EVALUATING THE OPTIMAL INNOVATIVE COST CONTROL TECHNIQUES USED IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY

BY

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ABSTRACT

The execution of construction projects commands a myriad of technological, human, organisational and natural resources. However, the construction and engineering undertaking of these projects are frequently overshadowed by economic difficulties, such as the high costs of construction materials, that have a negative impact on project costs. Cost overruns have been determined as a phenomenon continually plaguing the construction industry in both private and public sectors, and very few projects are completed within cost parameters. This research evaluated the barriers to the use of innovative cost control techniques during the construction phase, and determined the level of cost overruns on construction projects in South Africa; identified innovative cost control techniques used by construction firms on construction projects; established the optimal innovative cost control technique used in the South African construction industry; and uncovered the relationship between the level of use of innovative cost control techniques on construction projects and cost overrun.

Questionnaires were the chosen instrument for data collection and were circulated via Survey Monkey. A total of 123 questionnaires were returned, and they provided the base for the computation of study results. Statistical tools employed in the study included percentages, mean item score (MIS), and frequency distributions. A scatter plot was used to distinguish whether there was a correlation between the cost performance of projects and level of innovativeness by establishing a line of best fit through the set of the two variables. A line of best fit in the positive direction indicates that increased levels of innovativeness improves the cost performance of projects, while a line of best fit in the negative direction indicates that increased levels of innovativeness does not enhance project performance. The relationship between the level of innovative cost control techniques usage in construction projects and cost overrun was determined to be negative. This led to the conclusion that construction professionals are limiting themselves and are not exploring alternative or innovative cost control techniques. They were focused on project efficiency and productivity rather than cost overruns.

Innovative cost control techniques identified in the study were Earned Value Analysis (EVA), Last Planner System (LPS), 4D Scheduling, Fuzzy Project Scheduling, Integrated critical path and Line of Balance, and Reserve Analysis. Study findings determined that the critical contributors to cost overruns included tight project budgets, project complexity, a high frequency of change orders by clients and financial difficulties encountered by contractors. Perceived barriers to the implementation of innovative cost control techniques in projects by participants included a poor scope definition, a lack of training and technical skill of project personnel, poor understanding of cost analysis and variables involved in cost planning.

It also emerged that projects cannot meet project objectives, and construction organisations are not making use of the right tools and techniques to monitor and control construction costs. The research findings have shown that professionals have limited knowledge of innovative cost control techniques. This also concludes that they are not taking advantage of the features of new innovative techniques to tackle complex projects. This, therefore, means that complex projects will continue to experience cost overruns. This study concludes that top management of construction organisations are not training their staff to embrace new technologies and innovation.

To address the barriers to the use of innovative techniques, there should be increased investment on the part of construction organisations toward affording their workforce the relevant training, knowledge and technical skill required to implement the modern techniques for cost control identified in the report. The cidb should organise seminars and workshops on the usefulness and importance of innovative cost control techniques, and workers should embrace self-development and change. Government should implement policies on the use of innovative cost control techniques for their projects, and construction organisations should develop capacity in line with innovative cost control techniques.

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DEFINITION OF TERMS

Cost Control: Administering and regulating factors that have an impact on the allocated budget (Owens, 2007: 6).

Project Cost: The budgeted expenditure for delivery of a construction structure in accordance to conditions of a contract (Nadaf and Kulkarni, 2019: 2221).

Project Cost Overrun: The project costs that have surpassed the value of the contract sum for delivering of the construction structure (Nadaf and Kulkarni, 2019: 2221).

Contractor: Any person, firm, organisational entity, agent, or employee that takes on the delivery of professional services, goods with interconnected services, or engineering and construction works (Fisher, 2013: 1).

Innovativeness: A fundamental attitude in any managerial team or organisation to develop new ideas for the competitive edge or durability of their organisations (Zawawi et al., 2016: 89).

Technique: A method or procedure of applying systematic technological knowledge (Isman, 2012: 209).

Innovative Cost Control Techniques: These are techniques incorporating new methods or ideas used for administering and regulating factors that have an impact on the allocated budget of projects (Isman, 2012: 209; Owens, 2007: 6; Zawawi et al., 2016: 89).

ABBREVIATIONS

BIM: Building Information Modelling.

CAD: Computer Aided Design.

cidb: Construction Industry Development Board.

CPM: Critical Path Method

EVA: Earned Value Analysis.

EVM: Earned Value Management.

LOB: Line of Balance.

LPS: Last Planner System.

PERT: Project Evaluation and Review Technique.

UK: United Kingdom.

USA: United States of America.

WBS: Work Breakdown Structure.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The procurement of construction works in the public sector accounts for approximately R220 billion annually, which provides much of the necessary economic infrastructure and public services required for economic growth (cidb, 2017: i). As a means of realising and maximising these benefits within the allocated infrastructure budget, it is imperative to control infrastructure costs and limit any unnecessary burden on existing funds that finance government infrastructure programmes (cidb, 2017: i). Construction costs are the percentage of hard costs, including labour, material and equipment costs, required to set a structure in place. These costs are rounded up with the addition of site management and overheads, which are customary costs associated with undertaking business with a contractor (cidb, 2017: 9).

The implications of cost to projects has become a research area of concern globally and, therefore, cost control practices are being elaborated on as a means of elevating effectiveness and realising value for money (Kissi et al., 2016: 8). An immense amount of capital is required for project implementation, with project participants attentive toward achieving the stakeholders' goals within the allocated time, cost and quality constraints (Kissi et al., 2016: 8). Cost management consists of three elements; cost estimating, cost budgeting and cost controlling (Owens, 2007: 6). Cost estimating involves generating estimates and appraisals for the costs necessary for a resource to realise project tasks. Cost budgeting is associated with acquiring cost appraisals and combining them to establish an overall cost and baseline. Cost controlling is the administering and regulating factors that have an impact on the budget (Owens, 2007: 6). Techniques employed in the cost control of projects include earned value analysis (EVA), forecasting, variance analysis, trend analysis and reserve analysis (PMI, 2017: 260). EVA affords an early warning system to inherent risks and opportunities (Owens, 2007: 18).

Trend analysis examines past performance results in order to forecast future performances. It identifies anticipated slippages and alerts the project manager in advance to problems that may be experienced at a later stage of the project schedule (PMI, 2017: 262-263). Variance analysis evaluates the contrast between planned and actual performance, and the differences from an integrated viewpoint of the relationship between time, cost and resource variances to obtain a comprehensive outlook of variances on the project. This enables appropriate corrective or preventive actions to be applied (PMI, 2017: 262-263).

Forecasting involves the project team evolving a prognosis for the estimated cost at the anticipated completion time of the project. Predetermining the estimated cost at completion entails generating projections of scenarios and circumstances of the project's future based on existing performance data and other information available at the time of forecasting (PMI, 2017: 264). Reserve analysis is used in cost control to monitor the status of contingency reserves of the on-going project and to establish whether the present reserves would still be necessary, or if supplementary reserves would be required (PMI, 2017: 262-265).

Several internal and external factors have an impact on project costs during the initial stages of a project. Internal factors are those that are directly dependent on the party sponsoring the project, whereas, with external factors, the project sponsor has minimal or no control whatsoever on cost escalations (Shane et al., 2009: 224). Internal factors include: bias (the deliberate underestimation of costs to make certain that a project maintains its place in the construction programme), changes to project schedule (attainable at an increased cost), procurement strategy, changes to project scope (such as design alterations and scope creep – the susceptibility of multiple minor alterations to the project scope accumulating), project complexity (function of the project, or constructability issues) and poor cost estimations (Shane et al., 2009: 224).

External cost overrun factors include: market conditions (fluctuations to the macro environment), inflation (construction costs exceeding that of the anticipated estimate during the planning phase) and force majeure (unforeseeable circumstances out of the client's hands, such as natural disasters like floods and earthquakes, that can halt construction work leading to project delays, or creating the need for rework and repair). Circumstances brought about by third parties, such as strike action and changes to commodity prices, are out of the control of clients as well (Shane et al., 2009: 225).

The construction industry is imperative for the socio-economic growth of a country. Its significance includes increasing the GDP of a country, as well as elevating the quality of life through the provision of infrastructures such as roads, medical facilities and educational institutions. However, the infrastructure sector is also a convoluted and schedule-driven industry facing ceaseless obstacles, such as low productivity, substandard quality and cost overruns (Rahman et al., 2013: 286). Cost overruns are a significant obstacle, as they impact negatively on a country's development (Olawale et al., 2010: 509-526).

Cost overrun is a global phenomenon in the construction industry – barely any project is completed within allocated budgets. A study conducted by Flyvbjerg et al. (2003: 78) on project performance revealed that approximately nine out of 10 projects experienced cost escalations. The study sample was comprised of 258 companies spanning five continents and 20 countries. In Malaysia, a study on 359 projects revealed that only 46.8% of public sector projects and 37.2% of private sector projects had been completed within their allocated project budgets (Rahman et al., 2013: 286). Flyvbjerg (2014: 9) echoed similar sentiments, stating that cost overruns are an occurrence in both public and private sector projects, as overruns have remained high and unchanged in the 70 years that comparable data has existed. Regardless of geography, all continents and countries for which data exists experience cost overruns (Flyvbjerg, 2014: 9). In the United Kingdom (UK), the Wembley stadium experienced a 50% cost escalation, while the Scottish Parliament not only experienced a 900% cost overrun but a three-year time overrun as well. Similar to other countries, South Africa faces cost overrun problems. According to Baloyi and Bekker (2011: 53), the FIFA 2010 World Cup stadia in the country were completed with extensive cost overruns ranging between 5%-94%. The budget at the inception of the project was set at R6 billion, but by 2005, five years before the commencement of the tournament, this value had almost doubled to R10 billion (Chihuri et al., 2010: 65). Another South African project that exhibited cost overrun issues was the Gautrain rapid-rail link project. The budgeted cost was set at R7 billion, but escalated to R25 billion (Baloyi and Bekker, 2011: 53).

The prime causes of cost overruns in the construction industry are scope changes on site, unpolished designs at the time of tendering, inadequate cost planning and poor monitoring of project funds, delays brought about by cost variation and added works (Ramabodu et al., 2010: 137). According to Rahman et al. (2013: 288), cost overruns are the result of insufficient contractor site management, poor project design and documentation, inadequate financial control, slow rate of data and information sharing, high labour costs and a shortage of skilled personnel, escalation in the costs of materials and equipment, shortage of materials, poor project management practices and changes to scope. A study conducted by Windapo and Cattell (2013: 73) to determine the key challenges impacting the performance of the South African construction industry found that increases in the cost of building materials, access to affordable credit and high-interest rates ranked as the toughest obstacles in the industry. Another study conducted by the cidb (2017: i) supported the findings of Windapo and Cattell (2013: 73), revealing that, from a historical standpoint and evaluation of construction data, material costs will continually escalate at the rate of inflation. A trend that was discovered is that an escalation in building costs is brought about by increases in financing costs, risk circumstances and profit allowances set by contractors, in addition to a faltering Rand (cidb, 2017: i).

Azis et al. (2013: 2623) attributed reduced levels of cost overruns to the use of ICT, as the implementation of construction projects involves different groups of participants, such as civil engineers, contractors, sub-contractors. The incorporation of advanced information and information systems enables a quicker means to transmit data, and for practitioners to make timely decisions in problem-solving without delaying project tasks. A survey conducted by Olawale and Sun (2010: 509-

526) on the utilisation of cost control by companies in the UK revealed that 84% of professionals applied cost control methods on projects, while 16% indicated frequent use of cost control methods on projects. Techniques such as profit and loss at valuation dates, overall profit and loss, unit costing and EVA have been used on construction, while software such as WinQS, Microsoft Project and Asta Power Project are used for cost control (Olawale and Sun, 2010: 509-526). Memon et al. (2012: 50) undertook a study among contractors in Malaysia to assess the mitigation efforts used for cost control, and these included frequent progress meetings and regular coordination and communication among project participants.

Small to medium construction companies are utilising dated cost control procedures that are dependent on manual paper-based means – where cost engineers, graduates employed as site engineers and quantity surveyors make use of calculators and notepads to implement cost control analysis – as opposed to utilising more befitting tools and techniques and more complex technology available (Adjei et al., 2017: 16-17). According to Adjei et al. (2017: 17), firms depend on past experiences from previous projects due to the lack of knowledge on cost management, which has impacted the practice of project cost control. The difficulty of comprehending the more complex cost control techniques and tools is a challenge confronting professionals. Managers of construction firms are more concerned with variances in cost control for only a particular period in the project life cycle. They fail to address sources of cost variance and are unable to cope with change management procedures. Due to this, cost control in project implementation is often brushed aside (Adjei et al., 2017: 17-18). Cost managers are aware of the necessity to maintain and monitor construction costs but are unwilling to take the time to cultivate cost control templates for each respective construction project to utilise in the cost control process. Specific reservations are only made to some construction activities where variances in cost are anticipated to occur (Adjei et al., 2017: 17-18).

Despite ICT tools and knowledge being widespread in the infrastructure industry, construction firms are slow to incorporate and probe the potential advantages. Adjei et al. (2017: 18-19) are of the opinion that the poor mind-set of individuals toward the adoption of ICT is a problem in project delivery. Therefore, this research aimed to examine the cost control techniques in use by construction companies, and the barriers to the adoption of more complex technology in cost control on construction projects in South Africa.

1.2 STATEMENT OF THE PROBLEM

The execution of construction projects commands a myriad of technological, human, organisational and natural resources. However, construction and engineering undertaking of these projects are frequently overshadowed by economic difficulties, such as the high costs of construction materials, that have a negative bearing on project costs. Cost overruns have been determined as a phenomenon continually plaguing the construction industry in both private and public sectors, and very few projects are completed within cost parameters. Projects such as the FIFA World Cup stadia in South Africa and Wembley stadium in the UK have experienced cost overruns of 5%-94% and 50% respectively. The literature attributes cost overruns to changes in project scope, the escalation of plant and material costs, poor project management practices, inadequate planning and poor supervision of costs. Mitigation measures include the use of ICT and software, such as WinQS and Microsoft Project, to monitor and control costs during the construction phase. Techniques such as EVA, experience acquired from previous projects and incentives afforded to contractors based on project performance have been employed in preventing cost overruns. However, construction firms are still encountering cost overruns on projects, and this continues to be of concern. Limited research has examined the innovative cost control techniques in use on construction projects and barriers to the use of more innovative cost control techniques in the South African construction industry context. Therefore, this research evaluates the innovative cost control techniques in use and the barriers to the use of innovative cost control techniques on construction projects, with the aim to improve project performance in the construction industry.

1.3 RESEARCH QUESTIONS

What are the optimal innovative cost control techniques used in the South African construction industry?

1.4 AIM OF THE STUDY

The study examines the innovative cost control techniques used on construction projects and whether there are barriers to the use of innovative cost control techniques among contractors during the construction phase.

1.5 RESEARCH HYPOTHESES

H1: *The increased levels of innovativeness in cost control techniques improves the cost performance of projects for the planning of construction activities during the construction phase*.

H2: *The increased levels of innovativeness in cost control techniques improves the cost performance of projects for the monitoring and controlling of construction activities during the construction phase.*

1.6 OBJECTIVES OF THE RESEARCH

To realise its aim, the study sought to:

1. Ascertain the level of cost overruns on construction projects in South Africa.
2. Identify innovative cost control techniques used by construction firms in construction projects.

3. Determine barriers to the use of innovative cost control techniques in projects.
4. Find out whether there is a relationship between the level of use of innovative cost control techniques in construction projects and cost overrun.
5. Establish the optimal innovative cost control technique used in the South African construction industry.

1.7 SCOPE AND LIMITATIONS OF THE STUDY

There are several limitations that the researcher may encounter while conducting a research study (Simon, 2011: 2). There was a lack of available published literature on some of the identified innovative techniques to control costs during the construction phase. It cannot be guaranteed whether responses received from the issued survey were honest.

1.8 SIGNIFICANCE OF STUDY

It is envisaged that research into the barriers to the use of innovative cost control techniques on construction projects in South Africa sheds light on the existing techniques being employed by construction organisations to control costs during the construction phase, and will assist policy makers, such as the cidb and government, in developing strategies to promote the adoption and standardisation of more modern cost control techniques in the infrastructure sector. Finally, it is perceived that this study provides the base as a guide for further exploration into innovative cost control system implementation in the construction industry.

1.9 STRUCTURE OF THE RESEARCH REPORT

Chapter One – Introduction: The introduction provides a background and the motivation for the study. The challenges being encountered in the construction industry with regards to poor cost control practices are deliberated on, in addition to the outlining of the research purpose and objectives to be realised.

Chapter Two – Literature Review: The literature review presents an expansion on, and provides further in-depth investigation into the research question and outlined problems.

Chapter Three – Research Methodology: The research methodology gives an insight into the approach utilised to examine the research objectives. Surveys are discussed, as well as various techniques to best achieve the study objectives.

Chapter Four – Data Presentation, Analysis and Discussion: This Chapter presents the outcome of the data collected, and serves the purpose of either completely backing or, to some degree, contesting the reviewed literature.

Chapter Five – Conclusion and Recommendations: The conclusion conveys a synopsis of the core findings of the dissertation and ascertains whether the study objectives have been fulfilled. The recommendations offer several propositions into enhancing and eliminating the cost control practices being implemented in the construction industry today.

1.10 SUMMARY OF THE CHAPTER

The chapter introduced the research topic and gave an insight into the poor cost control practices being experienced in the construction industry. The background to the research problem, aims and objectives to be achieved, the significance of the study, limitations encountered, and structure of the research report were provided. The study will evaluate the barriers to the use of innovative cost control techniques during the construction phase.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Chapter two will provide a review of the literature by identifying innovative cost control techniques being applied by construction organisations on projects. The chapter begins by highlighting the causes of cost overruns affecting construction projects. It then identifies the innovative techniques being implemented by construction firms on construction projects to control costs, and subsequently discusses the barriers hindering their usage in the industry.

2.2 LEVEL OF COST OVERRUNS IN SOUTH AFRICA

Cost control is the process of keeping track of the project's status to revise project costs and oversee amends to the project cost baseline (PMI, 2017: 257). The cost baseline is the sanctioned project budget without inclusion of any management reserves that will be used to approve and supervise current and future project cost performance (Khamidi et al., 2011: 125). The main advantage of this process is that a consistent cost baseline is achieved during the course of the project (PMI, 2017: 257). According to the Construction Industry Institute (1987: 6), cost control should be approached as an application of Pareto's Law, in which 80% of project outcomes are influenced by 20% of the incorporated elements. Therefore, in implementing a cost control system, the notion is to confine and oversee in detail to those elements that possess the greatest likelihood of impacting the final project cost. Cost control entails scrutinising the relationship between the consumption of the project budget and the activities being executed for these expenditures (Construction Industry Institute, 1987: 6).

The process of cost control entails overseeing changes in the project cost when and as they occur, supervision of work performance against the funds consumed and management of anticipated cost overruns within tolerable margins (PMI, 2017: 258). Supervision of cost performance is conducted to sequester and distinguish variances from the sanctioned cost baseline, ensuring that change requests are dealt with in a timely manner, and safeguarding that expenditures do not exceed the sanctioned project budget (PMI, 2017:258). Conventional tools used to control and monitor the cost performance of projects include Gantt charts, control charts and milestones. However, these techniques track progress only in terms of time, while the important dimension of project cost performance is fundamentally overlooked (Venkataraman and Pinto, 2008: 107).

Gaetsewe et al. (2015: 41) undertook a study to determine the perception among consultants and contractors of cost overruns and project delays in the Northern Cape in South Africa. Study participants attested to an estimated 65% of public construction projects being subject to exceeding their allocated project budgets and schedules in the province (Gaetsewe et al., 2015: 41). Material price escalations and poor construction planning were pinpointed as the major underpinnings to projects exceeding their budgets. Similarly, Mulalo et al. (2018: 1268) revealed that 56.67% of contractors and consultants perceived projects as having a high level of cost overrun in the South African construction industry. 30% of participants perceived the levels of cost overrun as being moderate. Poor planning practices, fluctuation of material prices, high bank interest rates, inflation and high labour costs were identified by respondents as the main causes of overruns (Mulalo et al., 2018: 1268).

Monyane and Okumbe (2012: 196) identified four projects in the Free State Province of South Africa and sought to assess their cost performance upon project completion. Cost overruns ranged between 11-64% across all four projects, and reasons for the poor cost performance included variation orders from the client, re-appraisal of work and extensions to the projects' schedules (Monyane and Okumbe, 2012: 196).

2.3 FACTORS CAUSING COST OVERRUNS

Time and cost needs are scrutinised throughout the project management cycle and are important criterion in safeguarding the success of infrastructure projects (Memon et al., 2011: 58). In-spite of their significance, it is commonplace for construction projects to fail at realising objectives within the specified time and allocated budget. These overruns materialise in most construction projects and vary in size from one project to the next (Memon et al., 2011: 58-59). Despite construction costs being reliant on material and labour sourced locally, they are swayed by the cost of materials, fuel, equipment and plant imported into the country, while costs in the country of manufacture of the aforementioned commodities are taken into consideration as well (cidb, 2017: 10). Windapo and Cattel (2013: 75) echoed similar sentiments, stating that factors such as manufacturing costs, special levies, transport, VAT (value added tax) and storage costs impact the cost of building materials. The fluctuating Rand has had an impact on imported commodities, such as fuel and equipment, and a weaker Rand translates to contractors having to pay higher rates for these commodities. From the period of 2005-2010, the Rand has depreciated by approximately 30% (cidb, 2017: 11).

Table 2.1 provides insight into the different causes of cost overruns in the construction industry based on previous publications. Change orders by clients, financial difficulties by contractor, late payments by clients to contractors, frequent design changes and poor project planning and preparation were identified as most frequent occurring cause of cost overrun in the construction industry. These past studies on factors causing cost overruns had only focused on conventional cost control techniques, and not on innovative cost control techniques.

Table 2. 1: Causes of cost overruns in construction.

CAUSE OF COST OVERRUN	SOURCE	NUMBER OF TIMES CITED
Change orders by client during construction.	Baloyi and Bekker (2011: 61); Khabisi et al. (2016: 1315); Ahady et al. (2017: 982); Enshassi et al. (2010: 54); Doloi (2013: 272); Niazi and Painting (2016: 516); Ramabodu et al. (2010: 138); Aljohani et al. (2017: 140); Bassioni et al. (2013: 146); Zunjarrao (2017: 474); Bekr (2015: 30).	11
Financial difficulties faced by contractor.	Enshassi et al. (2010: 54); Khabisi et al. (2016: 1315); Memon et al. (2011: 65); Doloi (2013: 272); Niazi and Painting (2016: 516), Aljohani et al. (2017: 141); Zunjarrao (2017: 474).	7
Late payments by clients to contractors.	cidb (2017b: 27); Niazi and Painting (2016: 516); Abusafiya and Suliman (2017: 26); Khabisi et al. (2016: 1315); Aljohani et al. (2017: 141); Zunjarrao (2017: 474); Bekr (2015: 30).	7
Frequent design changes.	Sweis et al. (2013: 139); Enshassi et al. (2010: 54); Khabisi et al. (2016: 1315); Ahady et al. (2017: 983); Abusafiya and Suliman (2017: 26); Memon et al. (2011: 65); Bekr (2015: 30).	7
Poor project planning and preparation.	Khabisi et al. (2016: 1315); Abusafiya and Suliman (2017: 26); Memon et al. (2011: 65); Doloi (2013: 272); Bekr (2015: 30).	5
Material cost increases.	Ahady et al. (2017: 983); Baloyi and Bekker (2011: 60); Windapo et al. (2018: 49); Sweis et al. (2013: 137); Doloi (2013: 272).	5
Inaccurate quantity take-off.	Khabisi et al. (2016: 1315); Baloyi and Bekker (2011: 61); Sweis et al. (2013: 137); Abusafiya and Suliman (2017: 26); Bassioni et al. (2013: 146).	5
Poor economic conditions (inflation, currency rates),	Enshassi et al. (2010: 54); Ahady et al. (2017: 983); Naveenkumar and Prabhu (2016: 6472); Niazi and Painting (2016: 516); Bekr (2015: 30).	5
Lack of experience.	Sweis et al. (2013: 137); Memon et al. (2011: 65); Khabisi et al. (2016: 1315); Aljohani et al. (2017: 141).	4
Shortage of skilled labour.	Ahady et al. (2017: 983); Baloyi and Bekker (2011: 60); Naveenkumar and Prabhu (2016: 6472); Bekr (2015: 30).	4
Inaccurate cost estimates/ insufficient project budget.	Abusafiya and Suliman (2017: 26); Memon et al. (2011: 65); Zunjarrao (2017: 474).	3
Changes to project scope.	Khabisi et al. (2016: 1315); Ramabodu et al. (2010: 138); Bekr (2015: 30).	3
Mismanagement of resources by contractor.	Doloi (2013: 272); Aljohani et al. (2017: 141); Zunjarrao (2017: 474).	3
Shortage of manpower/site labour.	Ahady et al. (2017: 983); Baloyi and Bekker (2011: 61); Abusafiya and Suliman (2017: 26).	3

Table 2. 1: Causes of cost overruns in construction (Cont'd).

CAUSE OF COST OVERRUN	SOURCE	NUMBER OF TIMES CITED
Incomplete design documentation at the time of tendering.	Ramabodu et al. (2010: 136-138); Abusafiya and Suliman (2017: 26); Bekr (2015: 30).	3
Poor coordination with project team.	Khabisi et al. (2016: 1315); Ahady et al. (2017: 983); Bassioni et al. (2013: 146).	3
Poor site management.	Abusafiya and Suliman (2017: 26); Memon et al. (2011: 65); Naveenkumar and Prabhu (2016: 6472).	3
Mistakes during construction.	Abusafiya and Suliman (2017: 26); Memon et al. (2011: 65); Bekr (2015: 30).	3
Project complexity.	Baloyi and Bekker (2011: 61); Doloi (2013: 272).	2
Late delivery of materials and equipment.	Memon et al. (2011: 65); Enshassi et al. (2010: 54).	2
Shortage of materials on site.	Enshassi et al. (2010: 54); Ahady et al. (2017: 983).	2
Shortage of equipment and tools.	Enshassi et al. (2010: 54); Sweis et al. (2013: 137).	2
Unrealistic contract duration.	Memon et al. (2011: 65); Bassioni et al. (2013: 146).	2
Low labour productivity.	Abusafiya and Suliman (2017: 26); Naveenkumar and Prabhu (2016: 6472).	2
Corruption.	Niazi and Painting (2016: 516); Ahady et al. (2017: 983).	2
Schedule delay.	Abusafiya and Suliman (2017: 26); Bekr (2015: 30).	2
Poor choice of project location/construction site.	Sweis et al. (2013: 139).	1
Increase in labour cost.	Baloyi and Bekker (2011: 61).	1
Harsh weather conditions.	Sweis et al. (2013: 137).	1
Difference between selected bid and the consultants' estimate.	Baloyi and Bekker (2011: 61).	1
Governmental approval delays.	Sweis et al. (2013: 139).	1
Inaccurate material estimates.	Baloyi and Bekker (2011: 60).	1

2.3.1 Change orders

In spite of the unlikelihood of project delivery without any variation in the construction phase, the long process for the refinement of design change orders negatively affects the cost and duration of a construction project (Aljohani et al., 2017: 140). Variation orders can impact the estimated budget and construction schedule of a project due to rework, delays and subsequent claims (Bassioni et al., 2013: 141). Bekr (2015: 31) supported this opinion, stating that design changes during the construction phase leads to the rework of already completed activities that in turn prolong the project duration and increases losses in construction materials.

2.3.2 Financial difficulties for contractors

It is commonplace for contractors to endure financial problems during the construction stage, as they typically pay for work and receive progress payments from clients after completion of sections of the project or the entire project (Aljohani et al., 2017: 141). It is therefore crucial for contractors to have sufficient funds available to permit the undertaking of projects (Aljohani et al., 2017: 141). Niazi and Painting (2017: 516) echoed these sentiments, stating that the availability of liquid assets and financial capabilities of a contractor play a significant role in the completion of projects within stipulated time and cost. Cash flow difficulties for the contractor cause problems such as slow construction progress and declined productivity levels (Enshassi et al., 2010: 52). It renders the contractor unable to acquire much needed equipment for ongoing work, as well as impacting relationships with traders and suppliers (Enshassi et al., 2010: 52). Inevitably, reduced productivity will lead to project delays (Enshassi et al., 2010: 52) and incurrence of financial penalties (Aljohani et al., 2017: 141).

2.3.3 Delayed progress payments by the client

Delayed progress payments by clients is not only a critical factor that causes cost overruns in most countries, but can be a frequent, significant cause of project completion delays (Niazi and Painting, 2017: 516). It makes it difficult for contractors to meet project objectives due to their typically small cash reserves (Aljohani et al., 2017: 141). According to the cidb (2017b: 27), contractors pay high interest rates on bank loans due to their high-risk perception by commercial banks. Consequently, payment delays by clients to the contractor impacts their cash flow, rendering them incapable of servicing bank loans, and negatively affects their credit score (cidb, 2017b: 27). Untimely payments not only consume the time and money reserves of the contractor, but moreover cause a breakdown in the relationship between the two parties as a degree of trust is lost (Aljohani et al., 2017: 141). They increase project costs, as contractors are pushed to amend overhead costs to cover risk of payment delays.

2.3.4 Frequent design changes

The frequent occurrence of design changes has an effect on the estimated project budget with consequential results not only for the work package in which the change was directed but to successive work packages and overhead functions as well (Abusafiya and Suliman, 2017: 26). These changes present a delay to the project schedule, as they have to be reviewed and approved by the client (Aljohani et al., 2017: 140). Any modifications to the project design will have an effect on the initial project budget, the type and volume of construction materials needed and labour requirements (Bekr, 2015: 31).

2.3.5 Poor planning

Poor project planning during the design phase is a significant source of cost overrun, as it leads to a lack of clarity in the scope of works, an ambiguous design brief, an inadequate period for design coordination, the fast tracking of projects, variation orders and changes to the scope of works (Gaetsewe, 2015: 41). Consultants are either pressured into producing project documentation or they do not assign adequate time for the preparation of the documentation (Monyane and Okumbe, 2012: 195). The adeptness of the project manager in controlling and overseeing to the project baseline is dependent on competent reporting and feedback procedures (Doloi, 2013: 274).

2.3.6 Increasing material costs

The project manager and project team have little control over the prices of construction material, and this inherently remains a substantial risk and threat to any construction project (Baloyi and Bekker, 2011: 62). However, Doloi (2013: 276) stated that the control of the escalation of material prices is dependent on adept management of the procurement schedule and preparation of purposeful contract agreements with suppliers. Contractors often create their tender estimates according to present prices at local markets (Enshassi et al., 2010: 55). Given that the tender awarding process may take a variable amount of time, this increases the likelihood of price fluctuations of commodities such as materials. In the case of higher prices, the contractor faces the prospect of a high cost overrun during the construction phase (Enshassi et al., 2010: 54).

2.3.7 Lack of experience

The complexity of projects is becoming more common in the construction industry, exerting pressure on contractor expertise and the project duration (Aljohani et al., 2017: 141). The lack of experience by contractors in managing projects may lead to several problems, such as schedule delays and wastage of construction material, ultimately increasing project costs (Memon et al., 2011: 67). The likelihood of rework components increases, as unfamiliarity of project type or locations raises the cost of implementing projects (Aljohani et al., 2017: 141).

2.3.8 Insufficient project budget

The estimation of a project budget is an intricate exercise and, despite gradual improvement of techniques over the years, they remain imperfect (Aljohani et al., 2017: 141). Due to the inherent uncertainty of construction projects, contractors and clients become well versed about particular material and technological requirements of project undertakings once a project shifts from the design stage to the execution stage (Aljohani et al., 2017: 141). Consultants are typically the parties that generate evaluations of the amount of work to be undertaken and the budget of projects by using government price listings as a contractual basis for tenders (Heravi and Mohammadian, 2017: 35). Any misjudgement of the project scope and/or the amount of work by consultants will result in the actual final cost being potentially higher than the estimated cost (Heravi and Mohammadian, 2017: 35). Therefore, considering that time and cost underestimation is prevalent on construction projects in the tendering phase, delays and cost overrun is common (Heravi and Mohammadian, 2017: 35). A profuse number of construction organisations have engineers with deficiencies in understanding cost and value, and the consequential cost implications associated with the project design, and estimators being unfamiliar with estimating processes (Abusafiya and Suliman, 2017: 26). In some instances, some firms purposely include impractically low allowances to safeguard the attractiveness of their bids (Abusafiya and Suliman, 2017: 26).

2.3.9 Project complexity

The increasing complexity of design and constructability of modern projects makes it critical for the most ideal construction methods to be selected by contractors (Doloi, 2013: 271). The choice of contemporary techniques and methods that correspond with the complexity of construction site activities is important for the management of cost overrun (Doloi, 2013: 274). The performance of a contractor is typically assessed according to their ability to conform to cost, time and quality parameters set from the outset of the project (Doloi, 2013: 271). Inability by the contractor to grasp the project design and specifications of a project will lead to an inefficient construction process and poor productivity during the execution phase (Doloi, 2013: 271). Potential disputes may arise among project parties, consequently increasing the project cost. Changes made to a project's design could be due to the project's inherent complexity and uncertainty (Aljohani et al., 2017: 140).

2.3.10 Poor site management

According to Enshassi et al. (2010: 52), mismanagement on the construction site leads to constraints such as poor control and monitoring of projects, poor follow up on site progress, employees not being fully committed and an inaccurate distribution of works. These constraints also contribute to schedule delays (Enshassi et al., 2010: 52). Appropriate distribution of project resources and optimised use by contractors has a substantial effect on construction cost (Doloi, 2013: 276).

2.4 COST CONTROL TECHNIQUES

The innovative cost control techniques to be reviewed in this research report shall be Earned Value Analysis, the Last Planner System, 4D Scheduling, Fuzzy Scheduling, Line of Balance and Reserve Analysis.

2.4.1 EARNED VALUE ANALYSIS

Earned Value Analysis (EVA) is an integrated programme management tool that monitors the intricate interaction between project cost and time parameters to impart valuable feedback to management (Kenley, 2005: 105), and creates a comparison between the performance measurement baseline to that of the project schedule and cost performance (PMI, 2017: 261; Suresh and Ramasamy, 2015: 1080; Kenley, 2005: 130). The construction industry uses the technique as a time and cost control tool for the amalgamation of planning and management functions (Khamidi et al., 2011: 125). Subsequently, this analysis assists in establishing a standard for performance appraisal and oversees the time and cost constraints. Additionally, critical activities can be distinguished and dealt with during the course of the project (Suresh and Ramasamy, 2015: 1080).

Individual control of the project cost and schedule is susceptible to misinterpretation and, if managed separately, does not disclose an accurate measure of project performance, as it is possible to be aligned with the budget and yet not perform at a rate satisfactory to meet project schedule expectations (Kim and Ballard, 2000: 2; Kenley, 2005: 105-106). Khamidi et al. (2011: 125), Ratsiku and Musonda (2015: 6) and Venkataraman and Pinto (2008: 112) shared a similar opinion, stating that the integration of time and cost in EVA affords a more transparent understanding of project performance. The technique was developed by managers who realised that increased project complexity and proliferating management systems necessitated a justifiable degree of standardisation (Kenley, 2005: 131). It therefore serves a dual-purpose performance management system and as a mechanism of standardisation of the administration process (Kenley, 2005: 131). EVA is an improvement over more conventional accounting progress measures, as traditional methods put emphasis on planned expenditures and actual costs while EVA takes things further by examining actual project accomplishments (Suresh and Ramasamy, 2015: 1082; Ratsiku and Musonda, 2015: 5). This affords greater anticipation to potential risk pitfalls by project managers, thereby enabling them to develop appropriate risk mitigation plans based upon definite cost, schedule and technical progress of construction work (Suresh and Ramasamy, 2015: 1082).

According to Venkataraman and Pinto (2008: 114), earned value entails two key fundamentals: the Work Breakdown Structure (WBS) and a time phased budget for each respective work package. The WBS makes provisions in a hierarchical framework for information pertaining to individual tasks to be accomplished on the project and specific work packages. The WBS enables human resources to be allocated to match task requirements, and the project network developed from this data establishes the appropriate sequencing of tasks to be determined and provides the support to developing a time phased budget (Venkataraman and Pinto, 2008: 114). The establishment of a time phased budget enables the project team to distinguish the timing of budget expenditures that are mandatory to complete individual tasks.

2.4.1.1 Eva framework

EVA follows a three-dimensional approach consisting of Planned Value (PV), Earned Value (EV) and Actual Cost (AC). When a project is planned, it is broken down into WBS and further subdivided into smaller work packages (Padalkar and Gopinath, 2015: 2). Cost estimates and schedules are determined and attached to these work packages, from where they are subsequently grouped together in a way that allows the cost budget, master schedule and WBS to create the baseline of the project, representing the PV (Padalkar and Gopinath, 2015: 2). The PV is the authorised budgeted cost allocated to the scheduled project work, and represents the portion of the planned project budget to be spent at any given period of time, distributed by phase during the course of the project (PMI, 2017: 260; Khamidi et al., 2011: 126). The EV is the budget associated with the authorised work to be completed. It is typically used to determine the percentage completion of construction projects by assigning performance measuring criteria to each WBS component to appraise work progress (PMI, 2017: 261). The AC is the sum of direct and indirect costs incurred for work performed on project activities during the course of a given period. The EV appraises the summed-up cost of completing work (PMI, 2017: 261; Suresh and Ramasamy, 2015: 1080).

2.4.1.2 Eva performance indices

Project Managers can determine any project deviations from the plan and apply early corrective measures by monitoring performance indices (Najafi and Azimi, 2016: 67). These indices are elaborated on in Table 2.2 with a more detailed description and interpretation of each.

Table 2. 2: The performance indices associated with EVA.

DESCRIPTION	EQUATION	INTERPRETATION
Cost variance (CV) CV is the budget surplus or shortfall of a given period in the project cycle, expressed as the difference between the EV and AC, and represents the cost performance of a construction project. Once the project has been concluded, the CV will be the difference between the project budget at completion and that of the sum expended. The CV plays an important role in showcasing the relationship between a project's physical performance to that of costs incurred (PMI, 2017: 262; OAPM, 2014: 21).	CV=EV-AC	• If the CV value falls into the negative (CV<0), this means that the project budget has been exceeded, and it will prove problematic for the project to recover (Najafi and Azimi, 2016: 67). • If the CV has a positive value (CV>0), the project falls under the budget (Najafi and Azimi, 2016: 67).
Schedule variance (SV) The SV represents the schedule performance of projects. It is the difference between the EV and PV and measures the amount of time a project is ahead of or lagging behind its scheduled delivery date at a given time. The EVA SV serves the important role of revealing if a project is ahead of or behind the baseline schedule. SV is to be incorporated with schedule analysis to determine the true project schedule status (PMI, 2017: 262; OAPM, 2014: 20).	SV=EV-PV	• The SV value will eventually be equal to zero once the project has concluded, given that all planned values would've been earned (PMI, 2017: 262). • The SV metric must not be mistaken for an ahead of schedule or lagging in schedule parameter due to the availability of various EV calculation techniques but should rather be used as a routine indicator of schedule performance. It must be used in combination with schedule analysis to establish true project status (OAPM, 2014: 20).
Schedule Performance Index (SPI) The SPI is an interpretation of schedule efficiency denoted as the ratio of EV to PV. It is a measure of how effectively the project team is executing work activities. Occasionally, it is used hand in hand with the cost performance index (CPI) to predict final project completion assessments (PMI, 2017: 263).	SPI=EV/PV	• A SPI value greater than 1.0 indicates that the planned quota of work activities for a specific period is on par or ahead of schedule. • A SPI less than 1.0 indicates that the planned project work has not been fulfilled and is behind schedule. An index value less than 0.95 is used as a precautionary measure to indicate schedule slippage (OAPM, 2014: 26).
Cost Performance Index The CPI represents the cost efficiency of the budgeted project resources denoted as the ratio of EV to AC. It is regarded as the most significant EVA metric and assesses the efficiency of completed work (PMI, 2017: 263).	CPI=EV/AC	• A CPI value of 1.0 higher indicates that the work completed is equal to or below the original allocated budget. • A CPI value less than 1.0 indicates that the work completed has experienced cost overruns due to exceeding the original allocated budget (OAPM, 2014: 29).

2.4.1.3 EVA process

Venkataraman and Pinto (2008: 117-118) submit that the EVA process comprises of five steps. These are briefly explained accordingly in Table 2.3.

Table 2. 3: EVA process.

STEP		DESCRIPTION
1	Give a distinct definition of each project task, its necessary resources and a comprehensive budget for the task.	The WBS permits the project team to identify project activities and resources to be assigned to each particular task, including costs for plant and equipment, materials and personnel assignments. From the activity breakdown and resource allocations, cost estimates for respective project activities can be produced.
2	Generate schedules for project activities and usage of resources.	This step distinguishes on an interval basis the proportion of the total project budget assigned to each activity as well as resources to be used up during the project development cycle. This process establishes a direct link between the project schedule and budget.
3	Generate a time-phased budget.	The information gathered from step two enables the expenditures throughout the lifecycle of the project to be determined. The PV can be distinguished from this information, which serves as the project baseline. The PV will aid in determining the cumulative budget expenditure planned during any phase of the project development cycle.
4	Determine and aggregate the actual costs incurred for each project activity being executed.	The aggregate actual costs of executing a project activity outlines the actual cost of work performed. Furthermore, budgeted values for activities being executed can be computed.
5	Calculation of cost and schedule variances during the project's progression.	The PV, EV and AC information collected from the prior steps will be used to compute the cost and schedule variances while the project is ongoing. Any deviations of the schedule from the original PV will be attributed to the EV.

Source: Venkataraman and Pinto (2008: 117-118).

2.4.1.4 Disadvantages of EVA

Table 2.4 shows that the disadvantages of EVA include its inadequacy as a cost collection system, potential influence on results by management, the lack of cost control monitoring, a high level of requirements needed to execute the technique and an insufficiency of project indicators.

Table 2. 4: Disadvantages of EVA.

DISADVANTAGES	SOURCE	NUMBER OF TIMES CITED
Inadequate cost collection system as EV will not function unless accurate actual costs of the project are obtained.	Lukas (2008: 9), Mahdi et al. (2018: 56, 61), Pillay and Steyn (2013: 117).	3
There is potential managerial influence and/or control when reporting EV results.	Lukas (2008: 10).	1
Project managers do not generally monitor costs. Inaccuracy and poor timeliness of the costing system.	Gershon (2013: 13).	1
High level of requirements to learn and execute. High cost and time requirement to implement.	Zulkefli et al. (2017: 343).	1
Lack of support from top levels of management	Pillay and Steyn (2013: 113)	1
Insufficiency of project indicators and quality of construction. There is an overestimation of progress measurement based on cost.	Cândido et al. (2014: 167, 168).	1

2.4.2 THE LAST PLANNER SYSTEM

The Last Planner System (LPS) originated in the early 1990s as a project production control system, which was thought of as the missing element in the project management toolkit domineered by project controls (Ballard and Tommelein, 2016: 4). Project controls serve the purpose of establishing schedule and cost objectives in alignment with the scope of the project, along with overseeing the progression of the target achievements (Ballard and Tommelein, 2016: 4). Despite being developed over 20 years ago, the LPS remains generally unknown and misunderstood in parts of the engineering world (Cwik and Roslon, 2017: 2). It comprises of simple tools and new adaptations that afford the ideal solution for design and construction processes, and allows project managers to enhance project quality while meeting client expectations (Cwik and Roslon, 2017: 2). The last planner is the individual or group responsible for work undertaken by a production unit (Koskela et al., 2010: 539). This last planner plays the role of coordinating the actions of parties participating in the project to deliver project objectives (Ballard and Tommelein, 2016: 22).

According to Ballard and Tommelein (2016: 7), LPS serves the function of stipulating what tasks are to be undertaken and by which personnel: from milestones to phases between milestones; to practices within phases; to activities within processes. It assists with the scheduling and planning of tasks in order to realise project objectives and determines the specific project activities to be undertaken for day to day and weekly work plans (Ballard and Tommelein, 2016: 7). LPS enables the reliable release of work between specialists and the capability of discerning the current and future states of projects, in addition to learning from failures in order to successfully implement design and construction tasks (Ballard and Tommelein, 2016: 7).

According to Pellicer et al. (2015: 4878), the planning and control of LPS can be summed up in seven stages as shown in Table 2.5.

Table 2. 5: The seven stages of LPS.

STAGE	DESCRIPTION
1	The construction site manager (first planner, at times) develops the initial schedule by analysing the design of the project and contract.
2	A pull session (meeting) is held between the construction site manager and the last planner to review the construction schedule. The outcome of this meeting yields an approved master plan. This schedule may be circulated to stakeholders if necessary.
3	A look-ahead plan is developed from the master plan by the construction site manager. This details activity constraints and proposes the necessary means to avert them. It enhances the construction workflow.
4	The weekly plan is generated after every seven days with contributions made from last planners. It details work assignments to be undertaken for the following week.
5	In the midst of the weekly meeting, the compliance of the weekly plan is assessed by the last planners and possible reasons for non-compliance are identified.
6	The weekly results are publicised on the construction site, pointing out the performance of each respective party involved for each task concerned. Publicising the results, whether positive or negative, is a contributing factor in fortifying the commitment of last planners.
7	Every step in the process is documented and generates feedback to update the master plan with lessons being learned.

Source: Pellicer et al. (2015: 4878).

2.4.2.1 LPS integrated elements

The LPS concept comprises of five distinct integrated elements; the master plan, phase planning, lookahead planning, weekly work plan and percent plan completed. When executed systematically in practice, these elements bring about several advantages and add significant benefits to construction processes (Lean Construction Institute, 2007: 7). The master schedule describes the milestone level of project planning specific to the phases of a project (Lean Construction Institute, 2007: 7). It identifies all work packages for the entire project, as well as highlighting on major activities, their duration and sequence of implementation (Koskela et al., 2010: 539; Stratton et al., 2010: 3)

Phase planning involves partitioning the master schedule into numerous phases directed toward developing more comprehensive work plans, and establishes objectives that can be targeted by the project team (Koskela et al., 2010: 539; Stratton et al., 2010: 3). The significance of phase scheduling is to generate a plan for executing a phase of work that maximises value generation that is understood and supported by project participants involved (Lean Construction Institute, 2007: 11). Participants in phase scheduling are representatives of those who have activities to execute in the phase, such as the general contractor, sub-contractors and stakeholders such as clients and designers (Lean Construction Institute, 2007: 7). Lookahead planning entails focusing management attention on prepping tasks to be undertaken when the right time comes (Koskela et al., 2010: 539; Stratton et al., 2010: 3). The objective of this process is to limit uncertainty and determine and eradicate constraints that stand as obstacles during the lookahead period, which typically varies from 4-8 weeks (Stratton et al., 2010: 3). Ballard et al. (2002: 231) stated that lookahead windows could be briefer or lengthier depending on the swiftness of the project and lead times for construction materials, services and information. The lookahead window influences how far in the scheduled start date tasks from the master schedule are considered for input into the lookahead (Lean Construction Institute, 2007: 15). Long lead items are items unable to be incorporated into the lookahead window and, therefore, extending the window affords the ability for better control of the workflow (Ballard et al., 2002: 231). Lookahead planning assesses and acclimatises project budgets and schedules, drawing resources into action and screening tasks for which resources may be unavailable (Lean Construction Institute, 2010: 13). It controls and consolidates the workflow for the last planner. Upon a task being entered into the lookahead, the onus falls on the planner to prep the tasks for execution according to the scheduled time (Lean Construction Institute, 2007: 14-15).

Entry into the lookahead is controlled by explosion, screening and making ready (Lean Construction Institute, 2007: 15). Explosion entails breaking down tasks from the master schedule into greater detail to enable the last planner to screen task constraints (Hamzeh et al., 2012: 26). Screening identifies the status of activities in the lookahead window according to their constraints. Screening tasks eliminates those with absent prerequisites, such as directives, materials, information or manpower (Hamzeh et al., 2012: 26; Lean Construction Institute, 2007: 19). Making ready ensures reduced time, materials or equipment wastage by guaranteeing that tasks are ready for production purposes when required (Stratton et al., 2010: 3). Pulling involves taking action to eliminate task constraints to render them sound and ready for assignment in the weekly work plan by the last planner (Hamzeh et al., 2012: 26; Lean Construction Institute, 2007: 26).

Weekly work planning, also known as commitment planning, comprises of the highest level of detail before subsequently undertaking work (Hamzeh et al., 2012: 19). It showcases the link between the works of different specialist organisations and drives production procedures (Hamzeh et al., 2012: 19). Through committing only to work that can be implemented, the last planner shields production units from experiencing variability and uncertainty in upstream operations (Lean Construction Institute, 2007: 34). Shielding creates quality assignments, thereby improving the reliability of the last planner's weekly work plans as an alternative approach to construction workflow uncertainty (Hamzeh et al., 2012: 19). Execution of the last planner procedure therefore leads to a more reliable workflow, which enhances performance not only for weekly work plan implementation, but for production units downstream, in addition to improved planning whenever work is released (Hamzeh et al., 2012: 19; Lean Construction Institute, 2007: 34).

Percent Plan Completed (PPC) entails improving the project planning process through continued evaluations and learning lessons from failures (Koskela et al., 2010: 539). It measures workflow reliability, which is a LPS metric, assessing the extent to which a current commitment plan meticulously forecasts the state of a project at the beginning of the next planning period (Ballard and Tommelein, 2016: 40). Predictable work releases are typically tracked weekly, and the PPC makes a comparison between activities that were executed against those in the weekly work plan for that particular week. The PPC is calculated at the end of the planning period as a percentage of executed activities relative to those planned at the beginning of the week (Koskela et al., 2010: 540; Ballard and Tommelein, 2016: 20). Once the PPC has been calculated, it is important to identify reasons for failure, and to trace these reasons back to root causes that can be eradicated to avoid repetitions in future (Stratton et al., 2010: 4). Over a period of time, the PPC statistics pinpoint where further attention must be paid to attain improved results that can consequently improve learning processes in the project period (Stratton et al., 2010: 4).

2.4.2.2 Benefits of using LPS

Table 2.6 highlights the benefits afforded by the implementation of LPS on construction projects.

Table 2. 6: The benefits of using LPS in construction.

	BENEFITS	DESCRIPTION
1	LPS assists in stabilising project-based production systems.	LPS was developed explicitly for improving the planning and predictability of complex and ambiguous projects. Increased predictability enables easier integration of sub-assemblies fabricated off-site. This consequently minimises the number of project personnel required on-site and accelerates construction processes (Mossman, 2015: 4; Hussein et al., 2017: 2843).
2	LPS enables better proactive control of projects.	Project control in conventional project management typically revolves around catching things once they have gone wrong, such as the project team failing to meet programme deadlines. LPS is more proactive than reactive and focuses on making things happen by ensuring that tasks can be successfully implemented when planned. Planning and control system performance are assessed and improved with the view to manage and enhance project performance (Mossman, 2015: 5; Bhargav et al., 2015: 2).

Table 2. 6: The benefits of using LPS in construction (Cont'd).

	BENEFITS	DESCRIPTION
3	LPS supports good relationships.	Construction is a social process and LPS oversees construction workflow by establishing conversations and safeguarding an obligation to act at the precise time throughout construction processes. This helps build relationships and trust between project participants. Construction work is controlled through a system of production relationships that advocate for the delivery of projects in a timely fashion (Mossman, 2015: 5; Bhargav et al., 2015: 2).
4	LPS shortens waiting times.	LPS reduces waiting times by ensuring that necessary project requirements are in place before an activity is due to be executed. The waiting on materials, design information, plant and equipment are significant sources of waste and ambiguity and lead to disgruntlement among project participants (Mossman, 2015: 5; Hussein et al., 2017: 2843; Bhargav et al., 2015, 2).
5	LPS shortens the project duration.	The shortening of waiting times subsequently shortens the project duration. Cultivating synergy through the collective programming of project phases typically shortens the construction programme by 20% in comparison to that projected by first planners (Mossman, 2015: 5; Bhargav et al., 2015: 1).
6	LPS oversees conflicting objectives.	Projects encounter conflicting objectives, and trade contractors have distinct inclination to optimise personnel across several projects. The main contractor and project team seek to optimise the project delivery process, and controlling this complexity requires an elevated level of collaboration and communication. Traditional project management tools that only utilise CPM are insufficient, as they centre on only one of the flows, prior work (Mossman, 2015: 6; Hussein et al., 2017: 2843).
7	LPS reduces contractor costs.	LPS is an asset to site foremen as it improves their managerial skills, thereby freeing up senior management time. Site supervisors can plan weekly work activities and determine team performance daily. This enables them to predict the amount of labour required on a weekly or daily basis. Site foremen are capable of dealing with scenarios as they surface because decisions are based off facts reported on a weekly basis (Mossman, 2015: 8).
8	LPS conveys bad news promptly.	LPS anticipates bad news early before it escalates, thereby making it easier to minimise the impact and for corrective action to be implemented (Mossman, 2015: 8-9).

2.4.2.3 Disadvantages of LPS

Table 2.7 shows that the disadvantages of LPS include cultural barriers and the lack of transparency between project personnel, the lengthy client approval processes during the planning and controlling of projects, a lack of collaboration by project participants afforded by the system, the poor integration and coordination of work plans by project participants, and the tedious nature in planning and controlling the schedule due to the number of participants involved.

Table 2. 7: Disadvantages of LPS.

DISADVANTAGES	SOURCE	NUMBER OF TIMES CITED
There are cultural barriers and lack of transparency between project personnel (e.g. language).	Khanh and Kim (2013: 8), Cerveró-Romero et al. (2013: 715-716), Hussein et al. (2017: 2841).	3
Lengthy client approval processes during the planning and controlling of projects.	Khanh and Kim (2013: 9), Porwal et al. (2010: 553), Hussein et al. (2017: 2841).	3
There is a lack of collaboration by project participants afforded by the system.	(Porwal et al., 2010: 553), Hussein et al. (2017: 2841), Dave et al. (2015: 5, 7).	3
Poor integration and coordination of work plans by clients, contractors, suppliers.	Cerveró-Romero et al. (2013: 715-716), Khanh and Kim (2013: 8)	2
Planning and controlling the schedule is more tedious due to the significant number of project participants involved.	Khanh and Kim (2013: 9), Porwal et al. (2010: 553).	2
There is ambiguity in planning accountability.	Dave et al. (2015: 7), Cerveró-Romero et al. (2013: 715-716).	2
Poor understanding of the last planner concept by practitioners.	Khanh and Kim (2013: 9), Porwal et al. (2010: 553).	2
There is ambiguity in roles and responsibilities for core staff. It requires planning and for organisations to continuously train sub-contractors during the construction period.	Cerveró-Romero et al. (2013: 715-716).	1
There is lack of leadership, stakeholder support, commitment by top management.	(Porwal et al., 2010: 551- 553).	1
Poor supervision and quality control.	Hussein et al. (2017: 2841).	1
There is Inadequate standardisation of training material. There is inconsistent and incomprehensive IT support for LPS.	Dave et al. (2015: 7-8).	1
LPS does not take production rates into consideration.	Seppanen and Aalto (2005: 272).	1

2.4.3 4D SCHEDULING

According to Malsane and Sheth (2015: 54), the lack of progression in the construction sector can be attributed to the fragmented nature of traditional project delivery, which uses 2D Computer Aided Drafting (CAD) technology. The roles and responsibilities of project participants during the design and construction stages of a project are fragmented by the traditional project delivery method, as it hinders collaboration among contractors, construction managers and consultants. The use of 2D CAD drawings is inadequate to maximise collaboration among project participants (Malsane and Sheth, 2015: 54).

Engineers and architects typically generate fragmented CAD drawings for clients and contractors that lack cost and schedule integration and typically pose problems resulting in errors, project delays and complexity (Malsane and Sheth, 2015: 54). Setbacks to the construction schedule can cause imminent delays in project delivery and, as a result, several attempts have been enforced to develop scheduling in construction projects (Malsane and Sheth, 2015: 54). The 4D scheduling concept has existed for over 20 years but developing 4D schedules remained a challenge in the early years due to technological difficulties stemming from the generation of 3D models from 2D drawings, and in associating these CAD elements to real schedules (Basu, 2007: 1). However, advancements in technology are now making the case for 3D CAD elements to be the norm (Basu, 2007: 1). Off the shelf software such as Microsoft Project and Primavera develop effective 4D schedules and make it easier linking schedule packages to schedule outputs (Basu, 2007: 1).

2.4.3.1 BIM

An attempt that has revolutionised the construction industry is the introduction of Building Information Modelling (BIM) in construction planning (Ahankoob et al., 2012: 166). EUBIM (2017: 4) define BIM as a digital form of construction that draws together technological tools, digital representations and process improvements to enhance client and project outcomes. BIM assists in improved strategic decision making for infrastructure throughout the entire project cycle and is applicable to renovations, new builds and refurbishment of the built environment (EUBIM, 2017: 4). BIM technology has significant benefits for the infrastructure industry as it provides better cost control and reduces project duration (Eastman et al., 2008: 207). Modelling and simulation of construction processes has become commonplace in organisations external to construction, as they aid in eliminating project risk pertaining to cost, time and quality (Melzner et al., 2017: 185). The application of BIM is trending in the infrastructure sector as it promotes collaboration and information flow that subsequently leads to increased productivity and reduced project-related risk. Unlike traditional 2D drawings and schedules, BIM uses 3D enabled information models that comprise of a valuable set of properties that offers applications such as clash detection and visualisation of construction sequences (4D scheduling) (Melzner et al., 2017: 186). Conventional scheduling tools thrive in project level planning; however, they are incapable of easily generating solid lookahead and commitment schedules (Ahankoob et al., 2012: 167). Current CPM-based scheduling techniques lack the ability to track the information required or resource availability for each project activity (Ahankoob et al., 2012: 167).

2.4.3.2 4D schedule

4D scheduling challenges and alters numerous processes associated with traditional scheduling and does not only attach CAD elements to a conventional schedule, but also compels the scheduler to think distinctively and regulate the manner in which schedules are generated (Basu, 2007: 3). Gantt charts have typically been used as representation tools for project planning, but they lack a visualisation dimension of the project schedule and do not take into consideration spatial conditions and project specific quantities, with the onus falling on the schedulers' personal experience to safeguard the quality of the final schedule (Malsane et al., 2015: 56; Melzner et al., 2017: 187). Kassem et al. (2012: 1-2) shared a similar opinion, and stated that, given the significance of the project schedule to the implementation and control phases, sub-contractors, overall project cost and duration, they are typically developed by project managers with the drawings, specifications, contract documents, personal experiences and instinct. BIM construction planning tools extend beyond the conventional scheduling chart and make provisions for direct links to the design model to secure spatial data, which allows for an improved understanding and communication of the project schedule (Ahankoob et al., 2012: 166).

4D BIM tools allow for an improved quality control process by construction managers through the simulation of construction schedules that visually communicate and examine project tasks that, in turn, help to reduce delays and sequencing issues (Malsane et al., 2015: 56-57). BIM affords schedulers the capabilities of creating, editing and reviewing 4D models periodically, subsequently leading to the execution of higher quality and satisfactory project schedules (Eastman et al., 2008: 225). More modernised 4D scheduling approaches are automated and fuse 3D models with project schedules by linking the BIM model to process patterns and a topological structure, ensuring a consistent schedule of high quality and detail (Melzner et al., 2017: 187). Most project schedules are represented as Gantt charts and tend to be difficult to understand in the case of larger projects, as the comprehension of dependencies between independent activities is indistinctive (Melzner et al., 2017: 185-187).

2.4.3.3 4D modelling

Hartmann et al. (2012: 609) described 4D models as BIM-based applications that integrate project schedules with 3D representations of the project design and grant project managers the ability to visualise construction processes in time throughout all stages until completion. The layout of the construction site can be viewed at any point in time (Eastman et al., 2008: 18). Ahankoob et al. (2012: 168) stated that in addition to being a powerful communication and visualisation tool, 4D models provide greater insight into project milestones and construction processes. These models are inclusive of planning information, such as the commencement date for project component execution and assessing their level of criticality and slack. They present an instinctive interface between stakeholders and the project team to envision the assembly of a structure over a given period (Ahankoob et al., 2012: 168).

Contractors can simulate and evaluate prepared construction sequences with 4D CAD tools to present to the project team (Eastman et al., 2008: 215). Contractor knowledge is pivotal in the defining of a building model, as the contractor bears the responsibility for creating the model while the building design is in progress; from which accelerated feedback to estimate constructions costs, constructability and sequencing can be determined (Eastman et al., 2008: 215). The graphical simulation provides a substantial insight into daily construction activities, uncovering potential pitfalls and improvements that can be made (health and safety, site, plant and equipment, space availability issues) (Eastman et al., 2008: 18-19). Paper-based documentation does not offer this type of analysis. Table 2.8 describes the information provided by contractor building models that includes detailed building information, temporary components, specification information associated with each building component, analysis data related to performance levels and project requirements, and design and construction status.

2.4.3.4 4D scheduling benefits

Table 2.10 shows that the various benefits afforded by 4D scheduling to construction firms are visual communication, stakeholder collaboration, revelation of spatial constraints, schedule comparison and construction progress monitoring.

Table 2. 8: Information provided by building models.

INFORMATION PROVIDED	DESCRIPTION
Detailed building information.	This information provides graphical perspective of a building's components comparable to those showcased in construction drawings, along with capability of drawing out quantity and properties of components.
Temporary components.	Information pertaining to formwork, equipment and other components integral to planning and sequencing activities.
Specification information associated with each building component.	Information detailing textual specifications for all components to be purchased or constructed by the contractor.
Analysis data related to performance levels and project requirements.	Information inclusive of structural loads, cooling and heating loads for Heating Ventilation and Air Conditioning (HVAC) systems, luminance level targets etc. This information is purposeful for fabrication and Mechanical Electrical and Plumbing (MEP) detailing.

Table 2.8: Information provided by building models (Cont'd).

INFORMATION PROVIDED	DESCRIPTION
Design and construction status.	Information detailing the status of components and to monitor and control the progress of components pertaining to project design, procurement and installation.

Source: Eastman et al. (2008: 212).

2.4.3.5 Disadvantages of 4D scheduling

Table 2.9 shows that the disadvantages of 4D scheduling include an insufficiency of skilled professionals to enforce the technique, high software; hardware; time; and training requirements, unavailability of contractual requirements for BIM execution, poor demand by clients, and poor understanding of the business value of BIM by organisations.

Table 2. 9: Disadvantages of 4D scheduling.

DISADVANTAGES	SOURCE	NUMBER OF TIMES CITED
Lack of experienced and skilled professionals to enforce the technique	Ahmed et al. (2014: 537), Malacarne et al. (2018: 141), Kassem et al. (2012: 6-7), Romigh et al. (2017: 402).	4
There are high software, hardware, time and training costs required to implement the technique.	Kassem et al. (2012: 8), Kim et al. (2016: 50), Romigh et al. (2017: 397)	3
Unavailability of contractual requirements for BIM execution; there is an ambiguous return on investment with the technique; and there is limited BIM knowledge.	Ahmed et al. (2014: 537).	1
Poor understanding of the business value of BIM by organisations; there is a lack of contract type to promote its adoption; significant time and cost involved to implement the technique; and there is limited integration and collaboration between stakeholders.	Kassem et al. (2012: 5-7).	1
Lack of demand by clients; unsuitability with standard methods of measurement; and a lack of quality data sets.	Kim et al. (2016: 50, 55, 59)	1

Table 2. 10: The benefits of using 4D scheduling.

BENEFITS	DESCRIPTION
Visual communication.	4D simulations allow planners to visually communicate planned construction processes to stakeholders (Basu, 2007: 2; Swallow and Zulu, 2019: 8; Malacarne et al., 2018: 140, 147). Non-technical senior stakeholders that typically greenlight the projects get an understanding of the project scope, the expected times for project completion and manner in which current operations are likely to be impacted by construction activities (Basu, 2007: 2).
Collaboration of stakeholders.	It is commonplace for 4D models to be used in communities as a way of demonstrating to laypersons the manner in which a project may impact on important community concerns, such as traffic, or access to public services, such as hospitals (Eastman et al., 2008: 226; Basu, 2007: 2).
Logistics on site.	They enable better management of site access (to and within) tracking of large plant and equipment by planners (Eastman et al., 2008: 226; Swallow and Zulu, 2019: 8). Equipment sequences and access to lay-down areas is important and cannot be disregarded (Basu, 2007: 4). Utilising limited workspaces economically can save on the project cost and time. This is increasingly relevant when projects are situated in urban areas. 4D models can control and monitor workspaces on site by scheduling delivery times of materials and equipment according to where and when the workspace is available (Koo and Fischer, 2000: 259).
Revealing spatial constraints and coordination of trades in confined spaces.	Planners have the ability to synchronise expected times and space flow of trades on construction sites in addition to the synchronisation of work in confined spaces (Eastman et al., 2008: 226; Umar et al., 2015: 548; Romigh et al., 2017: 402). Multiples work crews in confined spaces may reduce productivity rates, in turn leading to project delays (Koo and Fischer, 2000: 255). While CPM schedules only disclose what is built and when, 4D models have an additional dynamic of where the building will take place. This therefore confirms whether work crews can undertake work in particular locations, or where building components can be physically placed (Koo and Fischer, 2000: 258).
Schedule and construction progress monitoring.	The identification of activities out of sequence of the CPM schedule can be difficult due to mutual dependencies of project activities. Given that 4D models display elements where and when they are built, this can reveal whether scheduled activities are in the correct sequence (Koo and Fischer, 2000: 254; Umar et al., 2015: 548, 550). Project managers possess the capability of easily making comparisons between project schedules and determining whether the project is ahead or lagging behind schedule (Eastman et al., 2008: 226).
Settling claims and disputes.	4D schedules and 3D modelling assist with claims and dispute resolution through visual presentation of the impact on a projects' cost and schedule (Basu, 2007: 3).
Anticipation of safety hazards.	Construction site safety hazards are a main contributor to unforeseen costs encountered by contractors and, given that all projects are unique in nature, it is problematic for project managers to predict all hazards occurring on site (Koo and Fischer, 2000: 259). Project managers can overcome this this by using 4D models to determine the times and locations of work to be carried out and use this information to determine the manner in which different work crews impact each other. Furthermore, identification of these problems allows project managers to amend the schedule by changing the sequence of activities (Koo and Fischer, 2000: 259).
Improved coordination of contractors.	Improved coordination can be realised by major subcontractors adopting a building model to detail their segment of the construction work. This enables early clash detection of activities in the schedule and speeds up off-site prefabrication that in turn reduces field costs and enhances accuracy (Eastman et al., 2008: 208).

2.4.4 FUZZY SCHEDULING

According to Pan and Yeh (2003: 1081), a common objective is to reduce the projected completion time even with resource constraints while still scheduling a project in which the duration of activities are typically considered deterministic. However, in practice, it is sometimes impossible to make precise estimations of activity durations, and these have to be considered non-deterministic. Probabilistic approaches were traditionally applied by modelling them off as random occurrences, but these methods were only theoretically credible and depended on the availability of sufficient information (Pan and Yeh, 2003: 1081). This is often not the reality in many projects, as activity durations cannot be forecasted due to a lack of information, but this uncertainty can be controlled effectively by the fuzzy set theory (Herroelen and Leus, 2005: 296).

Uncertainty comes in the form of the late delivery of construction materials on-site, the unavailability of materials when required, the absence of information indicating where materials are located on-site, exchange rate volatility or contractual issues, which may subsequently result in reduced productivity, schedule delays and cost overruns (Castro-Lacouture et al., 2009: 1097; Zhang et al., 2003: 39). Managing projects in an ambiguous environment depends on decisions based on irregular and uncertain information. Traditional CPM and PERT techniques use probabilistic views that fall short of fulfilling real world demands for project scheduling (Maravas and Pantouvakis, 2011: 62). Probabilistic theory entails assigning probability distributions to the information of random events, while fuzzy logic handles the imprecision of the information (Maravas and Pantouvakis, 2011: 62).

The term 'fuzzy logic' refers to a logic of estimation, and presents an easy way to arrive at a definite conclusion despite imprecise, uncertain or missing input information by imitating the way an individual makes decisions to control problems swiftly (Sooraj and Paul, 2018: 752; Shankar et al., 2011: 530). It mimics logical human thought and is less rigid compared to calculations performed by computers (Sooraj and Paul, 2018: 752). Fuzzy set theory affords project managers the capability of exercising their experience and knowledge in determining estimates of activity durations in an intuitive and subjective manner (Pan and Yeh, 2003: 1081). Bojadziev and Bojadziev (2007: 61, 91, 157) explained that the technique has been used for controlling, forecasting and decision-making purposes in environments associated with imprecision, uncertainty and subjectivity.

It is applied to control activities in imprecise environments, such as construction, where certain activities can commence when the demand on the quantity of several resources is manageable and where activity durations may change accordingly (Zhang et al., 2004: 40). The adoption of fuzzy logic in project scheduling and control provides a more accurate representation of results that do not always correspond with those of more traditional methods (Ponz-Tienda et al., 2012: 67). The output of the technique is typically a fuzzy schedule that points out the fuzzy start and end times for project activities. The fuzzy schedule assists by representing certain levels of freedom in the predicted project schedule to showcase the discretion management has when initiating particular activities slightly earlier or later when disseminating certain soft or hard constraints (Herroelen and Leus, 2005: 298).

2.4.4.1 Disadvantages of fuzzy scheduling

Table 2.11 shows that the disadvantages of LPS include insufficient research into the technique, a lack of transparency in processes, a lack of readily available data, and the difficulty in data accumulation.

Table 2. 11: Disadvantages of fuzzy scheduling.

DISADVANTAGE	DESCRIPTION
Insufficient research into the technique.	The adoption of fuzziness in the scheduling of projects has become a problematic matter to which a handful of papers have been chronicled and additional vigorous research is necessary Pan and Yeh (2003: 1081).
Lack of transparency in processes.	Maravas and Pantouvakis (2011: 68) describe fuzzy project scheduling as a promising alternative to more conventional scheduling techniques but despite this deduction, the on-going absence of transparency in the appraisal of project activity durations may obstruct its effectiveness.
Lack of readily available data.	Fayek and Tsehayae (2012: 6) identified a lack of sufficient and readily available data as a barrier to developing fuzzy expert models that can efficiently manage construction labour productivity.
Difficulty in data accumulation.	A further restraint to the implementation of fuzzy project scheduling is the difficulty in accumulating precise data in the form of fuzzy numbers or intervals Bonnal et al. (2004: 122).

2.4.5 INTEGRATED CRITICAL PATH AND LINE OF BALANCE

Line of balance method has been integrated with critical path method to evolve an innovative cost control technique (Ammar and Abdel-Maged, 2018: 517; Seppanen and Aalto, 2005: 271). Line of Balance (LOB) is a graphical method that is used to control the workflow of activities and is suitable for the construction industry due to the high level of repetition experienced in projects (Seppanen and Aalto, 2005: 271). In spite of the benefits provided by LOB, it has not gained international acclaim in the construction industry (Seppanen and Aalto, 2005: 271). Activity-based scheduling and location-based scheduling are classified as the two main methodologies for scheduling, and differ in the algorithms they apply to resolve scheduling problems (Firat et al., 2009: 3). Location-based scheduling hinges on tracking the continuity of workflow and work crews undertaking construction activities, and are primarily graphical techniques involving repetitive activities (Ammar and Abdel-Maged, 2018: 517). LOB is a location-based scheduling technique that allows for an uninterrupted workflow, as it takes into consideration the spatial dimensions of construction activities and pressure placed on resources (Polat et al., 2009: 1126). It balances the production rates between successive project activities in a manner that enables them to work continuously (Ammar and Abdel-Maged, 2018: 517).

According to Pai et al. (2013: 87) and Lucko and Gattei (2016: 38), LOB is a management control tool that showcases the processes, status, timing and phasing of project activities. It provides a means to making a comparison between a project's actual progress and a formal objective plan, analyses particular deviations from established plans and assessing their severity level relative to what remains in the project, promptly receives information pertaining to areas of concern and pinpoints areas that require corrective action, as well as forecasts future performance.

Activity-based scheduling methods entail completing projects as promptly as possible, but are unable to maintain a constant flow of resources in resource-dependent projects (Firat et al., 2009: 3). CPM is an activity-based schedule technique that is applicable to time-dependent project schedules. However, it is not suitable when spatial restrictions appear, whereas location-based scheduling approaches, such as LOB, remedy this obstacle and are equipped in dealing with spatial planning and offer greater effectiveness in resource planning (Firat et al., 2009: 3). Effective resource management is a critical managerial matter, as insufficient distribution of project resources can result in resource idleness and, consequently, an increase in costs (Ammar, 2019: 10). The main advantage of integrated LOB and CPM is the sustenance of work continuity, which culminates in learning development and reduces the idling time of work crews (Ammar and Abdel-Maged, 2018: 517-518).

2.4.5.1 LOB schedule characteristics

According to Ungureanu et al. (2019: 226), LOB is governed by three main principles: continuity, synchronisation and uniformity, and these are highlighted on in Table 2.12.

Table 2. 12: The three main principles governing LOB.

PRINCIPLES		**DESCRIPTION**
1	Continuity.	Any disruptions to work shall result in cost overruns as a result of time spent idling. Subsequently, there is an undesirable extension to the duration of a project. It is important to have control over the progress rate of activities to prevent such issues from surfacing, as they have direct influence over the manner that project resources are dispersed (Ungureanu et al., 2019: 226).

Table 2.12: The three main principles governing LOB (Cont'd).

	PRINCIPLES	DESCRIPTION
2	Synchronisation.	This entails the continuous occupation of each work location by work crews to eliminate any time spent idling. This minimises any potential conflicts among workers and can lead to an effortless rate of progress in the project (Ungureanu et al., 2019: 226).
3	Uniformity.	This represents the rate of uniformity, in which project resources are expended during the course of the construction period. It is a measure of resource levelling (usage), and successful execution of this criterion will ensure a consistent flow of project resources (labour, costs, equipment), consistent utilisation of production capacity, an improved quality control and the assurance that consistent technical planning controls are in place during the course of the construction phase (Ungureanu et al., 2019: 226).

Source: Ungureanu et al. (2019: 226).

Repetitive project scheduling requires assured, uninterrupted use of project resources along various repetitive units (Ammar and Abdel-Maged, 2018: 517). To sustain work continuity, it is mandatory for repetitive units to be scheduled in such a manner that enables prompt movement of work crews to successive units to fend off idle time (Ammar and Abdel-Maged, 2018: 517). Continuity can be accomplished by synchronising the movement of work crews between repetitive units within project activities (Ammar, 2019: 6).

2.4.5.2 LOB schedule development

The LOB technique manipulates worker hour estimates and the optimal crew size to produce an LOB schedule. Primary parameters required to produce an LOB schedule are: the number of locations, the production rate estimate for a typical unit, optimal crew size and the number of working hours (Ungureanu et al., 2019: 226; Ammar, 2019b: 3). These estimates are typically acquired from direct communication with the site manager, scheduler or subcontractors that are aware enough to emulate realistic project conditions as well as elements to activities (Pai et al., 2013: 85). Once the number of work crews required and their expected production rate for each respective activity is determined, an LOB diagram can be plotted depicting the work completed. The number of units produced is plotted against time where two parallel and oblique lines whose slope equals that of the actual production rate will indicate each activity's respective start and finish times (Pai et al., 2013: 85; Ammar, 2019b: 3). If there is a shortfall in the output of work required, adjustments can be made accordingly to increase the work progress rate (Pai et al., 2013: 89; Ammar, 2019: 4).

Such meticulous planning transcends the modelling capacity of CPM, whose non-time scaled network diagrams purely list activity durations and lack the transparency to disclose how quantitative results have been attained (Lucko and Gattei, 2016: 38). Activities that deviate from production plans can be identified from the LOB chart by the project manager, i.e. whether future scheduled activities are falling short of the schedule or if those completed by the time of a review are indeed complete (Pai et al., 2013: 87). The LOB schedule establishes the resource requirements for each project activity to achieve pre-specified project deadlines and preserve resource continuity (Ammar, 2019: 4). The lead times established in the production plan is valuable input that affords materials management the ability to submit purchase orders for materials, supplies or assemblies at certain periods, track the status, need and space requirements of inventory and plan for its eventual installation on-site (Lucko and Gattei, 2016: 38).

Unlike bar charts that display durations of a specific project activity, the LOB chart displays the progress rate of work encompassing all activities to be performed to stay on schedule, and the extensive relationship between a group of activities to that of the successive group (Pai et al., 2013: 86). It is unable to display the direct link between individual activities, but instead displays the output relationship between various activities. It is essential for an activity to be executed at a specified rate, as this is requisite for subsequent relationships to proceed and achieve a required progress rate (Pai et al., 2013: 86).

2.4.5.3 Advantages and disadvantages of the LOB technique

Tables 2.13 and 2.14 provide the advantages and disadvantages of the LOB technique. Table 2.13 shows that the top cited advantage of LOB is that it provides graphical presentation that exceeds what is offered by network schedules in the content of data, as both work and time can be visualised, thus making the project schedule easier to understand.

Table 2. 13: Advantages of the LOB technique.

ADVANTAGES	**SOURCES**	**NUMBER OF TIMES CITED**
It provides graphical presentation that exceeds what is offered by network schedules in the content of data, as both work and time can be visualised. This makes the project schedule easier to understand.	Su and Lucko (2016: 40), Pai et al. (2013: 90-91), Badukale and Sabinuddin (2014: 46).	3
Reduced schedule risk, as sub-contractors can be kept on site. Management of subcontractors is improved.	Seppanen and Alto (2005: 271), Badukale and Sabinuddin (2014: 47).	2
Consistent rate of productivity is realised because working crews are unlikely to interfere with each other’s work. There is improved schedule control because schedules are more realistic, as buffers are easily planned and examined.	Seppanen and Alto (2005: 271).	2

Table 2.13: Advantages of the LOB technique (Cont'd).

ADVANTAGES	SOURCES	NUMBER OF TIMES CITED
It affords an opportunity to analyse how changes from weekly plans impact the total project schedule. Project managers can anticipate midway through the project whether they can meet schedule requirements if they proceed at their present rate.	Seppanen and Alto (2005: 271), Badukale and Sabinuddin (2014: 47).	2
It has the ability to optimise project resources that are to be used on a large number of repetitive activities in different locations.	Badukale and Sabinuddin (2014: 47), Soini et al. (2004: 11).	2
LOB gives a clear assessment of work undertaken in a particular location at a specific time in the project. It provides for easier modification, updating and changing of the project schedule. Improved management of subcontractors. LOB provides visualisation of work crew location and productivity. It allows for easier time and cost optimisation analysis, as comprehensive data is readily available on each project activity.	Badukale and Sabinuddin (2014: 47).	1
Standardised progress reporting to management is afforded. There is a prompt assessment into the feasibility of the schedule. It reduces schedule risk and project duration.	Soini et al. (2004: 11).	1
Location-based techniques such as LOB improve the application of 4D CAD models in workflow analysis.	Pai et al. (2013: 90-91).	1
Planning backwards from the anticipated project delivery date can result in a realistic estimation of the start date. It is suitable for controlling assembly line-oriented activities with a considerable number of duplicate products in an effective way. Due to the graphical interpretation it provides, it supports management in implementing a high production-oriented workflow.	Lucko and Gattei (2016: 36-37).	1
Work continuity is maintained, therefore reducing idle time and promoting learning development.	Ammar and Abdel-Maged (2018: 517).	1

Table 2.14 shows that the key disadvantage of the LOB techniques cited in the literature is that full adoption of LOB in the construction industry remains unpopular, while bar chart and network-based techniques remain the favourite.

Table 2. 14: Disadvantages of the LOB technique.

DISADVANTAGES	SOURCE	NUMBER OF TIMES CITED
Full adoption in the construction industry remains unpopular, while bar chart and network-based techniques remain the favourite. LOB lacks a critical path, which is an expectation in all project schedules.	Lucko and Gattei (2016: 36-37), Pai et al. (2013: 85), Badukale and Sabinuddin (2014: 47).	4
Productivity rates in LOB schedules do not take into account the learning curve or the interchanging of individuals in work crews.	Badukale and Sabinuddin (2014: 47), Pai et al. (2013: 85).	2
Application of LOB in real projects loses the majority of benefits during the construction phase due to a variability of production rates and insufficiency of control mechanisms used on site.	Seppanen and Aalto (2005: 272).	1
It lacks the ability to showcase the relationship between activities, and this hinders its application to complex and dynamic schedules. It lacks the analytical qualities offered by CPM scheduling.	Su and Lucko (2016: 40).	1
The graphical presentation provided by LOB is usually only feasible for relatively simple schedules. However, with increased project complexity, it becomes difficult to draw significant conclusions, as schedules quickly become cluttered.	Ungureanu et al. (2019: 241).	1
Users can only divide the project by location and not into further systems such as trades.	Badukale and Sabinuddin (2014: 47).	1

2.4.6 RESERVE ANALYSIS

Uncertainty and risk inherent in construction projects has given rise to the majority of project plans incorporating contingency reserves in budgets and schedules (Steyn, 2001: 1). In spite of the lack of explicit classification of these reserves in many projects, they play an important role in the planning and implementation of projects (Steyn, 2001: 1). Reserve analysis establishes the amount of management and contingency reserve required for projects (PMI, 2017: 202). Contingency reserves are, at times, referred to as schedule reserves and account for project schedule ambiguity. They address the known-unknowns and may be a percentage of the estimated duration of project activities or a predetermined number of work phases (PMI, 2017: 202). Eldosouki et al. (2014: 864) described cost contingency reserves as a proportion of the project budget assigned to cover project risk.

Management reserves, on the other hand, are withheld sums of the project budget utilised for management and control objectives, and are reserved for unanticipated work that falls in line with the project scope (PMI, 2017: 202). They address the unknown unknowns that can have an impact on projects.

According to Jackson (2003: 1), contingencies mean different things to different project participants; that is, management, engineers, the construction department and cost engineers. The definitions of contingency based on project participants are outlined in Table 2.15.

Table 2. 15: The meaning of contingency to different project parties.

PROJECT PARTICIPANTS	DEFINITION OF CONTINGENCY
Management.	To management, it is the portion of the project budget that will hopefully not be spent but be returned, unused, as profit once the project has come to an end.
Engineers.	It is a savings account from which withdrawals can be made to cover supplementary expenses of underestimated or overlooked project expenses.
Construction department.	It is a reserve to be expended to cover supplementary expenses brought about by prolonged project schedules, poor productivity and construction difficulties.
Cost engineer.	It is a reserve that can be expended as cover for higher costs brought about by ambiguity at estimating phases such as indirect costs, underestimations of construction materials, plant and equipment and labour costs.

Source: Jackson (2003: 1),

The management of a project's costs begins in the marketing and sales stage once provisional cost estimates are generated (Kujala et al., 2014: 50). Prior to the execution phase, the budget is produced according to latest cost estimates while the planning stage sees resources being allocated to work activities, cash flows and contingencies that are usually set in place. During the execution stage, revenues are monitored, invoicing carried out and cost contingencies discharged (Kujala et al., 2014: 50). Comprehensive planning and controlling of contingency reserves of the allocated project budget is imperative to avoid cost overruns in the same manner that effective control of contingency reserves in the project schedule is instrumental in reducing the project duration (Steyn, 2001: 1).

2.4.6.1 Features of cost contingency

According to Baccarini (2004: 2), the fundamental features to the concept of cost contingency consist of reserve, risk, total commitment, project outcomes and risk management. The description of these features is highlighted in Table 2.16.

Table 2. 16: Features of contingency reserves.

FEATURES	DESCRIPTION
Reserve.	Cost contingency is a money reserve.
Risk.	Cost contingency caters to unforeseen events within the defined scope of the project.
Total commitment.	Cost estimates are generated inclusive of contingencies to determine the anticipated total project cost. The addition of contingencies in the project budget showcases the financial commitment to the project.
Project outcomes.	Contingencies have consequences to project outcomes. If set too high, it might promote reckless cost management and render the project uneconomical. If set too low, it may result in unrealistic and unsatisfactory performance outcomes.
Risk management.	Cost contingency is used hand-in-hand with various other risk management strategies, such as risk reduction and risk transfer.

Source: Baccarini (2004: 2).

For cost control purposes, reserve analysis is used to oversee the status of management and contingency reserves during the course of a project to establish whether there is any need to access the reserves or if supplementary reserves are required (PMI, 2017: 265). As construction activities advance, these reserves may be released as cover to the cost of risk responses or other contingencies (PMI, 2017: 265). The absence of a consistent and dependable method to determine construction cost contingency without exercising a stochastic approach typically results in project schedule and cost overruns, subsequently delaying the completion of projects (Amade et al., 2014: 10).

2.4.6.2 Methods to calculate contingency

The percentage method is the traditional approach used in the construction industry for the determination of cost contingency reserve, and is deterministic (Eldosouky et al., 2014: 864; Baccarini, 2005: 2). This method entails setting a percentage, typically 5-10% of the total construction cost, to cover cost contingencies. They are derived from instinct, experience and historical data (Baccarini, 2005: 2). However, this method is flawed, as total project contingency does not permit accountability for its expenditure (Jackson, 2003: 2). A percentage addition consequently leads to a single figure forecast of the estimated cost, which indicates a degree of certainty that is not substantiated (Eldosouki et al., 2014: 5). This furthermore renders the contractor susceptible to overcompensating for risk or underestimating risk (Baccarini, 2005: 2). Additionally, project parties consider the contingency as their own, and, due to it being unanticipated, it has no limit. The unreliability of the traditional percentage approach has therefore resulted in the search for more robust methods (Baccarini, 2005: 2).

Expected value method makes the assumption that risks to the project have been individually distinguished, including their monetary impact value and likelihood of occurrence (Eldosouki et al., 2014: 864). A risk-free scope estimate is generated at first, followed by the identification of risk events, which are evaluated in terms of an average and a maximum allowance (Baccarini, 2005: 2). Risk is classified as fixed and variable; variable risks are those events that will take place but the magnitude is uncertain, while fixed risks represent events that will occur in total or not at all (Mak and Picken, 2000: 132; Eldosouki et al., 2014: 2; Baccarini, 2005: 2). If the event happens to occur, the maximum cost will be incurred and, if not, no costs shall be experienced (Mak and Picken, 2000: 132).

2.4.6.3 Contingency management

Contingency allocation entails committing total cost contingency to respective project activities based on each activity's contribution to the project (Hammad et al., 2015: 1). Therefore, effective contingency management is important, as it can strongly influence the success of a project (Ford, 2002: 30). Contingency management is a series of processes set in place to control and track the contingency status of the whole project and each respective activity (Hammad et al., 2015: 1). According to Jackson (2003: 3), successful contingency management is dependent on the determination of uncertainties in projects and linking them to specific reserves, developing processes for the correct use of contingency reserves, and developing an information system revealing the contingency reserves applicable to the work under control of accountable personnel (managers) who control the manner in which these reserves are being expended and the outlook of trends for the remainder of the project (Jackson, 2003: 3). Monitoring trends shall permit judgements to be made as to when contingency balances may be transferred to less successful project areas (Jackson, 2003: 3).

According to Steyn (2001), the principal of aggregation plays an important role in contingency reserve management. It offers an effective way of minimising cost and duration considerably, as its application entails reserves being administered at project level rather than lower levels (such as activity or task levels) (Steyn, 2001 2-3). Project team members provide estimates of cost and duration but cannot make commitments on these project parameters. The onus instead falls on the project manager to make these commitments, while other parties may only make pragmatic estimates and honour them (Steyn, 2000: 4).

2.4.6.4 Disadvantages of Reserve Analysis

Table 2.17 shows that the disadvantages of Reserve Analysis include a lack of clearly defined and well documented processes, subjectivity involved as expert judgement is typically used to determine the bidding contingency reserve, difficultly in determining the total value of contingencies due to the multiple contingencies attached to the different WBS, and a lack of formal policies in place to manage contingencies.

Table 2. 17: Disadvantages of Reserve Analysis.

DISADVANTAGES	SOURCE	NUMBER OF TIMES CITED
There is a lack of clearly defined, and well documented contingency management processes	Ford (2002: 32); Mak and Picken (2000: 135)	2
Expert judgement is typically used to determine the bidding contingency reserve therefore subjectivity is a barrier as experience, knowledge, and skills of experts may vary or the setting of projects may differ from the ones familiar by experts.	Hammad et al. (2015: 1); Ford (2002: 32)	2
Determination of the total value of contingencies is difficult due to the multiple contingencies attached to the different WBS.	Kujala, et al. (2014: 54)	1
A lack of formal policies in place to manage contingencies. Construction/engineering organisations do not see the need to conduct reviews to determine project contingency accuracy at the project completion stage.	(Baccarini, 2005b: 7)	1
It lacks project management mechanisms to support decision making e.g. project managers use scheduling software for project status determination relative to milestones or deadlines set, but do not offer guidance for contingency management responses. There is deficiency in formal approaches, standardised tools and methods of practice.	(Ford, 2002: 32)	1

2.5 OPTIMAL COST CONTROL TECHNIQUES USED DURING THE CONSTRUCTION PHASE

Despite the existence of various innovative cost control techniques such as EVA, LPS, objective cost planning and reserve analysis, construction organisations still predominantly adopted more traditional methods to control project costs (Ayinde, 2018: 14; Oyeyipo and Odusami, 2016: 47; Haruna et al., 2017: 21; Cooray et al., 2018: 918-919; Premalal et al. 2017, 167; Olawale and Ming, 2009: 882; Chigara et al., 2013: 6-8).

A survey by Fortune and Grant (2005: 87) into project control in the UK revealed conventional monthly valuation analysis as the most popular project control system (70%) in use by construction organisations. This was followed by milestone monitoring, variance analysis, S-curves and EVA. Results indicated that more traditional approaches to project cost control were still widely being adopted in projects despite the claimed benefits of more innovative techniques such as EVA (Fortune and Grant, 2005: 88).

A study conducted by Ayinde (2018: 14) among construction industry practitioners in Nigeria determined that valuation of work in progress, record keeping, materials management and site meetings as the most frequent cost controlling techniques used on site. The valuation of work in progress was the most effective technique identified. Furthermore, Oyeyipo and Odusami (2016: 47) identified actual versus forecast reconciliation as the most effective cost control method used during the construction stage, followed by weekly cost reports, financial reports and cost value reconciliation. Haruna et al. (2017: 21) identified work programmes, monitoring and inspection and valuation of work as the most important cost control technique used by contractors in Nigeria.

Cooray et al. (2018: 918-919) identified project cost value reconciliation and forecasting as the techniques that have the most significant impact on project delivery among construction companies in Sri Lanka. However, MS project and earned value analysis were determined to be the most important cost controlling techniques adopted by contractors in Sri Lanka based on the ease they afford cost monitoring and their user friendliness (Premalal et al., 2017, 167).

Olawale and Ming (2009: 882) undertook a survey in the UK to establish the project control practices employed among contractors and consultants. The results showed that project cost reconciliation, EVA, actual versus forecast reconciliation and PERT are the preferred cost control techniques. Chigara et al. (2013: 6-8) analysed cost management practices adopted by contractors in Zimbabwe and found that variance analysis, cost value reconciliation and cost reports were the techniques mostly adopted to manage project costs.

2.6 LEVEL OF USE OF INNOVATIVE COST CONTROL TECHNIQUES ON CONSTRUCTION PROJECTS

In literature pertaining to construction organisations, there is no conclusive establishment on the level of usage of innovative cost control techniques. However, some studies indicate that these techniques have been applied to projects and yielded successful outcomes (Vertenten et al., 2009: 5; Suresh and Ramsamy, 2015: 1080; Khamidi et al., 2011: 126; Daniel et al., 2014: 614; Basu, 2007: 3; Kim et al., 2016: 50; Umar et al., 2015: 551).

Gershon (2013: 11) identified EVA as the most significant tool for monitoring and controlling project performance; however, it remains unused by most project managers and organisations. The concept of EV is being used by a select few construction firms in the South African construction industry, yet, despite recognition of the technique, its benefits have not been fully realised (Vertenten et al., 2009: 5). A study piloted by Nkiwane et al. (2016: 187) investigating EVA and project maturity showed that EVA awareness and understanding was low among consultants in South Africa. The results indicated minimal use of EVA in the directive control of projects (Nkiwane et al., 2016: 192).

Similarly, findings by Fortune and Grant (2005: 90) to establish the tools used by contractors and consultants in managing construction phase cost performance in the UK indicated that 73% of respondents were unfamiliar and had no awareness of EVA. The authors revealed that EVA adoption for project cost management for UK based clients was not widespread as only 24% of EVA users revealed that it provided greater levels of project cost control over more conventional tools they had used (Fortune and Grant, 2005: 90). Zulkefli et al. (2018: 345) showcased that EVA was still in its infancy in the Malaysian construction industry in a survey conducted to obtain the perception and enablers of the technique. The authors state that it is a less accepted technique used to assess project performance in the Malaysian construction industry (Zulkefli et al., 2018: 345). The majority of respondents (80%) did not apply EVA in their working environment due to a lack of expertise, knowledge and experience (Zulkefli et al., 2018: 345).

Kim et al. (2016: 50) stated that the adoption and implementation of 4D BIM in large construction companies is still rare in the Australian construction industry. However, in instances when it was used in projects, it provided benefits such as the reduction of project costs and project duration. A similar deduction was made by Umar et al. (2015: 551) in a study that sought to highlight the impact of 4D applications on integrated project delivery in the architecture, engineering and construction industry in Malaysia. The authors state that the increasing adoption of 4D BIM modelling in the sector has improved project coordination, led to reductions in project cost and time and provided an easier transfer of project planning (Umar et al., 2015: 551).

A study across four states in the USA by Romigh et al. (2017: 402) to investigate 4D BIM as a visualisation tool to assist in field operations showed that participants perceived the technique as insignificant at present time without sizeable time and money investments. 67% of participants were familiar with 4D BIM, while a third were new to the idea. Only 33% were actively using the technique (Romigh et al., 2017: 400).

Swallow and Zulu (2019: 1) delved into how construction industry professionals perceived the benefits and barriers to the implementation of 4D modelling in the UK. Results revealed that 70% of directors/managers and 74% of professionals had awareness of 4D. Awareness, however, did not give a true reflection of the degree of 4D adoption, as only 31.2% of study participants had actively adopted 4D modelling in their work environment, suggesting a low rate of 4D application in the construction industry (Swallow and Zulu, 2019: 6). Further observations indicated that parties that held director/managerial positions impacted 4D implementation within an organisation, as they had influence on organisational strategy and enactment of new practices (Swallow and Zulu, 2019: 8).

Kassem et al. (2012) similarly surveyed contractors and consultants across 31 organisations in the UK to uncover the barriers and drivers impacting the uptake of BIM and 4D in the architectural, engineering and construction industry. 80% of contractors indicated knowledge of 4D planning, with 72% having actively applied the technique on a project (Kassem et al., 2012: 4). 36% of consultants indicated awareness of 4D, with 60% acquiring this knowledge from the working level. Kim et al. (2016: 57) examined the uptake of BIM in the Australian construction industry, and respondents described the adoption of 4D and 5D as secondary in importance to 3D BIM capability, which remains in demand by clients.

In spite of LPS being widely adopted worldwide, it is new to many construction professionals (Porwal et al., 2010: 553). Resistance to change, lack of training, lack of human capital and poor leadership have hindered its implementation in organisations (Porwal et al., 2010: 553). Poor leadership in a case study in the USA by Hamzeh (2011: 284) led to a failed attempt in implementing LPS in an administrative building project. The implementation team reported a lack of experience with lean and LPS, and cited a strong resistance to change as the reason for the failed implementation (Hamzeh, 2011: 385).

Daniel et al. (2014: 613- 614) conducted a survey among registered contractors and construction professionals in academia in Nigeria to examine whether LPS practices could be applied to construction sites to minimise non-value adding activities. Results determined that last planner thinking practices were not observed or adopted regularly on construction sites in Nigeria due to resistance that slowed down full implementation of the technique. The majority of study participants reported benefits such as a reduction in cost and time, overruns, increased profit margins for contractors and minimised non-value adding activities on construction sites where LPS was effected (Daniel et al., 2014: 614).

Despite evidence of improved project performance and productivity brought about by LPS, adoption of the technique in New Zealand commercial construction has been slow (Fuemana et al., 2013: 682). The authors state that it is a relatively new system in New Zealand and its lack of exposure to clients and subcontractors has rendered it difficult to understand the full benefits provided (Fuemana et al., 2013: 685).

2.7 RELATIONSHIP BETWEEN THE USE OF INNOVATIVE COST CONTROL TECHNIQUES AND COST OVERRUN

Past studies have focused on the impact of work programmes, evaluation of work carried out, and actual versus forecasted reconciliation to control project costs (Otim et al., 2011: 370; Ayinde, 2018:

14; Olawale and Ming, 2009: 885). Otim et al. (2011: 367) conducted a study in Uganda to identify cost control techniques used in construction sites and their effectiveness in controlling project costs. The most common techniques identified were work programmes, evaluation of work carried out and inspection of works undertaken (Otim et al., 2011: 370). It was determined that there was no concrete evidence showcasing the effectiveness of these techniques to control costs, and that the lack of knowledge and management of the techniques contributed to poor implementation of projects (Otim et al., 2011: 370).

Similarly, Ayinde (2018: 11) undertook a study in Nigeria to determine cost control techniques employed by contractors and challenges to their usage. Results determined that cost control practices and procedures were lacking as practitioners were comfortable with conventional methods having minimal application of information technology (Ayinde, 2018: 16). These techniques included evaluation of work, record keeping, work programmes, and site meetings (Ayinde, 2018: 14). Olawale and Ming (2009: 885) established project cost value reconciliation and actual versus forecasted reconciliation as popular cost control techniques used by contractors in the UK construction industry. However, despite their popular application in projects, cost overruns were regularly experienced by the companies surveyed (Olawale and Ming, 2009: 886).

None of these studies had investigated the relationship between innovative cost control techniques and cost overruns. This emphasised the need to investigate the relationship between the level of use of innovative cost control techniques and cost overrun due to the predominant use of conventional cost control techniques.

2.8 BARRIERS TO THE USE OF INNOVATIVE COST CONTROL TECHNIQUES

A fundamental means of acknowledging the true value possessed by a technology within an industry is to grasp the barriers that may potentially hinder its extensive application (Kassem et al., 2012: 6). Mohamed and Sameh (2018: 61) concurred with this statement by indicating that one should ensure the presence of appropriate supportive requirements prior to implementing any new technique to a project or organisation. Kassem et al. (2012: 7) further stated that understanding these barriers is vital in order to safeguard the development of strategies used to overcome them. Table 2.18 indicates the various barriers to the use of innovative cost control techniques as identified by the literature. The Resistance to change, lack of experience, training, knowledge and skill, high resource requirements (cost and time commitments) and a lack of standardisation were the most frequently occurring factors hindering the implementation of innovative cost control techniques in projects.

According to Kassem et al. (2012: 7), a skilled workforce is vital when implementing new technologies to ensure successful achievement of project objectives. The lack of experience was identified as a major barrier to the adoption of EVA in projects among project managers in South Africa, as they had lack of exposure of the concept (Pillay et al., 2013: 104). Zulkefli et al. (2013: 104) likewise pointed to the lack of experience of construction professionals in effecting EVA in the Malaysian construction industry. Studies (Romigh et al., 2017: 402; Kassem et al., 2012: 6) in the USA and UK respectively determined that slow 4D planning and BIM adoption in the construction industry was due to lack of a knowledgeable and technically skilled workforce.

A survey among clients, contractors and consultants ranked the lack of training, knowledge and skilled professionals as the most detrimental factors to BIM adoption in Qatar (Ahmed et al., 2014: 543). According to Porwal et al. (2010: 553), LPS has been difficult to implement in construction due to lack of human capital, inexperience, skills and training and poor understanding of the concept. The integration of staff into projects without proper training in Mexico was identified as a barrier to LPS adoption by Cerveró-Romero et al. (2013: 716). Khanh and Kim (2013: 8) criticised the poor training development policies by organisations in Vietnam for the low implementation of advanced technology in construction. Malacarne et al. (2018: 141) stated that the high level of skill required to effect 4D BIM in Italy is either not readily available or tedious to acquire.

Table 2. 18: Barriers to the use of innovative cost control techniques.

BARRIER	SOURCE	NUMBER OF TIMES CITED
Resistance to change.	Zulkefli et al. (2018: 344), Fortune and Grant (2005: 90), Kassem et al. (2012: 7), Soini et al. (2004: 9), Ahmed et al. (2014: 543), Porwal et al. (2010: 551-553), Cerveró-Romero et al. (2013: 715), Kim et al. (2016: 55), Hussein et al. (2017: 2842), Romigh et al. (2017: 402).	10
Lack of experience, training, knowledge and skill.	Pillay et al. (2013: 104), Zulkefli et al. (2017: 342), Malacarne et al. (2018: 141), Kassem et al. (2012: 7), Romigh et al. (2017: 402), Ahmed et al. (2014: 543), Porwal et al. (2010: 551-553), Cerveró-Romero et al. (2013: 717), Khanh and Kim (2013: 9).	9
High cost and time requirements.	Zulkefli et al. (2018: 344), Fortune and Grant (2005: 90), Gershon (2013: 13), Malacarne et al. (2018: 147), Romigh et al. (2017: 402), Ahmed et al. (2014: 543), Porwal et al. (2010: 551-553), Kim et al. (2016: 55).	8
Lack of standardisation.	Malacarne et al. (2018: 147), Soini et al. (2004: 9), Ahmed et al. (2014: 543), Kim et al. (2016: 55), Bhargav et al. (2015: 7).	5
High level of scope requirements/poor scope definition.	Pillay et al. (2013: 104), Fortune and Grant (2005: 89), Gershon (2013: 13), Zulkefli et al. (2018: 344).	4

Table 2.18: Barriers to the use of innovative cost control techniques (Cont'd).

BARRIER	SOURCE	NUMBER OF TIMES CITED
Lack of awareness.	Pillay et al. (2013: 104), Zulkefli et al. (2017: 342), Fortune and Grant (2005: 88), Khanh and Kim (2013: 9).	4
Lack of leadership to spearhead change.	Pillay et al. (2013: 118), Porwal et al. (2010: 551), Hussein et al. (2017: 2842).	3
Lack of collaboration of project team.	Porwal et al. (2010: 553), Khanh and Kim (2013: 9).	2
Contractual and legal challenges.	Ahmed et al. (2014: 543), Porwal et al. (2010: 551).	2
Cultural barriers.	Cerveró-Romero et al. (2013: 717), Khanh and Kim (2013: 9).	2
Lengthy client approvals during the planning and controlling of projects.	Khanh and Kim (2013: 9), Hussein et al. (2017: 2842).	2
Role definition of team members.	Cerveró-Romero et al. (2013: 716).	1
Government intervention/policies.	Kim et al. (2016: 57).	1
Poor supervision and quality control.	Hussein et al. (2017: 2842).	1
Lack of software tool.	Soini et al. (2004: 1).	1
Inaccuracy of costing system.	Gershon (2013: 13).	1

Resistance to change was a barrier to the adoption of EVA in the Malaysian construction industry, as current control systems were deemed as satisfactory with no need for change (Zulkefli et al., 2018: 344). There was an understanding of EVA, but 80% of construction professionals said in a survey that they did not exercise the technique in their work environment due to the vague perception among construction organisations (Zulkefli et al., 2017: 342). Similarly, participants in a survey by Fortune and Grant (2005: 90) perceived their more conventional cost control techniques as adequate with no need for EVA.

Kassem et al. (2012: 6) reported similar findings with regard to 4D planning and BIM adoption, as people's unwillingness to adapt to a new system hindered the technique's implementation in the UK. There have been no tangible benefits of 4D planning or BIM in order to justify the high cost and requirements (Kassem et al., 2012: 7). Romigh et al. (2017: 402) acknowledged that 4D BIM has been successfully implemented in projects, but not yet to the degree where the high cost and time requirements of the method seem justified. According to Ahmed et al. (2014: 543), the rate of return (ROI) of 4D planning and BIM lacks clear definition, and this remains a hindrance to its implementation in Qatar. The resistance to adopt new ideas and ways of thinking has been a barrier to LOB adoption in construction (Soini et al., 2004: 10). Disruption of current processes has not been welcomed in the Qatar construction industry, and this has hindered the practice of 4D planning and BIM (Ahmed et al., 2014: 543).

The resistance to LPS use in the construction industry has been attributed to the poor attitudes and lack of commitment by construction professionals toward a new system of doing things (Porwal et al., 2010: 551-553). The authors go on stating that organisations remain satisfied with the way they've always done things (Porwal et al., 2010: 551). The lack of interest or demand by clients in the Australian construction industry impedes 4D BIM adoption, as no demand restricts investment into the technology (Kim et al., 2016: 56). A large amount of capital and time investment is an obstacle to the adoption of EVA in the Malaysian construction industry (Zulkefli et al., 2018: 344). Similarly, Fortune and Grant (2005: 90) identified the high cost of setting up and maintaining EVA as a detriment to implementing EVA in projects. The cost of changing the existing system and the change management issues that come along with it have impacted EVA implementation (Gershon, 2013: 13). According to Malacarne et al. (2018: 147), Italy has had difficulty in establishing 4D scheduling due to the high cost of the technologies required. The substantial cost of 4D integrating software is not ideal for local SMEs (Small to Medium Enterprises), and the number of software solutions required is both time-consuming and dependent on high levels of commitment (Malacarne et al., 2018: 147).

Kassem et al. (2012: 7) shared a similar opinion, and state that adoption has been slow in the UK AEC (Architecture, Engineering and Construction) industry due to the high costs related to hardware and software upgrades, training, start-up costs and the time to implement the technique. Other authors (Kim et al., 2016: 56; Romigh et al., 2017: 402; Ahmed et al., 2014: 543) also noted that the high initial cost requirements are detrimental to the adoption of 4D BIM and planning in the Australian, USA and Qatar construction industries respectively.

As a result of construction companies developing their own processes based on past experience and knowledge, it is difficult for software houses to develop a standardised process for 4D BIM (Malacarne et al., 2018: 147). Similarly, Soini et al. (2004: 9-10) stated that the lack of standardisation owing to undeveloped cost estimating tools has been a barrier to LOB implementation in the Finland construction industry. The quality of start-up data has not been standardised, and this adds to the workload of site personnel (Soini et al., 2004: 9-10). The standard methods of measurement and quality of data sets in the Australian industry lack the compatibility with 4D BIM, therefore inhibiting its implementation in the industry (Kim et al., 2016: 56). Ahmed et al. (2014: 543) similarly attested to the deficiency of industry standards for 4D planning and BIM in the Qatar construction industry. LPS adoption has been hindered due to the lack of standardised training material (Bhargav et al., 2015: 7).

The lack of standardisation in project designs impacts the contractors' ability to explore economies of scale, as it heightens the level of procurement required and increases the variation in resources necessary for project delivery (Damnjanovic et al., 2009: 88).

Standardisation ensures design repetition for repetitive elements, which, in turn, minimises waste and saves on cost for the contractor (Damnjanovic et al., 2009: 88). Jakobs (2016: 150) is of the opinion that standardised processes improve staff training and enhance the quality of deliverables, as the likelihood of errors and better control of rework cost is realised. The author stated that there is increased efficiency when implementing standards that have been modelled off recognised standards than when an organisation develops its own internal standards (Jakobs, 2016: 150). According to Mirza et al. (2013: 727), poor scope definition has negative repercussions on project performance. Appointing inadequate boundaries inflates the final project cost due to changes that interfere with project rhythm, leads to rework, prolongs the project schedule and diminish productivity (Mirza et al., 2013: 727). A significant contribution to poor scope definition is the deficiency in understanding or defining the scope from the onset of a project (Mirza et al., 2013: 727). According to a study by Pillay et al. (2013: 18), the tedious collecting of data and reporting requirements associated with EVA ranked as the second most significant barrier hindering the adoption of the technique in the South African construction industry. Similarly, a study by Zulkefli et al. (2018: 343) in the Malaysian construction industry revealed that respondents perceived EVA as having a significant number of rules and requirements to learn and implement. This factor was ranked the sixth most critical barrier to the adoption of EVA in the industry. Gershon (2013: 13) stated that the high frequency of requirements (long lists and its quantitative nature) puts off the user from using the technique. The study by Gershon (2013: 13) established that only 31% of respondents found that the technique generated more accurate data than more traditional cost control methods.

The absence of exposure was deemed the greatest barrier to the implementation of EVA in a survey by Pillay et al. (2013: 118) that aimed to solicit the perception of the technique among project managers in South Africa. Respondents professed a lack of confidence in implementing the technique in projects because of an average understanding of the concept (Pillay et al., 2013: 118). A study by Zulkefli et al. (2017: 342) determined that 20% of respondents rated the awareness of EVA implementation as difficult, while the majority (80%) rated awareness as neutral. 73% of study participants in the UK had no awareness of EVA (Fortune and Grant, 2005: 90). There was poor awareness of LPS among practitioners in the Vietnam construction industry, as it was still a new concept to them (Khanh and Kim, 2013: 9).

These past studies have provided information on the barriers to the use of innovative cost control techniques in countries such as the UK and USA. No such studies have been conducted in South Africa and the barriers affecting the use of innovative cost control techniques remain unknown.

2.9 CHAPTER SUMMARY

This chapter provided a review of the various causes of cost overruns in the construction industry and also highlighted the numerous innovative cost control techniques being adopted by construction firms to improve cost control and the overall performance of projects as they try to move on from more traditional approaches such as CPM and PERT.

Innovative cost control techniques reviewed included EVA, LPS, 4D scheduling, fuzzy project scheduling, LOB and reserve analysis. EVA is a tool that oversees the relationship between project cost and time parameters and provides feedback, enabling management to assess project schedule and cost performance. LPS is a production control tool promoting collaboration within the project team, and enables a more reliable and predictable production construction process. 4D scheduling is a BIM approach that allows for the planning, sequencing, visualising and monitoring of project activities during the construction process. Fuzzy scheduling is used for forecasting, controlling and decision making in uncertain and imprecise environments such as construction. LOB is a graphical location-based technique that controls the workflow of work activities. Reserve analysis determines the monetary amount of management and contingency reserves necessary to account for project ambiguity.

Benefits afforded by these methods to management include reducing project duration; improving cost control, improving the workflow of activities, improved progress reporting, improved communication and coordination of activities, enhanced schedule control and overall project performance. However, there are numerous barriers hindering the adoption of these techniques. such as resistance to change, lack of experience, training, knowledge and skill, high resources requirements (cost and time commitments) and a lack of standardisation. Chapter three presents the research method selected to undertake the study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research methodology is the manner in which a research question is resolved, and entails studying the various steps adopted by the researcher when examining the research problem and the logic behind these steps (Kothari, 2004: 8). The research methodology addresses how the research problem was defined, what data has been collected, the selected method of collection and why a particular technique to analyse data was selected (Kothari, 2004: 8). This chapter gives insight to the research design, method and procedure of data collection and the population of the study, and concludes with the ethical considerations of the study.

3.2 RESEARCH APPROACH AND DESIGN

There are two elementary approaches to research: quantitative and qualitative (Kothari, 2004: 5). Quantitative research entails producing data in quantitative form that can be subjected to meticulous scrutiny in a rigid manner, while qualitative research is associated with subjective evaluation of behaviour, attitudes and perspectives (Kothari, 2004: 5). However, results acquired from qualitative research may be in non-quantitative form and do not undergo meticulous quantitative scrutiny (Kothari, 2004: 5). Research can either be descriptive or exploratory. Exploratory research studies are used to advance familiarity or achieve fresh insight in a phenomenon, while descriptive research studies, on the other hand, accurately represent the characteristics of a particular situation, individual or group (Kothari, 2004: 2).

According to Kothari (2004: 31), research design is the organisation of conditions for data collection and analysis in a way that serves the purpose of interrelating the relevance of the research with economy in procedure. It establishes the model for the collection, evaluation and examination of data. The research questions in this study are designed to assess the barriers hindering the implementation of innovative cost control techniques on construction projects. The research can be classified as descriptive, as it aims to create an accurate depiction of respondents' perceptions and opinions highlighting the causes of cost overrun, and factors hindering the application of innovative techniques to control and monitor costs during the construction phase of projects in South Africa.

3.3 AREA OF STUDY

The study was conducted in South Africa, and the questionnaire administration method allowed for a better representation of the study population across the various projects undertaken in different provinces in the country.

3.4 POPULATION OF THE STUDY

The targeted professional in this study are i) Project Managers; ii) Quantity Surveyors; iii) Site Engineers; iv) Architects; and v) Construction Managers. The lists of the registered construction professionals in South Africa were obtained from the Times Construction Business Directory (2015). The population of the study comprised of project managers, construction managers, engineers, architects and quantity surveyors. These professionals were focused on based on their level of familiarity with cost control techniques.

3.5 SAMPLING TECHNIQUE AND SAMPLE SIZE

Probability sampling, specifically the random sampling technique, was used for the study. According to Brikci and Green (2007: 10), this sampling technique permits the deliberate selection of participants that are likely to provide valuable data for the research. The participation of diverse construction professionals in the study population enabled a wider array of perspectives on the barriers to the use of innovative cost control techniques during the construction phase in South Africa.

The total amount of contact emails used were 1400. A total of 140 responses were expected from study participants (see Table 3.1) because of the low responses received from postal emails (Fricker, 2015: 11). The sample size was therefore 10% (140/1400 x 100). A total of 123 questionnaires were collected and provided the base for the computation of study results. The completion rate of questionnaires was 87.85% (123/140 x 100). This study adopted 'missing completely at random' (MCAR) as the target level for eliminating missing data. In all responses received from study participants, none of the respondents failed to furnish essential information which would have affected the values of the variables investigated in this study.

Table 3. 1: Study population and sample size.

PROFESSIONAL GROUP	STUDY POPULATION	SAMPLE SIZE (10%)
Project Managers	212	21
Quantity Surveyors	405	41
Engineers	116	12
Architects	504	50
Construction Managers	163	16
Total	1400	140

3.6 METHOD OF DATA COLLECTION

A systematic literature review was used to frame the direction of the proposed study. The primary data was obtained from the examination of data from questionnaires issued to organisations to determine the innovative cost control techniques implemented during the construction phase as well as to identify the barriers inhibiting their usage.

Survey research entails the acquisition of data from one or more groups of a population pertaining to their opinion, characteristics or behaviour by asking questions and keeping record of responses received. The main objective is to gather insight into a large population by surveying a sample of that particular population (Leedy and Ormrod, 2015: 159). Singh (2006: 102) supported this view, stating that descriptive surveys provide a direct source of important information relating to human behaviour.

Questionnaires comprise of a series of questions printed or typed in a precise sequence on a form or set of forms that respondents are expected to read, interpret what is expected and respond accordingly in the spaces provided (Kothari, 2004: 100). The difference between a questionnaire and an interview schedule is that the former entails participants recording their responses independently, while the latter involves the interviewer asking questions and recording responses on an interview schedule (Kumar, 2011: 138). Structured questionnaires are those with defined, clear-cut and pre-determined questions (Kothari, 2004: 101). Questions are presented in the same order and with the same wording.

Unstructured questionnaires, on the other hand, are an instrument used by interviewers to solicit information about a particular topic from respondents, but the sequence and wording of questionnaires are not pre-determined (Kothari, 2004: 101). Questionnaires need to use simple and clear unambiguous language that avoids jargon that respondents may misunderstand (Leedy and Ormrod, 2015: 167). The questionnaire was kept short and precise so as to solicit information only necessary for the research undertaking, in line with the recommendations of Leedy and Ormrod (2015: 167). A proper sequencing of questions was done, which minimises the likelihood of individual questions being misunderstood or taken out of context (Kothari, 2004: 102). According to Mathers et al. (2009: 19), all questionnaires must take into account the level of literacy of respondents, expected response rate, resource availability and whether the questionnaire will be completed independently. The description of these criterion used in constructing the questionnaire are outlined in Table 3.2.

Table 3. 2: Criteria followed in constructing the questionnaire.

CRITERIA	DESCRIPTION
Level of literacy of respondents.	Respondents with low literacy levels will find completing questionnaires challenging, so a personal or telephone interview would be more appropriate.

Table 3.2: Criteria followed in constructing the questionnaire (Cont'd).

CRITERIA	DESCRIPTION
Expected response rate.	A motivated respondent is more likely to return a completed questionnaire. If good rates of responses are anticipated, mailed surveys may do. However, if a low response rate is anticipated, personal interviews are better suited to achieve higher response rates.
Resource availability.	It would be time-consuming for a researcher to interview a thousand participants. However, the researcher would be better suited to employ the use of questionnaires to the same number of respondents with relative ease.
Whether the questionnaire will be completed independently.	Questionnaires can either be conducted face-to-face by an interviewer, by means of telephone or independently by respondents. Differentiation of these methods is important, as it has a significant impact on the design of the questionnaire. Self-assessed questionnaires should be simple to understand, with clearly defined and laid out instructions, whereas a level of complexity can be applied given that an interviewer administers the questionnaire.

Source: Mathers et al. (2009: 19).

Questionnaires are less expensive than interviews, as they save on human capital and financial resources (Leedy and Ormrod, 2015: 160; Kothari, 2004: 100-101; Kumar, 2011: 141; Singh, 2006: 108). This is particularly noticeable when implemented collectively to a study population. Anonymity is afforded to respondents as there is no face to face interaction between the researcher and respondents and this grants the respondents comfort in disclosing accurate information to sensitive questions (Leedy and Ormrod, 2015: 160; Kothari, 2004: 100-101; Kumar, 2011: 141; Singh, 2006: 108). Questionnaires are free from researcher bias as respondents answer questions independently and large population samples can be used, therefore providing dependable and reliable data. (Leedy and Ormrod, 2015: 160; Kothari, 2004: 100-101; Kumar, 2011: 141; Singh, 2006: 108). Respondents are afforded ample time to answer questions in a well thought out manner and those not easily approachable can be contacted with less difficulty (Leedy and Ormrod, 2015: 160; Kothari, 2004: 100-101; Kumar, 2011: 141; Singh, 2006: 108).

Control of the questionnaire can, however, be difficult once it is issued to respondents, as the process is slow and many respondents do not return questionnaires, and this makes the questionnaire method prone to bias (Leedy and Ormrod, 2015: 160; Kothari, 2004: 101; Kumar, 2011: 141-142; Singh, 2006: 107). There is almost no opportunity to get clarification for questions not understood by respondents, which may also impact the quality of results. Mailed responses give respondents the chance to consult external people that may influence their opinions (Leedy and Ormrod, 2015: 160; Kothari, 2004: 101; Kumar, 2011: 141-142; Singh, 2006: 107).

Owing to the nature of the study, the chosen method of data collection was a questionnaire survey. The questionnaire is structured and comprises of open-ended and closed-ended questions (see Appendix D). Open-ended questions allow respondents to interpret questions, while closed-ended questions are defined in advance, therefore limiting the respondents to pre-determined responses provided (Mathers et al, 2009: 20). Questionnaires are less expensive than interviews, require less skill and training, allow for anonymity of respondents and are suitable to cover a large geographically scattered population (Kothari, 2004: 100-101; Ahmad, 2012: 3).

A section of the questionnaire required respondents to identify what they perceived as the causes of cost overruns on a particular project using a five-point Likert scale (1- Very high; 2- High; 3- Moderate; 4- Low; 5- Very low). Similarly, a second section of the questionnaire required respondents to indicate what they perceived as barriers to the use of innovative cost control techniques using a five point Likert scale with different variables (1- Strongly Disagree; 2- Disagree; 3-Neutral; 4- Agree; 5- Strongly agree). Likert scales are comprised of a series of statements that require participants to express approving or disapproving opinions toward an object or statement (Kothari, 2004: 85).

3.6.1 Questionnaire Format

Table 3.3 shows the four sections of the questionnaire (see Appendix D). Innovative cost control techniques that were investigated included: earned value analysis, the last planner technique, 4D scheduling, fuzzy scheduling, reserve analysis, eSUB construction software, objective cost planning, integrated critical path and line of balance and Q-Scheduling.

Table 3. 3: The four sections of the questionnaire used in the study.

SECTION	DESCRIPTION
A: Background information.	This section of the questionnaire gives demographic characteristics of the respondents.
B: Determining the level of cost overruns of an identified project.	Respondents identify a project they are conversant with and outline the type of project, the projected cost prior to construction and the final cost upon completion and identify the causes of cost overruns that led to the project exceeding the original budget.
C: Identification of innovative cost control techniques used by construction firms on construction projects.	This section implores respondents to identify innovative cost control techniques used in the planning, monitoring and control of construction activities during the construction phase in the identified project from section B.
D: Determining the barriers to the use of innovative cost control techniques on the identified project.	Respondents identify the barriers hindering the adoption and implementation of innovative cost control techniques on the identified project.

3.6.2 Questionnaire Administration

This section sought to establish the manner in which the questionnaire was administered.

Employing technology to facilitate questionnaires

Questionnaires have traditionally been conducted exclusively with pen and paper, but technological advances and increased computer literacy have given researchers the opportunity to share some of the burden of data accumulation and analysis (Leedy and Ormrod, 2015: 170). Database software programs provide researchers the names and addresses of prospective research participants, give information of individuals that have not received research participation requests, point out individuals that are yet to respond to participation requests and identify Individuals that require first or second email reminders to participate in the research (Leedy and Ormrod, 2015: 170).

Mailed questionnaire

This is the most common way of issuing questionnaires to prospective respondents (Kumar, 2011: 140). Addresses of respondents can be sourced from organisational databases or from members of a panel willing to participate in the study (Brace, 2004: 36). Paper-based questionnaires can be issued to a large number of people, therefore potentially saving the researcher on the expenses of travelling or making long-distance calls (Leedy and Ormrod, 2015: 260).

3.6.3 Method of administration

The research instrument, the questionnaire, was circulated via Survey Monkey, which is an online survey development cloud-based software. It is a programme that provides data analysis, sample selection, bias elimination and data representation tools (Alfaro, 2016: 6). Demerits of the program include email requests being left unopened by participants and the likelihood of a low rate of response in case there is insufficient marketing of the survey to the study population (Waclawski, 2016: 1).

Given that personal information is made available to the researcher, email reminders were sent to those respondents that had yet to participate in the study. The researcher additionally monitored the survey progress and observed the successful completion rate of questionnaires (Waclawski, 2016: 1).

3.7 METHOD OF DATA ANALYSIS

Upon conclusion of the research survey, the data collected was processed and analysed in accordance with the framework set in place at the time of generating the research plan (Kothari, 2004: 122). Analysis entails computing measures and probing for patterns in relationships present in data groups (Kothari, 2004: 122). Data analysis methods used were frequency distribution and percentage, mean item score and scatter plot. Microsoft word in tandem with Microsoft Excel were used to produce the histograms, bar charts, and scatterplots for the study. The scatterplots were used to establish the relationship between the level of use of innovative cost control techniques and cost overrun.

3.7.1 Frequency distribution and percentage

The number of items within a given class is known as the frequency of the given class or group (Kothari, 2004: 124). Entire groups and their respective frequencies are collated and classified in the form of a table known as frequency distribution (Kothari, 2004: 124). Categories were classified according to magnitude or in geographical, alphabetical or chronological order to facilitate comparison of the results, which were given as tabulated percentages (Kothari, 2004: 129).

3.7.2 Mean item score

The mean is the most common criterion of statistical averages and is calculated by dividing the total of given values by that of the total number of items (Kothari, 2004: 132). However, rather than calculating the simple mean of data, the weighted mean is calculated instead to determine the realistic average of data. The weighted mean assigns weights determining the significance of data points (Kothari, 2004: 132). It is calculated by the following formula:

$$\bar{X}_w = \frac{\sum w_i X_i}{\sum w_i}$$

Where $\bar{X}_w = \text{weighted item}$

$w_i = \text{weight of } i\text{th item } X$

$X_i = \text{value of the } i\text{th item } X$

Data analysis for this study was presented appropriately using tables and charts to interpret questionnaire responses. Frequency distribution and percentages were used to analyse the background information of participants, determine certain characteristics of specific projects participated in by respondents and for the identification of innovative cost control techniques used for planning, monitoring and controlling construction activities during the construction phase. Mean item scores were used in the determination of the causes of cost overrun on the identified construction projects and to determine the barriers to the use of innovative cost control techniques on the projects. Factors with an MIS score of 3.60 and above were deemed to have a high-level significance in this study, and this assessment level was applied in Sections 4.4.1 and 4.4.4.

3.7.3 Scatter plot

A scatter plot was used in section 4.3 to establish whether a relationship existed between the level of use of innovative cost control techniques in construction projects and the cost performance of projects. A scatter plot, also known as a scatter gram, showcases the relationship between two quantitative variables, with each dot on the graph a representation of a particular participant. The values of one variable are presented on the vertical axis while values of a second variable are presented on the horizontal axis (Moore et al., 2013: 2). A line of best fit, or trend line, is a line through a set of two variables, from which a correlation is established. The correlation describes the relationship between the two data sets. A positive correlation denotes the values of both sets of data increasing, while a negative correlation denotes the values of one set of data decreasing as the other set increases. No correlation denotes the absence of a relationship between the two data sets (Moore et al., 2013: 6). A scatter plot was applied in this study by assigning the cost performance of projects in the y-axis and the level of innovativeness in the x-axis. The direction of the scatter plot was used to establish the relationship between the cost performance of projects and level of innovativeness.

3.8 RELIABILITY AND VALIDITY

The reliability and validity of measurement instruments have an impact on the degree that a researcher can legitimately learn something from the phenomenon being investigated, the likelihood that the researcher will acquire statistical significance in data analysis, and the degree to which any important deductions can be drawn from the data by the researcher (Leedy and Ormrod, 2015: 114). Validity describes the extent that differences found within a measuring instrument truly reflect the differences amongst those undergoing testing while reliability focuses on the precision and accuracy of the measurement process (Kothari, 2004: 73).

Cronbach alpha was established as a measure of the internal consistency of a test or scale (Tavakol & Dennick, 2011: 53). Internal consistency defines the degree to which all elements in a test measure the same construct and therefore is connected to the interrelation between elements within the test. Internal consistency must be determined prior to undertaking a test for research purposes to safeguard validity (Tavakol & Dennick, 2011: 53). Cronbach's alpha reliability coefficient customarily ranges between 0 and 1, and greater internal consistency is achieved when this value is closest to 1 (Gliem & Gliem, 2003: 87). Cronbach's alpha coefficient range is interpreted as; < 0.9 (Excellent); > 0.8 (Good); > 0.7 (Acceptable); > 0.6 (Questionable); > 0.5 (Poor); and < 0.5 (Unacceptable) (Gliem & Gliem, 2003: 87). The Cronbach alpha coefficient for this study was 0.77 and therefore the data reliability and validity was acceptable based on the coefficient range.

3.9 ETHICAL CONSIDERATIONS

The majority of research ethical issues are classified into four categories: informed and voluntary participation, protection from malicious harm, privacy and transparency with professional associates

(Leedy and Ormrod, 2015: 120). The study was conducted with the full consent of participants, which was obtained prior to the commencement of the study (See Appendix A and B). Any misrepresentation of primary data was circumvented, along with any disingenuous information, and a level of discretion of the accumulated data was observed. The questionnaire was proofread by the supervisor and pilot tested using a focus group of PhD students at the Department of Construction Economics and Management. Any form of communication with participants was conducted with honest and complete transparency, and participants were treated with utmost respect. Priority was taken to protect the privacy of participants. Ethics clearance was obtained from the University of Cape Town, and can be found in Appendix C.

3.10 CHAPTER SUMMARY

The chapter highlighted the research design employed for the study. It presented the various methods of survey research, and highlighted that questionnaires are the most suitable data collection approach to use for the study. Additionally, it presented the study population, limitations, method of data analysis and the data collection procedure used for effective investigation of the research objectives. The following chapter provides an examination and deliberation of the study results.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the research findings based on responses from the questionnaires issued out to participants. It addresses the research objectives established in Chapter One, which aimed to evaluate the barriers to the use of innovative cost control techniques during the construction phase in South Africa.

4.2 DATA PRESENTATION

4.2.1 Background profile of the respondents

This section sought to establish the demographic characteristics of respondents.

4.2.1.1 Grade and specialisation of the respondents as listed on the cidb Register of Contractors

Table 4.1 indicates the grades and specialisation of research participants in accordance to the cidb register of contractors. As indicated in Table 4.1, the top two specialisations of respondents were Civil Engineering (CE) at 45.56%, and General Building (GB) at 44.44%. Specialist Contractors (SQ) were the third highest at 4.44%. The least common specialisations were Mechanical Engineering (ME), Electrical Engineering Works Infrastructure (EP), and Specialist Contractors (SQ) with a 1.11% representation each. cidb gradings of 1 and 2 were predominant under GB, with frequencies of 11 and 21 respectively, while cidb gradings of 1 and 2 were similarly predominant under the CE specialisation, with frequencies of 12 and 20 respectively. This indicated that the majority of respondents worked in GB and CE organisations with cidb grade 1 and 2.

4.2.1.2 Educational background of respondents

The study sought to establish the educational background of study participants, and the results are reflected in Figure 4.1. The majority, or 33.93%, of respondents hold a Bachelor's degree. This was followed by Matric certificate holders at 30.36% and N4-6/NTC4-6/Certificate/Certificate-diploma with less than Grade 12 at 23.21%. 14.29% of respondents were Master's degree holders and 0.89% hold a PhD. The results revealed the diversity of qualified professionals in the infrastructure sector, and their different perspectives can shed better light on the study objectives.

Table 4. 1: cidb grade and specialisation of study participants.

GRADE	GENERAL BUILDING (GB)	CIVIL ENGINEERING (CE)	ELECTRICAL ENGINEERING WORKS-INFRASTRUCTURE (EP)	SPECIALIST CONTRACTOR (SQ)	SPECIALIST CONTRACTOR (SO)	SPECIALIST CONTRACTOR (SH)	MECHANICAL ENGINEERING (ME)	TOTAL NUMBER	%
1	11	12	1	1	1	1	-	27	30.00
2	21	20	-	3	1	-	1	46	51.11
3	2	3	-	-	-	-	-	5	5.56
4	2	1	-	-	-	-	-	3	3.33
5	3	1	-	-	-	-	-	4	4.44
6	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-
9	1	4	-	-	-	-	-	5	5.56
TOTAL	40	41	1	4	2	1	1	90	
%	44.44	45.56	1.11	4.44	2.22	1.11	1.11		

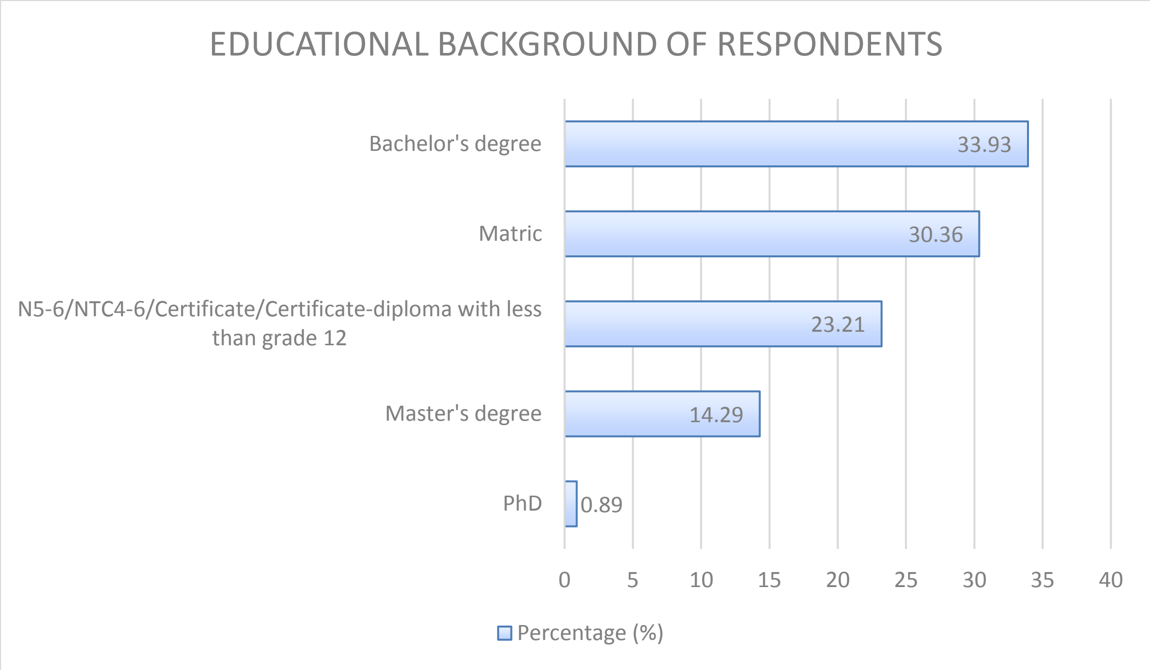

Figure 4. 1: Educational background of respondents.

4.2.1.3 Designation of respondents

The designation of respondents in their respective organisations are identified in Figure 4.2. The majority of respondents (35.29%) were project managers, followed by construction managers at 31.93%. Other designated positions in the study totalled to 28.57%, and included directors, civil engineers, contractors and a contracts manager. Quantity surveyors represented 11.76% and architects and site engineers made up 3.36% and 0.84% of the respondents respectively. This indicated that different perspectives from a diverse array of construction professions were represented in the study.

4.2.1.4 Area of expertise

The area of expertise of respondents is presented in Figure 4.3. It indicates that the majority (38.84%) of professionals had building and civil construction expertise. Building construction (32.23%) was the second highest area of expertise followed by civil engineering at 27.27%. Mechanical engineering works had the lowest frequency at 3.31%. Other areas of expertise identified by respondents included geotechnical engineering, property development, mining infrastructure and town planning, and these comprised of 12.40% of the study population. Special construction/specialist made up 9.09% of the respondents.

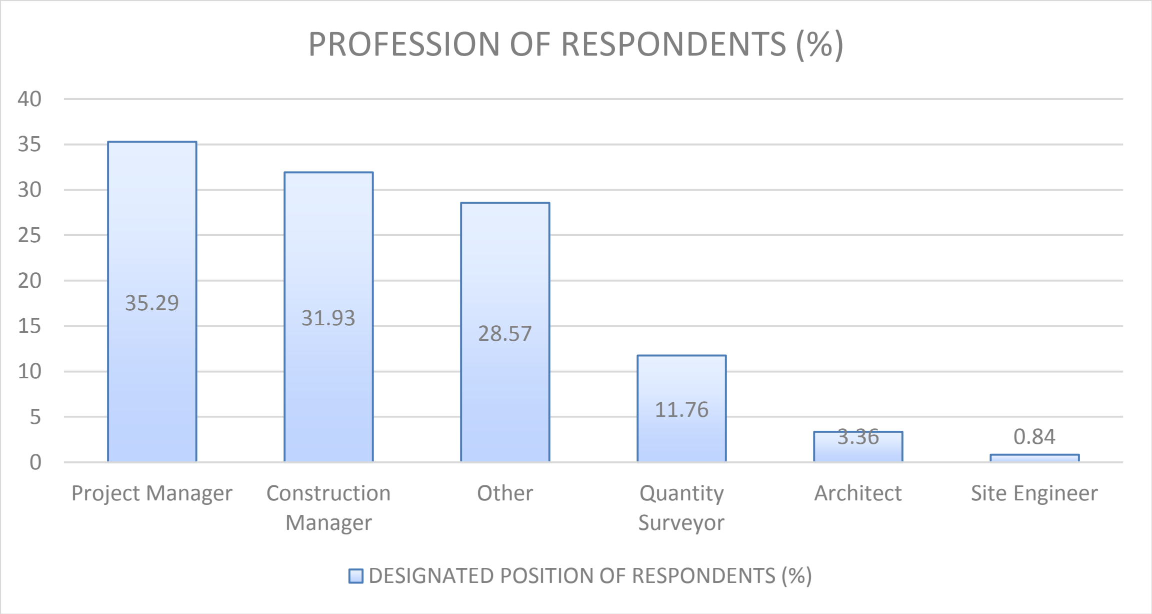

Figure 4. 2: Profession of respondents.

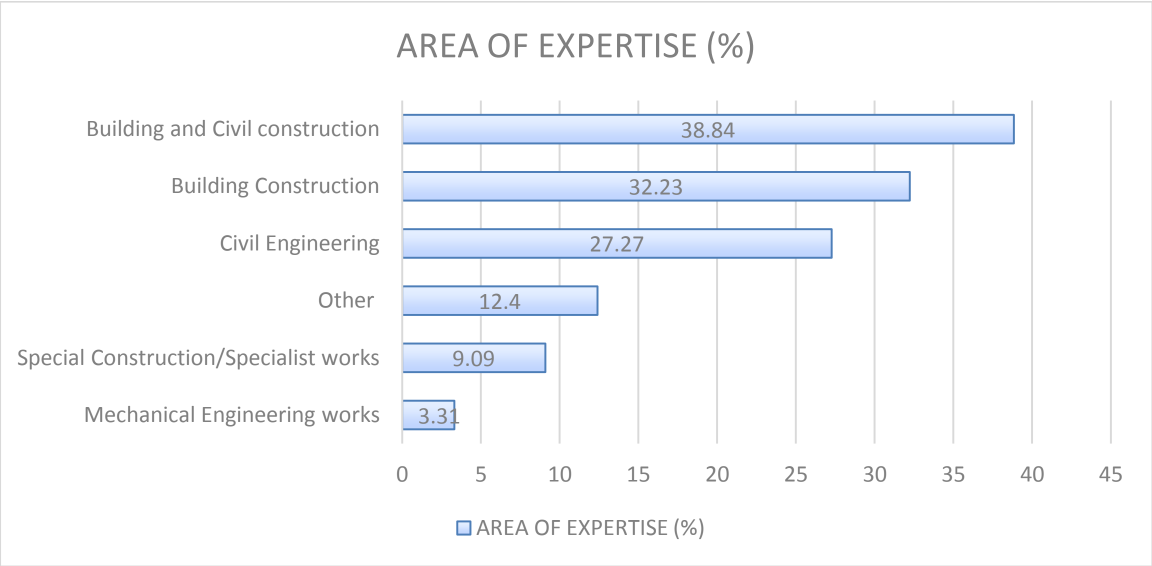

Figure 4. 3: Area of expertise of respondents.

4.2.1.5 Location of head office

The location of respondents' head offices are identified in Figure 4.4, and results indicated that the majority were located in the KwaZulu-Natal province, making up 33.61% of the survey. Gauteng had the second highest representation at 27.73%, followed by the Eastern Cape at 14.29%. The Western Cape followed at 13.45%, and the North West province at 10.08%. 5.88% and 4.2% of head offices were located in the Free State and Limpopo respectively. Mpumalanga and the Northern Cape had the lowest number of head office locations at 2.52% each.

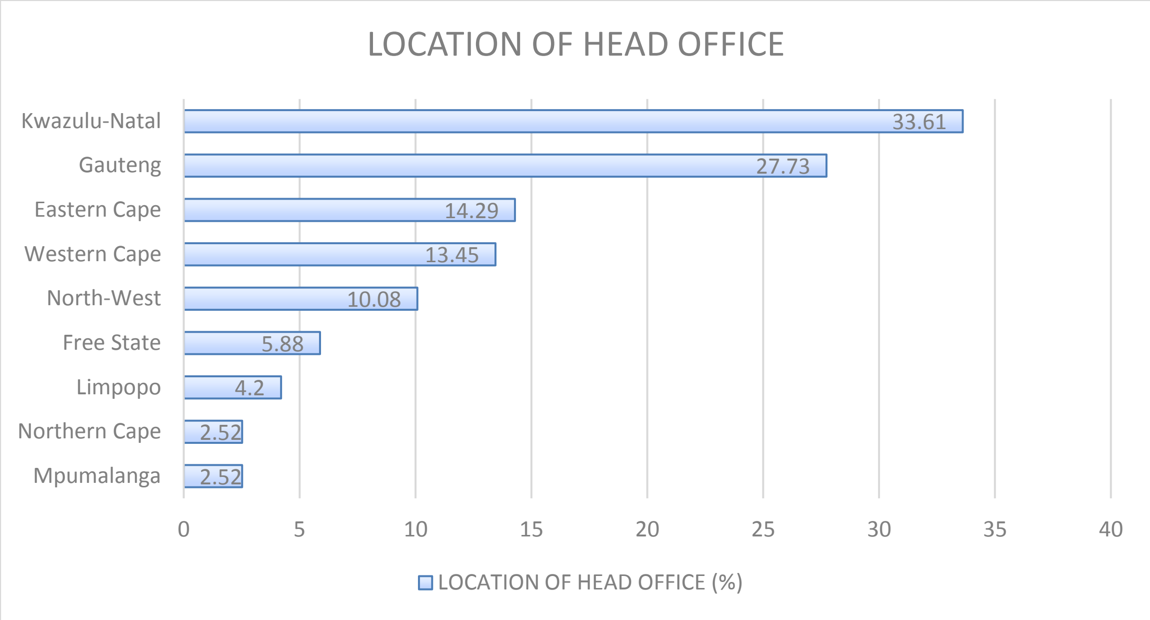

Figure 4. 4: Location of head offices.

4.2.1.6 Number of employees in organisation

The employee count in respondents' organisations are identified in Figure 4.5, and results indicated that 55.26% of organisations comprised of 1-10 employees, while organisations with over 40 employees had the second highest proportion at 21.05%. 12.28% of organisations had an employee count in the 11-20 range, 8.77% in the 21-30 range and 2.63% had an employee count in the 31-40 range.

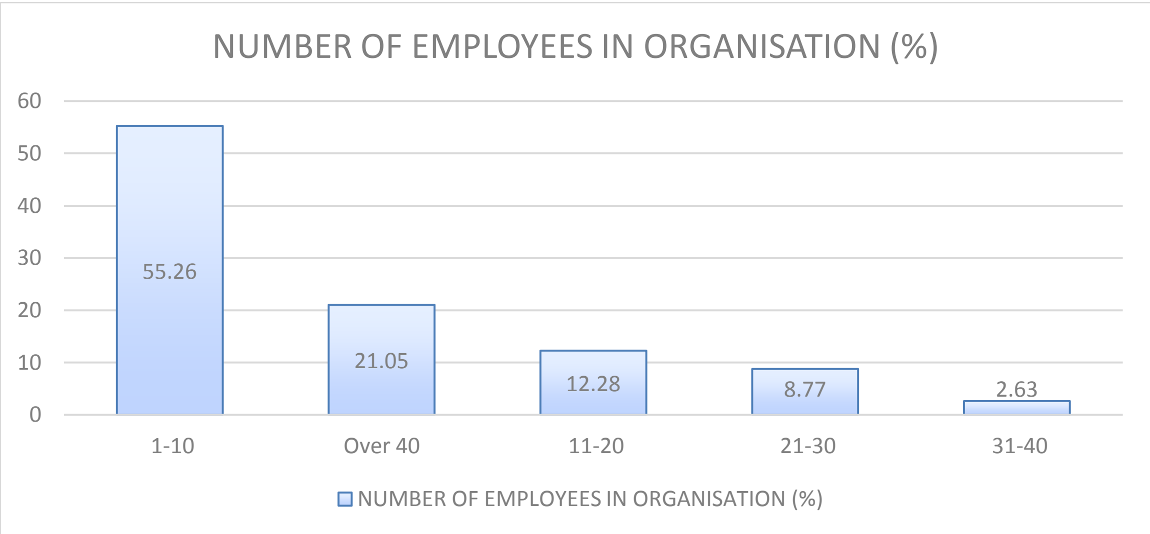

Figure 4. 5: Number of employees in organisation.

4.2.1.7 Year of establishment of organisation

The year of establishment of respondents' organisations is presented in Figure 4.6. The majority of organisations (38,94%) were established between 2001 and 2010, while 29.20% came into being after 2010. The rest of the organisations were established preceding the year 2001, with 15.93% founded before 1980, 9.73% between 1991 and 2000 and 6.19% between 1980 and 1990. Nearly three quarters of the organisations have existed for at least 10 years or more, therefore indicating that the majority of study participants completing the questionnaires are senior individuals holding senior positions in their respective organisations.

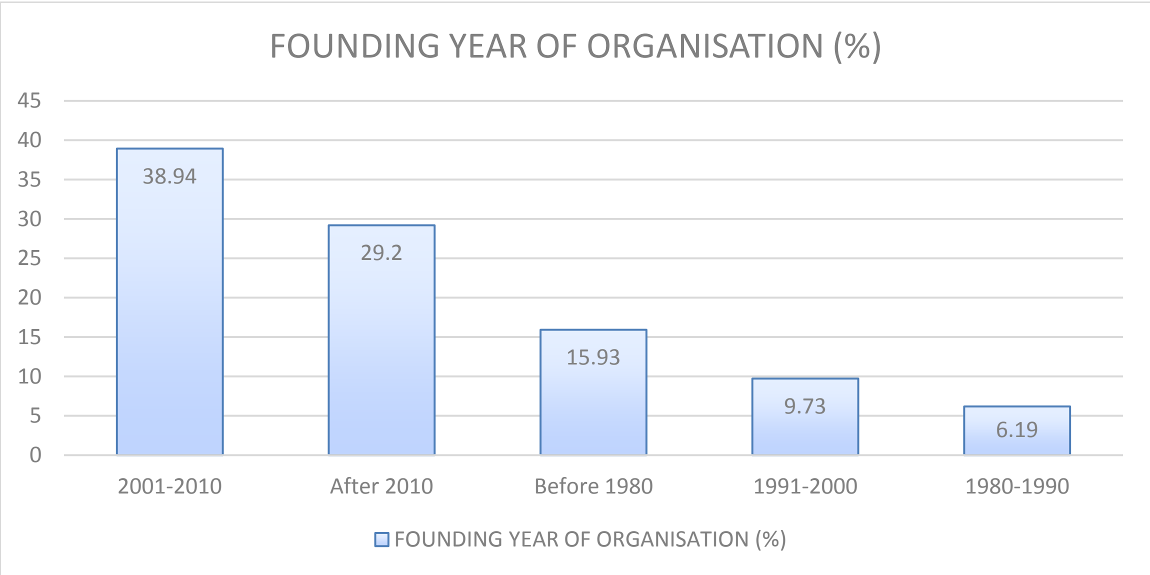

Figure 4. 6: Founding year of organisation.

4.2.1.8 Region of operation

The organisations' region of operations were identified, and the results are showcased in Figure 4.7. Most participants (40.68%) had operations at provincial level, followed by operations at national level at 33.05%. Local level operations stood at 28.81%, international level at 17.80%, while operations were lowest at regional level at 14.41%.

4.2.1.9 Years of working experience

The number of years of working experience of study participants is indicated in Figure 4.8. The most experienced respondents were in 21-30 and over 30-year categories, making up 13.68% and 17.95% respectively. The majority of respondents partaking in the study (28.21%) had 11-20 years of working experience. This was followed by respondents with 6-10 years of experience at 24.79%. The least experienced respondents, with 0-5 years of experience, comprised 15.38% of the study. It therefore can be concluded that respondents to the survey are well experienced, as 59.84% had over 10 years of working experience, therefore improving the quality of collected data.

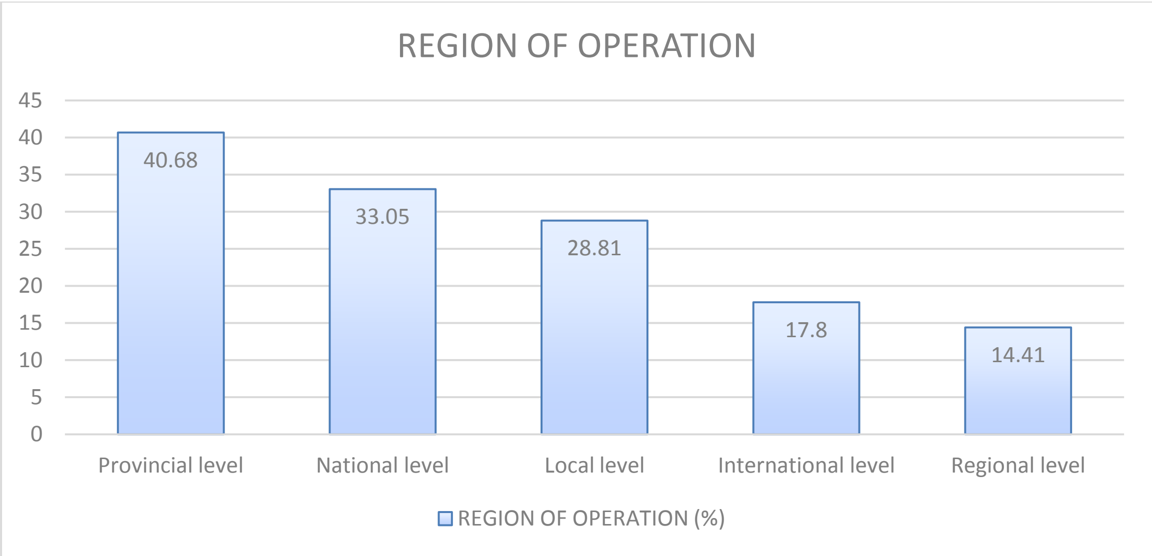

Figure 4. 7: Region of operation of organisations.

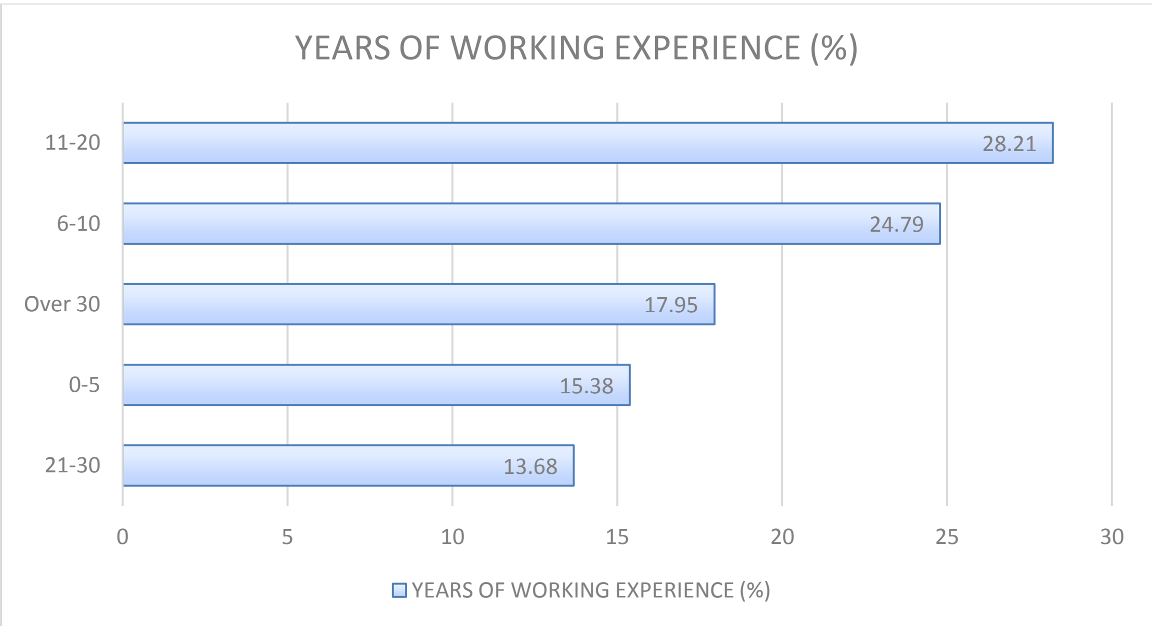

Figure 4. 8: Years of working experience of respondents.

The background profile of the respondents – education and experience, including the company they work for, show that the information they provided will be reliable.

4.2.1.10 Number of projects participated in within the past 5 years

The number of projects participated in by respondents within the past 5 years are recorded in Figure 4.9. 37.14% of respondents had participated in 1-5 projects over the past 5 years, making up the majority of the study. 28.57% participated in 6-10 projects, while 19.05% partook in between 11 and 20 projects. The most active respondents, who contributed to 21-30 and over 30 projects, had the lowest frequency counts at 6.67% and 8.57% respectively.

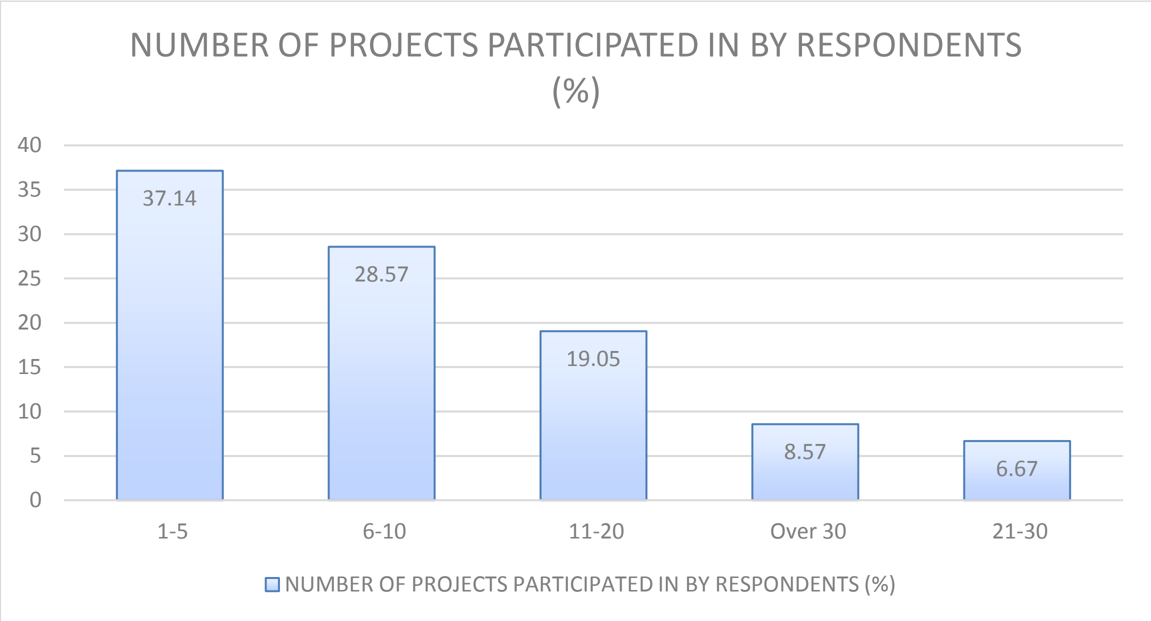

Figure 4. 9: Number of projects participated in over the past five years.

4.2.2 Level of Cost Overruns on Construction Projects in South Africa

This section required respondents to answer a series of questions about a project that they were conversant with and had completed within the last five years.

4.2.2.1 Location of project identified

The study sought to know the location of projects identified by respondents, and results are presented in Figure 4.10. 31.58% of projects were located in KwaZulu-Natal, making up the majority of the study. This was followed by Gauteng at 14.47% and the Eastern Cape at 13.16%. 11.84% of projects were located in the Western Cape, and 9.21% in the North West province. Mpumalanga had 7.89% of projects, while 5.26% were in the Free State. The least number of identified projects were situated in Limpopo and the Northern Cape, with frequencies of 2.63% and 3.95% respectively.

4.2.2.2 Initial cost of the project

The initial costs of projects identified by respondents are indicated in Figure 4.11. 46.97% of projects had an initial cost of less than R1 million, and this accounted for the majority of the study. 22.73% of projects had an initial cost of over R40 million, while 19.70% of projects were in the R1-10 million budget range. Projects in the R10-20 million and R20-40 million range had the lowest frequency counts at 7.58% and 3.03% respectively.

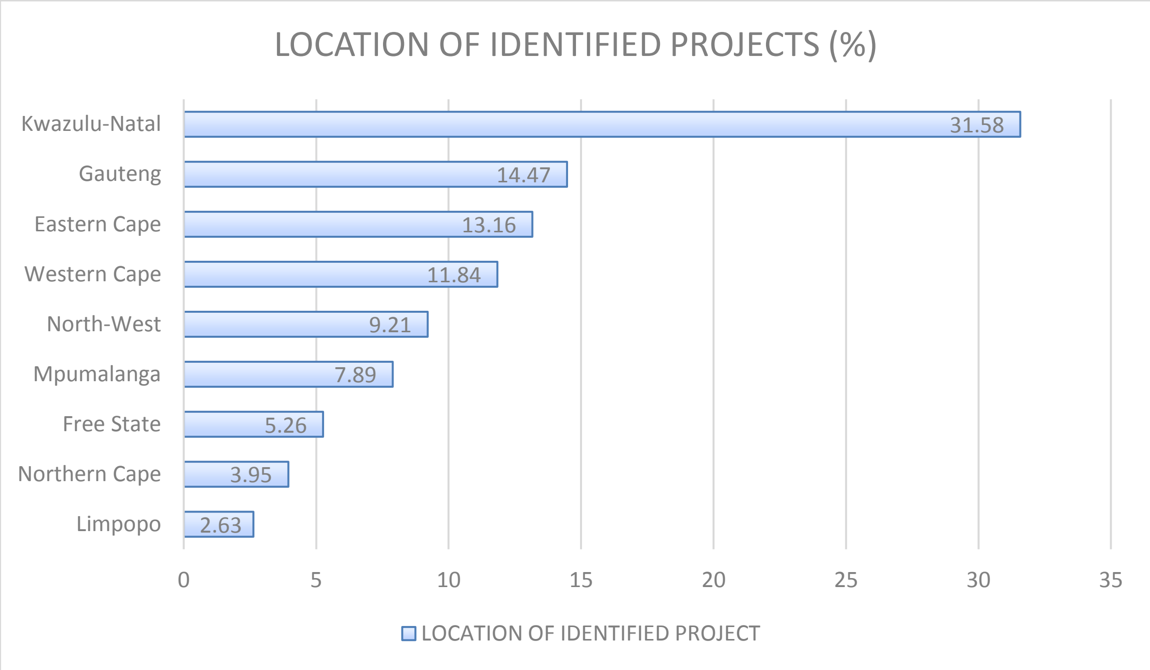

Figure 4. 10: Location of identified project.

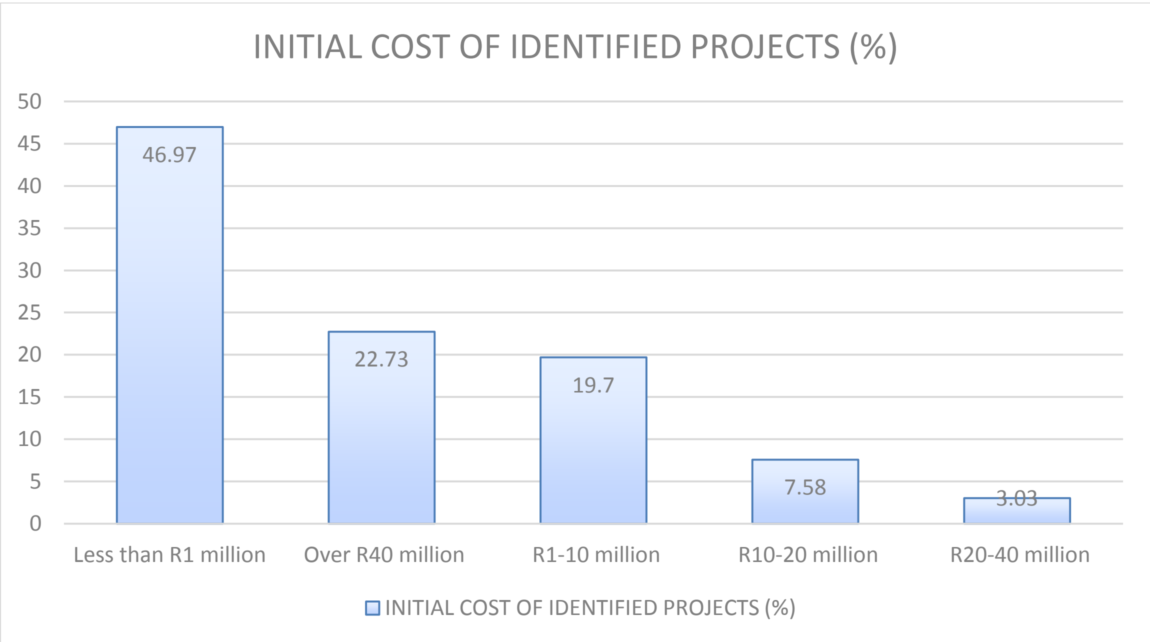

Figure 4. 11: Initial cost of projects.

4.2.2.3 Final cost of project

The final costs of projects identified by respondents are indicated in Figure 4.12. Projects that cost less than R1 million accounted for 39.39% of the study, while those in the R1-10 million range accounted for 22.73%. The final cost of projects in the over R40 million and R10-20 million range stood at 21.21%

and 10.61% respectively. Projects in the R20-40 million range had the lowest frequency count at 6.06%.

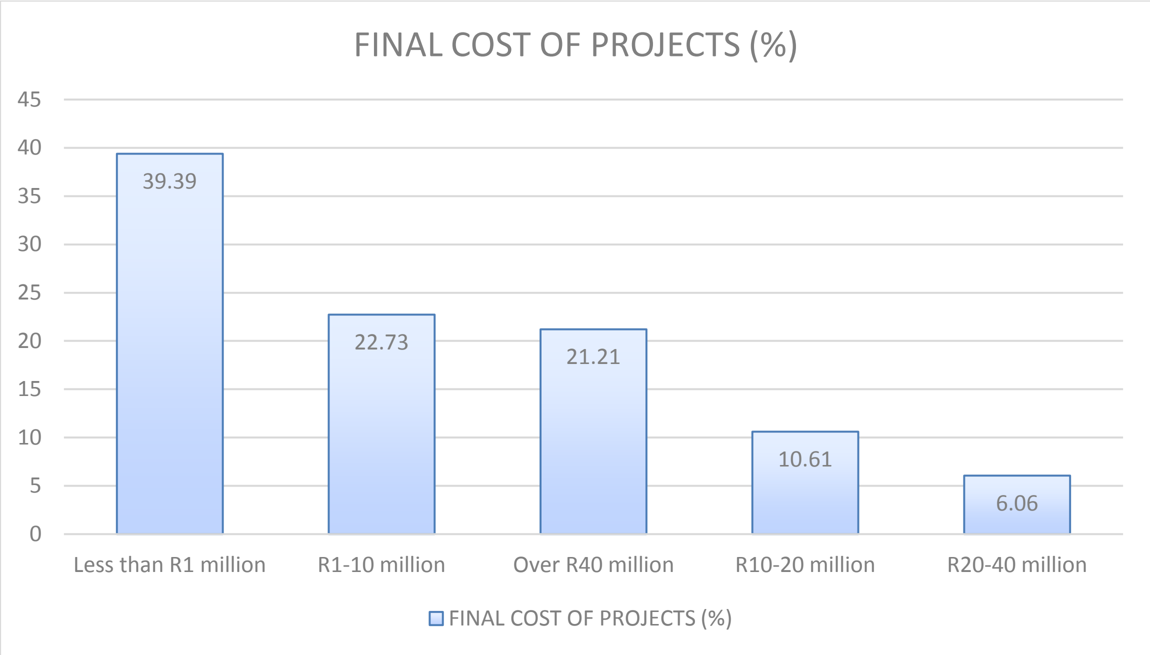

Figure 4. 12: Final cost of projects identified by respondents.

4.2.2.4 Type of project

The different project types identified by respondents are showcased in Figure 4.13. 20.24% of projects identified were renovations, 20% housing projects, 18.82% commercial buildings and 11.76% were industrial buildings. Other project classifications identified were civil construction, mining infrastructure, biogas and chemical plants, and these accounted for 43.53% of the study.

4.2.2.5 Procurement method selected for the project

Procurement methods applied to the identified projects by respondents are revealed in Figure 4.14. The majority of respondents employed the traditional procurement method in projects, accounting for 50% of the study. Management contracting was the second most common procurement strategy at 24.42%, followed by the integrated project delivery system at 16.28%. The design and build procurement method was the fourth most common at 15.12%. Other procurement methods identified by respondents were purchase delivery, RFQs and formal tenders, and these accounted for 10.47% of the survey.

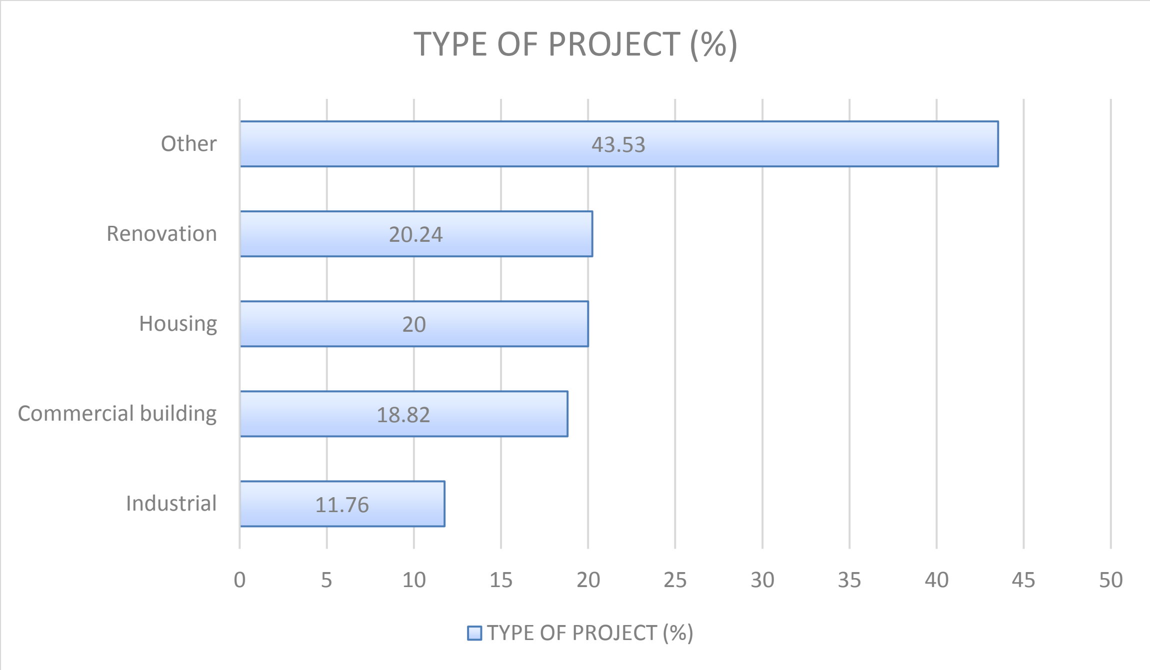

Figure 4. 13: Type of projects identified by respondents.

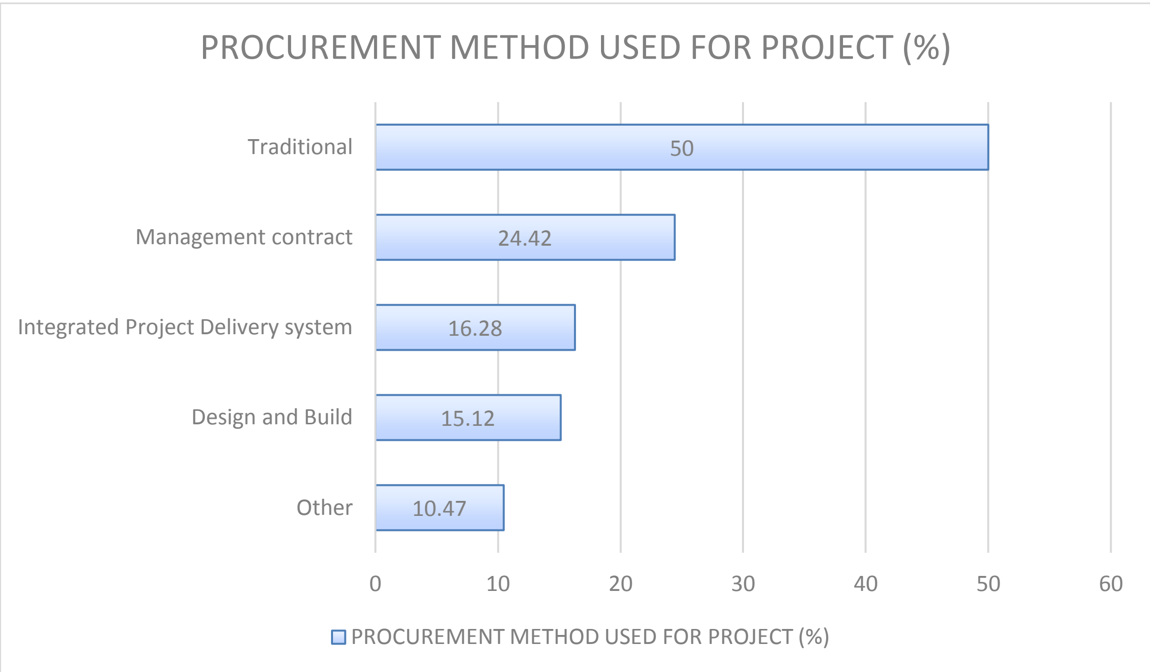

Figure 4. 14: Procurement method used for project.

4.2.2.6 Causes of cost overrun on projects

This section of the study provides the factors causing cost overruns in the projects identified by respondents. Causes were identified and rated as perceived according to a five-point Likert scale – 1- Very low; 2- low; 3- Moderate; 4- high; 5- Very high – in order to distinguish their mean item score and ranking. The results can be observed in Table 4.2. A look at Table 4.2 indicates that an insufficient project budget, project complexity, high frequency of change orders by the client and financial obstacles experienced by contractors fell within point 3 of the Likert scale. Point 3 on the Likert scale means that study respondents perceived these aforementioned factors as having moderate significance in causing cost overruns of projects in the South African construction industry. The rest of the factors in Table 4.2 fell in the 2-point range of the scale, therefore indicating low significance in causing cost overruns of projects.

4.2.3 Innovative Cost Control Techniques Used in South Africa

This section required respondents to identify innovative cost control techniques employed for the planning, monitoring and control of construction activities during the construction phase of the identified project.

4.2.3.1 Innovative cost control techniques used for planning construction activities

The innovative cost controlling techniques used by respondents for the planning of construction activities during the construction phase are displayed in Figure 4.15. They include earned value analysis, last planner, eSUB construction software, objective cost planning, fuzzy scheduling, 4D scheduling, reserve analysis, Q-scheduling and integrated critical path and line of balance. Objective cost planning was the dominant technique employed for the planning of construction activities, with 38.75% of respondents adopting the method. This was followed by earned value analysis at 37.50%, and integrated critical path – CPM and line of balance - LOB (combines the attributes of the conventional CPM and LOB) at 35%. The rest of the innovative techniques were used significantly less by respondents, with last planner at 17.50%, 4D-scheduling at 11.25% and Q-scheduling at 10%.

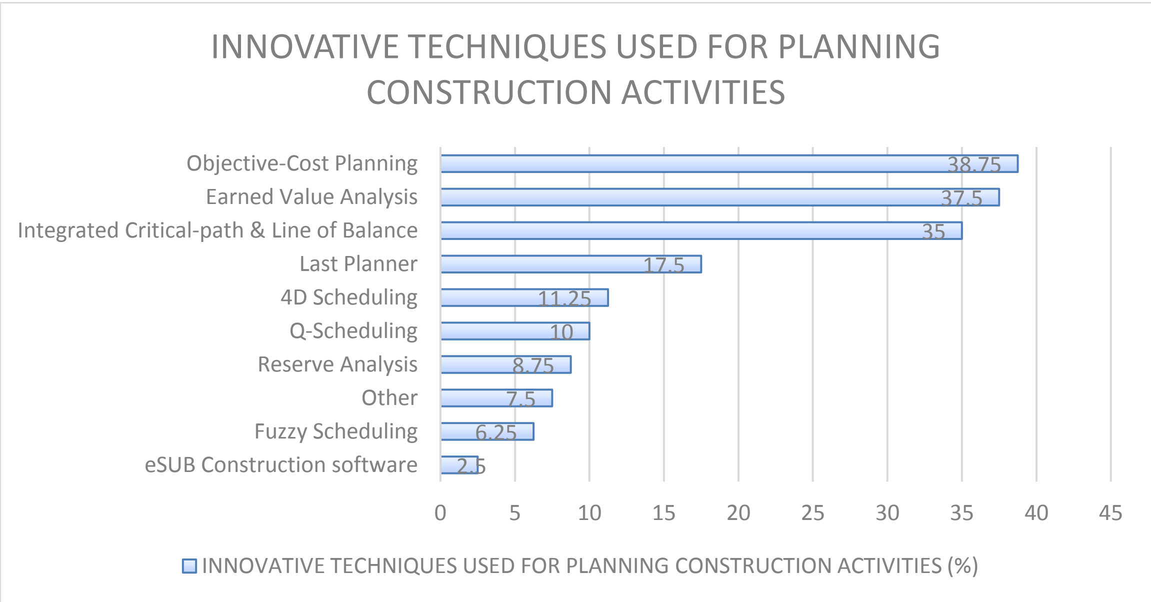

Figure 4. 15: Innovation cost control techniques used for planning construction activities.

Table 4. 2: Causes of cost overruns.

CAUSES OF COST OVERRUNS	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW	TOTAL	MIS
Insufficient project budget.	13	26	23	8	9	79	3.33
Project complexity.	8	24	32	5	7	76	3.28
High frequency of change orders by client.	8	19	28	14	9	78	3.04
Financial obstacles experienced by contractors.	9	24	19	13	14	79	3.01
Delayed progress payments to contractor.	15	15	17	16	16	79	2.96
Late approval of design documentation.	11	15	25	19	11	81	2.95
Impractical contract duration.	7	11	28	22	10	78	2.78
Poor communication channels between project parties.	6	14	26	17	15	78	2.73
Market inflation.	6	15	25	15	16	77	2.74
Difficulty in acquiring permits from authorities.	10	13	22	12	21	78	2.73
High labour costs.	6	15	24	17	16	78	2.72
Delays in design documentation evaluation.	7	14	18	24	14	77	2.69
Shortage of technical personnel.	5	15	23	16	18	77	2.65
Delayed site delivery to contractor.	7	12	21	25	15	80	2.64
Absence of leadership to spearhead innovation.	2	15	28	18	15	78	2.63
Poor strategic vision.	3	18	18	20	17	76	2.61
Corruption.	14	10	10	14	29	77	2.56
Delayed site mobilisation.	2	12	27	22	15	78	2.54
Low labour output.	4	11	25	18	18	76	2.54
Lack of expertise by consultants.	6	13	20	15	23	77	2.53
Unavailability of equipment and materials in local markets.	6	10	21	21	19	77	2.52
Poor implementation.	3	9	26	24	14	76	2.51
Late delivery of construction materials.	8	8	22	15	23	76	2.51

Table 4.2: Causes of cost overruns (Cont'd).

CAUSES OF COST OVERRUNS	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW	TOTAL	MIS
Inadequate site management by contractors.	4	15	17	21	21	78	2.49
Poor inspection plan.	5	8	21	24	17	75	2.47
Mismanagement of material (poor handling and waste).	5	9	23	19	23	79	2.42
Lack of motivation.	3	11	22	17	25	78	2.36
Hostility between labour.	5	8	21	18	25	77	2.35
Inferior quality of material.	3	7	24	19	25	78	2.28
Errors made in the construction stage.	3	9	17	25	23	77	2.27
Currency changes.	6	7	18	16	30	77	2.26
Poor equipment output.	2	7	23	19	25	76	2.24
Legal disputes between project parties.	5	7	17	17	31	77	2.19
Frequent change of subcontractors.	3	7	13	23	32	78	2.05

4.2.3.2 Innovative cost control techniques used for monitoring and controlling construction activities

The cost controlling techniques used by respondents for the monitoring and controlling of construction activities during the construction phase are identified in Figure 4.16. EVA was the most common technique used by respondents, with 44.74% adopting the method. Integrated critical path and line of balance was the second most common technique employed in projects at 34.21%, while objective cost planning ranked third at 27.63%. Last planner was utilised by 17.11% of respondents, and 10.53% used 4D-scheduling.

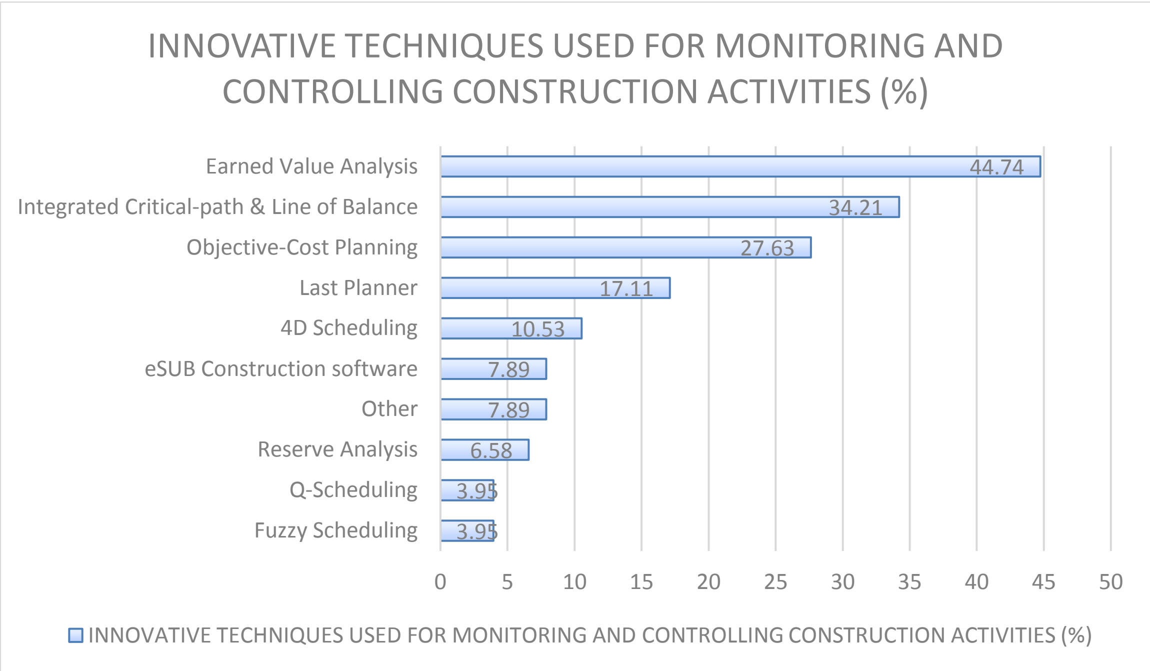

Figure 4. 16: Innovation cost control techniques for monitoring and controlling construction activities.

4.2.4 Optimal Cost Control Technique used in the South African Construction Industry

This section establishes the most optimal innovative cost control technique employed by respondents for the planning, monitoring and controlling of construction activities during the construction phase. Table 4.3 indicates the most significant innovative cost control techniques used by respondents for the **planning** of construction activities. Objective cost scheduling was identified as the most optimal technique, at a 38.75% adoption by respondents. Earned value analysis was the second most used technique at 37.50%, and integrated critical path and line of balance came in third at 35.00% use.

Table 4.4 indicates the most significant techniques adopted by respondents for **monitoring and controlling** of construction activities as determined from section 4.4.2. Earned value analysis was the most optimal technique applied to projects at 44.74% use by respondents. Integrated critical path and line of balance was the second highest implemented technique at 34.21%, followed by objective cost planning at 27.63% use.

Table 4. 3: Top optimal techniques for planning construction activities.

	OPTIMAL INNOVATIVE TECHNIQUES FOR PLANNING CONSTRUCTION ACTIVITIES	FREQUENCY OF USE BY RESPONDENTS (%)
1	Objective-Cost Planning.	38.75
2	Earned Value Analysis.	37.50
3	Integrated Critical path and Line of Balance.	35.00

Table 4. 4: Top optimal techniques for monitoring and controlling construction activities.

	OPTIMAL INNOVATIVE TECHNIQUES FOR MONITORING AND CONTROLLING CONSTRUCTION ACTIVITIES	FREQUENCY OF USE BY RESPONDENTS (%)
1	Earned Value Analysis.	44.74
2	Integrated Critical path & Line of Balance.	34.21
3	Objective-Cost Planning.	27.63

4.2.5 Barriers to the use of innovative cost control techniques on projects

This section identifies what respondents perceived as the barriers to the use of cost control techniques on identified projects. The barriers were assessed according to a five-point Likert scale: 1- Strongly Disagree; 2- Disagree; 3-Neutral; 4- Agree; 5- Strongly agree to distinguish their mean item score and ranking. The results can be observed in Table 4.5. A look at Table 4.5 indicates that all the barriers to the use of innovative cost control techniques fall within point 3 on the Likert scale. Point 3 on the Likert scale represents 'neutral', and results therefore mean that study respondents were unaware, or have little knowledge, of the barriers to the use of innovative cost control techniques on projects.

4.3 TEST OF HYPOTHESES

The study sought to test the hypotheses that the increased level of innovativeness of cost control techniques used improves the cost performance of projects for the planning, monitoring and control of construction activities during the construction phase. The data table that was used to obtain the level of use of innovative cost control techniques by respondents in projects for planning, monitoring and controlling of costs during the construction phase is shown in Appendix E and F. Additionally, it indicates the cost performance of projects relative to whether cost overrun or underrun was experienced upon project completion.

A scatter plot was used to distinguish the correlation between the cost performance of projects and level of innovativeness by establishing a line of best fit through the set of the two variables. A positive correlation denotes an increase in both sets of data, while a negative correlation denotes an increase in one set of data values as the other data set decreases.

Table 4. 5: Barriers to the use of innovative cost control techniques.

BARRIERS TO COST CONTROLLING TECHNIQUES	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE	TOTAL	WEIGHTED MEAN
Scope requirements of technique.	3	2	23	24	19	71	3.76
Resistance to change.	1	5	24	31	14	75	3.69
Training.	2	9	13	31	15	70	3.69
Technical skill.	3	8	19	26	17	73	3.63
Lack of standardisation.	1	9	17	35	10	72	3.61
General expertise of team members.	2	5	24	32	11	74	3.61
Role definition for team members.	2	7	21	30	12	72	3.60
Involvement of Quantity Surveyor in planning processes.	4	10	15	29	16	74	3.58
Cost analysis.	3	7	21	26	14	71	3.58
Cost control concepts by the organisation.	2	8	22	30	10	72	3.53
Details in designs.	1	12	18	31	11	73	3.53
Knowledge of cost control by professionals.	4	9	18	30	12	73	3.51
Cost data availability.	2	14	19	24	15	74	3.49
Variations throughout the project execution phase.	3	10	17	37	8	75	3.49
Education for appropriate data retrieval on construction sites by professionals.	6	5	25	27	11	74	3.43
Divulging information among project participants.	5	6	25	30	9	75	3.43
Research level into cost control in South Africa.	6	5	29	20	13	73	3.40

In the scatter plot for this study, the cost performance of projects is represented by the y-axis while the x-axis represents the number of innovative techniques employed (level of innovativeness) on projects to control costs. The values were plotted on scatter plots (see Figures 4.17, 4.18, and 4.19), and a line of best fit established using a tool on Microsoft Excel. A line of best fit in the positive direction indicates that increased levels of innovativeness improves the cost performance of projects, while a line of best fit in the negative direction indicates that increased levels of innovativeness does not enhance project performance.

4.3.1 Hypothesis 1: Increased level of innovativeness of cost control techniques used improves the cost performance of projects for the planning of construction activities during the construction phase

Hypothesis 1 set to establish whether increased levels of innovativeness improved the cost performance of projects in planning construction activities during the construction stage. Figure 4.17 revealed the level of innovativeness of cost control techniques against cost performance of projects for the **planning** of construction activities during the construction phase. Results indicated that there was a negative relationship between the level of innovativeness and cost performance, as cost performance decreased as the number of techniques used increased. Therefore, it can be deduced that the application of several innovative techniques for the planning of construction activities did not improve the cost performance of projects.

4.3.2 Hypothesis 2: The increased levels of innovativeness in cost control techniques improves the cost performance of projects for the monitoring and controlling of construction activities during the construction phase

Hypothesis 2 set to establish whether increased levels of innovativeness improved the cost performance of projects in monitoring and controlling construction activities during the construction stage. Figure 4.18 revealed the level of innovativeness of cost control techniques against cost performance of projects for the **monitoring and controlling** of construction activities during the construction phase. Results indicated that there was a negative relationship between the level of innovativeness and cost performance, as cost performance decreased as the number of techniques used increased. Therefore, it can be deduced that the application of several innovative techniques for the monitoring and controlling of construction activities did not improve the cost performance of projects.

Figure 4.19 shows the level of innovativeness of cost control techniques against cost performance of projects for the **planning, monitoring and controlling** of construction activities during the construction phase. Results indicated that there was a negative relationship between the level of innovativeness and cost performance, as cost performance decreased as the number of techniques used increased. Therefore, it can be deduced that the application of several innovative techniques for planning, monitoring and controlling of construction activities did not improve the cost performance of projects.

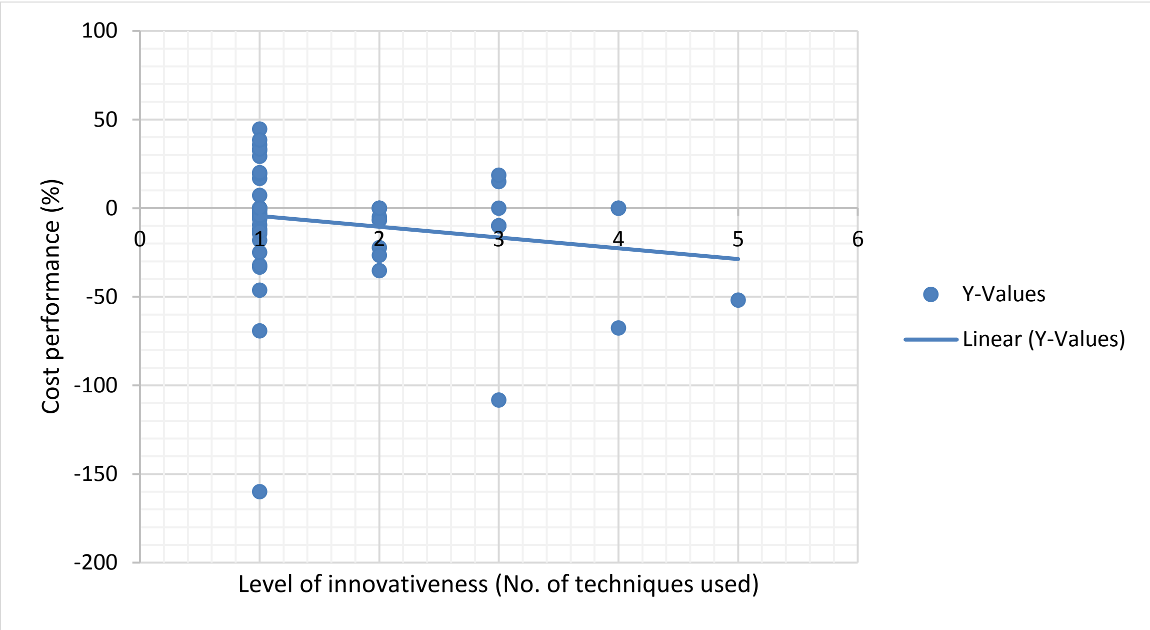

Figure 4. 17: Level of innovativeness and cost performance for the planning of project costs.

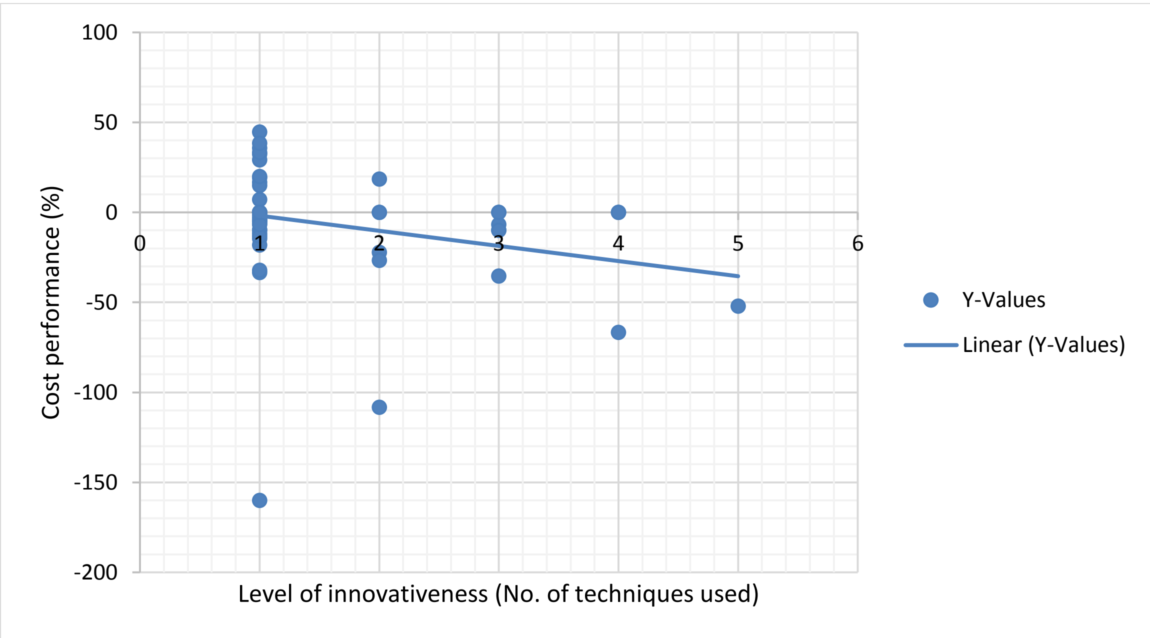

Figure 4. 18: Level of innovativeness and cost performance for monitoring and controlling project costs.

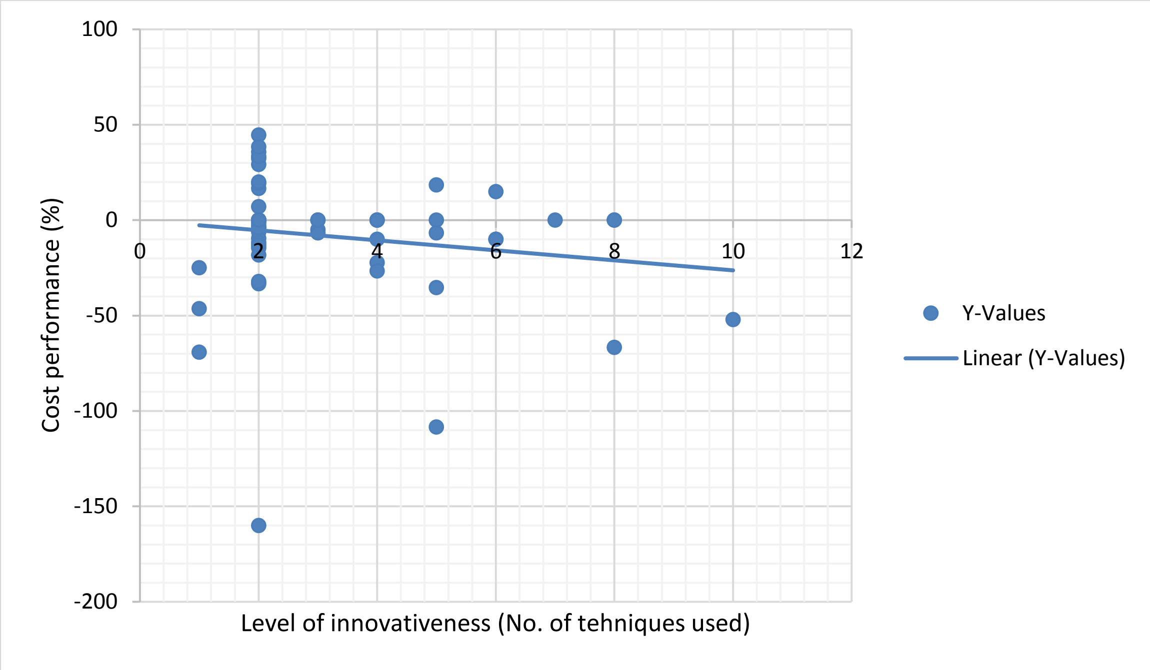

Figure 4. 19: Level of innovativeness and cost performance for planning, monitoring and controlling project costs.

4.4 DISCUSSION OF FINDINGS

The research set out to examine the use of innovative cost control techniques on construction projects, and whether there were barriers inhibiting their implementation in projects by construction professionals during the construction phase. This section deliberates the results of the study and aligns the results to the reviewed literature. The following study objectives established in chapter one shall be reviewed to determine whether they have been satisfied:

1. Ascertain the level of cost overruns on construction projects in South Africa.
2. Identify innovative cost control techniques used by construction firms in construction projects.
3. Determine barriers to the use of innovative cost control techniques in projects.
4. Find out whether there is a relationship between the level of use of innovative cost control techniques in construction projects and cost overrun.
5. Establish the optimal innovative cost control technique used in the South African construction industry.

4.4.1 Determining the level of cost overruns on construction projects in South Africa

The reviewed literature established that effective cost control practices are detrimental for the socio-economic growth of a country. However, cost overruns continue to be a global phenomenon plaguing the construction industry, as relayed by Flyvberg et al. (2003: 78). South Africa faces this problem, as revealed by the findings of the research study.

66 survey respondents disclosed cost performance data of identified projects, and 31 (47%) of these encountered cost overruns. Of the 31 projects, 15 (48.4%) experienced overruns ranging from 0-10% over the project budget while 11 projects (35.5%) experienced overruns ranging from 11-50%. 5 projects (16.1%) suffered overruns exceeding 50% of their allocated project budget. 35 participant projects (53%) were completed in accordance to budget parameters, with 13 (19.7%) of these affording cost savings to management, as they were below the allocated budget. This is indicative of a trend of poor cost performance and control by construction organisations despite the majority being completed according to budget, as nearly 50% of identified projects had experienced cost overruns. The evidence of the study attests to the findings by various authors (Gaetsewe et al., 2015: 41; Mulalo et al., 2018: 1268; Monyane and Okumbe, 2012: 196) who revealed the high level of poor cost performance prevalent in the South African construction industry, with overruns ranging from 11-65%. In the case of the construction of the 2010 World Cup stadia, the overruns extended as high as 94% (Baloyi and Bekker, 2011: 53).

The causative factors contributing to cost overrun collected from the survey among construction professionals in South Africa were compared with factors identified by different authors from previous studies. Factors with an MIS score of 3.60 and above were deemed as significant for this study. However, factors from Table 4.2 were not deemed to be significant, as they had an MIS score of less than 3.60. Factors were therefore classified as moderately significant and of low significance based on variables on the Likert scale. The moderately significant factors identified were insufficient project budget, project complexity, a high frequency of change orders by client and financial difficulties of the contractor. The rest of the factors had a low significance to the study. Comparisons reveal moderate similarities (relatively the same) between study respondents and those from previous studies. Change orders by clients during the construction phase, financial difficulties of the contractor, late payments by clients to contractors, frequent design changes and poor project planning and implementation were the major causes of cost overrun in prior studies.

Insufficient project budgets had the highest MIS score of 3.33 and was the 11th most frequently occurring cause of cost overrun in previous studies (see Table 2.1). This indicates the high level of competitiveness in the South African construction industry, as companies try to win tenders with the lowest possible bid, and suggests that a high proportion of project budgets in the country are inaccurately estimated or underestimated on purpose to maintain the competitiveness of tender bidding. Abusafiya (2017: 26) supports this opinion and stated that some construction organisations deliberately include unrealistic allowances to safeguard the attractiveness of bids. It additionally indicates a lack of expertise by contractors in executing projects that leads to schedule delays, material wastages and rework that stretches the project budget, as highlighted by Memon et al. (2011: 67). Poor judgements on work to be undertaken will result in an inaccurately estimated budget with consequential effects on the final cost.

Project complexity had the second highest MIS score of 3.28 and was the 19th most frequent cause of overrun based on previous studies. This suggests that the South African construction industry has not as yet adapted to the level of advanced techniques, expertise, methods and technologies used in other countries in effectively managing project complexity. This is evident from the cost performance of identified projects in the survey, as almost half (43%) of the projects experienced cost overrun, therefore insinuating that projects were of complex nature. This deduction is affirmed by the findings of Doloi (2013: 274), as the author states that the selection of the most suitable construction methods and techniques in accordance to the complexities of the activities to be undertaken on the construction site are critical to prevent cost overrun. The moderate level of significance of project complexity also points out to a lack of experience by contractors, for example, that they are unaccustomed to the project type and location. Aljohani et al. (2017: 141) states that this unfamiliarity increases the cost of project execution, as the likelihood of rework is increased. Similarly, Doloi (2013: 271) states that the contractor's inability to grasp the project design and specification compromises the efficiency of the construction process and diminishes productivity in the implementation phase. Complex projects are associated with high degrees of intricate plans, schedules and estimations, and any prominent omissions of either of these aspects can lead to change orders that could delay project progress and increase costs.

The high frequency of variation orders brought about by the client had an MIS score 3.04. This factor was the most frequent cause of cost overrun based on previous studies. Additional requirements to the project scope throughout the construction phase will result in cost overrun, as drawings have to be amended, the project schedule is affected, and the quantity of material and labour required has to be revised. These observations fall in line with the findings of several authors (Aljohani et al., 2017: 140; Bassioni et al., 2013: 141; and Bekr, 2015: 31) who state that any refinements made to the project design during the construction phase will cause already completed work to be reworked, will prolong the project schedule and will lead to losses in materials. An extension to the project schedule may result in unforeseen conditions, such as inflation of material prices and fluctuation of currency rates, that have to be factored in due to the time taken to refine scope changes. The contractor faces the likelihood of cost overrun during the implementation phase in the case of higher inflated material prices, as pointed out by Enshassi et al. (2010: 54). This factor suggests that a significant rate of rework and delays is common in South African construction projects due to poor planning and control in the design stage and, as a result, the construction phase suffers. Gaetsewe (2015: 41) supports this statement, as the author links the lack of clarity in the scope, ambiguous design briefs and variation orders to poor planning.

Financial difficulties faced by the contractor had an MIS score of 3.01 and was ranked the second most frequent cause of cost overrun in previous studies. This is an essential factor, as the financial standing of the contractor is important over the course of the project. They must possess the capability of paying site personnel, purchasing construction materials such as cement and reinforcement bars, purchasing or renting of equipment and machinery and paying subcontractors for work effected. Any cash flow issues will impact productivity and prolong the project schedule that will inevitably result in cost overrun. The literature is supportive of these deductions, stating that the availability of liquid assets and financial capability of contractors plays a major role in ensuring that projects are implemented successfully in accordance to time and cost parameters set out by management (Niazi and Painting, 2017: 516; Aljohani et al., 2017: 141; Enshassi et al., 2010: 52). Enshassi et al. (2010: 52) state that poor cash flow slows down productivity and renders the contractor unable to buy resources for the project. This leads the researcher to presume that the majority of contractors have small cash reserves and, for the most part, are dependent on regular and timely progress payments by clients to safeguard their cash flow. This is evident from the findings of Aljohani et al. (2017: 141) that state that it is commonplace for contractors to encounter financial obstacles during the construction phase.

4.4.2 Identification of cost control techniques used by construction firms on construction projects

The research sought to identify the innovative cost control techniques employed by construction professionals for planning, monitoring and controlling of construction activities during the construction phase. The reviewed literature identified and reviewed techniques such as EVA, LPS, fuzzy scheduling, 4D scheduling, reserve analysis and LOB. Survey results revealed that respondents adopted these innovative techniques in addition to objective cost planning, eSUB construction software, Q-scheduling, CANDY & CCS integration, model maker, cost to complete analysis and a cost/time integrated management system for planning, monitoring and controlling purposes. Objective cost planning, EVA and integrated critical path and LOB were the most dominant techniques used, while eSUB construction software and fuzzy scheduling were the least popular. The results indicate that the South African construction industry is progressive and evolving to the more modern methods, techniques and technologies available for planning, monitoring and controlling project costs. EVA, objective cost planning and integrated critical path and LOB had the most significant usage because, while they are innovative cost control techniques, they are by no means new to the construction industry and have already been in practice in the sector.

4.4.3 The most optimal cost control techniques used in the South African construction industry

The study established that an extensive selection of cost control techniques were being adopted by construction organisations in South Africa. The most effective techniques employed for planning construction activities were objective cost planning (38.75%), EVA (37.5%) and integrated critical path and LOB (35%). The most common techniques used for monitoring and controlling construction activities during the construction phase were EVA (44.74%), integrated critical path and LOB (34.21%) and objective cost planning (27.63%). Therefore, it can be deduced that these innovative cost techniques were the most optimal as deliberated by respondents. Innovative cost control techniques with a usage level of 25% and above were deemed as optimal in this study. EVA, objective cost planning and integrated critical path and LOB were the most optimal cost control techniques because EVA improves project efficiency, integrated critical path and LOB maximises on resources while maintaining work continuity and objective cost planning is focuses on the project objective.

However, a review of the literature revealed that traditional techniques were still dominantly being used by construction organisations for planning, monitoring and controlling of project costs during the construction phase (Ayinde, 2018: 14; Oyeyipo and Odusami, 2016: 47; Haruna et al., 2017: 21; Cooray et al., 2018: 918-919; Premalal et al. 2017, 167; Olawale and Ming, 2009: 882; Chigara et al., 2013: 6-8).

EVA was the only identifiable innovative cost control technique considered optimal by construction organisations based on previous studies from the reviewed literature (Premalal et al., 2017: 167; Olawale and Ming, 2009: 882). The South African construction industry readily adopts a wide range of innovative cost control techniques as reported in the survey results (see Figure 4.15 and Figure 4.16), therefore giving a strong indication of outdated published literature, as it fails in showcasing the widespread implementation of modern cost control techniques.

4.4.4 Determination of the barriers to the use of innovative cost control techniques

As aforementioned in section 3.8.2, factors with an MIS score of 3.60 and above were deemed as significant barriers to the use of innovative cost control techniques, and will be discussed in this section. These factors were extensive scope requirements of techniques, resistance to change, the lack of training of personnel, the lack of technical skill of personnel and the lack of standardisation (see Table 4.5).

The extensive scope requirements of innovative techniques had the highest MIS of 3.76 and ranked as the fifth most frequently occurring barrier in previous studies. This suggests that a majority of respondents are not acclimatised to the level of requirements demanded by innovative cost control techniques for effective use. The terminologies, processes and/or formulas associated may be difficult to grasp by the project team and stakeholders, which would impact the way communication is conveyed between project participants. The reviewed literature supports this deduction as several authors (Pillay et al., 2013: 104; Fortune and Grant 2005: 89; Gershon 2013: 13; Zulkefli et al., 2018: 343) alluded to the tedious high reporting and data collection nature of EVA. It is in the opinion of the researcher that construction organisations prioritise ease of use and understanding when introducing a new technique to their organisations. Therefore, the high significance of this factor potentially exposes inadequacy of knowledge, skill and expertise by construction professionals in the South African construction industry to cope with the demands of modern cost control techniques.

The resistance to change had the second highest MIS of 3.69 among respondents, whereas this ranked as the greatest barrier to innovative technique implementation in previous studies (Zulkefli et al. (2018: 344), Fortune and Grant (2005: 90), Kassem et al. (2012: 7), Soini et al. (2004: 9), Ahmed et al. (2014: 543), Porwal et al. (2010: 551-553), Cerveró-Romero et al. (2013: 715), Kim et al. (2016: 55), Hussein et al. (2017: 2842), Romigh et al. (2017: 402). This indicates that construction professionals from the survey and those from prior studies do not see the value afforded by modern cost controlling techniques. Construction is a capital-intensive industry requiring significant monetary investment to make a profit. If the value in using a technique is not seen as an asset but rather as a detriment to that profit, it shall not achieve widespread adoption. This is evident in the findings of authors (Kassem et al., 2012: 7; Romigh et al., 2017: 402; Ahmed et al., 2014: 543) who state that there have been no tangible benefits to justify the high cost and time requirements necessary to implement 4D BIM.
The reviewed literature attributed the slow adoption of innovative cost control techniques to the resistance by construction organisations in changing from the old way of doing things to more modern methods (Zulkefli et al., 2017: 342; Fortune and Grant, 2005: 90; Soini et al., 2004: 10; Porwal et al., 2010: 551). This was a theme picked up on by several authors and indicates that conventional techniques in use by construction organisations are adequate, and function well enough to achieve project objectives. Survey results indicated that numerous innovative cost control techniques were in use in the South African construction. However, the cost performance on identified projects did not justify their adoption, as 43% had encountered cost overruns. It begs to question whether the more innovative techniques outperform more conventional methods of cost control given the high proportion of projects with cost overrun that also used innovative cost control techniques that were observed in the study.

Alternatively, the resistance by organisations to change to modern methods showcases the poor attitude of construction professionals toward improving and evolving current processes into more efficient and profitable ones. It showcases the lack of vision in adapting to a changing environment considering the pace of technology. This opinion is supported by Porwal et al. (2010: 551-553), as the authors attribute this reluctance to a lack of commitment by construction professionals.

The lack of training and technical skill had the third and fourth highest MIS scores at 3.69 and 3.63 respectively, while they were the second most frequently occurring barrier to implementation of modern cost control techniques in previous studies. This is indicative of the skills gap that continues to exist and burden the construction industry, as there is lack of adequately experienced and trained human capital to champion the move away from traditional techniques. Several findings from the reviewed literature attested to this deduction, as the authors attributed the poor adoption of 4D BIM, EVA and LPS in the industry to inadequate levels of knowledge, skill, experience and training of construction professionals (Romigh et al., 2017: 402; Kassem et al., 2012: 6; Zulkefli et al., 2013: 104; Porwal et al., 2010: 553; Malacarne et al., 2018: 141). This further suggests that there is a lack of initiative by construction organisations globally in investing toward skills acquisition and acclimatising employees to newer technologies. Khanh and Kim (2013: 8) are supportive of this opinion, as they criticise the poor training development policies of organisations and linked it to the low application of advanced technology in construction. Professionals are not motivated to adopt these modern cost control techniques given that the research results showed that the methods have no significant impact on cost control.

The absence of standardisation results in construction processes working independently of each other and can cause significant variation in the end product. This factor had the fifth highest MIS score of 3.61 and was the fourth most frequent occurring barrier based on previous studies. Several findings in the reviewed literature pointed to the lack of standardisation of processes, tools and procedures hindering the implementation of innovative cost control techniques such as LOB and 4D BIM (Malacarne et al., 2018: 147; Soini et al., 2004: 9-10; Bhargav et al., 2015: 7). Absence of standardisation can lead to a prolonged construction schedules, increased likelihood of rework and reduced profit for the company as organisations have to develop their own internal standards and tools. The literature review shed light on how the standardisation of processes improves the training of staff and enhances the quality of deliverables (Jakobs, 2016: 150). This deduction suggests standardisation can contribute toward resolving two of the identified significant barriers from the survey: the lack of training and inadequate technical skill of professionals. Increased expertise of site personnel will minimise the frequency of errors and reduce the levels of rework, thereby saving on construction costs for the contractor. Standardisation will allow for repeated processes to be applied on projects similar in nature, therefore increasing efficiency and limiting waste.

4.4.5 Relationship between the level of innovativeness of cost control techniques and cost overruns on projects

Survey findings indicated a negative relationship between the level of innovativeness and cost performance of projects for planning, monitoring and controlling construction activities during the construction phase. This reveals that projects encountered cost overruns regardless of the application of modern cost control techniques. These results are consistent with the findings of Fortune and Grant (2005: 90), as the authors determined in a study that only 24% of EVA users in the UK attested to the technique providing greater levels of project cost control over more traditional methods.

The research hypotheses established in Chapter one (see section 1.5) were that the increased levels of innovativeness in cost control techniques improved the cost performance of projects for the planning of construction activities during the construction phase (H1); and that the increased levels of innovativeness in cost control techniques improved the cost performance of projects for the monitoring and controlling of construction activities during the construction phase (H2). It was determined from Figure 4.17, 4.18, and 4.19 that the increased levels of innovativeness in cost control techniques did not improve the cost performance of projects for the planning, monitoring, and controlling of construction activities during the construction phase. This therefore does not validate the hypotheses.

The results are, however, inconsistent with the findings of Kim et al. (2016: 50), Umar et al. (2015: 551) and Daniel et al. (2014: 614), who all reported reductions in project cost and duration in projects where innovative cost control techniques, such as 4D scheduling and LPS, were implemented. These studies were undertaken in Australia, Malaysia and Nigeria respectively. The contrasting results suggest that the South African construction industry may suffer from a lack of understanding of modern techniques and be deficient of experienced and skilled personnel to implement them successfully. Results further suggest a lack of significant investment and commitment by construction organisations to improve processes and methods to adapt to new technologies.

4.5 CHAPTER SUMMARY

The research findings revealed that the study objectives were fulfilled. The chapter was centred on: the scale of cost overrun in South African projects, the causes of cost overrun in the construction industry, innovative techniques used to control project costs and the barriers hindering the use of these techniques. Study objectives were deliberated and presented in the chapter through application of statistical instruments, such as the mean item score, frequency distribution and percentages.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter provides a summary of the research findings while highlighting the study objectives set in Chapter one. The research report is subsequently concluded and provides recommendations on the basis of generated study results and suggestions for further research.

5.2 SUMMARY OF FINDINGS

The majority of professionals in the study were project managers and construction managers, while the highest level of education attained by respondents were bachelor's degrees, matric, and N4-6/NTC4-6/Certificate/Certificate-diploma with less than Grade 12. Areas of expertise were highest in building and civil construction, civil engineering, and build construction. The majority of respondents had 11-20 years of experience, followed subsequently by those with 6-10 years of experience and over 30 years of working experience.

The preceding chapters outlined the level of cost overrun in projects in South Africa as well as underlining their major causes. Innovative techniques of cost control were identified, and an investigation was undertaken to determine their level of implementation by professionals in the South African construction industry. The findings sought to identify the barriers to implementing innovative techniques for planning, monitoring and controlling projects during the construction phase, and to establish whether a relationship existed between their level of use and cost overrun.

5.2.1 Objective 1: Ascertain the level of cost overruns on construction projects in South Africa

The objectives were deliberated on, and it emerged that projects in the South African construction industry experienced a high level of cost overrun: 43% of identified projects exceeding their project budget, with some overrun levels exceeding upwards of 50% of their initial project budget. The majority of overruns experienced were in the 1-10% and 11-50% range. The top five identified causes of cost overrun in South Africa were an insufficient project budget to satisfy project objectives and project complexity, as the inability to grasp the project design and specifications will compromise the efficiency of the construction process. The high frequency of change orders by the client ranked, third as refinements made to the project design and scope during the construction phase would cause rework and prolong the project schedule. Financial difficulties faced by the contractor ranked fourth, as poor cash flow affects the contractor's ability to pay site personnel and subcontractors, and to purchase materials and equipment. The fifth ranked cause was delayed progress payments to the contractor by the client, as this further burdened the financial resources of the contractor. These sources of cost overrun were moderately similar to that of the reviewed literature.

5.2.2 Objective 2: Identify innovative cost control techniques used by construction firms in construction projects

The following innovative cost control techniques were identified to have been implemented for planning, monitoring and controlling of construction activities during the construction phase: EVA, LPS, eSUB construction software, objective cost planning, fuzzy scheduling, 4D scheduling, reserve analysis, Q-scheduling, integrated critical path and LOB, model maker, cost to complete analysis and CANDY CSS.

5.2.3 Objective 3: Find out whether there is a relationship between the level of use of innovative cost control techniques in construction projects and cost overrun

It was established that there was a negative relationship between the level of cost control techniques used and cost performance of projects for planning, monitoring and controlling of projects during the construction phase. Numerous projects (43%) had encountered cost overruns regardless of having implemented modern methods of cost control.

5.2.4 Objective 4: Determine barriers to the use of innovative cost control techniques in projects

The study explored the barriers to the use of innovative cost control techniques in projects, and revealed that scope requirements of techniques, the resistance to change by organisations, the lack of training and technical skill and the lack of standardisation of tools and processes are the hindrances to successful implementation of these techniques.

5.2.5 Objective 5: Establish the optimal innovative cost control technique used in the South African construction industry

In concluding, the most optimal cost control techniques identified for the planning of construction activities were objective cost planning (38.75%), EVA (37.50%) and integrated critical path and LOB (35.00%), whereas the most optimal techniques for monitoring and controlling construction activities were similarly EVA (44.74%), integrated critical path and LOB (34.21%) and objective cost planning (27.63%).

5.3 CONCLUSION

Based on the study findings, the study concludes that project cost overrun continues to impact projects negatively not only in South Africa, but on a global scale, owing to impractical budgets, project complexity and the frequent occurrence of variation orders, to list a few reasons.

The first objective sought to ascertain the level of cost overruns on construction projects in South Africa. It was subsequently determined that construction projects' cost overrun levels were high. Projects cannot meet project objectives, and construction organisations are not making use of the right tools and techniques to monitor and control construction costs. The second objective was to identify innovative cost control techniques used by construction firms in construction projects, and the third objective was to determine barriers to the use of innovative cost control techniques in projects. Scope requirements of technique, resistance to change, lack of training, poor technical skill and the lack of standardisation were found to be the most significant barriers. Hence, this study concludes that top management of construction organisations are not training their staff to embrace new technologies and innovation.

The fourth objective sought to establish whether there was a relationship between the level of use of innovative cost control techniques in construction projects and cost overrun. The relationship was determined to be negative. This led to the conclusion that construction professionals are limiting themselves and are not exploring alternative or innovative cost control techniques. They were not focused on cost overruns, but rather project efficiency and productivity.

The last objective established the optimal innovative cost control technique used in the South African construction industry. The research concludes that professionals are not taking advantage of the features of new innovative techniques to tackle complex projects – suggesting that complex projects will continue to experience cost overruns.

In sum, the study confirmed that modern techniques were indeed implemented on projects by construction organisations in South Africa. However, in spite of their adoption to better plan, monitor and control costs during the construction phase, cost overrun continues to be rife in the industry. There is an imperfect implementation of these methods because barriers, such as resistance to change, lack of expertise and technical skill, impede the successful and effective application of these innovative techniques.

5.4 RECOMMENDATIONS

This section of the report provides suggestions by the researcher formed from the basis of analysis of the reviewed literature and survey responses. The following were the recommendations generated:

- There should be increased investment on the part of construction organisations toward affording their workforce the relevant training, knowledge and technical skill required to implement the modern techniques for cost control identified in the report.
- Professionals in the construction industry should spearhead change toward more innovative technologies. For the purpose of growth, it is important to move away from the old way of thinking and adapt to the continuously changing project environment engendered by increased complexities. This will provide an edge against competitors. Initiatives such as workshops should

be part of the organisational development policy in order to create awareness of the new technologies available to be exploited, change poor attitude perceptions and promote ingenuity.

- The cidb should organise seminars and workshops on the usefulness and importance of innovative cost control techniques.
- Workers should embrace self-development and embrace change.
- Government should implement policies on the use of innovative cost control techniques for their projects.
- Construction organisations should develop capacity in line with innovative cost control techniques.
- Professionals should acquire more knowledge of innovative cost control techniques.

5.5 AREAS FOR FURTHER RESEARCH

This report has created the need for further exploration into innovative cost control technique implementation in the construction industry. The following are suggestions for further research:

- Further research in the project management field to assess the level of preparedness of construction organisations in implementing innovative cost control systems.
- A qualitative or mixed method study should be conducted to broaden the understanding of the impact of innovative cost control techniques on project performance.
- Specific case studies of the optimal cost control techniques will extend the understanding of the impact and benefits of these innovative cost control techniques.

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APPENDICES

APPENDIX A: Letter of Consent and Confidentiality

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Department of Construction Economics and Management
Faculty of Engineering and the Built Environment
University of Cape Town
Level 1.07, Snape Building, Upper Campus
Rondebosch, 7701
Cape Town

14 June 2019

Dear Prospective participant,

Re: Evaluating the barriers to the use of innovative cost control techniques during the construction phase

You are hereby invited to participate in an ongoing MSc (Project Management) research project aimed at evaluating the barriers to the use of innovative cost control techniques during the construction phase.

This is a research being undertaken by Leju Duku, an MSc (Project Management) student under the supervision of Associate Professor Abimbola Olukemi Windapo of the University of Cape Town. The outcome of the study will be presented to the Department of Construction Economics and Management in partial fulfilment of the requirement for the award of an (MSc) in Project Management.

This research does not pose any known risks and does not request any sensitive information. This research will identify and establish the optimal innovative cost control technique used in the South African construction industry. It shall determine barriers to the use of innovative cost control techniques on projects and determine if there is a relationship between the level of use of innovative cost control techniques on construction projects and cost overrun.

The questionnaire can be completed in approximately 20 minutes. All useful comments that will aid the researcher in carrying out the study are welcome. All subjects of this research and any information that you shall provide will be protected with unreserved confidentiality.

Should you have any queries or questions for clarification purposes about the study, do not hesitate to contact me on 0782681521 or DKXLEJ001@myuct.ac.za. Your timely response will be appreciated.

Thank you for your assistance.

Mr. Leju Duku
(MSc student/Principal Researcher)

A/Prof. Abimbola Olukemi Windapo
(Supervisor)

APPENDIX B: Consent Form

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

CONSTRUCTION ECONOMICS AND MANAGEMENT DEPARTMENT

Leju Duku (MSc Project Management student)
University of Cape Town
Level 1.07, Snape Building
Upper Campus
Rondebosch, 7701
Cape Town
Cell: +27-782681521
Email: DKXLEJ001@myuct.ac.za

CONSENT FORM

Title of the research project:

"Evaluating the barriers to the use of innovative cost control techniques during the construction phase"

Name and position of the researcher:

Leju Duku, MSc (Project Management) student, Department of Construction Economics and Management, University of Cape Town.

Please respond to the following:

	Please tick
1. I have read Mr. Duku's cover letter and understand what kind of information he is seeking from me.	
2. I agree to answer the questions posed in this study, and provide accurate information to the best of my ability.	
3. I understand that my participation is voluntary and that I am free to withdraw at any time without offering reasons.	
4. I agree to take part in this study.	

Name of the participant (on behalf of the company): ……………………………………………

Signed: ……………………………… Date……………………………………

Leju Duku (Principal researcher) Signature: …………………….... Date: ……………..

NOTE: All the information provided by you on behalf of the company will be treated as strictly confidential. The result will be presented in aggregate format and no individual disclosure will be made.

APPENDIX C: EiR Approval

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form before collecting or analysing data. The objective of submitting this application prior to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the EBE Ethics in Research Handbook (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Laju Duku
Department		Construction Economics and Management
Preferred email address of applicant		DKXLEJ001@myuct.ac.za
If Student	Your Degree: e.g., MSc, PhD, etc.	MSc Project Management
	Credit Value of Research: e.g., 60/120/180/360 etc.	60
	Name of Supervisor (if supervised):	Associate Professor Abimbola Olukemi Windapo
If this is a researchcontract, indicate the source of funding/sponsorship		n/a
Project Title		Evaluating the barriers to the use of innovative cost control techniques during the construction phase

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Laju Duku	[signature]	14 Jun 2019

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Abimbola Windapo	[signature]	14 Jun 2019
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduateresearch (including Honours).	NJEN-TSU TUAN	[signature]	20 June 2019
Chair : Faculty EiR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.			

Page 1 of 2

APPENDIX D: Questionnaire

Questionnaire

INSTRUCTIONS

KINDLY ANSWER THE FOLLOWING QUESTIONS BY CROSSING [X] THE APPROPRIATE RESPONSE OR FILLING IN YOUR ANSWERS IN THE SPACES PROVIDED.

SECTION A: BACKGROUND INFORMATION

This section of the questionnaire gives the demographic characteristics of respondents. Please tick the appropriate responses where applicable.

1. **Company name (optional)**:

   ……

   ……

2. **Grade and specialisation (GB or CE) listed on the cidb Register of Contractors**:

   ……………………………………………………….

3. Kindly indicate your highest Educational background of the respondent:

PhD	☐	Master's Degree	☐	Bachelor's Degree	☐
Matric	☐	N4-6/NTC4-6/Certificate/Certificate-diploma with less than Grade 12			☐

4. What is your designated position in your organisation?

Project Manager	☐	Quantity Surveyor	☐	Site Engineer	☐
Architect	☐	Construction Manager	☐	Other	☐

If (other), please specify

……

5. **Area of expertise**:

Special construction/Specialist works	☐	Building construction	☐
Mechanical engineering works	☐	Building and Civil construction	☐
Civil Engineering	☐	Other	☐

If (other), please specify

……

6. **Location of head office:**

Gauteng	☐	Mpumalanga	☐	Free State	☐
Eastern Cape	☐	Western Cape	☐	Kwazulu-Natal	☐

Northern Cape ☐ Limpopo ☐ North-West ☐

7. **State the number of employees in your organisation [e.g. 5]:**

   ……………………………………………......

8. **When was your organisation established:**

   ……………………………………………......

9. **Region of operation:**

   Local level ☐ Provincial level ☐ Regional level ☐

   National level ☐ International level ☐

10. **Years of working experience in the Construction Industry: [e.g. 10 years]**

    ……………………………………………….

11. **Indicate the number of construction projects participated in, in the past 5 years:**

    ……………………………………………….

SECTION B: DETERMNING THE LEVEL OF COST OVERRUN OF THE CONSTRUCTION PROJECTS YOU IDENTIFIED

Identify a project you are conversant with and which was completed within the last five years. Use this project in answering the following questions.

1. Location of the project:

   ……………………………………………………………………………………..

2. Initial cost of the project (Rand)

   ……………………………………………………….

3. Final cost of the project:

   ……………………………………………………….

4. **What type of project:**

   Commercial building ☐ Housing ☐

   Renovation ☐ Industrial ☐

   Other ☐

   If (other), please specify

   ………

5. **Procurement method used for the project:**

   Traditional ☐ Design and Build ☐

   Management contract ☐ Integrated Project Delivery system ☐

   Other ☐

   If (other), please specify

   ………

6. What were the causes of the identified project exceeding its original budget (tick all that is applicable), and what was its degree of impact on a five point rating scale (from **very low** to **very high**)?

CAUSES OF OVERRUNS		DEGREE OF IMPACT				
		Very high	**High**	**Moderate**	**Low**	**Very low**
	Project complexity					
	Absence of leadership to spearhead innovation					
	Poor strategic vision					
	Insufficient project budget					
	Poor implementation					

CAUSES OF OVERRUNS		DEGREE OF IMPACT				
		Very high	High	Moderate	Low	Very low
	Delayed progress payments to contractor					
	Delayed site delivery to contractor					
	High frequency of change orders by client					
	Late approval of design documentation					
	Impractical contract duration					
	Poor communication channels between project parties					
	Financial obstacles experienced by contractors					
	Delayed site mobilisation					
	Frequent change of subcontractors					
	Errors made in the construction stage					
	Inadequate site management by contractors					
	Lack of expertise by consultants					
	Delays in design documentation evaluation					
	Poor inspection plan					
	Project complexity					
	Low labour output					
	Shortage of technical personnel					
	Lack of motivation					
	Hostility between labour					
	High labour costs					
	Late delivery of construction materials					
	Mismanagement of material (poor handling and waste)					
	Unavailability of equipment and materials in local markets					
	Inferior quality of material					
	Poor equipment output					
	Corruption					
	Market inflation					
	Difficulty in acquiring permits from authorities					
	Currency changes					
	Legal disputes between project parties					

SECTION C: IDENTIFY INNOVATIVE COST CONTROL TECHNIQUES USED BY CONSTRUCTION FIRMS ON CONSTRUCTION PROJECTS

1. Please indicate the innovative cost control techniques used in the **planning** of construction activities during the construction phase of the identified project (tick all that are applicable).

COST CONTROL TECHNIQUE		
1	Earned Value Analysis	
2	Last Planner	
3	eSUB Construction software	
4	Objective-Cost Planning	
5	Fuzzy Scheduling	

COST CONTROL TECHNIQUE		
6	4D Scheduling	
7	Reserve Analysis	
8	Q-Scheduling	
9	Integrated Critical path & Line of Balance	
10	Other	

If (other), please specify other cost control techniques or methods your organisation used in the **planning** of construction activities during the construction phase of the identified project.

………

………

………

2. Please indicate the innovative cost control techniques used for **monitoring and controlling** of construction activities during the construction phase of the identified project.

COST CONTROL TECHNIQUE		
1	Earned Value Analysis	
2	Last Planner	
3	eSUB Construction software	
4	Objective-Cost Planning	
5	Fuzzy Scheduling	
6	4D Scheduling	
7	Reserve Analysis	
8	Q-Scheduling	
9	Integrated Critical path & Line of Balance	
10	Other	

If (other), please specify other cost control techniques or methods that your organisation used for **monitoring and controlling** of construction activities during the construction phase of the identified project.

………

………

………

SECTION D: DETERMINING BARRIERS TO THE USE OF INNOVATIVE COST CONTROL TECHNIQUES ON THE IDENTIFIED PROJECT

2. Please indicate what you perceive as the barriers to the use of innovative cost control techniques on the identified project on a five point rating scale (from **strongly disagree** to **strongly agree**)?

	BARRIERS TO COST CONTROLLING TECHNIQUES	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	Education for appropriate data retrieval on construction sites by professionals					
	Research level into cost control in South Africa					
	Knowledge of cost control by professionals					
	Technical skill					
	Training					
	Cost data availability					
	Cost analysis					
	Lack of standardisation					
	Cost control concepts by the organisation					
	Scope requirements of technique					
	Involvement of Quantity Surveyor in planning processes					
	Variations throughout the project execution phase					
	Divulging of information among project participants					
	Details in designs					
	General expertise of team members					
	Role definition for team members					
	Resistance to change					

APPENDIX E: Cost performance of identified projects

Cost performance of identified projects and techniques used for planning, monitoring and controlling construction activities.

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST OVERRUN (RANDS)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
1	9 000 000	11 000 000	-2 000 000	EVA, Objective cost planning	EVA, Objective cost planning
2	14 000 000	14 000 000	0	LPS, 4D-Scheduling, Objective cost planning	EVA
3	37 000 000	37 500 000	-500 000	Integrated critical path & LOB	Integrated critical path & LOB
4	5 000 000	5 550 000	-550 000	EVA, Objective cost planning, Integrated critical path & LOB	EVA, Objective cost planning, Integrated critical path & LOB
5	4 650 000	4 830 000	-180 000	EVA	EVA
6	416 410	458 051	-41 461	EVA, LPS, Objective cost planning	LPS
7	598 000	635 000	-37 000	Q-scheduling	Reserve Analysis
8	-	-	-	-	-
9	75 000 000	75 000 000	0	EVA	EVA, Integrated critical path & LOB
10	900 000 000	1 200 000 000	-300 000 000	Model maker	Model maker/ Bill cost
11	135 000 000	135 000 000	0	EVA	EVA
12	293 000	293 000	0	EVA, Fuzzy scheduling	EVA, Fuzzy scheduling
13	300 000	250 000	+50 000	Reserve analysis	Q-scheduling
14	560 000	310 000	+250 000	Fuzzy scheduling	Fuzzy scheduling
15	157 167.82	157 167.82	0	EVA, Fuzzy scheduling, Objective cost planning, integrated critical path & LOB	EVA, Objective cost planning, integrated critical path & LOB
16	450 000 000	450 000 000	0	EVA	LPS
17	20 000 000	20 000 000	0	eSUB	Objective cost planning
18	138 000 000	142 000 000	-4 000 000	Objective cost planning	CANDY & CCS integration
19	300 000	300 000	0	Integrated critical path & LOB	LPS
20	200 000	200 000	0	Objective cost planning	Objective cost planning
21	425 000	287 326.32	+137 673.68	LPS	LPS
22	250 000	650 000	-400 000	Objective cost planning	Integrated critical path & LOB
23	1 200 000 000	1 280 000 000	-80 000 000	4D-scheduling, Integrated critical path & LOB	4D-scheduling, Integrated critical path & LOB, EVA

Cost performance of identified projects and techniques used for planning, monitoring and controlling construction activities (Cont'd).

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST OVERRUN (RANDS)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
24	4 000 000	4 200 000	-200 000	Q-scheduling, Objective cost planning	eSUB
25	1 300 000	1 300 000	0	Objective cost planning	Objective cost planning
26	173 635.87	123 000	+50 635.87	Objective cost planning	Integrated critical path & LOB
27	-	-	-	EVA, LPS, 4D-scheduling, Reserve analysis, Objective cost planning, Integrated critical path & LOB	EVA, LPS, 4D-scheduling, Reserve analysis, Objective cost planning, Integrated critical path & LOB
28	500 000	550 000	-50 000	EVA, 4D-scheduling, Reserve analysis	EVA, 4D-scheduling, LPS
29	490 000	490 000	0	EVA, 4D-scheduling, Objective cost planning, integrated critical path & LOB	EVA, 4D-scheduling, Objective cost planning, integrated critical path & LOB
30	1 000 000	1 000 000	0	LPS	EVA
31	-	-	-	Integrated critical path & LOB	EVA
32	-	-	-	EVA, LPS, Integrated critical path & LOB	EVA, LPS
33	-	-	-	EVA, Q-scheduling	EVA
34	-	-	-	EVA, 4D-scheduling, Objective cost planning, Integrated critical path & LOB	Integrated critical path & LOB
35	-	-	-	Integrated critical path & LOB, cost/time management system	Integrated critical path & LOB
36	57 000 000	46 000 000	+11 000 000	Objective cost planning	Integrated critical path & LOB
37	42 000 000	39 000 000	+3 000 000	Integrated critical path & LOB	Objective cost planning
38	100 000	85 000	+15 000	EVA, Reserve analysis, Integrated critical path & LOB	EVA, Reserve analysis, Integrated critical path & LOB
39	5 000 000	5 000 000	0	Objective cost planning	Objective cost planning
40	-	-	-	-	-
41	2 000 000	2 100 000	-100 000	EVA	EVA
42	25 000 000	Ongoing	-	Integrated critical path & LOB	Integrated critical path & LOB, Objective cost planning

Cost performance of identified projects and techniques used for planning, monitoring and controlling construction activities (Cont'd).

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST OVERRUN (RANDS)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
43	-	-	-	LPS, Fuzzy scheduling, Integrated critical path & LOB, objective cost planning	EVA, eSUB, 4D-scheduling, Q-scheduling, objective cost planning
44	500 000	400 000	+100 000	Objective cost planning	Objective cost planning
45	2 314 000.82	2 534 000.82	-220 000	LPS	LPS
46	28 000 000	28 000 000	0	EVA, Objective cost planning	EVA, Objective cost planning, Integrated critical path & LOB
47	2 050 000 000	2 090 000 000	-40 000 000	No techniques used	No techniques used
48	500 000 000	760 000 000	-260 000 000	eSUB, 4D-scheduling, Q-scheduling, objective cost planning, integrated critical path & LOB	eSUB, 4D-scheduling, Q-scheduling, objective cost planning, integrated critical path & LOB
49	-	-	-	4D-scheduling, integrated critical path & LOB	4D-scheduling, integrated critical path & LOB
50	1 400 000	900 000	+500 000	LPS	eSUB
51	3 000 000	5 000 000	-2 000 000	LPS, Fuzzy scheduling, Reserve analysis, Q-scheduling	eSUB, Fuzzy scheduling, Reserve analysis, objective cost planning
52	-	-	-	EVA	EVA
53	247 000 000	276 000 000	-29 000 000	Integrated critical path & LOB	Integrated critical path & LOB
54	307 000	250 000	+57 000	EVA, LPS, Reserve analysis	EVA, LPS
55	820 000	1 200 000	-380 000	Objective cost planning	-
56	240 000 000	275 000 000	-35 000 000	EVA	EVA
57	-	-	-	-	-
58	782 000	923 980	-141 980	Integrated critical path & LOB	Integrated critical path & LOB
59	470 000	470 000	0	Objective cost planning, Integrated critical path & LOB	EVA, Integrated critical path & LOB
60	600 000	400 000	+200 000	Objective cost planning	EVA
61	400 000	246 000	+154 000	EVA	EVA
62	69 000 000	78 000 000	-9 000 000	Integrated critical path & LOB	Integrated critical path & LOB

Cost performance of identified projects and techniques used for planning, monitoring and controlling construction activities (Cont'd).

	INITIAL COST (RANDS)	**FINAL COST (RANDS)**	**COST OVERRUN (RANDS)**	**TECHNIQUE USED FOR PLANNING**	**TECHNIQUE USE FOR MONITORING AND CONTROLING**
63	158 000 000 000	Ongoing	-	EVA, integrated critical path & LOB	EVA, integrated critical path & LOB
64	240 000	250 000	-10 000	Objective cost planning	LPS
65	336 000	336 000	0	Objective cost planning	EVA
66	620 000 000	Ongoing	-	Integrated critical path & LOB	Integrated critical path & LOB
67	15 000 000	16 000 000	-1 000 000	EVA, Integrated critical path & LOB	LPS
68	-	-	-	Objective cost planning	LPS
69	2 500 000	2 500 000	0	Objective cost planning, Q-scheduling	Objective cost planning
70	-	-	-	Objective cost planning, Q-scheduling	EVA
71	110 000	110 000	0	-	-
72	663 569 000	877 017 957	-213 448 957	EVA	Objective cost planning
73	7 000 000	7 000 000	0	EVA, LPS, objective cost planning, integrated critical path & LOB	EVA, LPS, objective cost planning, integrated critical path & LOB
74	-	-	-	LPS	EVA
75	17 000 000	23 000 000	-6 000 000	EVA, Integrated critical path & LOB	EVA, Integrated critical path & LOB, Objective cost planning
76	-	-	-	Handled by contractor	Cost to complete analysis
77	75 000 000	95 000 000	-20 000 000	EVA, Integrated critical path & LOB	EVA, Integrated critical path & LOB
78	650 000	1 100 000	-450 000	Objective cost planning	-
79	360 000	750 000	-390 000	LPS, Objective cost planning, Q-scheduling	eSUB, Objective cost planning
80	405 000	400 000	+5000	-	-
81	170 000	170 000	0	Reserve analysis	Reserve analysis
82	2 000 000	2 000 000	0	-	-
83	361 000	361 000	0	-	-
84	12 000 000	15 000 000	-3 000 000	EVA	-
85	200 000	220 000	-20 000	-	-

Projects with cost **overruns** and techniques employed for cost planning, monitoring and controlling of construction activities.

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST OVERRUN (RANDS)	COST PERFORMANCE (%)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
1	9 000 000	11 000 000	-2 000 000	22.22	EVA, Objective cost planning	EVA, Objective cost planning
2	37 000 000	37 500 000	-500 000	-1.35	Integrated critical path & LOB	Integrated critical path & LOB
3	5 000 000	5 550 000	-550 000	-10.00	EVA, Objective cost planning, Integrated critical path & LOB	EVA, Objective cost planning, Integrated critical path & LOB
4	4 650 000	4 830 000	-180 000	-3.87	EVA	EVA
5	416 410	458 051	-41 461	-9.96	EVA, LPS, Objective cost planning	LPS
6	598 000	635 000	-37 000	-6.19	Q-scheduling	Reserve Analysis
7	900 000 000	1 200 000 000	-300 000 000	-33.33	Model maker	Model maker/ Bill cost
8	138 000 000	142 000 000	-4 000 000	-2.90	Objective cost planning	CANDY & CCS integration
9	250 000	650 000	-400 000	-160	Objective cost planning	Integrated critical path & LOB
10	1 200 000 000	1 280 000 000	-80 000 000	-6.67	4D-scheduling, Integrated critical path & LOB	4D-scheduling, Integrated critical path & LOB, EVA
11	4 000 000	4 200 000	-200 000	-5.00	Q-scheduling, Objective cost planning	eSUB
12	500 000	550 000	-50 000	-10.00	EVA, 4D-scheduling, Reserve analysis	EVA, 4D-scheduling, LPS
13	2 000 000	2 100 000	-100 000	-5.00	EVA	EVA
14	2 314 000.82	2 534 000.82	-220 000	-9.51	LPS	LPS
15	2 050 000 000	2 090 000 000	-40 000 000	-1.95	No techniques used	No techniques used
16	500 000 000	760 000 000	-260 000 000	-52.00	eSUB, 4D-scheduling, Q-scheduling, objective cost planning, integrated critical path & LOB	eSUB, 4D-scheduling, Q-scheduling, objective cost planning, integrated critical path & LOB
17	3 000 000	5 000 000	-2 000 000	-66.67	LPS, Fuzzy scheduling, Reserve analysis, Q-scheduling	eSUB, Fuzzy scheduling, Reserve analysis, objective cost planning
18	247 000 000	276 000 000	-29 000 000	-11.74	Integrated critical path & LOB	Integrated critical path & LOB

Projects with cost **overruns** and techniques employed for cost planning, monitoring and controlling of construction activities (Cont'd).

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST OVERRUN (RANDS)	COST PERFORMANCE (%)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
19	820 000	1 200 000	-380 000	-46.34	Objective cost planning	-
20	240 000 000	275 000 000	-35 000 000	-14.58	EVA	EVA
21	782 000	923 980	-141 980	-18.16	Integrated critical path & LOB	Integrated critical path & LOB
22	69 000 000	78 000 000	-9 000 000	-13.04	Integrated critical path & LOB	Integrated critical path & LOB
23	240 000	250 000	-10 000	-4.17	Objective cost planning	LPS
24	15 000 000	16 000 000	-1 000 000	-6.67	EVA, Integrated critical path & LOB	LPS
25	663 569 000	877 017 957	-213 448 957	-32.17	EVA	Objective cost planning
26	17 000 000	23 000 000	-6 000 000	-35.29	EVA, Integrated critical path & LOB	EVA, Integrated critical path & LOB, Objective cost planning
27	75 000 000	95 000 000	-20 000 000	-26.67	EVA, Integrated critical path & LOB	EVA, Integrated critical path & LOB
28	650 000	1 100 000	-450 000	-69.23	Objective cost planning	-
29	360 000	750 000	-390 000	-108.33	LPS, Objective cost planning, Q-scheduling	eSUB, Objective cost planning
30	12 000 000	15 000 000	-3 000 000	-25.00	EVA	-
31	200 000	220 000	-20 000	-10.00	-	-

Projects with cost **underruns** and techniques employed for cost planning, monitoring and controlling of construction activities.

	INITIAL COST (RANDS)	**FINAL COST (RANDS)**	**COST UNDERRUN (RANDS)**	**COST PERFORMANCE (%)**	**TECHNIQUE USED FOR PLANNING**	**TECHNIQUE USE FOR MONITORING AND CONTROLING**
1	14 000 000	14 000 000	0	0.00	LPS, 4D-Scheduling, Objective cost planning	EVA
2	75 000 000	75 000 000	0	0.00	EVA	EVA, Integrated critical path & LOB
3	135 000 000	135 000 000	0	0.00	EVA	EVA
4	293 000	293 000	0	0.00	EVA, Fuzzy scheduling	EVA, Fuzzy scheduling
5	300 000	250 000	+50 000	+16.67	Reserve analysis	Q-scheduling
6	560 000	310 000	+250 000	+44.64	Fuzzy scheduling	Fuzzy scheduling
7	157 167.82	157 167.82	0	0.00	EVA, Fuzzy scheduling, Objective cost planning, integrated critical path & LOB	EVA, Objective cost planning, integrated critical path & LOB
8	450 000 000	450 000 000	0	0.00	EVA	LPS
9	20 000 000	20 000 000	0	0.00	eSUB	Objective cost planning
10	300 000	300 000	0	0.00	Integrated critical path & LOB	LPS
11	200 000	200 000	0	0.00	Objective cost planning	Objective cost planning
12	425 000	287 326.32	+137 673.68	+32.39	LPS	LPS
13	1 300 000	1 300 000	0	0.00	Objective cost planning	Objective cost planning
14	173 635.87	123 000	+50 635.87	+29.16	Objective cost planning	Integrated critical path & LOB
15	490 000	490 000	0	0.00	EVA, 4D-scheduling, Objective cost planning, integrated critical path & LOB	EVA, 4D-scheduling, Objective cost planning, integrated critical path & LOB
16	1 000 000	1 000 000	0	0.00	LPS	EVA
17	57 000 000	46 000 000	+11 000 000	+19.30	Objective cost planning	Integrated critical path & LOB
18	42 000 000	39 000 000	+3 000 000	+7.14	Integrated critical path & LOB	Objective cost planning
19	100 000	85 000	+15 000	+15.00	EVA, Reserve analysis, Integrated critical path & LOB	EVA, Reserve analysis, Integrated critical path & LOB
20	5 000 000	5 000 000	0	0.00	Objective cost planning	Objective cost planning
21	500 000	400 000	+100 000	+20.00	Objective cost planning	Objective cost planning

Projects with cost **underruns** and techniques employed for cost planning, monitoring and controlling of construction activities (Cont'd).

	INITIAL COST (RANDS)	FINAL COST (RANDS)	COST UNDERRUN (RANDS)	COST PERFORMANCE (%)	TECHNIQUE USED FOR PLANNING	TECHNIQUE USE FOR MONITORING AND CONTROLING
22	28 000 000	28 000 000	0	0.00	EVA, Objective cost planning	EVA, Objective cost planning, Integrated critical path & LOB
23	1 400 000	900 000	+500 000	+35.00	LPS	eSUB
24	307 000	250 000	+57 000	+18.57	EVA, LPS, Reserve analysis	EVA, LPS
25	470 000	470 000	0	0.00	Objective cost planning, Integrated critical path & LOB	EVA, Integrated critical path & LOB
26	600 000	400 000	+200 000	+33.33	Objective cost planning	EVA
27	400 000	246 000	+154 000	+38.50	EVA	EVA
28	336 000	336 000	0	0.00	Objective cost planning	EVA
29	2 500 000	2 500 000	0	0.00	Objective cost planning, Q-scheduling	Objective cost planning
30	110 000	110 000	0	0.00	-	-
31	7 000 000	7 000 000	0	0.00	EVA, LPS, objective cost planning, integrated critical path & LOB	EVA, LPS, objective cost planning, integrated critical path & LOB
32	405 000	400 000	+5000	+1.23	-	-
33	170 000	170 000	0	0.00	Reserve analysis	Reserve analysis
34	2 000 000	2 000 000	0	0.00	-	-
35	361 000	361 000	0	0.00	-	-

APPENDIX F: Cost performance of projects and innovative techniques use for planning, monitoring and controlling cost.

CASE	EVA	LPS	eSUB	OBJECTIVE COST PLANNING	FUZZY SCHEDULING	4D SCHEDULING	RESERVE ANALYSIS	Q-SCHEDULING	INTEGRATED CPM & LOB	CANDY CCS	MODEL MAKER	PLANNING	MONITORING AND CONTROLLING	COST PERFORMANCE (%)
1	x			x								2	2	-22.22
2	x	x		x		x						3	1	0.00
3									x			1	1	-1.35
4	x	x							x			3	3	-10.00
5	x											1	1	-3.87
6	x	x		x								3	1	-9.96
7							x	x				1	1	-6.19
8	x								x			1	2	0.00
9											x	1	1	-33.33
10	x											1	1	0.00
11	x				x							2	2	0.00
12							x	x				1	1	+16.67
13					x							1	1	+44.64
14	x			x	x				x			4	3	0.00
15	x	x										1	1	0.00
16			x	x								1	1	0.00
17				x						x		1	1	-2.90
18		x							x			1	1	0.00
29				x								1	1	0.00
20		x										1	1	+32.39
21				x					x			1	1	-160.00
22	x					x			x			2	3	-6.67
23			x	x				x				2	1	-5.00
24				x								1	1	0.00
25				x					x			1	1	+29.16
26	x	x				x	x					3	3	-10.00
27	x			x		x			x			4	4	0.00
28	x	x										1	1	0.00
29				x					x			1	1	+19.30
30				x					x			1	1	+7.14
31	x						x		x			3	3	+15.00
32				x								1	1	0.00
33	x											1	1	-5.00
34				x								1	1	+20.00

Cost performance of projects and innovative techniques use for planning, monitoring and controlling cost (Cont'd).

CASE	EVA	LPS	eSUB	OBJECTIVE COST PLANNING	FUZZY SCHEDULING	4D SCHEDULING	RESERVE ANALYSIS	Q-SCHEDULING	INTEGRATED CPM & LOB	CANDY CCS	MODEL MAKER	PLANNING	MONITORING AND CONTROLLING	COST PERFORMANCE (%)
35		x										1	1	-9.51
36	x			x					x			2	3	0.00
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-1.95
38			x	x		x		x	x			5	5	-52.00
39		x	x									1	1	+35.71
40		x	x	x	x		x	x				4	4	-66.67
41									x			1	1	-11.74
42	x	x					x					3	2	+18.57
43				x								1	-	-46.34
44	x											1	1	-14.58
45									x			1	1	-18.16
46	x			x					x			2	2	0.00
47	x			x								1	1	+33.33
48	x											1	1	+38.50
49									x			1	1	-13.04
50		x		x								1	1	-4.17
51	x			x								1	1	0.00
52	x	x							x			2	1	-6.67
53				x				x				2	1	0.00
54	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
55	x			x								1	1	-32.17
56	x	x		x					x			4	4	0.00
57	x			x					x			2	3	-35.29
58	X								x			2	2	-26.67
59				x								1	-	-69.23
60		x	x	x				x				3	2	-108.33
61	-	-	-	-	-	-	-	-	-	-	-	-	-	+1.23
62							x					1	1	0.00
63	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
64	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
65	x											1	-	-25.00
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-10.00