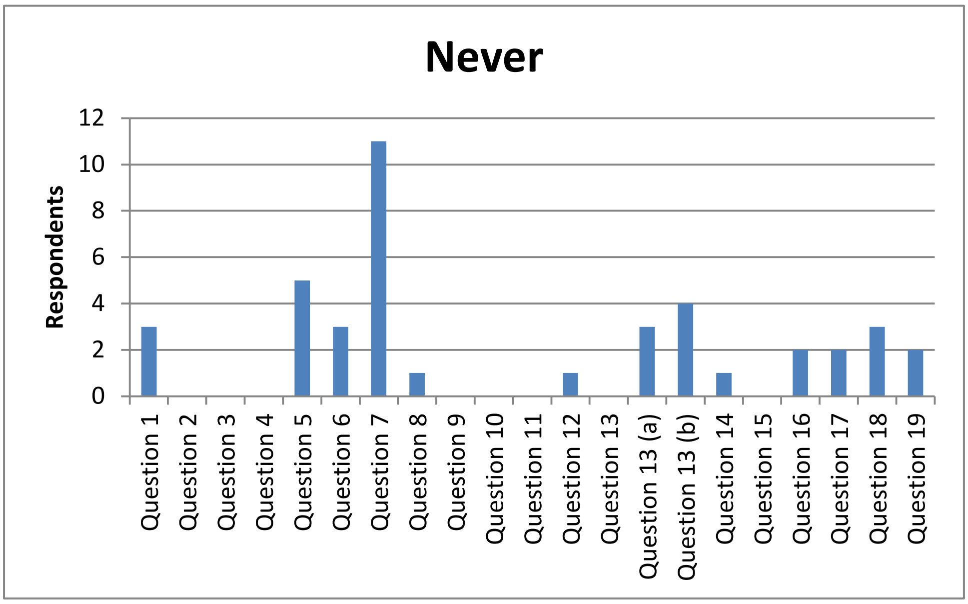


Figure 11: Factor(s) Which Never Cause Design Changes

Question 7 (Change in design codes post project commencement) was rated by 20 respondents as a factor which rarely contributes to design changes. The same factor was again rated by 11 respondents as a factor which never causes design changes.

4.5 Other Causes of design changes

The respondents were offered an opportunity to list other causes of the design changes not listed in the questionnaire. The following additional causes were established thorough this research.

- Not correctly interpreting the scope requirements and developing acceptable schedule at bid stage to allow sufficient time for engineering to produce quality deliverables.
- High turn-over of key personnel
- Late Client comments.
- Weak management: The inability to make hard decisions, over-rule design disciplines and maintain tight control on project budget and schedule.

- Inefficient systems: Most consultant systems are set up for document management and not data management. You can get away with this on small projects, but not larger ones. The engineering data of management from mass balance to requisition to be stream-lined.
- Insufficient change management personnel to deal directly with employer/client to shield the consultant's design team from unnecessary disruptions and changes.
- Limited knowledge about existing infrastructure.
- Non involvement of construction team during design reviews and no proper constructability reviews during design.
- Inexperienced Employer team not providing support to the consultant and with no consideration for time or cost objectives.
- Poor interface management between engineering disciplines, equipment suppliers and other third parties on site.
- Constant interruptions by the Employer.

4.6 The Main Cause of Design Change

Based on the analysis the top three factors ranked to be the main causes of design changes are:

- Unrealistic time frame for completion of design
- Insufficient equipment information resulting in assumptions in the early stages of design and
- Insufficient/unknown information regarding site conditions during design phase

The other factors/causes of design changes are the change in scope of work and non-attendance of experienced personnel and critical stakeholders at design reviews and later enforcing design change.

Other causes of design changes not included in the 19 possible causes were provided by the respondents. They could not be objectively analysed as they were provided by few respondents and other respondents were not provided with an opportunity to comment on them.

4.7 Party (ies) Mainly Responsible for Design Changes

The sub-problem to the research is to establish which party or parties are mainly responsible for design changes. Based on the two main causes of change, i.e. from question 8 and 11, the associated responsible party was selected based on the respondent's opinion. The responsibility analysis for the two questions is presented below:

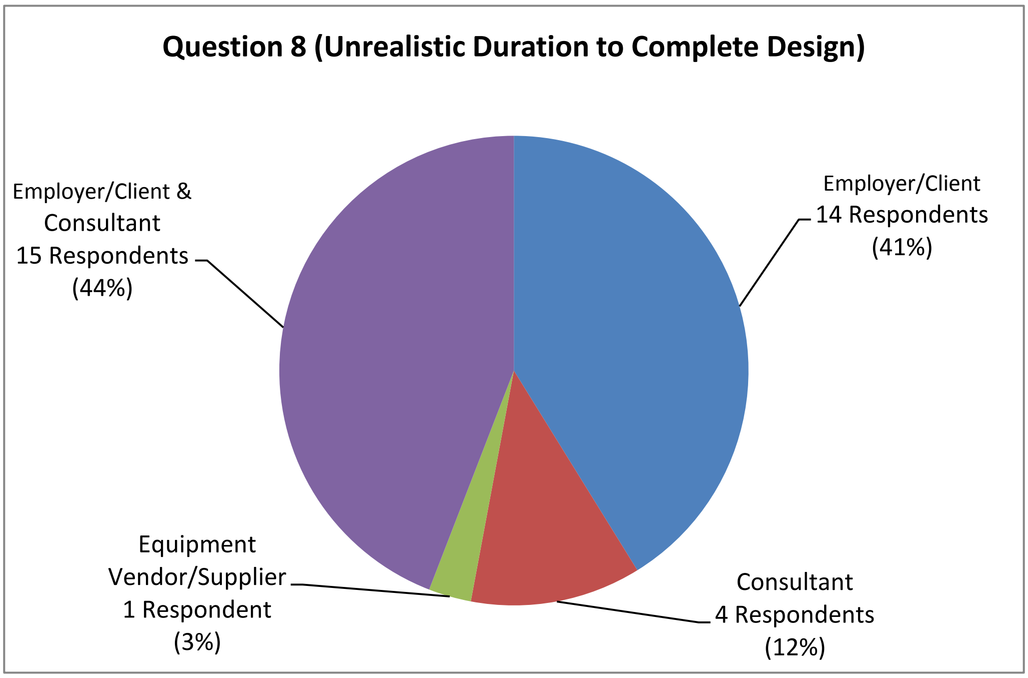


Figure 12: Reasonable Party (ies) for the change (Q8)

15 respondents ranked both the employer and the consultant as jointly responsible for the cause of design change. 14 respondents are of the opinion that the employer is responsible for the changes.

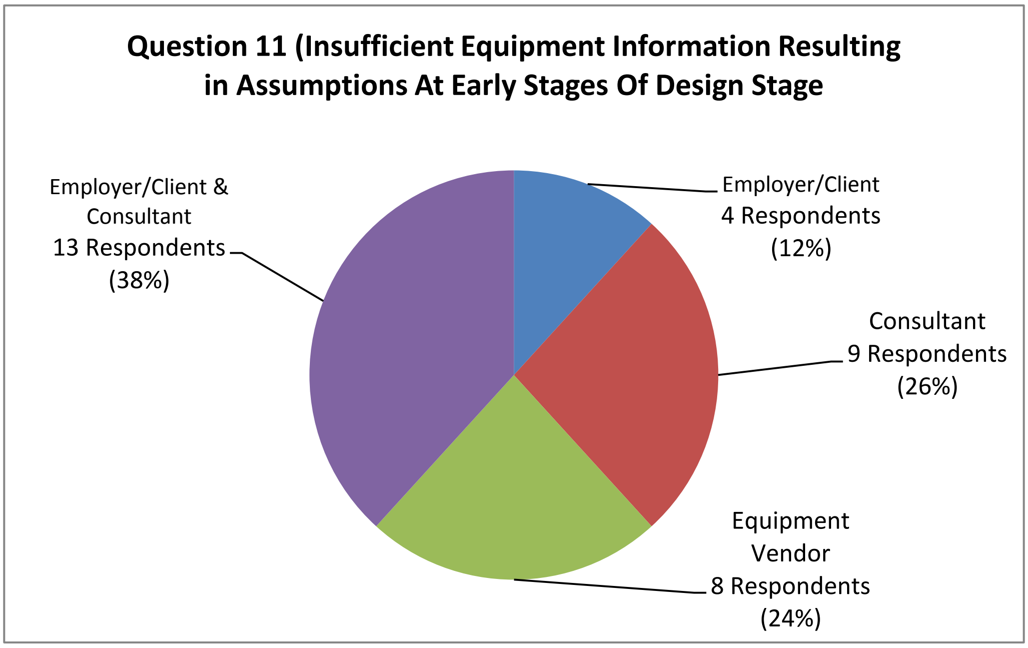


Figure 13: Reasonable Party (ies) for the change (Q11)

Figure 4.11 indicates that 13 of the respondents deem both the employer and consultant jointly responsible for the design change due to insufficient equipment information resulting in assumptions in the early stages of the design stage.

4.8 Design Team Members Experience

Sub-problem 2 relates to the design team skills and their ability to identify changes as they develop and minimise such changes. Figure 14 below indicates that 19 of the respondents are unsure about the impact of inexperienced personnel on design changes. It can thus be concluded that the lack of experience by the design team is a factor that has a minimal effect on the design changes compared to other factors.

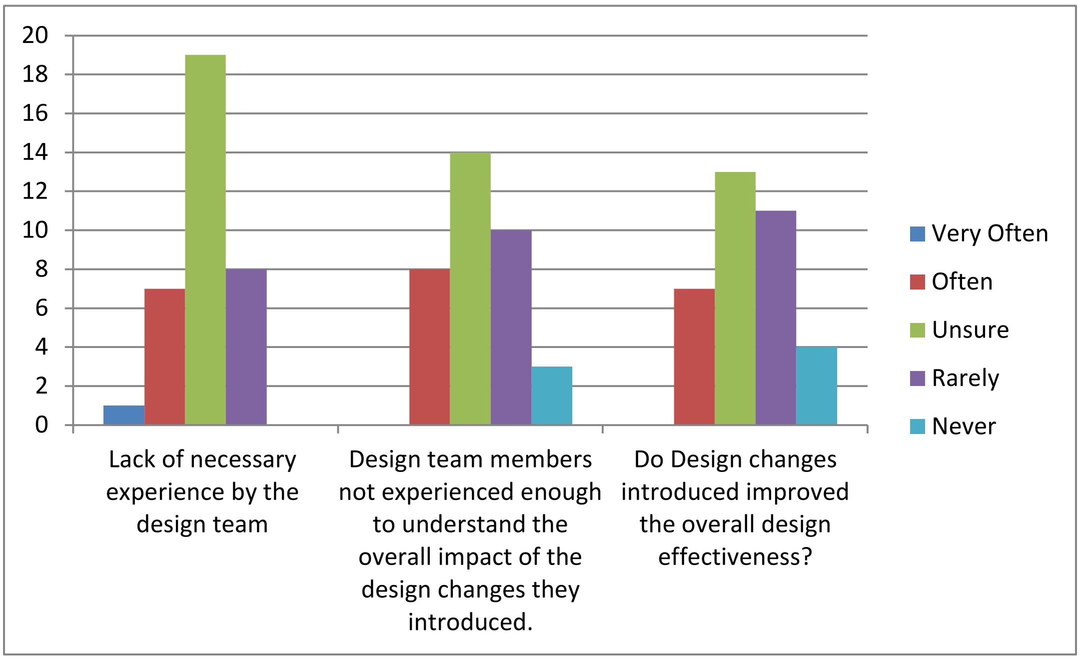


Figure 14: Design Team Skills and Impact on Design Changes

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The objective of this study was to identify the causes of design changes in petrochemical process plant projects in the Mpumalanga and Free State Provinces in South Africa. The sub-problems were to establish the parties responsible for the design changes introduced and to determine if the personnel utilised in the design phase of the project are skilled and experienced enough to identify changes as they occur and minimise such changes. Factors of the design changes were to be determined.

Based on the results carried out within this study it was established that the top three main causes of design changes are the unrealistic time frame for the completion of the design, secondly the lack of sufficient equipment information at early design stages of the project results in assumptions been made by the project team. Thirdly, insufficient/unknown information regarding site conditions during design phase.

The unrealistic time frame and unavailability of sufficient equipment information results in design changes as the design team have to make assumptions regarding equipment to be used in an attempt to fast track activities. The normal sequence is for the design to continue until equipment design information can be determined. The equipment vendor on the other hand can recommend process equipment only after sufficient design requirements and specification is available.

The other factors causing design changes in projects and lead to design changes are the change in scope of work and non-attendance of sufficiently experienced personnel and critical stakeholders at design reviews and later enforcing design change.

It is concluded that both the employer and the consultant are equally responsible for the identified main causes of design changes in petrochemical process plant projects.

It is further concluded that although inexperienced personnel are utilised in the design team, they sometimes contribute to the design changes, but this is not rated highly compared to other factors which causes design changes. Impact due to inexperience personnel is minimal.

5.2 Recommendations

Based on the conclusions mentioned above, the following recommendations are made:

- The Employer to present realistic project durations at tender stage, allow sufficient time for design to be progressed prior to moving to the next stage of the project.
- It is important that scope requirements be correctly interpreted by the project team and sufficient time be allowed in the early stages of the project for this activity to be undertaken. This will promote alignment among the project team members.
- The consultant to engage the equipment vendor as early as possible during the design stage. This promotes knowledge sharing and assumptions relating to the equipment can be tested with the equipment vendors earlier to minimise changes.
- Both the Employer and the Consultant are to ensure that sufficiently experienced personnel and critical stakeholders attend the design reviews to minimise design changes at a later stage.

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Questionnaire

1. INTRODUCTION
Design changes are encountered in execution of chemical process plant projects in South Africa. Such changes cause strained relationship among contracting parties in particular between the Employer and the Consultant as they result in schedule delays and normally attract additional costs, a situation unwelcomed.
2. OBJECTIVES
The aim of this research is to find out what is the cause of design changes when executing process plant projects in South Africa (to identify the factor leading to design changes). The cause of design changes resulting in project delays and the recommended measures identified through this study can be implemented by contracting parties in future projects, thus reducing the number of extension of time disputes in the industry.
3. INSTRUCTIONS
Please take a look at the following questionnaire and try to answer correctly and accurately, as many questions as possible. All the information gathered here will be kept strictly confidential and will be used only for research and analysis without mentioning the person or company names. WHEN YOU HAVE COMPLETED THE QUESTIONNAIRE, PLEASE RETURN IT TO ME VIA EMAIL NO LATER THAN THE **18 JUNE 2012**. MY EMAIL ADDRESS IS: andrew_maherry@fwuk.fwc.com If you have any queries please contact me on 071 850 0561 Thank you very much for your cooperation.

Section A: General Information

1. **What is your years experience in chemical process plants Projects?**
   a) Less than 2 years
   b) 3 years to less than 5 years
   c) 5 to 10 years
   d) Over 10 years
2. **What is the total number of chemical process plants projects you have worked on in the previous 5 years?**

   Answer : …………………….
3. **Which organisation are you currently part of ?**
   a) Employer
   b) Consultant
   c) Equipment Vendor/supplier

SECTION B: Factors Leading to Design Change

Considering the projects you have completed in the last 5 years and those you are currently involved in answer the following questions relating to the factors causing the design change in projects. The cause of design changes were derived from reviewed literature and you are to rate each design change factor according to frequency of occurrence based on your personal experience. For each cause of design change you are to indicate the responsible party or parties for the change.

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
1. Insufficient design requirements contained in the bidding documents.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
2. Change of design requirements after contract award.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
3. Insufficiently defined scope of work	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
4. Change in scope of work	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
5. Change in design specification after contract award.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
6. Ambiguous design specifications resulting in rework.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
7. Change in design codes post project commencement.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
8. Unrealistic duration to complete design (resulting in project team forced to make assumptions, not thoroughly assessed until latter part of the design stage).	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
9. Insufficient/unknown information regarding site conditions during design phase, e.g. underground condition.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
10. Inconsistent drawings with site conditions.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
11. Insufficient equipment information resulting in assumptions at early stages of design.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
12. Insufficient/poor quality of early stages design work resulting in changes in the subsequent design stage, e.g. incomplete basic engineering package.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
13. Lack of necessary experience by the design team (inadequate design skills).	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
13 (a) Do you think design team members were experienced enough to understand the overall impact of the design changes they introduced?	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
13 (b) Considering question 13(a) above , do you think design changes introduced improved the overall design effectiveness?	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
14. Inadequate design reviews	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
15. Sufficiently experienced personnel and critical stakeholders not attending design reviews later enforcing design change (new requirement).	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
16. Lack of knowledge of available material and equipment to be used.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
17. Lack of coordination or poor communication during design stage.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Cause of Design Change	Frequency of occurrence	Responsible party/parties for the change
18. Change is employer's financial status resulting in redesign to optimise costs, e.g. change in material specification or reduction of equipment.	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier
19. Other (s) Specify:	Very Often Often Not sure Rarely Never	Employer Consultant Equipment Vendor/Supplier

Thank you for taking time to complete this questionnaire.