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OBSTACLES TO QUALITY MANAGEMENT IN SOUTH AFRICAN INFRASTRUCTURE PROJECTS-

THE CASE OF ROUTE 21 (R21) FROM NATIONAL ROUTE 1 (N1) TO O.R TAMBO INTERNATIONAL AIRPORT

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

Johannesburg, 2012

Declaration

I declare that this research report is my own unaided work, save for express acknowledgements and references to the work of others cited in the work. It is being submitted to the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to the university or any other University.

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(Signature of Candidate)

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(day) *(month)* *(year)*

Abstract

This research report identifies obstacles to quality management in South African infrastructure projects, using the R21 GFIP project as case study. A questionnaire was used to collect intrinsic project information. Triangulation method was used to analyse questionnaire results, literature survey and project data supplied by SANRAL (archive data).

The efficiency in administering sound quality management is diminished with increase in project pressure, leading to the adoption of shortcut procedures, constructing work with incomplete designs in place and using untested material in some portions of work, to meet stringent completion deadlines for FIFA 2010 World Cup.

Strong linkages are identified between significant obstacles that overwhelm quality, including incomplete designs. Top management is not transient and must champion the quality agenda. Hence there is a strong and coordinated need for a structured mechanism to reinforce experiences and lessons learnt from previous projects to curb reoccurrence of similar obstacles.

Key words: Obstacles, Quality, Infrastructure, Management, FIFA 2010 World Cup

Dedication

This research report is dedicated to my wife, Fadzai for her unwavering support; my late mother, Emma who laid the foundation of my education and my daughter, Kelly who always provided the inspiration and motivation.

Acknowledgements

I would like to express my sincere gratitude to my supervisor, Dr Anne Fitchett, to whom I am heavily indebted for her enduring commitment, constructive criticism, academic rigor, feedback and excellent guidance that led to the successful completion of this research.

Special thanks also go to Solomon Kganyago (aka Solly), the SANRAL project manager for R21 Gauteng Freeway Improvement Project for his permission to allow me to undertake this research. I also acknowledge the permission given by J.A Grobler, the project leader representing the design consultant-Vela VKE, to allow me to conduct the research.

This research is a result of the contribution made by all the participants of the survey so I would like to acknowledge their input.

I am especially grateful to my wife for the support, companion and patience through this academic journey.

“If the only tool you have is a hammer, then every problem looks like a nail. If you only have an economics, or legal, or engineering perspective, then guess what your problem looks like?”, (Orr and Metzger, 2005:1)

Table of Contents

CONTENTS **Page**

Declaration ii
Abstract iii
Dedication iv
Acknowledgements v
Table of Contents vii
List of Figures xi
List of Tables xiii
Nomenclature xiv

Chapter 1: Introduction 1
1.1 Background 1
1.2 Research Problem Statement 9
1.3 Limitations and Parameters of the Study 11
1.4 Structure of the Report 12

Chapter 2: Literature Review 14
2.1 Introduction 14
2.1.1 Background 14
2.1.2 Origins and Evolution of Quality 17
2.1.3 Definition of Terms 22
2.1.3.1 Project Implementation 22
2.1.3.2 Quality 22
2.1.3.3 Total Quality Management (TQM) 23
2.1.3.4 Quality Assurance (QA) 25
2.2 Discussion on Factors that may affect Quality 25
2.2.1 Simulations and Influencing system characteristics 26

2.2.2 Compromises in stages prior to construction stage 28
2.2.3 Workmanship and associated challenges 30
2.2.4 Best Practice guided by the Kaizen Principle 32
2.2.4.1 How the SACEM assess performance 34
2.2.4.2 SACEM Benefits 37
2.2.5 Working Habits and Culture of People 37
2.2.6 Safety of Employees. 42
2.2.7 Contractor Selection 44
2.2.8 Shortage of Skilled Manpower 47
2.2.9 Fragmentation 49
2.3 Effects of Failing to Address Obstacles to Quality Management. 50
2.3.1 Rework 50
2.3.2 Project Delays, Overspending and Quality Defects 52
2.4 Conclusion 52

Chapter 3: Research Methodology 55
3.1 Introduction 55
3.2 Data Collection 55
3.3 Data Analysis 56
3.4 Types of Triangulation 57
3.4.1 Data Triangulation 57
3.4.2 Researcher Triangulation 58
3.4.3 Theoretical Triangulation 58
3.5 Ethical Conduct 59
3.6 Questionnaire Design 60

Chapter 4: Case Study Overview 62
4.1 Project Location and Type 62
4.2 Project Objectives 64

4.3 Specific Concerns 66
4.3.1 Implementing the project at night-time 66
4.3.2 Incomplete contractual documents 67
4.3.3 Weather conditions 67
4.3.4 Material Shortages 68
4.3.5 Traffic Accommodation 68
4.3.6 Contractors working on the same site 69

Chapter 5: Data and Results Analysis 72
5.1 Introduction 72
5.2 Response rate to questionnaire 76
5.3 Summary of data obtained from SANRAL 78
5.4 Analysis of Results 80
5.4.1 Design 80
5.4.2 Inclement weather 91
5.4.3 Contract Documentation and Contractual Decisions 94
5.4.4 Traffic accommodation and Health and Safety 101
5.4.5 Material Supplies and Supply Chain 107
5.4.6 Different contractors working on the same site 117
5.4.7 Rework 120
5.4.8 Culture, capacity and quality decisions 125
5.4.9 Other identified obstacles to quality management not included in the questionnaire 129
5.4.9.1 Industrial action 129
5.4.9.2 Penalties charged for omissions. 130
5.5 Conclusion 131

Chapter 6: Conclusions and Recommendations 134
References 141
APPENDIX A: THE QUESTIONAIRE 156
APPENDIX B: RAW SURVEY RESULTS 164
APPENDIX C 170
PROJECT ARCHIVE DATA 170
APPENDIX C 1: MINUTES – WORK PACKAGE G 171
APPENDIX C 2: MINUTES – WORK PACKAGE H 172
APPENDIX C 3: MINUTES – WORK PACKAGE J 173

List of Figures

Figure 1.1 General Road Deterioration and Maintenance Model. 3

Figure 1.2 SANRAL Road Network - Age Trend 4

Figure 1.3: Road Network Condition Data 5

Figure 1.4 Heavy Vehicles Weighed Per Province per Annum 6

Figure 1.5: Relationship between Road User Cost and International Roughness Index 7

Figure 1.6: Composition of Road User Cost 8

Figure 2.1 Evolution of Quality 18

Figure 2.2: Juran's Triple Role concept Applied to Construction 20

Figure 2.3: Generic TQM Model 24

Figure 2.4: Ability to Influence Construction Costs Over Time. 28

Figure 2.5: The Structure of SACEM 34

Figure 2.6: The Construction Project Success Bridge: 48

Figure 2.7: Fishbone Rework Cause Classification 51

Figure 4.1 The R21 Project Location. 64

Figure 4.2 Summary overview of the R21 Project 71

Figure 5.1 Schematic representation of Data Analysis 73

Figure 5.2: Project Management Knowledge Areas according to PMBOK 74

Figure 5.3: Cyclic construct Model of transforming data into information, knowledge and experience. 75

Figure 5.4: Percentage Participation by respondents. 76

Figure 5.5: Respondent views on design questions 89

Figure 5.6: Respondent views on inclement weather 93

Figure 5.7: Respondent views on contract documentation and contract decisions. 98

Figure 5.8: Respondent views on traffic accommodation and health and safety. 103

Figure 5.9: Respondent views on material supplies and supply chain 112

Figure 5.10: Supply Chain Responsiveness: Conceptual Framework 114

Figure 5.11: Respondent views on different contractors working on the same site. 119

Figure 5.12: Respondent views on rework. 122

Figure 5.13: Respondent views on culture, capacity and quality decisions. . 127

Figure 6.1: Illustration of incomplete design at the core of quality management problems 135

List of Tables

Table 2.1: Definitions of Quality 23

Table 2.2: Structure of the Contractors in South Africa 31

Table 2.3: Explanation of the SACEM Model 36

Table 2.4: Sources of Safety Problems and their Effects 43

Table 4.1 Work Packages for the R21 Project 63

Table 5.1: Designation of Survey Respondents 77

Table 5.2: Data obtained from SANRAL 79

Table 5.3: Questionnaire responses to question 5.3 105

Table 5.4: Summary of recorded accidents 107

Table 5.5: Rework Impacts from different studies 124

Table 5.6: Penalties per work package 130

Nomenclature

SANRAL	:	South African National Roads Agency Ltd
GFIP	:	Gauteng Freeway Improvement Project
R21	:	National Route 21
N1	:	National Route 1
ORTIA	:	Oliver Reginald Tambo International Airport
FIFA	:	Federation of International Football Association
SACEM	:	South African Construction Excellence Model
TQM	:	Total Quality Management
PMBOK	:	Project Management Body of Knowledge
LOS	:	Loss of Service
RUC	:	Road User Cost
CIP	:	Contractor Incubator Programme
CLP	:	Contractor Learnership Programme
EPWP	:	Expanded Public Works Programme
ISO	:	International Organisation for Standardisation
TCQ	:	Techno-craft Quality
QA	:	Quality Assurance
PADRE	:	Plan-Approve-Do-Review-Evaluate
EPMK	:	Executive Project Management Knowledge
PMCK	:	Construction Project Management Knowledge
BBBEE	:	Broad Based Black Economic Empowerment
HREC	:	Human Research Ethics Committee
R24	:	Route 24
FIDIC:		*Federation Internationale Des Ingeneiurs-Conseils* (French for International Federation of Consulting Engineers)
VO	:	Variation Orders
ACI	:	American Concrete Institute

UTFC	:	Ultra-thin Friction Course
SUP	:	Site Utilisation Plan
SMME	:	Small to Medium Micro Enterprises
CI	:	Continuous Improvement
SADC	:	Southern African Development Community
CIDB	:	Construction Industry Development Board
CII	:	Construction Industry Indicators

Chapter 1: Introduction

1.1 Background

Road construction has evolved over centuries, but every project is unique even if there appears to be little deviation from practices and procedures documented over the years. Owners, construction material, contractors, project managers and project sponsors change and as a result, project specifications also change with regard to scope, risk, cost, rising client expectations, regulatory requirements, amount of capital invested and the quality.

Almost all infrastructure projects have a certain acceptable degree of quality requirements that guide the levels of effort to be coordinated and harnessed at every construction stage so that the quality expectations of the end product are met. The iterative nature of construction processes in delivering a final project that meets the expected quality levels requires that obstacles at each stage of construction are dealt with decisively. This is so because road construction is regarded as a combination of science and art even though the mix designs and structural designs are determined through carefully controlled experiments and established equations, (White, 2006).

There are different ways of constructing a road pavement, each of which may be appropriate for a combination of factors such as temperature, pavement thickness, material properties as well as the experience of contractors, (White, 2006). A combination of all factors as listed above, if not carefully controlled, may result in the quality of construction becoming elusive.

After construction, continuous road deterioration is a fact of life due to traffic, natural aging, weather (heat, cold, rain) and physical damage. As the infrastructure deteriorates, it is the society that becomes grounded and paralyzed by the inability to move and transport goods and services in an economically sound road network. The National Route 21 (R21), one of Gauteng's busiest connecting roads, is not an exception.

The general road deterioration model is shown in Figure 1.1. The loading on the pavement consist of millions of stresses of relatively small magnitude that accumulate, causing gradual deterioration of the pavement until the level of service becomes unacceptable. The figure shows the road in very good condition soon after construction and it deteriorates to good condition and then fair condition; poor and very poor. Whilst at fair condition, resealing can bring it back to good condition but if nothing happens, it further deteriorates to poor condition. The cost of taking the road to good condition from poor condition becomes three times the cost of bringing it back to good condition from fair condition, (Gautrans, 2009). When the road is left to deteriorate to very poor condition, the cost of bringing the road to very good condition is six times the cost of attending to the road whilst in fair condition. The road reaches a stage whereby it cannot be maintained anymore but needs heavy rehabilitation or reconstruction.

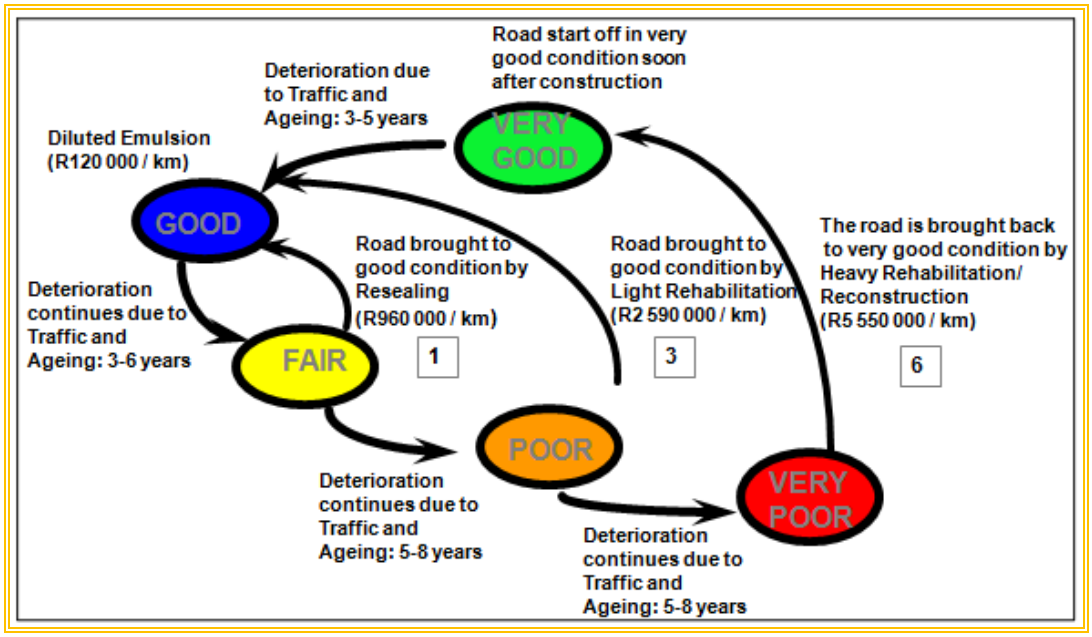


Figure 1.1 General Road Deterioration and Maintenance Model (*Source*: Gautrans, 2009).

During the life-time of a road, it is expected to provide the backbone to sustainable economic prosperity of a nation or region through efficient mobility of goods and services, (Gautrans, 2009).

The South African National Road Authority Limited (SANRAL) embarked on the Gauteng Freeway Improvement Project (GFIP) to which the National Route 21 (R21) project is part of, because of a number of reasons that include:

i. Aging SANRAL Road Infrastructure.

Figure 1.2 shows that 78% of SANRAL's road network is older than the original 20 year design life as of 2008. Fourteen (14) percent have got less than 10 years of life left and only 2% are new, 0-5years.

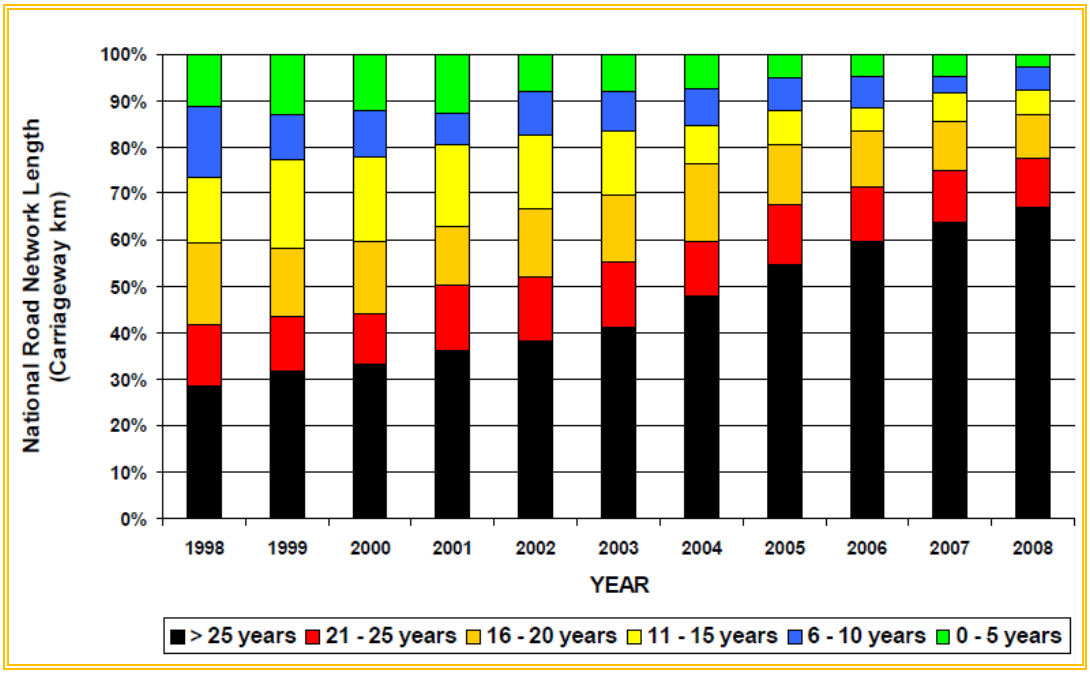


Figure 1.2 SANRAL Road Network - Age Trend (*Source*: Kannemeyer, 2009)

The total road network with known road condition data for SANRAL, provinces, metros and municipalities, is shown in Figure 1.3 which shows a decreasing trend in record keeping of road condition data from SANRAL (100%); provinces (82%); Metros (64%), and municipalities with 4%. Adequate and reliable road condition information is critical in informing an effective road maintenance strategy by way of optimising available funding so that it is strategically allocated in order to benefit the entire road network. SANRAL has up-to-date data that also allows other decisions that minimise the long term costs of preserving the road network in a desired condition state to provide the optimum level of service (LOS), (Kannemeyer, 2009).

Authority	Paved		Gravel		Total		
	Length	Data	Length	Data	Length	Data	% Data
SANRAL	16,170	16,170	0	0	16,170	16,170	100
Provinces - 9	48,176	47,088	136,640	103,733	184,816	150,820	82
Metros - 9	51,682	40,737	14,461	1,789	66,143	42,527	64
Municipalities	37,691	10,866	302,158	2,124	339,849	12,990	4
Total	153,719	114,861	453,259	107,646	606,978	222,507	
% Data	75		24		37		

Figure 1.3: Road Network Condition Data (*Source*: Kannemeyer, 2009)

ii. An increase in heavy vehicles

Figure 1.4 shows a general increase in the number of heavy vehicles and an increase in vehicle sizes, applying inconsistent tyre pressures in Gauteng roads and other provinces. An increase in the size and number of heavy vehicles trafficking the section of road under consideration means faster road deterioration. Loads imposed by small private cars do not contribute significantly to structural damage to road pavements but heavy vehicles advance the structural damage; some heavy vehicles bearing unbalanced loading and unequal tyre pressures do cause significant structural damage through accumulation of damage, (Gautrans, 2009).

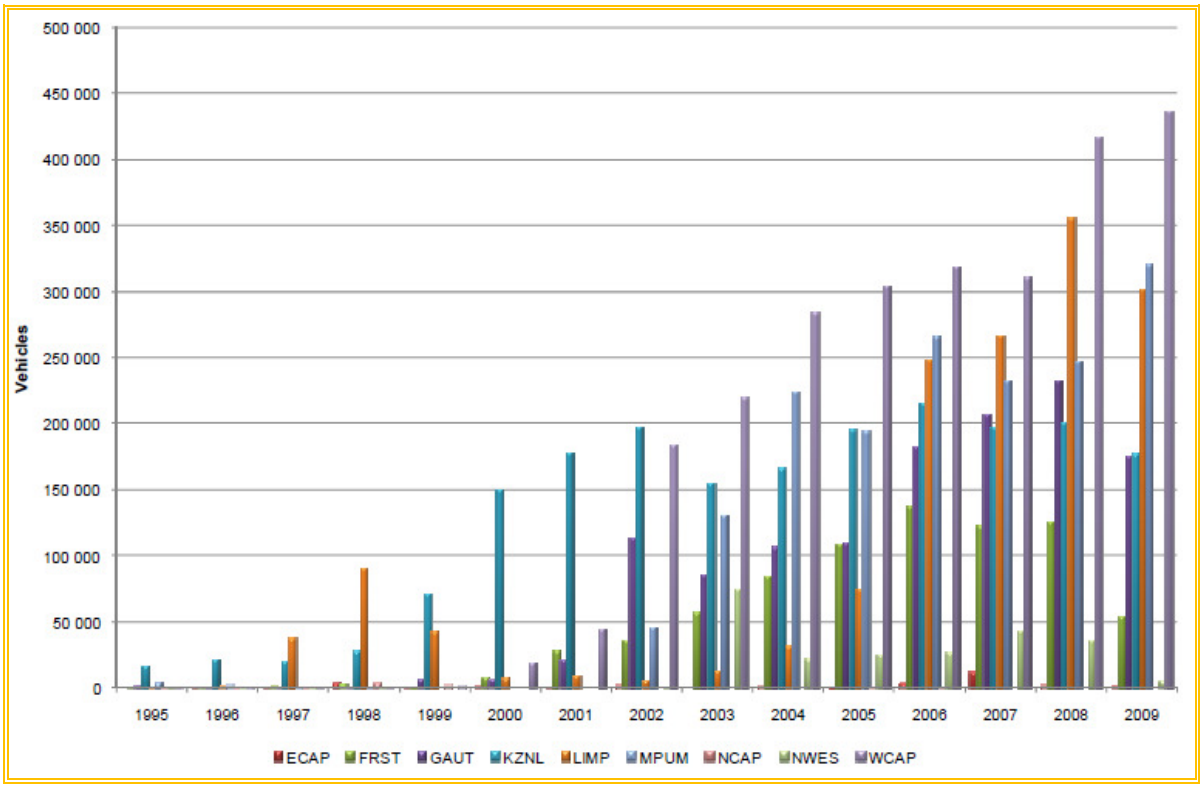


Figure 1.4 Heavy Vehicles Weighed Per Province per Annum (*Source*: Roux, 2010)

iii. FIFA 2010 World Cup

Road R21 is a major link between the OR Tambo International Airport and Pretoria, the capital city of South Africa. This major corridor was experiencing demand that is greater than the available capacity before the 2010 FIFA World Cup, as could be witnessed by traffic congestion levels during peak periods. The hosting of the World Cup resulted in increased traffic and caused more congestion. Congestion is a non-productive activity characterised by slower speed, longer trip time and increased standing time; it results in increase in road user costs (RUC), (Berthelot *et al*., 1996) and increased carbon emissions. The existing roadway requires expansion or upgrade to improve the Level of Service of the road; reduce the “stop-go” situation; reduce fuel consumption through less congestion which results in

less carbon emissions and more importantly, this infrastructure investment improves the citizens' quality of life.

The relationship between Road User Cost and Roughness is shown in Figure 1.5.

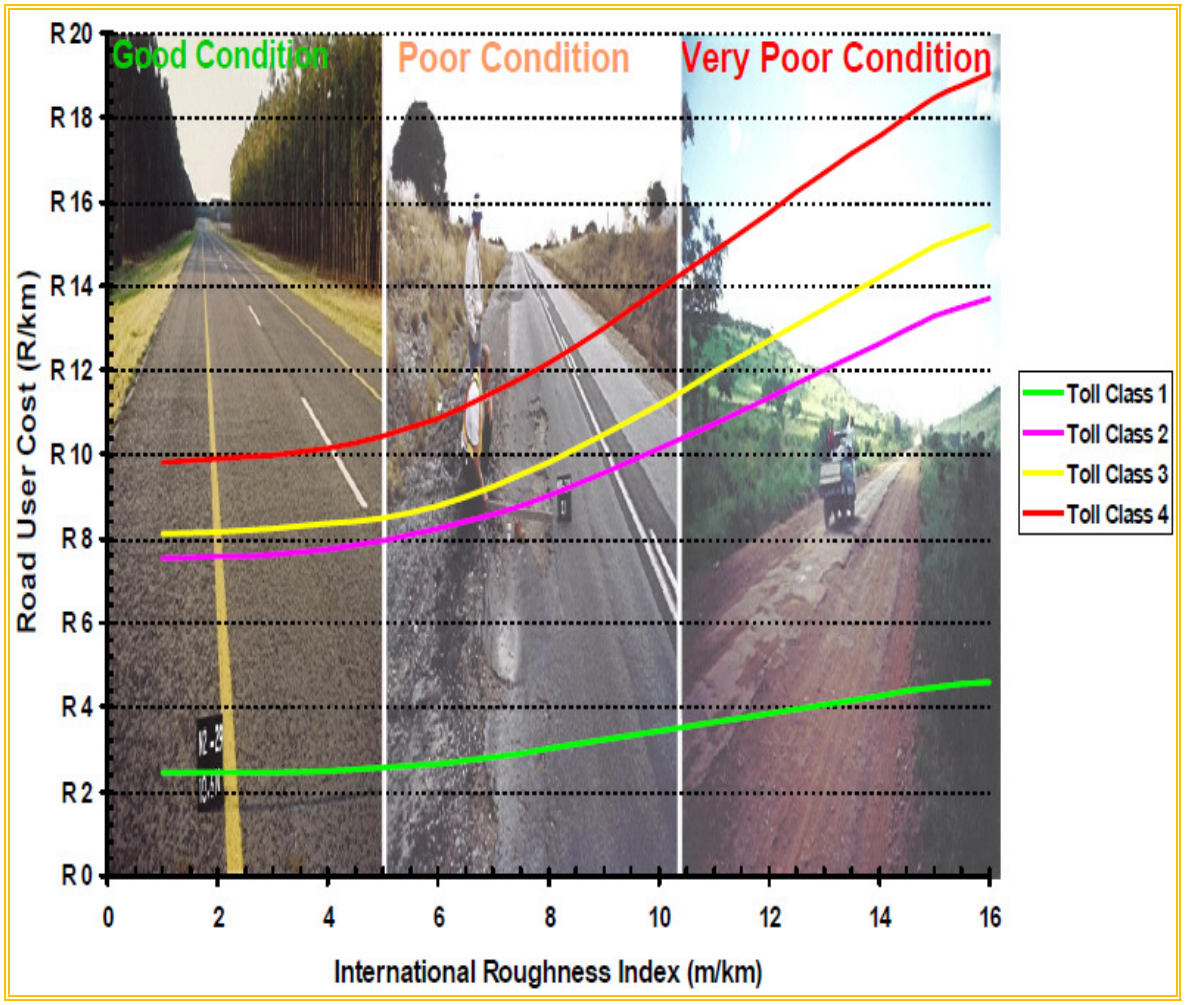


Figure 1.5: Relationship between Road User Cost and International Roughness Index (*Source*: Kannemeyer, 2009)

Low Roughness is essential for riding comfort, and over the years, roughness has become the international measure of how road users perceive a road

condition, (Berthelot *et al*., 1996). The rate of roughness progression is a function of time, traffic loading, materials, climate and the season, (Berthelot *et al*., 1996). As roughness progresses, road conditions deteriorate from good to very poor condition on all road classes (Figure 1.5). As such, the road loses its efficiency of purpose and road user costs increase.

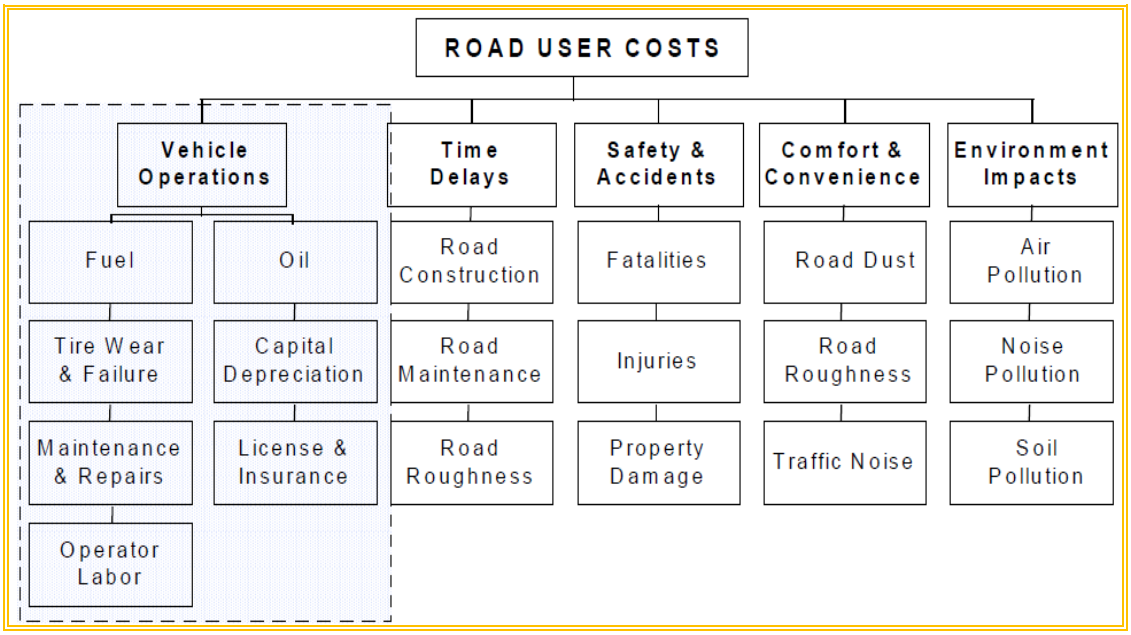


Figure 1.6: Composition of Road User Cost (*Source*: Berthelot *et al*., 1996)

As indicated by Berthelot *et al*. (1996) in Figure 1.6, the total road user costs comprise the contribution of all the influencing parameters such as: vehicle operations; time delays; safety and accidents; comfort and convenience and environmental impacts.

1.2 Research Problem Statement

The purpose of this study is to identify obstacles to quality management during the delivery of infrastructure projects. Quality management and control during road construction follows common methods that have been widely accepted as best practices in the field over the years, (White, 2006). Road construction cannot, however be reduced to simple laid down rules due to a number of variables that are involved. Some variables may not have clear cut quality procedures to follow but may require past experience such as working during the night, requiring high levels of concentration.

The R21 project had strict deadlines so that it could provide smooth traffic flow during the 2010 FIFA World Cup, (Kannemeyer, 2009). Such significant events come with huge amount of pressure to everyone involved including consultants, contractors and project managers. This pressure can culminate in some procedures going wrong which may lead to poor quality control and management. The project however was not meant to be a FIFA 2010 World Cup project but the need for additional road capacity during the event was taken into consideration during the design and documentation stage of the project, resulting in construction milestones to be achieved for the event, (Kannemeyer, 2009). While studies have been done on some aspects that impede on quality (both in other sectors and the construction industry), the true nature of obstacles to quality management are not clearly documented and not well understood because reworks have become the order of most projects, (Koskela, 1992). Also lacking are clear explanations for the difficulties in implementing the documented and known quality processes in construction in South Africa. It is also important to specify under what conditions certain obstacles to quality cannot be eliminated and the appropriate methods to address them.

Hugo and Martin (2004) argue that Highway practitioners face problems for which information already exists, either in documented form or undocumented experience and practice. The latter often results in fragmented, scattered and unevaluated solutions to problems such as inadequate quality. Some valuable experience that can provide working solutions may be overlooked due to lack of documentation. Experience and expertise is very important when it is used to make decisions about what control checks need constant monitoring and improving with objective evidence rather than subjective opinion.

Inadequate quality has become a recurring theme and one of the most important deciding factors considered by clients (individuals, large corporations, government and quasi-government organisations) in choosing among competing needs, (White, 2006). There is a need to better understand obstacles to quality management and be able to prepare appropriate methods of addressing them before they lead to poor quality and rework resulting in compromised performance levels of the finished piece of infrastructure.

In seeking to contribute answers to the obstacles of quality management to infrastructure projects, the following research question was investigated:

What obstacles to quality management are present during the delivery of infrastructure projects in the South African context?

Secondary to the main question above is:

How best can the identified obstacles be eliminated to avoid rework?

1.3 Limitations and Parameters of the Study

This research is concerned with identifying obstacles to quality management during construction of road infrastructure projects regardless of the perspective from which construction is approached. It is important to note that infrastructure projects are applicable to almost all industries (such as Information Technology, Manufacturing, Engineering, and Construction). Therefore the chosen case study is not necessarily representing the rest of the South African Infrastructure Projects.

Construction approaches differ since organizations are believed to be complex and open social systems and can make independent future decisions, (Hindle, 2000). A number of variables are involved during construction and contractors have varying approaches to construction and the effect is that each approach may have different obstacles. Formulation of methods and procedures of addressing the obstacles is outside the scope of this particular research, though suggestions may be made of methods to address them.

The obstacles identified in this research could be applicable to other infrastructure projects (Information Technology, Manufacturing, and others not discussed in this report), but this research is particular to the R21 road construction Project. A project evolves through various stages or phases of development but the research tries to identify obstacles to quality management during the construction (project delivery) phase.

The findings of this research aim to protect the interests of the client, at the same time protecting the integrity and reputation of the contractor through good practices. Obstacles identified in this research may not be an exhaustive list of obstacles to quality management. Conclusions are drawn

and recommendations for further research on aspects outside the scope of this research but impacting on quality management are made. Obstacles that could not be addressed in this study are recommended for further analysis at a higher level. Although the identified obstacles cause inadequate quality, quantification of the total cost implications of the obstacles is not fully covered in this study.

The sample of the analyzed information and responses is limited to contractors specifically working on the R21 project for road construction and outcomes might not hold for larger firms or those located in other parts of the country experiencing weather conditions different to Gauteng and different work pressure conditions. The contractors providing ancillary work packages, such as street lighting, are also not included in the study.

1.4 Structure of the Report

The research report addresses obstacles to quality management on the R21 infrastructure project in six chapters, as follows:

a. *Chapter 1* describes the background to the research problem and the research problem statement containing the research question. In addition, it states the limitations and parameters of the study. It also outlines the structure of the research report.

b. *Chapter 2* provides an extensive review of the existing literature on the research question so as to draw from professional journals, internet searches and books as well as setting the context of the research. It also contains definitions of common terms used in quality management.

c. *Chapter 3* provides the research methodology and it discusses the research technique used to achieve the research objectives.

d. *Chapter 4* is the case study overview which describes the location of the project and brief description of the work involved; project objectives, the project specific concerns and the summary overview of the project.

e. *Chapter 5* provides analysis and interpretation of data collected from the questionnaires, literature and archive data from SANRAL in a synthesised manner.

f. *Chapter 6* discusses the insights and findings of chapter 5 and develops conclusions and recommendations on identified obstacles as well as recommendations for potential further study. It also aligns the research objectives with the findings of the research.

The sources used in the report are cited in the reference in alphabetical order to enable the reader locate the source of information and also to acknowledge the original author's work.

The appendices contain relevant and useful information that could not be placed in the main body of the report but supports and validates the content and findings of the report, such as the questionnaire and archive data.

Chapter 2: Literature Review

2.1 Introduction

This chapter reviews the relevant literature on the subject and in particular, it considers the back ground to the obstacles to quality management in South African infrastructure roads projects, the origins of quality philosophy as a whole which then led to the development of quality in each industrial sector, definitions of key terms used in describing the state of the quality, discussion of the factors that can significantly impact on the quality of the delivered project and the conclusion providing the remarks as to why the this research is important.

2.1.1 Background

Construction projects account significantly for the wellbeing of the national economy and the ineffectiveness of the construction sector has negative ripple effects on other sectors (Milford *et al.*, 2000). The construction industry is important for the reasons that (a) it provides employment for individual professionals, consultants and construction companies across the spectrum (small, medium or large), (Latham, 1994; Van Wyk, 2004:4);
(b) emerging contractors receive on the job training on construction projects offered by government through such programmes as the contractor incubator programmes (CIP) and contractor learnership programmes (CLP) on Expanded Public Works Programmes (EPWP) projects with the aim of integrating the contractors in the main stream construction industry, (Fitchett, 2008); (c) it is a key delivery mechanism for the improvement of economic and social infrastructure, (Latham, 1994); (d) it provides training to lower skilled operatives who, later or immediately, can contribute in providing

innovative engineering solutions and high quality work, (Van Wyk, 2004); (e) this is the way a government converts its revenue into national assets, (Hindle, 2000) and (f) infrastructure development plays a significant role in alleviating poverty, (Van Wyk, 2004) one of the key Millennium Development Goals, (Fitchett, 2008). This indispensable role that the construction industry plays cannot be ignored and the same can be said about quality management in delivering construction projects that are efficient and fit for purpose.

Unlike other sectors such as manufacturing and service industries, the construction industry is viewed as one with poor emphasis on quality, (Mahmood *et al.*, 2006). However, simply observing that improvements are possible is not sufficient to provoke actual change. Opportunities exist to ensure that quality levels are maintained throughout the various stages that infrastructure projects undergo, guided by clearly coordinated and consistent ways of construction. The stages that infrastructure projects undergo are:

i. Concept (feasibility study, project brief, identify alternatives etc);
ii. Design and Development phase (planning the project);
iii. Implementation or Construction phase (setting up, establishing and executing work packages, controlling time, scope, quality and cost and resolving problems);
iv. Handover or commissioning phase (close out report, testing, acceptance, operation and maintenance) (Burke, 2008 and Frimpong, 2003).

Each stage has its quality requirements that influence the overall expected quality levels of the finished product, (Conradie and Roux, 2008; Mohammed and Abdullah, 2006; Woodward, 1997). This report evaluates quality obstacles at the construction phase which is critical because more parties are involved at this stage than at all other stages. It is usual at a design or planning phase to involve the client, his representative and the consultant.

At construction stage, the client, his representative, the consultant, the contractor, the sub-contractors and suppliers are involved, (Mohammed and Abdullah, 2006). All have their own agendas and allegiances. This long delivery chain brings with it complicated variations and combinations which result in unforeseen obstacles to quality management. It is important to view the contribution of each of these parties in a synergetic way rather than as antagonistic, (Egan, 1998; Hindle, 2000; and Latham, 1994). Thus continuous and sustained improvements in quality are achievable through focus of all efforts in delivering the customer expectations. The tendency in most consulting, contracting and other engineering organisations, however, is to engage in competition rather than collaboration, (Duncan, 2010).

Standards follow a global trend for purposes of conformity and business promotion: suppliers who do not subscribe to international standards are not preferred in the procurement regulations set out by the client. The system of standards today, as managed by ISO, is built on the concept of voluntary affiliation, (Taylor *et al.*, 2008), where countries and organisations decide whether to join or not. The same approach is shared by Mohammed and Abdullah (2006) in their observation that marketing pressure has become a factor in ISO registration but is short-lived during implementation. ISO compliant consultants are believed to be worsening the situation because many of them are not from the construction background and do not understand the construction processes. Taylor *et al.*, (2008) have documented what they believe are common obstacles in delivering quality as follows:

a. There is a lack of systematic approach to quality;
b. There is no system to analyse sources of quality problems;
c. Management discourages reporting of quality problems;
d. People see procedures as a deterrent to creativity and only there to create extra work;

e. Quality requires a common effort but there is lack of management capacity to create groups that collaborate efficiently;
f. Management personnel to lead quality efforts are not selected on the basis of their competence and thus they are not aware of the importance of a quality culture in the organisation;
g. Monopolistic nature downgrades the importance of delivering quality products;
h. There is a perception that top management will take all decisions which makes the group effort useless and ultimately result in poor quality.

2.1.2 Origins and Evolution of Quality

Quality started with the manufacturing industry before its implementation transcended industry type and has evolved over many years. The different stages of quality evolution are indicated in Figure 2.1. The evolution until 1990 has been reported by Feigenbaum (1991 cited in Hassan *et al.*, 2000) and the Techno-craft Quality (TCQ) was reported by Kolarik (1995 cited in Hassan *et al.*, 2000).

External forces such as limited market expansion, market fragmentation and intense global competition, among others, have been cited as the cause of this evolutionary trend.

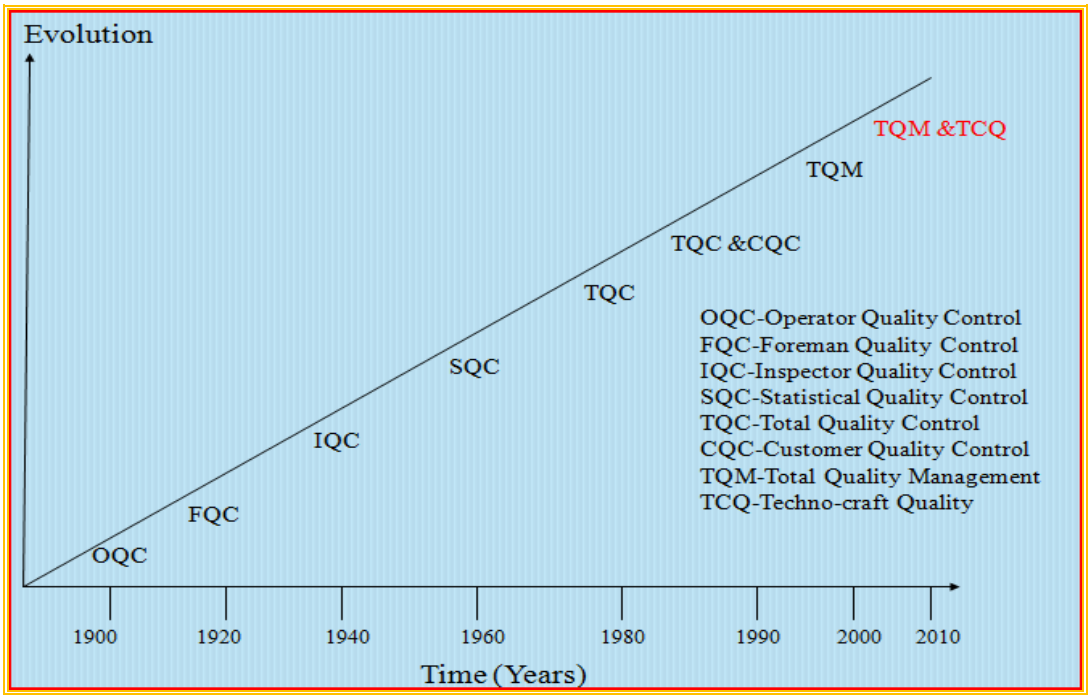


Figure 2.1 Evolution of Quality (*Source*: Author)

The key attributes of each of the quality approaches shown in Figure 2.1; their relevance and application to the construction industry is explained below:

- *Techno-craft Quality (TCQ)* is technology intensive and the technology in the TCQ paradigm (such as simulation) is considered to bring to an end guesswork, time lag and faulty execution by providing customers exactly what they want whilst maintaining the performance levels and it derives from TQM (Kolarik, 1995 cited in Hassan *et al.*, 2000). TQM is still widely used pending proper documentation of TCQ which is regarded as an extension of TQM at this stage. The evolution of quality has been in tandem with the need to solve current quality problems at that particular period of time, with a shift in client requirements. The TCQ paradigm needs automated and integrated machinery, to which Hassan *et al.* (2000) indicated the challenges of this paradigm at this

stage, that traditional quality tools (statistical process control, supplier audits and sampling inspections) appear to be insufficient to cope with advances in technology to support this paradigm. Although there is a recognisable degree of automation in the construction industry, issues pertinent to actual quality controls on a construction site remain complex.

- *Total Quality Management (TQM)* is an organisation-wide quality management approach (Lee and Chen, 2011) that places emphasis on leadership commitment; continuous improvement and elimination of waste (see section 2.1.3.3) with the aim of increasing internal and external customer satisfaction (Ngowi, 2000). Besides being widely applied in the manufacturing sector, this paradigm has gained usage in the construction industry although the implementation of TQM at project level lags that at company level (Mohammed and Abdullah, 2006) and many of the failures can be attributed to a misunderstanding of TQM as well as the widespread perception that TQM is for manufacturing only (Ahmed *et al.*, 2002).

  Figure 2.2 identifies that a construction process effectively requires three parties – owner; designer and constructor. Each party in the process performs three roles (supplier; processor and customer) for the other in a cyclic manner as shown in Figure 2.2. The process starts with the owner and ends with the owner. The owner supplies the requirements to the designer; receives the facility from the contractor; and is responsible for the operation of the facility. The sequential flow of activities in Figure 2.2 indicates that construction is a process; as such the TQM principles that have been applied to other processes are potentially adoptable to the construction industry (Ahmed *et al.*, 2002).

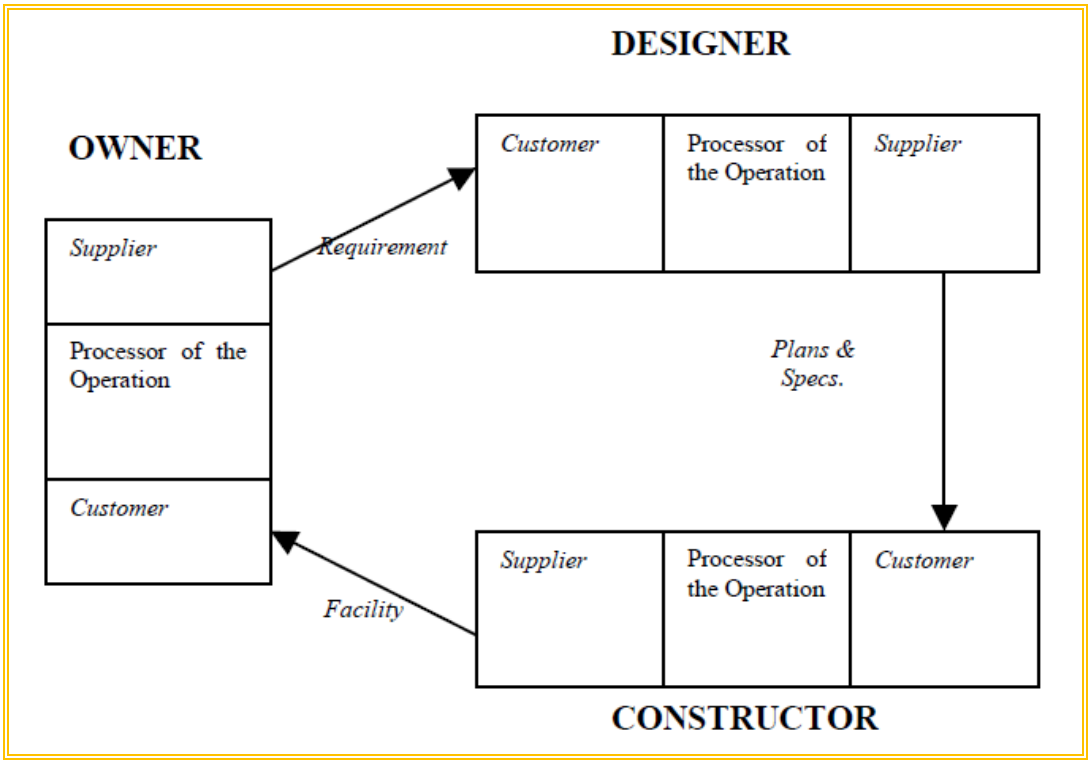


Figure 2.2: Juran's Triple Role concept Applied to Construction (*Source*: Ahmed *et al.*, 2002).

- *Operator Quality Control (OQC)* was inherent in manufacturing industry up until the end of the nineteenth century. A small number of craftsmen were responsible for the manufacturing of a complete product and each craftsman exclusively controlled the quality of his work (Ahmed *et al*, 2002). Literature does not show that it has been applied to the construction industry.
- *Foreman Quality Control (FQC)* followed from OQC as a result of the development of the large-scale factories during the industrial revolution. Craftsmen performing similar tasks were grouped together and supervised by a foreman who assumed the responsibility for the quality of their work (Ahmed *et al.*, 2002). This paradigm got widespread use in the construction industry where a foreman supervised a group of construction workforce. While standards existed

for measuring quantity of items, standards for quality were less prevalent (Dooley, 2000).

- *Inspector Quality Control (IQC)* gained extensive use during the First World War when the manufacturing systems in large organisations became more complex and required specialised skills.
- *Statistical Quality Control (SQC)* directly evolved from IQC during the Second World War when efficiency became a key theme in the mass production of goods and when more technical problems occurred. Inspectors were provided with statistical tools such as sampling and control charts. The concept of acceptance sampling was developed under this paradigm (Ahmed *et al.*, 2002).
- *Total Quality Control (TQC) and Customer Quality Control (CQC)* evolved due to an increase in user quality requirements that led to an increase in customer demand for higher quality products. The challenges of the specific customer demands could not be met by statistical quality control method, hence the total quality control which took into consideration the customer needs.

Client requirements and demands continuously changed and become sophisticated in terms of quality of products. As such, client requirements have played a major role in transforming quality as well as crafting terms that led to the understanding of quality of today.

2.1.3 Definition of Terms

Various terms related to quality on infrastructure projects have be used in this report. Their use in this report is in the context in which they are defined, noting that various authors have different definitions.

2.1.3.1 Project Implementation

Egan, (1998) defines project implementation as the translation of the generic product into a specific project on a specific site for a specific customer. This definition points out that there are variables during project implementation such as site conditions, implementation team, suppliers and the client requirements.

2.1.3.2 Quality

The everyday use of the word has to be differentiated from the use with regard to quality management on infrastructure projects. The definition of quality on infrastructure projects has undergone a number of adaptations with changes in approaches and techniques, and hence has been defined differently by different people, (Hassan *et al*., 2000). Table 2.1 shows various definitions of quality that have been put across by renowned authors on quality. Crosby's definition (1979 cited in Hassan *et al.,* 2000) has been expanded by Woodward, (1997:105) to read "a comparison between a standard achieved and the standard required and specified".

Table 2.1: Definitions of Quality (*Source*: Hassan *et al*., 2000)

Quality guru/ authority	Definition
Juran	Fitness for use (1964), conformance to specifications (Juran, 1988)
Crosby	Conformance to requirements (Crosby, 1979)
Fegienbaum	Total composite . . . will meet the expectations of customers (Fegienbaum, 1983)
Deming	Aims at the needs of the customer, present and future (Deming, 1986)
Taguchi	Loss to society (Taguchi, 1986)
ISO 9000	Totality of features and characteristics of a product or service . . . to satisfy stated or implied need (IS0 9000, 1992)

2.1.3.3 Total Quality Management (TQM)

TQM is composed of three elements namely Total (made up of the complete organisation); Quality (as a condensed summary of the definitions in Table 2.1, the total degree of excellence i.e. fitness and conformance that the product or service provides to the customer in present and future) and Management (the act, art or manner of planning, organising, directing and controlling). Management's involvement in quality issues should not overshadow the roles and contribution of engineering towards quality. Whilst it is acknowledged that TQM is not a clear-cut concept, it is generally understood as an organisation's strategy for improving product and service quality, (Joiner, 2006). The high performance is a function of the alignment between the organisation's systems or processes and various contextual success factors. This has been put in a model by Silvestro, (2001) known as the Generic TQM model as shown in Figure 2.3. The model explains that the realisation of TQM is based on six core precepts which require the full

implementation of the supporting peripheral precepts, in a holistic manner rather than a step-wise process of implementing one precept at a time.

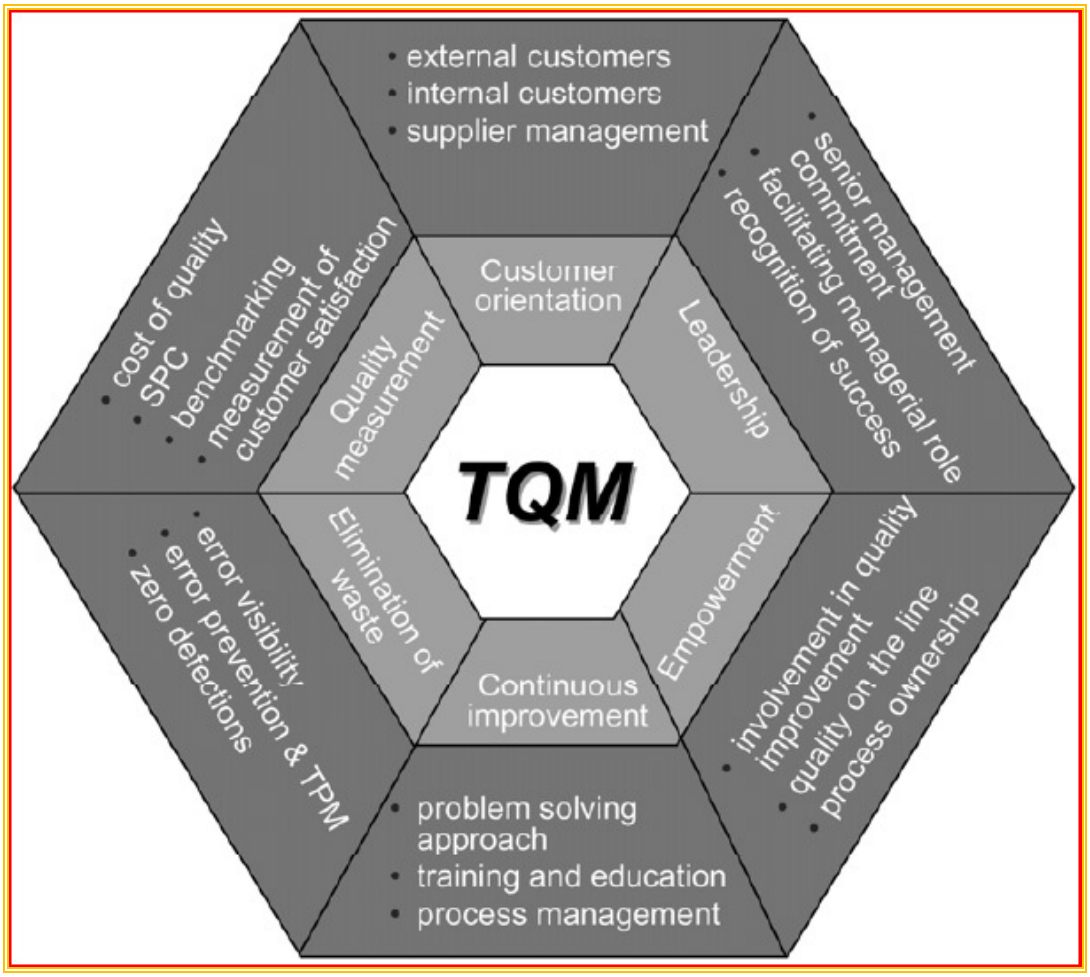


Figure 2.3: Generic TQM Model (*Source*: Silvestro, 2001)

Considering all the factors in Figure 2.3, TQM can be defined as a systematic management approach for an organisation as a whole, comprehensive and integrated concept for attaining customer satisfaction through improvement in all the six core precepts shown in Figure 2.3, all through teamwork and collaborative effort.

The definition of TQM is considered to be binomial (0, 1) since one either deploys all the six or one does not practise TQM, (Ryan and Moss, 2005).

Therefore firms that only focus on customer orientation yet they ignore empowerment are not practicing TQM.

2.1.3.4 Quality Assurance (QA)

This term has been described as the approach adopted by an organisation to demonstrate that its work is carried out within strict quality procedures, (Woodward, 1997). Ngowi, (2000:2) defines QA as:

> "all those planned and systematic actions necessary to provide adequate confidence that a production or service will satisfy the given requirements for quality".

Hassan *et al*., (2000) simply define QA as "concerned with making sure that quality is what it should be".

2.2 Discussion on Factors that may affect Quality

Over and above the factors discussed below, all the parties involved during the construction stage need to clearly understand of their obligations and roles, limits and more importantly, work as a team to fulfil the quality specifications as required by the client. All effort must aim to eliminate all the inefficiencies and inconsistencies that might fragment the project strategy leading to poor quality. To effectively implement the principles of quality management, it is important to understand the working of the conventional methods of managing quality in the construction industry. Such methods include contractual provisions (section 5.4.3); safety as guided by occupational health and safety (OHS) regulations (section 2.2.6); TQM (sections 2.2.4 and 2.2.5). However, Koskela (1992:32) notes that:

> "in conventional managerial approaches, no special effort is made to eliminate defects, errors, omissions, etc and to reduce their impact; or it is thought that a fixed optimal level of quality exists."

Knowing the provisions of the conventional methods in managing quality should provide the basis and levels of special effort required to bring up quality to expected levels.

2.2.1 Simulations and Influencing system characteristics

Conradie and Roux, (2008) single out the importance of predictive simulations to aid in evaluating the performance of various designs of buildings and other infrastructure before construction commences. Simulations reduce our reliance upon raw judgement and intuition. Simulations and other computer modelling systems can minimise problems and improve efficiency on the construction site. Simulations can also be used to evaluate causes of 'below expectation' performance of some infrastructure projects. When this happens, the simulation investigations are aimed at revealing what went wrong during implementation or execution of works for purposes of correcting it or improving the design. So whilst technology is a good tool to have, it cannot on its own solve efficiency and quality problems on site. Evolving road design software packages (such as Civils 3D) have simulation features that allow one to view and do driving simulation over the finished road alignment. Although there are technological improvements in the quality of production drawings within the design aspect, the construction industry still holds the view of issuing hard copy documentation in line with the processes outlined in the methods of managing construction quality (Alshawi and Ingirige, 2003).

While design is a critical phase in the success of any project, this report focuses on what could go wrong and impede on the quality during the

construction phase of an infrastructure project. Failure to execute well means that an organisation will not be successful even if there is a great construction strategy in place, good quality products and experienced workforce (Lepsinger, 2010). Lepsinger, (2010) explores “The Five Bridges” to close the execution gap and he identifies the characteristics and competencies that make closing the execution gap possible. These are (a) structure that supports execution;
(b) alignment between leader behaviour and company values; (c) company-wide coordination and cooperation; (d) employee involvement in decision making and (e) the ability to manage change. The efficiency, consistency and the resolve of an organisation to deliver a quality project are highly dependent on the “five bridges” above because, for example a structure that supports execution enhances accountability, coordination, communication and decision making as close as possible to where execution is taking place. The “five bridges” need to be in place and to be properly maintained all the time because execution is not a ‘single-point’ event but rather an ongoing process.

The construction phase is critical in this study because in this phase, the ability of the stakeholders to influence system characteristics or changes (such as design) is very low hence the obligation of the construction team to get it right the first time as indicated in Figure 2.4.

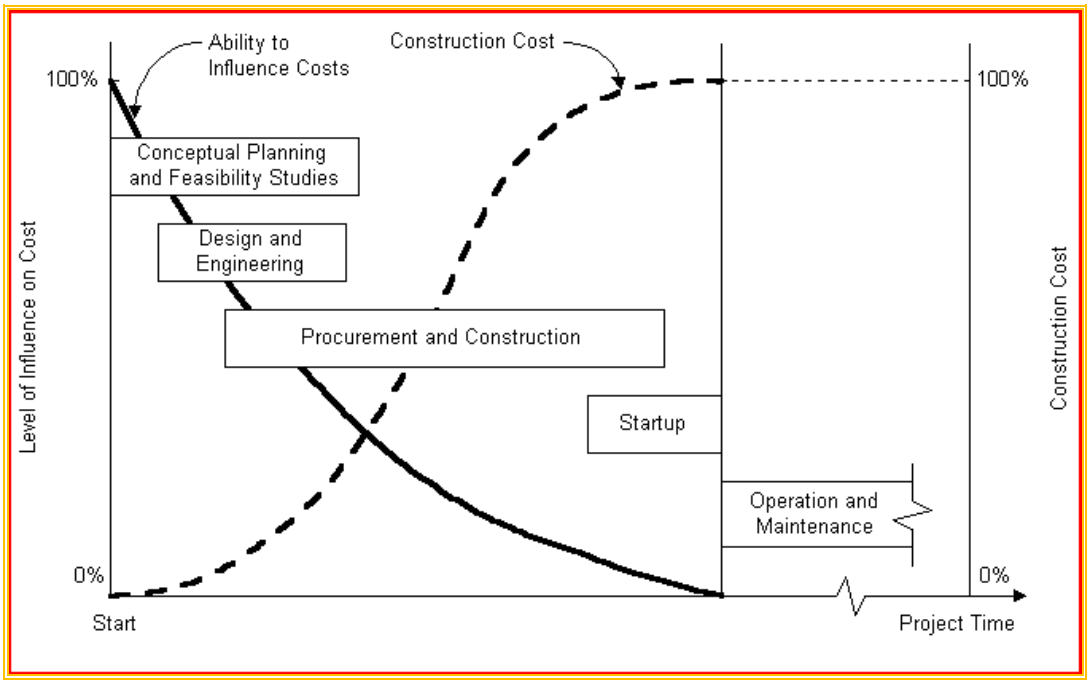


Figure 2.4: Ability to Influence Construction Costs Over Time (*Source*: Hendrickson, 2008).

At construction stage, construction or production costs have been committed and quality is expected to improve without further increase in costs. Whilst the influence on system characteristics diminishes rapidly as the system proceeds from one phase to the next, construction decisions taken during construction have a huge influence on the continuing operating costs and revenues over the facility lifetime (Hendrickson, 2008).

2.2.2 Compromises in stages prior to construction stage

Challenges to quality management at construction level can also be attributed to compromises that take place in up-stream phases such as in design phase (Hendrickson, 2008). If it is recognised after the construction process had long begun that the design adopted for construction has short-comings or is inadequate, it is not automatic that the next best design will be adopted. In

most cases, the identification of short-comings in up-stream phases takes place during construction and this does not translate into providing immediate solutions during construction. Sparrius (1998 cited in Conradie and Roux, 2008:100) postulated that:

> "in service problems experienced downstream are symptoms of neglect upstream. Upstream problems can only be solved upstream."

Underestimating the time; effort; experience; and information required to produce a complete design may result in hasty and inadequate designs which can result in poor quality control measures due to design omissions. Designing using generic solutions (experience and perceived client expectations) without due regard to actual site and local conditions often give rise to improvising during construction to suit site conditions with regard to constructability (Conradie and Roux, 2008).

Shortage of skilled workforce at the design stage results in the adoption of 'Typical Designs' in quest to save time and money (Rwelamila, 2001). This results in the adoption and application of a generic solution to site conditions that are different and using such generic solution to prepare tender documents often results in the occurrence of huge variations, (Rwelamila, 2001). Mahmood *et al.,* (2006) share the same viewpoint that there are excessive variations that result from lack of constructability of the typical design.

Kwakye, (1997:86) states that:

> "The establishment of a bench mark for quality is difficult even for a client with unlimited resources, and is even more difficult to measure and control during design. However, it is generally accepted that, while the assessment of quality of construction is a subjective matter, quality can be measured against design drawings and specifications.....in this

> regard, the design is rationalised to a simplified construction and, additionally, quality levels are clearly specified in the contract documentation; ..quality of design is ambiguous and a matter of individual judgement..."

While the assertion by Kwakye (1997) calls for the design team to have experienced design individuals capable of exercising correct quality judgements; and specifying unambiguous specifications and standards to be used, it points out that the construction method has to be known at design stage in order to rationalise the design in line with the construction method; otherwise the design of a project is a great influence on determining the method of construction and the requisite health and safety interventions (Smallwood, 2004). The decision regarding the use of a standard must be consistent (e.g. recycled asphalt and new asphalt cannot be mixed) and abiding by the standard selected for use must be non-negotiable in attempts to solve time and cost problems, (Woodward, 1997). Also, Ahmed and Kangari (1995 cited in Ahmed and Azhar, 2006:1) allude to the view of Kwakye (1997) that:

> "..most of the products of the construction industry are once offs,...hence, attainment of quality level in the construction industry is difficult both to specify and to monitor."

2.2.3 Workmanship and associated challenges

The South African Government is the single biggest client of construction projects, making up between 40% and 50% of the entire domestic construction expenditure (Dlungwana *et al.,* 2002). Van Wyk (2004) reports government expenditure on civil engineering to be 75%. Government spends on infrastructure through direct expenditure by various ministries or quasi-

government institutions such as the South African National Roads Agency Limited (SANRAL). Workmanship on a construction project bears attributes of formal education and yet the construction industry in South Africa is the fourth highest employer of workers having no formal education, after agriculture, households and mining (Van Wyk, 2004).

Dlungwana *et al.,* (2002:2) note that contractors face multiple challenges that lead to slow delivery of infrastructure projects. The challenges include lack of capacity both within public sector institutions and contractors' pool of personnel; low productivity; low profit margins; and importantly, poor quality workmanship (Dlungwana *et al.,* 2002). Milford *et al.,* (2000) also cite chronic resource shortages and institutional weaknesses as the challenges facing the construction industry in developing countries.
Efforts have been made by the construction industry to classify the South African contractors into categories that will relate to the size or amount of work they can tender for and be able to perform (Dlungwana *et al.,* 2002). The simplified structure is shown in Table 2.2.

Table 2.2: Structure of the Contractors in South Africa (*Source*: Dlungwana *et al.,* 2002)

CATEGORY	ECONOMIC SECTOR	ANNUAL TURNOVER	MANAGEMENT SKILLS LEVEL
SMALL	FORMAL	LESS THAN R10M	VERY POOR & FAIR
	INFORMAL		
MEDIUM	FORMAL	R10M – R50M	POOR, FAIR, GOOD & VERY GOOD
	INFORMAL		
LARGE	FORMAL	ABOVE R50M	FAIR, GOOD & VERY GOOD

In spite of this effort to categorise the contractors into size and capability, there is poor contractor performance within each defined category, with major indicators being poor quality and late completion of projects. Categorising

contractors as such does not do away with project oversights that result in cost overruns, losses, possible closure as well as poor quality management activities (Engineering and Physical Sciences Research Council, 2004; Egan, 1998).

2.2.4 Best Practice guided by the Kaizen Principle

The kaizen principle harbours the concept of total quality management (TQM). An understanding of construction as a process (Figure 2.2) (Ahmed *et al*, 2002) that needs continuous improvement has a direct link to the continuous improvement of TQM's six core precepts in an organisation (Figure 2.3). The kaizen principle of continuous improvement means an efficient, cost effective and competitive manner of carrying out construction activities ensuring a continuous improvement in quality. Construction companies need this kind of principle to continuously improve in their quest to deliver good quality projects. This is important because the quality goals are dynamic in line with technological advancements. In order to embrace the kaizen principle, the culture of individuals; groups of people; and the whole organisation needs to be positive and receptive to continuous improvement initiatives at all times. There are, however, no measurable objectives aimed at changing the culture of employees to align it with quality objectives (Taylor *et al*., 2008). The contractors themselves need to be constantly working on projects otherwise the on-and-off situation undermines the kaizen principle because the contractor may lose employees during times when there is no work. Huge employee turnover becomes costly and increases waste because there is no continuity. New employees require training and need time (without maximum production) to fit into the culture of the organisation. However, Thwala & Monese (2008) argue that construction projects are rarely similar and identical undertakings are virtually non-existent. While identical

undertakings are non-existent, the process of construction itself is repeated in its essentials from one project to another.

Woodward, (1997:106) agrees with Thwala and Monese, (2008) that:

> "Construction is usually once-off, and therefore there is no opportunity to progressively learn from one unit of production to the next in order to improve quality."

A similar view is shared by Koskela (1992:32) that:

> "processes in construction frequently have only one run, making continuous improvement difficult, and the impacts of quality problems are accentuated."

For this reason, it is important to 'get it right first time' because, unlike manufactured products, one cannot 'take it back'. It is important to note that getting it right requires high competency levels and experience whilst at the same time the limited number of construction projects do not enable retention of experienced professionals or allow the inexperienced people to gain the necessary experience, (Van Wyk, 2004:6). Other reasons like international demand and low local rewards may also influence experienced professionals to move companies. However, Woodward, (1997:114) agrees that past experience helps in delivering quality works by stating that:

> "...most inspired and durable works were not created by such tools (i.e. books of rules etc), but by the intuition combined with keen observation of past experience and commonsense..."

By the same token, experience only matters when it is the experience of doing the right things in a correct manner. So it is important to consolidate all areas expected to impact on the quality of the finished product because the team and team effort is the source of the weakest link.

A tool has been developed to ensure continuous improvement through the concept of Total Quality Management both at corporate level and at the construction site level.

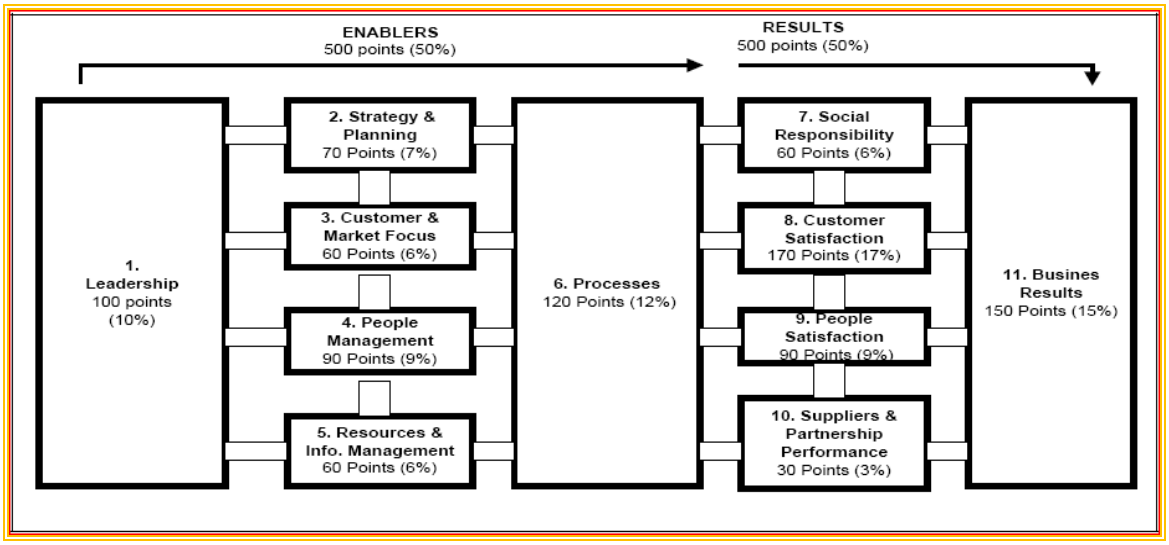


Figure 2.5: The Structure of SACEM (*Source*: Dlungwana *et al*, 2002)

The South African Construction Excellence Model (SACEM), (Dlungwana *et al*., 2002) is diagnostic in nature and uses eleven key management areas that are linked to each other. Activities on the 'enablers' side have an influence on the 'results'.

2.2.4.1 How the SACEM assess performance

SACEM's primary aim is to identify areas of improvement and strengths of the contractor and focus the effort accordingly, to areas that need improvement. Questions on a scoring scale of 0-3 relating to the overall performance of the contractor are asked ('0' means the activity is not done or has not started and '3' means the activity is fully achieved). A contractor whose score is close to 1000, the possible total score, has a well managed business and shows good results.

The UK has developed a similar comprehensive system to monitor firms' performance (notably quality) but the real effect on industry cannot be seen yet (Milford *et al.*, 2000). This report will explore if it is an obstacle not to have a successfully implemented system to measure performance of contractors.

The other bottleneck that arises because of too many contractors emerging is the use of untrained workers. Emerging contractors do not have adequate financial resources and so they lack training before embarking on the actual works (Thwala and Mvubu, 2008). This sets up the contractor for failure, because without training, the contractor can not release the full potential of its people (Table 2.3).

Table 2.3: Explanation of the SACEM Model (*Source*: Dlungwana *et al.,* 2002)

Component of SACEM Model	How the component leads to improved Quality
Leadership	The behaviour and actions of the executive and all other leaders must inspire, support and promote ethical business excellence.
Strategy and Planning	The policies, reviews strategies and plans formulated by management must bear the desired outcome.
Customer and Market Focus	The contractor determines the needs, requirements and expectations and enhances relationships ensuring satisfaction of customers and markets.
People Management	This is how the contractor releases the full potential of its people.
Resources and Information Management	This is how the contractor manages and uses resources and information; effectively and efficiently.
Business Processes	How the contractor uses resources and information to support its plans
Impact on society	How the contractor satisfies the perception of the local community and society; the impact on society.
Customer satisfaction	This is the client's perception of the contractor's products, services and other satisfaction measures as envisaged by the client.
People Satisfaction	How the contractor satisfies its people as perceived by the people themselves including other satisfaction measurements.
Suppliers and Partnership Performance	What the contractor achieves with its suppliers and partners
Business Results	This is what the contractor is achieving in relation to its planned business objectives in satisfying stake holders in the company. The contractor can be measured by results, trends and targets in comparison with competitors or bench marks.

2.2.4.2 SACEM Benefits

The envisaged benefits of SACEM include:

a. It assists contractors to assess their performance and improve their productivity, quality and effectiveness;
b. Contractors can use it o bench mark their performance;
c. Contractors' risk profiles can be easily identified and managed appropriately;
d. Use of SACEM can lead to repeat customers. (Dlungwana *et al.*, 2002)

2.2.5 Working Habits and Culture of People

The procedures can be laid down for everyone to follow but critically important is the culture and the working habits of people in an organisation over and above the specifics of the working environment and conditions for each project. Control of a construction project requires the understanding of the culture of the industry. Taylor *et al.,* (2008) emphasise the 'people dimension' of the origin of problems in the project implementation phase. Du Plessis (2003 cited in Thwala and Monese, 2008:5) comments that:

> "In project environments, people can be viewed as contributing problems and constraints or as providing solutions and opportunities."

In construction projects, there is a high level of personal operative input and very low level of automation, (Woodward, 1997). This is even more relevant to most government projects seeking to create employment by using labour intensive techniques. The construction industry relies heavily on contract employees just for the duration of the project but Drucker, (2002:6) warns organisations of the 'people dimension' when he says:

> "Every organisation must take management responsibility for all the people whose productivity and performance it relies on- whether

they're temps, part-timers, employees of the organisation itself, or employees of its outsourcers, suppliers and distributors."

Mahmood *et al*., (2006:2) define culture as:

> "...the pattern of arrangement, material or behaviour which has been adopted by a society (corporation, group or team) as the accepted way of solving problems: as such, culture may be taken to include all the institutionalised ways and the implicit beliefs, norms and values and premises which underline and govern behaviour."

Lack of commitment and foresight by management with regard to training on quality presents a significant threat to quality, especially when management develop an impression that capacity building through training does not translate to a corresponding improvement in the quality but instead is a waste of financial resources. Capacity building process is critical to indoctrinate and align employees with the culture of the organisation so that employees can identify with their work and company objectives of quality.

Globalisation and the generally accepted skills shortages in the construction industry mean that management has to deal with employees from divergent cultural backgrounds at various levels e.g. national culture, industry culture, organisational culture, professional culture, etc. Zuo and Zillante, (2008) concede that there are limited studies done on culture at a project level but the available studies indicate that:

i. National culture impacts on quality management and hence has an impact on the quality or performance of construction projects. This view is shared by Ngowi, (2000:2) when he says that "TQM takes on some of the host country's cultural values, rather than attempting to change them". TQM does not necessarily assume the culture of the host organisation.

ii. The implementation of Total Quality Management (TQM) in construction projects is influenced by both the national culture and the organisational culture.
iii. The culture of the construction industry is characterised by adversarial relationships and fragmented approaches.

The efforts to meet the required quality standards on construction projects show a general shift from Quality Assurance (QA) under ISO 9000 to Total Quality Management (TQM). ISO 9000 registration is regarded as a stepping stone towards TQM (Lee and Chen, 2011). QA in itself as a program awaiting specific implementation does not ensure good quality, but only ensures realisation of specifications to satisfy the needs of the customer and is an external quality system designed for external certification (Lee and Chen, 2011). Full implementation of TQM increases competitiveness, customer satisfaction, reduces waste and improves working lives of employees (Ngowi, 2000) because TQM stresses the involvement of everyone inside an organisation, (Lee and Chen, 2011). Registering for ISO compliance is relatively easy as an organisation, but with lack of experience and exposure among the construction workers, performance related problems arise, (Mohammed & Abdullah, 2006). The existence of ISO 9000 in companies does not align with the deep-rooted operational practices and procedures needed to achieve customer satisfaction (Willar *et al.*, 2010).

In the South African context, Smallwood (2000) identified only three contractors that use strategies close to TQM but not TQM itself. However:

> "although the strategies do not constitute a formal TQM strategy per se in terms of principles, supporting elements and steps, they do incorporate aspects of the aforementioned", (Smallwood, 2000:5).

Smallwood (2000) concluded that such lack of quality management systems in South African construction companies is among the causes of poor

contractor performance. The findings by Smallwood (2000) are similar to the findings by Ahmed *et al.* (2002) that the method and techniques to implement quality management in the construction industry are still to be developed. The lack of quality management systems in South African construction companies can be attributed to the construction industry in South Africa being regulated by the Construction Industry Development Board (CIDB). Within the CIDB structures, there is the Construction Industry Indicators (CII) that measure performance in terms of client satisfaction; health and safety; quality of work delivered; and quality of tender documents and specifications used, among others (CIDB, 2010).

The failure or successful implementation of TQM largely depends on the deep understanding of the philosophy behind its origins and how it is integrated in the organisation as a whole. TQM originated in Japan and it harbours Japanese philosophy of a holistic, integrated approach to quality management which in itself is a cultural foundation. Implementing TQM in organisations which do not share the cultural values upon which it was founded can result in failure, (Ngowi, 2000).
The constituent cultures that make TQM successful include:

i. Supportive leadership – a culture conducive to its implementation is centred on top management's commitment of the cause through putting in place, supportive structures. Studies conducted in United Kingdom, Singapore and Hong Kong show that the initial stages of implementation of any quality management system is very encouraging but it becomes a burden to all parties involved if the right approaches are not adopted, (Mohammed and Abdullah, 2006). Smith *et al.*, (1993 cited in Mahmood *et al.*, 2006) has done studies that indicate that TQM is likely to fail 18-24 months into the endeavour irrespective of the approach used due to the cultural position of the company. Supportive leadership then becomes responsible for formulating a strong quality

policy and strategy. Committed leadership ensures that the agenda for quality improvement is driven forward in well communicated manner.

ii. Culture of continuous improvement – the plan-do-check-act cycle as recognised by prominent quality experts such as Deming, Juran and Crosby suits a continuing process like manufacturing. Retting and Simons, (1993 cited in Ngowi, 2000) modify the cycle to be relevant to construction projects. It reads Plan-Approve-Do-Review-Evaluate (PADRE). Mohammed and Abdullah, (2006) concur with this view point because products are processed by a single entity, a situation not typical in the construction industry where different contractors work on the same project. The dominating level of quality of the finished piece of work is equal to the quality of the lowest performing contractor.

iii. TQM emphasises prevention rather than detection of faults. Formal and systematic training enables employees to identify areas of possible quality problems and take corrective action at an early stage. Mahmood *et al.,* (2006) notes that quality begins and ends with training.

iv. Culture of teamwork – teamwork creates cross-boundary communication and co-operation making it easy to solve problems. Teamwork allows various sections or departments of the organisation to work together in ways that cannot be done through individual job specifications, (Mahmood *et al*., 2006).

v. Culture of empowerment and respect for people – the people dimension is a vital element if TQM is to be a success. Empowering employees by way of easy access to information and making decisions allows them commitment and ownership for decisions they make. Management can only trust permanent employees to make decisions on behalf of the company rather than temporary employees employed only for the duration of the project.

vi. Supplier Partnership – materials can be a source of quality problems, so it is important to have a supplier quality management in place.
vii. A culture of effective communication – effective communication is vital in directing employees towards the corporate goals, (Mahmood *et al.*, 2006).

2.2.6 Safety of Employees.

Safety is a major issue on construction sites and it affects the commitment of employees to delivering quality projects. Employee commitment frequently changes in response to change in project conditions, (Thwala and Monese, 2008).

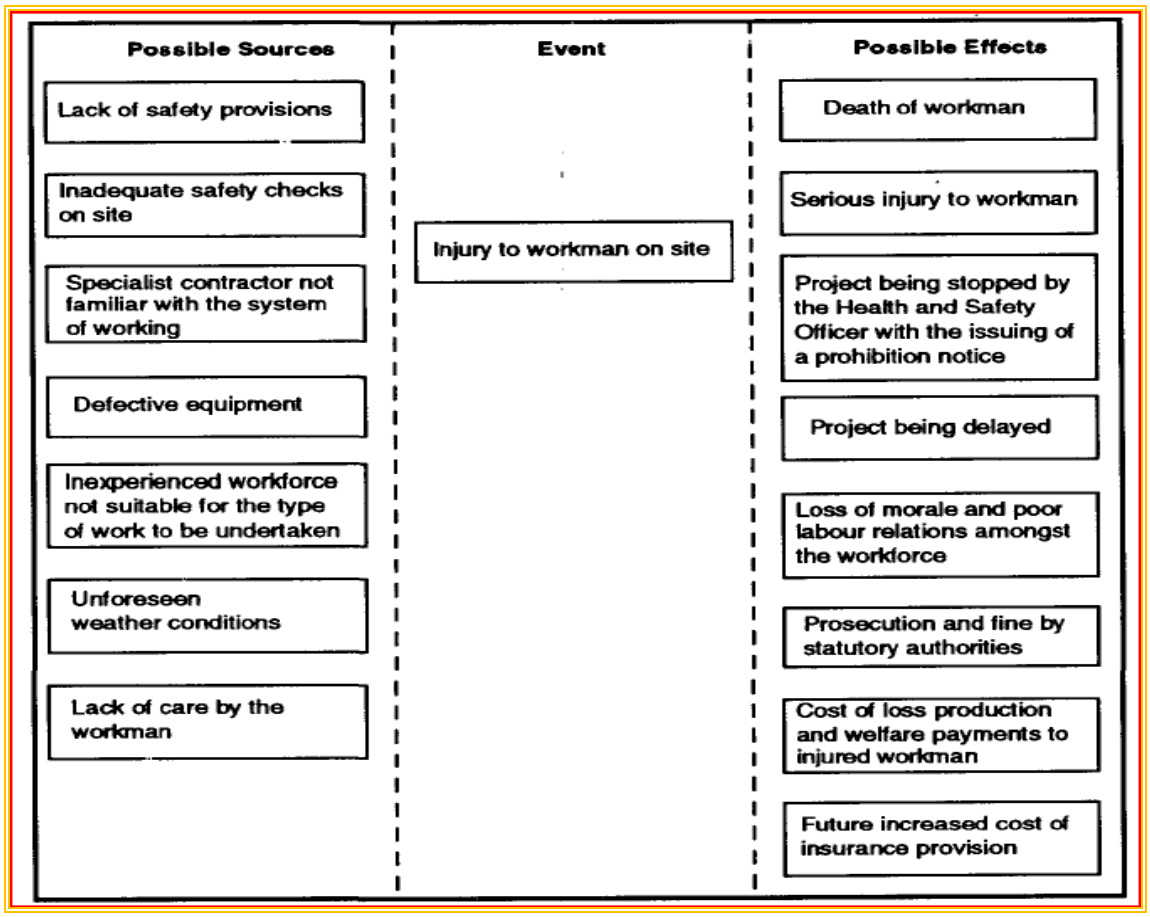
Another aspect of employee safety relates to job security and associated threats. Employees who feel threatened become reactive, counterproductive and may passively resist progress (Cunningham, 2008). Training is important to instil confidence in employees in carrying out site operations. Site conditions need to be clearly understood well in advance before site establishment so that there is less time and effort spent in making the site safe to work on (Kwakye, 1997).

Safety has to be one area of mutual interest among all the players from a point of view of getting better value for the client in relation to cost, time and quality, as well as improving cash-flow and profits for consultants and contractors.

If challenging completion targets and milestones are set prior to construction (which is the norm in the construction industry), then construction site conditions must be conducive for production. Workers work in an environment

created by management (Smallwood and Deacon, 2001). If the site conditions are not worker-friendly, the output or productivity will be low because of lack of efficiency and low productivity will have negative and undesirable quality effects. Not only will quality be bad but costs will also increase (Woodward, 1997). Smallwood (2000) maintains that the promotion of health and safety; quality; and contractor performance in South Africa will be difficult, as long as the division between design and construction persist. After rating the project parameters that are impacted upon by inadequate health and safety on a construction project, Smallwood (2004) found that quality and productivity predominated, with 80.8% and 87.2% respectively.

Table 2.4: Sources of Safety Problems and their Effects (*Source*: Flanagan and Norman, 1999)



Generally, deficient safety on site reduces project economic gains. Themes such as zero accidents; design for safety and making zero accidents a reality need to be put at the forefront during construction at all levels i.e. the client, contractor, site employees including the project site leader. A few safety problems are highlighted in table 2.4.

2.2.7 Contractor Selection

There is a general tendency in the construction industry to award projects to the lowest bidder. For this reason, there is seldom an established relationship between the client and the contractor. The client expects his interests to be protected through provisions in the contract agreement. This is a narrow sense of interpretation of responsibility and accountability (Egan, 1998) and furthermore, this procedure of contractor selection puts the client at risk of sub-standard work (Ngowi, 2000). This is so even though infrastructure projects have always been considered unpredictable with regard to delivery time, completion within budget and more importantly, meeting the standards of quality expected. The lowest price does not translate directly to lowest cost and the mentality of clients that low price means low cost often leads to poor delivery of projects (Rwelamila *et al*., 1999).

Late selection of sub-contractors contributes to poor quality of constructed work. The selected sub-contractor will tend to make a haste to start with works on site without thorough briefing (Rwelamila, 2001). The contractor needs a fair amount of time to assess the client's needs and efficiently convert the needs into improved productivity through value addition engineering. This situation could be worsened by engaging contractors or sub-contractors on bonus schemes because they will concentrate their attention on the speed of production and not quality (Woodward, 1997).

The selection of constructors exclusively on the basis of tendered price presents its own challenges in terms quality improvement. The tendency to select constructors on tendered price is widely seen as one of the greatest barriers to improvement (Egan, 1998). He further portrayed the construction industry as one that is competitive on price and not quality.

The increase in the number of contractors coupled with the 2008 recession may lead to what Latham (1994) described as 'bid low, claim high' following 1989/90 recession. The practice describes consultants and contractors who seek to obtain work at all cost and would aim to make profit through claims and extras as the project progresses. This practice is conflict driven and the end result of such conflicts is poor quality work, delays and cost escalations which the client is not ready to pay, let alone anticipate.

Separating the responsibility for design and construction can inhibit the implementation of good quality because the two teams understand the same design differently and often do not know each other. Communication between the two teams becomes complicated and often there is no shared culture of quality (Woodward, 1997). Also, Smallwood (2000) maintains that the promotion of health and safety; quality; and contractor performance in South Africa will be difficult, as long as the division between design and construction persist. The recommendation not to separate design from construction is deeply rooted in the publication of the Banwell report of 1964, which had, as one of its key findings, that the traditional separation between design and construction impacts quality (Allen, 1996). The implementation of the recommendations not to separate design from construction have been inherently resisted or ignored by the construction industry (Kagioglou *et al*, 1999); (Allen, 1996); (Hindle, 2000) and the continued championing of separate contracts for design and construction even today is a reflection of such resistance.

Partnering, as a procurement practice has gained usage over the years and many nations approve of it after it gained credibility from proven success in the UK and other western countries including the USA (Egan, 1998). Whilst partnering may be defined in various ways, the Construction Industry Institute (1991) cited in Bresnen and Marshall (1999:230) defines partnering as:

> "long-term agreements between companies to co-operate to an unusually high degree to achieve separate yet complimentary objectives."

NEDO (1991) cited in Bresnen and Marshall (1999:230) defines partnering as:

> "a long-term commitment between two or more organisations for the purpose of achieving specific business objectives by maximising the effectiveness of each participant's resources."

Effectively, the above definitions are similar, but more importantly, they both reflect a win-win agreement; and the synergetic framework that allows sharing of resources to achieve more through a clear definition of responsibilities of each party in the partnership.

Partnering has, among many benefits: a more compact management approach; reduces disputes because all parties (client, contractor, suppliers, project designer, and other parties) share the same interest; and an awareness that if there is poor quality work, they all lose on both the current project and future projects due to bad publicity. Other advantages that can be realised through partnering include team working and innovation in efficient methods. It is important to note that all the partnering arrangements that can be done must not interfere with the free market regulations which may come back to haunt the quality improvement efforts (Hindle, 2000).

2.2.8 Shortage of Skilled Manpower

Shortage of skilled and experienced manpower can affect the quality from various perspectives like poor supervision; lack of complete designs and other project documents; lack of organisation and coordination among parties involved and the general lack of efficiency among others, (Rwelamila, 2001).

The continuously changing and mobile labour force can lead to problems related to continuity and hence quality, (Woodward, 1997). The departure of highly skilled workforce from one project to another does not mean a stop in the works but means carrying on with a less experienced workforce. It must be stated, however, that the labour force in the construction industry is willing, adaptable and able to work under some of the harshest conditions. They are largely a semi-skilled and itinerant workforce with a wide disparity in their levels of competence (Woodward, 1997). This calls for the construction industry to recognise this fact and treat its people as its greatest asset rather than a commodity.

Egan (1998) concedes that there is a general crisis with regard to training. Too few people get trained to replace the ageing skilled workforce with few acquiring the technical and managerial skills necessary to get the full value for money from the new techniques and technologies currently available in the market. Young graduates lack mentoring and in-house training and this forces them to gain their experience at the expense of their clients.
The sustainability of the enterprise is key to the capacity and skills development because there is an improvement in quality and performance with a repeat of work from clients.

Shortage of skilled manpower to effectively implement project management can manifest itself through lack of balanced curricula of project management

at higher learning institutions. Rwelamila (2007:6), after studying the curriculum of nine higher learning institutions argues that technical expertise in quantity surveying, civil engineering, construction management and architecture is not the most important requirement for successful project management.

Figure 2.6 shows the Construction Project Success Bridge which explains the need to balance between Strategic (executive) Project Management Knowledge (EPMK) and Construction Project Management (coalface) Knowledge (PMCK).

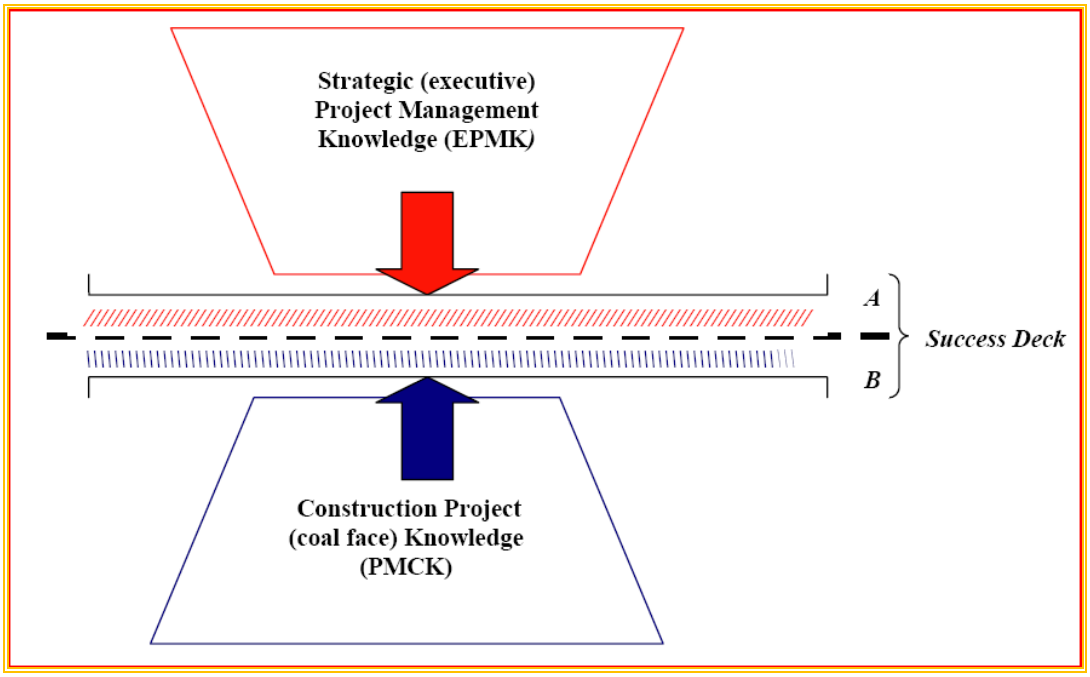


Figure 2.6: The Construction Project Success Bridge (*Source*: Rwelamila, 2007)

The studies indicate that the curriculum of most of the institutions produce graduates that are strong in construction project knowledge (PMCK) and

weak in strategic project management knowledge (EPMK). This scenario presents a skewed knowledge base capable of supporting a weak 'success deck' of the construction project success bridge.

2.2.9 Fragmentation

Fragmentation is believed to be one of the obstacles to quality improvements. The South African government has embarked on a number of programmes to develop contractors e.g. the use of emerging contractors on EPWP projects; broad based black economic empowerment (BBBEE) programmes; Public Private Partnerships, etc. In terms of dealing with variable workloads, this is a positive endeavour but there is serious negative side related to contractual relations which prevent continuity of teams, which continuity is essential to efficient working, (Egan, 1998).

There is a lack of competency testing of small firms entering the construction industry. The fragmented structure of the construction industry, comprising a large number of small firms organised in temporary coalitions to address individual problems, presents obstacles to quality management, (Latham, 1994). As a result, there is a strong belief that leadership with regard to quality in construction comes more from the client than from contractors and consultants.

Lack of trust between consultants (designers) and contractors; contractors and sub-contractors; and contractor and client has escalated the quality problems. Slow payments by government have also contributed towards low quality of the final product. Some emerging contractors are undercapitalised, do not have a healthy cash flow and will not manage to finance the project from their own resources and will vacate the site before the project is

completed because of their high levels of insolvency, (Rwelamila, 2002; Odeh and Battaineh, 2002).

Fragmentation also leads to low levels of investment in research & development in the construction industry, thereby creating innovation barrier. The formation of the Construction Industry Institute in 1983 was necessitated by the need to close the fragmentation gap and bring the role players into a cooperative environment so that research and development in the construction can be collectively funded, (Fayek & Hampson, 2009:16).

Section 2.2 presented a brief overview of factors that have a potential to significantly impact on quality management initiatives and result in flawed project delivery process. During construction, each of the factors has a unique way in which it can impede quality, either by itself or working in unison with other factors.

2.3 Effects of Failing to Address Obstacles to Quality Management.

Most businesses have deployed some type of quality initiative in their operations (Silvestro, 2001). Yet, a number of infrastructure projects have quality problems leading to re-work, cost and time overruns, disputes, accidents, losses through material waste, high operational and maintenance costs, claims for extra costs, company liquidations due to loss of market share and other inefficiency causes, as the major problems.

2.3.1 Rework

According to Hwang, *et al.* (2009), rework has various synonymous terms which include ‘quality deviations’, ‘non-conformance’, ‘defects’ and ‘quality

failures' and Love *et al.* (2000 cited in Hwang *et al.* 2009) characterize rework as unnecessary effort of redoing a process or activity that was incorrectly implemented the first time. The terms used to refer to rework indicate that it is an endemic symptom of an obstacle that hinders work from being done right the first time.

Although there is no industry-wide standard to measure rework, a pilot study by Fayek, *et al.* (2003) indicates that almost every infrastructure project has some level of rework even those reputable organisations which have some sound quality management systems. Fayek *et al.* (2003) categorise and present possible causes of rework incidences as shown in Figure 2.7.

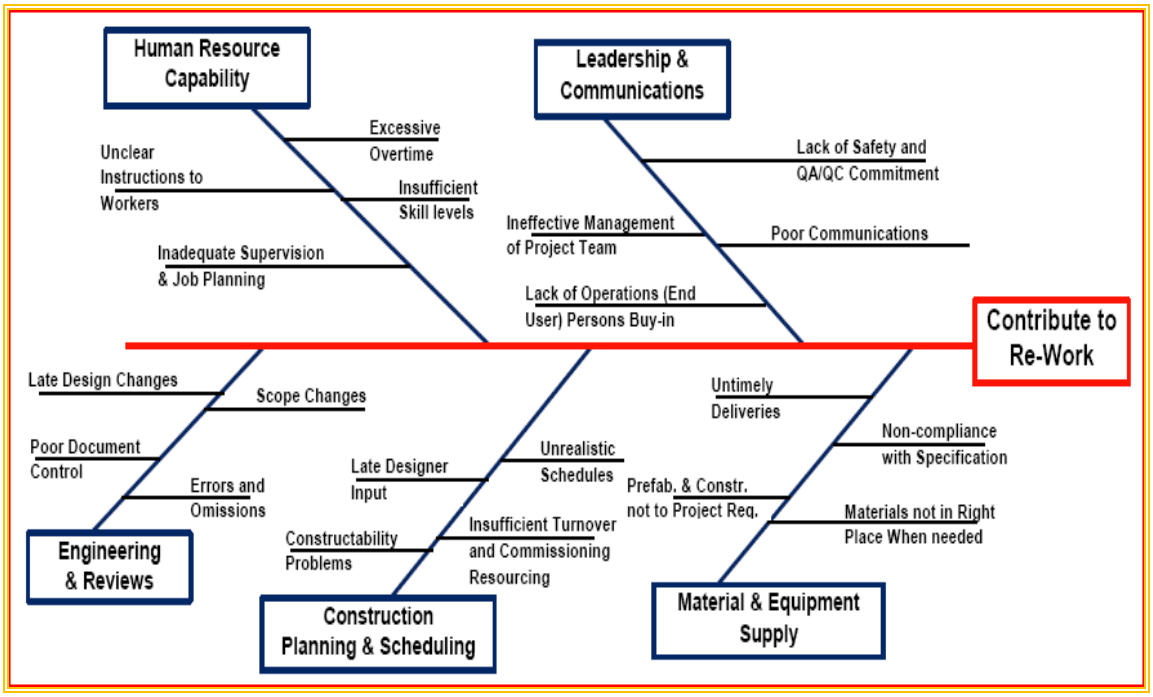


Figure 2.7: Fishbone Rework Cause Classification (*Source*: Fayek *et al.*, 2003)

Five generic causes of rework in the construction phase of a project are identified by their pilot study as: human resource capability; leadership and communications; engineering and reviews; construction planning and reviews

and materials and equipment supply. Some impacts of rework are summarised in Table 5.5.

2.3.2 Project Delays, Overspending and Quality Defects

While the above are common problems besetting the project delivery process of infrastructure projects, these problems can not be entirely blamed on the project implementing team alone but also the client requirement changes which translate to changes in specifications (Engineering and Physical Sciences Research Council, 2004). A number of decisions during project delivery are made based on assumptions using the existing information and experience. Often the assumptions made lead to changes (internal or external) that mostly affect delivery time, cost and quality.

2.4 Conclusion

The literature acknowledges that a number of quality obstacles affect the performance and delivery of infrastructure projects emanating from the complicated, large and diverse nature (including being project-based) of the construction industry but the nature of the obstacles are not fully explored and documented.

There are a number of reports alluding to the deep concern that the construction industry lags behind and under-achieves with regards to quality when compared to other industry sectors. The period leading up to 2010 saw the South African construction industry grow due to the real need to construct soccer stadia; constructing and upgrading airports; and Gauteng Freeway Improvement Scheme. The growth was driven more by the need rather than efficiency and competitiveness of the industry to deliver the infrastructure.

While it is known that 2010 FIFA World Cup spurred the infrastructure demand during this period, it is important to understand how the quality obstacles were overcome alongside the pressure to deliver World Cup infrastructure (including the R21 project) on time.

Total Quality Management at company level has been successfully implemented but TQM at project level has not been successful. Because construction is project-based, obstacles at project level are the ones that predominantly affect quality management (although many of the obstacles exist at company level, for example, training). A better understanding of the cause(s) is sought by this report, because every project has its own peculiarity in terms of size, information available about the project and complexity.

ISO compliance at company level is viewed as creating a vicious circle without flexibility, emphasising bureaucracy and paperwork but deficient in quality improvement, (Mohammed & Abdullah, 2006). A number of problems have been reported with regard to the implementation of ISO 9000 in other countries such as Malaysia, Hong Kong and UK but it is not only the implementation of ISO 9000 that presents problems to quality management but also conditions specific to the South African construction environment. Despite increasing problems caused by cultural issues, comparatively, little attention is given to address it.

The lifespan of most construction projects is invariably long and may undergo modifications at unforeseen times. It becomes difficult to estimate the quality demands as a result of changes or modifications due to the nature of once-off projects. Also the variability of the construction environment on site (inclement weather conditions and sub-surface conditions in particular) inhibits good quality.

The fragmented structure of the construction industry leads to continued selection of new teams to manage projects. This inhibits the development of skilled and experienced teams. Allen (1996) opines that “it is not always possible to employ the same team” on a construction project.

Through a study of the R21 project, the following aspects of quality management in the construction industry are addressed:

i. The culture of management and workforce. How the management and workforce view the TQM processes and its culture including the commitment it requires.
ii. Stages prior to construction where processes are compromised will also be addressed and also in areas where workmanship leads to poor quality.
iii. The link between poor quality and safety of employees, shortage of skilled manpower, contractor selection and fragmentation will also be investigated.
iv. It is also important to find out how contractors use the kaizen principle to handle the complicated nature of the construction industry.
v. The balance of all the competing needs of quality i.e. time, cost and scope need investigating including change management tools to guard against time and cost overruns without compromising quality.
vi. ISO registration versus ISO compliance. ISO registration is perceived to be easy while ISO compliance is demanding and difficult.

Chapter 3: Research Methodology

3.1 Introduction

This chapter outlines the methods that were used in an effort to explore obstacles to quality management in the delivery of infrastructure projects. The first aspect of the study involved understanding the topic area through a literature review to explore commonly experienced problems within quality management and the objectives of the study. The factors that could lead to inferior quality as indicated in Chapter 2 were investigated. The choice of the R21 project out of other possible infrastructure projects (railway, airports, water supply systems, wastewater treatment plants and high rise buildings) for study was because (a) the road is a major means by which 2010 FIFA World Cup spectators would access the OR Tambo International Airport from Pretoria; (b) the road is a major trade and travel route that links with northern Africa for delivery and haulage trucks accessing the industrial areas of Kempton Park, Benoni, Springs and other industries on the East Rand area; (c) It is an ideal project with many main contractors and sub-contractors required to produce infrastructure of the same quality.

3.2 Data Collection

It is desirable in this study to determine the obstacles to quality management on infrastructure projects. The information used in this study of the R21 Project was be obtained through questionnaires sent out to main contractors, sub-contractors and the client's project managers who were all expected to complete the questionnaires. The distribution of the questionnaires to the contracting companies aims to cover the whole spectrum of management, thus top, medium and lower level including those directly involved with quality management. The purpose of the questionnaires is to uncover what the real quality problems are during the process of delivering an infrastructure project.

The preparation of the questionnaires is based on the objectives of the current study. To a lesser extent, direct observations by the researcher during site visits are used to draw conclusions.

The questionnaires were chosen to provide information in this study because there could be specific information particular to the project, information which can only be provided by the contractors and project managers who were directly involved with the project. These are primary sources of information. To augment the findings of the literature survey and questionnaire survey, project documented information was obtained from the client, SANRAL, with the aim of contextualising and ascertaining the relevance of the data with regard to the aim of this study.

3.3 Data Analysis

The findings obtained from the questionnaires are analysed in a descriptive manner to interpret the data and understand the impact with relation to quality management. Analysis involves preparing the data for analysis, understanding the data, representing the data and interpreting the data (Creswell, 2003). Reliance is made on the views of the participants (primary sources) to the aspects being studied. The underpinning method of analysis of results to this research is triangulation. The triangulation method of analysis is used to analyse data collected from participants through questionnaire survey; information contained in the existing literature and project documented information obtained from SANRAL.

Triangulation provides a quick turnaround between data collection and presentation of results because it relies on multiple sources of data. It can also be used when the available data is too little or too much or when the 'best' data is not available or when rapid intervention measures to improve

the quality are required (Wang and Duffy, 2009), and it does not require commitment from only one philosophical system (Creswell, 2003). Triangulation draws insights from both qualitative and quantitative analyses in the study of the same phenomena from varied dimensions to strengthen the validity and reliability of research (Wang and Duffy, 2009), thus it confirms findings through convergence of different perspectives. This is helpful in eliminating biases and deficiencies that may emanate from using a single method of analysis.

It is worth mentioning however that each method of analysis has its own advantages and disadvantages in relation to the type of data to be collected; nature of the project and the context of the study (i.e. assumptions made about the study).

3.4 Types of Triangulation

Triangulation has been mostly regarded as the application and combination of two or more data sources, approaches or methods, to the investigation of the same problem or phenomenon, with the aim of increasing the validity of the findings (Denzin, 1970 cited in Wang and Duffy, 2009). This way, the weaknesses or bias of one method are eliminated. There are four main types of triangulation that were distinguished by Denzin, (1970 cited in Wang and Duffy, 2009) and are described below.

3.4.1 Data Triangulation

This method applies the use of different sampling strategies and different sources of data but with similar foci to enable the comparison of information to check consistency and validation. Within data triangulation, there is:

a. Time Triangulation which attempts to take the factors of change into consideration through the collection of data at different time intervals.
b. Space Triangulation attempts to employ the cross-cultural technique in the collection of data. This overcomes the limitations of studies carried out within the same culture or sub-culture.
c. Person Triangulation engages different individuals, groups, communities, organisations or societies in the collection of information. The discovery of data by one group is independent of the other.

This last triangulation method is applied in this research with data collected from the whole spectrum of people involved - the project managers, the contractors, sub-contractors, quality managers and some general employees. This whole group of people are different in their approach and interests but share the same focus. They also have different cultural backgrounds and represent different organisations.

3.4.2 Researcher Triangulation

This method occurs when two or more researchers are deployed in the collection and analysis of data about the same phenomenon. This method is useful to compensate for single researcher bias because each researcher has their own observational styles. By the nature of this study, this method will not be applied in this investigation.

3.4.3 Theoretical Triangulation

In this method, the same research findings are examined using two or more theoretical perspectives for interpretation. Different professionals from outside the same field or from different disciplines can be brought in to do the analysis. More information will be gained by understanding how results can

be affected by different assumptions and principles. Using different analytical frameworks also helps to eliminate intrinsic personal biases. Also, this method enables a deeper understanding of the results as investigators can explore various ways to make sense out of the available data.

3.4.4 Methodological Triangulation

Methodological triangulation engages the use of multiple methods to study the phenomenon. The methods or approaches may include interviews, direct observation or any other relevant method that could be employed. The methodological method can be used in the following two ways;

a. Within-method triangulation, which involves the use of two or more different methods within the same research.
b. Across-method triangulation, which uses both qualitative and quantitative methods.

Triangulation allows the integration of qualitative and quantitative research methods so that they are not seen as opposing methods but different perspectives to evaluate the same phenomenon. The convergence of results from two different perspectives helps to confirm results whilst divergent results enrich the explanations for the phenomenon. Triangulation also helps to add meaning (richness and depth) to research by creating complementary findings.

3.5 Ethical Conduct

Research involving human elements who volunteer to participate in research and volunteer their views demands that their rights be protected so that the research becomes ethically responsible.
Baghdadabad (2008) identifies three traditional ethical concerns as:

a. Informed consent - introducing the research to potential participants truthfully and acquiring their consent;
b. Right to privacy – keeping the subjects anonymous;
c. Protection from harm – providing a guarantee that the research will cause no harm, physical, emotional or other.

From the above, care needs to be taken so that people are not treated as mere objects of study but their dignity and welfare remain intact; research must be fair in both conception and implementation and at the same time seeking to maximize the collection of useful information.

To ensure ethically sound research, the researcher received an Ethics Clearance Form from the Human Research Ethics Committee (HREC) of the University of the Witwatersrand.
Section 3.6 discusses the questionnaire design and the structuring of the invitation letter (attached to the questionnaire) which gives a brief description of the project and what it intends to achieve.
The questionnaire is attached in Appendix A.

3.6 Questionnaire Design

The questionnaire was designed to gather survey data that is directly related to quality management on the R21 project. The questions were formulated (length, wording and order) in a consistent, simple but robust manner to facilitate accurate feedback that is easy to interpret without distortions to the gathered solid data.

The assurance of confidentiality helps the respondents to give quality feedback, without bias. Lack of bias in the data translates to lack of bias in the reporting.

Choi and Ibbs (1994) cited in Ahmed *et al* (2002:15) conclude that "data collected in construction project usually lacks consistency in structure and compilation." In view of the above, the rating system of *"yes"*; *"No opinion"*; and *"No"* was used for its simplicity and consistency in obtaining accurate data to address the objectives of the study. The rating system also considers that time is of essence to the respondents and therefore the rating system was developed to enable the respondents to give accurate information in as little time as possible.

The questionnaire has eight sections containing questions on factors discussed in section 2.2 as identified by the literature; personal experiences and other specific concerns discussed in section 4.3. The ninth section requires the respondents to elaborate on their choice of answer.

The choice of triangulation as a method of data analysis was informed by the objectivity of the method in analysing the same phenomena from three perspectives and arriving at an informed; balanced and meaningful conclusion. Triangulation also instils confidence in the results by avoiding the bias associated with the analysis of data from one source.

Chapter 4: Case Study Overview

4.1 Project Location and Type

The National Route 21 (R21) project is part of Gauteng Freeway Improvement Project (GFIP) under the authority of South African National Road Agency Limited (SANRAL). The project originated to address the challenges of SANRAL's deteriorating road network and be able to handle the increase in heavy vehicles using the road. During the planning of the Gauteng Freeway Improvement Project, SANRAL took other transport modes into consideration (the Gautrain, Metrorail and Bus Rapid Transport) so as to provide citizens with a choice regarding the mode of transport they want to use. The GFIP is aimed at improving the level of service of the road by upgrading it to 4-lane road in each direction under various work packages. The R21 project has three work packages; G, H and J from N12 to Hans Strydom Interchanges.

The project designs for the R21 project were carried out by one consulting engineer-Vela VKE for consistency purposes. The description for each work package is shown in Table 4.1.

Table 4.1 Work Packages for the R21 Project (*Source*: Author)

Package	Description from	Description to	Type of work	km	Contract Sum	Contractor
G	Olifantsfontein Interchange	Hans Strydon Interchange	Median widening to 4-lanes each direction with full depth of pavement construction. Addition of auxiliary lanes at on and off ramps. Bridge widening and drainage improvements as well as Median lighting.	17.6km	R719 340 000.00 (incl.vat) A 20 months contract from 3.05.2008 to 02.05.2010	Raubex Construction
H	Benoni Interchange	Olifantsfontein Interchange	Median widening to 4-lanes each direction. Addition and widening of auxiliary lanes at on and off ramps. Bridge widening and Median lighting.	12.3km	R610 387 407.99 (incl.vat) A 20 months contract from 03.05.2008 to 02.05.2010	Power Construction
J	Rietfontein Interchange	Pomona	Phase 1 involved surfacing between Pomona and R24 Interchange. Phase 2 involved median widening to 4-lanes each direction; addition of auxiliary lanes at on and off ramps; Bridge widening and median lighting.	11.63km	R396 722 880.39 (incl.vat) A contract from 29.06.2009 to 28.05.2010 for Phase 1 (11 months) and to 28.02.2011 for Phase 2 (20 months).	Patula Construction (Now Esorfranki Civils)

The location of the project is shown in Figure 4.1. The project runs from Ekurhuleni Metropolitan Municipality to Tshwane Metropolitan Municipality in Gauteng. The work also includes the upgrading and construction of bridges.

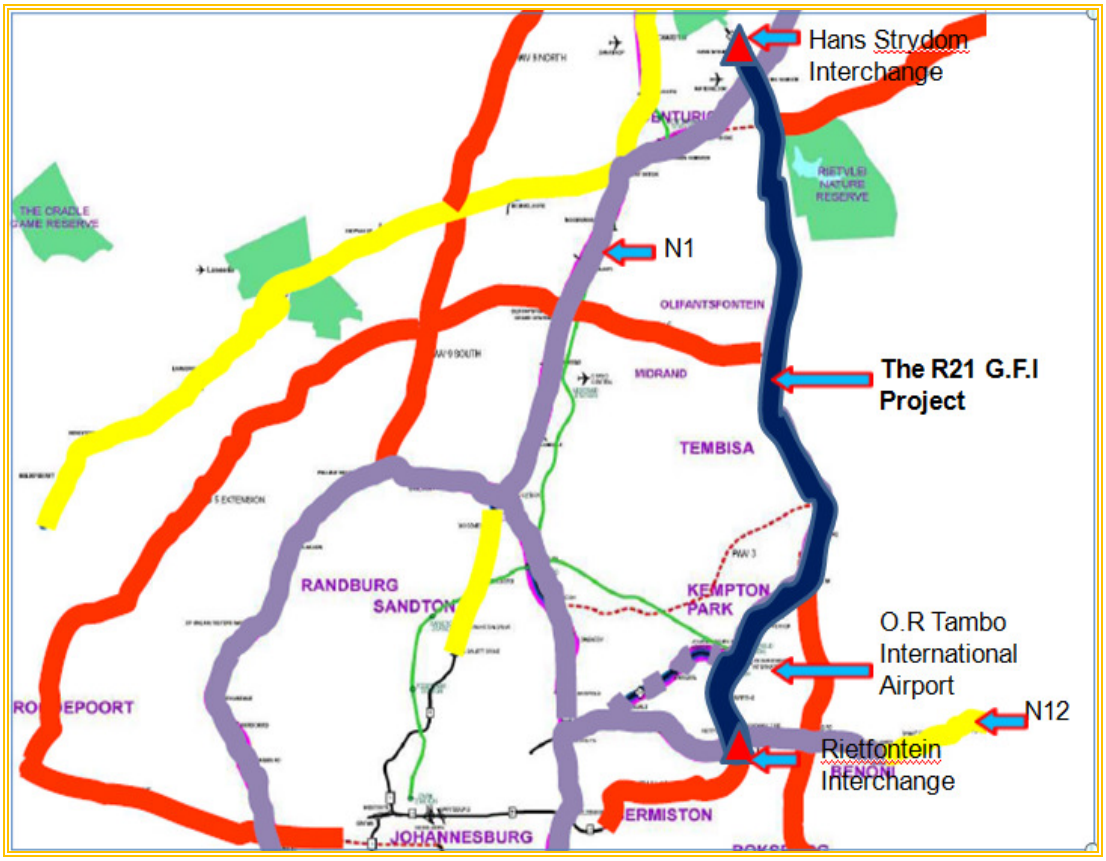


Figure 4.1 The R21 Project Location.

4.2 Project Objectives

Everyone involved on the project had their varying objectives, and moreover, the objectives of this project from the client's side are multifaceted. The objective of the R21 project as part of the GFIP (which is a far-reaching upgrading programme for the province's major freeway network) is to provide

a sustainable, safe and reliable strategic road network system so as to optimise, traffic flow, the movement of freight and passengers in order to grow the economy.

The project objective can be achieved if all the quality of the work is at par with the expectations of client and all the stakeholders including ordinary consumers. A clear understanding of the obstacles to quality management provides clients, contractors, project managers and project sponsors with a tool to effectively guard against poor quality management in delivering their projects.

With the main objective of the project as indicated, a number of supporting objectives of the R21 project can be derived and defined thus:

a. To reduce congestion levels by increasing capacity so that the demand posed by the Gauteng's growing traffic is met. High congestion levels increase the road user costs and also lead to unsafe driving conditions. High levels of congestion also mean high carbon emissions which is detrimental to the environment.
b. To improve the level of service (LOS) to acceptable levels and also to reduce the backlog by restoring the aging road network so that the road becomes more reliable and improve the travel times. The road becomes suitable for trafficking by the ever increasing number of heavy vehicles.
c. As a modern economy, investing in such infrastructure brings with it, the accelerated economic prosperity through efficient mobility of goods and services and this ultimately improves the quality of life.
d. To create employment. This is in line with urgent present societal expectations when delivering infrastructure projects.

The findings of this research help to gain knowledge and add to the existing body of knowledge with regard to obstacles to quality management and help

to achieve the project objectives as well as to identify and close the gaps existing on the current quality management approaches.

4.3 Specific Concerns

There are specific concerns regarding R21 project that drew interest in wanting to understand more about obstacles in providing quality management to the project. The following specific concerns are considered:

4.3.1 Implementing the project at night-time

The R21 project was executed both at night and during the day but it is working at night that is of a major concern both quality wise and with regard to safety of workers. Working during the night presents an opportunity to do the work more effectively, because the fast moving traffic is at off-peak and high traffic volumes during the day that can pose a serious safety issue are reduced during off-peak times. The other reason for working at night is to reduce congestion levels along the stretch of the works. It is difficult during the day to work in or near travel lanes. The pressure of the project also forced night operations because the road had to be open up for the 2010 FIFA World Cup. Planning to be pro-safe at all times takes education, engineering and enforcement (3E's) (Molai and Nyarirangwe, 2010) to all parties involved, especially road users and workers. Safety is paramount to ensure that employees are confident whilst carrying out their work. Motorists who slow down in order to look at construction work in progress compromise safety.

Poor visibility, inadequate lighting and worker fatigue are some of the issues that may compromise safety at night. While night work reduces delays to motorists, it brings with it more constraints to contractors: time is required to set up traffic control devices and remove them early before the morning rush.

Quality of the work may get compromised through worker sleep deprivation, effect of circadian rhythms (changes in biological processes due changes in sleeping patterns) and fatigue – all leading to low motivation levels; low energy levels; low cognitive performance and low concentration ability (Norman, 2011) .

4.3.2 Incomplete contractual documents

Walker and Pryke (2009) point out that even when the designs and construction documents are produced by the same team for different project packages, document incompleteness levels vary and such variation results in different levels of efficient project execution. Construction contracts are generally believed to be incomplete (Walker and Pryke, 2009). Contractual incompleteness is believed to be a significant factor leading to lack of construction process efficiency hence sub-standard quality. Though the levels of contractual incompleteness are not fully explored as yet, it is believed to impact on overall construction process efficiency (Walker and Pryke, 2008). Contractual incompleteness is typically defined:

> "as contracts that tend to specify every transaction dimension, but not necessarily all relevant information" or "by inability to describe certain events ex ante, even if those events and their implications are easily recognised ex post" (Walker and Pryke, 2009:1263;1271).

4.3.3 Weather conditions

The R21 project was executed mostly in the cold months of May and June. Low temperatures associated with May and June weather conditions have effects on asphalt paving and structural concrete placing. Specifications generally stipulate the temperature limits below or beyond which paving cannot continue (Grove and Brink, 2006). Cold weather affects compaction

because the mix may easily get out of the compaction temperature range; cold weather also affects aggregate coating; ease of placement and the general workability of the mix; asphalt rheology (deformation and flow characteristics) is affected. Also concrete that freezes during its early curing stages suffers permanent damage as water expands when it freezes. In spite of the specification limits, the work must be carried out. The extra effort needed to do quality work under such conditions tend to raise the costs.

4.3.4 Material Shortages

The 2010 FIFA World Cup saw the demand for asphalt and bitumen used on road construction increase, leading to acute shortages. The shortages have resulted in delays in completing the GFIP project and such delays have an effect on the project continuity, which has an effect on quality. Delays also result in additional costs through contractor contract extensions (extension of time). Salleh (2009) characterises such material shortages as creating instability of construction processes which causes discontinuities and "for this reason, local contractors are not able to maintain and develop permanent supervisory staff and skilled labour" (Salleh, 2009:12). Material shortages create skills gaps which have a direct impact to quality.

4.3.5 Traffic Accommodation

The traffic accommodation was not provided during the survey stage. Such deficiencies when no traffic accommodation was provided at survey stage means that noise levels from 'live' traffic was not reduced or controlled, yet some survey equipment gives good quality data on noise-free conditions; at the same time, the surveyors are not allowed to cross the median of the road during survey (Wiesner, 2008). Also, serious safety concerns for surveyors

producing benchmark surveys for use during the design stage were not adequately addressed.

The space restrictions added to the challenges posed by 'live' traffic on the route. SANRAL did not tolerate any reduction in the availability of existing lanes thus forcing the opening of emergency lanes to normal traffic and also reducing the widths of other lanes during construction. Traffic accommodation at some bridges required the use of a superbeam method (heavy steel beams used to support the deck while traffic was allowed to go through) to accommodate heavy volumes of traffic, especially at the R24 intersection that links to the OR Tambo airport. The staging method (where a carriageway is closed from traffic to allow construction and then opened when construction is complete) would have not worked considering the daily volumes of traffic and pedestrians requiring access to the airport.

4.3.6 Contractors working on the same site

Because various contractors working on a project have different objectives, having two or more contractors working on the same site (especially where the Gautrain crosses the R21) may create problems with site access and safe working surroundings. This can happen even if some activities performed by different contractors are different and can in theory run parallel, from the project management perspective. There is a great deal of collaboration and co-ordination that is required from all contractors involved. Tight deadlines and other constraints (penalties; early completion bonuses) can dictate the need for different contractors to work at the same site at the same time hence the strong need for the facilitation of a collaborative working environment. The adversarial relationships that inhibit coordination and stifle cooperation, believed to be in existence between parties to a construction project demands investigation.

The above mentioned factors indicate the specific concerns though these and other factors (See Appendix A for other factors contained in the questionnaire) related to construction projects in general and those that are particular to South Africa are all investigated. Given the complex contractual scenario described above, the adequacy or limitations in quality management, of the FIDIC contract conditions used in this project is investigated.

Figure 4.2 shows a summary overview of the R21 Project comprising three work packages namely G, H and J.

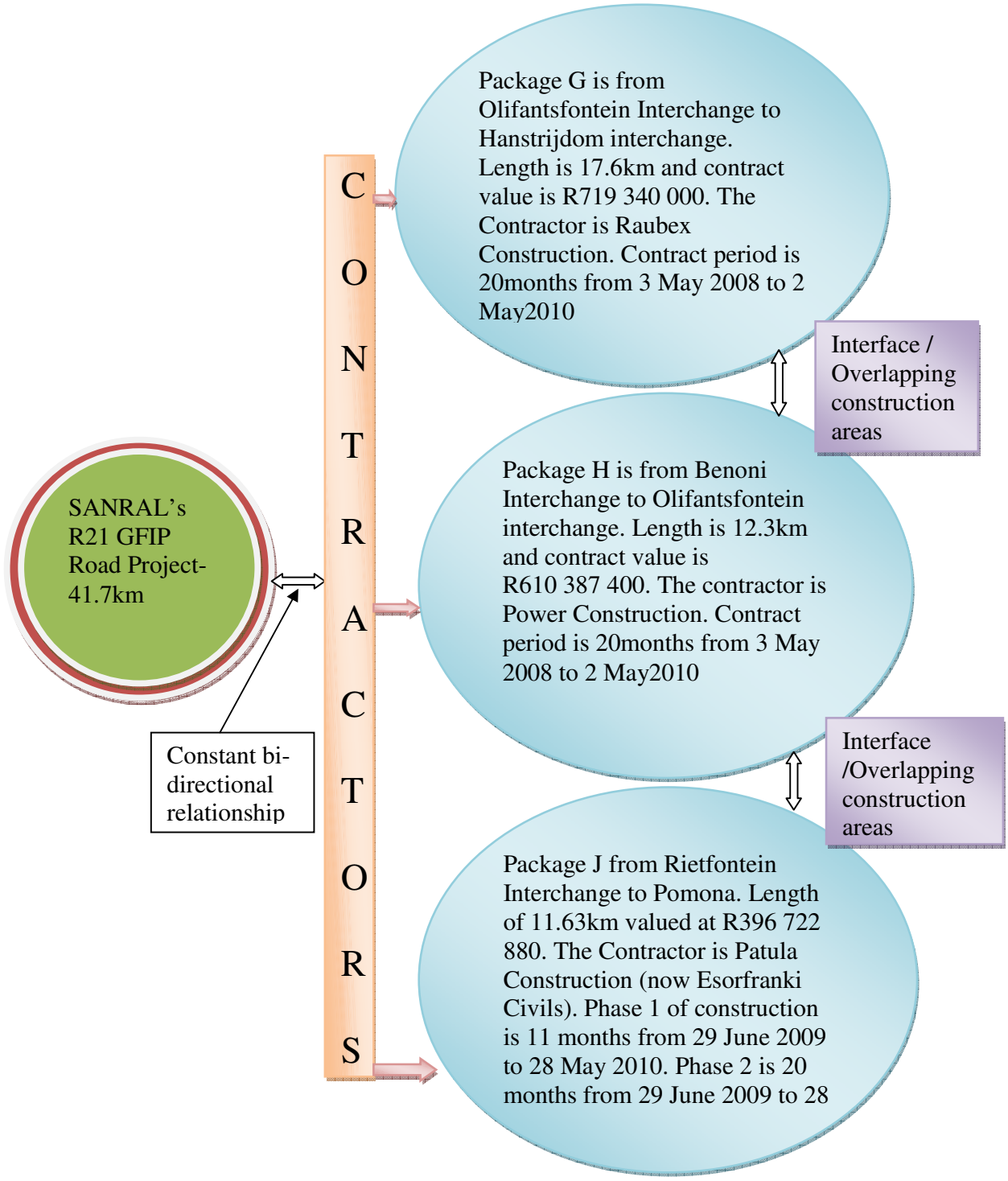


Figure 4.2 Summary overview of the R21 Project (*Source*: Author)

Chapter 5: Data and Results Analysis

5.1 Introduction

This research report investigates obstacles to quality management on South African infrastructure projects. The Route 21 (R21) project from National Route 1 (N1) to O.R Tambo International airport (ORTIA) was chosen as a case study for the investigation. Although there might be a large number of potential obstacles to quality management on infrastructure projects, those obstacles deemed to have the greatest impact to quality management have been investigated regardless of whether the obstacles emanate from the tools used during construction, techniques of construction or methodologies used during construction. Every attempt has been made during the investigation and analysis (using triangulation method) to remain objective as to how each inherent obstacle manifests as an obstacle to quality management. Triangulation data analysis method was chosen to analyse data obtained from the questionnaire survey, data made available by SANRAL (project documents, which are referred to as 'archive data' in this analysis) and data contained in the literature; to increase confidence in the results. The schematic representation of the data analysis process is shown in Figure 5.1. The raw questionnaire survey results are shown in Appendix B and analysis of the literature is contained in chapter 2. Table 5.2 lists the information that was obtained from SANRAL for the three work packages (G, H and J) of the R21 Project. The project archive data provides the third component of the triangulation process. The archive data qualifies some questionnaire responses. The summary of the archive data is explained in section 5.3.

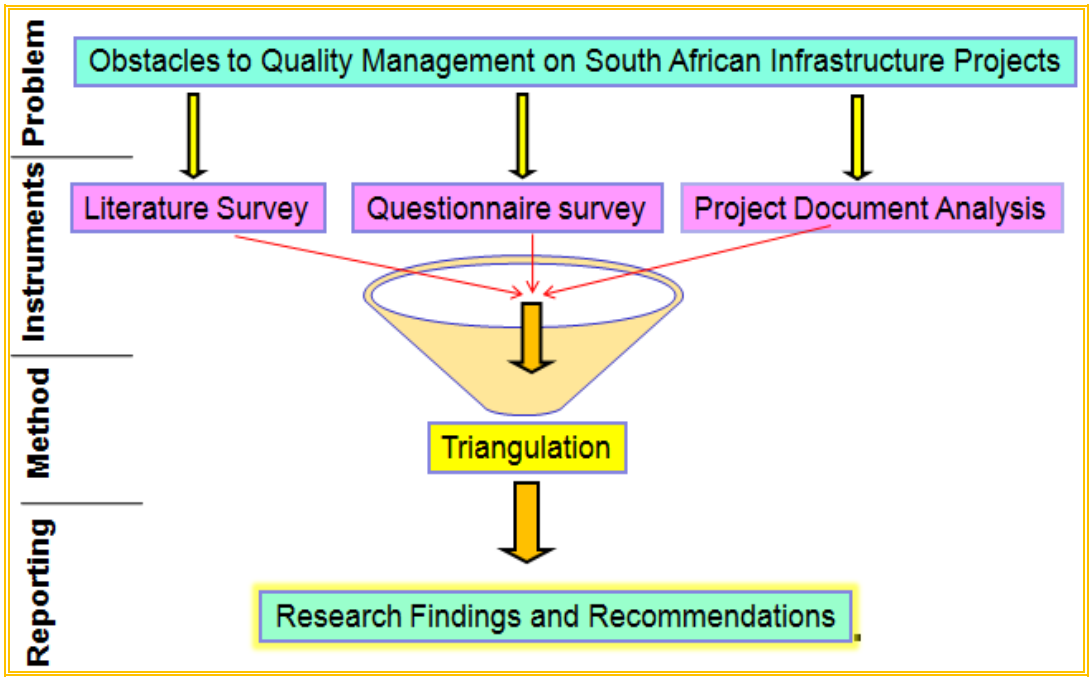


Figure 5.1 Schematic representation of Data Analysis (*Source*: Author)

Quality is one of the nine project management knowledge areas (Figure 5.2). Within each of the nine areas, changes in - client requirements; project management tools and skills levels; technological advancement (equipment and processes); project environment (change of government, potentially hampering clarity and predictability about future project funding) and business environment (business leaders and their commitment), have the potential to inhibit effective project delivery and quality management (Salleh, 2009).

Figure 5.2 also shows the 'triple constraint' at the core of project management, namely the competing goals of time, cost and quality which need to be satisfied within the confines of the defined quality expectations. The presence of the 'triple constraint' is an indication that there is no clear-cut answer on how to balance the three because the three constraints are not at all times equal in priority.

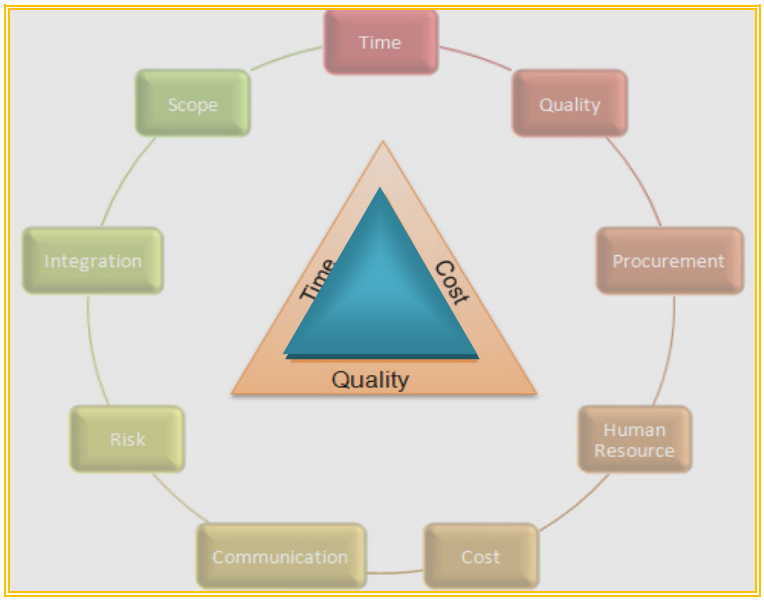


Figure 5.2: Project Management Knowledge Areas according to PMBOK (reproduced with modifications from Skeen, 2010).

If the key constraint is cost, then all efforts to change time (duration or end date of project) or scope to achieve better final quality become compromised. Some clients tie the final delivered product to the contract (project value agreed in the contract) even if it becomes apparent during the project lifetime that the scope needs to change, which has direct influence on the cost. The project scope is the one that expressly articulates and endows all the facets required to achieve certain defined quality levels of the final result. It is a clear understanding of the scope that allows a project manager to define the required skills. Time may become a constraint (immovable end date) as may quality. The 'triple constraint' is a fundamental tool for project management when effectively managed. However, the presence of the 'triple constraint' or knowing about it is not a direct prescription of the actual actions that are taken on a construction site in order to successfully deliver quality infrastructure projects.

The analysis below seeks to provide insight into factors that may be a profound impediment to quality management on infrastructure projects. For the three instruments (literature survey, questionnaire survey and project documentation) used to gather data objectively, the data from each instrument is synthesised, organised and analysed in a way that comprehensively captures the main tenets of the underlying obstacles. The organised data is explained to become accessible; purposeful; relevant; and meaningful information. The ready availability and accessibility of knowledge promotes sound experiences for the workforce which benefits the quality of work. The cyclic model representation is shown in Figure 5.3.



Figure 5.3: Cyclic construct Model of transforming data into information, knowledge and experience (*Source*: Author).

In Figure 5.3, knowledge becomes easily and effectively conveyed to all levels of the workforce to enable quick and relevant quality decisions. Knowledge existing in individuals as skills, personal capability and experience is also fostered to enhance quality performance. The knowledge that maps

well to the required quality levels is a precursor to the much needed experience. The gained experiences enable the workforce to carry out their work intelligently, responsively and efficiently in the face of the dynamic project environment.

5.2 Response rate to questionnaire

The research methodology, the measuring instrument and other collected data were discussed extensively in chapter 3. A total of 30 questionnaires were administered by hand to the contacted respondents who comprised three contractors' representatives, the client (SANRAL) and the design consultant (VelaVKE), in an attempt to elicit their feedback. The respondents included top management down to clerks of works. The number of the returned questionnaires is 13, representing a response rate of 43% (Figure 5.4). All the returned questionnaires were at least 80% complete which rendered the questionnaires usable. The response rate of 43% is above the normal rate of 20 – 30% for posted and hand delivered surveys (Okon *et al*, 2010) or unsolicited surveys (Vanier and Rahman, 2004) and therefore it is reasonable to conclude that a satisfactory and acceptable response rate was met in this study.

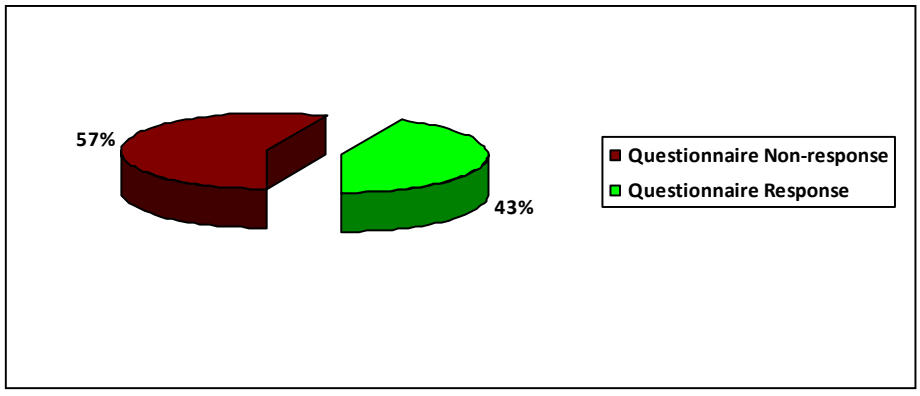


Figure 5.4: Percentage Participation by respondents (*Source*: Author).

This analysis assumes that the questionnaires were completed by one individual regardless of the possibility that two or more people might have collaborated to complete the questionnaire in an attempt to present a balanced response.

Table 5.1 further categorises the questionnaire respondents' designation and influence on the project. The project documents also confirm the information contained in Table 5.1 for all the three work packages (G, H and J) in so far as the seniority and project responsibility is concerned.

Table 5.1: Designation of Survey Respondents (*Source*: Author)

Classification of influence or authority	***Designation***	***Number of respondents***	***Percentage (%)***
Top Management	Project Manager (Employer's representative)	1	8
Top / Middle Management	Site Agent	5	38
Middle Management	Assistant Site Agent and Quantity surveyor	2	15
Middle Management	Resident Engineer	1	8
Middle Management	Materials Technician	2	15
Lower Management	Clerk	1	8
Others	Other (details not indicated on the questionnaire)	1	8
TOTAL		**13**	**100**

The possible reasons for not responding to the questionnaire could be any or all of the following:

i. Two of the three contracts (Work Packages G and H) had reached project completion so project personnel had moved off the sites and were occupied on other projects such that time was not available to them.
ii. When a project closes, organizations restructure and redeploy people in various capacities and roles, and this has the potential of making people fail to see the importance of completing the survey when no longer involved on the completed project.
iii. Non-response could be due to employee alienation or indifference to the organization's responsibilities, without care whether the organization improves or not; performs its mandate or not.
iv. The survey was conducted at a time when SANRAL's GFIP tolling fee proposal was a contested issue between Gauteng Provincial Government and SANRAL which might have resulted in potential respondents considering it as sensitive and becoming hesitant to respond to the questionnaire.
v. Other respondent characteristics such as difficulty in recalling information or difficulty in accessing the information needed to respond to the requirements of the questionnaire might affect responses.

5.3 Summary of data obtained from SANRAL

Table 5.2 summarises the project data obtained from SANRAL and the format in which it was made available so that its relevance can be ascertained for full resonance with the aim of this study. The information in Table 5.2 applies to the three work packages - G, H and J. The three work packages were managed and implemented under FIDIC conditions of contract as three

separate and distinct construction contracts between contractor and client, administered under different and unique conditions.

Table 5.2: Data obtained from SANRAL (*Source*: Author)

Requested Information	Form in which Information was supplied
1. **Project scope**	Tender documents
2. **Record of changes of construction process**	Minutes - as appendices
3. **Variation order certificates**	Minutes - as appendices
4. **Contract documentation**	Contract documents
5. **Record of contractual delays**	Minutes - as appendices
6. **Record of re-work**	Minutes – as appendices
7. **Project Progress minutes**	Minutes
8. **Work inspection records**	Recorded in the minutes

The different conditions include: (1) the scope of work; (2) the skills and technical capability available to each contractor (the quality and quantity of labour resources of each contractor team); (3) management approach adopted by each contractor; (4) site conditions and site access issues peculiar to each contractor; (5) contract complexity; and (6) duration of each work package. However, the design engineer for the three work packages is the same, with the design separated from construction. This introduces two sources of accountability to the client; the design consultant and the contractor. The questionnaire and literature survey have identified some possible obstacles to quality management. Similar obstacles are documented in the set of archive data made available by SANRAL. The obstacles identified by the three approaches are explored in detail in the ensuing

sections of this chapter to provide the context and mechanism by which they impede quality. Due to the integrative nature of the construction process, the identification of all quality problems may not be possible. Each contractor's level of effectiveness, efficiency, conformity, adoptability and performance in response the demands and conditions of each work package, determines the ability to address various quality obstacles as they arise.

5.4 Analysis of Results

The analysis is underpinned by the framework shown in the schematic representation of Figure 5.1 and the analysis further attempts to identify the degree to which contractors demonstrated their innovation and commitment to quality. Questions two (2) to nine (9) in the questionnaire survey were not necessarily ranked according their significance of impact or their influence in the manner in which they may present themselves as obstacles to quality management. Central to the analysis is to accord each obstacle similar attention within the context of the project. The complete aggregate of the questionnaire survey results is shown in Appendix B. The questionnaire survey results are analysed below concurrently with data from literature survey and project archive data.

5.4.1 Design

Complete, clear and flawless designs play a pivotal role to the successful delivery of a project and they immensely contribute to quality of the finished project. However, whilst flawless designs may be produced, they are almost impossible to produce in an infrastructure project context where the processes are highly integrative in nature. There are different forms and causes of design incompleteness of varying extent and gravity of their impact

on quality management initiatives. A contextual understanding, in this analysis, of an incomplete design is a design that does not fulfil the project scope (either as set out at the project onset or changed during project lifetime); falls short of achieving set quality standards; a design that causes rework; a design lacking relevance and not serving intended purpose; a design that causes scope changes because the design excludes (or omits) some critical information pertinent to the delivery of the project as a whole, to predetermined quality levels (question 2.1 of the questionnaire survey).

The completeness of a design or lack thereof, creates the confluence of the following factors, whether individually or combined:

1. Scope changes or “scope creep” (due to priority changes, funds availability, unrealistic expectations, unforeseen design omissions, to accommodate the work within available funds, value engineering, change in regulations and others). Scope changes (regardless of the cause) at a time when project implementation has gained momentum and enthusiasm impact negatively on quality.
2. Time constraints (including delays that can lead to inflation related cost increases) result in embarking on cost cutting procedures that impede the desired quality outcome. Subjecting the design engineer to unrealistic timeframes to conclude the design presents a serious time constraint that can result in the design engineer submitting incomplete designs.
3. Wrong interpretation and understanding of the scope of the bigger project requirements as well as the project’s subcomponents that form the building blocks that interrelate to create the complete project.
4. Complexity of the design work and experience at hand (lack of the incumbent skills). Designing of complex project elements require experienced and skilled personnel who can use their expertise to

capture and reflect a true understanding of the scope as required by the employer, in the design.

5. A design may reflect all the project priorities but when the design is overly optimistic or ambitious, it creates pressure that leads to compromising quality through shortcut procedures to meet the time deadlines.
6. Designs not finalised before award of the project. Completeness of a design means definitive and comprehensive plans that allow for: quality specifications that will be used to control quality to be known; identification of existing alternatives to construction by matching the design to the available plant and methods; and also the selection of the optimal solution. The drive to quickly complete construction work often leads to awarding of the project before designs are finalised, as can political pressure.
7. Paying insufficient design attention to smaller components of a bigger project (such as drainage requirements of the road, traffic accommodation, unforeseen sub-surface conditions)

Effects of incomplete design with specific regard to quality management are immense and cannot be overlooked. These include lack of meaningful cohesion and integration within the project team emanating from having a different understanding of different project elements or sub-elements which results in the emerging of negative working relationships. Negative working relationships among those charged with the mandate to successfully deliver a quality project are the origins of many quality problems and they breed substandard work because of the lack of efficiency due to lack of the much needed consensus on the leading-edge strategies to approach the project. Whilst it is used as a mechanism to provide checks and balances on the adequacy of the design, the separation of design and construction presents barriers to quality management. The FIDIC conditions of contract separate

design and construction and by so doing, it creates two sources of accountability (design engineer and contractor) to the employer. Each is tasked with a specific role on the project. The design engineer designs the project and the contractor constructs the physical project using the designs produced by the design engineer. The contractor's expertise is often not sought at the design stage. During construction, the contractor may raise constructability issues that require changes to the scope and such changes occur in an ad hoc manner such that their management is not in line with best practise in quality management.

An analysis of the questionnaire survey responses regarding five design questions asked (Figure 5.5) and an analysis of information contained in the documents obtained from SANRAL (Table 5.2) reveal some aspects of flawed or incomplete designs that impact on quality by inhibiting the optimum and efficient utilization of project resources. This leads to substandard work through lack of clarity and continuity on design aspects, wrong material quantities affecting continuity, wrong cash flow predictions resulting in unplanned work stoppage and restart. Incomplete designs also cause material wastage, rework and compromises safety, even if the contractor has a sound technological base from which to address quality shortcomings. Failure to finalize designs before the award of the contract is a design shortcoming that creates fundamental impediments to quality management efforts over the construction period of the project. This is because quality has to be planned and built into the design, using less work and resources than fixing or reworking a poor-quality final product. Thus the planning and building of quality in the design has synergistic effects on performance and quality management effort (Ahire and Dreyfus, 2000). Appendix VI for work package H, Appendix VII for work package G and Appendix V for work package J list the designs issued in line with design changes done during construction as a result of changes to approved processes, which reflect the incompleteness of

the design. The responses to question 2.2 of the questionnaire survey (Figure 5.5) attest to that. 54% of the respondents answered *"yes"* to the question while 8% answered *"no opinion"* and 38% answered *"no"*.

In view of the number of changes to the approved construction process, the questionnaire responses to question 2.2 are in accord with project archive data. The 'Contract Expenditure' appendices for all the work packages had no provision for use of 'Special Materials' in the original tender details (Appendix XI for package J; Appendix I for package G and Appendix XI for package H). Work package H did not utilize special materials in the final measured work, but package G and J did. The special materials force the introduction of a change to the conventional or standard construction techniques and procedures. The negative effect of change from known construction methods to less familiar methods is that there is less employee confidence, less knowledge and confidence in handling both machinery and materials and this negatively impact on quality. Proper planning of the design for construction using special materials, because of time constraints, gets done with the design consultant having the idea of shifting the risk to the contractor or adding contingencies as buffers to cost, time and quality performance. A poorly planned design too leads to poor quality of construction because there is no optimization of resources. The planning of quality of the expected delivered project in the early stages of concept and design phases (Figure 2.4; PMBoK, 2000) present the core of professional quality management where few resources have been used in those phases and the opportunity for constructive change is high at low cost (Duncan, 2000). Quality should not only be expected at the tail end of the project, but must be built into the design (quality function development) at the initial stages in tandem with the construction method to be used. Item 24.36 of package H clearly express the disappointment and frustration of the contractor after asphalt on the south bound carriageway failed prematurely, indicating that the quality of work done

was substandard. Whilst the choice of technology is influenced by labour availability, available information and other factors, it is also influenced by the response of the supply chain to the material requirements.

The ease with which the quality performance levels specified in the design can be achieved, with minimal variations, illustrates the completeness of the design in a structured and easy to follow manner. A huge number of variations signal the need for intervention through crafting of isolated solutions developed and packaged for implementation to remedy evident quality problems or to rework the design to make it constructible. The three work packages have 65 issued variation orders as contained in the minutes (23 for package G; 25 for package H and 17 for package J), all necessitated by the quest to bring quality back on track through design changes (enhancements or corrections to the design after initial specifications have been approved) and other unforeseen site conditions. This is also corroborated by 69% of respondents who answered *"yes"* to question 2.4 (Figure 5.5), while 8% answered *"no opinion"* and 23% answered *"no"*. Changing a design during construction usually means going back a few steps to ensure that the changes are formalised (captured and documented) to ensure that the implementation adheres to the framework of the new specifications.

Despite the conscious effort to produce a design that is accurate, complete and meets all the set quality standards, circumstances arise that can lead to design omissions or specification errors: unintentional design deficiencies found in a design that will compromise the project quality performance if uncorrected. They are unintentional if it is considered that the design consultant is not negligent. Their existence in a design puts the quality and integrity of the whole design into jeopardy. Questions 2.1 and 2.3 of the questionnaire survey were aimed at probing such design omissions and

specification defects in a design. The effect of omissions and specification errors on a project has far reaching consequences on quality management, which include impacting on the project's critical path, leading to 'quick fixes' that compromise quality. This may affect the motivation of the project team resulting in the team losing focus of the main goal and if not corrected, the end result is that desired performance levels will not be met leading to operation and maintenance costs soaring. These costs are more noticeable to the client than what goes into the various components of the final project because the client's main interest lies more in the final delivered project that will undergo natural continual evaluation for effective performance as it is used for the purpose. Both questions 2.1 and 2.3 received similar response where 15% answered *"yes"* that there were design omissions and specification defects in the design. However, 31% answered *"no opinion"* while the majority of 54% answered *"no"*. The 15% of respondents who answered *"yes"* does not necessarily suggest that the effect of design omissions and specification defects on quality management was minimal in impacting on quality. Since it is the objective of the project team on each project, to meet the predetermined quality specifications, such an objective might have been impacted upon by design omissions and specification defects witnessed in the design.

Item 24.18 for package G describes the construction of a cut-off beam and drain without the contour plan in place. The unavailability of such information is a reflection of lack of attention being given to the work at hand resulting in the contractor having to proceed with work without adequate design and thus compromising quality. This finding correlates well with the questionnaire responses given to question 2.5, an open-ended question which required identifying 'any other design issues that negatively affected quality of the project'. The respondents expressed that other design factors that might hamper effective quality management include (Appendix B):

i. Drainage designs were not done and the contractor had to carry out designs as work progressed.
ii. Construction of some work began and proceeded without designs. Designs were issued for construction and delivered to site late when construction had already begun without designs, causing lower quality.
iii. Some design decisions caused construction drawings to be delayed in delivery to site, compromising progress.

Section 5.3, describes the archive data, which shows that the contractor was solely responsible for construction, using designs produced by the consultant charged with the responsibility to carry out designs. Responses to question 2.5 augment the archive data whereby the contractor had to wait for designs to be delivered (late) to site for construction, an indication that the design aspect was not the responsibility of the contractor. The contractor is expected to take a leading role in upholding the quality standards set in the design, during construction. Because time was of essence and designs from the consultant were being delivered late for construction, some contractors proceeded with work without designs while other contractors carried out design work so that construction was not forced to stop. Having a client allowing a contractor to carry out design work as construction progresses on a project that is not design-build (DB) might indicate that the contractor is allowed to set the quality standards for the client instead of the consultant. In other words, the contractor may produce a design according to the contractor's understanding of the scope and not the client's requirements or the contractor may produce a limited design in line with the technical or financial capacity of the contractor. Whilst it is a demonstration by the contractor of technical effectiveness, efficiency, adaptation and the propensity to act innovatively, it can be considered as a survival tactic. Also, this delivery method points to the client divesting responsibility for the project away from

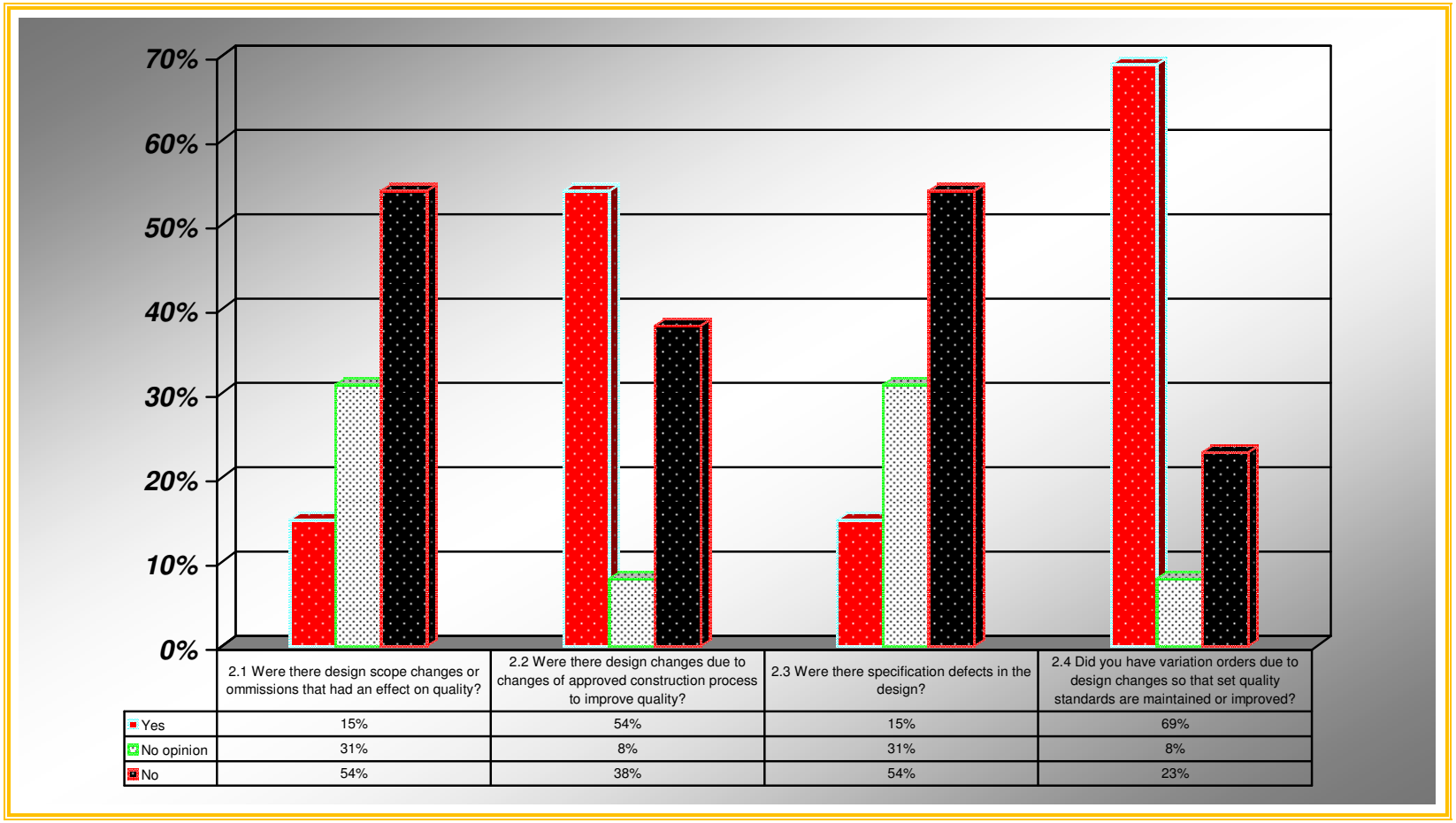
the consultant[1]. In this way, the client exposes itself to project cost overruns (because the contractor will claim for design work) and huge variation orders (VO's) or change orders as witnessed in this project. From a quality standpoint, it is paramount to ensure that the design consultant fulfils the obligation of properly finalising a design that has all the quality aspects built in the design, describing unambiguously, the final deliverable product in enough detail that a contractor can produce it to its quality specifications in entirety.

The objective of question 2 (questions 2.1 to 2.5) of the questionnaire survey was to investigate the completeness of the R21 project design, from different dimensions, to determine if the problems confronting quality management during the construction process are imbedded in the incompleteness of the design.

Literature has indicated that a complete design is critical for effective quality management through, among others:

1. Allowing a clear, comprehensive and complete site briefing
2. Having all the quality aspects built in the design
3. Allowing a smooth and unambiguous processes during construction
4. Having smooth integration of the design into the construction process(es)
5. Minimising scope changes and variations which result in out of sequence operations
6. Eliminating cost overruns, no rework and project finishing on time.
7. Promoting safety (Rwelamila *et al.,* 1999; Love *et al.,* 2010; Duncan, 2000; Smallwood and Haupt, 2005).

[1] Under such circumstances, the responsibilities become blurred. Legal and ethical issues are likely to arise should there be early or premature project failure.



	2.1 Were there design scope changes or ommissions that had an effect on quality?	2.2 Were there design changes due to changes of approved construction process to improve quality?	2.3 Were there specification defects in the design?	2.4 Did you have variation orders due to design changes so that set quality standards are maintained or improved?
Yes	15%	54%	15%	69%
No opinion	31%	8%	31%	8%
No	54%	38%	54%	23%

Figure 5.5: Respondent views on design questions

The literature also indicates that quality management problems during project delivery (construction phase) are a manifestation of shortcomings in the up-stream phases of project development (such as design) leading up to construction, (Knights and McCabe, 1999; Love *et al*., 2010). The findings from question 2 (questions 2.1 to 2.5) of the questionnaire indicate that the R21 project suffered incomplete designs and this lack of completeness in the up-stream phase compromised quality management efforts during construction, through scope changes and design changes emanating from change of construction process that had the effect of disrupting the construction program and generating a large number of variations.

The issuing of many addenda during construction to clarify matters is an attempt to complete an incomplete design. The incomplete designs were also confirmed by the data from SANARAL (project archive information).
The questionnaire sought to determine what other factors contributed to loss of quality and literature indicates that the blame of failing to institute effective quality management on an infrastructure project cannot be entirely squared on design or its principal consultant, but should be seen as an implementation problem (Knights and McCabe, 1999). This suggests that even though a design is complete and procedural (a clear design with all its diverse detail and an orderly progression of processes for action), it may seriously overstate the capacity of the contractor to control and manage quality. It is not always the case that what a complete design seeks to propagate, a final delivered project performing to predetermined quality specifications, will be realised all the time.

5.4.2 Inclement weather

Inclement weather belongs to the category of *force majeure* events in FIDIC contract, which also includes earthquakes and other natural disasters. Inclement weather can significantly affect quality on a construction project if it strikes during project delivery, by way of inhibiting contractual parties from fulfilling their obligations because such events are unforeseeable, unexpected, difficult to avoid or control and are external in nature. Inclement weather results in work stoppage (causing delays) and disruption of work activities[2], leading to the need for extension of time and also often resulting in change to site working conditions when work resumes. It may impact on quality of material stored on site, may affect machinery and other equipment and can cause damage to work partially complete, all resulting in adverse impact to project quality, over and above contract delays and additional costs.

The project documents (archive data) indicate that the R21 project suffered quality impediments resulting from inclement weather. Item 19.9 in the minutes and appendix XII for work package J; item 24.63 and appendix XII for work package G and item 24.56 and appendix XII for work package H indicate the effects of inclement weather on each of the three work packages. Adverse weather conditions affected efficiency, continuity of work and disrupted the consistency needed to maintain required quality levels as dictated by the design. Inclement weather impinges on quality through its effects on workmanship, which is affected when weather conditions cause worker discomfort either through heavy clothing during rainy and cold periods or when muscle flexibility and movement is affected by cold or rainy weather conditions. This situation also presents unsafe working conditions. The quality

[2] By definition, critical path activities will always be taking place in road construction and almost every work activity is affected by inclement weather. The FIDIC conditions of contract distinguish between average / normal and exceptional climatic conditions in the area. The contractor bears the risk of the average or normal conditions and is expected to plan and price for their effects accordingly.

of the material (especially for road construction) can be affected through increased chances of contamination under inclement weather conditions, leading to deterioration of the quality of the material.

Great supervision competency is required to be able to control the work processes under inclement weather conditions to ensure that quality is not compromised. Proper preparedness and the correct competency levels might keep the quality on track, but it is not always the case, as can be seen from the questionnaire survey where most respondents (question 3.2, an open ended question which enquired 'how did you intervene to ensure that such conditions have minimum effects on quality of the work') indicated that they did nothing; waited for bad weather to go past and rectified problems.

Two questions were asked (question 3.1 and 3.2) in the questionnaire survey about the effect of inclement weather on quality of the R21 project. The responses to question 3.1 are reflected in Figure 5.6 and responses to question 3.2 are documented in Appendix B, but also discussed in detail below. The results of question 3.1 (Figure 5.6) reflect that the quality of the workmanship was susceptible to inclement weather. The impact on quality is evident, though the severity of the impact cannot exactly be quantified in measurable terms. 47% answered *"yes"*; 15% answered *"no opinion"* and 38% answered *"no"*.

The intervention methods identified by the respondents in question 3.2 to ensure that force-majeure events do not affect quality are:

i. Do nothing and just compensate the contractor for time lost.
ii. Wait for the adverse conditions to pass and rectify the problems caused.
iii. Re-programme the work and obtain additional supplies.
iv. On cold days, cover up concrete and stabilised layer with plastic sheet to prevent freezing.

v. Work longer hours.

vi. Change curing methods and work program.

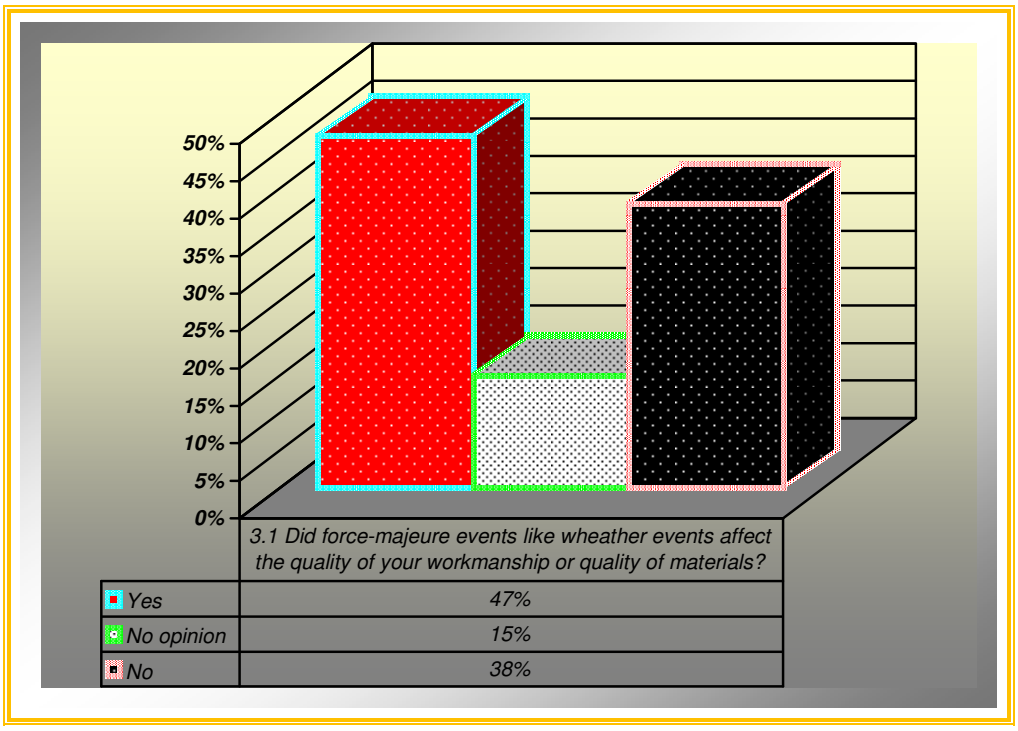


Figure 5.6: Respondent views on inclement weather

An in-depth analysis of the respondents' intervention measures listed above reflects general lack of pro-activeness and preparedness to be responsive and mitigate the impact of inclement weather. The evident lack of a clear and well articulated response strategy or plan in place, to deal with an obstacle that can hamper quality management efforts may lead to instituting impromptu, uncoordinated and generally inadequate mechanisms to address the effects of the obstacle to quality. The literature survey, questionnaire survey and project archive data confirm the disturbing finding that the lack of adequate response to inclement weather impairs quality. Contractors need to have a clear response mechanism in place to avoid exacerbating the situation.

5.4.3 Contract Documentation and Contractual Decisions

Contract documentation presents an attempt to provide the overarching role of creating the framework from which:

1. The contract is managed throughout the implementation (construction period) of the project;
2. The predetermined levels of quality are set (in the scope and specification), enforced and achieved;
3. The client defines and fulfils his duties, responsibilities, obligations and rights to the contractor as per the provisions of the contract documents, and vice-versa;
4. Opportunistic hazards are mitigated whilst benefits are optimised;
5. The legally enforceable, express agreements and regulatory frameworks are drawn (Grossman and Hart, 1986; Turner and Simister, 2001; Walker and Pryke, 2008).

Therefore, the completeness of the contract documents is pivotal because it creates the confines within which critical project decisions are made. It creates the platform for efficient and timeous exchange of both design and management information in an endeavour to ensure that a quality project that meets all the performance levels is delivered efficiently. Incomplete contract documents are defined as incomplete in the sense that they are finalised on incomplete information (Grossman and Hart, 1986). Contractual arrangements finalised on incomplete information present a credible threat to efficient enforcement of obligations of one party by the other, resulting in opportunistic behaviour and manipulation by parties to the contract, by taking advantage of some silent, unobservable features of the contract at the beginning of the project or unclear statements that may hinder contractor performance.

The completeness of contract documents is a function of complete designs which communicate design intent before site work commences (Walker and Pryke, 2008). The three work packages of R21 project were issued with revised drawings and site instructions as site work progressed (444 for work package G; 392 for work package H; and 261 for work package J). The issuance of site instructions as site work progresses is reminiscent of indentified shortcomings that need correction in the contract documents. Such inadequacies need correction so that quality remains on track and in the rectification process (through site instructions, revised drawings, etc) ambiguities and complexities related to the understanding and working with new instructions can be created. Such ambiguities and complexities have an effect on the quality of work and they would require measures and methods not provided for in the contract for their correction. The predominance of site instructions is a result of the incompleteness of the contract document (Ndihokubwayo and Haupt, 2009).

Road construction is a stepwise process where the next stage of construction cannot proceed if the prior stage is not certified complete to the satisfaction of the team or individual responsible for approving and certifying completeness of each construction stage. The task of approving construction work for completeness is a procedural task during construction. Failure to undertake a procedural task is a practice that contributes to an omission (Simpeh *et al*., 2011). Such omissions manifest in the form of understaffing and inexperience (Simpeh *et al*., 2011), such that concluding contract documents based on understaffed and inexperienced personnel renders contract documents incomplete in so as the expected construction efficiency, due diligence and effective communication is concerned. Past experience and working history play a major in determining the degree of contractual completeness (Walker and Pryke, 2008).

Question 4 (questions 4.1 to 4.5) of the questionnaire survey sought to determine the completeness of the contract documents; complexity and ambiguity of contract documents; and the impact on quality of the decisions taken based on the dictates of the contract documents.

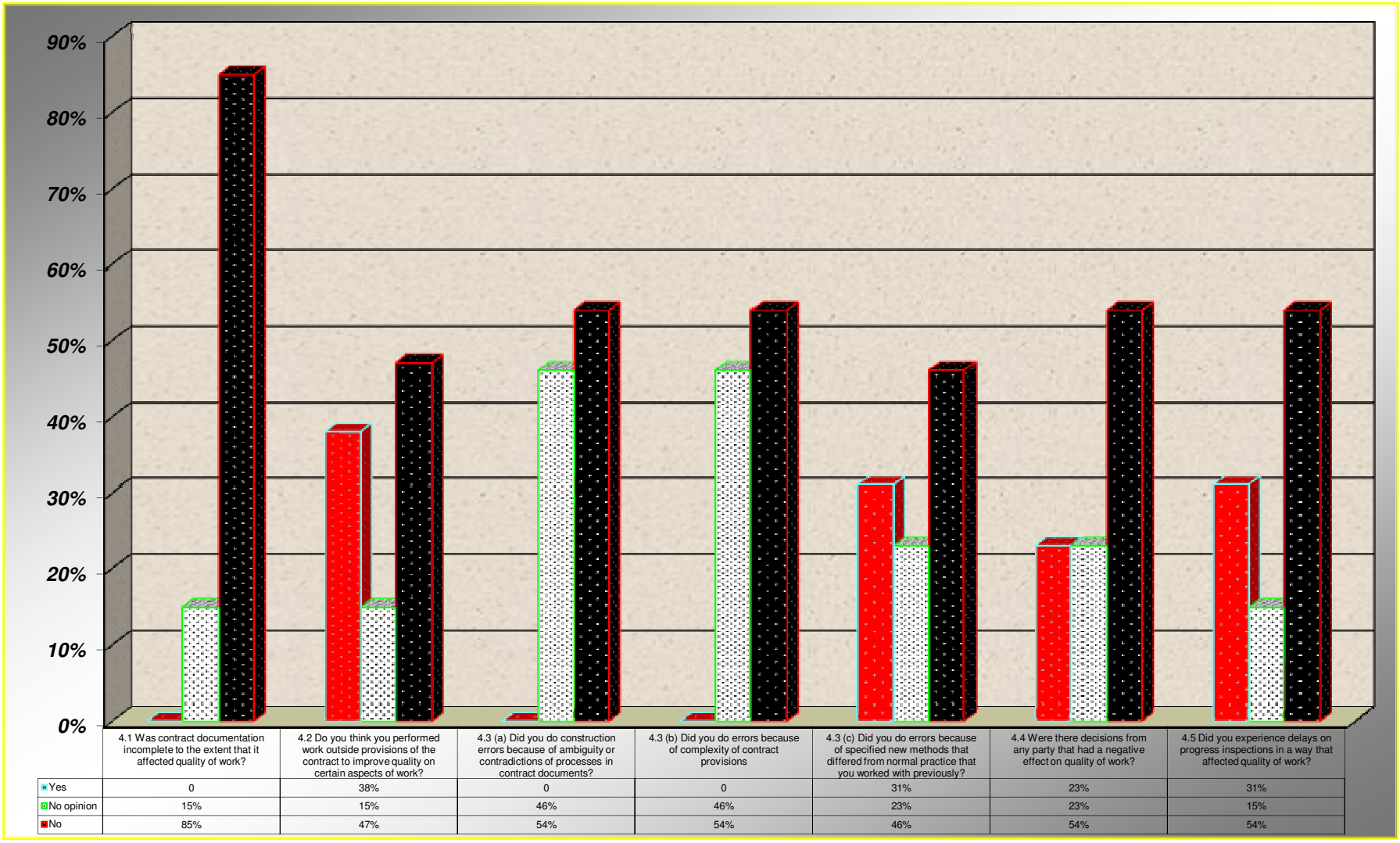
Figure 5.7 exhibits the responses to question 4 and the provenance of incomplete contract documents is apparent from the graph. As has been seen and explained in question 2.2 on how change in construction method resulted in change in design, responses to question 4.3 (c) illustrate a similar phenomenon where 31% of respondents answered *"yes"* that construction errors occurred 'because of specified new methods of construction that differed from normal practice that you worked with previously'. Material shortages resulted in specifications of new material different from the one specified in the original design and this necessitate the change in the construction method. Table 5.1 which shows the designation of survey respondents indicates that the respondents were all key project members. One of the disturbing findings from question 4 (question 4.1 to 4.5) responses is that some key project members had *"no opinion"* to the answers of all the questions.

It is a reasonable expectation that such key members would know whether contract documentation is complete or not, through their constant acquaintance with such contract documentation, but 15% had *"no opinion"*, in question 4.1. The *"no opinion"* answer, also, might be an indication that the completeness of contract documents is not so easy to define. Walker and Pryke, (2009) view incomplete documentation as a root cause for construction process inefficiencies.

Earlier, in question 2.5, it was noted that the contractor, whose duty was only to construct works based on a design produced by a design consultant,

carried out designs so that work could proceed. Although this could be argued as best practise meant to benefit the quality of the project, this is an example of work 'performed outside provisions of the contract to improve quality on certain aspects of work', to which 38% of the respondents answered *"yes"* in question 4.2. Besides the noble cause of wanting to uphold the quality standard of the project, other motivating factors might be at play in wanting to do work outside the confines of contract documentation.
Such other motivations may include identifying contractual deficiencies and making use of them to maximise profits, such as through claims for incomplete definition of scope or lack of mutual understanding of scope. In itself, performing work outside the provisions of the contract is a characteristic consistent with deficiencies in the contract documentation.

Alarming from the responses to question 4.3 (a) and 4.3 (b) is the 46% of the respondents who had *"no opinion"* if 'construction errors occurred because of ambiguity or contradictions of processes outlined in the contract documents' or if 'errors occurred because of contract provisions'. As key project team members, the respondents should be expected to make a clear call between *"yes"* or *"no"*, on the demands of the contract provisions, whether they were ambiguous, they contradicted each other, or they were complex in a way that caused construction errors. A large number of respondents having *"no opinion"* to the two questions can only suggest their lack of a full, holistic understanding of the contract documents. At the same time, a large number of the responses suggest shortcomings in the effectiveness of communication and training of project personnel such that ineffectiveness resulted through everyone involved not fully understanding the requirements of contract document provisions. Only 54% of the respondents were sure to answer *"no"*.



	4.1 Was contract documentation incomplete to the extent that it affected quality of work?	4.2 Do you think you performed work outside provisions of the contract to improve quality on certain aspects of work?	4.3 (a) Did you do construction errors because of ambiguity or contradictions of processes in contract documents?	4.3 (b) Did you do errors because of complexity of contract provisions	4.3 (c) Did you do errors because of specified new methods that differed from normal practice that you worked with previously?	4.4 Were there decisions from any party that had a negative effect on quality of work?	4.5 Did you experience delays on progress inspections in a way that affected quality of work?
Yes	0	38%	0	0	31%	23%	31%
No opinion	15%	15%	46%	46%	23%	23%	15%
No	85%	47%	54%	54%	46%	54%	54%

Figure 5.7: Respondent views on contract documentation and contract decisions.

Contract documents provide a formal framework structure, through which exhaustive instructions and decisions relating to the project are issued to one by the other; either by the client, the design consultant or the contractor, essentially, by any of the contracting parties with a vested interest in the successful completion of the project (Ndihokubwayo and Haupt, 2008; Walker and Pryke, 2008). It is important for a project of this nature to make a distinction between good and bad decision, good decisions being those that result in actions that produce positive quality outcomes. Such decisions were conveyed to contractors through site instructions, according to the archive data available. It was observed in question 2.5 that late decisions about finalisation of design aspects negatively impacted on quality. Some of the penalties (appendix X B for work package H and J; appendix XI B for work package G) indicated in the archive data from SANRAL are a reflection of bad project decisions taken, decisions that impacted detrimentally on quality. 23% of questionnaire responses to question 4.4 concur with archive data that there were some decisions taken that had a negative effect on quality of the work.

The highway construction process is a staged process where one stage may not commence before the earlier stage is certified complete. For example, road surfacing may not start before all the layer works (base, sub-base, and sub-grade) are certified. Delays in conducting project inspections (or progress inspections) and approving completion or recommending identified rectifications on a construction stage that has a bearing on the continuity of work activities, halts construction and result in delays to complete the whole project. The effect of the consequences of such delay is the creation of critical work backlog and this translates to pressure to catch up lost time. The mechanism by which delays in conducting progress inspections impact quality is cumulative in nature, by way of:

a. loss of work continuity;

b. pressure to recover lost time through accelerated work rate, with contractors applying for permission to work on Saturdays, night shifts and public holidays (item 24.43 for work package G; item 19.14, 19.15 and 19.17 for package J; item 24.62 on work package H);
c. the frequent effect of increasing project delivery costs resulting from inefficiency costs, through costs of securing plant and material that could have been used on the next stage of construction, claims by the contractor if such a delaying event is not caused by the contractor.

Delays in approving certain aspects of work are well documented in the project archive data (for example, items 19.57 and 19.67 for work package J; 24.18 for work package G; item 24.42 for work package H) and the above effects are all evident in the documents. Also, 31% of the survey respondents to question 4.5 answered *"yes"* that they experienced delays in progress inspections resulting in quality of the work being affected.

The insight gained out of this particular question (question 4) reflects that while a complete contract has a fundamental role in communicating the project intent and controlling and directing a project to a predetermined and desired quality outcome, (a) a complete contract is difficult to define holistically, (b) a complete contract is not a panacea to all potential quality problems likely to arise during construction, (c) a complete contract cannot identify unknown site conditions peculiar to each project , (d) parties responsible for project construction need to understand the contract documentation to fulfil the contractual purpose, otherwise however complete the contract documents might be, if not understood by the responsible parties, it will give rise to quality problems.

5.4.4 Traffic accommodation and Health and Safety

A major freeway improvement project has a potential of negatively impacting on travellers by disrupting their established travel patterns and may also affect economic activities linked to the particular freeway under improvement, and adjoining areas. A comprehensive, consistent and effective traffic accommodation method on a road construction site is aimed at minimising incidences that disrupt or hamper the smooth flow of traffic, which in turn may disrupt progression of construction work. In addition, comprehensive traffic accommodation method promotes maximisation of road safety practices at and around the construction area, by restricting traffic to appropriate and safe routes – all in an endeavour to create safe working environment because the work environment affects the mental acuity of workers (European Transport Safety Council, 2011; Hinze, 1997 cited in Smallwood, 2002).

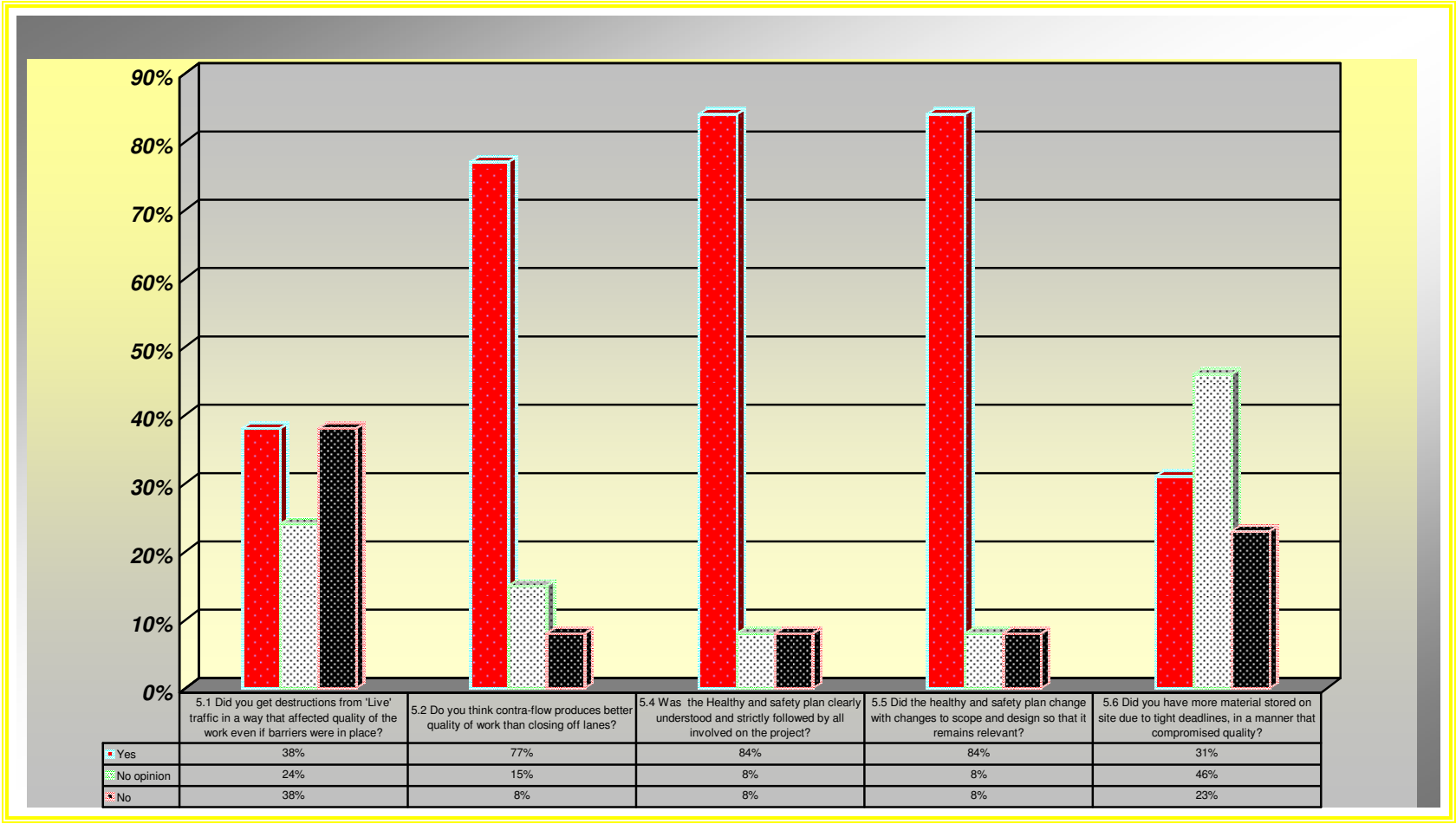
Five questions (5.1 to 5.5) in the questionnaire survey sought to investigate whether the traffic accommodation method and health and safety plan used during construction had any undesirable effect on quality management initiatives. The responded views are reflected in Figure 5.8.

The frequent occurrence of accidents on a construction site might be a reflection of a number of issues, some of which are: poorly managed traffic accommodation plan; impatient motorists ('live' traffic) failing to observe the speed limit in the construction zone; and construction employee fatigue leading to lapses in abiding by the safety plan. Also, the occurrences of accidents on a construction site culminate in unsafe working conditions to those working on the project. Accidents also result in indirect project costs through reduced productivity, clean-up costs, replacement costs, delay costs, rescheduling costs and wages paid while the injured is idle (Hinze, 1994 cited in Smallwood and Haupt, 2005).

A safe working environment promotes quality work since employees are confident and their attention is directed at the work that needs to be done and not worrying about injuries or possible death. Apart from delays, accidents destroy the work momentum and disrupt work continuity thus affecting quality. Predominant aspects that are negatively affected by inadequate health and safety are productivity and quality (Smallwood and Haupt, 2005).

Unsafe working conditions create the potential of affecting the morale of productive employees leading them to commit less effort, causing more quality concerns. Thirty eight (38%) percent of the survey respondents (question 5.1) were distracted by 'live' traffic in manner that affected quality of their work.

The distractions to workers can happen in the form of accidents in the construction zone whereby the vehicle(s) involved in an accident enter the barricaded work zones and endanger the lives of the workers; aggressive driving in the construction zone; verbal abuse from enraged motorists; and the general noise generated by passing vehicles as well as construction machinery. Disturbing from the questionnaire responses to question 5.1 is the 28% of respondents who had *"no opinion"* on whether 'live' traffic impacted on their quality of work or not. It is expected that such respondents (Table 5.1), entrusted to deliver the project, should have intimate knowledge of how 'live' traffic impacts on their quality of work. A detailed account of the accidents that occurred in the construction zone is recorded in the archive documents and they are briefly summarised in the following paragraph.



	5.1 Did you get destructions from 'Live' traffic in a way that affected quality of the work even if barriers were in place?	5.2 Do you think contra-flow produces better quality of work than closing off lanes?	5.4 Was the Healthy and safety plan clearly understood and strictly followed by all involved on the project?	5.5 Did the healthy and safety plan change with changes to scope and design so that it remains relevant?	5.6 Did you have more material stored on site due to tight deadlines, in a manner that compromised quality?
Yes	38%	77%	84%	84%	31%
No opinion	24%	15%	8%	8%	46%
No	38%	8%	8%	8%	23%

Figure 5.8: Respondent views on traffic accommodation and health and safety.

Item 24.14 of package G shows a record of two hundred and sixty five (265) accidents to date and six (6) are construction related (also shown in Appendix II). Item 19.31of package J shows a record of 394 accidents of which 15 were construction related and Appendix I shows 30 more accidents to bring the total to 494. Out of the 30 accidents, five were construction related. Package H recorded 328 accidents to date, (Appendix 1 of work package H minutes). Because road construction takes place adjacent to an existing roadway, it is difficult to completely cordon off the site (using permanent safety fixtures) from foreign intrusion causing disruptions to operations that have a significant bearing to quality of the finished work. Accidents within the construction zone form part of the unwanted foreign intrusion in the barricaded construction site because of their causing of disruptions to construction work. The nature of disruptions is such that they are unanticipated. As such, the workforce is caught unprepared to mitigate the effects of disruptions before they interrupt work continuity and cause quality problems.

The selection of a particular traffic accommodation method is guided by certain fundamental project requirements such as: minimising the occurrence of accidents; producing good quality work; enabling the selected construction method to be used without difficulties, complications and delays; and other envisioned benefits and considerations such as time of work and traffic volumes. Question 5.3 (open ended) enquired about the method of traffic accommodation used to control traffic in the construction zone (for example, contra-flow or closing of lanes to be worked on while adjacent lanes are open to traffic), while question 5.2 sought project participants' opinion on whether contra-flow facilitates better quality work than other methods. An analysis of the project participants' response to question 5.3 shows that, while other traffic management methods (short term lane closures during the night working times and lane constriction or shifting) were used (Table 5.3), contra flow method was predominantly used.

Table 5.3: Questionnaire responses to question 5.3 (*Source*: Author)

Traffic accommodation method	*Frequency*
Contra Flow	*9*
Intermittent Lane Closure	*5*
Lane Constriction (shifting)	*2*

The extensive use of the contra flow method is in tandem with 77% of the respondents' claim in response to question 5.2 that contra flow method produced better quality work than other methods. However, 8% of the respondents answered *"no"* to question 5.2 and 15% answered *"no opinion"*. The 15% who answered *"no opinion"* might be an expression of substantial gaps in communication (and possibly coordination), among project members, of critical project information that have significant implications to quality management[3]. Communication of key project information helps to augment the quality management efforts by clarifying issues timeously and also by taking necessary corrective action immediately.

Quality management on a construction project is primarily concerned with conformance to the demands of the finalised design and adhering to the design decisions, by making effective use of such tools as the health and safety plan. In order to fulfil that, the health and safety plan utilised throughout the construction process must also be influenced considerably by decisions that are made during the design process, so that it becomes effective in preventing quality problems. Workers play an integral role in ensuring that the health and safety plan achieves its goal of guiding construction quality to the required levels by minimising occurrence of accidents and other incidences that can impact on quality. The workers can play a leading role by:

[3] *"No opinion"* could also be interpreted as an acknowledgement that different methods are best in different situations.

a. Clearly understanding what the health and safety plan is communicating and being able to follow every step of it with due diligence;
b. Ensuring that whenever there are scope changes, the health and safety plan's needs are incorporated in the changes or the safety plan is modified so that the plan remains relevant at all times;
c. Accessing frequent education and training about safe work practices, during construction.

Workers need to be able to leverage the provisions of the health and safety plan in order to maximise quality output and performance, not only during the construction process, but well after the construction process is completed because health and safety of a facility such as a road must remain a living feature throughout the useful life of the road.

The questionnaire responses to questions 5.4 and 5.5 (Figure 5.8) where 84% of respondents answered *"yes"* to both questions suggest that the project participants clearly understood and followed the dictates of the health and safety plan to realise improved quality of construction. Also, the health and safety plan changed in line with changes to the scope so that the plan remained relevant, suggesting that the quality objectives were built into the project from the onset and not inserted in the project as an after-thought. However, the responses to question 5.4 and 5.5 do not show a positive correlation with the recorded amount of accidents that occurred within the construction zone (discussed above and also shown in Table 5.4).

In the United Kingdom (UK), 912 construction accidents occurred over a 12 year period from April 1997 to March 2009 (Construction Intelligence Report, 2010). 8% of the accidents were related to road building or repair. This gives a total of 73 road building or repair accidents over a 12 year period. In Austria, about 120 accidents occur at road construction zones in a year

(European Transport Safety Council, 2011). A total of 1 087 accidents recorded over a 3-year period on a single programme does not compare favourably with such international statistics. Such high accident rate may translate into fatalities, which are unfavourably high for South Africa (Smallwood and Haupt, 2005).

Table 5.4: Summary of recorded accidents (*Source*: Compiled from project data)

Work Package	***Recorded Accidents***
G	*265*
J	*494*
H	*328*
Total	***1087***

In the context of quality management, the occurrence of such a high number of recorded accidents suggests suppressed reality on the feedback from questionnaire respondents to questions 5.4 and 5.5. Item 24.11 and 24.12 for package G and 24.12 for package H show that the health and safety plan was not strictly followed by all workers and instead, some breached the health and safety plan, such as the contractors directly employed by SANRAL as recorded in the archive data. Also, the archive data reveal that the workers underwent training after accidents had already occurred, a sign that the workers were reactive to the health and safety plan, as opposed to being proactive.

5.4.5 Material Supplies and Supply Chain

Material is the generic, absolute and vital ingredient without which construction cannot commence, continue and conclude successfully. Those

tasked with ensuring availability of material need to understand the environment from which material will come as well as the method of availing the material, in line with material requirements, material specifications, material selection (material management) and other complex material logistics that are not part of this study (Ahmed et al, 2002).

Question 5.6 sought to ascertain if tight delivery deadlines demanded the storing of more than necessary material on site (in anticipation of immediate use) in a way that compromised quality. The project responses to question 5.6 are shown in Figure 5.8 and the results are discussed in detail below.

Question 5.6 (Figure 5.8) and question 6 (6.1 to 6.7 in Figure 5.9) were directed at determining if material supplies (procurement), storage and handling presented challenges to quality management during construction. Quality of construction largely depends on the quality of the constituent materials, over and above workmanship, construction effort and other factors. In that respect, material can give rise to quality problems in various ways that include: wrong specifications; contamination; improper method of handling and poor site storage methods; using material that was not specified for the final design (prompted by running out of the original material); working outside the approved limitations of the material; not following the recommended construction procedure; and making deliveries of material out-of-sequence (not in line with the construction activities taking place on site at that particular time of material delivery).

Of the questionnaire responses obtained from question 5.6,'Tight project delivery deadlines means having more material stored on site and increase in operations on site in a manner that compromises quality ;was this the case with your project?', 31% answered *"yes"*; 46% answered *"no opinion"* while 23% answered *"no"*. While storing of more material on site than what is

actually required saves time (idle time during which material requisition forms are completed and time taken to transport the material to site) leading to increased productivity, it also yields unintended quality outcomes by creating congested working areas. The most plausible explanation for the large number of respondents (46%) who had *"no opinion"* can only be explained by suggesting that respondents were not involved in the material movements to and from site. The respondents were predominantly from middle to upper management and they were not directly affected by congested working areas. Also, the management of material on site was limited to a small number of personnel.

While material shortage is not only caused by: supplier default (due to failure to meet demand or other reasons); procurement method used; industry regulations and issues of transportation logistics, it is also rooted in incomplete designs, erroneous designs and unclear designs. Incomplete designs may lead to inaccurate material estimates and cause material shortages on construction site. This in turn impedes quality because material shortages cause disruptions and delays such that work may have to stop and restart (lack of execution continuity), thus the consistency and momentum required to be maintained so that set quality standards are met is destroyed. Love *et al* (2010) indicate that there is over reliance on 3-D CAD design systems and there is lack of design audits, to verify the accuracy of the design. There is a 30% loss of efficiency when work changes are being performed (Thomas, 1999). The work changes can be construed as changes to material (including material specification), the stop-start of work resulting from material shortages and design changes. According to Taylor and Ford (2006), temporary work stoppages degrade project performance. Sufficient design effort is a vital cog in producing a complete design from which the right amount of material is calculated.

Feedback from the questionnaire survey shows that 47% of the respondents responded *"yes"* to question 6.1 and 6.2, that quality of the work suffered due to material shortages, which affected project continuity and consistency; and also that material shortages caused contract delays that had a detrimental effect on quality. Besides directly impacting negatively on quality, material shortage also negatively impacts productivity as work cannot be accomplished in the absence of requisite material, resulting in increase in project costs through the inefficient utilisation of other resources deployed for the project (information, machinery and labour). This constitutes waste of resources, which include waiting, transporting, moving, over-production, inspection, inventories and producing defective work or products (Koskela, 1992).

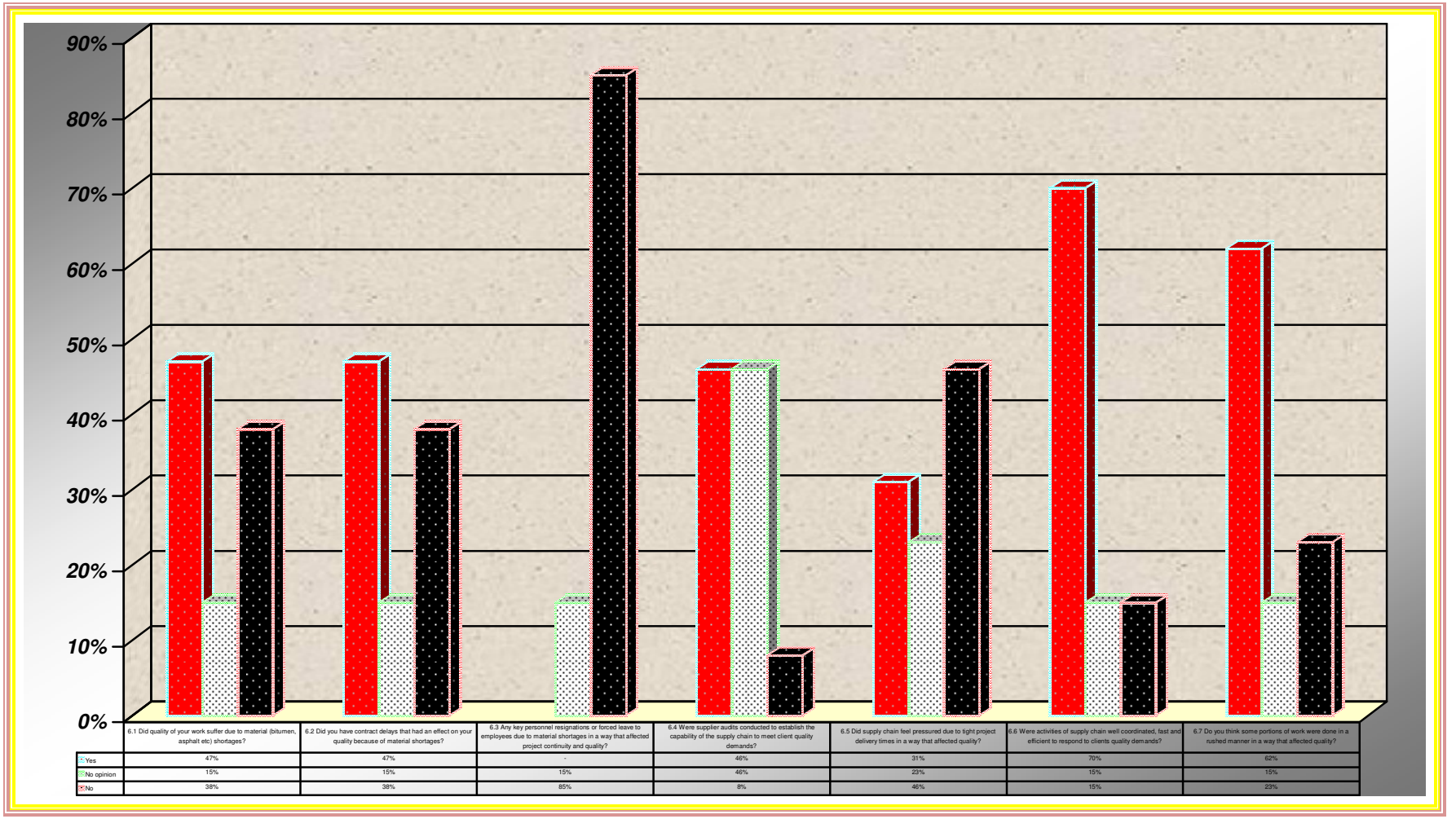
Item 24.47 and 24.50 on package H and Item 24.47 on package G and Item 19.46 on package J indicate material shortages (ultra thin friction course (UTFC), bitumen and G1 base material). There were country-wide material shortages (bitumen in particular) due to demand that exceeded supply, caused by the fact that several road projects were implemented at the same time, to be ready for use during the 2010 FIFA World Cup.

Supplier audits are designed and carried out to ascertain the capability and capacity of the preferred suppliers to effectively and efficiently supply material that complies with required specifications, consistently, in right quantities, by following the agreed quality conformance parameters during the material supply process. The findings of the audits help with realistic sequential planning of the project and scheduling of activities, as well as to gain confidence, transparency and trust with the suppliers, with a view to forging long term relationships where the interfaces are clearly defined (Egan, 1998).

Question 6.4 of the questionnaire survey was aimed at determining if supplier audits were carried out to ensure overall success of the material supply during construction. The process of conducting supplier audits also sensitises the material suppliers about how committed the client is to quality. 46% of the respondents answered *"yes"* that supplier audits were conducted.

It is the expectation that key project personnel will be privy to such audits having been conducted or not, but a large percentage of respondents (46%) had *"no opinion"* whether such audits were conducted or not. This result does not auger well with quality requirements since such key project personnel are expected to know the quality levels to be achieved by suppliers and be able to tell if there are any deviations, discrepancies or nonconforming materials.

Subjecting material suppliers to pressure to deliver the material brings with it its own quality concerns. Because the suppliers are bent on maximising profits, subjecting them to pressure may cause some suppliers to neglect their own quality procedures in producing the material. The principal outcome of not following strict quality checks is the supply to the project site of material the quality conformance of which has not been tested and verified, leading to consequential compromise on quality. Investment of time and effort in careful planning for optimal solutions for minimal or zero disruptions to material supply is a critical determinant in ensuring that material suppliers are not put under pressure and hence the subsequent successful completion of the project within the set quality parameters. The findings from the questionnaire respondents to question 6.5 reflect, from the 31% of respondents who answered *"yes"*, that the supply chain felt pressured due to tight delivery deadlines in a way that affected quality. Some set project completion dates, such as for use during the FIFA World Cup, are not movable and this alone can be the source of pressure. However, the majority of the respondents (46%) answered *"no"* whilst 23% had *"no opinion"*.



	6.1 Did quality of your work suffer due to material (bitumen, asphalt etc) shortages?	6.2 Did you have contract delays that had an effect on your quality because of material shortages?	6.3 Any key personnel resignations or forced leave to employees due to material shortages in a way that affected project continuity and quality?	6.4 Were supplier audits conducted to establish the capability of the supply chain to meet client quality demands?	6.5 Did supply chain feel pressured due to tight project delivery times in a way that affected quality?	6.6 Were activities of supply chain well coordinated, fast and efficient to respond to clients quality demands?	6.7 Do you think some portions of work were done in a rushed manner in a way that affected quality?
Yes	47%	47%	-	46%	31%	70%	62%
No opinion	15%	15%	15%	46%	23%	15%	15%
No	38%	38%	85%	8%	46%	15%	23%

Figure 5.9: Respondent views on material supplies and supply chain

McCutcheon *et al* (1994 cited in Reichhart and Holweg, 2007), define responsiveness as being equal to the delivery lead-time for a certain product. The fast, efficient and timely response by the supply chain to the client's quality demands suggest an in-depth understanding of the design demands by the material suppliers. Egan (1998) asserts the need to integrate the design and construction processes with the suppliers, so that there is effective use of skills and knowledge of suppliers and contractors from the beginning of the project.

Because contracts (between clients, contractors, suppliers, sub-contractors) are primarily tools used to manage and regulate relationships among contracting parties (Item 5.4.3), it becomes difficult to cascade complete information to the material suppliers. For the supply chain to be fully responsive in their activities, they need all the relevant information pertaining to the design and construction methodology, over and above other relational factors expressed in Figure 5.10.

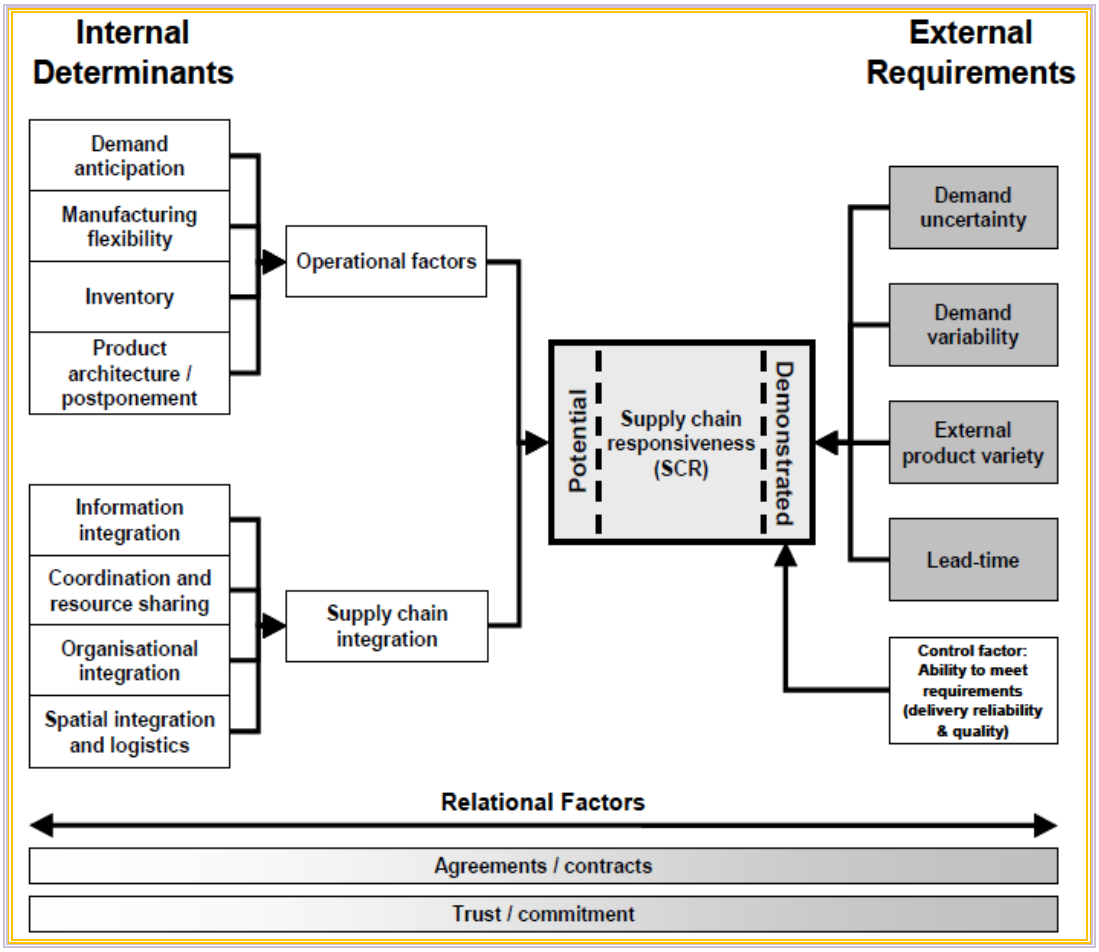


Figure 5.10: Supply Chain Responsiveness: Conceptual Framework (*Source*: Reichhart and Holweg, 2007)

Of the survey respondents to question 6.6, 70% answered *"yes"* that the activities of the supply chain were well coordinated, fast and efficient enough to respond to the client's quality demands. Respondents who answered *"no opinion"* and *"no"* to question 6.6 were 15% in each category. From Figure 5.10, the responsiveness of the material suppliers can also be understood to be a reflection of their understanding of the complex nature and the inter-relatedness of various factors (external and internal) of the construction industry and using this understanding as a propellant in meeting client quality expectations. According to Gidado (1996), the complex nature of the

construction industry originates from a number of sources: the resources that are employed; the environment in which construction takes place; the level of scientific knowledge required; and the number and interaction of different parts in the workflow.

There are rewards for accelerating project delivery, but the acceleration does not have to be at the expense of quality. Question 6.7 of the questionnaire survey: ‘do you think some portions of work were done in a rushed manner, racing against time in a way that affected the quality of the works’, sought to find out if stringent project deadlines created time pressure that caused poor quality work. Time pressure is a function of unrealistic scheduling of construction activities. The adequacy or lack thereof of initial design data to give accurate time forecast for a construction activity has an impact on project scheduling. Inaccurate time forecasting can form the basis of time pressure in delivering a project activity.

The archive documents contain clauses that point to the fact that there was time pressure on the R21 project. The mooting of time recovery techniques, such as working on weekends, is the result of pressure, especially when working on weekends is not stipulated in the contract documents and it results in increase in project costs. It is easy to commit mistakes that hamper quality initiatives when working under pressure. Item 24.62 on package H and Appendix VIII Variation Order number 16 on package G reflect pressure to deliver the project for use during the 2010 FIFA World Cup. The time pressure also caused variation orders as indicated on Appendix VII on package H, VO 15. Time pressure to deliver a project leads contractors to embark on shortcut techniques to construction procedures in order to save time and avoid penalties, at the expense of quality and safety. Shortcuts predominantly lay seeds for quality problems, problems which will require time and money to rework. The frustrations expressed in Item 24.36 of

package H after the asphalt section failed prematurely clearly shows that the contractor did not feel good about producing poor quality work but the tight time deadlines created an environment that fostered poor quality. It is important to realistically schedule construction work in correlation with the construction method and technology to be applied on the work.

62% of survey respondents answered *"yes"* to question 6.7 of the questionnaire survey, indicating that some work was accomplished in rushed manner in a way that affected the quality of the work. As opposed to 15% and 23% of respondents who answered *"no opinion"* and *"no"* respectively, 62% is a high number, representative enough to conclude that time pressure contributed to quality challenges that the project faced.

The resignation of key employee(s) at a time when the project execution is progressing efficiently at peak levels creates disruptions with specific regard to information flow and also creates labour variability. The resulting effect is lack of efficient use of information and subsequent impact on productivity (measurement of rate of output per unit time or effort). The absence of a key member of the team impacts the team's production according to McDonald and Zack (2004), who refer to this phenomenon as 'the missing man syndrome'. The diagnosis of this phenomenon on this project, in question 6.3, where 85% answered *"no"*, revealed that it was not significant and project continuity and quality were not affected by it.

5.4.6 Different contractors working on the same site

The R21 project was packaged into three work packages (packages G, H and J). Each of the three work packages was managed and implemented as a separate and distinct construction contract between contractor and client (described in section 5.3). An area of overlap is created where one work package connects to the other (an interface area) and this introduces a complex interplay of contractual obligations and rights. Because of time constraints to deliver the project for the FIFA World Cup, another set of complex dimensions can be introduced by bringing on site other contractors for purposes such as relocation of services (water mains, power lines, telecommunication cables and others) and surveys of missing data, to work parallel to main contractors for work packages G, H and J. At one of the work packages (work package J), a separate contractor working on the Gautrain Rail Link (rail over road) was introduced, further compounding the issue of rights and liabilities. Given the above, it is important, in order to avoid claims related to late site handover, that:

a. A site utilisation plan that comprehensively captures circumstances and issues that may lead to site access disputes be prepared;
b. The affected contracting parties understand and agree to the site utilisation plan.

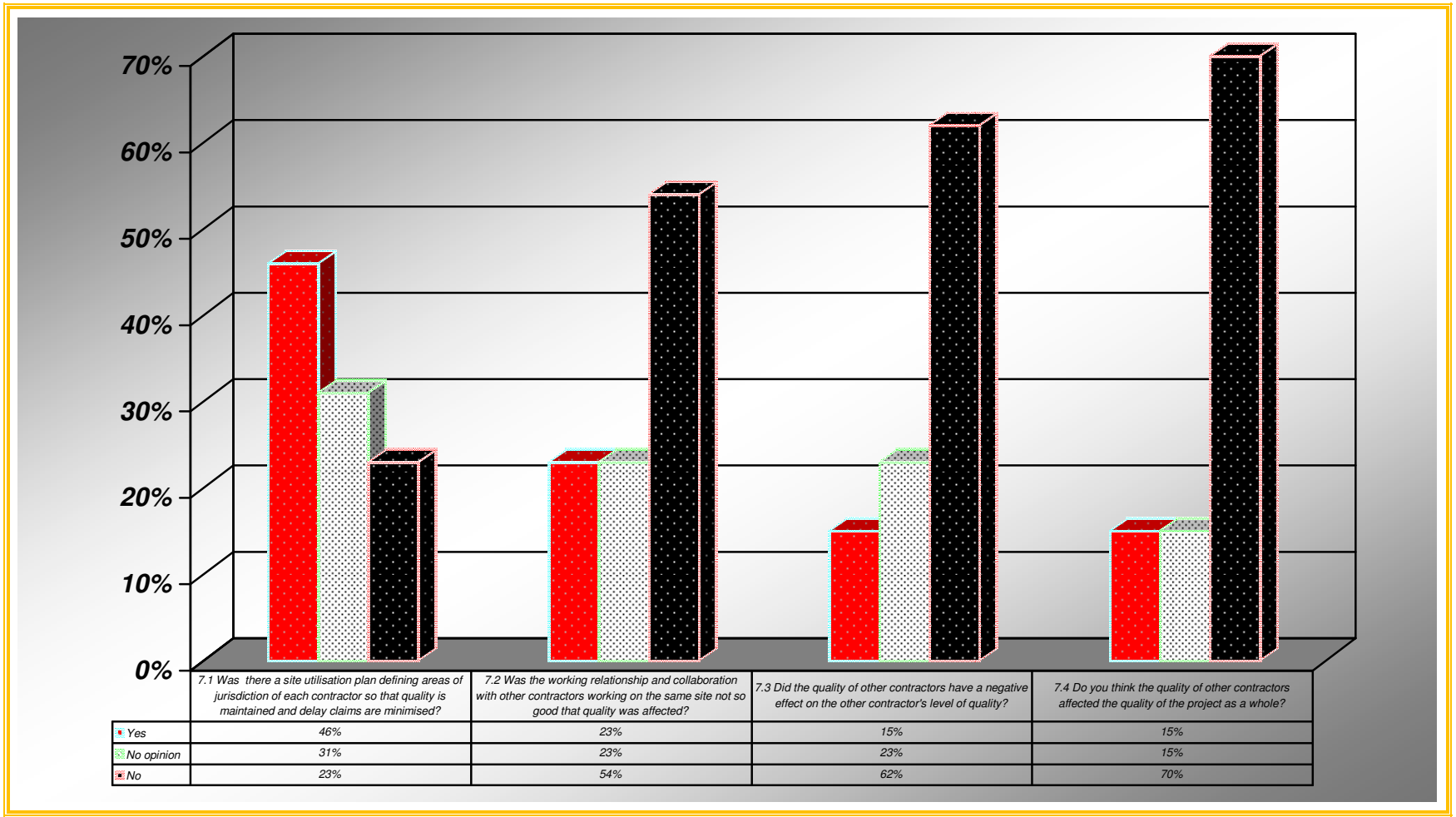
Question 7 (7.1 to 7.4) of the questionnaire survey investigated issues encompassing: having other separate contractors working parallel to main contractors on the same site; the relationship among the contractors working on the overlapping areas (interface areas) and whether the quality of work by one contractor influenced quality of the other, and ultimately quality of the whole project. The responses to question 7 are shown in Figure 5.11.

Apart from the main contractors for the construction of the three work packages, the main contractors had sub-contractors working under them.

Package J had 31 subcontractors (Appendix III A), package G had 30 subcontractors (Appendix IV A) and package H had 22 subcontractors (Appendix III). The subcontractors were classified in three main categories: Established contractors; BE's (emerging subcontractors) and SMME subcontractors. The large number of sub-contractors requires that clearly understood site utilization plans (SUP) be in place to be able to achieve the set quality objectives.

Evidence from the archive documents show that claims for accidents that took place at the interface of package H and package G indicating that poor quality work was done at the interface (Package H, Appendix XIIIB). Neither of the two contractors wanted to accept liability for the claims, an indication of how contractors become risk averse at the expense of quality.

The same is reflected from the responses obtained from question 7.1 where 23% answered *"no"* that the site utilisation plan defined areas of jurisdiction of each contractor so that quality is maintained and delay claims are minimised. Item 24.32 of package G alludes to the fact that there was lack of good cooperation and co-ordination at the interface with the neighbouring project. This information is in agreement with 23% of the survey respondents who answered *"yes"* to question 7.2, that the working relationship and collaboration with other contractors was not good enough to assure the required quality. It is quality of the work at the overlapping area (the interface) that suffers, whilst disputes easily arise under such conditions. The knock-on effects of such misunderstandings include stifling effective and efficient communication such that the formal or informal discussions of how to improve quality work on the overlapping areas do not take place. This is a reflection of lack of comprehensive interface management.



	7.1 Was there a site utilisation plan defining areas of jurisdiction of each contractor so that quality is maintained and delay claims are minimised?	7.2 Was the working relationship and collaboration with other contractors working on the same site not so good that quality was affected?	7.3 Did the quality of other contractors have a negative effect on the other contractor's level of quality?	7.4 Do you think the quality of other contractors affected the quality of the project as a whole?
Yes	46%	23%	15%	15%
No opinion	31%	23%	23%	15%
No	23%	54%	62%	70%

Figure 5.11: Respondent views on different contractors working on the same site.

The responses obtained from question 7.3 and 7.4, produced 62% of respondents answering *"no"* that quality of work of one contractor had an effect on the level of quality achieved by the other contractor; and 70% of respondents answering *"no"* that quality levels of other contractors affected quality levels of the entire project. These results indicate quality problems were localised within each work package. Thus if a work package under one contractor suffered quality problems, it does not imply that the adjacent work package under a different contractor will also suffer quality problems. Further, the responses suggest a lack of awareness of the impact of low coordination at the interfaces.

5.4.7 Rework

Rework is one of the construction aspects that has received extensive research attention in the construction industry, but yet it remains a common occurrence that continues to plague construction projects. Fayek *et al* (2003) define rework as activities in the field (construction site) that have to be done more than once, or activities which remove work previously installed as part of the project, where no change order (variation order) has been issued and no change of scope has been identified by the client. This definition also shares a common theme as identified by Love *et al*. (2000; 2010) that rework relates to the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time. Various studies by different authors have shown converging findings about the effects of rework. Rework degrades project performance, increases project costs, delays a project's delivery, (Taylor and Ford, 2006; Fayek et al, 2003; Love *et al*, 2008), affects profitability, and affects reputation of the organisations involved (Love *et al*, 2008). Additionally, rework causes dissatisfaction to the client.

Commissioning to undertake rework is an indication of a realization of inferior quality of work that needs to be remedied by re-doing the work. The three questions in question 8 (8.1 to 8.3) of the questionnaire were intended to establish if rework occurred where quality of work was not acceptable; the causes of rework (as an open ended question) and the quantification of the rework as a percentage of the total project value (as an open ended question). The questionnaire results of question 8 are portrayed in Figure 5.12.

The results shown in Figure 5.12 indicate that the three work packages of the R21 project went through the rework process to rectify identified quality deficiencies. This is evident from 77% of the questionnaire respondents who responded to question 8.1 by answering *"yes"* that there was rework done on some parts of their contract where quality standards were not acceptable. Rework attempts to uplift the unacceptable quality levels to predetermined acceptable levels of quality.

However, 8% of respondents did not undertake rework on their sections of the project[4]. Worth noting is the statistic of the 15% of respondents who had *"no opinion"* whether rework occurred on their contracts or not. The employer's representative, who is the project manager (Table 5.1) and occupies top management with regards to authority on the project, had *"no opinion"* if rework occurred on the project or not. A senior quantity surveyor with one of the main contractors, who is in middle management in terms of authority on the project, also had *"no opinion"* if rework occurred on the project or not. Such senior project team members who are considered influential in ensuring the successful completion of the project to

[4] The respondent was mainly involved with excavations and concrete work where there were no rejections.

predetermined quality standards are expected to be aware of the occurrence of rework activities on such a high level project.

Question 8.2 of the questionnaire was an open-ended question which required respondents to identify the main causes of rework on the project. The underlying factors that have been identified by respondents as contributing to rework show profound linkages to the already investigated possible obstacles above, which include tight project deadline, inclement weather conditions, incomplete designs, materials shortages and inexperienced project personnel.

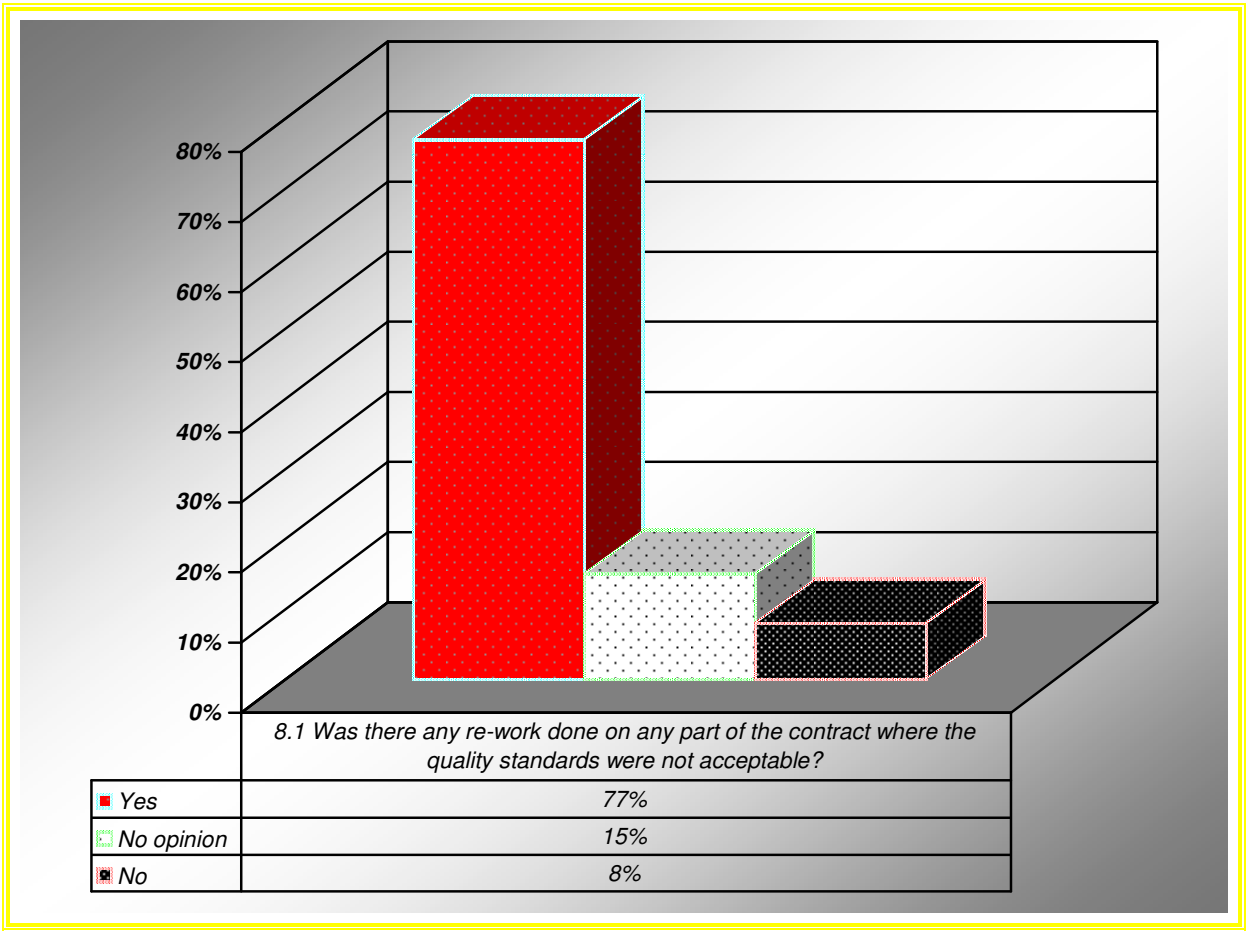


Figure 5.12: Respondent views on rework.

The respondents cited the following causes for rework (also in Appendix B):

i. Insufficient effort by the contractor
ii. Inexperienced staff
iii. Time restrictions
iv. Bad weather
v. Incomplete designs – Love et al., (2010) also identified that rework arises from design changes, errors and omissions that often stem from scope uncertainty and the contracting strategy adopted.
vi. Bitumen shortages (which gave rise to density problems)
vii. Tight tolerances
viii. Insufficient compaction leading to failure of layerworks
ix. Some sections were constructed without approved laboratory tests.

The interaction of the factors identified above (and the unidentified factors) in different project elements presents a challenge to quality management initiatives. The complex and unpredictable ways in which project elements interact increase the likelihood of rework occurring (Love *et al*., 2010). According to Love *et al*. (2010) the complex situation is further exacerbated when activities are undertaken concurrently due to issues associated with schedule pressure placed on individuals.

Question 8.3 was also an open ended question that wanted to identify the levels of rework that took place, quantified as a percentage of the total project value. From the experience of running the project, the respondents' estimates for rework costs ranged from 1% to 5% [5]. However, these estimates are not inclusive of the indirect cost of time lost during inclement weather conditions, during schedule delays, during events where employees would go on strike and other unproductive times when shortage of material was prevalent.

[5] The total project cost (package G, H and J) is R1.73billion. This means that between R17.3 million and R86.3 million went towards rectifying identified quality deficiencies.

In comparison to literature, this range of rework costs is common. Love *et al*. (2010) found rework costs to range from 5% to 20%. Palaneeswaran, (2006) summarised the impact of rework from different studies as shown in Table 5.5. Whilst the studies have shown that rework is endemic to infrastructure projects, the cost of rework varies from one project to the other in tandem with project complexity, available skills levels and other project features that are unique to a project.

Table 5.5: Rework Impacts from different studies (*Source*: Palaneeswaran, 2006)

Source	Impacts on project performance
Barber et al. (2000)	▪ This UK based study examined the quality failure costs in two highway construction projects (procured using Design-Build-Finance-Operate). The quality failure costs were 16% and 23% when the costs of delay were also included. If the costs of delay were excluded, the corresponding quality failure costs were 3.6% and 6.6%.
Josephson et al. (2002)	▪ The cost of defects identified from seven building projects in a Sweden based study ranged between 2.3% to 9.3% of contract value ▪ In another Sweden based study, the quality failure costs were found to be 6% of original contract value
Fayek et al. (2003)	▪ From the 108 field rework incidences in a Canada based study, the following findings were derived as cost contribution summary: (a) Engineering & Reviews – 61.65%; (b) Human Resource Capability – 20.49%; (c) Materials & Equipment Supply – 14.81%; (d) Construction Planning & Scheduling – 2.61%; and (e) Leadership & Communication – 0.45%.
Rhodes and Smallwood (2003)	▪ In a South Africa based study, the cost of rework was found to be 13% of the value of completed construction ▪ In the same article it was reported that a research conducted by the Associated General Contractors of America found that the average cost of rework (from nine industrial projects) was 12.4% of the project cost
Love and Edwards (2004)	▪ Construction Industry Development Authority in Australia found that average cost of rework in projects without a formal quality management system is 6.5% of contract value (and the high value for a project under lump sum procurement was 15%). However, the average cost of rework for projects with a quality system was found to be 0.72%. ▪ In another Australia based study (Love, 2002) 161 projects were studied and the mean of direct and indirect rework costs were found to be 6.4% and 5.6% of the original contract value, respectively. However, this study revealed that project procurement type may not have significant influence on the rework costs
Marosszeky (2006)	▪ In this Australia based study (in New South Wales), the rework costs on the average were found as 5.5% of contract value, that include 2.75% as direct costs, 1.75% indirect costs for main contractors and 1% indirect costs for subcontractors.

5.4.8 Culture, capacity and quality decisions

Section 9 of the questionnaire sought to explore the contribution of the culture of the construction industry project personnel in causing quality performance problems. The impact of the decisions made within that cultural context regarding quality is also investigated. Construction projects are often undertaken by individuals originating from different cultural backgrounds and harbouring diversified culture, brought together for a common cause of delivering a successful project. Culture is a set of values, beliefs, norms, attitudes and habits (Kwan and Ofori, 2001), that play a unique role in the way individuals approach problems as well as the way in which they structure solutions to problems that may arise during project implementation. Cultural attributes at the project implementation level may include antagonism, blame culture, mistrust, poor communication and resistance. Rwelamila *et al*. (1999) find that poor construction project performance in most African countries may be due to a failure to consider cultural issues, especially the concept of *ubuntu*. They conclude that if the *ubuntu* principles are lost, the individual's commitment to the project is lost.

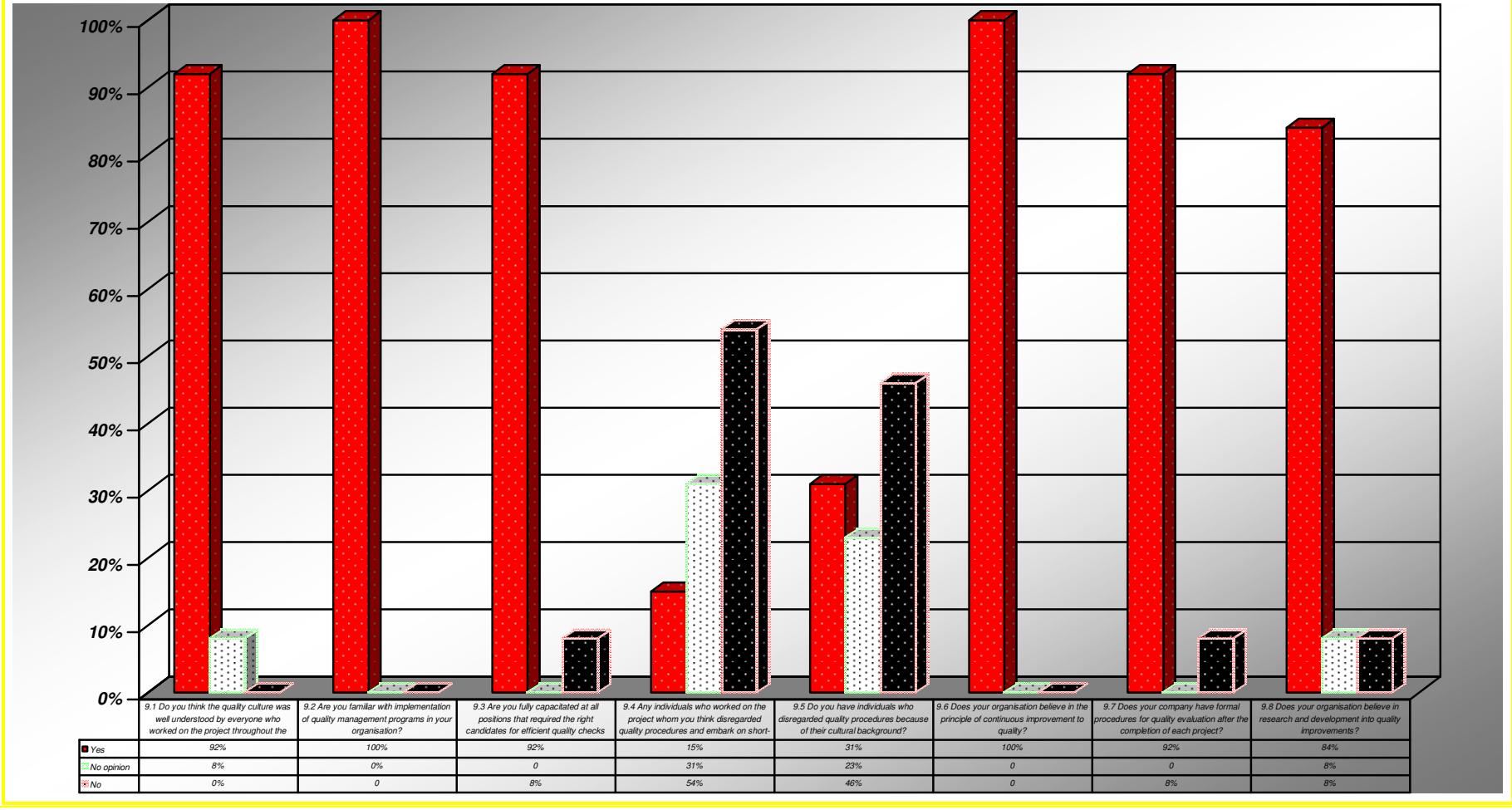
Also investigated in this section was the occupation of key decision making positions by participants adequately qualified for the positions. Feedback from the respondents is shown in Figure 5.13.

The responses from question 9.1 (where 92% answered *"yes"*) indicate that quality culture was well understood by everyone who worked on the on the project. The response from question 9.2 where 100% of respondents answered *"yes"* indicate that they are familiar with the quality management programs in their organisation. However, responses to question 9.1 and 9.2 are at variance with the responses obtained from earlier sections. For example, in question 2.5, respondents indicated that some designs were

issued late for construction, at a stage when construction had already begun on site; in question 8.2, respondents indicated that designs in the case of drainage systems were not done and also that some sections of road were constructed without approved laboratory tests. If every project team member embraced the quality culture and every team member was familiar with quality management, construction work would not have progressed without designs in place (either late designs or no designs at all) and laboratory tests on all sections of the project would have been used to verify the suitability of the material to use for construction, through quality conformance tests.

The transgressions through embarking on shortcut procedures by authorising construction work to progress in the absence of designs and using material that is not tested in the laboratory indicate a disregard for quality procedures. To that effect, 15% of the respondents answered *"yes"* to question 9.4. Noteworthy is the 54% of respondents who answered *"no"* to question 9.4, to say there are no individuals who disregarded quality procedures. This sounds like mere rhetoric, given the responses to questions in the earlier sections and also that rework levels reached 5% of total project cost.

The responses obtained from question 9.5 gave 31% of respondents indicating that the reason why some individuals disregarded quality procedures is because of their cultural background, although the question did not go further to identify the exact cultural attributes that caused individuals to disregard laid down quality procedures.



	9.1 Do you think the quality culture was well understood by everyone who worked on the project throughout the	9.2 Are you familar with implementation of quality management programs in your organisation?	9.3 Are you fully capacitated at all positions that required the right candidates for efficient quality checks	9.4 Any individuals who worked on the project whom you think disregarded quality procedures and embark on short-	9.5 Do you have individuals who disregarded quality procedures because of their cultural background?	9.6 Does your organisation believe in the principle of continuous improvement to quality?	9.7 Does your company have formal procedures for quality evaluation after the completion of each project?	9.8 Does your organisation believe in research and development into quality improvements?
Yes	92%	100%	92%	15%	31%	100%	92%	84%
No opinion	8%	0%	0	31%	23%	0	0	8%
No	0%	0	8%	54%	46%	0	8%	8%

Figure 5.13: Respondent views on culture, capacity and quality decisions.

Responses from question 9.3 reflect that 92% of the respondents affirmed that their organisation was fully capacitated with right candidates at all positions for efficient quality checks throughout the implementation of the project. Whilst this could be true, some respondents to question 8.2 indicated that there were inexperienced project personnel on the project which led to rework. Reflected in the same section are the incomplete designs, also an indication[6] of inexperienced staff.

Question 9.6 received 100% response rate that the respondent's organisation subscribes to the principle of continuous improvement (CI) in quality. This is also corroborated by the information contained in the archive documents that the staff establishment for all the contractors underwent training. Appendix IIB for package J, Appendix II B for package H and Appendix III B for package G show the site staff complement. The scope of the training for all the three packages was designed to include engineering skills, entrepreneurial skills and generic skills for both permanent and temporary staff. Continuous training helps to practice and fully understand the kaizen principle of continuous improvement (at small and gradual pace) that lead to efficiency and consistency which ultimately produce quality improvements. Continuous improvement is also the main thrust of total quality management (TQM). Continuous improvement allows the refinements of the project delivery methods until errors are minimal or eliminated. However, Love *et al*. (2010) indicate that learning within the project environment is stimulated by knowing and understanding rework causes, an aspect that was largely ignored, as discussed above.

The organisations have indicated (through a 92% positive response to question 9.7) that they have in place, formal procedures for quality evaluation

[6] Incomplete designs and documentation could equally be the result of time pressure, consultants cutting corners to maximize profit, etc.

after the project is completed. This is an instance of internal quality management initiatives of self evaluation by the contactor to highlight areas for further improvements. 84% of the respondents to question 9.8 have indicated that organisations are committed o research and development, which can also be a tool used to strengthen areas of weakness with regard to the holistic internal quality management procedures.

5.4.9 Other identified obstacles to quality management not included in the questionnaire

The archive documents helped in identifying other obstacles to quality management that were not included in the questionnaire, but could impact on quality.

5.4.9.1 Industrial action

While industrial action can take many forms, the most common is that employees, acting through the directive of their unions, can stop work and refuse to obey instructions as directed, may embark on a go slow, may destroy the constructed portions of work and may close access to area of work, often causing loss of productive time. The documents show that work package H experienced strike action by construction employees (appendix XIII A), which resulted in a claim of R1,153,313.10 for loss, expense and extension of time. The claim was however rejected by the client. From the above data, strike action drives up costs and exerts pressure on the contractor under circumstances where an appeal for extension of time is rejected. Working under pressure, in a rushed manner in order to recover lost time, can lead to compromised quality of work. The mechanism by which industrial action impacts quality is cumulative and self-perpetuating in nature, through loss of work continuity, pressure to recover lost time, and increase in project delivery costs.

5.4.9.2 Penalties charged for omissions.

If a contractor commits an omission that carries an insignificant penalty and the omission results in less loss than paying the fine, contractors may deliberately commit omissions.
Penalties emanate from relevant contract clauses and are a way of enforcing standards (design, construction, quality and others) on the contractor.

Table 5.6: Penalties per work package (*Source*: Author)

Work Package	*Total Penalty*	*Appendix*	*Project Value*
H	R465,500.00	X B	R597,206,076.00
G	R277,855.00	XI B	R882,956,964.00
J	R1,156,000.00	X B	R417,778,485.00

The total value of the contract in relation to the penalty charged (Table 5.6) clearly shows that the contractors do not feel the pain of the penalties, which can be considered negligible in comparison to the value of the contract. Penalty number R21/3 for package G shows that the contractor carried out the work with no designs in place and also that the contractor did not comply with contract provisions and specifications. Working without completed and approved designs compromises quality. Penalties charged under package J and H also were for failing to comply with specifications. Charging penalties for failing to comply with quality specifications does not correct the omission and results in compromised quality.

5.5 Conclusion

This research has drawn out some broad scale findings from comparative literature survey, archive project data and questionnaire survey, in order to identify obstacles to quality management on infrastructure projects.

An analysis of the archive data and questionnaire survey affirm that the project team members were senior enough to command great project authority in guiding the project to the desired quality outcomes. However, some project decisions made by some project team members during construction were not consistent with their seniority. Such decisions include: allowing construction to progress when the designs that are expected to guide construction were not available; allowing construction of some sections of road without approved laboratory tests; issuing construction drawings late causing construction to commence in the absence of these drawings; and delaying making critical design decisions.

Design completeness is a major determinant of quality in construction work. Meticulous project scheduling and planning, construction methods used, material quantities (material take-off), employee health and safety during construction and other construction related activities are heavily dependent on the design. Design incompleteness is shown to have played a significant role in compromising quality management efforts during construction. The fact that the designs were being done and delivered to construction site for construction (some late, when construction had already started) show that designs were incomplete at the time that the contractor was selected. Rwelamila *et al*. (1999) conclude a similar finding after a study in eight SADC countries that designs are incomplete at the time that the contractor is selected. Incomplete designs prompt contractors to embark on short-cut construction procedures that undermine quality. Koskela, (1992) identifies

design as the source of quality problems. If the designs are incomplete, as has been observed in this study, and a contractor is selected based on the price obtained from the provisions of the very incomplete design, then this is a recipe for variation orders as identified in this study. Under such a situation where designs are incomplete, Rwelamila *et al* (1999) underscore the point that the client cannot describe with certainty, what it is the contractor is being invited to construct.

Some of the identified causes of rework are not new to the construction sector, yet lessons learnt from prior projects to avoid the causes seem not to be used to avoid them on future projects. To effectively manage against causes of rework, it is imperative for project managers to understand various project elements and how they interact with one another. The interdependence among construction activities on a construction project is not sequential, not predictable, and constrains efficiency of project delivery processes hence the difficulty in understanding the interaction of the activities. Love *et al*. (2010) assert that 'understanding how variables interact with one another and the underlying conditions that contribute to rework provides a new view to be acquired that can lead to behaviour adjustment'. Rework is a form of waste and so it is important to eliminate the causes of rework rather than to cope with the effects of rework.

Material shortages affect project scheduling, result in cost overruns, cause project delays (time overrun) and quality problems arise by exerting pressure on the construction employees to recover lost time, which results in quality setbacks. It is not a simple process to gain lost time without an increase in costs through allocating more resources to the project.

This study has shown that culture plays a contributing role to quality problems, confirming the literature. It is important to recognise the cultural profile of the construction workforce and acknowledge it in order to harness their commitment to the work they do.

Chapter 6: Conclusions and Recommendations

Quality remains a potent feature of a finished project often used to determine whether the finished project is acceptable for handover or not. This research project is aimed at identifying obstacles to quality management that are present during the delivery of infrastructure projects in the South African landscape, using the GFIP R21 project as a case study. Understanding the true nature of quality management obstacles and their manifestations place clients, consultants and contractors alike in a responsive and proactive position to understand the challenges of incomplete designs, material shortages, inclement weather, time pressures and other critical quality defining parameters that can hinder effective quality management during implementation of an infrastructure project.

While incomplete design might be a reflection of substantial gaps in the prior conceptualisation phase or other poorly planned activities, the analysis of the results has pointed to incomplete project designs as the epicentre of quality problems, from which most of the other identified obstacles are firmly rooted, (Figure 6.1). Independent and naturally occurring events (inclement weather) and other external factors such as industrial action further compound the challenge to achieving the requisite quality. Incomplete designs cause costly variations that also compromise the project completion date and impact on other quality obstacles (shown by the horizontal arrow within the ‘incomplete design’ box). Adopting incomplete designs means that contracts are concluded on incomplete information, shown by the vertical arrow from ‘incomplete designs’ to ‘incomplete contract documents’. The result is poor quality of constructed work which inherently gives rise to rework, high operation costs and a compromised facility lifespan.

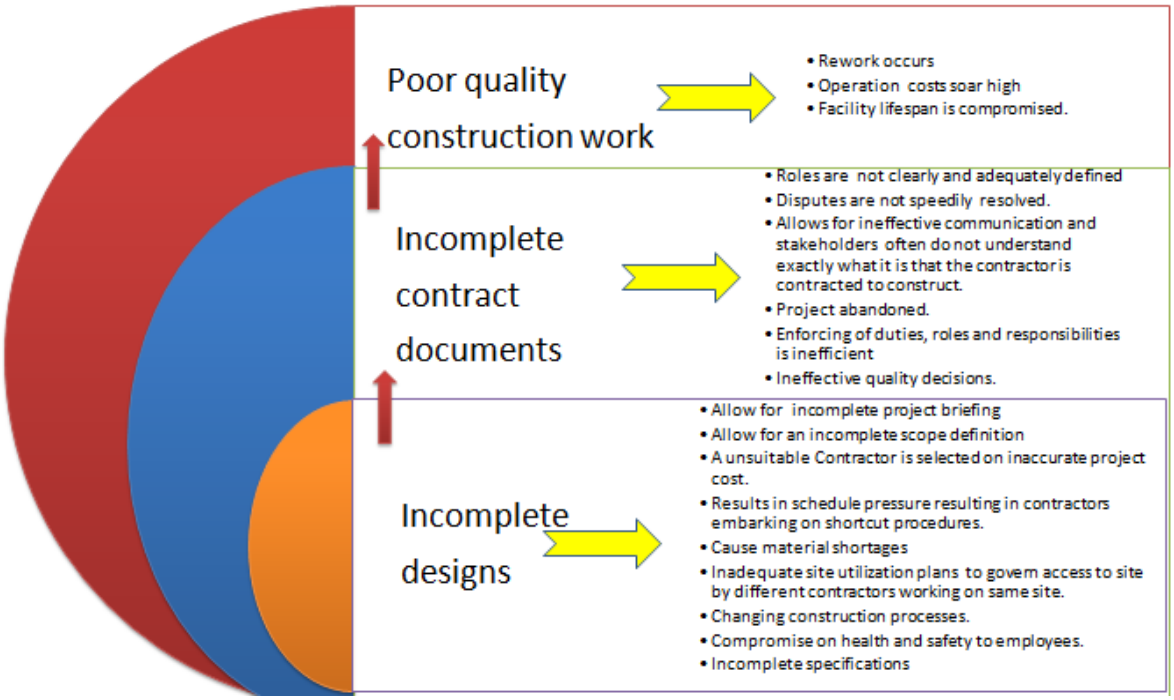


Figure 6.1: Illustration of incomplete design at the core of quality management problems (*Source*: Author)

Added impetus to achieve highest level of completeness of the design is a feature that demonstrates commitment to constructability of the design. The design phase, being an upstream process relative to construction, needs to be complete so that the downstream construction process also derives benefits through efficient and flawless construction. Subsequent quality judgments, actions and decisions taken about the project work are based on appropriate factual and realistic data as provided by a complete design. This is an important relationship between design and construction which must never be overlooked. In the wake of shortage of engineering skills, the designs need to be sufficient to be able to communicate to the project team, the intent of the design team, including the quality specifications to meet during construction. The tendency when unforeseen problems occur on a

construction project is a rush to resolve them, often ignoring the underlying causes of the problems.

In an endeavour to eliminate design ambiguity, it is highly encouraged that, during the project design, the contractor be consulted so that all the assumptions built into the design by the consultant are known to the contractor. The contractor's expertise on the design to determine the level of difficulty of construction must be sought well before the design process is complete. This process may also take place during the constructability review, which is an important process that a design has to undergo because some computerised design methods tend to ignore the site's practical realities. The design can be deficient of errors but if the design is imposed on contractor whose expertise was not acknowledged in the early stages of the design, the good design can become a source of quality flaws. There is need for the contractor to be clearly aware of what the expectations exactly are during construction before developing the 'it can't be done' mindset which can disorient the focus of the contractor on quality. Involving the contractor at an early stage at design stage allows the building of important relationships with the design consultant.

The study shows that material shortages played a significant contributory role towards quality problems on the project. Noteworthy is that the availability of good quality material delivered on time cannot rescue quality in the absence of consistent workmanship, in bad weather conditions and when the interaction of these and other factors on a project environment is not well understood. While it may be a reflection of poor procurement method, prolonged material shortage signals the need to identify, through research, alternative road building material. While it may take a long time before research can identify an important replacement for bitumen and asphalt (key road construction materials in short supply during construction of the

R21project), there is a need to advance innovation towards finding alternative materials so that there is a substitute should the shortages witnessed on the R21 project persist. Currently, there is no accepted substitute for bitumen so that, even having anticipated the shortages would not have resulted in the approval of alternative specifications[7].

The innovation into new road building materials is becoming imperative given the need to comply with strict environmental requirements as well as climate change requirements. Government is the biggest client of infrastructure projects and is responsible for promulgating and enforcing environmental regulations and legislation, so it is in government's interest to act as the effective patron for such research. By using innovative materials and methods in its own projects, government can show lasting commitment by providing the necessary funding as well as creating a conducive environment for innovative research.

By realizing that there are no quick fixes to quality in the construction industry (evidenced by costly rework), it is crucial that all the identified obstacles find resonance among stakeholders (project owners, designers, contractors and project managers) throughout the lifecycle of the project by crafting an effective framework that speeds up the learning process from prior projects so as to avoid repeat occurrence of obstacles found to be significantly associated with quality problems. This will act as an effective deterrent to the repeated occurrence of obstacles to quality management during construction. All the parties tasked with ensuring good quality in construction need to follow the processes that produce good quality and avoid shortcuts. That said, it must be acknowledged that one major characteristic of construction industry

[7] For example, sulphur extenders can be used to substitute a proportion of bitumen in the asphalt mix depending on the class of road (Timm *et al*, 2009; Strickland *et al*, 2008). The sulphur extenders are added to modify bitumen properties. In this study, bitumen itself was in short supply.

low-level workforce (semi-skilled and lower) is that they are predominantly transient (ILO, 2001) necessitating the importance of the culture of quality being championed by professionals, client representatives and senior management in the construction companies – those who are 'permanent' staff.

Complete and high-quality contract documents play a pivotal role in delivering construction projects successfully. Further research is also important to enable a clear distinction between complete and incomplete contractual documents. By clearly defining the attributes of incomplete contract documents, contractors become better placed in raising awareness of the shortcomings to the employer well in advance. Apart from raising awareness, contractors become better prepared to handle the lacking aspects of the contract documents. Some contractors exploit incomplete tender and contract documents to make claims for extras as their primary mechanism for putting in a competitive bid yet being able to generate a significant profit, the mechanism of which Turner and Simister (2001:8) call 'opportunism'. One possible method of avoiding this is the need to achieve goal alignment between the client (whose primary goal is to operate the finished product and achieve the purpose) and the contractor (whose primary goal is to maximise profits during the course of delivering the product), (Turner and Simister, 2001).

In an endeavour to craft holistic quality methods and processes (including their monitoring and efficient control mechanisms) that result in high quality work, it is important to extend this research to establish if the identified obstacles to quality management in this particular project are prevalent in other types of infrastructure projects and not just road construction. A significant range of quality practices have been introduced within the construction sector internationally but achieving the desired quality levels

continues to be a problem. In order to successfully bridge the performance deficit identified in this project, it is recommended to introduce complementary perspectives to provide new methods of improving quality performance. The new methods need to extend beyond what currently exist in the literature and include aspects related to local conditions and practices. It is also important to advance research towards understanding the project participants' exact cultural constructs that infringe on the quality management of a project and affect project performance. It is important to understand the 'best practice' cultural orientations responsible for improving quality so that the trajectory of quality on any particular project is maintained at a high level. Only if the cultural factors are clearly understood can they be recognised and used to achieve quality of the project. Cultural research should, however, be expected to be continuous rather than being final because of the dynamic nature of culture.

Effective communication of key project information (including project performance) among the project team allows for timely feedback that is critical to achieve continuous improvement, so that gained experiences are reinforced as they inform similar or repeating work processes. A multiplicity of subcontracting arrangements may present challenges with regard to effective communication owing to difficulties in directly controlling employees belonging to various subcontractors.

The central role of the professionals (both in client representative organisations and construction companies) in driving the project quality agenda cannot be overemphasized. They assume a leading role in setting the example from which all other quality initiatives can be initiated, such as effective communication. Quality needs to be built into the mainstream design process so that the expected quality of the finished project is known. The

involvement of the contractor at an early stage of design phase helps with the facilitation of flawless construction.

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APPENDIX A: THE QUESTIONAIRE

Obstacles to Quality Management in South African Infrastructure Projects -The Case of Route 21 from National Route 1 (N1) to O.R. Tambo International Airport.

My name is George Rugodho, Student Number 403419 and I am a MSc student at University of the Witwatersrand, Johannesburg, South Africa. My research topic is “Obstacles to Quality Management in South African Infrastructure Projects -The Case of Route 21 from National Route 1(N1) to O.R. Tambo International Airport”. This is a research report whose primary objective is to identify obstacles to quality management on infrastructure projects. The intention is to provide a clear understanding of the obstacles to all stakeholders involved including clients, contractors, project managers and project sponsors so that they can effectively guard against poor quality management in delivering their particular projects.

I believe that you can offer valuable contributions to this report to make it achieve its purpose. I will be grateful for your participation in the completion of this questionnaire. Your participation will take about 20 minutes of your time and this would make a major contribution to the results of this research report, which results can be made available to the participants on request.

My supervisor is Dr Anne Fitchett who can be contacted at Anne.Fitchett@wits.ac.za for any queries that you might have in relation to this study. This study is also guided by the ethical policies of University of the Witwatersrand.

George Rugodho (MSc student)
403419@students.wits.ac.za

Instructions

All the information that you provide will be kept confidential.

Answer all questions according to the best of your knowledge, skills, experience, understanding and opinion. Choose an answer that best describes and fits the activities of the project as it unfolded.

You may provide your name or organisation **IF** you wish but this is optional and any provided name will remain confidential.

1. General Information

Complete the table below.

Name (Optional)	
Designation or position	
Date	

2. Detailed issues: Design

Indicator or Question	Yes	No opinion	No
2.1 Were there design scope changes or design omissions that had an effect on quality of the work?			
2.2 Were there design changes due to changes of the approved construction processes (choice of technology) to improve quality?			
2.3 Were there some specification defects in the design?			
2.4 Did you have variation orders (VO's) due to design changes (or any other cause) so that set quality standards are maintained or improved?			
2.5 Are there any other design issues that negatively affected quality of the project	Please elaborate in section 10.below.		

3. Inclement weather

Indicator or Question	Yes	No opinion	No
3.1 Besides project delay, did force-majeure events like weather events (too cold, too hot, wet e.t.c), affect the quality of your workmanship or quality of materials?			
3.2 How did you intervene to ensure that such conditions have minimum effect on quality of the work?	Please elaborate in section 10.below.		

4. Contract Documentation and Contractual Decisions

Indicator or Question	Yes	No opinion	No
4.1 Was contract documentation incomplete to the extent that it affected quality of the work?			
4.2 Do you think you performed work outside the provisions of the contract in order to improve the quality on certain aspects of the work?			
4.3 Did you do construction errors because of: a. ambiguity or contradictions of processes or methods in the contract documents			
b. complexity of contract provisions			
c. contract provisions that specified new methods that differed from usual or normal practice that you worked with previously.			
4.4 Were there decisions from any party (consultant, client, contractor etc) that you think had a negative effect on the quality of the work?			
4.5 Delays on progress inspections or approvals by the relevant section can affect quality. Did you experience such delays in a way that affected quality of the work?			

5. Traffic Accommodation and Health & Safety

Indicator or Question	Yes	No opinion	No
5.1 Did you get distractions from “live” traffic in a way that affected quality of the work even if barriers were in place?			
5.2 Do you think contra-flow of traffic produces better quality work than closing off lanes to be worked on while adjacent lanes are open to traffic?			
5.3 Which method of traffic accommodation was used?	Please elaborate in section 10.below.		
5.4 Was the Healthy and Safety Plan clearly understood and strictly followed by everyone involved on the project in a way that improved quality?			
5.5 Did the Healthy and safety Plan change with changes to scope and design so that it remains relevant in ensuring good quality until the end of construction works.			
5.5 Tight project delivery deadlines means having more material stored on site and increase in operations on site in a manner that compromises quality ;was this the case with your project?			

6. Material Supplies and Supply chain

Indicator or Question	Yes	No opinion	No
6.1 Material shortages (asphalt, bitumen) are known to affect project continuity, consistency and quality: did quality of your work suffer due to material shortages?			
6.2 Did you get any contract delays that had an effect on your quality because of the material shortages?			
6.3 Were there any key personnel resignations or any forced leave to employees because of material shortages (or any other reason) in a way that affected project continuity and quality?			

6.4 Were supplier audits conducted to establish the capability of the entire supply chain to meet client's quality demand?			
6.5 Did the supply chain feel pressured due to tight delivery times during project delivery period in a way that affected quality?			
6.6 Were the activities of the supply chain well co-ordinated, fast and efficient enough to respond to the client's quality demands?			
6.7 Do you think some portions of the work were done in a rushed manner, racing against time in a way that affected the quality of the works?			

7. Different contractors working on the same site.

Indicator or Question	**Yes**	**No opinion**	**No**
7.1 There are other contractors doing parallel work especially on overlapping areas on the same site-was there a site utilisation plan defining areas of jurisdiction of each contractor so that quality is maintained and delay claims are minimised?			
7.2 Was the working relationship and collaboration with other contractors working on the same site not so good that quality was affected?			
7.3 Did the quality of other contractors have a negative effect on the other contractor's level of quality?			
7.4 Do you think the quality of other contractors affected the quality of the project as a whole?			

8. Re-work

Indicator or Question	Yes	No opinion	No
8.1 Was there any re-work done on any part of the contract where the quality standards were not acceptable?			
8.2 What do you think caused the re-work?	Please elaborate in section 10.below.		
8.3 At how much would you quantify the re-work as a percentage of the project value?	Please elaborate in section 10.below.		

9. Culture, capacity and Quality decisions

Indicator or Question	Yes	No opinion	No
9.1 Do you think the quality culture was well understood by everyone who worked on the project throughout the project life?			
9.2 Are you familiar with the implementation of quality management programs in your organisation?			
9.3 As an organisation, are you fully capacitated at all positions that required the right candidates for efficient quality checks throughout the project?			
9.4 Do you think there are individuals who worked on the project and disregard the quality procedures and embark on short-cuts or processes without quality checks?			
9.5 Do you have individuals who worked on the project whom you think disregard quality procedures because of their cultural background?			
9.6 Does your organisation believe in the principle of continuous improvement to quality?			
9.7 Does your company have formal procedures for quality evaluation after the completion of each project?			
9.8 Does your organisation believe in research and development into quality improvements?			

10. Elaborate on any other aspects that you think might have affected quality. You may also expand on the indicators from 2 to 9 above and you may use the reverse side if you need extra space.

Indicator or Aspect	Elaboration
Elaboration of Item 2.5	
Elaboration of Item 3.2	
Elaboration of Item 5.3	
Elaboration of Item 8.2	
Elaboration of Item 8.3	
Any other indicators that you feel you need to elaborate on.	**Elaboration**

APPENDIX B: RAW SURVEY RESULTS

1. General Information

Complete the table below.

Name (Optional)	
Designation or position	
Date	

2. Detailed issues: Design

Indicator or Question	Yes	No opinion	No
2.1 Were there design scope changes or design omissions that had an effect on quality of the work?	15%	31%	54%
2.2 Were there design changes due to changes of the approved construction processes (choice of technology) to improve quality?	54%	8%	38%
2.3 Were there some specification defects in the design?	15%	31%	54%
2.4 Did you have variation orders (VO's) due to design changes (or any other cause) so that set quality standards are maintained or improved?	69%	8%	23%
2.5 Are there any other design issues that negatively affected quality of the project	i. drainage designs were not done and contractor had to do designs as work progressed. ii. Some designs were issued for construction at a late stage of construction when construction had begun which caused lower quality. iii. Design decisions caused drawings to take long to deliver to site.		

3. Inclement weather

Indicator or Question	Yes	No opinion	No
3.1 Besides project delay, did force-majeure events like weather events (too cold, too hot, wet e.t.c), affect the quality of your workmanship or quality of materials?	47%	15%	38%
3.2 How did you intervene to ensure that such conditions have minimum effect on quality of the work?	i. do nothing and compensate contractor for time lost. ii. Wait for bad whether to go past and rectify problems caused by bad weather. iii. Re-programmed work and obtained additional suppliers iv. On cold days, cover up concrete and stabilised layer with plastic sheet to prevent freezing. v. Work longer hours. vi. Change curing methods and work programme. vii. Re-organised planning.		

4. Contract Documentation and Contractual Decisions

Indicator or Question	Yes	No opinion	No
4.1 Was contract documentation incomplete to the extent that it affected quality of the work?	0%	15%	85%
4.2 Do you think you performed work outside the provisions of the contract in order to improve the quality on certain aspects of the work?	38%	15%	47%
4.3 Did you do construction errors because of: a. ambiguity or contradictions of processes or methods in	0%	46%	54%

the contract documents			
b. complexity of contract provisions	0%	46%	54%
c. contract provisions that specified new methods that differed from usual or normal practice that you worked with previously.	31%	23%	46%
4.4 Were there decisions from any party (consultant, client, contractor etc) that you think had a negative effect on the quality of the work?	23%	23%	54%
4.5 Delays on progress inspections or approvals by the relevant section can affect quality. Did you experience such delays in a way that affected quality of the work?	31%	15%	54%

5. Traffic Accommodation and Health & Safety

Indicator or Question	**Yes**	**No opinion**	**No**
5.1 Did you get distractions from "live" traffic in a way that affected quality of the work even if barriers were in place?	38%	24%	38%
5.2 Do you think contra-flow of traffic produces better quality work than closing off lanes to be worked on while adjacent lanes are open to traffic?	77%	15%	8%
5.3 Which method of traffic accommodation was used?	i. contra-flow with half widths constructed lanes. ii. lane closures for short term during night and sometimes during the day. iii. lane shifting. iv. All methods of traffic management were used.		
5.4 Was the Healthy and Safety Plan clearly understood and strictly followed by everyone involved on the project in a way that improved quality?	84%	8%	8%

5.5 Did the Healthy and safety Plan change with changes to scope and design so that it remains relevant in ensuring good quality until the end of construction works.	84%	8%	8%
5.5 Tight project delivery deadlines means having more material stored on site and increase in operations on site in a manner that compromises quality ;was this the case with your project?	31%	46%	23%

6. Material Supplies and Supply chain

Indicator or Question	Yes	No opinion	No
6.1 Material shortages (asphalt, bitumen) are known to affect project continuity, consistency and quality: did quality of your work suffer due to material shortages?	47%	15%	38%
6.2 Did you get any contract delays that had an effect on your quality because of the material shortages?	47%	15%	38%
6.3 Were there any key personnel resignations or any forced leave to employees because of material shortages (or any other reason) in a way that affected project continuity and quality?	0%	15%	85%
6.4 Were supplier audits conducted to establish the capability of the entire supply chain to meet client's quality demand?	46%	46%	8%
6.5 Did the supply chain feel pressured due to tight delivery times during project delivery period in a way that affected quality?	31%	23%	46%
6.6 Were the activities of the supply chain well co-ordinated, fast and efficient enough to respond to the client's quality demands?	70%	15%	15%
6.7 Do you think some portions of the work were done in a rushed manner, racing against time in a way that affected the quality of the works?	62%	15%	23%

7. Different contractors working on the same site.

Indicator or Question	Yes	No opinion	No
7.1 There are other contractors doing parallel work especially on overlapping areas on the same site-was there a site utilisation plan defining areas of jurisdiction of each contractor so that quality is maintained and delay claims are minimised?	46%	31%	23%
7.2 Was the working relationship and collaboration with other contractors working on the same site not so good that quality was affected?	23%	23%	54%
7.3 Did the quality of other contractors have a negative effect on the other contractor's level of quality?	15%	23%	62%
7.4 Do you think the quality of other contractors affected the quality of the project as a whole?	15%	15%	70%

8. Re-work

Indicator or Question	Yes	No opinion	No
8.1 Was there any re-work done on any part of the contract where the quality standards were not acceptable?	77%	15%	8%
8.2 What do you think caused the re-work?	i. insufficient effort by the contractor. ii. inexperienced staff iii. time restrictions. iv. bad weather v. incomplete designs or designs not done in the case of drainage. vi. Bitumen shortages (densities problems) vii. Tight tolerances viii. Insufficient compaction led to failure of layerworks.		

	ix. Some sections were constructed without approved laboratory tests.
8.3 At how much would you quantify the re-work as a percentage of the project value?	i. 2-5%. ii. 4% (asphalt work was rushed due to world cup). iii. 1.5% iv. 1%

9. Culture, capacity and Quality decisions

Indicator or Question	Yes	No opinion	No
9.1 Do you think the quality culture was well understood by everyone who worked on the project throughout the project life?	92%	8%	0%
9.2 Are you familiar with the implementation of quality management programs in your organisation?	100%	0%	0%
9.3 As an organisation, are you fully capacitated at all positions that required the right candidates for efficient quality checks throughout the project?	92%	0%	8%
9.4 Do you think there are individuals who worked on the project and disregard the quality procedures and embark on short-cuts or processes without quality checks?	15%	31%	54%
9.5 Do you have individuals who worked on the project whom you think disregard quality procedures because of their cultural background?	31%	23%	46%
9.6 Does your organisation believe in the principle of continuous improvement to quality?	100%	0%	0%
9.7 Does your company have formal procedures for quality evaluation after the completion of each project?	92%	0%	8%
9.8 Does your organisation believe in research and development into quality improvements?	84%	8%	8%

APPENDIX C

PROJECT ARCHIVE DATA

The project archive data is the R21 project information and project documents made available by SANRAL for purposes of the research. A summary of the information made available is contained in Table 5.2. Tender documents and contract documents for the three work packages (G, H and J) of the R21project are available and were referred to during the course of the research but are not attached in the appendices because of their size.

The project minutes for work packages G, H and J are attached in appendices C1, C2 and C3 respectively. Key among other information contained in the minutes is record of changes of construction process; record of variation orders; record of contract delays; record of rework; record of project progress; and record of work inspection. Minutes capture discussions, decisions made and responsibilities of each of the project participants during the course of the project. They are an important and formal tool of communication to the client; client representative; contractor; and subcontractors in ensuring that all parties are informed of project progress.

For confidentiality purposes, the names have been removed from the minutes.

APPENDIX C 1: MINUTES – WORK PACKAGE G

APPENDIX C 2: MINUTES – WORK PACKAGE H

APPENDIX C 3: MINUTES – WORK PACKAGE J