Cape Peninsula University of Technology

INNOVATIVE PRACTICES FOR EFFECTIVE MANAGEMENT OF BUILDING PRODUCTION PROCESSES WITHIN URBAN CENTRES

by

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DECLARATION

I, Laura Faith Pinfold, declare that the content of this thesis represents my own unaided work, and that the content has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

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Signed Date

ABSTRACT

Urbanisation and globalisation are the foremost trends propelling the growth and development of cities and towns in the world today. The Cape Town central business district is an example of an urban centre that is required to deal with rapid urbanisation. The increasing number of inner-city developments evoked the congested construction sites and are rapidly becoming the norm within the industry. Innovative building production management is crucial in driving productivity which includes reducing cost at all stages, from planning to completion. However, from several literatures, construction firms are not significantly proactive towards innovative technology that could enhance the efficient delivery of building production. The improved building production management is advancing at a slow pace both in South Africa and internationally. Hence, this research analyse the strategies that could significantly enhance current building production processes and establish the effective management systems that could enhance efficient building production in the urban centres. Innovative methods of stimulating building production processes are needed to ensure that building projects are completed within timeframes and budgets.

The research method is both quantitative and qualitative using surveys for data collection. This type of research aims to record an accurate and adequate description of the problem statement and the sub-question. Data for the study are collected through observations, semi-structured and unstructured qualitative interviews and quantitative close-ended questionnaires administered to construction stakeholders working in the Western Cape Province, South Africa. This research focuses on the City of Cape Town to gain an understanding of the dynamics of innovation in building production processes within the building industry. The population of this research include building project managers, registered contractors as well as consultants. Quantitative data obtained from the structured questionnaire design was analysed with descriptive statistics, Statistical Package for Social Science (SPSS) software 21 and content analysis are used to analyse the qualitative data obtained through interviewees.

This study revealed that costs and time are the most critical factors in building construction management in the urban centres of Cape Town. These strategies: lean construction, just-in-time construction, knowledge management, prefabrication, preassembly, modularisation, and off-site fabrication techniques, are methods in construction that could effectively enhance building production processes, lessen the construction costs and time of construction in the urban centres, without compromising quality. Based on these research findings, the use of technology is proving to be useful during all stages of building construction. Noteworthy, Building Information Modelling (BIM) is an emerging technology that is globally accepted in the construction industry and its application is gaining momentum. This study established that BIM trend in South Africa is progressive in-use during building production. The South African construction industry is using BIM extensively during the initiating and planning stages of projects. BIM needs to be utilised to its full potential and be supported through various policy frameworks by the different stakeholders from the architecture, engineering and construction (AEC) sectors, such as the statutory councils and the government agencies. The staged adoption of BIM and a new policy framework in the South African AEC sector needs to be put in place. The use of other technologies to enhance building production processes include location awareness technology (LAT), remote sensing using unmanned aerial vehicles (UAV), laser scanners and bar code scanners. BIM technology is a catalyst for change, with information replacing documents and knowledge becoming an asset. The convergence of building production methodologies and technology is facilitating better management of information.

This research reveals the strategies that are currently being employed during building production processes in urban centres, identifies problems and constraints on building production processes in urban centres, analyse the factors that help mitigate weakness in current building production processes, ascertain qualifying ways of improving building production processes in urban centres, and conclusively establish an effective management systems framework that could significantly enhance building production processes in urban centres. The adequate implementation of this framework will enhance resources utilisation, less cost of construction, and perpetual stakeholders' satisfaction.

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I express my sincerest appreciation to my supervisor: Dr Julius Fapohunda for his substantial role and individual inputs to this study.

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GLOSSARY OF TERMS

Bar code scanner — used to enter information rapidity into a computer system. Applications include material inventory control, project scheduling, labour time cards, drawing review and monitoring, tool issue and equipment control.

Building information modelling (BIM) — computer software that facilitates communication of data, knowledge and design solutions between project participants — BIM can assist with problems related to interoperability and information integration

Building production processes — the organisation and management of the plans, equipment, materials and labour involved in the construction of a building while complying with contractual specifications

Constructability of design — integration of construction design into management

Equipment (machinery) economics — the process of selecting a particular type of machine and the understanding of costs that result from equipment ownership and operation on a project

Innovative technology — is the process through which new or improved technologies are developed and brought into widespread use

Just-in-time methods — the coordination of production planning, sourcing and logistics, in order to have just the right amount of inventory available to meet the demands of production processes

Knowledge management — the preservation of valuable knowledge; capturing the creativity of individuals; lessons learned and historical information

Lean production methods — to eliminate any waste of time, effort or money by identifying each step in the building production process and then revising or cutting out steps that do not create value

Location awareness technology (LAT) — indoor location sensing systems that are pertinent to decision-making and tracking progress, as well as to safety in construction projects. Applications that deliver online content to users based on their physical location

Point cloud scanner — tool for three dimensional (3D) modelling and analysis in the architecture, engineering, and construction (AEC) domain. Point clouds can be acquired by laser scanning or imaged-based/photogrammetric methods

Prefabrication — manufacturing of components of a building at a factory off-site

Unmanned aerial vehicle (UAV) — also called a drone, is used for aerial surveillance by providing pictures or video footage that can be either directly transmitted for live viewing or recorded — the information collected can be used for recording progress and site planning

Wireless camera — video surveillance — wireless security cameras are closed-circuit television (CCTV) cameras that transmit a video and audio signal to a wireless receiver through a radio band. Wireless security cameras allow users to leverage broadband wireless Internet to provide seamless video streaming over the Internet.

LIST OF ABBREVIATIONS

3D	—	three-dimensional
4D	—	four-dimensional
AEC	—	architecture, engineering and construction
BCA	—	building construction authority
BIM	—	building information modelling
CBD	—	central business district
CAD	—	computer aided design
GIS	—	geographic information system
GPS	—	global positioning system
IFC	—	industry foundation classes
IDM	—	information delivery manual
IFD	—	international framework for dictionaries
LAT	—	location awareness technologies
UAV	—	unmanned aerial vehicles
UDZ	—	urban development zone

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION AND RATIONALE

The continued growth of inner city building construction, coupled with the mounting costs of land in urban centres, puts pressure on building construction firms to manage building construction projects effectively. Due to the complex nature of building construction in urban centres innovative methods of construction management are needed to increase a building construction firm’s competitiveness. Confined space, congested access and the proximity to overcrowded public places all pose challenges when it comes to inner-city construction. Despite these challenges construction firms in South Africa tend not to be innovative or dynamic when it comes to inner city building construction. The use of technology can significantly assist in real-time management of materials, equipment and workers on a congested construction site. Location awareness is important and hence this research investigates innovative building production management in urban centres within the City of Cape Town and investigates if building construction companies find technology useful on confined construction sites (Pinfold and Fapohunda, 2014).

Building management consists of five phases; it begins with initiation, followed by planning, executing, monitoring and ends when the building is functional after the closing stage. Sequencing of these processes does not necessarily have to run consecutively and there can be nested processes within the project. High cost of correcting errors once construction is underway can be avoided if the initiating and planning stages produce good, functional design that is technically and economically sound. Achieving this requires multidisciplinary input from practitioners which demands a tremendous amount of coordination and collaboration. Innovative management methods become critical so that the cost and time of a project is kept to a minimum and a return on the investment can be realised as soon as possible.

This research specifically investigates innovative practices for effective management of building production processes within urban centres. Urban centres of the modern city are characterised by land-use areas which distinctly define the urban centre. Within the urban centre land-use is divided into various business districts, manufacturing concentrations, and residential precincts. Furthermore these land-use areas or zonings work in conjunction with policy plans and other tools in land management. Zonings are intended to ensure that the core of an urban centre is maximised for business opportunities. As a result the central business district averages the highest land value and taxes paid; higher than any other part of the city. Consequently the central business district has a greater concentration of tall buildings than other areas of the city.

A large number of construction projects in the Cape Town urban centre focuses on single building improvements or the upgrading of existing urban infrastructure. Construction in an urban centre has unique challenges, such as having to demolish existing buildings and cart away the rubble, manage existing water pipelines, manage existing water pipelines and electricity cables, and dispose of waste generated. Seldom do you get a Greenfield site in an urban centre. Building construction firms need to be dynamic in the sense that they must be willing to learn in their pursuit for progress.

The construction industry is constantly being challenged by ever-more complex building projects (Hardie, 2010:389). Decision-making is significant and critical due to the complicated nature of construction projects, specifically in an urban centre. In addition the diversity of activities within the industry means building construction management needs to be more varied than in the past. Despite these challenges the construction industry internationally, has been slow to embrace the potential of innovation and the use of technology for improving building production processes (Hardie, 2010:390). Because the construction industry plays a major role in the economy, generating both employment and wealth, it is imperative that methods in building production management be researched. Through research, critical factors which are restricting innovative practice can be identified so that assistance can be sought to enable an environment for innovation.

This research problem was identified on the basis that generally construction firms in South Africa appear to be lagging behind in the use of innovative technology that could help improve construction management processes in urban centres. Numerous opportunities exist for utilising remote sensing and location awareness technology (LAT) that will subsequently generate additional information and knowledge. Furthermore, untapped tacit knowledge can now be effectively managed using technologies which facilitate the public's contribution in adding, modifying, or deleting content in collaboration with others. Harnessing of tacit knowledge can improve production in the future. Due to advancements in technology and fluctuations in the world economy, changes in work ethics and the way work is organised must be acknowledged. Knowledge management is considered vital for the survival of organisations and is becoming a key resource in construction management.

The construction industry in South Africa is central to the economy, yet civil and building construction has low productivity and poor performance (Tobin & Magenuka, 2006:3). Hence there is a need for innovative practices for effective management of building production processes within urban centres. Innovative solutions are necessary to meet the demands of the economy, conditions in urban centres and new types of buildings and structures. The objective of this study is to gain an understanding of the technologies being used by construction firms in the City of Cape Town when building in congested urban areas. Furthermore the techniques and technologies used for managing projects on congested sites in urban centres are investigated.

1.1.1 The City of Cape Town

The City of Cape Town is located in the south west of South Africa in the Western Cape province (see Figure 1.1) and covers an area of 2 479 square kilometres (SA, 2008). The Cape Town central business district is historically located adjoining the harbour and is connected via transport links to the adjoining urban centres (see Figure 1.2). Urban development in Cape Town began in 1861. In the 1950s and 1960s the inner city neighbourhoods of Cape Town become dilapidated as the wealthier people left the inner city to settle in newly created outlying suburbs; this movement resulted in the urban decay of the older residential areas within and around the central business district. Now the urban centre of Cape Town is characterised by a mix of old factories, shops and houses (see Figure 1.3). Most of these buildings were built in the 19th century when there were no cars and most people walked to work. In the 1970s the construction of the freeway system, along with market forces, facilitated the exodus of people from the urban centre. Biddy (2009) (cited in Spillane et al.) argues that cities are not expanding, but are being redeveloped from within, adding to the existing urban fabric. Congested site construction is rapidly becoming the norm when building construction occurs in urban environments.

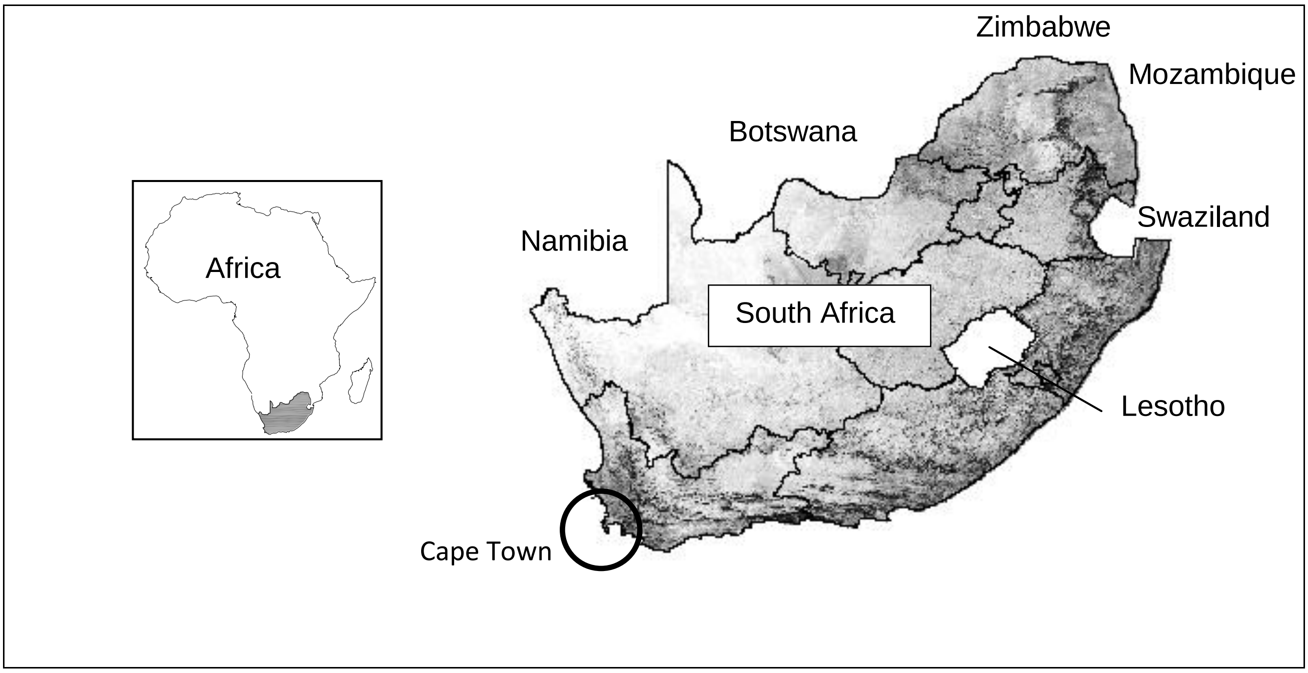

Figure 1.1: Location of the City of Cape Town

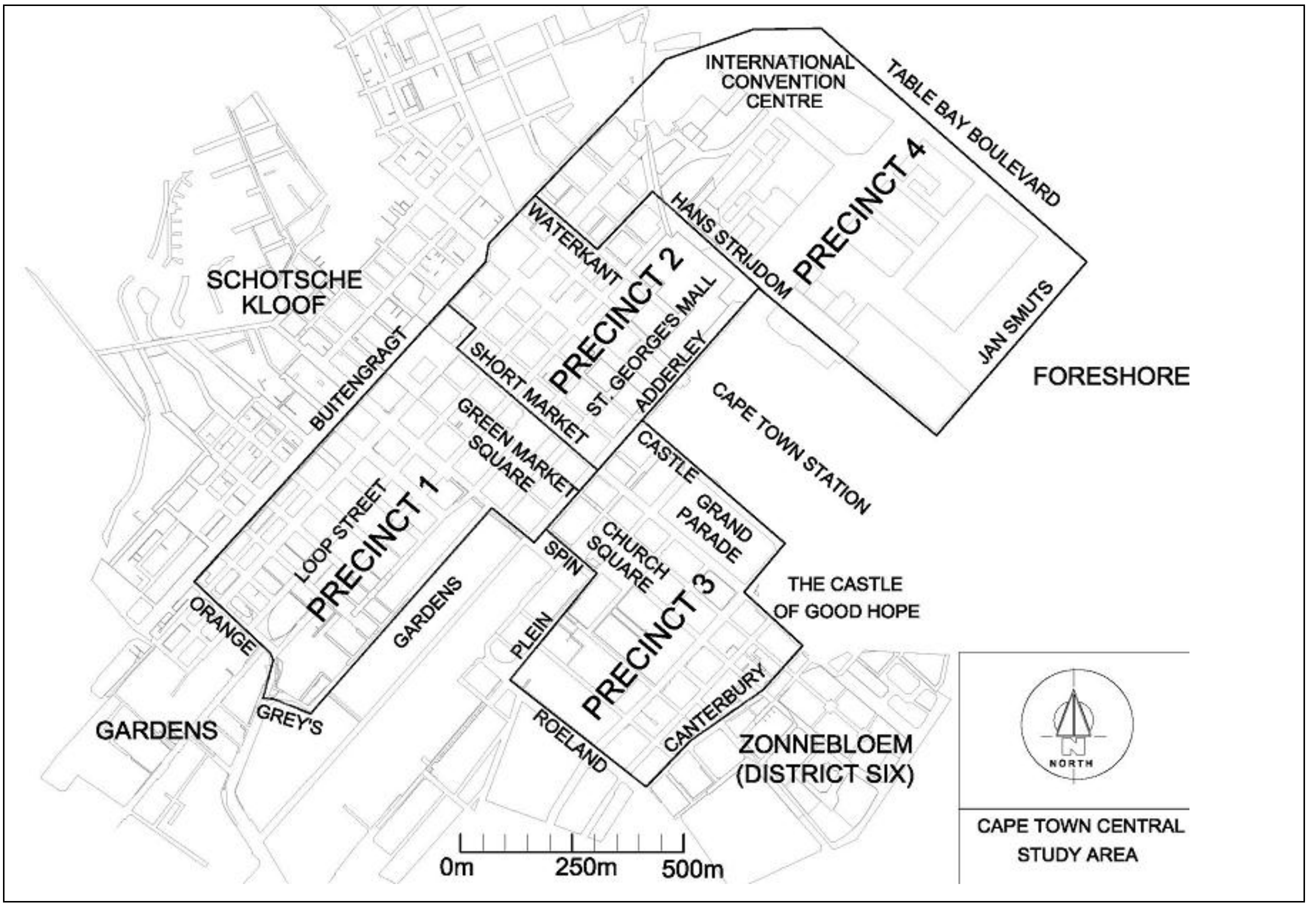

Figure 1.2: Cape Town Central Business District

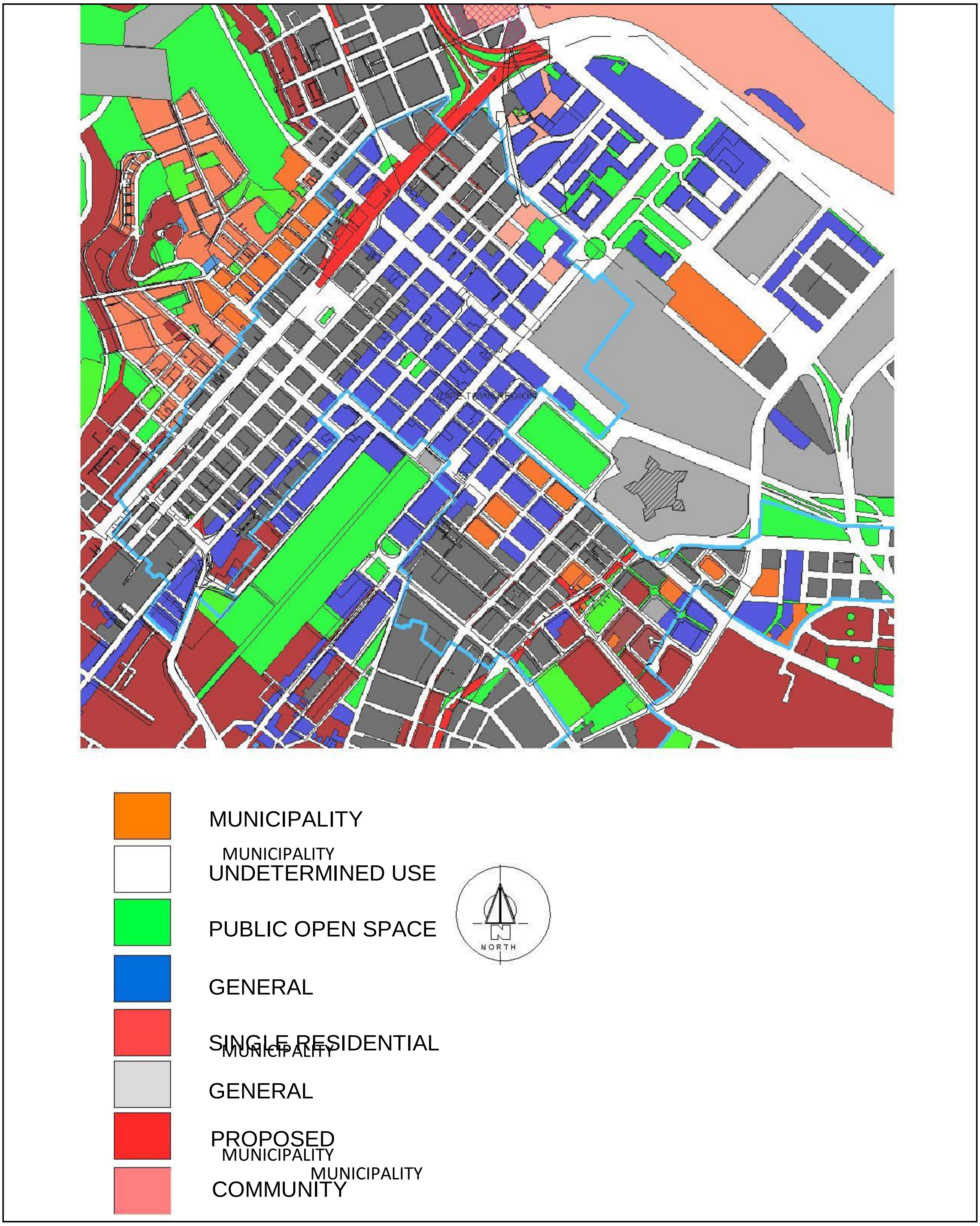

Figure 1.3: Cape Town Central Business District Zoning Map (CMC Database and SGO Spatial Data)

1.1.2 Organisations and People Affected by Building Construction within Urban Centres

Organisations and people that are affected by the project are referred to as stakeholders. Thus it is important to identify the stakeholders and to understand the influence stakeholders have on a project and vice versa. Negative stakeholders must be identified as soon as possible so their issues can be mitigated at the outset of the project. Furthermore it is important that negative issues be mitigated as soon as possible. Failure to do so can result in extended timelines and the delays that usually result in cost implications. Building construction in urban centres provides a host of unique problems than can, and often does, test a management team.

1.2 BACKGROUND TO THE RESEARCH PROBLEM

Innovative building production management is crucial in driving productivity which includes reducing cost at all stages, from planning to completion. Furthermore the need to address issues such as conservation, waste management and the effective use of resources, has led to the use of innovative technology in building production processes. Building construction in urban centres has become competitive, with land being at a premium due to urbanisation which is accruing at an unprecedented rate. Building management in congested urban centres requires interactive planning that effectively manages the massive investments in infrastructure and safeguards historical heritage structures.

The need for convergence during building production processes has stimulated the use of new technologies. Advances in 3D visualisation are progressing apace with virtual reality and immersive virtual reality becoming exceedingly possible. Hidden problems in a design can be exposed by 3D visualisation, and can then be rectified before resources are committed. Simulation can predict the impact of changes and extensions, as well as what actions need to be taken in a disaster response (Dasgupta, 2013:7).

To improve the design and build phases, 3D model-based design is increasingly being used in the construction process; this includes integrated BIM, Geographic Information Systems (GIS), and survey and laser scanning in a 3D visualisation environment. Thus the advantage of using model-based design is that communication and coordination is improved between all stakeholders.

1.3 STATEMENT OF RESEARCH PROBLEM

Generally construction firms are not significantly innovative or dynamic when it comes to improving building production processes. Hence this becomes problematic as the success of building construction in urban centres hinges upon the ability of the construction firm to be strategic, which is to know what resources are available, and what capabilities to develop in order to fulfil some planned goal.

The problem is that improved building production management is advancing at a slow pace both in South Africa and internationally, because of the delayed response by potential users in the construction industry. Construction managers admit that the construction industry is slow in adopting available technology (Zeiss, 2013:24). Subsequently this research investigates why construction managers are reluctant in bring in the necessary acceleration. A shortage of engineers and skilled resources in South Africa is exacerbating the need for greater productivity. A fundamental transformation of the construction industry is needed to improve productivity. Furthermore this will involve an investment in technology to ensure that production is transformed and expanded.

1.4 RESEARCH QUESTIONS

The central research question of the study is to attempt to answer the following:

1. What are the strategies that are currently being employed during building production processes in urban centres?
2. How efficient are current building production processes in urban centres?
3. Why construction firms are significantly reluctant to absorb both new management practices and innovative technologies that would enhance building production processes in urban centres?
4. What are the strategies that could significantly enhance current building production processes in the urban centre?

1.5 AIM AND OBJECTIVES

AIM: The aim of this research is to analyse the shortcomings of current building production processes in urban centres, so that appropriate interventions can be identified, unearthed and established.

OBJECTIVES: The objectives of this research are to investigate current building production processes in urban centres and to evaluate the competitive success of a construction firm.

The central and interrelated objectives of the study are:

1. To investigate the strategies that are currently being employed during building production processes in urban centres.
2. To identify problems and constraints on building production processes in urban centres.
3. To identify the factors that help mitigate weakness in current building production processes.
4. To ascertain qualifying ways of improving building production processes in urban centres.
5. To establish effective management systems that would significantly enhance building production in urban centres

1.6 RESEARCH METHODOLOGY AND DESIGN

This research is descriptive in nature. The research method is both quantitative and qualitative using surveys for data collection. This type of research aims to record an accurate and adequate description of the problem statement and the sub-question. The aim of the survey is to provide a broad overview of a representative sample of a large population. The study is deductive since the initial observation is based on available facts.

A comparative literature review is done to identify existing building production strategies in urban centres and how contemporary technological solutions have helped mitigate production problems. In cases where contemporary technological solutions have been used, research will be undertaken to investigate how these solutions have been practically implemented. A sample is gathered in the City of Cape Town using a survey questionnaire; the processed results will be used to examine the shortcomings in current building production processes in urban centres so that appropriate interventions can be identified and proposed.

1.7 RESEARCH POPULATION

This research focuses on the City of Cape Town to gain an understanding of the dynamics of innovation in building production processes within the building industry. The population of this research will include building project managers, registered contractors as well as consultants.

1.8 SIGNIFICANCE OF THE RESEARCH

Urbanisation and globalisation are the foremost trends propelling the growth and development of cities and towns in the world today. The Cape Town central business district is an example of an urban centre that is required to deal with rapid urbanisation. Innovative methods of stimulating building production processes are needed to ensure that building projects are completed within timeframes and budgets.

To facilitate the enhancement of productivity through the intelligent use of resources and information, an understanding of the driving force behind the development of building production processes within urban centres is imperative. Innovative building production processes in urban centres will result in smarter building projects that can achieve and deliver on their envisaged outcomes. Construction managers need to understand to what degree innovative building production methods can and are being used in the industry. Reluctance by the construction industry to use innovative technology needs to be understood. Young professionals, educated in technology, need to push the industry forward because younger professionals tend to be uninhibited and creative when using technology, unlike many of the older generation. However, experienced senior professionals in technology must be encouraged in introduce and guide young professionals in the new technology. Young professionals could be the catalyst for innovation through their use and teaching of technology.

The issue of a collective reality in the construction industry is dependent on association. Collaboration, transparency and efficiency are among the greatest challenges facing the global construction industry today (Fosburgh, 2015:62). A big challenge in building production is maintaining a seamless flow of data across work processes. In many instances this spans a mix of often incompatible or poorly integrated technologies. As a result, data silos develop among stakeholders; data is not shared as projects progress, and there is no single source for master data.

Change in building production processes will involve the same people who are already in the industry. Accordingly the technology skills within the industry are improving and the related technology is expected to become standard practice in the coming years. Part of this study is to determine to what degree technology is being used in current building production processes in the City of Cape Town. Construction projects and teams are increasingly dispersed geographically, with architects, engineers, contractors and field teams often operating in different time zones or even continents. It takes many professionals to design, build and then operate a large modern building and the amount of coordination and communication needed is immense. This study will provide statistics regarding the significance of the hypothesis stating that construction firms are not innovative or dynamic when it comes to improving building production processes.

1.9 EXPECTED OUTCOMES, RESULTS AND CONTRIBUTIONS OF THE RESEARCH

This research is expected to provide an evidence-based rationale for the critique of current building production processes within urban centres. Although innovative practice differs from one project to another, it is speculated that there are some enabling features that are common; these common features will be identified — additionally, factors that inhibit innovative practice will also be exposed.

1.10 SUMMARY OF CHAPTERS

Chapter One – Introduction: This chapter presents an introduction that investigates the innovativeness of construction firms in the City of Cape Town. It provides the rationale for the study which includes a brief explanation of the development of the City of Cape Town and the management of building production processes within its urban centres. The background to the research is discussed clarifying the research problem and statement. The research aim and objectives are outlined and the research questions are specified. The research methodology and design along with the delineation of the research and its significance are discussed. The expected outcomes, results and contributions of the research are highlighted.

Chapter Two – Literature review: This chapter is a review of current literature on the topic. Strategic building production processes such as lean production methodology, just-in-time delivery of materials, the use of innovative technology, knowledge management and prefabrication are discussed. Building production challenges within urban centres such as noise, vibration, dust and illumination are investigated. Space, machinery, storage of materials, labour productivity and congested sites in urban centres are examined. Innovation in building production processes includes linear and non-linear approaches to innovation, as well as innovation and culture. A brief description is given of the City of Cape Town in which the study has been done. Contemporary technologies currently used in building construction projects are described. These include building information modelling, point-cloud-scanners, bar-code-scanners and hand-held collection devices. Finally a review of project management is given.

Chapter Three – Methodology: This chapter defines the research methodology and design. Research philosophies include ontology, epistemology, inductive, and deductive reasoning. Research methodology and research strategies such as the quantitative, qualitative and mixed-method approaches are debated, as well as other research methods such as case studies. Research techniques, questionnaire design and data collection methods are made known. The choice of a particular research design must take into account the type of study; such a design would include sampling, data collection methods, data analysis, and reliability and validation of data. Finally there is a discussion on ethics in research along with limitations and scope of this study.

Chapter Four – Data Analysis: This chapter begins with results of the preliminary pilot study. This study includes a description of the participants, as well as the qualitative data analysis. The questionnaire survey is evaluated, and descriptions of the sampling method, data collection technique and reliability of research instrument. The presentation of results includes an investigation into:

- the strategic building production processes currently employed
- how effective strategic management practices are in enhancing building production processes
- the problems and constraints in building production processes
- investigation into the occurrence and related inconvenience of challenges on building
- the factors that contribute to alleviating weakness in current building production processes

The findings concerning the extent, to which innovative technologies contribute to building production during the initiating, planning, executing, monitoring and closing stages of construction process, are documented. Furthermore, the investigation into why construction firms are reluctant to invest in innovative building production processes is summarised. Additionally the individual perspectives of questionnaire respondents on current use of strategic management methods are presented.

Chapter Five - Summary, Recommendations and Future Research: This chapter gives the synopsis of the study, as well as recommendations and future research opportunities.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Construction is an important part of every economy and culture in the world (Egmond, 2012: 95). Furthermore the foundation of building development comprises of building infrastructure necessary for the functioning of countries and cities. However, construction projects seldom finish on time and not always meet cost estimates (Awodele et al., 2012:182; Akintoye et al., 2012:3; Egmond, 2012:96; Nadim, 2012:209). Likewise the efficient use of construction resources in the building process is essential for the successful completion of projects. Although much research has been done on identifying building project delays, more needs to be done in implementing innovative ways to mitigate difficulties in the South African building industry. Thus the increase in the number of inner city developments suggests that congested site construction is now becoming the norm in this sphere of the construction industry. Additionally the complex nature of construction in urban centres includes confined space, congestion and restricted access. Thus creating challenges such as personnel having to function in close proximity to each other and to potentially dangerous equipment, increased personnel management, project planning issues, coordination of management and increased resource management (Spillane et al., 2011:139).

2.2 STRATEGIC MANAGEMENT OF BUILDING PRODUCTION PROCESSES

Nadim, (2012:209) gives a broad description of construction as being the entire supply chain from obtaining raw materials to on-site construction activities that include associated professional services. Furthermore Nadim (2012:209) stresses that the construction industry has many problems and challenges which include failure to meet market demands, skills shortages and poor quality of product. Nadim (2012:209) indicated that, there are many initiatives worldwide to improve building production processes. Accordingly the first objective of this study is to investigate what strategic building production processes are currently being employed in the urban centres in and around Cape Town. According to Goulding and Rahimian (2012:158) strategic management in construction is organising and aligning corporate assets, in order to achieve business goals within the context of a corporate’s operating market sector. Thus organisations are required to fully understand needs, maximise business prospects and improve their business efficiency (Prehalad & Hamel, 1990; Lee & Dale, 1998; Remenyi & Sherwood-Smith, 1998; Lee & Sai On Ko, 2000; Porter, 2008).

New production philosophies have evolved over the years using new sets of methodologies, techniques and tools. Lean production methods continue to expand globally and have gradually made their way into the construction industry (Leonard, 2010:101). Riezebos et al. (2009:237) stipulates that lean production has been very effective in increasing competitiveness within the manufacturing industry and is now imparting similar benefits to the construction industry. However, the use of lean construction methods sometimes can be counterproductive if for instance employees become despondent and suspicious of management's intentions.

Other strategic building production methods include knowledge-based systems for competitive decision-making (Witlox & Timmermans, 2000). Additionally visual representation of a construction site is becoming useful using technologies such as BIM with 3D modelling capability that supports a wide range of construction management tasks such as construction planning, constructability review and site layout planning (Liang et al., 2011). Real-time position measurements during construction can assist in facilitating a variety of construction tasks at an operational level. Kim et al. (2005) suggests that using laser-scanning technology to produce point cloud information can also be useful for rapid on-site spatial-modelling.

2.2.1 Lean Production Methodology and Supply Chain Management

Emuze (2012:3) describes supply chain management as the constant flow of information, materials and funds between different and independent stages in the life cycle of a project, while Meilling, Backlund and Johnsson (2012:152) describe lean construction management as the continuous improvement of activities within a construction project. In lean construction management the focus is on improving the whole building production process, while supply chain management integrates building production into a seamless process. According to Emuze (2012:1), supply chain management in construction was first introduced as a performance management tool, to address the inability of projects to meet agreed delivery targets. Terry and Smith (2011:8) list the core elements of lean construction as:

- an understanding on the client's perspective with regard to the cost, quality and time regarding the project

- the identification of the processes needed to deliver on the client's requirements, a process which includes identifying individual steps that add value and individual steps that do not add value — this addresses the value stream in the process
- a critical analysis of each step in the building production process to ensure a holistic, balanced approach through understanding the dependencies of work flows to ensure minimal delays at interfaces — this develops a more efficient flow in the process
- an awareness that each stage is a contribution to the next stage and must be delivered at the right time, quantity and quality — this strengthens the pull of the process
- an attempt to improve continuously and strive towards perfection

Thus lean construction hinges on efficient supply chain management that ensures a safe work environment and conditions that are conducive to a good work environment (Eriksson, 2010:40).

In 1999 Green (cited in Walker 2012:125) indicated that there are dangers in blindly accepting management innovations such as lean construction and supply chain management. Walker (2012:125) believes that a workforce subjected to these innovations can become despondent, believing that their jobs could become redundant. Workers may reduce their productivity to prolong the project. Unproductive time can be a source of great loss even when work methods are very good. Maximum productivity is a result of action by management with the cooperation of workers. Emuze (2012:14) believes that there is a need to understand the risk and uncertainties pertaining to lean construction management in order to fully realise its potential. Lean construction method in building production comprises a variety of systems that share certain principles including the just-in-time methods philosophy.

2.2.2 Just-in-Time Management of Materials

Sui Pheng, (2011:91) described just-in-time methods as the supply of materials to a construction site on demand, so that materials are installed or used almost immediately on arrival without having to be stored on site for any length of time. Salem et al. (2006:169) referred to just-in-time methods as a concept where an inventory of materials is not desirable and should be regarded as a waste of time and space. Just-in-time methods are to minimise inventories and to manage the sequence of material delivery to satisfy demand.

Cost reduction is achieved by minimising the levels of inventory while the materials are not cluttering up valuable space. The initial investment in setting up just-in-time methods may require more skilled employees with higher training costs (Waters, 2009; Polat & Arditi, 2005). Sui Pheng and Shang (2011:91) remarked that just-in-time methods must not be in contravention of industry-related legislation such as building regulations, local authority laws, and statutory laws. Furthermore it would be beneficial if all the stakeholders, such as the contractor, subcontractors, suppliers and clients, implement just-in-time methods for it to have maximum effect.

Sui Pheng and Shang also mentioned that developing countries have common characteristics that are likely to impact on just-in-time methods implementation. These are implementation costs, costs of technology and maintenance, labour productivity and labour costs (see Figure 2.1).

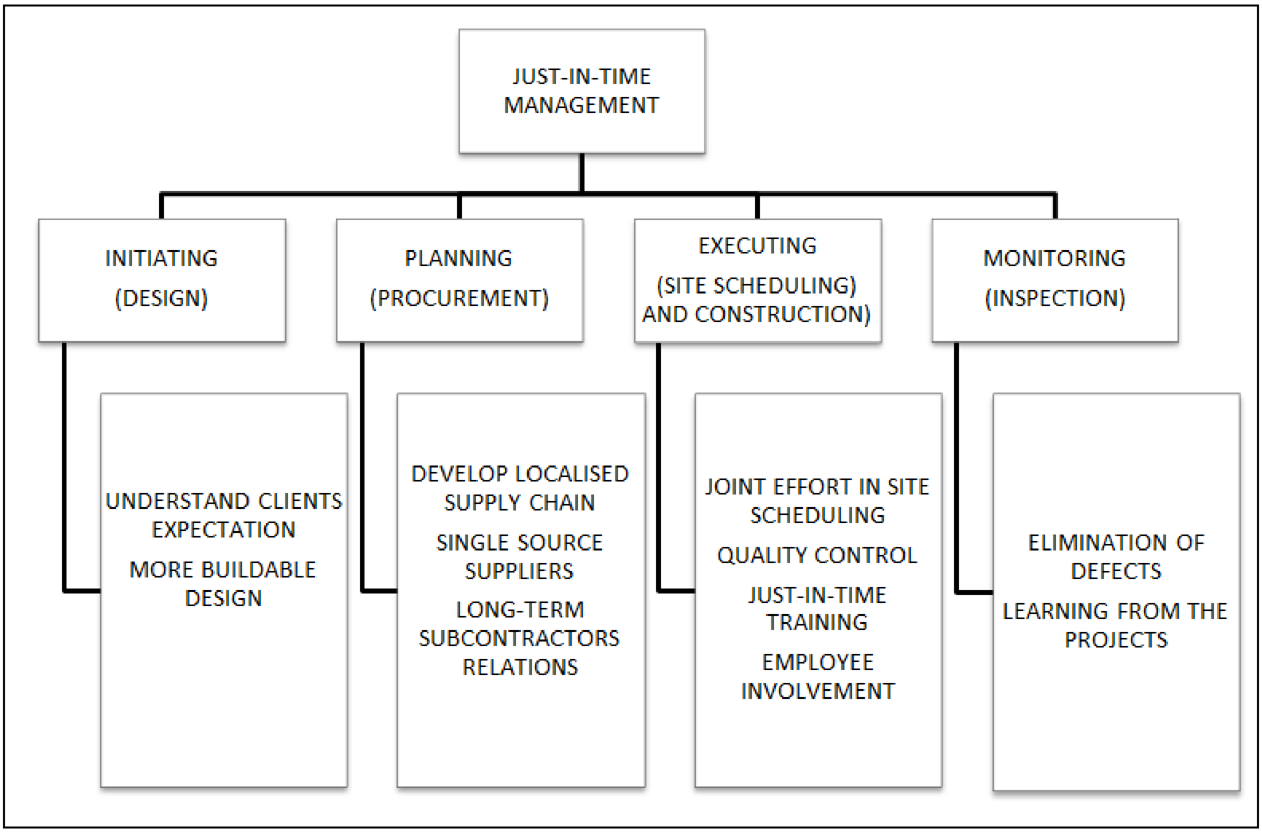

Figure 2.1: Framework for just-in-time methods implementation (Sui Pheng & Shang, 2011:107)

2.2.3 The Use of Technology in Building Production Management

The term 'innovation' is defined as something that is perceived as being new. Furthermore Sewart and Fenn (2006) noted that innovation in construction is in the product, process and organisation of a project. The success of building construction in the urban centre hinges upon a strong sense of strategic intent (Lim & Peltner, 2011:283). Pedersen (1996) considers construction innovation as inevitably involving the application of technology, while Lim (2014:553) deems innovation in construction to be more than technology-related. From this, there seem to be two distinct forms of innovation in construction: non-technical innovation related to organisational and managerial aspects, and technical innovation.

Akintola et al. (2012:3) and Panuwatwarich et al. (2008) believe that innovation by applying improved methods is necessary to retain competitiveness. Akintola et al. also stated that a method involves production procedures, while organisation is managing the firm and implementation of new strategies. Hardie (2010) believes innovation in construction brings about a major improvement of a product or system. Encouragement of innovation activity in business enhances performance and maintains growth. Innovation in construction involves both attitude and structural change (Hardie, 2010:395). Sedean et al. (2003) suggest that creating innovation through technology can as a consequence result in innovation permeating throughout the firm. Furthermore Sedean et al. (2003) suggest that innovation is not necessarily the degree of technical improvement but rather the act of taking advantage of an idea.

a) Automated construction

Currently the use of computer software and automation in construction is seen as innovation. The purpose of using computer software in construction is to facilitate the communication of data, knowledge and design solutions between project participants. Isikdag et al. (2008) described BIM as a major innovation in technology that can assist with problems related to interoperability and information integration. An alteration in existing processes inevitably incurs risk. Risk management is important when considering factors such as cost, who will be affected and who will be accountable.

b) New technology

According to Hardie (2010:387) the international construction industry has not adapted quickly enough to both new technologies and new management practices. The lack of responsiveness to more broad-minded management methods has led to many construction firms lagging behind in new management techniques and the use of technology. Hardie (2010:387) observes the desire of governments to support management strategies that inspire to continuous improvement and innovation. Lim and Peltner (2011:283) state that the significant improvement of technology in recent times has encouraged construction firms to invest in these innovative ways to improve their competitiveness.

c) Radical project delivery

The construction industry needs to collectively adopt a culture that fosters innovation. Sidwell et al. (2004) state that the core challenges of the construction industry in Australia are to develop radical project delivery processes that concentrate on solving problems in procurement strategies, implementation of processes, information availability and the removal of 'non-value added' activities. Egan (1998) believes that improvement by innovation depends on the methods used for enabling improvement. These include working conditions, skills and training, and use of technology. By using technology, collaboration of design throughout the professional team can be achieved. The use of technologies such as computer aided design (CAD) and BIM facilitate the rapid exchange of information with regard to design changes. Zawdie (2012:20) believes that innovation does not take place in a vacuum and that the culture within institutions requires a shift which introduces the necessary flexibility for a generation of new ideas.

d) Space management

It has been ascertained that, considering all the activities on a congested construction site, space management becomes the most important task (Tommelein & Zouein, 1993; Sawacha et al., 1999; Spillane et al., 2011:143). Yun-Yi Su (2010:1) explained that innovation using LAT technologies assists in all stages of building production and supports important decision-making tasks in the field. Razavi et al. (2012:239) explained that location awareness is needed for decision-making and for tracking progress. Health and safety can also be improved using LAT. The challenge is that LAT has been less than satisfactory for inside measurement but rather outdoor environments. The obstruction of signals by buildings and tree canopies places limitations on the outdoor tracking ability of a global positioning system (GPS). Satellite technology cannot receive radio signal inside a building. Recent developments in indoor location sensing systems have overcome this limitation by using radio frequency identification: this offers significant potential on construction sites. A wide range of protocols need to be followed for indoor location systems to be sufficiently accurate.

e) Remote Sensing

Yun-Yi Su (2010:4) indicated that bar code scanners and CCTV cameras are useful on a construction site. Yun-Yi Su (2010:4) believes that manual data collection on-site is a task that is nearly impossible when recording on-going construction work. As a result only approximate estimation of work can be collected with undesirable accuracy. Razavi et al. (2012:239) concurs with You-Yi Su that tracking and monitoring can result in better management practices. Remote sensing and monitoring of personnel in real-time can improve construction safety by warning equipment operators and personnel in the proximity of potential risk. Yun-Yi Su (2010:7) highlighted the importance of timely and accurate feedback information which describes actual operational data on the construction site. Without timely and accurate feedback, the accuracy of the updated project database is effected (Davidson & Skibniewski, 1995; Navon & Sacks, 2007) hence many critical decisions cannot be made in a timely manner.

2.2.4 Knowledge Management

Knowledge management is the preservation of knowledge and the capturing of the creativity of individuals (Egbu, 2012:236). The reason for managing knowledge in construction is to facilitate learning by minimising the time it requires. Globalisation is a phenomenon that cannot be ignored, with global operations which include mergers and takeovers, and where multi-national organisations share knowledge. Furthermore construction is usually characterised by short-term work contracts for the labour force. Egbu (2004:301) believes that the knowledge and expertise of staff are important catalysts for innovation in building projects. Ebgu suggested that knowledge must be effectively managed so that intellectual capital within an organisation is not lost. Knowledge management, as defined by Talukhaba and Taiwo (2009:33), is the exploitation and development of knowledge assets within an organisation, while knowledge management is defined by Kale and Karaman (2012:336) as the ‘creation and management of an environment that encourages knowledge to be created, shared, learned and organised for the benefit of the firm’. Furthermore the earliest studies of knowledge management have been based on technical perspectives such as information systems and technical aspects including processes, managerial tasks and technology. Recent research has moved away from the technical aspects and focused on the social aspects, like: the attitudes of people toward others; management; authority; relationships between people; reward systems; and authority structures. Contemporary research studies focus on the social-technical perspective which identifies primary knowledge practices. Knowledge is a vital project resource that contributes to organisational innovation and can provide a competitive edge in building construction. Knowledge provides performance-enhancing benefits for construction project management (Talukhaba & Taiwo, 2009:33). Talukhaba and Taiwo add that large Japanese companies rely on knowledge creation to foster long-term innovation and strong business performance. Knowledge exchange includes the need and motivation for parties to exchange ideas and to be compatible to make such knowledge transferable (Walker, 2012:126). Thus this creates not only intellectual capital, but also social capital. Social capital is organisation, networking and relationships within the network.

KNOWLEDGE MANAGEMENT				
PROCESSES		OUTCOMES		
		Technical Knowledge	Social Knowledge	
Acquisition	Searching and finding new knowledge	Facilitate rapid collection, storage and exchange of knowledge	Organisational culture	set of values; norms; belief; expectation and assumptions
Application	Utilising knowledge to improve the efficiencies of operations	Integrate fragmented flow of knowledge	Organisational structure	sharing knowledge across boundaries; motivate to share knowledge; facilitate criterion and discovery of new knowledge; promotes collective rather than individual behaviour; knowledge exchange between social actors
Conversion	Transfer of knowledge between social actors	Create new knowledge		
Protection	Securing knowledge for inappropriate illegal use			

Table 2.1: Knowledge management (Kale & Karaman, 2012)

Tacit knowledge rather than explicit or codified knowledge, results in innovation in building projects (Egbu, 2004:301). Despite this understanding, Egbu suggested that tacit knowledge is not adequately researched in the building industry. Information processing is the norm in managing unplanned changes in construction projects however Senaratne and Sexton (2008:186) argued that a better understanding of knowledge can be used to manage unplanned change.

Tacit knowledge is socially constructed and shared between project team members. The level of awareness of knowledge management in the South African construction industry is known to be medium to high however the measurement of performance in construction project performance is not correlated to knowledge management. Further research needs to be done in South Africa to facilitate the making of a business case for the use of knowledge management in project management (Talukhaba & Taiwo, 2009:33). The capturing of tacit knowledge in the construction industry is unusual (Egbu, 2012:242). Generally epistemologists have neglected the human element of knowledge. Knowledge is socially constructed and therefore context-specific. Human action determines the knowledge that is responsible for conditioning the environment in which people work (Nokaka & Takenchi, 1995; Davenport & Prusac, 1998; Habermas, 1984). Social constructivism is a concept that cannot be ignored in construction as we now live in a knowledge-based society (Egbu, 2012:237). Knowledge management converts tacit knowledge into explicit knowledge, which in turn is valuable in innovation. Mode 1 knowledge, referred to by Gibbons et al. (cited in Egbu, 2012:242), is stored in libraries and on the Internet. Mode 2 knowledge is created in the context of application and results from practice. Ways of capturing tacit knowledge is through: brainstorming; face-to-face interaction; training and apprenticeship; storytelling; job rotation and shadowing.

2.2.5 Prefabrication and Modularisation in Construction

Prefabrication, or pre-assembly, refers to off-site fabrication, off-site production and off-site construction and off-site manufacturing (Goodier & Gibb, 2005; Pan et al., 2005).There has been a shift from traditional methods of construction toward prefabricated higher standards and is becoming the global trend in construction. Therefore this shift presents challenges for the construction industry in integrating prefabricated construction with the existing traditional methods. However the obstacles in pre-assembled construction are the negative perception of the architectural value (Azman et al., 2012:53). However the main benefit of prefabrication includes fast track completion of projects and high-quality products.

Prefabrication in construction processes is being opposed from both clients and their advisor (Pasquire & Connoll, 2002:2). Concerns about design limitations and increased capital cost are perceived by clients as a disadvantage of prefabrication although initially there is often a saving. Clients believe that prefabrication has a limited benefit on saving time and reducing waste, due to accidental damage and mishandling (Pasquire & Connoll, 2002:2). The benefits of prefabrication are: reduced labour and consequently a reduced health and safety risk; less waste; less site co-ordination activity and a shorter installation time.

2.3 BUILDING PRODUCTION CHALLENGES WITHIN URBAN CENTRES

Cities are not expanding but redeveloping from within, adding to the existing urban fabric (Biddy, 2009) (cited in Spillane et al.). Thus congested construction sites are becoming more common in the building industry.

The continued growth of urban centres and the mounting costs of land in central business districts, require that construction firms be competitive in the management of construction projects in these areas (Ellis, 2002). The complex nature of construction in urban centres requires innovative methods to mitigate these challenges. Furthermore confined space, congestion and overcrowding, and the merging of new buildings within shells of existing structures, all pose challenges (see Plate 4,11,12). In many instances building additions need to be structurally supported by existing buildings, which must be able to carry the additional load. Most urban centres are located in the old part of the city where buildings are archaic (South Africa, 2008:61). Foundations of new buildings need to be designed and constructed in a way that prevents damage to neighbouring structures. Deformation monitoring of existing buildings is required to prevent serious cracking as a result of vibrations from piling and construction processes. Consequently this is a serious consideration when building in urban centres, and usually results in additional expenses; if not meticulously monitored, damage of adjoining buildings may lead to litigation and major expenses to repair these buildings that can cause serious delays in project completion. Furthermore the effect of building construction on existing buildings cannot always be predicted, but with due diligence the process can usually be controlled so as not to cause undue damage in the adjoining buildings.

2.3.1 Noise, Vibration, Dust and Illumination

The major nuisances associated with construction in urban environments are noise, vibration, dust, and the illumination of night-time work (Peurifoy et al., 2011:725). The effect of these nuisances must be mitigated so that tenants and businesses in the construction phase are not inconvenienced (South Africa, 2008:61). In urban centres dust creation becomes a critical issue and must be closely monitored and controlled. Dust suppression and alleviation of its environmental impact has to be addressed. Many building projects in urban centres involve refurbishing and demolition in confined spaces. Demolition activities usually involve excavators and hydraulic breakers (see Plate 5.5, 5.6). This equipment produces dust during demolition, particularly when dry material is being broken or cut (such as concrete). The issue of dust on a contraction site is a common problem. Wallace and Cheung (2013:344) have researched the effect of airborne dust particles and the health hazards of inhaling dust and suggest alternative methods for dust control. Visibility due to dust is another hazard that needs to be monitored. Wallace and Cheung pointed out that contractors are under pressure to control environmental conditions, especially dust emissions. Wallace and Cheung have researched new dust suppression methods and reported on their efficiency and effectiveness as compared to present suppression techniques. Wallace and Cheung found that the most useful method of dust reduction on sites is using wet methods and local exhaust ventilation. Subsequently this method diminishes dust but creates uncontained slurry, making the working area slippery and potentially hazardous. However the disadvantage of using local exhaust ventilation systems is that it creates noise and electrical hazards due to cables used to power the equipment. According to Isnin et al. (2013:128) construction personnel are exposed to dust and other harmful emissions caused by specific building materials. This dust contributes to poor air quality on site and can lead to respiratory problems and severe chronic diseases. Activities causing dust may involve dismantling of the existing dry walling and other fixtures, scraping of existing paint finishes, and partial demolition to accommodate extensions to beams walls and floors. Other activities may involve the chipping of existing floor surfaces, grinding, drilling, or the removal of contaminated debris that can release a range of particles.

In urban centres excessive noise is unacceptable to neighbouring office blocks, residential accommodation and retail during the day. Restaurants, schools, old age homes, places of worship and entertainment venues are affected at night. Care must be taken to control the movement of vehicles to and from the site especially delivery of concrete and other noisy activities. Work on public holidays and weekends is difficult but is sometimes needed to accommodate deliveries that need to be made outside normal working hours. During normal working hours traffic volumes are high and the delivery of material to site can create unacceptable congestion to public traffic. Additionally the inconvenience of earth moving trucks to and from the construction site can be a danger to traffic. Furthermore backup alarms of mobile plant can be especially troublesome in creating irritating noises. Work hours can be severely affected due to the limiting of unacceptable noise. Additionally vibration emanating from pile driving at the start of a project, can be is most troublesome. Other vibrations can be generated by compacting machinery, vibratory rollers, and blasting operations. According to Peurifoy et al. (2011:726) noise can be defined as sound that is too loud, unexpected, or uncontrolled. Machinery is the biggest contributor of noise on a construction site. It is important that project managers invest in machinery that runs quietly and is fitted with effective silencers on the exhaust outlet. Furthermore, operating machinery at lower power decreases the noise made during operation. In extreme cases project managers might have to consider differently powered machinery with alternative power sources, such as tower cranes that are powered by electric motors instead of diesel engines. Project managers must ensure that plant is not running unnecessarily or left idling for a long time, for example — leaving a concrete mixer running while concreting has been halted because of a problem, or leaving a compressor idling when work has been delayed. Project managers must consider re-routing truck traffic away from streets that are located near offices or other noise sensitive areas.

2.3.2 Space and Machinery

The performance of building project processes in urban centres relies on efficient management of labour and personnel productivity, efficient use of plant and equipment, and controlled management of materials and space.

Research on congested urban construction sites was done by Spillane et al. (2011:141) in three urban development sites situated respectively in Ireland, Liverpool and Chicago. Spillane et al. found that stockpiling of construction waste material on site was an issue because of the limited space available. Furthermore the close proximity of workers to large plant and machinery on a confined site creates a health hazard, because of sustained high noise levels and air pollution. Additionally there is the danger of physical contact between man and machine. Providing temporary storage room on site was also identified as a problem which compromised site efficiency. The three core underlying issues found by Spillane et al. (2011) were the problem of co-ordination and management of site personnel, the lack of space, and overcrowding of workplace.

Congestion on a construction site in an urban centre with difficult access increases the risk of using machinery longer than planned and occurring more costs. Furthermore government-initiated action such as health and safety requirements and labour regulations applied to congested sites can directly influence equipment decisions. Control of sound and emissions from construction are receiving greater regulatory attention in urban centres of the USA (Peurifoy et al., 2011:11), and this trend is likely to find international acceptance. Construction equipment is specifically designed by the manufacture to perform certain mechanical operations, mostly under normal conditions. The project manager must ensure that machinery can operate at its capacity and do the task its intended without undue restrictions: due to the congestion of an urban site. According to Peurifoy et al. (2011:14) it is not always obvious which machine is best for a particular project task. It is important that the project manager keeps assessing the project site and employs equipment that can best accomplish the work. Hence the project manager must understand the capabilities of machines and the tasks to be performed.

The tower crane is usually the machine of choice in urban centres because it accommodates site conditions that are restrictive, Peurifoy et al. (2011:588) state that such cranes can be selected to suit the required lift height and reach. On urban sites there is generally no need for mobility and if powered by electric motors these cranes hardly add to the noise level. Additionally pile driving equipment is required on certain sites. Piles are classified by the materials they are made of or the use of the pile.

2.3.3 Storage of Materials

Materials delivered to site must either be stored on site or used upon delivery which will require a strict productivity sequence. If material is stored on site it must be placed where it will be accessible at the time that it is to be used; because of space constraints material should be stored on site for a minimum time. Another constraint on a construction site in an urban centre is when ready mix concrete may be delivered (see Plate 5.13, 5.14). Furthermore during peak traffic trucks may not be able to manoeuvre around the site.

Space on a construction site is a resource that must be effectively managed. Space management is essential for accommodating materials on site, personnel productivity and health and safety in close proximity to large plant and machinery; a well-organised site layout design is essential to achieve this. Due to confined space more detail is needed in managing personnel. The coordination of work on site needs to be more precise. When sites are congested any acceleration of program of works will dramatically increase the risk of decreased safety margins. Furthermore, Sanad et al. (2008) emphasise that the more congested a site is, the more noise is likely to be generated.

2.3.4 Labour Productivity and Congested Sites

An area of concern researched by Spillane et al. (2012) is labour productivity. Labour productivity is defined as the ratio between inputs such as labour, material and plant, and outputs such as the value of completed work. Productivity is defined by Spillane et al. (2012) as the 'ratio between earned work hours and expended work hours'. Factors that influence the productivity of labour identified by Spillane et al. (2012), include over-manning; stacking of trades; lack of materials; extended overtime; changing working time; shift work and schedule compression.

Spillane et al. (2012) made use of a mind map diagram to identify and disseminate the impact of constructing structures in an environment where space is important and requires effective, continuous management (Tommelein & Zouein, 1993). Documenting the factors which impact on personnel productivity on a confined construction site, aids on-site project managers in identifying the critical factors this will enable them to implement remedial and in doing so, will assist in the implementation of mitigation measures to reduce or eliminate a lowering of on-site productivity (see Figure 2.2 & 2.3).

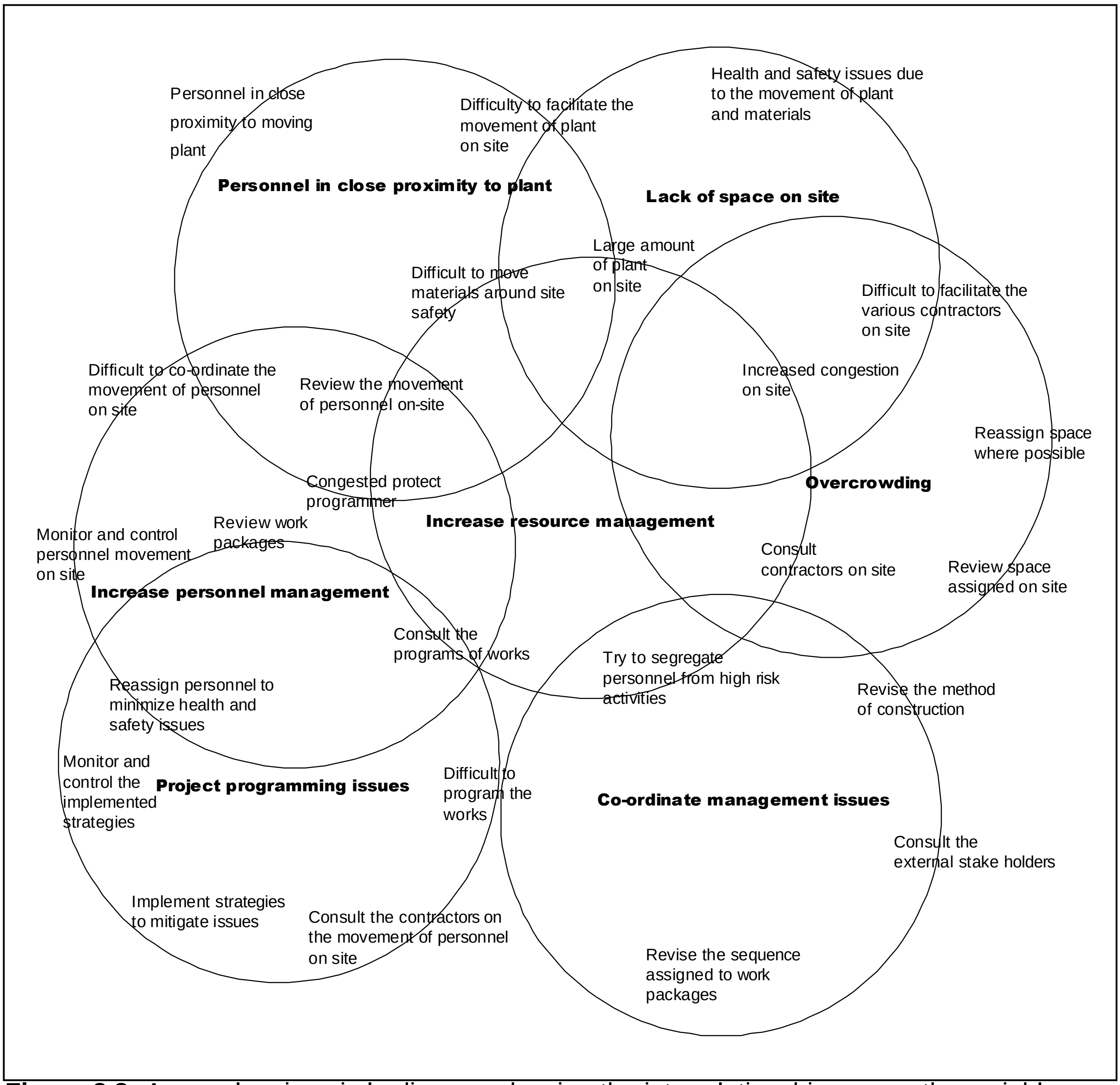

Figure 2.2: An overlapping circle diagram showing the interrelationship among the variables on construction sites within urban centres (Spillane et al., 2012)

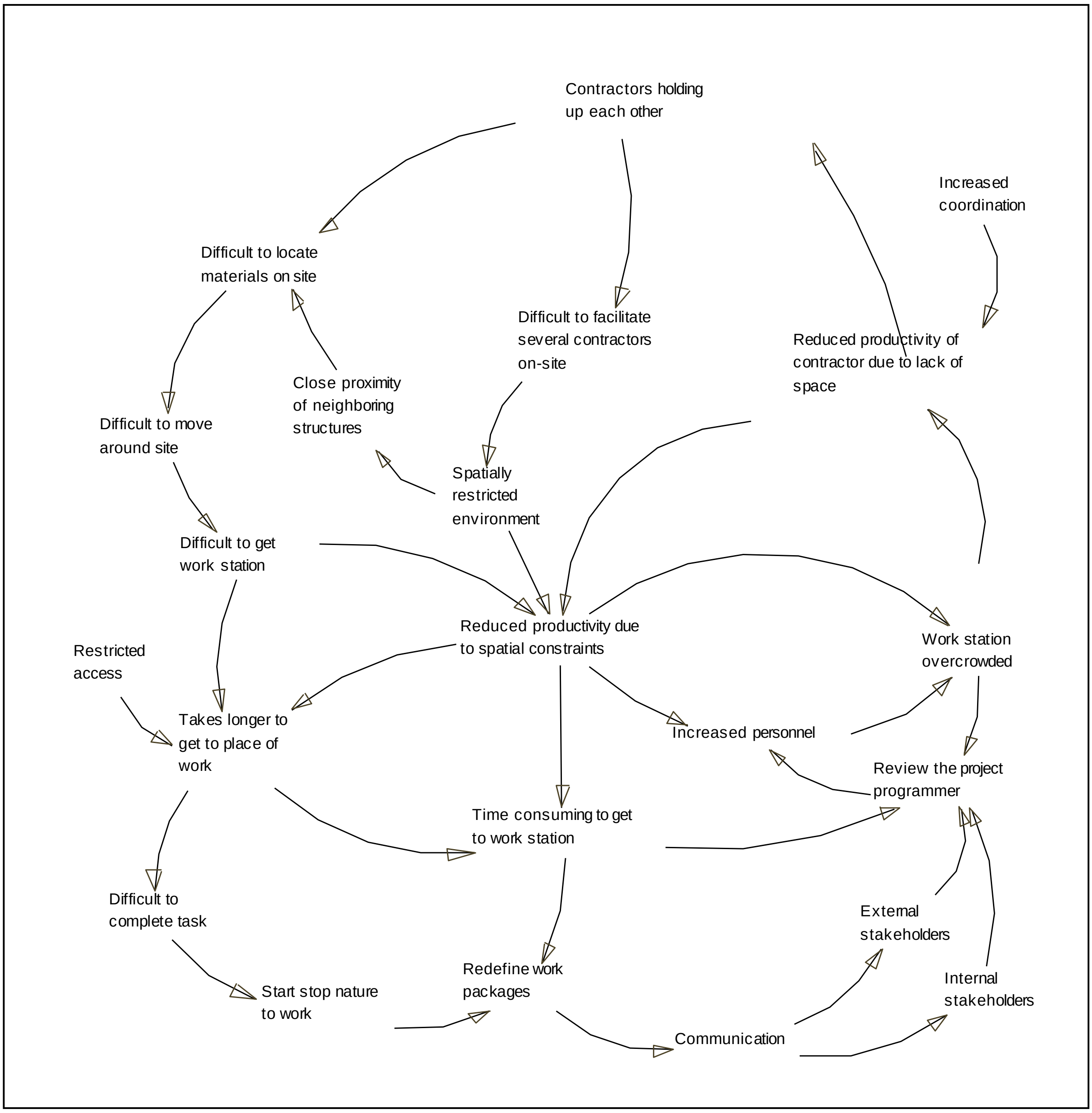

Figure 2.3: Casual loop diagram of factors impacting on personal productivity (Spillane et al., 2012)

2.4 INNOVATION IN BUILDING PRODUCTION MANAGEMENT

Construction is undergoing changing conditions, resulting from urbanisation and globalisation. Urbanisation and globalisation are demanding buildings and infrastructure with reduced environmental impacts and cost. This has required the impetus to search new methods (Tah, 2012:348).

2.4.1 Linear and Non-Linear Approach to Innovation

Zawdie (2012:21) referred to two different approaches to innovation, being the linear and non-linear approach.

The linear approach starts by producing new ideas about new combinations. New ideas are then translated through the process of design, engineering and production. Furthermore this approach sees innovation as both product and process where new combinations replace the old. Linear innovation is approached in two ways being the supply or technology/science push and the demand pull with feedback loops. However the linear approach fails to capture the full extent of the complexity of institutional context of innovation. Zawdie (2012:23) sees the linear approach as 'naive abstraction of the complex innovation processes'.

The non-linear approach is a comprehensive approach to innovation known as an 'innovation system framework'. Furthermore the non-linear method is founded on the understanding that knowledge cannot just be produced in specific research organisations or universities and then simply transferred to passive users. Knowledge of institutional and organisational factors underlying the innovation process cannot be assumed to be fixed as in the linear system. Instead they evolve to suit prevailing local circumstances including the stakeholder's perspective. Hence the non-linear approach differs from the linear in that it involves knowledge of all major elements simultaneously, coupled with interactive communication paths. It includes feedback loops to gather internal inputs, new technology ideas and external market and social needs. Innovation systems can be seen as development of social systems in their achievement of their strategies.

2.4.2 Innovation and Culture

Liu and Fellows (2012:63) believe cultural classification has been widely used to typify the construction industry. Furthermore the separation of functions and activities through perceived cultures causes fragmentation and lack of coordination of the components and affects performance of both product and process. Social rules of interplay are dependent on co-operation structures. Innovation occurs in response to an emerging culture or reaction that challenges and dominates an existing culture. Gebhartt (2005) suggests that innovation is about cultural belief, a belief which is acknowledged by other actors. According to Liu and Fellows (2012), culture represents a tradition of who we are, what we believe and what we know. Social processes and cultural change in a construction firm can have an effect on the modes of production. Hadjimanolis (2010) advocate that innovation is embedded in culture and that construction company culture varies between different countries and organisations. Innovation culture reflects the social dynamics of self and collective aspirations. Innovation culture exists when an organisation encourages innovation through leadership and nurtures creativity and communication. Innovation culture develops and launches values and attitudes within a firm which involve changes that clash with conventional employee behaviour, but may in turn create highly effective cultural and managerial conversions regarding innovativeness. Hence it must be noted that there is no single type of culture that is ideal for the development and adoption of innovation as culture can hinder or stimulate innovation (Van Duwanbden & Thaens, 2008).

2.5 DEVELOPMENT IN SOUTH AFRICAN URBAN CENTRES

Research into innovative practices for effective management of building production processes within urban centres is necessary because the construction industry is constantly being challenged with evermore complex building projects (Hardie, 2010:389). Urbanisation and globalisation are the foremost trends in propelling the growth and development of cities and towns in the world today. Cape Town is an example of an urban centre that is required to deal with rapid urbanisation. Innovative methods of stimulating building production processes are needed to ensure that building projects are completed within timeframes and budgets.

Owing to the complicated nature of a construction project, decision-making becomes a significant but difficult process. Furthermore the increasing diversity of activities within the sector means that the character of such projects is more varied than in the past. Despite these challenges the construction industry internationally, has been slow to embrace innovative technology.

In the past the urban centre of a city was inclined to be compact because of the lack of transport. Hence the modern city sprawls as a result of better transport, which facilitates lateral suburban growth (Hartshorn, 1992:220). Indeed the first, and probably best known model of urban structure, is the Burgess model (Dear, 2000:17). Burgess's model published in 1923 of the concentric growth of cities, suggests growth occurs as expansion in a radial pattern. Thus the urban centre, or more commonly known as the central business district, is in the middle of the Burgess model (see Figure 2.4). Burgess illustrated urban growth as nested concentric rings developing from the centre and spreading outward. Bandcock (2002:184) stated that the Burgess concentric city development model predicts what type of land use or zoning can be expected, moving outward from the centre. The reasons for concentric growth of city expansion are many. One of them is the dynamics of the real estate market, where higher status income groups move towards the periphery and are replaced by the income status group immediately below them, who then move into areas that have been vacated. According to Pacione (2001:133) the Burgess model has been widely criticised as being too simple and was developed when motorised transport was uncommon.

Hoyt, a well-known economist, came up with the sector theory model which accepted the central business district but suggested that the various groups expand outwards from the city centre along railway lines, highways, and other transportation arterials. Hartshorn (1992:224) explained that Colby, an American urban geographer, contributed to the understanding of the spatial structure of the city by showing that the dynamic forces of the city continually interact to encourage activities to concentrate and disperse at the same time. Periods of steady, if somewhat irregular, small scale enlargement following localised lateral expansion within the central business district can be replaced with the so-called 'burst'; this is where the central business district expands rapidly in a very short time.

The third type of growth that can happen is the breakup of the central business district into at least two discrete parts. The central business district in fact becomes a poly-nuclear central area rather than a central district. Post 1970 the oil price crisis put an end to mass production and stable growth (SA Valuer, 1997). The higher oil price immediately upset property prices in distant suburbs as interest rates went up and transport became expensive. In the 1990s electronic communication, industrial globalisation, post modernism and the inception of democracy in South Africa, all created uncertainty.

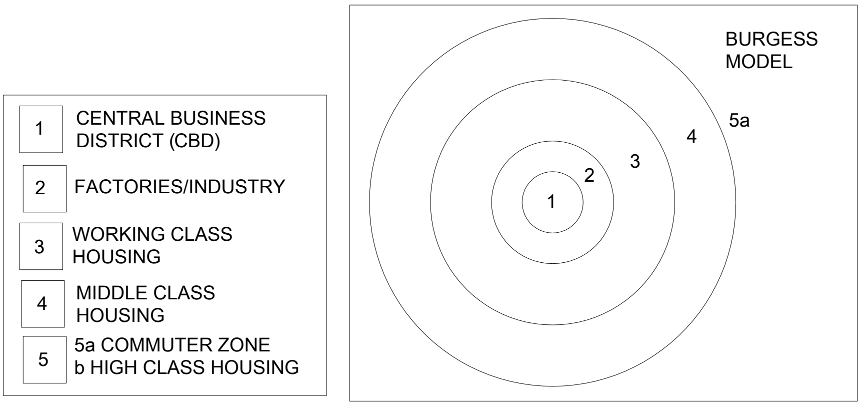

Figure 2.4: Burgess Model (Hartshorn, 1992)

The shape and purpose of the urban centre has traditionally symbolised the socio-economic vitality and strength of the city. Pacione (2001:151) stated that the key characteristic of the inner city is its accessibility. Furthermore the inner city contains prime real estate, demanding specialised uses (Harthorn, 1992:334). Subsequently this central accessibility and high land values create intensity in land use. Developers seek to maximise space through high-rise buildings. Thus the urban centre is usually located in the older part of the city. Large numbers of working people and visitors traditionally move in and out of the urban centre. Most activities take place during the weekday business hours. Pacione (2001:152) points out that the modern urban centre has developed a strong tourist and convention trade function. Several functional areas make up the inner city. Hartshorn stated that the built environment of the core usually consists of high-rise buildings, a financial district, hotels, a convention district and retail. Typically surrounding the core will be government buildings, a medical district, skid row, and wholesale and warehouse areas. However the boundary of the central business district moves over time as rundown areas are abandoned and new territory, mainly towards the higher income sections of the city, is incorporated. Furthermore the street plan of the inner city has a significant influence on the various districts within the urban centre.

The dispersed and segmented structure of South African cities is largely a legacy of the apartheid policy applied prior to 1994. Cities in South Africa are striving towards becoming more efficient in form and functionality. Well-located investment in the urban centre is preferred, as opposed to fragmented, dispersed development that places huge demands on government for additional bulk infrastructure in outlying areas and which may undermine long-term prosperity (Sinclair-Smith & Turok, 2012:391).

2.5.1 The Cities of Johannesburg and Cape Town

Johannesburg was founded in the 1880s and from an economic perspective is the most important city nationally. More than anything else, this inland city owes its existence to the discovery of gold on the Witwatersrand. Johannesburg has assimilated a wide variety of cultures related to its origin as a mining town. As a consequence of the mines, Johannesburg developed into a major industrial centre in the early 20th century. However the urban centre of Johannesburg experienced a long period of decline starting in the 1970s. Subsequently the Central Johannesburg Partnership was established in 1992 to encouraged urban renewal. A city improvement district was created by the partnership and together with local business they assisted faltering municipalities with management skills. This led to further collaboration with local businesses when privately-funded public services such as street cleaning, and marketing of the city were undertaken.

Figure 2.5: Cape Town Urban Centre (Urban Design Framework, City of Cape Town, 2006)

Cape Town (see Figure 2.5) is South Africa's third largest city with a population of approximately 3.7 million (SACN, 2015). Wilkinson (2004:218) classed Cape Town as a medium-sized city and went on to say that the population of Cape Town is ethnically diverse. Furthermore the urban centre has always been a cosmopolitan settlement with the seaport embracing sailors and cultures from all over the world. Traditionally the Bo-Kaap is a Moslem community referred to as the Malay quarter, while Oranjezicht was mainly a Jewish community. District Six was a mix of ethnic origin ranging from White, Coloured and Black residents (Ududu, 1999). Cape Town is the economic powerhouse of the Western Cape

Province. Furthermore the areas of economic growth are business and financial institutions, retail and wholesale manufacturing. Interestingly the growth in the city in the last six years can be attributed to the building of the International Convention Centre, property investment in the central business district, and an increase in the tourist industry subsequent to the Soccer World Cup 2010 and initiatives such as the Urban Renewal Programme. Furthermore the strength of the economy of the city is in its diversity; however, since 1995 there has been a shift toward the service sectors which is in line with global trends (SA, 2008). Cape Town has a local economy that employs a formal labour force of 1.02 million people, which produced an overall output of some R94 billion in 2002 (Wilkinson, 2004:218). There is a large concentration of informal traders in the city. In line with national government's rejuvenation policy for major cities, the urban centre has changed significantly over the past decade. Furthermore the establishment of the Cape Town Partnership in 1999 consisting of the public sector, private sector, community sector and non-government organisations has a mandate to manage, promote and develop the urban centre of Cape Town, and to reverse the urban decay that had set in. The partnership has been instrumental in restoring basic urban management systems and has managed to enhance urban renewal by retaining both local and foreign investors in the city, as well as attracting further investment. In the process of urban renewal many buildings have been renovated and restored. Property investors in the urban centre are extremely fortunate that in the Western Cape old and historic buildings are generally faster and less disruptive to renovate than elsewhere, and investors can thus expect a rapid return on their investments. Many of these old, historically important but neglected buildings have been upgraded from derelict commercial properties, to beautifully restored residential complexes.

A decade ago the Minister of Finance announced a tax exclusion zone within the urban centres of Cape Town known as the Urban Development Zones (UDZs) (see Figure 2.6). As a result these exclusion zones encourage refurbishments and construction of commercial properties through tax incentives for investors. In the period from 2006 to 2012 there were 337 applications received with a total construction value of 2.13 billion Rand and total value of refurbishments of 1.23 billion Rand. As a result construction has been accelerated in the proclaimed UDZ areas and refurbishment of buildings increased (see Figure 2.7). Greater Cape Town has two UDZs, one in central Cape Town and the other in Bellville along Voortrekker Road (South African Revenue Service).

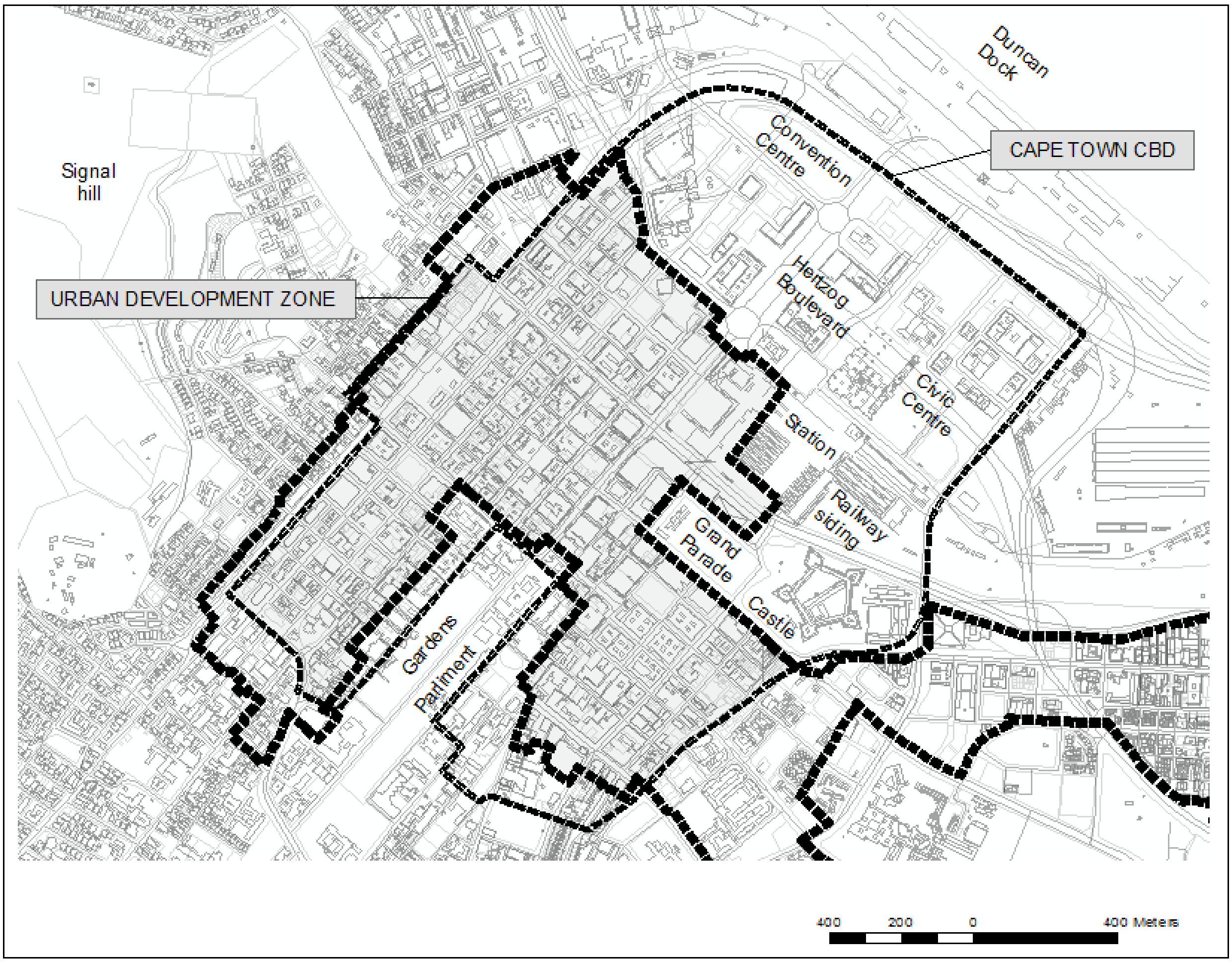

Figure 2.6: Cape Town Urban Development Zone (compiled from the City of Cape Town spatial data, 2015)

Increased residential accommodation available in the inner city is attracting people and families with different household structures, values, needs, class and expectations. As a result the ability of the urban centre to adapt to the influx of an increased residential population is important for its sustainability. Furthermore by creating a new sense of place, the urban environment will provide attractive inner-city living and ensure that it continues to develop as a people-friendly terrain. Densification of the urban centre is essential to offset the sterility that once characterised the urban centre. Therefor the encouragement of residential living in the inner city will contribute to a more vibrant area, tending to offer twenty-four hour entertainment with clubs, bars and dining venues, which will attract tourists and patrons. Thus the urban centre is one of the major commercial hubs of the city and it is important that it is rejuvenated into a vibrant and friendly place, with convenience and good management making it accessible to all. Furthermore new residential development in the urban centre is breathing new life into the inner city.

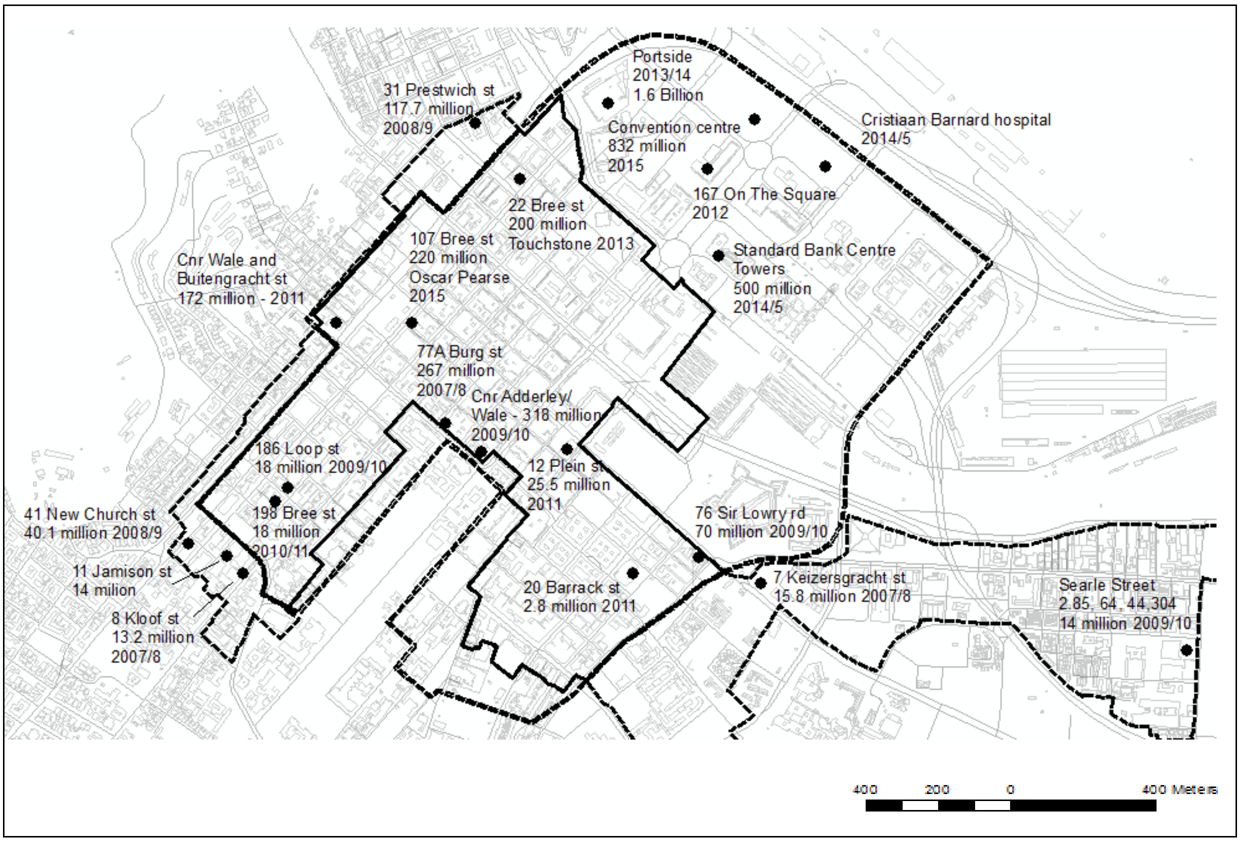

Figure 2.7: Important construction projects with a value greater than R10 million in Cape Town's urban centre (compiled from the City of Cape Town spatial data)

The scale of residential growth envisaged for the Cape Town urban centre requires an increase in basic services to provide for the predicted increase in inner-city dwellers of about 100 000 people. According to local architect Pieterse (2007), commercial buildings in the Cape Town urban centre that not functioning efficiently provide an ideal opportunity for developers to purchase and convert them into residential units at low cost and high return.

2.6 INNOVATIVE TECHNOLOGY FOR CONSTRUCTION MANAGEMENT

Problems facing the construction industry in South Africa are inherent in most construction industries worldwide however approaches by different countries to project organisation is different. The underlying social, political, and legal factors in each country provides us with an opportunity to learn from other construction professionals on how to promote innovative practices in construction.

2.6.1 Building Information Modelling

Continuous planning is essential during all the processes of building construction management. A continuous plan is often presented using a Bar chart or Gantt chart, which shows the relationship between construction activities and corresponding times, as well as logistical restrictions between activities. Existing standard software is useful but does not represent nor communicate the spatial and temporal aspects of construction schedules effectively. In order to improve building production processes, knowledge and information needs to be continuously shared and collaborated among stakeholders throughout all the stages of the project.

Building design requires good communication and collaboration between stakeholders (Moum, 2006 cited in Rahimian, 2012:321). In reality design is explicit and is concurrent learning about the nature of the problem and the diversity of attainable solutions. Design is said to be a prediction concerned with how things ought to be (Lawson, 1997 cited in Rahimian, 2012:321). Cross (2007) believes that a pencil sketch is a communicative tool that orchestrates the intellectual thinking process and develops the design aptitude. However there needs to be feedback and dialogue to enable vague ideas to be expressed, represented, reconsidered, revised and applied. CAD has provided benefits for the conceptual designer, by allowing a huge amount of realistic and professional representations of the design to be developed within a limited time, hence transferring tacit design knowledge into an explicit form accessible by all the other stakeholders (Griffith et al., 2003). However CAD software is unable to support instinctive design processes. Kalay (2004) notes that computers are only design support tools that make a designer aware of inconsistency in construction checklists. Whyte et al. (2007) describes virtual reality as an emerging design support tool that can manipulate in real-time and be used collaboratively to explore different stages of the construction process while Eastman et al. (2008) believes BIM is the most promising development in the construction industry in this regard. Moreover the principle of BIM is collaboration between various stakeholders at different phases of a construction project to support and reflect the roles of those stakeholders. BIM can facilitate information sharing amongst several participants. Tah (2012:354) acknowledged that knowledge-based virtual prototyping for decision support in project management has been slow to make an impact in the construction industry. Isikdag (2012:385) clarified that BIM momentum is now changing the architecture, engineering and construction (AEC) industries in a way which is likely to cause a change in the general construction process, toward intelligent construction and intelligent buildings. Consistency and precision can be realised using BIM, which provides efficient team work, better collaboration and better co-ordination and automated information management processes.

Woudhuysen and Abley (2004:3) pointed out that information technology is a key enabler of change in the construction processes. Two-dimensional CAD was the first enabler of collaboration between consultants and contractors, however 2D CAD offers very little or no improvement over hand-drawn drawings in the pursuit of a coordinated design. Woudhuysen and Abley (2004) believe that three-dimensional CAD presents a much more useful way of achieving a step change in the efficiency of project teams. Having a constant reference back to a single 3D model generally enhances clarity and reduces ambiguity. Furthermore information can be added to improve the planning and construction sequence, the delivery of materials and other site logistics. Woudhuysen and Abley (2004:3) believe that construction has approached critical mass as far as the understanding and experience of building modelling by senior technical and managerial staff. However, there are many difficulties being encountered by pioneering teams. One aspect identified as important for progress in BIM is the need for standardisation. Interoperability through open standards such as those presented by the International Alliance for Interoperability is a step forward, but not yet commonly used by, or accessible to, for lay users. However interoperability and collaboration also relies on the calibre of the people involved and the way they work, as opposed to the tools they use. Innovation is essential to develop CAD skills and refine software. Developing momentum depends on individuals. BIM is best used early in a project when macro decisions have to be made.

Venkatachalam (2014:144) stated that the adoption of BIM in South Africa and other developing nations is slow because of socio-economic factors. Venkatachalam believes that despite the numerous benefits of using BIM, challenges still remain in its implementation. Kiprotich (2014:43) revealed that construction firms in South Africa have shown significant interest in BIM since the turn of the new millennium. Kiprotich (2014:15) stated however, that contractors are concerned that BIM blurs the distinction between design and build. Kiprotich indicated that intellectual property also becomes an issue considering that BIM is a collaborative tool. Bengtson (2010) (cited in Kiprotich, 2014:35) indicated that the perception in the construction industry in South Africa is that BIM capability is overrated and this poses the greatest challenge. Although BIM can hold vast amounts of information, it requires additional expertise to manage large data sets. Kiprotich (2014:35) pointed out that regardless of the fact that computer hardware and software are developing quickly, big BIM projects become overloaded and slow down the model.

Porwal and Hewage (2013) (cited in Venkatachalam, 2014:146) indicated that BIM is now being widely used in countries such as the United States of America, United Kingdom, Australia, Hong Kong and Canada. Venkatachalam believes that it depends on the readiness of the industries as to whether they adopt this technology. Venkatachalam went on to say that government and regulatory bodies need to exert a greater influence towards the use of BIM. Venkatachalam believes that the South African construction industry is reluctant to deviate from their traditional ways of delivering construction projects. Thus the tendency is for construction managers to continue with traditional 2D and 3D drawings. Venkatachalam's study revealed that affordability and lack of knowledge are a hindrance in the adoption of BIM. Furthermore, people-related readiness is generally inadequate. Barlish and Sullivan (2012) (cited in Mutale, 2014:136) believe that the challenges in the implantation of BIM are; that benefits may be vague; the cost of introducing a new system; possible conflict between stakeholders; fear of the new system; and its effect on jobs.

Bryde et al. (2013) (cited in Mutale, 2014:136), and Olatunji (2011) noted the following disadvantages and advantages of implementing BIM:

Disadvantages:

- corporate costs such as software and technology acquisition
- training, hardware and contingency service

Advantages:

- cost and time savings
- improved communication and effective control of other project parameters

2.6.2 Building Information Modelling in the United Kingdom

Venkatachalam (2014:146) noted that the United Kingdom construction industry together with the United Kingdom government, has implemented a program to incorporate BIM. Furthermore the government encourages construction firms to use BIM for all public sector centrally-procured construction projects. The 1990s saw the decline of a once strong construction industry in the United Kingdom. During this time the United Kingdom suffered high interest rates, inflation, and fierce competition. In 1994 the British government commissioned Sir Michael Latham to review procurement and contractual arrangements in the United Kingdom construction industry, with the intention of tackling contentious issues affecting growth within the industry at the time. Amongst many recommendations outlined in the report, Latham acknowledged that to reduce costs, the design and costing process should link with the construction process. Latham insisted that the ineffectiveness of the industry was a problem and that industry practices were ineffective, fragmented and unable to provide a proper service for client's needs; also the industry displayed a lack of regard for its employees. Furthermore Latham was a campaigner for partnering and collaboration among construction companies in order to increase efficiency through honesty, trust, commitment, co-operation and shared appreciation among team members (Latham, 1994). Many of the recommendations and targets set by Latham were not achieved and in 1997 Sir

John Egan was asked to carry out a similar assessment, but this time on the efficiency and quality of delivery of construction in the United Kingdom.

The Egan report emphasised the need for integration and collaboration between processes and teams (Egan, 1998:8). However this report also did not reached its recommended targets: however, since the Egan report there has been a paradigm shift towards the integration of design and costing with the construction process through the introduction of BIM. During the 1970s and 1980s CAD, along with the invention of the computer, revolutionised work practices in the construction industry (Damien et al., 2009). Design and costing became more accurate with increased efficiency of the drawings that were used. Two-dimensional CAD projects later became 3D modelling which again changed the design process for the better. According to Pattison (2011) this new method of design and costing reduced the amount of waste produced and increased the turnover in the United Kingdom construction industry by around 2%. Liu et al. (2011) concurred that the biggest cause of waste in the construction industry occurs at the design stage. Subsequently the next step beyond 3D modelling is using BIM in the design and costing process. Where 3D models are just points, lines, 2D shapes and 3D volumes, 3D BIM models contain quantitative and qualitative data (Damian et al., 2009). BIM is object-orientated and rich in diverse information attached to each object (Isikdag et al., 2008). A primary difference between 2D drawing and 3D modelling is that 3D BIM modelling is interactive so that when changes are made, they are applied across the entire design, updating and checking all other views, removing mistakes and increasing effectiveness (Azhar & Sketto, 2010). BIM is much more organised in that many of the risks are transferred to the pre-construction stages, therefore controlling costs and design fluctuations earlier on. Cerovsek (2011) agreed that 3D BIM models allow analyses of the constructability of a project, assisting with construction.

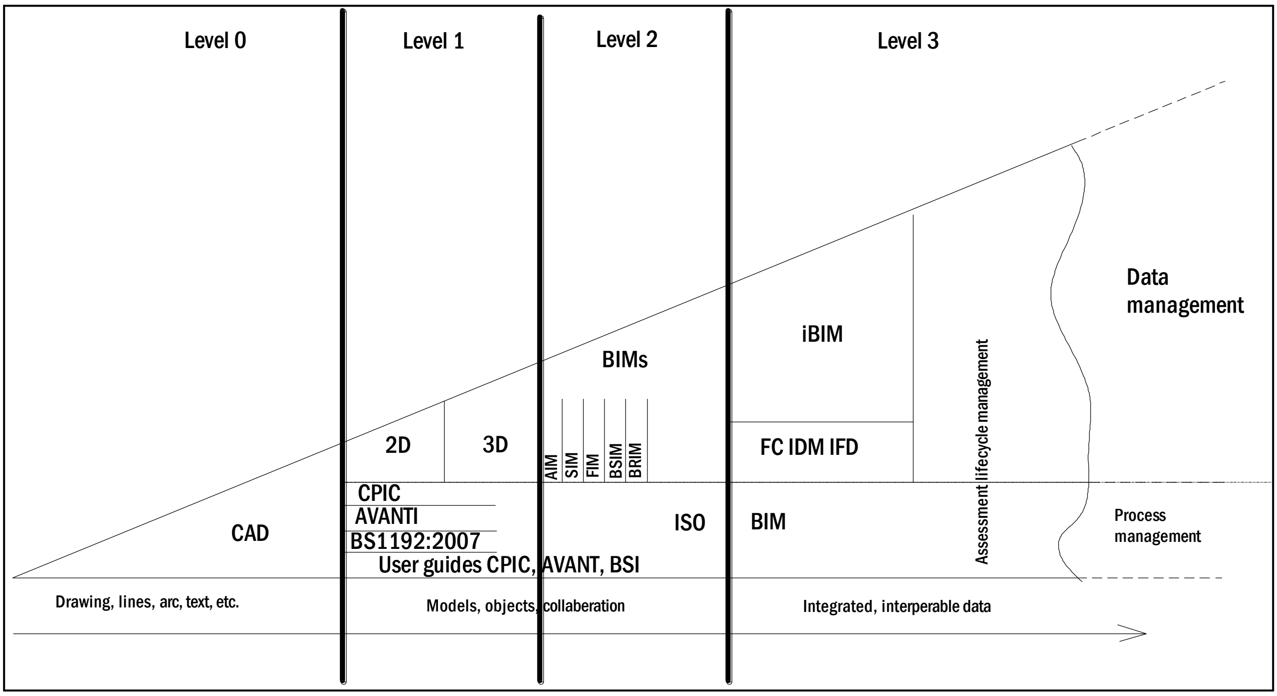

Figure 2.8: BIM Evolutionary Ramp – Construction Perspective (Bew et al., 2008)

Bills of quantities (BOQs) formalise the itemising and estimating of all potential works associated a construction project, such as the cost of labour and plant. The use of 2D CAD drawings at design stage for the BOQs is represented as level 0 on the BIM evolutionary ramp (Bew et al., 2008). Level 1 symbolises the introduction of 3D modelling where all project information is available. In level 2 technologies becomes more integrated into BIM. Level 3 is the open process; data integration enabled by the Industry Foundation Classes (IFD), Information Delivery Manual (IDM) and the International Framework for Dictionaries (IFD) in which information is exchanged and delivered in a project (see Figure 2.8). According to the United Kingdom's Business Innovation and Skills Investors report (2010), the majority of United Kingdom construction firms are at level 1 and are encouraged to move to level 2.

The Singapore government also promotes the use of BIM through the Building Construction Authority (BCA). It offers incentives, productivity funding, training and education to build up BIM usage in the industry. The BCA has mandated the phasing in of BIM e-submissions from July 2013 to July 2015.

2.6.3 Point cloud scanners

A point cloud is a group of electronic data points that share the same coordinate system. These points are usually in three-dimensional space, defined by X, Y, and Z coordinates; these points are used to represent the outside surface of an object. Tuttas et al. (2014:341) explained that point clouds can be acquired with laser scanners or imaged-based, photogrammetric methods. A 3D laser scanner can only collect information from a surface that is not obscured. Gleason (2013:2) explained that a scanner sends out high density laser beams that are measured in phase shifts as they return to the scanner. Scanning hardware can detect colour which gives more value to the display of point cloud information. Scanners have the ability to send out thousands of beams per second, resulting in a 'point cloud' of data (see Figure 2.9).

Becker (2015:66) stated that terrestrial laser scanning technology has become one of the most interesting topics in geomatics in the last few years. Becker went on to say that fifteen years ago there were very few companies working with the early versions of this technology. According to Gleason (2013:2) scanning in the construction industry was mostly been used to model existing structures from point clouds, nevertheless point clouds are now being used for many different applications relating to construction work. Point clouds can be applied in building process monitoring, used within BIM (Tuttas et al., 2014:341). According to Kim et al. (2013) progress monitoring on a construction site can be done where point clouds are generated by a fixed stereo camera system. Gleason clarified that once the fieldwork has been done, all the individual scans are adjusted and orientated together so that the object model creation process can be done. Gleason goes on to say that the 3D model created from the new data provides enormous opportunities. There are constraints to using point cloud data which must be considered. The processing of 3D laser scans requires a lot of computer power; lack of sufficient computer power will halter the processing of huge data volumes. Gleason noted that scanning can be a time consuming endeavour, resulting in very large and complex datasets. Gleason cautioned that scanning technology projects must be well planned. Attempting to recreate every single element in a single area can lead to loss of focus and failure to meet the broader objectives. Attempting to capture smaller elements is often impractical and unnecessary. Gleason acknowledged that these tolerances can be set in the scanning hardware, to regulate the laser beams; such settings are known as the resolution and quality setting.

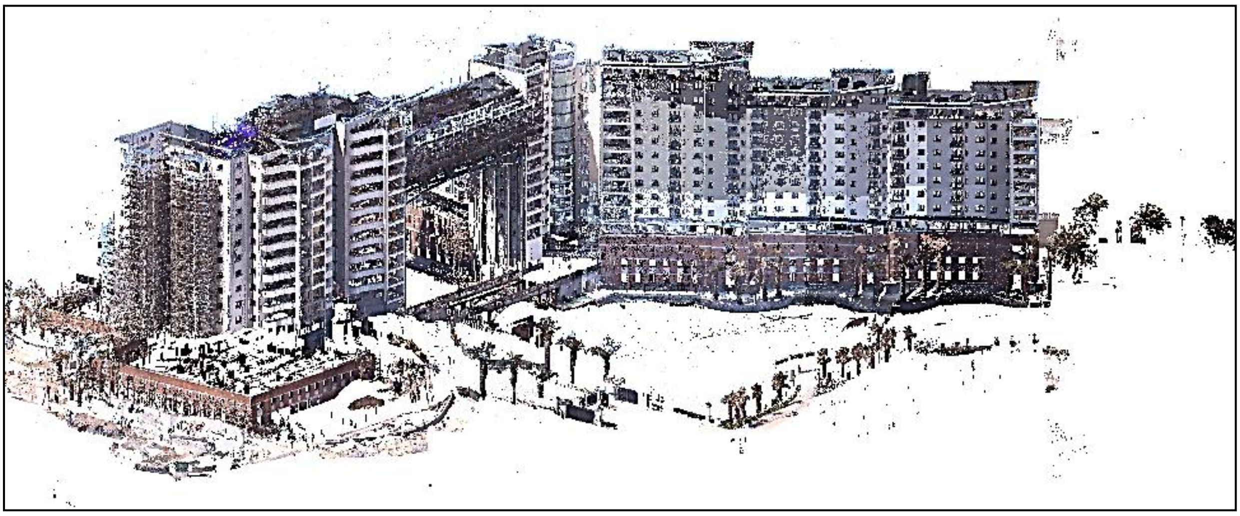

Figure 2.9: Point cloud scan of Knightsbridge, Century City, Cape Town (Hellig & Abrahamse, 2006)

2.6.4 Bar Code Scanners and Hand Held Collection Device

Bar code scanning enables resource allocations and deliveries of materials to be tracked on a construction site. Pizzagalli (2001:6) believes technological advances in computing and electronic transfer is an area that the construction industry has been slow to grasp. Grip (1991:7) stated that this technology has been extensively used in the manufacturing and retail industry since the 1980s. As the construction industry moves slowly but consistently towards a wider acceptance of computer and electronic technology, there is a huge potential for increased productivity, improved quality and reduced cost, to the benefit of all parties involved. Labour and equipment tracking could benefit from this application. Pizzagalli (2001:6) goes on to say that current methods of handling labour and equipment tracking require data to be handled many times, with a greater chance of error. Furthermore, Pizzagalli (2001:7) stated that the advantage of transferring cost data directly onto computer rather than sending it to a control office in paper form, allows better manipulation of data for more meaningful information for management. Pizzagalli (2001:7) believes that this system will save time, which will result in lower cost for contractor and owner by freeing up of time for the project Manager.

2.7 BUILDING PRODUCTION MANAGEMENT

The tools and techniques specific to project management require ground-breaking ways of application. Project managers need to improve on their specific qualities such as knowledge, performance and personal behaviour. Organisations and people that are affected by the project are referred to as stakeholders. It is important to identify the stakeholders and to understand the influence they have on a project. If negative stakeholders are not identified early they can delay a project. Furthermore it is important that negative issues be mitigated as soon as possible. Failure to do so can result in extended timelines and have cost implications.

Building construction in urban centres provides a host of unique characteristics that challenge a project management team. The unique nature of building sites in urban centres presents issues such as congestion, confined areas and restrictive conditions (Spillane et al., 2011:139). As stated in PMBOK (2008), projects are ‘temporary endeavours that produce a unique product, service or result and have a beginning and end’. Although projects are temporary, the duration of a project can vary from brief to lengthy. A project continues until it is finished or cannot be completed. According to Talukhaba and Taiwo (2009:34), construction projects present a variety of complex and varied scenarios.

A project management team or organisation is responsible for applying knowledge uniformly and determining what appropriate skills, tools, and techniques are required for any given project. Furthermore the PMI (2008) states that project management is the discipline of managing projects successfully and is widely regarded as the most efficient way of introducing change. Duncan (1996:27) explains the concept of project management as a number of interlinked processes which include project processes, process groups, process interactions and customising process interactions.

According to Duncan (1996:3), project management is a process that motivates people to plan and control activities. Project management is the organising and direction of action. Duncan (1996:3) goes on to say that project management evolved to plan and control modern industrial and commercial projects. Construction projects follow the same project management principles as in industrial and commercial projects but are different in that site conditions are exposed to the elements and therefore incur risk that is not present in the controlled environment of industrial and commercial projects. Awodele (2012:181) pointed out that risk is a permanent element in everyday decision-making that could affect the three conventional objectives of any construction project, being cost, time and quality. Risk emulates from the uncertainty associated with pursuing a particular course of action. Risk occurs when a decision is based on insufficient or inaccurate information. Managing risk is a forward-thinking act where for a particular process, an attempt is made to assess the downside or upside of actions or interactions. Risk management maximises the opportunity, that is increases the probability and impact of events favourable to the project.

Project management is made up of five processes: initiating, planning, executing, monitoring and closing (see Figure 2.10). These processes flow within specific knowledge areas (set out in Table 2.2). The relationship between the process groups and knowledge areas is linked and therefore any factors that affect one process will have consequences for the next. Every project has the potential for change and therefore requires the project management to be progressive and iterative throughout the life cycle of the project. This involves continuously updating and improving the project plan when new information is obtained. As the project evolves so the level of detail increases with added information.

	INITIATING	**PLANNING**	**EXECUTING**	**MONITORING CONTROLLING**	**CLOSING**
INTEGRATION	Develop Charter	Develop Project Management Plan	Direct and Manage Project Execution	Monitor and Control Project Work Perform Integrated Change Control	Close Project or Phase
SCOPE		Collect Requirements Define Scope Create WBS		Verify Scope Control Scope	
TIME		Define Activities Sequence Activities Estimate Activity Resources Estimate Activity Durations Develop Schedule		Control Schedule	
COST		Determine Budget Estimate Costs		Control Costs	
QUALITY		Plan Quality		Perform Quality Control	
HUMAN RESOURCE		Develop Human Resource Plan			
COMMUNICATIONS	Identify Stakeholders	Plan Communications		Report Performance	
RISK		Plan Risk Identify Risks Perform qualitative / quantitative Risk Analysis Plan Risk Responses		Monitor and Control Risks	
PROCUREMENT		Plan	Conduct	Administer	Close

Table 2.2: Process groups and Knowledge areas (Project Management Institute PMBOK, 2008)

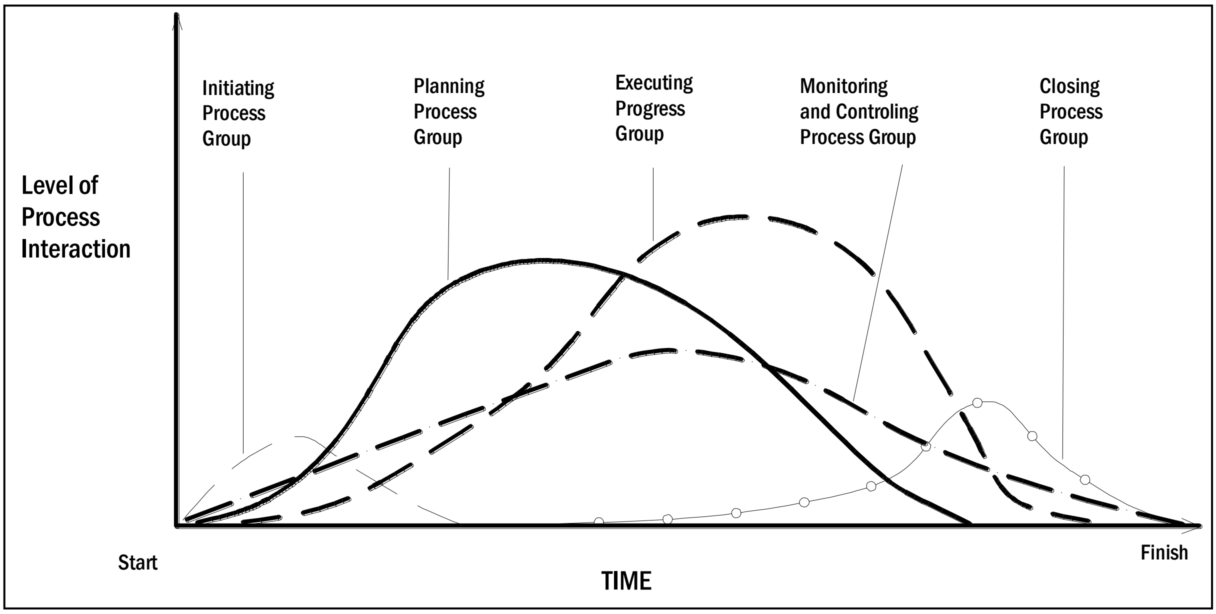

Figure 2.10: Process groups (Project Management Institute PMBOK, 2008)

2.8 CHAPTER SUMMARY

This chapter provides an integrated overview of existing trends and leading opinions concerning the concept of innovative practices for effective management of building production processes within urban centres. The purpose of this literature review was to establish the theoretical framework for the study, to indicate where the study fits into the broader debate and thus to justify the significance of this research project against the backdrop of previous research. This body of knowledge covers existing theories, models, concepts, definitions, and other findings.

Strategic management of building production processes include lean production methodology and supply chain management. Just-in-time management of materials is a component of lean methods and is a way of reducing time and cost without compromising quality. The use of technology and automated methods of construction provide a solution to project delivery and space management via remote sensing. Knowledge management and prefabrication are other important methods of improving building production processes. Building production challenges within urban centres include noise, vibration, dust and illumination. Space, machinery, storage of materials and labour productivity are factors identified as challenging on congested construction sites. Innovation in building production management is essentially considered. Linear and non-linear approaches to innovation are discussed, as well as innovation and culture. Two South African cities are compared and the character of their urban centres outlined. The potential of using innovative technology for improved building production is investigated. BIM, LAT, point cloud scanners, bar code scanners and hand held collection devices are mentioned. The basic principles of project management are outlined. The next chapter, chapter three, is to present the research methodology and design.

CHAPTER THREE

RESEARCH METHODOLOGY AND DESIGN

3.1 INTRODUCTION

The purpose of this chapter is to describe the study perspective by presenting the research methodology and design. Mouton (2008:56) pointed out that research methodology focuses on the research process and the kind of tools and procedures to be used. Mouton explained that research design focuses on the end product by determining the type of study to be done and what kind of result is aimed at. The research design focuses on defining how to adequately respond to the research question. This chapter begins with the classification of research philosophies and further justifies the research choice, research techniques, and research design.

3.2 RESEARCH PHILOSOPHIES

Scotland (2012:9) mentioned that research philosophy, or the research paradigm, is based upon its ontology, epistemology and methodology. Scotland explained that ontology is the nature of reality, and epistemology as the view on what constitutes acceptable knowledge. Methodology and methods is described as the model behind the research process. Wahyuni (2012:69) described ontology as the study of being, what constitutes reality and the perception a researcher has regarding reality and the actual way things work. Wahyuni concurs with Scotland and described epistemology as being concerned with the type and form of knowledge, and how knowledge can be produced, developed and transferred. Scotland referred to methodology as a strategic plan of action which supports the selection of a particular method.

Mouton (2008:138) affirmed research as ‘the process by which someone has identified a real-life problem and translated it into a research problem’. Cohen et al. (cited in Maree & van der Westhuizen, 2008:33) suggested that a research problem is when a scientist selects phenomena from real-life and makes these into objects of enquiry. Cohen et al. believe that in daily life there is a hunger for knowledge to assist in the management of daily difficulties. Scientific knowledge is generated to validate descriptions, models and theories of the world. In doing research there is a need to understand the epistemological and methodology of research approach (Mouton, 2001:141).

3.2.1 Ontology

Ontology questions the assumptions researchers make about the way the world works and their views about how the world works. Two aspects of ontology are the scientific method or objectivism, which portrays the position that objects exist in actuality outside of social concerns, and subjectivism which are the social occurrences created from perceptions and consequent actions that produce knowledge (Nieuwenhuis, 2008a:53).

3.2.2 Epistemology

Epistemology is concerned with things that constitute acceptable knowledge in a field of study. The main epistemological question revolves around the difference between studying the social world and studying the natural world. Thus a researcher studying the natural world would view the objects studied more objectively embracing what is known as the positivist position to the development of knowledge. Social scientist on the other hand places less authority in the data collected and more on the feelings and attitudes known as interpretivism (Maree & van der Westhuizen, 2008:31).

3.2.2.1 Positivism

Scotland (2012:10) described the ontological approach of positivism as one of realism. Realism is when objects are independent of the researcher. Thus discovery exists independently of the researcher (Pring, 2000:59). However Wahyuni (2012:71) believes that ontologically positivists share the common view that social reality is external and objective. The description of positivist epistemology is impartial, and absolute knowledge is discovered about an objective reality. Thus epistemologically positivists believe in the use of a scientific approach for developing numeric measures to acquire acceptable knowledge. Therefore positivists start with a hypothesis and then test the theory using statistics to present their research findings. However, positivists do use different philosophical assumptions. Jansen (2007:21) stated that positivism signifies that only objective, observable facts constitute the basis for science. Theological or metaphysical claims must yield to positivism, with positivism explained in terms of scientific laws. Creswell (in Wahyuni, 2012:71) like many others (Nieuwenhuis, 2008a:53), advocated that because positivists believe that knowledge is revealed or discovered through the scientific method, different researchers studying the same thing will arrive at a similar result if using a similar research process. Thus positivists believe that a universal generalisation exists, that can be used across environments. Newman (cited in Wahyuni, 2012:71) added that a positivist adopts a value-free measure of the facts independently of the intentions of people. Researches in the positivist paradigm prefer a deductive data analysis strategy (Jansen 2007:17).

3.2.2.2 Interpretivism

Wahyuni, (2012:71) explained that understanding is reality constructed by social actors and people's perception of that understanding. Scotland (2012:11) referred to the ontological position of interpretism as relativism, where relativism is the view that reality is subjective and differs from person to person. Scotland went on to say that interpretivist epistemology is subjectivism based on real world phenomena. Cohan et al. (2007:19) believes that interpretivism means that the social world can only be understood from the position of individuals who are part of it. Interpretivism aims to create an awareness of hidden social forces and structures. Creswell (2009:8) mentioned that interpretive methodology is focussed on understanding phenomena from an individual's perspective.

Nieuwenhuis (2008a:53) believes that precise, systematic and theoretical answers to complex human problems are not possible with the ontological position of interpretivism. An emphasis is put on the participant's frame of reference and how they see things from within. Interpretivism is based on the assumption that there is not one reality but many and interpretivist researchers therefore carryout their studies in natural context to reach the best possible understanding. According to Jansen (2007:37) researchers in the interpretive paradigm prefer inductive analysis.

3.3 SCIENTIFIC REASONING

According Heit and Rotello (2010:805) one of the most important open questions in scientific reasoning is the difference between inductive and deductive reasoning and how they are related. Knuaff et al., (2002:203) described reasoning as: 'a cognitive process that yields from given premises. It occurs whenever human beings make implicit information explicit'.

3.3.1 Inductive Reasoning

Lawson (2005:716) stipulated that inductive reasoning is when a scientist measures aspects of the phenomenon being studied. Thereafter the measurements are analysed and generalisations are made where generalisations are referred to as theories. Inductive reasoning presumes that a scientist can do a study simply by measuring, recording and describing what they encounter without preconceived expectations or hypothesis. Mouton (2008:117) described inductive reasoning as a generalisation that involves applying inferences from specific observations of a theoretical population.

3.3.2 Deductive Reasoning

Lawson (2005:716) specified that the first step in deductive reasoning is speculation, followed by the generation of a hypothesis. Subsequently the second step is to test the hypothesis by gathering observations or conducting experiments. Knuaff et al. (2002:203) refers to deductive reasoning as defining the truth of the principles to ensure the truth of the conclusion. Mouton (2001:117) like Knuaff et al. believes that deductive reasoning involves drawing conclusions from premises. The conclusions in a deduction argument are already contained explicitly or implicitly in the premise. Mouton listed the most common forms of deductive research as:

- deriving a hypothesis from theories and models: the deductive derivation of research hypothesis from a theory of model
- conceptual explanations — where the meaning of a concept is explained through the deductive derivation of what it is

3.4 RESEARCH METHODOLOGY

Mouton (2008:144) presents a choice of research designs and highlights the advantages and limitations of each design. Mouton's topology of design types includes four possibilities:

- Empirical verses non-empirical
- Using primary data verses analysis of secondary data
- The nature of the data: numerical versus textual data
- The degree of control: highly structured (laboratory) conditions verses natural field settings.

Empirical studies are observational or experimental rather than theoretical. Empirical studies provide answers to a particular question or hypothesis. Non-empirical studies involve conceptual, philosophical analyses, theory, and model building. Thus the empirical question asked in this study is: How effective are building production processes in urban environments? Alternatively stated: What strategies can be used to mitigate weakness in building production process in urban centres?

The methodology investigates how to find out about things and how knowledge is gained, such as principles that guide our research practice. Furthermore the methodology is specific and provides guidance on what tasks need to be done, as well as focussing on certain methods or tools in the research process. Thus the methodology documents issues such as: sample design and sampling methods; data collection methods and fieldwork practice;

measurement; data capturing and data editing; data analysis; and finally, shortcomings and sources of error.

3.5 RESEARCH STRATEGIES

Research is about creating new knowledge by solving problems through structures which follow an acceptable scientific methodology. Accordingly the difference between solving problems in our daily life and conclusions reached through scientific methods is that scientific methods consist of systematic observation, and the classification and interpretation of data. Thus there are practical steps that need to be taken during research in order to arrive at the answers to the research questions. These steps are referred to as methodology. At each step in research, methods, procedures and models must be chosen that best suit the objectives.

Ivankova et al. (2008:254) mentioned the three recognisable approaches to the procedure of conducting research as being a quantitative, a qualitative and a mixed method. Ivankova et al., emphasised further, that the choice of an approach depends on the researcher's moral alignment, being either positivist or interpretivist. It also depends on the type of knowledge wanted, which could be objective factual information, subjective personal experience, or both. When conducting surveys to obtain knowledge, either by interview or questionnaire, such surveys can be either open-ended or closed-ended, or both. Ivankova et al. (2008:254) explains that each approach has its own resolve, method of inquiry, approaches to the collection and analysing analysis of data, as well as and standards for determining quality. Punch (2009:4) describes the terms 'quantitative research' and 'qualitative research' as:

- the way of thinking about the social reality being studied, and the way of approaching it and conceptualising it
- the designs and methods used to represent the way of thinking, and to collect data
- the data themselves — numbers for quantitative research, words for qualitative research

3.5.1 Quantitative Approach

Ivankova et al. (2008:254) explained that the researcher using the quantitative approach relies on numerical data to analyse the relationship between variables. Typically a research study that employs the quantitative research approach is a survey study or an experiment. For qualitative research a researcher relies on a positivist approach to knowledge, which according to Tashakkori and Teddie (cited in Ivankova et al., 2008:255), implies the existence of one objective reality. Thus the quantitative research method is testing an identified problem by measuring with numbers. Accordingly this allows the researcher to test a theory through statistical analysis. Thus the aim of quantitative methods is to test the predictive generalisation of a theory by identifying significant differences in the hypothesis, as opposed to the qualitative method which enquires about the social or human aspects of a problem.

Advantages of qualitative research:

- The researcher can measure and analyse data that already has a constructed theory
- Research findings can be generalised if the sample is sufficient
- It is useful for collecting large populations
- Data collection and analysis can be fast
- Dependent and independent variables can be studied in detail
- It can be used to test a hypothesis using statistics

Disadvantages of qualitative research:

- The context of the research is ignored
- It does not discuss the meaning of objects or study objects in their natural setting
- Normally a large population needs to be studied to achieve accurate results

Although quantitative research is valuable, it is not always useful. Researchers must not become fixated into thinking about research problems from only one perspective. Qualitative studies explore phenomenon that are not easy to measure.

Studies which are usually quantitative in nature are surveys and experimental designs. Surveys are intended to provide a broad overview of a representative sample of a large population. Typical applications of the survey method is attitudinal surveys, tracer studies, public opinion polls, community-based surveys, organisational surveys and needs assessment surveys. Furthermore the experimental design includes laboratory and natural field studies. Laboratory studies aim to provide a casual study of a small number of cases under highly controlled conditions, typically in a laboratory. Thus the deduction is derived from the use of experimental and comparison groups, repeated measures over time and randomisation techniques. Therefore the application of this research method varies from fundamental/basic experiments as in natural and behavioural science to more applied clinical trials. Furthermore field experimental design aims to provide a broad overview of a representative sample of a large population. Additionally field experiments are conducted in natural settings rather than in artificial settings like a laboratory. The application of field experiments are social applied experiments that aim at tracking change over time such as baseline studies.

3.5.2 Qualitative Approach

Qualitative evaluation research is essentially about finding the narrative behind the numbers. Thus qualitative research design is used when something needs to be measured or a phenomenon needs to be explored where there is not a clear-cut way to measure it, or there is something that we want to understand, that is better explored through words in a personal narrative rather than through measurement. While there are some types of research design which fall neatly in either the quantitative or the qualitative category this is mostly not the case. Ivankova et al., (2008:259) differentiated between three categories of qualitative research, namely the empirical/analytical approach, where statistical analysis is used to measure what is observable for the purpose of predicting, explanation, and control, the interpretive approach, which explores purpose, motives, intentions, and truths through making complex phenomena clear and understandable and the critical approach, which exposes social contradictions and social injustice, and which seeks to enlighten.

Studies that are usually qualitative in nature include ethnographic research which aims to provide an in-depth account of a set or group of people in a community. This is to be entrenched in the worlds of the people being studied and produces insider perspectives of the people and their practices. Ethnographic case studies aim to provide an in-depth account of a small number of cases (less than 50). Ethnographic case studies focus mainly on social work. Participatory research is qualitative in nature that involves researching the subjects or participants of the research to discover the environment of research participants. Evaluation research describes and evaluates the performance of programs in their natural settings, focussing on the process of implementation rather than on quantifiable outcomes. Evaluation research is designed to answer the question of whether an intervention has been properly implemented. Typically this includes program monitoring and performance measure. Empowerment evaluation is the use of evaluation techniques, concepts and findings to foster development and independence. Furthermore this method of research is used in implementation evaluations rather than outcome evaluations. The comparative, cross cultural and cross nation studies focuses on similarities and differences between groups such as individual organisations, cultures countries, societies, institutions and even individuals.

Advantages of qualitative research:

- It is useful for initial studies that will inform further qualitative research
- This type of research does not have to be vigorously designed before it is initiated

- The researcher has the freedom to allow the study to evolve
- More detailed information is gathered using comprehensive, written descriptions, as well as visual information from photos
- The data has a social context; this is an advantage for the social sciences

Disadvantages of qualitative research:

- The researcher becomes very involved in the study and becomes subjective
- The researcher can become biased when interpreting data, resulting in skewed data
- This research method is very time-consuming

3.5.3 Mixed Method

Ivankova et al., (2008:259) suggested that although quantitative and qualitative research differ in how knowledge is acquired and how research questions are addressed; both methods be applied to the same research problem. A quantitative approach looks for the relationship between variables, while qualitative approach seeks an in-depth understanding of an individual's experience. Each of these approaches covers different and specific perspectives of the research problem. A mixed research approach has the benefit of allowing a more holistic investigation, using both quantitative and qualitative techniques within the same study. Ultimately the results from both quantitative and qualitative investigations are integrated at some stage during the research process, to produce a comprehensive result. The qualitative or the quantitative study could be dominant in the research, with the qualitative analysis building descriptions and themes of the central phenomenon, and the quantitative analysis describing trends and relationships. De Vos et al. (2011:395) suggested that the use of both the qualitative and the quantitative approach increases the reliability of observations. De Vos et al. (2011:300) mentioned that the triangulated approach provides the researcher with a way to thoroughly present the assumption in each stage of the quantitative and qualitative study. Furthermore the mixed research method allows for more divergent findings and includes all stakeholders, giving a voice to all, and helps ensure an equitable impact of the research. Both text and numeric information are collected to answer the research questions (Ivankova et al., 2008:253).

3.5.4 Other Research Methods

Other research designs include statistical modelling, computer simulation studies and the case study research method.

Statistical studies aim to develop accurate models or representations of the real world. Specification of a model constitutes the idea that was theorised about the process in the real world. Statistical techniques are used to generate expected values that are compared with actual data. Statistical research designs are typically used to model financial data or model trends in society (Mouton, 2008:163).

The difference between statistical analysis and a simulation model is that statistical analysis requires a statistical analysis program where a simulation model is normally run to produce an output.

The case study research method refers to the process in which a case is examined in detail and analysed in depth, using the research tools most appropriate to the enquiry. The case study research method is done developmentally over time and is highly contextual. Data collection and analytical methods can be qualitative or quantitative, depending on what best suits the research question and the type of case. In comparative case research, researchers compare two or more cases relevant to a particular research question.

3.6 RESEARCH TECHNIQUES

According to Maree and Pieterson (2008a:155) there are many different ways in which surveys are conducted and care must be taken to choose the most appropriate for the particular study. Maree and Pieterson (2008a:155) stipulated that survey designs should take into account the following:

- Sample issues such as sample size and the minimum response rate that is acceptable
- The type of questionnaire needed to address the specific survey, what type of data will be gathered by the questions and the statistical techniques that will be used to analyse the data
- Interview issues: these include adequate training of the interviewer. Care must be taken to ensure that inadequate and unsatisfactory responses are identified and eliminated
- The collection method used, could be via mail or e-mail or personal interview

3.6.1 Questionnaire

Maree and Pieterson (2008a:158) stressed that the most important part of the research process is the collection of data. Therefore the questionnaire will differ to suit the type of survey being done. Thus the researcher must correlate the type of data that needs to be generated and the statistical techniques used to analyse the data. Maree and Pieterson continued by saying that when designing a questionnaire the following require attention:

- The layout of the questionnaire
- The sequencing of the questions
- The wording of questions
- The response categories

Furthermore Maree and Pieterson (2008a:158) stated that the instructions in the questionnaire must be simple, clear and precise. It is imperative that the questionnaire appear to be user-friendly. Neat printing and spacing will help that respondents are not intimidated by the questionnaire. It is important that the question sequence suits all the respondent types expected to answer the questionnaire. It is normal to start with questions that are easy to answer.

Bell (cited in Maree & Pieterson, 2008a:158) mentioned two types of questions in a questionnaire: open-unstructured, and closed-structured questions. An open-unstructured question allows the respondent to write a word, phrase or comment regarding the question. Closed-structured are used for testing a hypothesis such as a proposed suggestion.

3.6.1.1 Closed-Structured Questions

Maree and Pieterson (2008b:161) mentioned that with closed-structured questions the respondent has to choose between options. Maree and Pieterson explained that analyses of closed-structured questions are generally easer to analyse than open-unstructured questions.

The advantage of closed-structured questions is that they are simple to answer, and coding and statistical analysis are simple. Also sensitive questions are more easily answered. The disadvantage of closed-structured questions is that the question might suggest an answer that the respondent might not have thought of. Furthermore, closed-structured questions often do not require much thought, making it easier to answer the questions on a random basis.

3.6.1.2 Open-Structured Questions

Hopkins (cited in Maree & Pieterson, 2008a:158) mentioned that open-ended questions allow respondents an opportunity to give an honest answer to the question and to provide detail. In doing this, the respondents thought process is revealed. In the case of complex questions respondents have an opportunity to adequately answer the questions. Thus the disadvantage of open-ended questions is that the different opinions of respondents may be very different making analysis challenging. Open-ended questioning requires more time for respondents to think carefully about their response.

3.6.2 Interview

Nieuwenhuis (2008b:87) identified interviews as two-way discussion in which the interviewer asks the participant questions so that the participant's beliefs, ideas, views, opinions and behaviour can be collected and understood. Interviews are predominant in qualitative research. Semi-structured interviews are commonly used to corroborate data emerging from other resources. Structured interviews are where questions are detailed and developed in advance.

3.7 RESEARCH DESIGN

Research design is a blueprint or strategy that guides the arrangement of the research. Thus research design focuses on the type of study being planned and what kind of result should be achieved. Research design considers the research problem or question and focuses on the logic of the research. Furthermore research design defines the kind of evidence that is required to address the research question adequately and therefore provides linear steps in the research process that specifies the way the research is executed. Thus research design is tailored to address different kinds of research questions (Mouton, 2008:56).

Braun (2015) formulated the following questions when considering research design:

- What is already known?
- What questions are to be answered?
- How should the data be collected?
- How will the study be conducted?

Braun explained that precise information about what is needed to fulfil the purpose of the research constitutes the research objective. Subsequently the delimitation of the research objective includes considering what the population is going to be and if the results will be generalised.

3.7.1 Choice of Research Design

The issue of building construction in congested urban centres has attracted studies over the years, and hinges upon the ability of the construction firm to be strategic. Among the authors who have studied construction in congested urban centres are: Hardie, M. Spillane, J. Ryedale, L. Von Melding, J. Konanahalli, S. Jaiyeoba, B. Tijani, L. Egbu, C. Isnin, Z. Ahmad, S. Yahya, Z. Wallace, and K. Cheung, W. There is a need for construction firms to be innovative and dynamic in a sense that they must constantly learn in their pursuit for progress. The construction industry internationally, and in South Africa, has been broadly criticised as being reluctant to incorporate innovative capabilities for the improvement of management practices. The various studies referred to above, constitute an established body of knowledge that formulates the research objective, questions and research methods employed for this study (see Table 3.1).

Research questions	**Objectives**	**Research methods employed**
What strategic building production processes are currently being employed in urban centres?	To investigate what strategic building production processes are currently being employed in urban centres.	Questionnaire/Interviews
How effective are building production processes in urban environments?	To identify problems and constraints in building production processes in urban centres.	Questionnaire/Interviews
What strategies can be used to mitigate weakness in current building production process in urban centres?	To identify the factors that help mitigate weakness in current building production processes.	Questionnaire/Interviews

Why are current construction firms reluctant to absorb both new management practices and new technologies to enhance building production processes in urban centres?	To establish the reasons for the reluctance of construction firms to absorb both new management practices and new technologies to enhance building production processes in urban centres.	Questionnaire/Interviews
How could building production processes in urban centres be managed effectively?	To propose effective management systems for building production in urban centres	Recommendations

Table 3.1: Research questions, objectives and research method

The scientific reasoning used in this study, to answer the research questions formulated, is the deductive approach. A deductive approach starts from a general level of focus, then through analyses of new data, the research questions are answered. Furthermore a mix of qualitative and quantitative methods is used with the main instrument of data collection being the survey method using a questionnaire. Quantitative research is used because of its potential to generalise large populations and its high measurement consistency. The quality and success of this research method is dependent on the accurate formulation of the questionnaire, interview effectiveness and the selection of an appropriate statistical technique to analyse the data.

The following pertain to the research design for this study:

- This study is classed as descriptive in that it describes, explains and interprets the status-quo of building production processes in Cape Town's urban centres and the trends that are evident in the use of innovative technology.
- It described why construction firms are reluctant to absorb both new management practices, and new technologies to enhance building production processes in urban centres.
- The research design sought professional opinion by means of surveys using a meta-theory paradigm of variable analysis.
- The selection of participants in this study used the non-probability sampling method.
- A structured questionnaire was designed for gathering data pertaining to the research questions.

- The data gathered was analysed using descriptive statistical techniques such as the mode, the median and the mean, while the spread of distribution was described using the range and the standard deviation.

This study was conducted over three distinct phases. The first phase involved an exploratory study, which employed qualitative data-gathering techniques to orientate the researcher with regard to the study, and to modify and debug the process, with the expected result being a smooth run for the main enquiry. The second phase entailed the data collection and analysis, employing quantitative data-gathering techniques to evaluate the empirical question of the current state of building production processes in urban centres and to establish what innovative practices is being employed to effectively manage building production processes within urban centres. The third phase entailed the interpretation and validation of data through interviews conducted.

3.7.2 Exploratory Study

The exploratory study was conducted to guide the researcher on two specific issues, namely: the conceptualisation of the problem, as well as assist the researcher in deciding on the suitability of the evaluation procedure. De Vos et al. (2011:236) explained that the exploratory study forms an integral part of the research process. An exploratory study is done beforehand to clearly define the problem. There are three aspects of the exploratory study that assisted the researcher in preparing for the main study:

- a study of the literature
- obtaining the experience of experts in the field
- testing the measuring instruments

A literature study enabled the researcher to situate this study with current knowledge. Literature was gathered both locally and internationally to discover what existing building production strategies are being used in urban centres, and how contemporary technology solutions have helped in this regard.

As far as engagement with experts in the field is concerned, the researcher conducted key-person interviews with a selected group of individuals, mainly to define the problem more accurately and to gain valuable evidence on the more technical and practical aspects of the research undertaking. Through the preliminary study, a sample was gathered from urban centres in Cape Town using structured interviews and a questionnaire to establish what enabling and inhibiting factors influence industry-level innovation. The sampling framework consisted of project managers, registered contractors, as well as consultants and private owners residing the greater Cape Town area.

These interviews brought perspectives not previously considered, to the fore, and were helpful in shaping the researchers personal views (De Vos et al., 2011:239). The interviews were mainly open-ended to explore participant perceptions towards urban construction (Nieuwenhuis, 2008b:87). Finally the questionnaire was assessed to see if it does in fact, adequately measure the status of building production processes, and to what degree construction firms are using innovative technology to mitigate challenges of construction in urban centres.

The questionnaire was subsequently redesigned and questions sequenced in a logical manner to prevent confusion. The instructions on the questionnaire were clear and provided the respondent with a simple way to indicate their choice. A reasonable sized font and uncluttered layout ensured that the format of the questionnaire was user-friendly. The time required to complete the questionnaire was no more than 20 minutes. An explanation of the sequence of the questions was provided at the start of the questionnaire so that respondents would not feel intimidated. The first section of the questionnaire comprised the biographical information, which was intended to put the respondent at ease before the main batches of questions were attempted. The next section dealt with the research questions. Questions were grouped together under their respective themes, as set out in the research objectives. The relevant and appropriate questions asked included:

- Management principles and practices, that is: planning, controlling, coordinating and others.
- Project management knowledge and techniques; these included areas such as risk management, knowledge management, cost management and time management.
- Projects constraints and objective activities: cost, time and quality
- The availability and utilisation of construction resources: materials, manpower and machinery

These questions are in the context of construction in urban centres. The research objective was divided into separate sections, with the respective research questions and sub-questions included in the questionnaire. This enabled the discussion of findings and reports to be logical.

The language used in the questionnaire was clear and free from use of slang or abbreviation. The questions were unambiguous and to-the-point, so that respondents knew exactly what was being asked. Only one question was asked at a time and questions did not prompt the respondent in any specific direction. The questions were simple and did not require specific knowledge beyond the capabilities of the respondents. The survey presented closed-structured questions where respondents had to indicate the responses to a given numeric scale. This allowed the researcher to determine the knowledge, attitude and perception of the respondent on a particular question.

3.7.3 Samples and Sampling

According to Punch (2009:50) all empirical research involves sampling. Sampling needs to fit in with the research logic and depends very much on what the study is trying to establish, and what the strategy is for doing that. Maree and Pieterson (2008b:172) described two major classes of sampling methods: probability methods, and non-probability methods. In probability sampling each element in the population has a known, non-zero probability of being selected. There should be no human or subjective interference in this process. The sampling methods for a small population include (see Figure 3.1):

- Unrestricted random sampling — homogenous population
- Systematic sampling —– homogenous population
- Stratified sampling — heterogeneous population
- Quota sampling — heterogeneous population
- Concentration sampling — heterogeneous population

The nature of the research problem will determine the most appropriate method to be used.

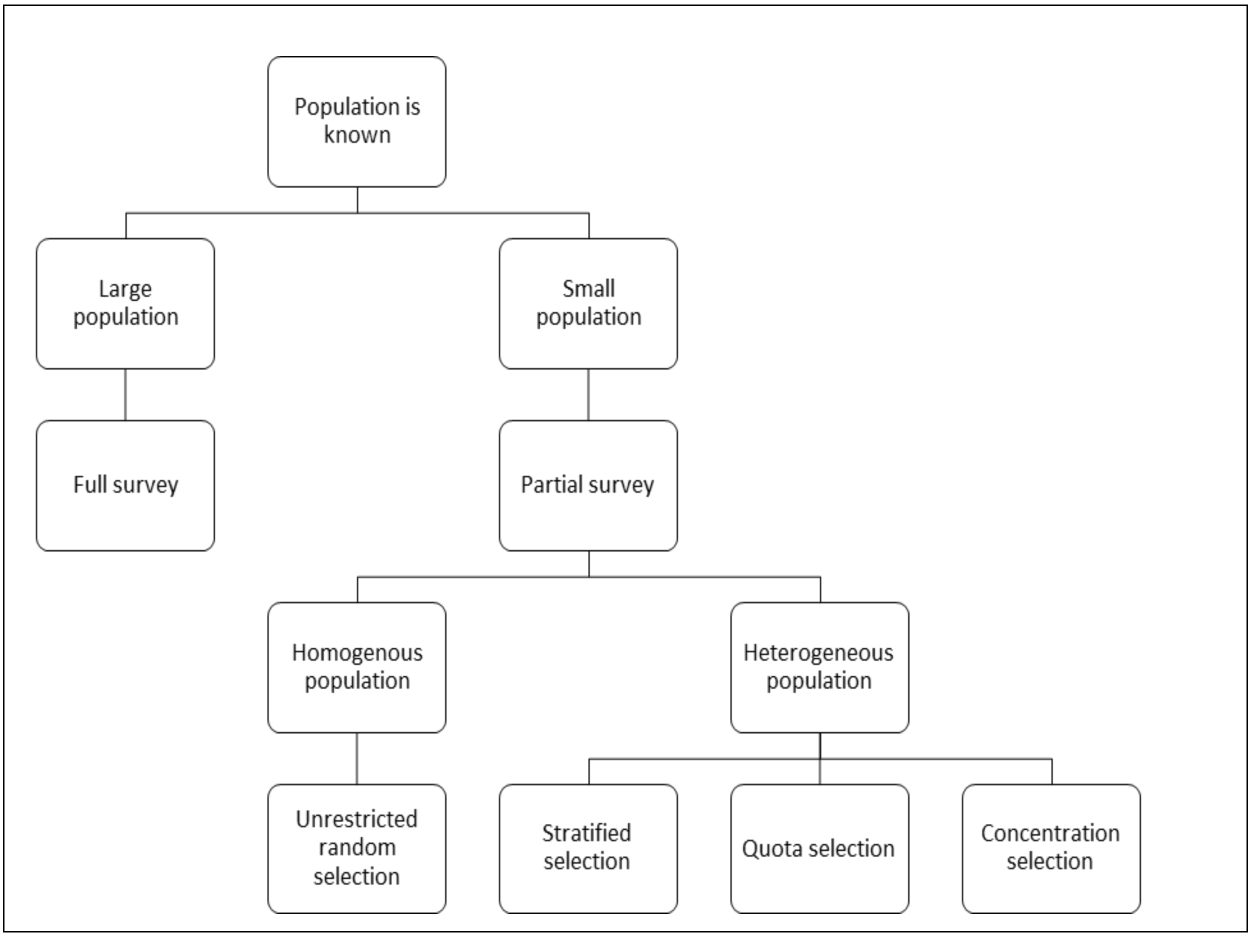

Figure 3.1: Population and selection (Braun, 2015)

The random selection of population elements is not used for non-probability sampling. Maree and Pieterson (2008b:176) stipulate that non-probability sampling may or may not represent the population well. Furthermore Maree and Pieterson (2008b:176) identified the following situations in which a researcher may consider using non-probability sampling:

- results are needed urgently because not much time is available
- the sample is for measuring the measuring instrument
- in the development stage of a survey preliminary studies have to be done
- not much money is available
- the survey population is hard to locate

Maree and Pieterson (2008b:178) stated that the size of a sample is very important and that if a sample is too small it will be invalid in the data analysis phase. In probability sampling, larger samples will better represent the population than smaller samples. Thus Maree and Pieterson (2008b:178) listed the following three factors which determine the sample size:

- type of statistical analysis of the data
- the required accuracy of results

- the population characteristics

3.7.4 Data Collection Methods and Achievement of the Research Objectives

Braun (2015) explained that the conventional form of data collection is through face-to-face interviews, written interviews and telephonic interviews. Other means of data collection include computer-aided telephone interviews, computer-aided personal interviews and online questionnaires (see Figure 3.2).

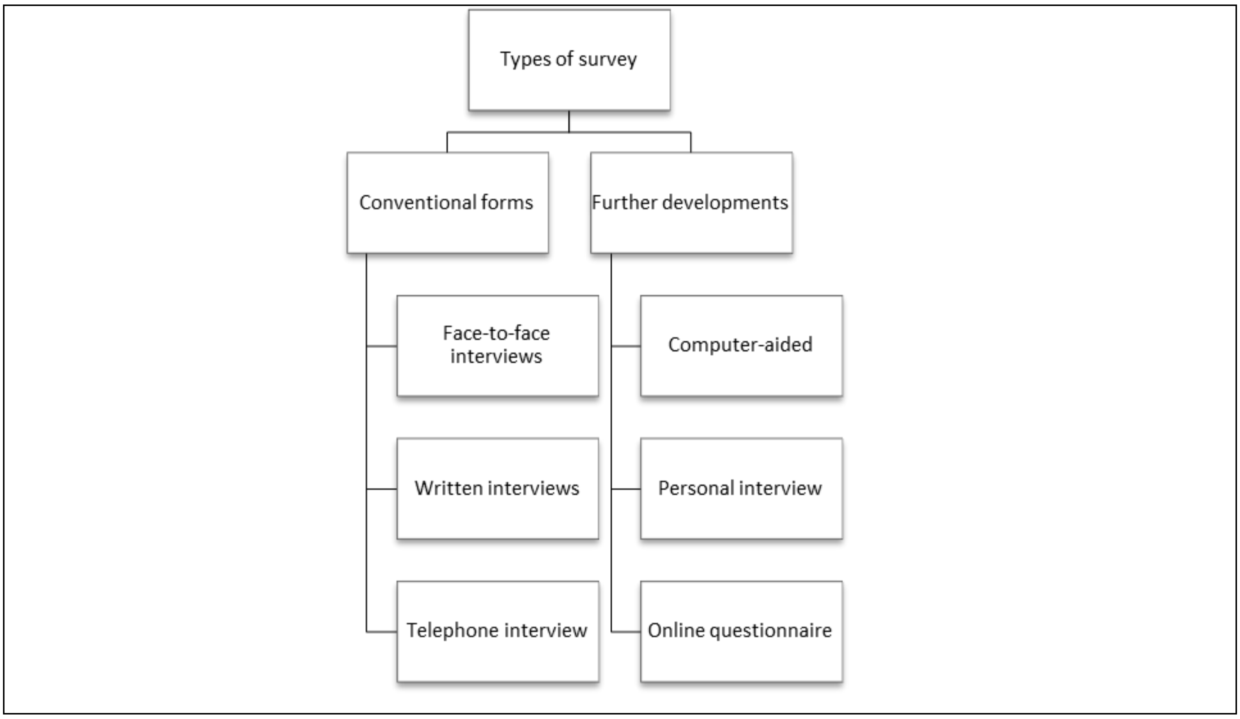

Figure 3.2: Types of survey (Braun 2015)

The main research objective of this study was subdivided into four separate objectives, each addressing a specific research question. The questionnaire was structured to accommodate each objective separately, requesting information by posing the appropriate research question.

The first objective investigates what strategic building production processes are currently being employed in urban centres. The exploratory study done during this study, and the literature reviewed, has exposed five building management methods that have been identified as strategic and innovative. Respondents were asked to indicate to what degree they felt these building management methods are used in building production processes in urban centres:

- Lean production methods — encompassing waste reduction, focus on the production planning and control process, continuous improvement, and co-operative relationships and a systems perspective

- The use of innovative technology — contemporary technology solutions
- Knowledge management — the preservation of valuable knowledge and capturing the creativity of individuals
- Just-in-time methods — the coordination of production planning, and sourcing and logistics (such as have just the right amount of inventory available to meet the demands of production processes)
- Prefabrication — manufacturing of sections of a building at an off-site location

The second research objective identifies problems and constraints in building production processes in urban centres. The first set of questions associated with this objective asks how effective these strategic building production methods are in addressing the nine major knowledge areas in the management of building projects in urban centres. The knowledge areas referred to are:

- Integration management
- Scope management
- Time management
- Cost management
- Quality management
- Human resource management
- Communication management
- Risk management
- Procurement management

The next set of questions enquired to what extent certain challenges pose a problem during construction in urban centres. The following challenges encountered in construction in urban centres, were identified from previous studies (Spillane et al., 2011; Egbu, 2012).

- Congested space on site
- Restricted access for delivery of materials
- Safe movement of materials around site
- Limited storage of materials on site
- Damage to material on site
- Locating material on site
- Overcrowding of personnel
- Coordination management issues
- Project program issues
- Increased personnel management

- Increased resource management
- Personnel in close proximity to machinery
- Difficulty in communicating on site
- Health and safety issues

The third research objective identifies the factors that help mitigate weakness in current building production processes in urban centres. The first set of questions in this objective associated to this research objective asks to what degree the following innovative technologies support each of the five building production processes in construction management (Initiating, Planning, Executing, Monitoring, and Closing):

- building information modelling (BIM)
- location awareness technology (LAT)
- point cloud scanners
- bar code scanners
- remote sensing – UAV/Drone
- wireless camera - Video Surveillance

The second question associated with this research objective asks to what extent these innovative technologies can mitigate the challenges identified during construction in urban centres.

The fourth research objective establishes the reasons why construction firms are reluctant to absorb both new management practices and new technologies that could enhance building production processes in urban centres. The following reasons were investigated:

- money/finance/cost
- logistical difficulties
- risk/comfort zone
- waiting for improvements in the technology/management methods
- lack of knowledge/experience with technology/management methods
- training of personnel
- affording experimental time
- sharing/exchange of information
- weak management

The last question of the questionnaire explores individual perspectives on current building production processes (management of cost, time and quality) in South Africa. Participants were asked to rate on a simple rating scale if they agreed or not with the following statements regarding the status of building production processes, specifically in urban centres:

- Current building production processes in South African are advanced and competitive.
- Current building production processes in South African are internationally aligned.
- Current building production processes in South Africa need to be modernised.
- There are strategies in place to mitigate weaknesses in the current building production processes in South Africa.
- Automation and technology is being used to improve building production workflows in South Africa.
- Knowledge management enhances competitiveness and contributes to improved building production processes.
- The construction industry in South Africa is reluctant to use innovative technologies

3.7.5 Data Analysis

The function of the survey instrument was to pose questions that provide answers to the research problem. The tool used to analyse this data was the descriptive statistical method. Analysis includes arranging the data into themes, patterns, trends and relationships (Mouton, 2008:108). Braun (2015) describes descriptive statistics as numerical and figural preparation of data. Descriptive statistics is the scientific discipline for the study of mass phenomena and is a collective word for a number of statistical methods (Pieterson & Maree, 2008a:183). These statistical tools are used to organise and summarise the data and provide an initial understanding of the data characteristics (see Figure 3.3).

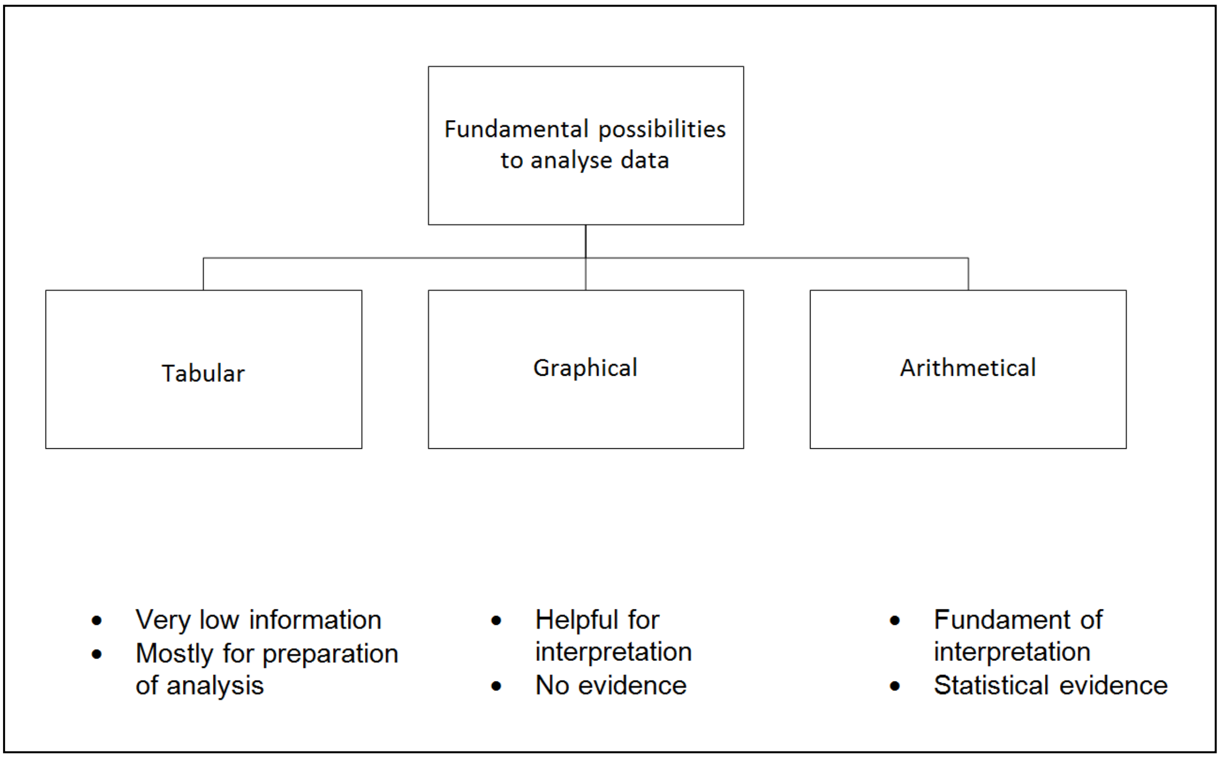

Figure 3.3: Fundamentals of data analysis (Braun, 2015)

3.7.5.1 Descriptive Statistics

Petersen and Maree (2008a:186) described descriptive statistics for quantitative data as numeric values representing the quantitative variables spread across a certain range of values. Petersen and Maree (2008a:186) explained that the distribution of values can be described in terms of location, spread and shape. Hence a pictorial representation of the data is displayed using various graphs.

The location of distribution is described by the most characteristic value that best describes the entire set of values. The mode is the value that occurs most frequently. However the mode does not accurately describe the centre of a distribution. The median represents the middle value distribution. The mean represents the most commonly used measure of location.

The spread of a distribution expresses the natural scattering of the measured values about some central tendency, while the range of distribution is the difference between the highest and lowest values. Additionally interquartile range is the range of the middle 50% of the data. Furthermore variance measures the amount of spread of the data values around the mean value, while the standard deviation is the square root of the variance. Hence the importance of calculating the variance and standard deviation is to compare one distribution with the other. Variance and standard deviation is also important in the area of statistical inference.

Standard deviation is important for standardisation to facilitate comparison scores from different groups (see Figure 3.4).

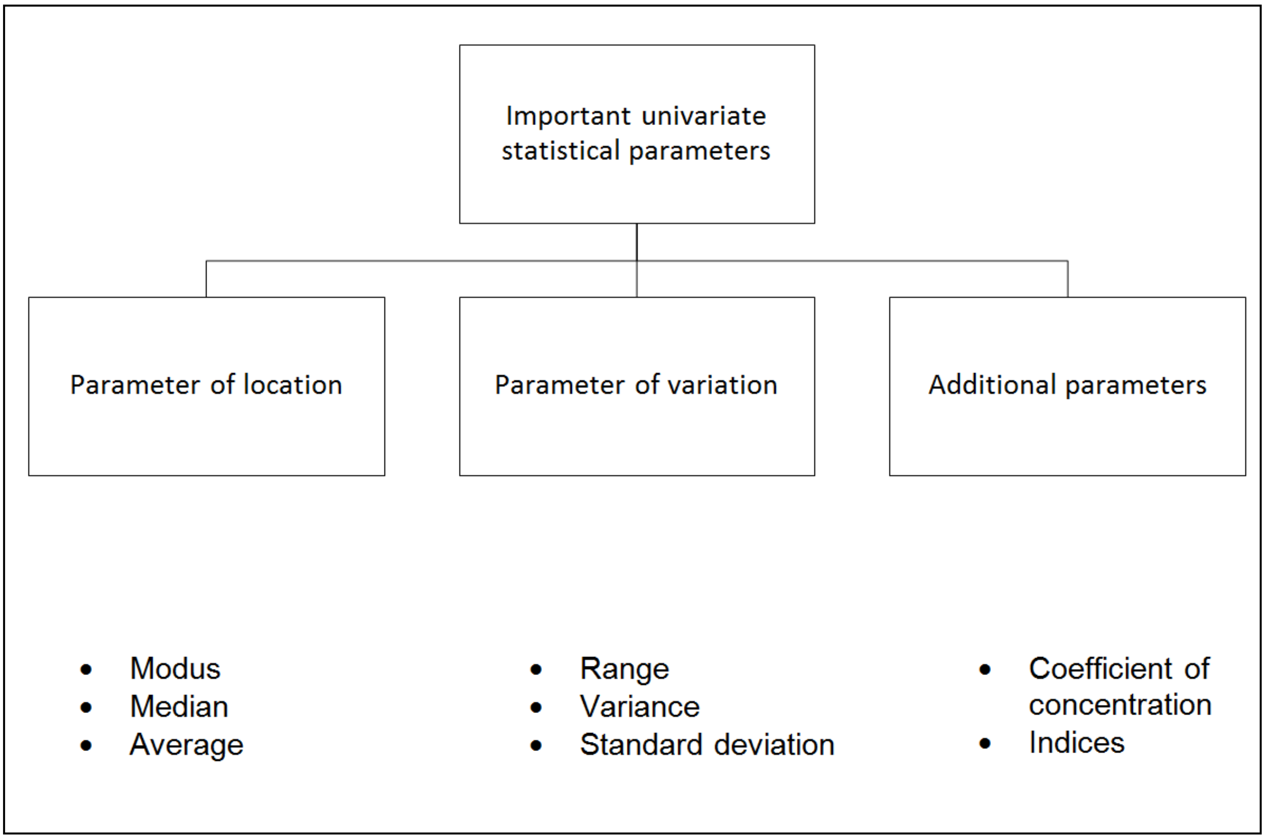

Figure 3.4: Univariate statistical parameters (Braun, 2015)

The shape of data is best described by figures. The numerical way of describing shape is with scenes and kurtosis. Skewness describes how far the distribution deviates from symmetry. Positive and negative skewness describes the tail of the data being either positively or negatively skewed. Furthermore kurtosis of distribution describes how much the distribution peeks or flattens.

3.7.5.2 Graphic Representation of Data

Graphic representation of data is useful to visually observe the form of data. Three popular figures are the histogram, the frequency polygon and the box and whisker plot. The histogram is useful in showing the distribution of data namely the shape, spread and location. The box and whisker plot displays the three quartiles of a distribution. This clearly shows how spread out the values are, whether the shape is symmetrical, or not, and the central location of the data.

3.7.5.3 Inferential Statistics

Inferential statistics (not used in this study) is used to generalise or draw conclusions about a population. Mouton (2008:118) explained that statistical inference relies heavily on probability theory. Probability theory is quantifying the likelihood or chance of occurrence of an event. If the outcome cannot be predicted it is said to be random or due to chance. A probability may be seen as the long-run relative frequency of an event occurring. Although the outcome is unpredictable, a regular pattern, governed by probability, will emerge after many repetitions. An important part of inferential statistics is estimation such as statistics are calculated from the sample data and those values are then used as estimates of the corresponding population parameters (Pieterson & Maree, 2008b:201).

3.7.5 Reliability and Validity

Pietersen and Maree (2008c:215) explained that reliability of the research instrument must be tested for correlation using the Cronbach's alpha coefficient. A result of zero shows low reliability and a result of one shows high reliability. To test the correlation of coefficient a questionnaire must be answered twice by the same respondent over an adequate time period. Maree and van de Westhuizen (2008:37) suggested that data verification displays reliability and validation that demonstrates responsibility in the way the research has been constructed. Maree and van de Westhuizen (2008:37) proposed that the researcher validates data collected, by having the instrument, being the questionnaire, reviewed by experts. Maxwell (cited in Maree & van de Westhuizen 2008:38) stated that validity is not an inherent property of a particular method, but pertains to the data, accounts, or conclusions reached by using that method in a particular context for a particular purpose.

3.8 Ethics

It is imperative that a researcher obtain the necessary ethical clearance from the ethics committee of their institution when dealing with human beings or animals in any empirical research. Proper and improper research must be established and the researcher must abide by the guidelines put out by the institution. Informed consent must be obtained before the researcher engages in questions. This consent is usually verbal, however during follow-up surveys the researcher must present the participant with a letter of consent which must be signed. The participant must be informed that they can withdraw at any time. The researcher must ensure that the participant is not subjected to any physical or physiological harm. Researches must strive to be honest, respectful and sympathetic. The participant must be informed of the confidentiality of the results and findings of the research and that they will remain anonymous (Maree, 2008:298).

3.9 SCOPE, LIMITATION AND DELIMITATION

The scope of the study is limited to the personnel managing construction in the City of Cape Town's urban centres. The focus of the study was on the central business district of the City of Cape Town: Architect (2), Contracts Manager (10), Engineer (28), Facilities Manager (2), Forman (7), Laboratory Technician (1), Project Manager (12), Consultant (6), Quantity Surveyor (33), Site Agent (7), Junior Contracts Manager (1), Junior Engineer (2), Junior Quantity Surveyor (16), Site Supervisor (1), Surveyor (7) and Technician (4), the total sample being 139.

Questionnaires were distributed to structural engineers, quantity surveyors and architects. Surveys conducted on construction sites were distributed with time constraints and were completed during lunch time. This is due to the workload on construction sites and reluctance of personnel to have their work interrupted.

This research investigates why construction managers are reluctant to bring in the necessary technology that could accelerate innovation and improve building project processes in urban centres. Non-probability sampling was used because the variety of construction personnel who may possibly participate could not be determined beforehand. Furthermore this study was specifically related to Cape Town's central business district. Cape Town's urban centre has a unique character with many low historic buildings and narrow streets. The selection of construction management methods, contemporary technology and factors that affect construction in urban centres was determined from the preliminary study conducted in Cape Town's central business district. While space was made on the questionnaire for respondents to suggest 'other' factors, the questionnaire was constructed to deal with the issues identified in the preliminary qualitative survey.

3.10 CHAPTER SUMMARY

This study uses both quantitative and qualitative research methods. Survey data collection is the method used for statistical analysis. This research is classed as descriptive in that it describes, explains and interprets the status-quo of building production processes in Cape Town's urban centre, and the knowledge, attitudes and perceptions of the respondents in the use of innovative technology. The study is deductive since the initial observation is based on general facts with a move to more specific details on improving innovation in building production processes in urban centres. An exploratory study was done to test and ascertain the appropriateness of the research instrument. The final questionnaire was designed using closed-ended questions. The samples are collected from the City of Cape Town; specifically construction firms operating within the urban centre. Face-to-face interviews were the main source of data gathering during the research findings validation. However, both telephonic and email methods were also used. The quantitative data was analysed using statistics to identify the most characteristic value that best describes the entire set of values. The location and distribution of results are described using the mode, median and mean measures, while the spread of distributions are described using range and standard deviation.

CHAPTER FOUR

DATA COLLECTION ANALYSIS AND DISCUSSION OF FINDINGS

4.1 INTRODUCTION

This chapter presents the data collected from the questionnaire survey conducted with building construction professionals. The purpose of the survey was to systematically collect primary data in the field in order to obtain information about the attitudes, values, habits, ideas, characteristics, feeling, opinions, perceptions, plans and beliefs of the selected population as affirmed by Maree and Petersen (2012:155).

4.2 PRELIMINARY STUDY

This preliminary qualitative study was based on a non-probability sampling. Participants were selected on expertise in construction management and the involvement of innovative technology and management experience. The sample was selected explicitly for the purpose of obtaining the robust possible source of information to assist with the compilation of the main quantitative research questionnaire. The sample size consisted of ten (10) participants. Respondents were asked predetermined questions in a semi-structured interview.

4.2.1 Description of the Participants

The participants were all professional practitioners who have been involved in construction management for at least ten years. Participants selected spend at least one day a week on a construction site and have experience in using innovative technology for construction site management. The participants included civil engineers (2), engineering surveyors (5), a project manager (1), a contracts manager (1) and a quantity surveyor (1). The age of the participants ranged from thirty five to sixty years. All participants have a degree on respective disciplines of practice.

4.2.2 Qualitative Data Analysis

The preliminary study consisted of six, semi-structured questions. The theme of the questions was ‘innovative methods for improving building production management’. This qualitative investigation interviews respondents to obtain information on: strategic building production processes currently being employed in Cape Town’s central business district, the constraints on current building production processes in urban environments, the strategies that can be used to mitigate weakness in current building production process in urban centres, and the reason that warrant construction firms being reluctant to adopt both new management practices and technologies that could enhance building production processes in urban centres. This qualitative data was analysed using the narrative method. Sequences, chronology and processes in the data were tracked to reveal the findings from the discussion. Narrative strings such as commonalities, major emerging themes in a past, and future context were identified. Coding was used in the analysis, to divide the text into meaningful segments and themes.

During the interviews respondents were asked about the latest remote sensing technologies used to provide real-time access to the location of materials, equipment and workers on a congested construction site. The following questions were posed:

- The confined characteristic of construction sites in urban centres makes location awareness critical. What do you think of this statement?
- Can location awareness technologies improve manual processes and support important decision-making tasks in the field?
- Do you think location awareness technologies and geospatial data is useful for construction management on confined sites?
- Empirical evidence shows that the use of automation and integration technologies improve construction productivity and exhibit tight integration of data, and provide a workflow solution that improves production. Yun-Yi Su (2010:1) suggested that innovation using enhanced location awareness technologies to improve building processes and to support important decision-making tasks in the field is important. What do you think of this statement?
- Talukhaba and Taiwo (2009:33) define knowledge management as the exploitation and development of knowledge assets within an organisation. Kale and Karaman (2012:336) define knowledge management as the ‘creation and management of an environment that encourages knowledge to be created, shared, learned and organised for the benefit of the firm’. Do you think knowledge management can be beneficial for improving building production in urban centres?
- Isikdag et al. (2008) refer to BIM as a major innovation in technology that can assist with problems related to interoperability and information integration. Do you think innovative technology can make a difference to building practices in urban centres?

The following conversations were recorded:

Reflective notes	Comments during discussion	Codes
Note concerns In the use of technology	*…location awareness technology has the ability to identify your location using GPS and Wi-Fi technology. It can be used with many devises such cell phones. Questions to be asked is how reliable are they, what are the costs, will it provide a competitive edge, how do you get end-user bye in - is it a reliable product?…(I1)*	LAT (TECH) [COST] 'EXEC' #COORD
Supports the use of technology Note the concern for job loss	*…I agree with this. In South Africa there can be huge improvement on how technology can be used to improve building production processes. With the use of location awareness technology fully interactive BIM can be introduced on site. Site management systems will allow the flow of 3D spatial, financial and material information to be seamless between the field and office. I believe the uptake of these technologies is slow in South Africa due to the possibility of technology causing job loss…(I2)*	BIM LAT (TECH) [HR] 'EXEC' 'MONITOR' #COORD
Criticises commitment of engineers to technology	*…engineers have not been trained to use such technology. Engineers still use manual methods such as pen and paper. The big issue is the client has no money to pay for this technology…(I3)*	[COST] [RISK]
Supports technology – believes it is practical on construction sites	*…universities are currently promoting the use of technology in construction management. A technology such as BIM is useful in identifying 3D space. Laser scanners are ideal for measuring as built (as is) after construction. Point cloud is the result and can easily be fed into software programs to create a BIM model. BIM is fantastic in preventing waste – time delays and futuristic monitoring of labour…(I4)*	BIM LASER S LAT (LEAN) [SCOPE] 'CLOSING' #PROG
Believes that technology will	*…aerial photography can be used to monitor progress on site. Weakly surveys can be done quickly and cheaply.*	RS LASER S (TECH)

save time Believes construction in urban centres has space challenges	*<u>Laser scanning</u> to create 3D models is another remote method of doing this…(I5)* *…yes on congested sites space has to be managed carefully. It becomes more important to know <u>where</u> materials are, where the construction <u>program is lagging</u> and <u>how many</u> subcontractors can be accommodated at one location…(I6)*	[QUALITY] [TIME] [COST] 'MONITOR' #RES LAT (LEAN) [TIME] 'EXEC' #LOC
Concern for the environment – believes technology encourages multidisciplinary Interaction Technology can help change our behaviour as construction managers Smart cities/smart construction Concerned about stakeholders	*…<u>CCTV</u> cameras are useful for reporting where the object is and what the conditions are like around it. <u>Location awareness</u> technology is now allowing us to monitor almost anything. When building rubble is discarded I would like to know <u>where it goes</u>. Sensors and <u>microelectronics</u> are getting smaller and cheaper which is making objects smarter. What does it mean if we know where everything is? Location awareness technology is a <u>low energy device</u> that can live up to one year on a single charge for a long time and tell you in real-time where things are – if you attach it to building rubble <u>we learn</u> where our construction garbage really goes…(I7)* *…<u>location awareness technology</u> allows you to study any complex system. So what <u>awareness</u> comes from this? – It will make us <u>rethink</u> our actions next time – the capacity for behavioural change is one aspect that can be incorporated with this technology another is awareness. Location awareness technology is human curiosity into the material world. We can extend our vision and our censors and make it part of the environment. Location awareness technology ensures that we know where it is and what it is. Connecting all these objects together is <u>connecting people together</u> i.e. construction managers are being connected to computer scientists, utility people are connected to electronic engineers – there is an amazing coming together of disciplines around this new connectivity – it is making*	CCTV LAT (TECH) [QUALITY] 'MONITOR' #MAT LAT (KM) [SCOPE] 'MONITOR' #PROG

	construction sites smarter – there is now a new opportunity to gather data for the public good…(I8)	
Combining building processes – initiating /planning/ design	*…model-based BIM allows communication with each other for project coordination. BIM can be used to measure 'as-built' or green/brown field site. Surface models can be incorporated into design using BIM…(I9)*	BIM (KM) (INT) [COMM] 'PLAN' #COMM
geospatial concerns – link things together spatially	*…Unified coordinate system all geo-referenced. Projects are created faster. Scanners can be used in as-built and to capture concrete structures. BIM is effective in redesign – adjust the model…(I10)*	LASER S (TECH) (LEAN) [TIME] 'MONITOR' 'PLAN' #COMM
building models are useful from initiation / design	*…BIM is ideal for structural engineers – robot structure analysis - transmit wind, lateral forces, decide how large horizontal beams must be designed and ultimately columns and raking members…(I11)*	BIM (KM) (LEAN) [INT] 'INIT' 'PLAN' #COMM
Additional site information available at no extra cost using technology	*…design for steelwork and concrete – no revisiting the site to infill data that has been missed. Laser scanning gives a comprehensive survey – in renovations existing beams are automatically surveyed. Positioning of foundations can be planned so that traffic can be accommodated…(I12)*	LASER S (KM) (LEAN) [INT] 'INIT' 'PLAN' #COMM
Smart phones – supports open source software (aps)	*…bar code scanning using red laser technology – you can download a bar code scanning application for a cell phone free from the Internet.. Using the camera you scan the barcode and the Internet will find the information concerning the product. You can use a web cam – this is free – you scan in your bar code. You can get a free bar code generator from the Internet. – you can also create a barcode in excel…(I13)*	LAT BAR CCTV (TECH) [COMM] 'MONIT' #COMM
Note the use of geospatial technology to manage	*…material tracking system – you can check where items are if the construction supervisors cannot find it – where has it gone? – maybe another site. What do you do? Buy*	LAT BAR

location of materials Supply and demand of materials Note the need to reduce waste – concerned about space on construction sites in urban centres	*another one. If a critical beam is needed now and nobody knows where it is or when it was removed it could be very costly. This will also affect crane* <u>*time*</u> *(crane waiting). You might have to reorder or refabricate. Material* <u>*tracking*</u> *technology can* <u>*find anything*</u> *in the inventory anytime from anywhere in the world within five seconds – all inventory items can be accessed over the* <u>*Internet*</u> *– a* <u>*barcode*</u> *is attached to the item or packaging, when the item is placed on site the GPS* <u>*coordinates*</u> *are recorded. When the item is moved or installed the label is scanned again and its status updated. You can get the* <u>*real-time*</u> *status on your materials, machines and tools – when an item is scanned the time is recorded, its exact* <u>*location*</u> *– when an item is on the move it can be tracked so that you know when it will arrive or where it is – so you know when an item is on site. When the item is installed the scan code records this and releases it from the inventory…(I14)* *…materials* <u>*management*</u> *- develops and manages sources of supply.* <u>*Procurement*</u> *– if materials are closely monitored it might be that storage of the material is not necessary and therefore no need for a store i.e. just in time delivery.* <u>*Lean management*</u> *depends on knowing the rate at which materials are arriving and the rate at which the materials are being used, this is always different and should be carefully* <u>*monitored*</u>*. It is necessary to keep a stock of items because the delay between procurement and arriving on site has to be managed i.e. the rate at which you receive material from the market is not the same as the rate at which the material is being used.* <u>*Location awareness technology*</u> *and* <u>*bar code scanning*</u> *is useful for keeping an inventory of stock of items to meet the future demands. A decision needs to be taken on when to order materials – let's use for example nuts and bolts. We use a certain amount in one week – two methods of procurement can be used – to purchase every week (irrespective of the*	(TECH) [RISK] [PROC] 'EXEC' 'MONIT' #COMM LAT BAR (JUST) (LEAN) [PROC] [COST] 'EXEC' 'MONIT' #DAM #LOC #RES #MAT #ACC

Note the concern of vehicle access to site in urban centres	*quantity there) or to purchase when the <u>supply</u> is low. The monitoring of stock is very important in any industry. We need to <u>optimise</u> supply chain management. The bullwhip effect is when demand information is distorted as it moves away from the end-use customer therefore high safety stock is stored to compensate – in an urban centre it might be necessary to consider <u>delays in the transporting</u> of material. Transport delays might mean <u>keeping stock</u> of materials on site – I asked a mechanical Foreman once why he had so much duct tape on site – he replied he might need it and he wanted control of it. The pallet holding the tape was moved three times before it was used…(I15)*	
Technology of lean management go hand in hand	*…<u>lean projects</u> are very organised – lower cost, better schedules, and better <u>quality</u>. A lean team is developed by doing things differently (innovation) – the level of waste must be managed – true value verses non-value – to produce the right product at the right time. There is a focus on <u>value of the team</u> over self-interest. Value is what the customer is willing to pay for and non-value is the waste. Waste could be work that needs to be redone or redesigned. This is a <u>waste of time</u> and materials. <u>BIM</u> is a tool that can manage unclear or latent information…(I15)*	BIM (LEAN) (JUST) [COST] [TIME] [PROC] #CON #DAM
Note the concerns	*…<u>prefabricated</u> material brought on site when needed. The disadvantage of modular construction is <u>overdesign and unnecessary transportation.</u> Over-processing leads to waste, this could be due to a lack of information. <u>BIM</u> is a solution to a lack of communication and mistrust… (I16)*	BIM (PREFAB) [TIME] [QUAL] 'INIT' 'PLAN' 'EXEC' #HEALTH #MACHIN
Note the concern for efficiency – also health and safety	*…excessive motion (energy) of <u>construction workers</u> on site is wasteful. This can contribute to <u>health and safety</u> issues. Labour <u>movement</u> on site must be constructive and work related. <u>Location awareness technology</u> and <u>CCTV cameras</u> can be used to monitor and make sense of unnecessary movement – this unnecessary movement*	

Note the importance shown for human capital	*might be looking for tools/materials that are missing. Bar Code scanners can help solve this problem on site. Labour might need to ask their managers questions and therefore move around looking for them. Communication becomes important on site especially on congested sites in urban centres. Personnel not on site can create unnecessary delays. Scanning in and out is essential. Transporting material from one place to another is waste – multiple moves of stockpiles or clearing materials out of path for machinery is a result of a poor site layout. Early deliveries also add to congestion. Just-in-time delivery must be carefully managed. If not, this could lead to contractors waiting for materials and not being able to start – being idle. This has a knock-on effect on other contractors. Waiting for design details is another type of delay. BIM can assist in this. Unused human capital is another waste. Knowledge management is important for utilising people's knowledge and taking it forward to the next project. Knowledge management reduces waste and increases the value in building production processes – low morale and lack of collaboration can have negative consequence to the cost of a project. People need to be included in design and problem solving – learning must be encouraged…(I17)*	CCTV BAR LAT (LEAN) (JUST) (TECH) [TIME] [COST] [INT] [HR] 'EXEC' 'MONIT' #PER #COMM #HEALTH #OVER
Support for controlled environment off site	*…modular construction and prefabrication changes the trends in which we build. Green BIM saves time and money using prefabrication. Using prefabrication modularisation fills the skilled labour gaps – less disruption for construction in urban centres. Significant competitive advantage, higher quality of buildings and just in time delivery of materials – improved site safety - BIM allows design to identify opportunities for prefabrication of parts – even before they break ground. Building does not have to be done ad hock on site but can be pre-designed using BIM – repetitive parts of the building can be prefabricated efficiently…(I18)*	BIM (PREFAB) [PROC] [HR] [QUAL] [COST] [TIME] 'INIT' 'PLAN' 'EXEC' #CON #STORAGE #RES #HEALTH

Table 4.1: Interview data

4.2.3 Results of Qualitative Preliminary Study

During this survey data emerged that provided revealing insights of new knowledge. The frequency of coded data in Table 4.2 shows a consistency of phrases in the text that verifies the authenticity of the results. The diverse sources of data resulted in comparable responses imparting confidence in the data. The data gathered are only in the context of the selected participants and therefore cannot be significantly generalised to a broader audience. The results were used to design the main quantitative survey questionnaire. The frequency of findings was calculated by dividing the number of times the coded topics appeared in the text of the eighteen conversations.

$$F(\%) = \sum Code \,/ \sum Discussions$$

Description	Code	Frequency (%)	Rank
Building Management Methods			
Lean construction methods	(LEAN)	44	1
Use of innovative technology	(TECH)	44	1
Knowledge management	(KM)	22	2
Just-in-time methods	(JUST)	17	3
Prefabrication	(PREFAB)	11	4
Knowledge Areas in Project Management			
Time management	[TIME]	49	1
Cost management	[COST]	39	2
Quality management	[QUAL]	22	3
Procurement management	[PROC]	22	3
Human resource management	[HR]	17	4
Communication management	[COMM]	11	5
Risk management	[RISK]	11	5
Scope management	[SCOPE]	11	5
Integrated management	[INT]	1	6
Management Challenges in Urban Centres			
Difficulty communicating on site	#COMM	39	1
Restricted access for delivery of materials	#ACC	17	2
Increased resource management	#RES	17	2
Health and safety issues	#HEALTH	17	2
Congested space on site	#CON	11	3
Safe movement of materials around site	#MAT	11	3
Damage to material on site	#DAM	11	3
Locating material on site	#LOC	11	3

Management Challenges in Urban Centres			
Coordination management issues	#COORD	11	3
Project program issues	#PROG	11	3
Limited storage of materials on site	#STORAGE	1	4
Overcrowding of personnel	#OVER	1	4
Increased personnel management	#PER	1	4
Personnel in close proximity to machinery	#MACHIN	1	4
Innovative Technologies			
Location awareness technology	LAT	56	1
Building Information Modelling	BIM	43	2
Bar Code Scanners	BAR	22	3
Point Cloud Scanners	LASER S	18	4
Closed-circuit television (CCTV) cameras	CCTV	17	5
Remote imagery / UAV/drone	RS	1	6
Project Management Processes			
Monitoring	'MONIT'	50	1
Executing	'EXEC'	44	2
Planning	'PLAN'	33	3
Initiating	'INIT'	22	4
Closing	'CLOSE'	1	5

Table 4.2: Summary of preliminary qualitative study

These results in Table 4.2 reflect the participant's perception on building production processes in urban centres. Attitudes, understanding, knowledge and feelings of the respondents view were obtained. This information was used to inform the design of the research questionnaire.

During the discussions, it was revealed that the most paramount building construction management methods currently being used in Cape Town's urban centres is lean construction, innovative technology, just-in-time delivery of materials and prefabrication. When discussing the nine knowledge areas in project management, time, cost, quality and procurement management were consistently mentioned, while human resources, communication, risk, scope and integration management were seldom mentioned.

The unusual conditions experienced on construction sites in urban centres were discussed. Communicating on site was believed to be an issue and was widely discussed, while restricted access for delivery of materials was a factor that was commonly associated with construction sites in urban centres. Increased resource management and health and safety issues were frequently mentioned. The consequence of congested space on site in locating materials, the safe movement of materials and the damage to materials was raised. Coordination management and project program issues were identified, while storage space, overcrowding of personnel leading to increased management was mentioned. Personnel in close proximity to machinery was revealed as an issue, but was not widely discussed.

The use of contemporary and innovative technology to assist in building construction management in urban centres was discussed. The emerging use of LAT was widely discussed and the use of BIM was repeatedly referred to. Bar code scanners, point cloud scanners and CCTV were mentioned as being useful. UAVs were revealed as the most contemporary technology, but not much was known about the use in construction.

Among the five processes in project management, the monitoring and execution stages of a project were most significant. Planning and initiating were referred to specifically with regard to BIM technology, while the closing stage was only mentioned on one occasion.

4.3 QUANTITATIVE QUESTIONNAIRE SURVEY

4.3.1 Sampling Method

The population of this research consists of all building construction management personnel that are involved in managing building projects in the City of Cape Town's urban centres. The range of participants include foreman, junior and senior managers, architects, quantity surveyors, site-engineers and contract managers. It is almost impossible to randomly sample the entire population of building construction management personnel working in the City of Cape Town's urban centres; therefore the non-probability sampling method was used. Furthermore, this method was used to accommodate the time and money constraints of this study but not jeopardised robust findings. The disadvantage of using the non-probability sampling method is that, it does not give all the individuals in the population an equal chance of being selected for the study, however it is not feasible, practical or theoretically practical to do random sampling in this situation.

4.3.2 Data Collection

The initial qualitative pilot study was used to collect data, based on an interpretive philosophy that aimed at establishing how the participants perceive building production processes in urban centres. This was done through individual, face-to-face interviews to collect information about their attitudes, understanding, knowledge and feelings, in an attempt to approximate their view of the situation. The analysis of the data informed the design of the main questionnaire.

The reliability of the main questionnaire was tested using the test-retest method. This method involves administering the questionnaire to the same subjects on two or more occasions. The first set of scores is compared with the second set, by calculating a correlation coefficient. Furthermore the validity of the questionnaire was confirmed through the scrutiny of experts who ensured a high degree of face validity. Questionnaires were then personally delivered to the potential respondents and collected once completed. The distribution and collection of questionnaires was facilitated by selected practitioners that helped to distribute and collect the responses. The snowball sampling method was used to gather more information about other potential participants in the survey. This method assisted in expanding the sample size. Convenience sampling was also employed by visiting construction sites in the City of Cape Town's urban centres to obtain interviews. This method provided a good spread of construction managers on site and proved to be quick and cheap. Questionnaires were filled in manually using pen and paper, as well as electronically using an iPad tablet.

4.3.3 Reliability of Research Instrument

The calculation of Cronbach's alpha coefficient was used to estimate the internal consistency associated with the scores as derived from the scale or composite scores. The determination of reliability is important as it is impossible to have validity associated with the scores of the scales in the absence of reliability. It is important to do this type of analysis before doing any other type of analysis on the data. Cronbach's alpha helps to determine if it is justifiable to interpret scores that have been aggregated together. The value of Cronbach's alpha coefficient for each section of the questionnaire is indicated in the table below. The value should be close to 1. Cronbach's alpha shows that Section 2 of the questionnaire with 10 items, has a coefficient value of 82% of the variability of a composite score. This percentage (82%) of the variance in this composite score is therefore considered a true score variance or the internally-consistent reliable variance. The table below indicates that Section 3 has an internally-consistent reliable variance of 90%, for Section 4 it is 96% and for Section 5 it is 82%. All the questions in the questionnaire combined gave an internally-consistent reliable variance of 94%. The criterion for identifying an estimate of acceptability is a score of more than 70%, so according to Cronbach's alpha coefficient values the questionnaire was found to be satisfactory in terms of the reliability of the test (Pietersen and Maree, 2008c:216).

Question number	Headings	Number of items	Cronbach's alpha coefficient values
Section 2	Strategic management methods used in urban centres	10	0.82
Section 3	Problems and constraints in building production processes in urban centres	37	0.90
Section 4	The factors that help alleviate weakness in current building production processes	30	0.96
Section 5	Why construction firms are reluctant to invest in innovative building production processes	9	0.82
Sum	All questions combined	86	0.94

Table 4.3: Reliability of Research Instrument

4.3.4 Biographical Information of Respondents

4.3.4.1 Sample Structure

The sample population was made-up of personnel in the building construction industry, that included technicians, engineering surveyors, site supervisors, site agents, quantity surveyors, project managers, consultants, laboratory technicians, foreman, facilities managers, engineers, contracts managers and architects (see Figure 4.1). Also included in the sample were third year students with one year work experience in the construction industry and B-degree students who had qualified in the building construction industry or had completed other qualifications and had more than one year experience in the construction industry. The total number of respondents was 139.

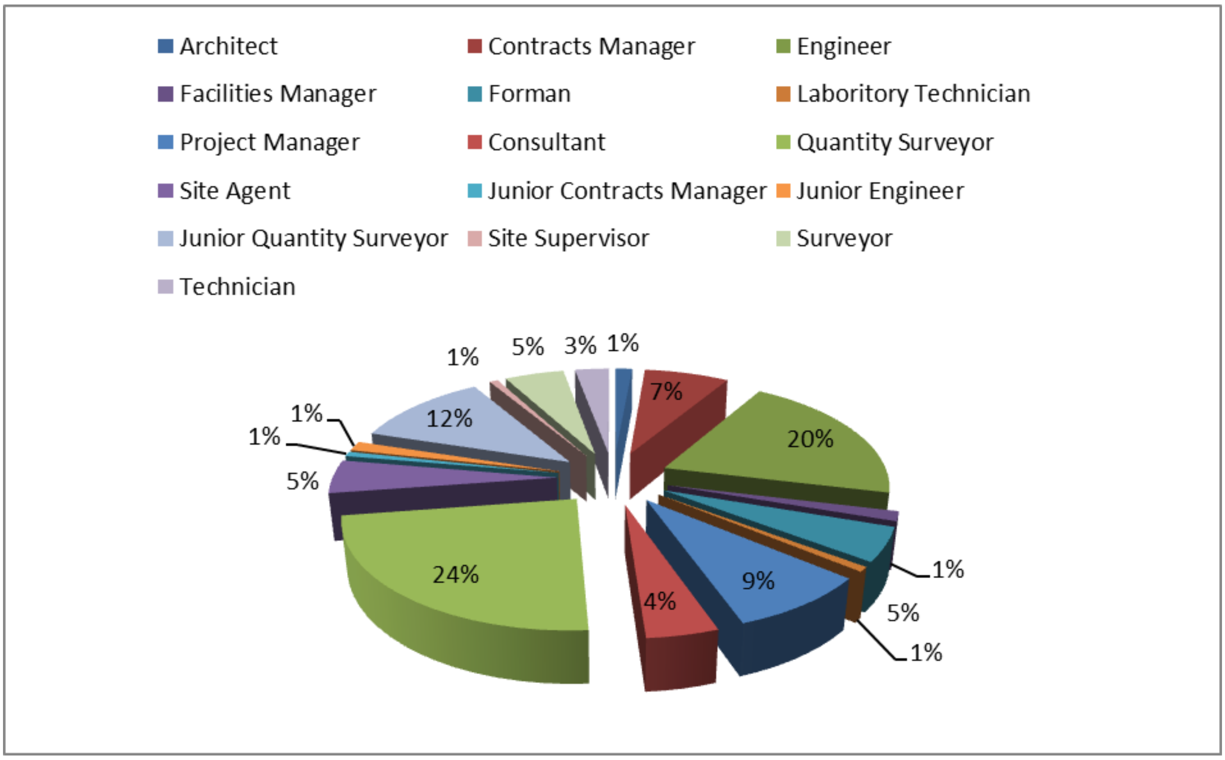

Figure 4.1: Sample of respondents

4.3.4.2 Age Groups

Table 4.4 presents the age groups of surveyed respondents. The majority of respondents (69%) were below the age of twenty six years 69% with the balance (31%) above twenty six years.

Age	Frequency	Percentage
Below 26	62	45
26 to 30	34	24
31 to 35	17	12
36 to 40	10	7
41 to 45	4	3
46 to 50	7	5
51 to 55	3	2
56 to 60	2	1
Total	139	100

Table 4.4: Age of respondents

4.3.4.3 Highest Formal Qualification

Figure 4.2 represents the highest qualification obtained by the respondents approached in this study. Respondents with a matric certificate represented 17% of the total sample while respondents with a National Diploma in construction management or equivalent represented 52% of the total sample. Respondents with a Bachelor Degree in construction management or equivalent represented 31% of the total sample. The spread of respondent's qualification is consistent with the sample taken.

These results imply that the National Diploma in construction management or equivalent is a valuable qualification among the workforce on a construction site. Personnel with this qualification are being significantly regarded in building management.

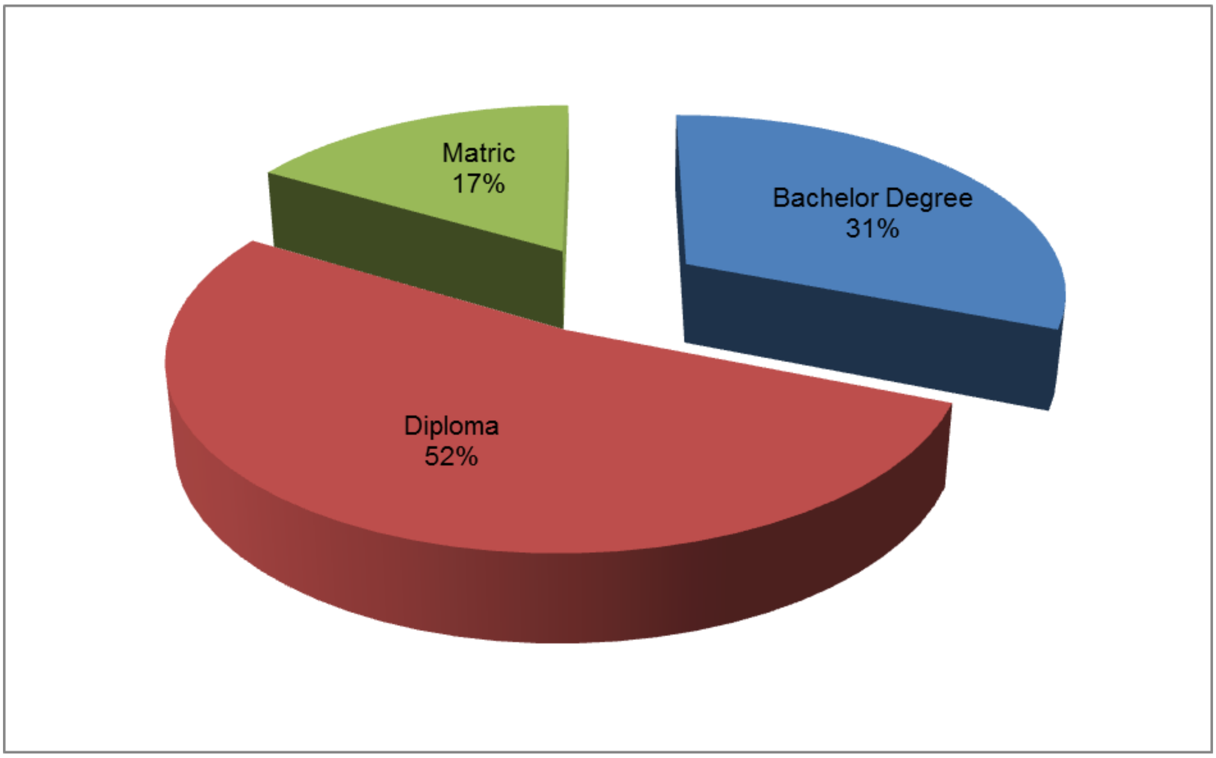

Figure 4.2: Highest formal qualification of respondents

4.3.4.4 Employers of the Respondents

Respondents were employed by a variety of construction business companies/enterprises. These included architectural firms (3%), construction companies (60%), facilities management firms (1%), government departments (2%), project management firms (7%), quantity surveying practices (22%), real estate companies (1%) and sub-contracting companies (4%). The majority of respondents were employed by construction companies (see Figure 4.3).

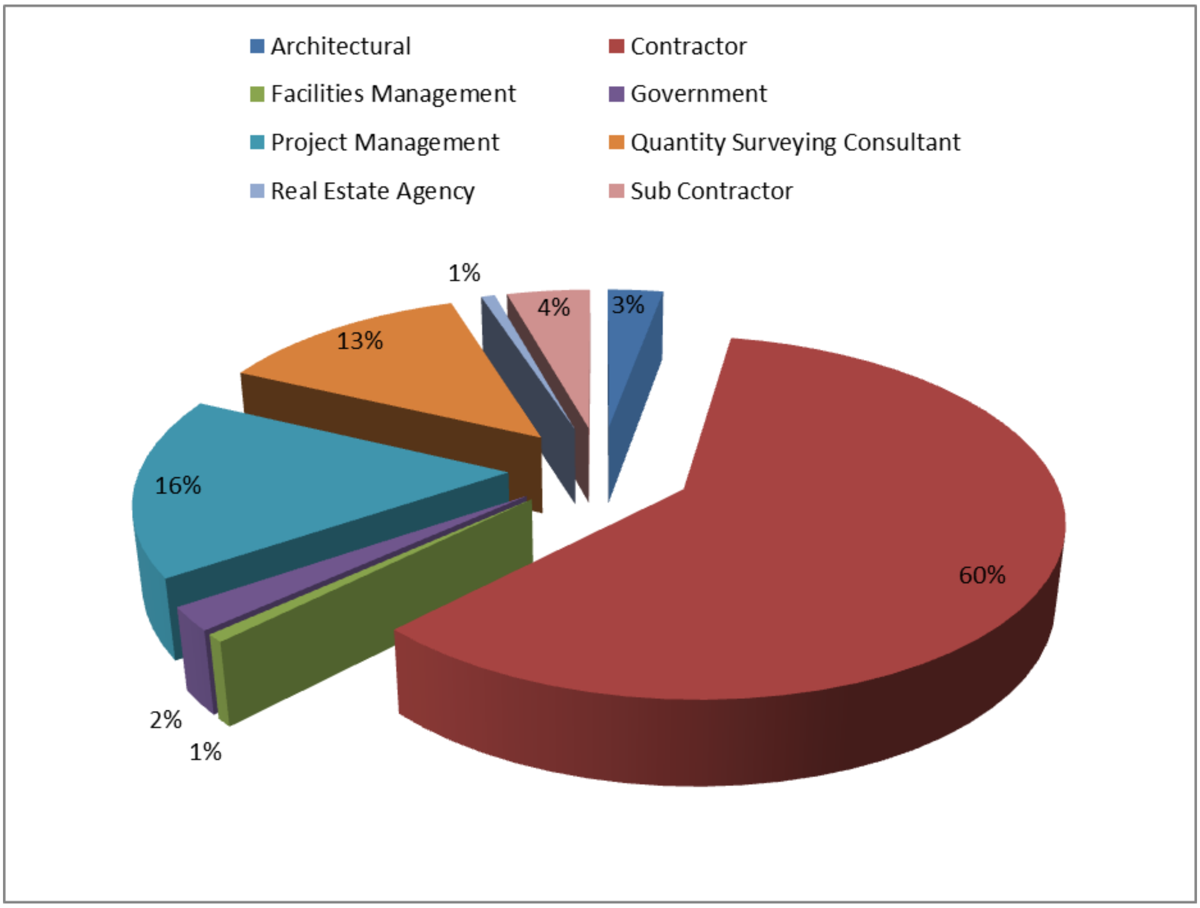

Figure 4.3: Types of firms respondents belong to

4.3.4.5 Gender of the Respondents

Table 4.5 shows that the majority (63%) of respondents in the survey were male, and the minority (37%) were female.

Gender	Frequency	Percentage
Female	51	37
Male	88	63
Total	139	100

Table 4.5: Gender of respondents

This is consistent with trends in the construction industry regarding genders.

4.3.4.6 Urban Centres Represented in the Survey

The majority of respondents have construction experience in the Cape Town central business district (55%). Examples of experience in other urban centres in greater Cape Town include Bellville urban centre (14%), Claremont urban centre (1%) and the Philippi central urban centre (1%). Urban centres outside the greater Cape Town area include

Somerset West urban centre (1%), Paarl urban centre (1%), Stellenbosch urban centre (1%) and East London urban centre (1%). Respondents also indicated that they had experience in urban centres other than those indicated on the questionnaire (23%), however, did not specify the place.

Urban centre experience	Frequency	Percentage
Cape Town	77	55
Other	32	23
Bellville	20	14
Somerset West	3	3
Claremont	2	1
Philippi Centre	2	1
East London	1	1
Paarl	1	1
Stellenbosch	1	1
Total	139	100

Table 4.6: Urban centre experience

4.4 PRESENTATION OF RESULTS

4.4.1 Investigation into Strategic Building Production Processes Currently Being Employed in Urban Centres

The objective of Section 2 of the questionnaire was to investigate what strategic building production processes are currently being employed in urban centres. The first research question asked in Section 2 of the questionnaire is 'how often strategic management methods are being used in building production processes?' Respondents were asked to indicate the extent to which each method was practiced, using a five-point scale, where 1 = 'not at all', 2 = 'sometimes', 3 = 'often', 4 = 'generally', and 5 = 'almost always'. As presented in Table 4.7, and for easy visualisation in Figure 4.4, the mean of the scaled responses indicate that the use of 'Knowledge management' (mean 3.52) is the highest ranked management method currently used in building production processes. The responses indicated that 'Knowledge management' is 'generally' used (36.0%) in building production processes. The use of 'Just-in-time delivery of materials' method was ranked second (mean 3.35) and was also considered as being 'generally' (32.4%) used in building production processes. The use of 'Lean construction methods' (mean 3.30), 'Use of innovative technology' (mean 3.21) and use of 'Prefabrication' (mean 3.09) were indicated as being used 'often' (39.6%, 33.8% and 33.8% respectively). On average 1% of respondents left this part of the questionnaire out.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Knowledge management	138	5.8	11.5	26.6	**36.0**	19.4	0.7	3.52	1.11	1
Just-in-time delivery of materials	139	7.2	16.5	27.3	**32.4**	16.5	0.1	3.35	1.15	2
Lean construction methods	138	4.3	16.5	**39.6**	22.3	16.5	0.8	3.30	1.07	3
Use of innovative technology	139	5.0	21.6	**33.8**	26.6	12.9	0.1	3.21	1.08	4
Prefabrication	137	12.9	15.1	**33.8**	23.7	12.9	1.6	3.09	1.20	5

Table 4.7: The extent to which current building production management methods are being used

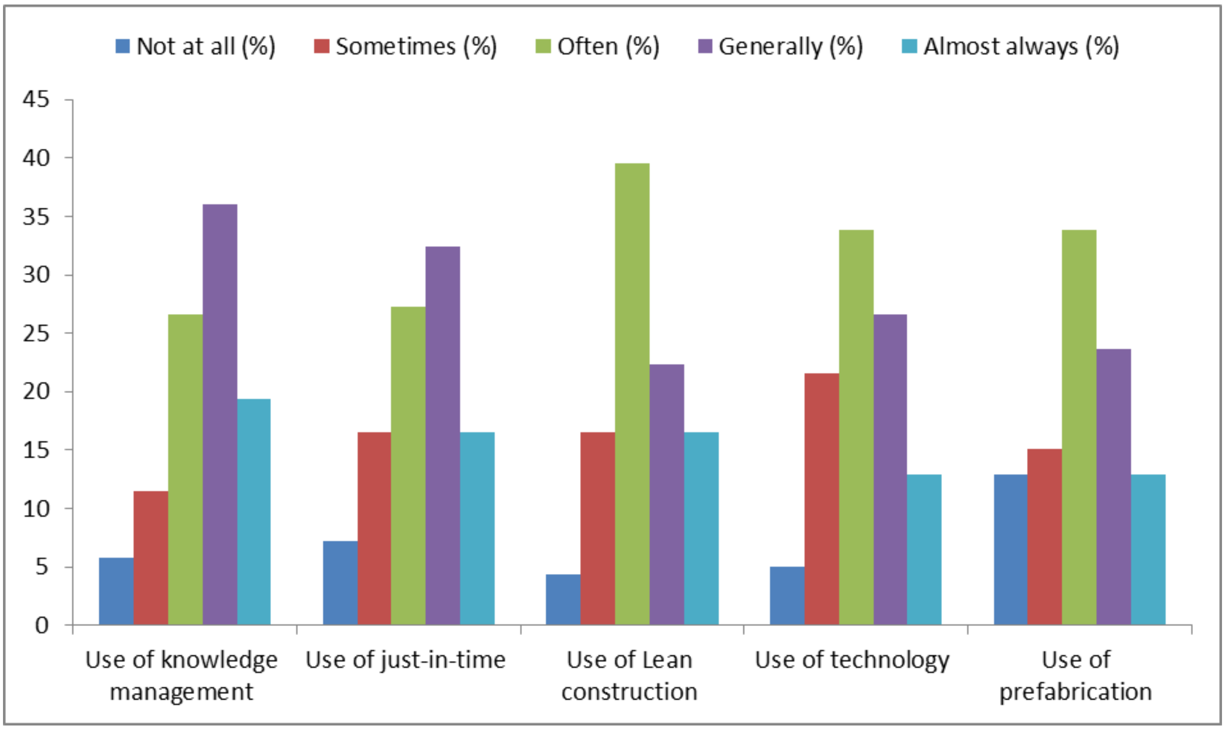

Figure 4.4: The extent to which current building production management methods are being used

4.4.2 Investigation into Effective Strategic Managing Practices in Enhancing Building Production Processes

The second question asked in Section 2 of the questionnaire was 'how effective strategic managing practices are in enhancing building production processes?' Respondents were asked to indicate the effectiveness of each method using a five-point scale, where 1 = 'not at all', 2 = 'sometimes', 3 = 'often', 4 = 'generally', and 5 = 'almost always'. As presented in Table 4.8 and depicted in Figure 4.5, the mean of the scaled responses indicated that the use of 'Knowledge management' (mean 3.79) as the highest ranked effective strategic management method. The responses indicated that 'Knowledge management' is 'generally' effective (40.3%) in building production processes. The 'Use of innovative technology' was ranked second (mean 3.75) and was also considered as being 'generally' effective (38.1%) in building production processes. The use of 'Lean Construction methods' (mean 3.58), 'Just-in-time delivery of materials' (mean 3.52) and 'Prefabrication' (mean 3.34) were indicated as being used 'often' (31.7%, 27.3% and 27.3% respectively). 1% of respondents did not respond to this part of the questionnaire.

	N	**Not at all (%)**	**Sometimes (%)**	**Often (%)**	**Generally (%)**	**Almost always (%)**	**No response (%)**	**Mean**	**Std. Deviation**	**Rank**
Knowledge management	138	1.4	12.2	18.7	**40.3**	26.6	0.8	3.79	1.02	1
Use of innovative technology	138	0.7	14.4	20.1	**38.1**	25.9	0.8	3.75	1.03	2
Lean construction methods	137	5.8	9.4	**31.7**	25.2	26.6	1.3	3.58	1.15	3
Just-in-time delivery of materials	137	8.6	10.1	**27.3**	26.6	25.9	1.5	3.52	1.23	4
Prefabrication	137	10.1	12.2	27.3	**31.7**	17.3	1.4	3.34	1.20	5

Table 4.8: The perceived usefulness of building production management methods

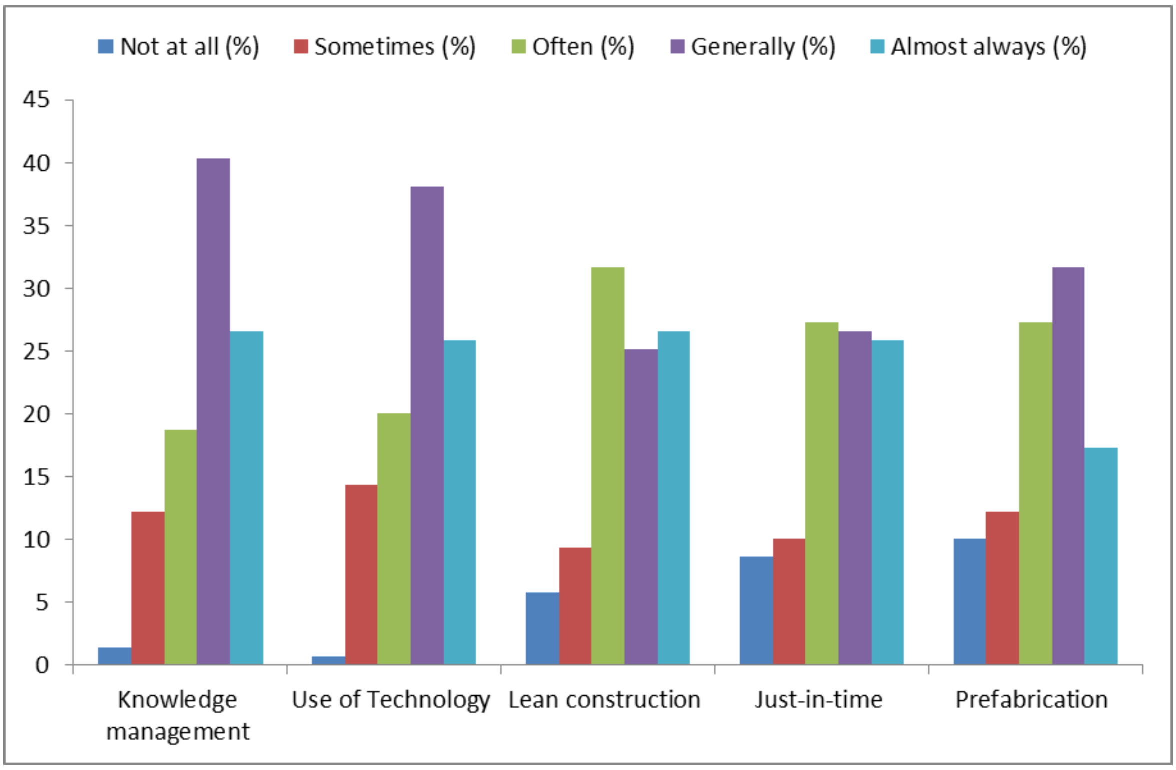

Figure 4.5: The usefulness of building production management methods

4.4.3 Investigation into Problems and Constraints in Building Production Processes in Urban Centres

The objective of Section 3 of the questionnaire was to identify problems and constraints in building production processes in urban centres; the first question in this section is 'how effectively (based on frequency) do current building production processes address the nine knowledge areas in project management?' Respondents were asked to indicate the effectiveness of building production management in implementing each knowledge area using a five-point scale, 1 = 'not at all', 2 = 'sometimes', 3 = 'often', 4 = 'generally', and 5 = 'almost always'. As presented in Table 4.9 and Figure 4.6, the mean of the scaled responses indicates that 'Quality management' (mean 4.08) is regarded as being 'almost always' effective (40.3%) using current building production management methods. 'Cost management' (42.4%), 'Time management' (38.1%), 'Procurement management' (38.8%), 'Communication management' (35.3%), 'Risk management' (28.8%), 'Scope management' (37.4%) were all rated as 'generally' effective using current project management while 'Human resource management' (33.8%) and 'Integrated management' (41.7%) were all rated as 'often' effective using current project management methods. On average, less than 1% of respondents did not answer this part of the questionnaire.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Quality management	138	0.7	5.8	18.7	33.8	**40.3**	0.7	4.08	0.94	1
Cost management	139	1.4	5.0	15.1	**42.4**	36.0	0.1	4.06	0.92	2
Time management	139	1.4	7.2	18.7	**38.1**	34.5	0.1	3.97	0.98	3
Procurement management	138	2.2	5.0	28.1	**38.8**	25.2	0.7	3.80	0.95	4
Communication management	138	0.7	11.5	32.4	**35.3**	19.4	0.7	3.62	0.95	5
Risk management	139	2.9	15.8	27.3	**28.8**	25.2	0	3.58	1.12	6
Scope management	139	2.9	7.9	36.0	**37.4**	15.8	0	3.55	0.95	7
Human resource management	139	3.6	15.1	**33.8**	28.8	18.7	0	3.44	1.07	8
Integrated management	139	2.9	15.1	**41.7**	28.8	11.5	0	3.31	0.96	9

Table 4.9: The effectiveness (based on frequency) of current building production processes in addressing the nine knowledge areas in project management

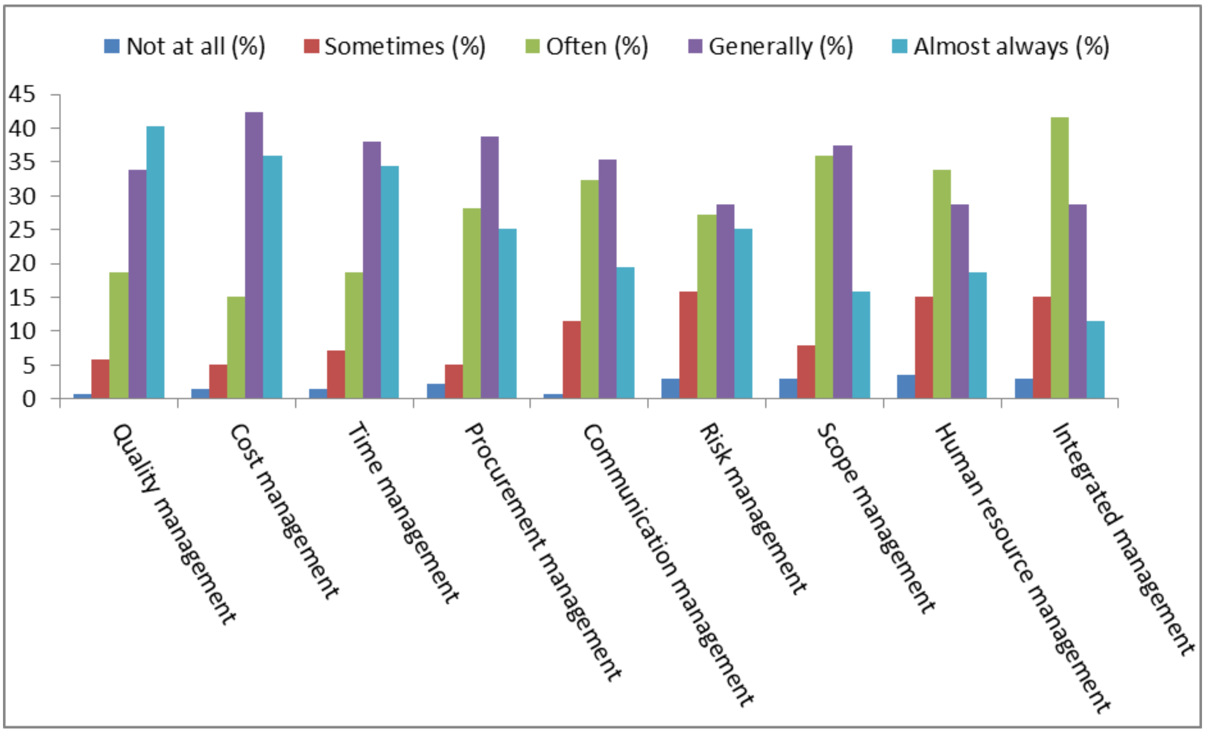

Figure 4.6: The effectiveness (based on frequency) of current building production processes in addressing the nine knowledge areas in project management

4.4.4 Investigation into the Level of Occurrence and Level of Inconvenience of Challenges on Building Sites in Urban Centres

The second question asked in Section 3 of the questionnaire enquires about the level of occurrence and level of inconvenience of challenges on building sites in urban centres. Respondents were asked to indicate the occurrence and inconvenience using a five-point scale, 1 = 'not at all', 2 = 'sometimes', 3 = 'often', 4 = 'generally' and 5 = 'almost always'. As presented in Table 4.10 and Figure 4.7 the mean of the scaled responses indicates that the issue of 'Safe movement of materials' (mean 3.5) on site in an urban centre 'generally' (38.8%) occurs the most. The results show that 'Restricted access for delivery of materials' is ranked second (mean 3.2) occurring 'often' (25.5%) with 'Limited storage of materials' (mean 3.1) occurring 'generally' (25.8%). Project program issues, congested space, Locating material, Health and safety issues, Increased resource management, Damage to materials, Personnel in close proximity to machinery all occurred 'Generally' with Difficulty communicating and overcrowding of personnel only occurring 'Sometimes'. On average (2%) of respondents did not answer this part of the questionnaire.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Safe movement of materials	137	7.2	10.8	25.9	**38.8**	15.8	1.5	3.5	1.11	1
Restricted access for delivery of materials	137	12.9	18.0	**24.5**	21.6	21.6	1.4	3.2	1.33	2
Limited storage of materials	136	18.7	13.7	22.3	**25.9**	17.3	2.1	3.1	1.37	3
Project program issues	137	7.9	25.9	**28.1**	22.3	14.4	1.4	3.1	1.18	4
Congested space	138	10.1	18.7	**35.3**	23.7	11.5	0.7	3.1	1.14	5
Locating material	136	11.5	21.6	**28.1**	25.2	11.5	2.1	3.0	1.20	6
Health and safety issues	136	13.7	24.5	**26.6**	15.1	18.0	2.1	3.0	1.31	7
Increased resource management	136	12.9	21.6	**34.5**	20.1	8.6	2.3	2.9	1.14	8
Damage to material	136	10.1	26.6	**34.5**	18.0	8.6	2.2	2.9	1.10	9
Personnel in close proximity to machinery	136	15.1	23.7	**28.8**	18.7	11.5	2.2	2.9	1.23	10

Coordination management issues	136	13.7	25.2	**35.3**	15.8	7.9	2.1	2.8	1.12	11
Increased personnel management	136	12.9	25.2	**36.7**	16.5	6.5	2.2	2.8	1.09	12
Difficulty communicating	137	**23.0**	**23.0**	22.3	20.9	9.4	1.4	2.7	1.30	13
Overcrowding of personnel	136	19.4	**29.5**	27.3	18.0	3.6	2.2	2.6	1.11	14

Table 4.10: Challenges on a building site in urban centres (occurrence)

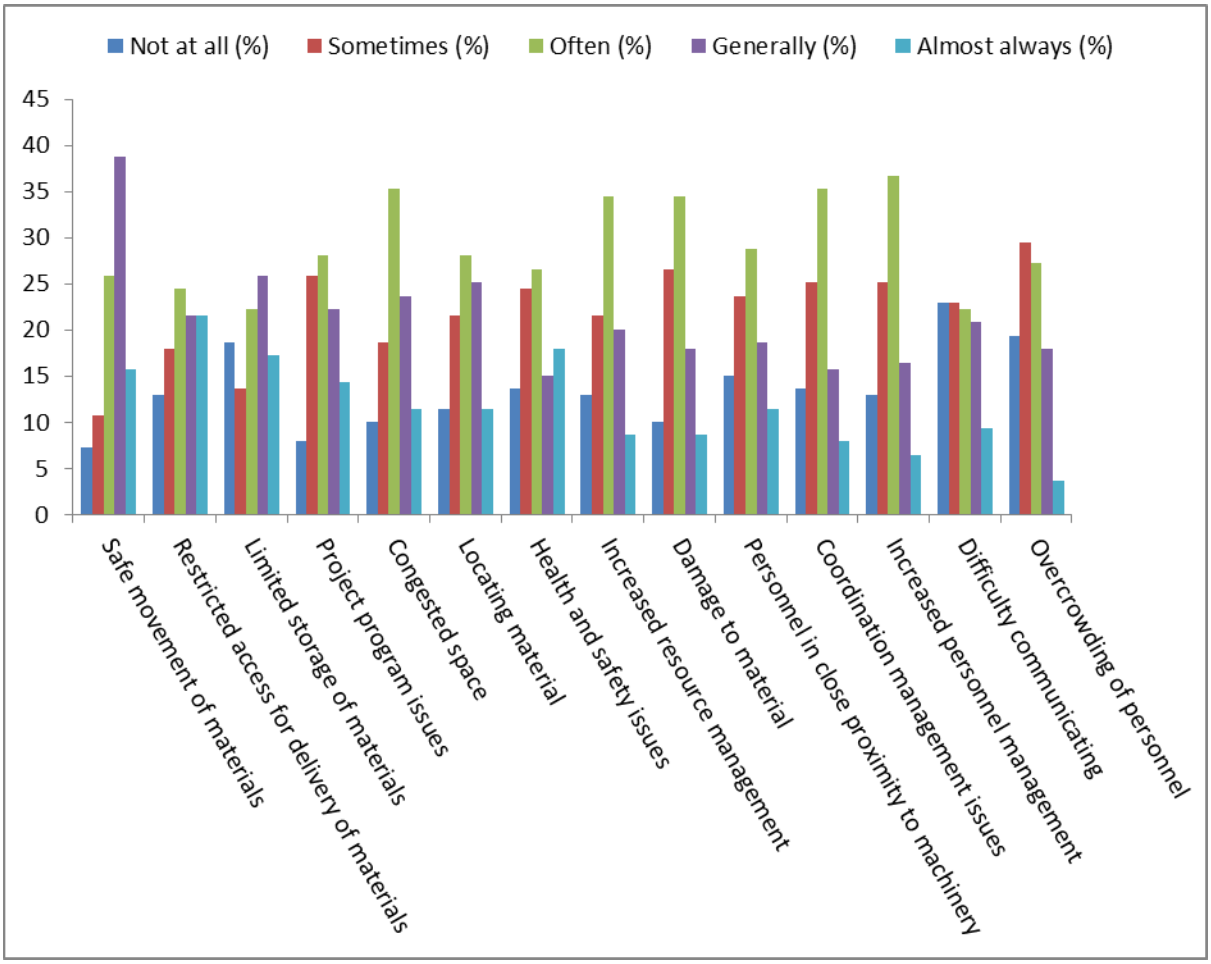

Figure 4.7: Challenges on a building site in urban centres (occurrence)

Table 4.11 and Figure 4.8 shows that the mean of the scaled responses indicates that the issue of 'Damage to material' (mean 3.3) and 'Congested space' (mean 3.2) is 'often' (23.7%) an inconvenience on site in an urban centre. 'Restricted access for delivery of materials' was also regarded as 'often' (26.6%) an inconvenience. 'Limited storage of materials' was considered as only 'sometimes' an inconvenience while 'Health and safety issues', 'Safe movement of materials', 'Project program issues', 'Personnel in close proximity to machinery', 'Difficulty communicating', 'Coordination management issues', 'Locating material' and 'Overcrowding of personnel' were all considered as 'often' an inconvenience.

'Increased personnel management' was only considered as an inconvenience 'sometimes'. Approximately 6% of respondents did not answer this part of the questionnaire.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Damage to material	130	8.6	21.6	23.7	15.1	**24.5**	6.5	3.3	1.32	1
Congested space	134	10.8	20.1	**23.7**	19.4	22.3	3.7	3.2	1.32	2
Restricted access for delivery of materials	131	15.8	14.4	**26.6**	21.6	15.8	5.8	3.1	1.32	3
Limited storage of materials	129	15.8	**20.9**	17.3	20.1	18.7	7.2	3.1	1.39	4
Health and safety issues	131	15.8	18.7	**26.6**	11.5	21.6	5.8	3.0	1.39	5
Safe movement of materials	131	14.4	20.1	**24.5**	20.9	14.4	5.7	3.0	1.29	6
Project program issues	132	7.2	28.8	**30.2**	15.8	12.9	5.1	3.0	1.15	7
Difficulty communicating	132	**20.9**	19.4	**20.9**	18.7	15.1	5.0	2.9	1.38	8
Personnel in close proximity to machinery	131	17.3	22.3	**23.7**	21.6	9.4	5.7	2.8	1.26	9
Coordination management issues	132	15.1	23.0	**30.9**	18.0	7.9	5.1	2.8	1.17	10
Locating material	131	16.5	23.0	**29.5**	14.4	10.8	5.8	2.8	1.23	11
Overcrowding of personnel	131	20.9	16.5	**31.7**	18.0	7.2	5.7	2.7	1.22	12
Increased resource management	131	17.3	23.0	**32.4**	16.5	5.0	5.8	2.7	1.13	13
Increased personnel management	131	19.4	**29.5**	24.5	18.0	2.9	5.7	2.5	1.11	14

Table 4.11: Challenges on a building site in an urban centre (inconvenience)

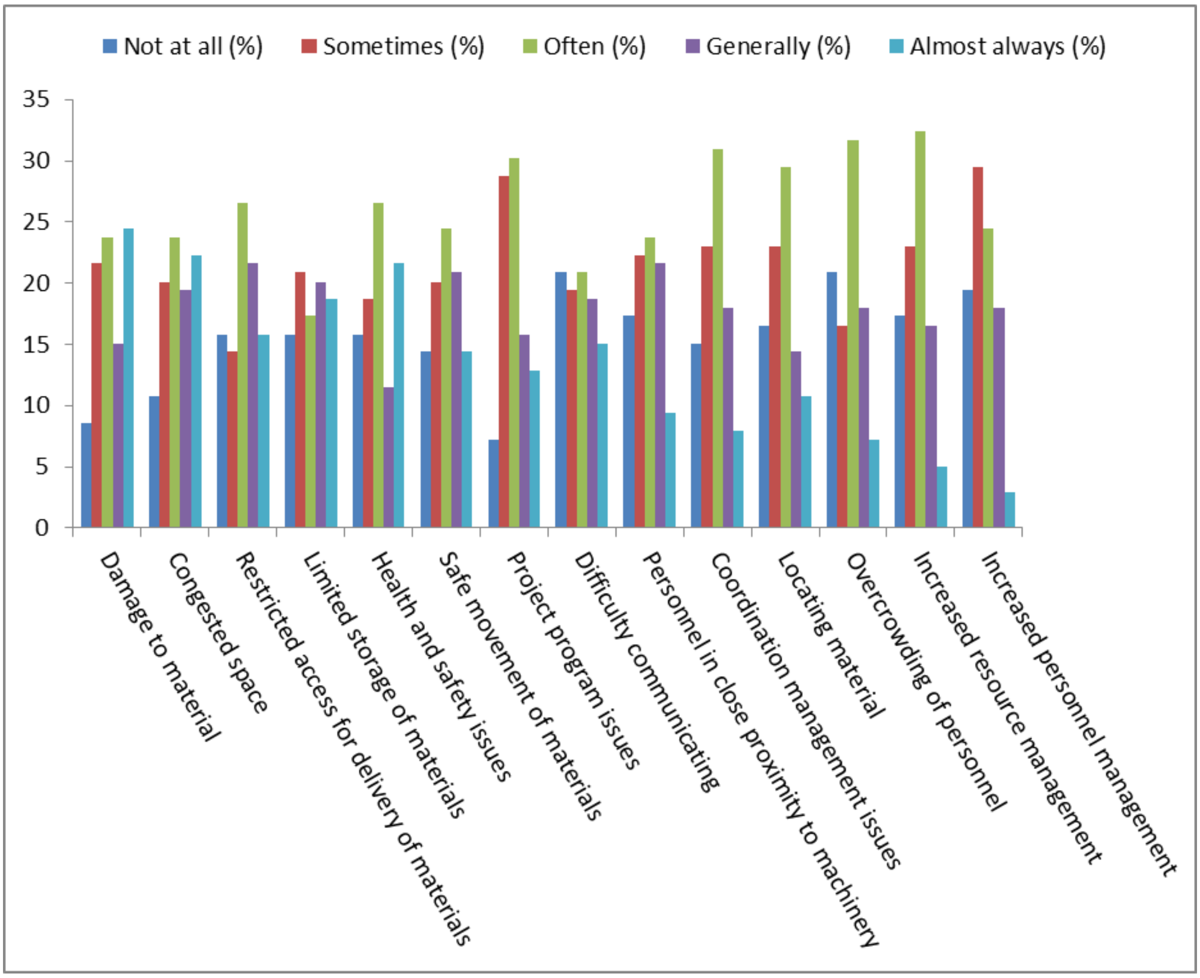

Figure 4.8: Challenges on a building site in an urban centre (inconvenience)

4.4.5 Investigation into the Factors that Help Alleviate Weakness in Current Building Production Processes

The objective of Section 4 of the questionnaire is to identify the factors that help alleviate weakness in current building production processes. Respondents were asked to indicate the usefulness of each technology using a five-point scale, 1 = 'not at all', 2 = 'sometimes', 3 = 'often', 4 = 'generally' and 5 = 'almost always'.

4.4.5.1 Investigation into the Extent Innovative Technologies Enhance Building Production Processes during the Initiating Stage of a Construction Project

The first question asked was to what extent innovative technologies enhance building production processes during the initiating stage of construction project. As presented in Table 4.12 and Figure 4.9 the mean of the scaled responses indicates that the 'Advantage of BIM technology' (mean 3.7) 'almost always' (32.4%) enhances the building production process during the initiating stage of a construction project. The majority of respondents indicated that 'Advantage of Point Cloud Technology' (23%), 'Advantage of Remote Imagery Technology' (33.1%), 'Advantage of LAT Technology' (28.1%), 'Advantage of Bar Code

Scanner Technology' (38.1%) and 'Advantage of CCTV Technology' (44.6%) do not assist in the initiating stage of a project at all. Not all respondents answered this part of the questionnaire (14%).

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Advantage of BIM technology	120	8.6	8.6	18.0	18.7	**32.4**	13.7	3.7	1.34	1
Advantage of Point Cloud technology	121	**23.0**	17.3	17.3	13.7	15.8	12.9	2.8	1.45	2
Advantage of Remote Imagery technology	120	**33.1**	13.7	14.4	10.1	15.1	13.6	2.5	1.52	3
Advantage of LAT technology	122	**28.1**	19.4	18.7	11.5	10.1	12.2	2.5	1.36	3
Advantage of Bar Code Scanner technology	117	**38.1**	12.2	10.1	12.2	11.5	15.9	2.4	1.51	5
Advantage of CCTV technology	118	**44.6**	12.9	5.8	9.4	12.2	15.1	2.2	1.52	6

Table 4.12: The usefulness of innovative technology in the initiating stage of a construction project

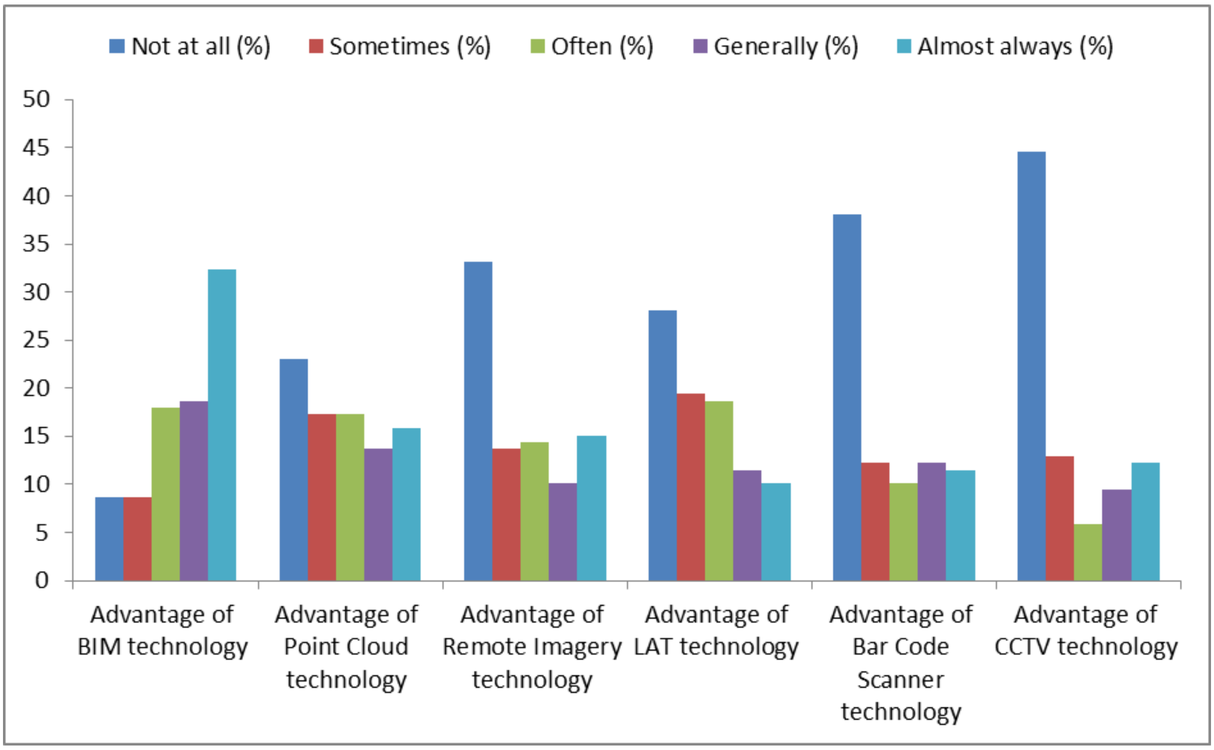

Figure 4.9: The usefulness of innovative technology in the initiating stage of a construction project

4.4.5.2 Investigation into the Extent Innovative Technologies Enhance Building Production Processes during the Planning Stage of a Construction Project

The second question asked was to obtain the extent of which innovative technologies enhance building production processes during the planning stage of construction management. The mean of the scaled responses indicates that the 'Advantage of BIM technology' (mean 4.1) 'almost always' (46%) enhances the building production process during the planning stage of a construction project (Table 4.13 and Figure 4.10). The majority of respondents indicated that 'Advantage of Point Cloud technology' (22.3%), 'Advantage of Remote Imagery technology' (25.9%), 'Advantage of Bar Code Scanner technology' (31.7%), 'Advantage of LAT technology' (29.5%) and 'Advantage of CCTV technology' (38.8%) do not assist in the planning stage of a project at all. On average (13%) of respondents did not answer this part of the questionnaire.

	N	**Not at all (%)**	**Sometimes (%)**	**Often (%)**	**Generally (%)**	**Almost always (%)**	**No response (%)**	**Mean**	**Std. Deviation**	**Rank**
Advantage of BIM technology	125	5.8	5.8	10.8	21.6	**46.0**	10	4.1	1.21	1
Advantage of Point Cloud technology	118	**22.3**	14.4	13.7	20.1	14.4	15.1	2.9	1.46	2
Advantage of Remote Imagery technology	123	**25.9**	16.5	13.7	13.7	18.7	11.5	2.8	1.53	3
Advantage of Bar Code Scanner technology	122	**31.7**	12.2	13.7	15.8	14.4	12.2	2.6	1.52	4
Advantage of LAT technology	120	**29.5**	14.4	14.4	15.1	12.9	13.7	2.6	1.48	5
Advantage of CCTV technology	117	**38.8**	13.7	10.1	9.4	12.2	15.8	2.3	1.50	6

Table 4.13: The usefulness of innovative technology in the planning stage of a construction project

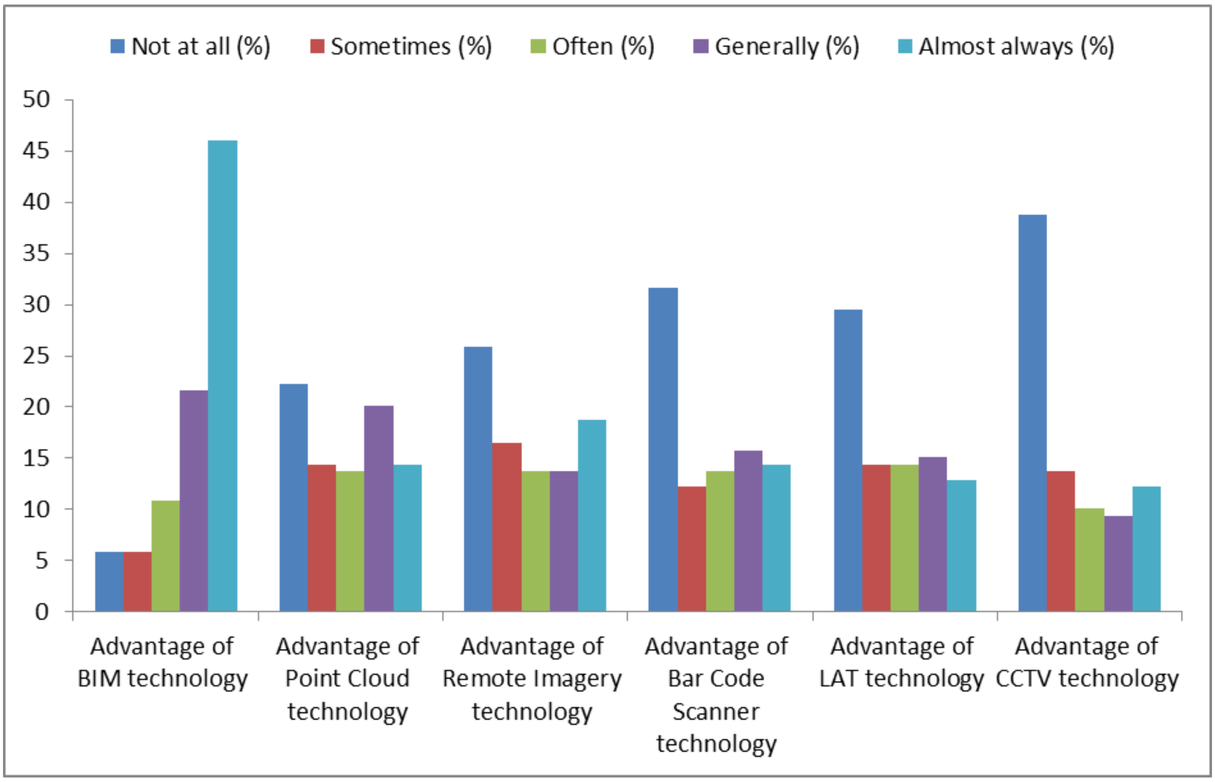

Figure 4.10: The usefulness of innovative technology in the planning stage of a construction project

4.4.5.3 Investigation into the Extent Innovative Technologies Enhance Building Production Processes during the Executing Stage of a Construction Project

The third question asked was to what extent innovative technologies enhance building production processes during the executing stage of construction management. Table 4.14 and Figure 4.11 indicate that the 'Advantage of BIM technology' (mean 3.5) 'generally' (27.3%) enhances the building production process during the execution stage of a construction project. The majority of respondents indicated that 'Advantage of CCTV technology' (22.3%) and 'Advantage of Remote Imagery technologies' (27.3%) do not assist in the executing stage of a project at all, however 'Advantage of LAT technology' (23.7%) 'generally' enhances the building production process during the execution stage while 'Advantage of Point Cloud technology' (24.5%) often does. On average (14%) of respondents did not answer this part of the questionnaire.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Advantage of BIM technology	118	8.6	7.9	20.1	**27.3**	20.9	15.2	3.5	1.25	1
Advantage of LAT technology	120	16.5	14.4	15.1	**23.7**	16.5	13.8	3.1	1.41	2
Advantage of CCTV technology	119	**22.3**	10.1	15.1	17.3	20.9	14.3	3.1	1.53	3
Advantage of Point Cloud technology	121	17.3	12.9	**24.5**	18.7	13.7	12.9	3.0	1.34	4
Advantage of Bar Code Scanner technology	119	**19.4**	**19.4**	16.5	15.1	15.1	14.5	2.8	1.42	5
Advantage of Remote Imagery technology	119	**27.3**	12.9	18.0	14.4	12.9	14.5	2.7	1.46	6

Table 4.14: The usefulness of innovative technology in the executing stage of a construction project

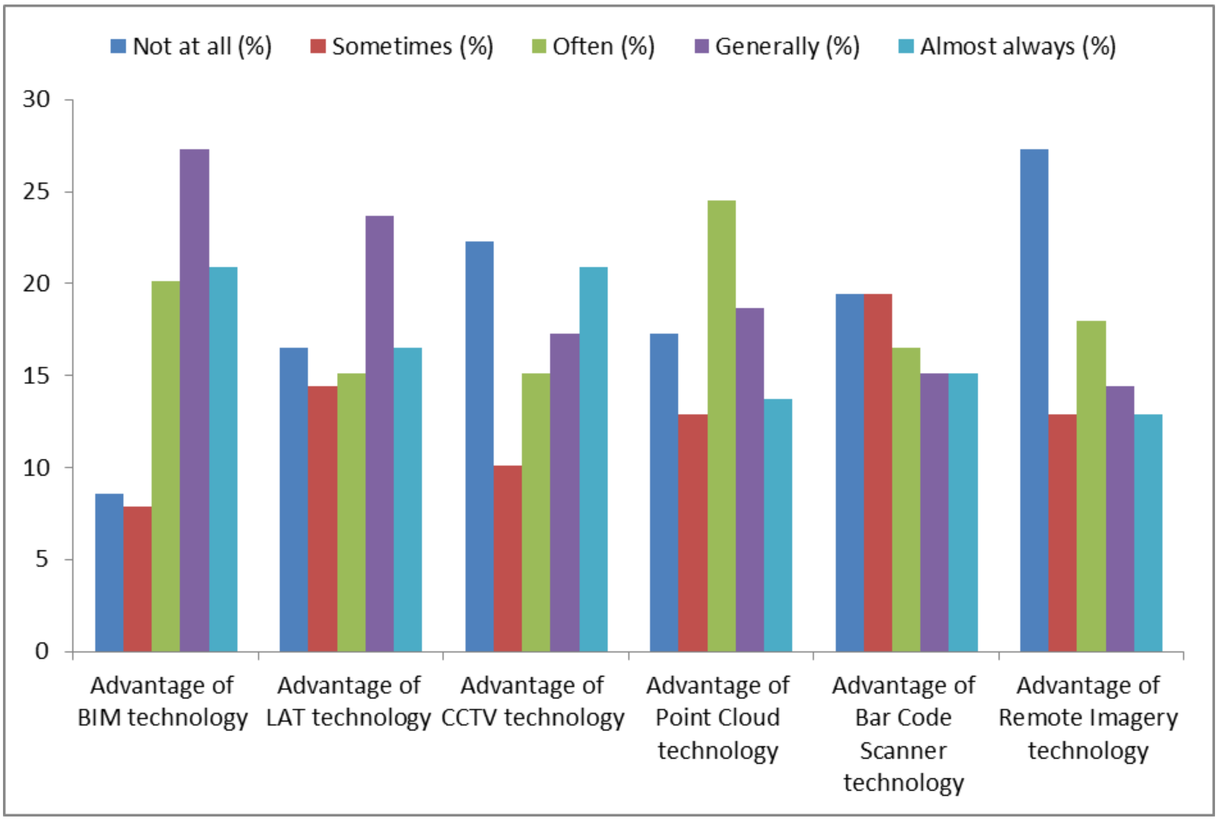

Figure 4.11: The usefulness of innovative technology in the executing stage of a building project

4.4.5.4 Investigation into the Extent Innovative Technologies Enhance Building Production Processes during the Monitoring Stage of a Construction Project

The fourth question asked was to what extent innovative technologies enhance building production processes during the monitoring stage of construction management. As presented in Table 4.15 and Figure 4.12 responses indicates that the 'Advantage of BIM technology' (mean 3.6) 'generally' (27.3%) enhances the building production process during the execution stage of a construction project. The majority of respondents indicated that 'Advantage of CCTV technology' (29.5%) 'almost always' enhances the building production process during the execution stage of a construction project however the mean (mean 3.3) suggests that it's 'often' used. The results show that 'Advantage of Bar Code Scanner technology' (25.9%) and 'Advantage of Remote Imagery technologies' (28.1%) do not assist in the monitoring stage of a project at all, however 'Advantage of LAT technology' (23.7%) and 'Advantage of Point Cloud technology' (23%) often does. On average (13%) of respondents did not answer this part of the questionnaire.

	N	**Not at all (%)**	**Sometimes (%)**	**Often (%)**	**Generally (%)**	**Almost always (%)**	**No response (%)**	**Mean**	**Std. Deviation**	**Rank**
Advantage of BIM technology	120	5.0	12.2	18.7	**27.3**	23.0	13.8	3.6	1.19	1
Advantage of CCTV technology	121	21.6	8.6	10.8	16.5	**29.5**	13	3.3	1.61	2
Advantage of LAT technology	121	**19.4**	12.2	18.0	18.0	**19.4**	13	3.1	1.46	3
Advantage of Point Cloud technology	120	18.0	15.1	**23.0**	15.8	14.4	13.7	2.9	1.37	4
Advantage of Bar Code Scanner technology	123	**25.9**	13.7	15.1	16.5	17.3	11.5	2.8	1.51	5
Advantage of Remote Imagery technology	119	**28.1**	11.5	18.0	12.9	15.1	14.4	2.7	1.50	6

Table 4.15: The usefulness of innovative technology in the monitoring stage of a construction project

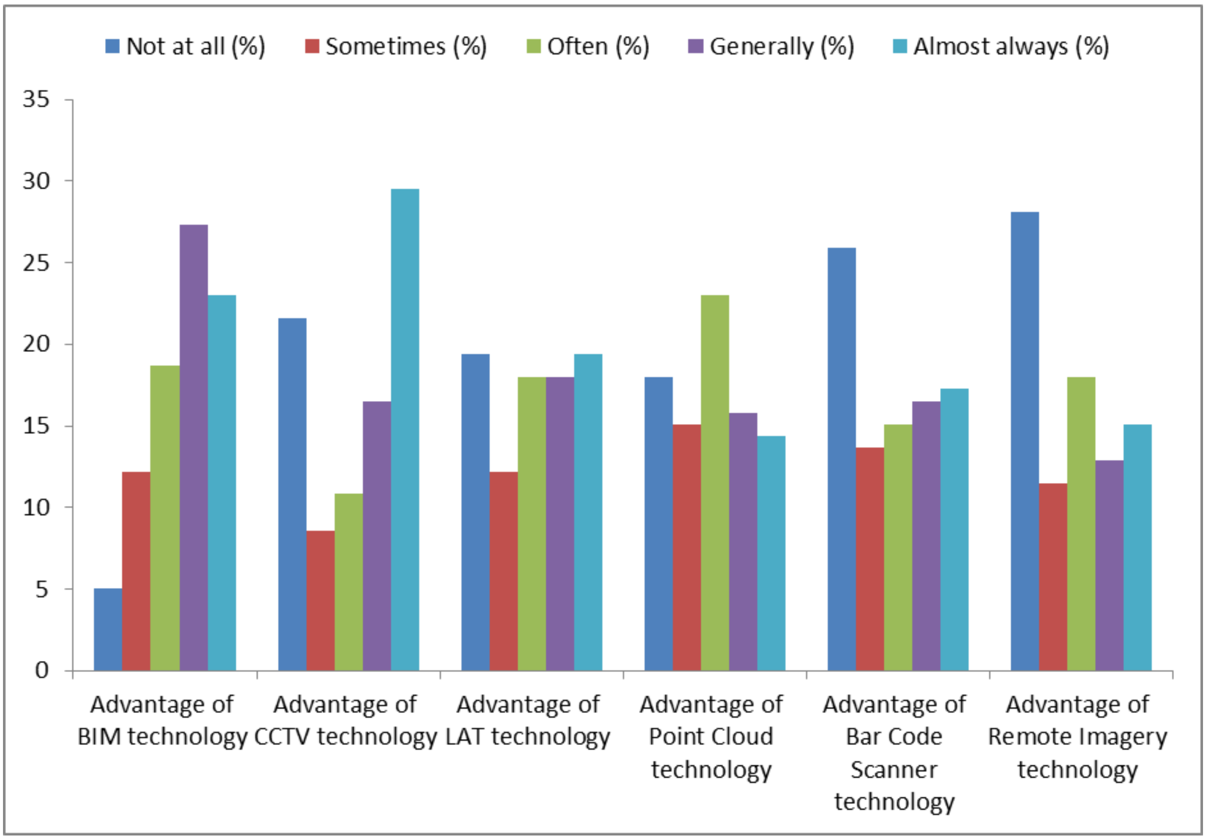

Figure 4.12: The usefulness of innovative technology in the monitoring stage of a construction project

4.4.5.5 Investigation into the Extent Innovative Technologies Enhance Building Production Processes during the Closing Stage of a Construction Project

The fifth question asked was to what extent innovative technologies enhance building production processes during the closing stage of construction management. As presented in Table 4.15 and Figure 4.13 the mean of the scaled responses indicates that the advantage of BIM technology (mean 3.5) 'generally' (23%) enhances the building production process during the closing stage of a construction project. The majority of respondents indicated that CCTV technology (27.3%), LAT technology (25.2%), Point Cloud technology (25.2%), Barcode Scanner technology (33.1%) and Remote Imagery technologies (32.4%) does not enhance the building production process during the closing stage of a construction project. On average (15%) of respondents did not answer this part of the questionnaire.

	N	Not at all (%)	Sometimes (%)	Often (%)	Generally (%)	Almost always (%)	No response (%)	Mean	Std. Deviation	Rank
Advantage of BIM technology	118	8.6	10.8	19.4	**23.0**	23.0	15.2	3.5	1.29	1
Advantage of CCTV technology	119	**27.3**	14.4	9.4	12.2	22.3	14.4	2.9	1.62	2
Advantage of LAT technology	117	**25.2**	16.5	19.4	10.1	12.9	15.9	2.6	1.42	3
Advantage of Point Cloud technology	120	**25.2**	23.0	15.8	8.6	13.7	13.7	2.6	1.41	4
Advantage of Bar Code Scanner technology	117	**33.1**	13.7	14.4	10.8	12.2	15.8	2.5	1.48	5
Advantage of Remote Imagery technology	118	**32.4**	18.7	13.7	8.6	11.5	15.1	2.4	1.43	6

Table 4.16: The usefulness of innovative technology in the closing stage of a construction project

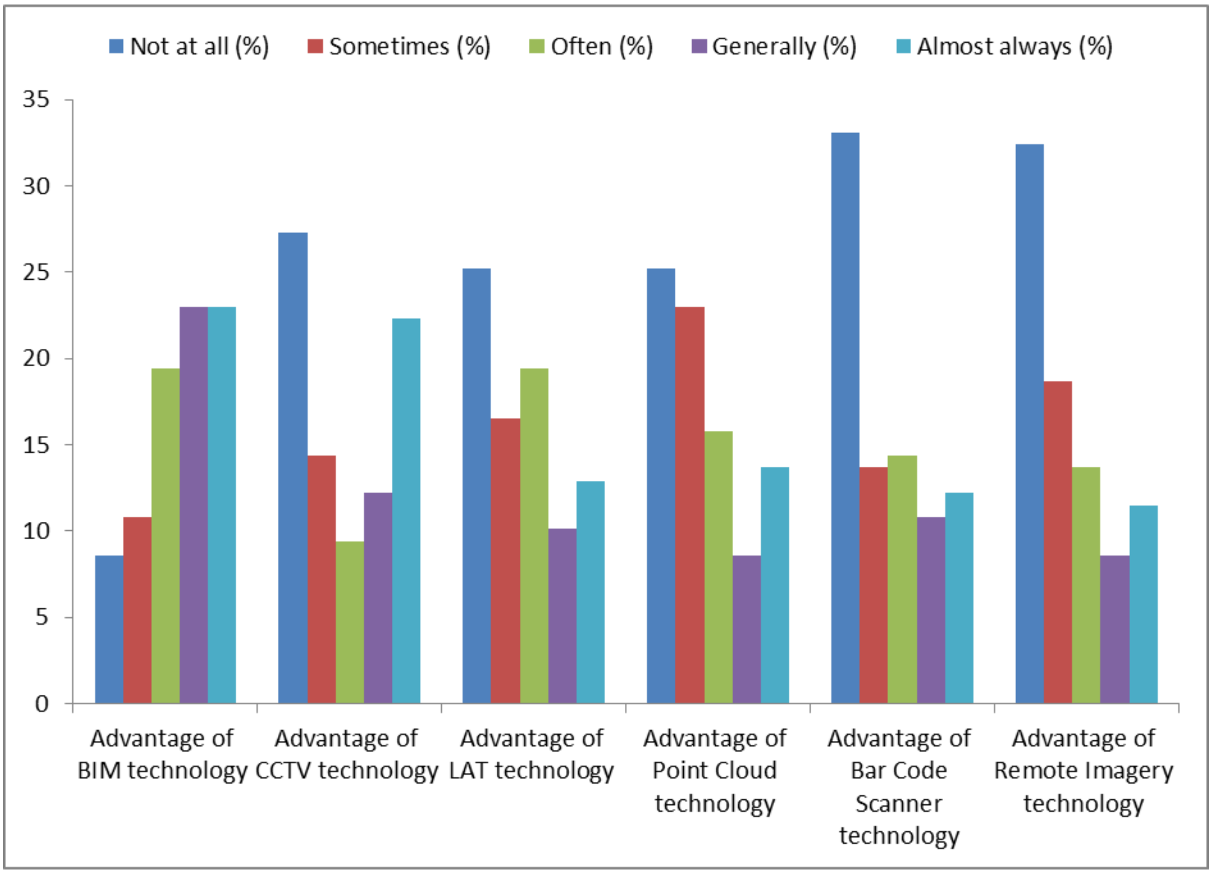

Figure 4.13: The usefulness of innovative technology in the closing stage of a construction project

4.4.6 Investigation into why Construction Firms are Reluctant to Invest in Innovative Building Production Processes

The objective of Section 5 of the questionnaire is to investigate why construction firms are reluctant to invest in innovative building production processes. The question asked is to what extend do these issues influence a construction firm's decision to invest or not to invest in new strategic management methods on construction sites. Respondents were asked to indicate the extent to which each issue has an influence on a construction firm's decision to invest or not to invest in new strategic management methods on construction sites using a five-point scale, 1 = not at all, 2 = sometimes, 3 = often, 4 = generally and 5 = almost always. Table 4.17 and Figure 4.14 show that investing in innovative construction management methods on construction sites almost always (50.4%) is influenced by the cost. Strong leadership is often (26.6%) a factor that influences on a construction firms decision. Risk, logistics, training of personnel and lack of knowledge of innovative technologies generally influences a firm's decision. Experimental time, sharing of information and technology development was thought to often influence this decision. On average (15%) of respondents did not answer this part of the questionnaire.

	N	**Not at all (%)**	**Sometimes (%)**	**Often (%)**	**Generally (%)**	**Almost always (%)**	**No response (%)**	**Mean**	**Std. Deviation**	**Rank**
Cost	138	3.6	5.0	18.0	22.3	**50.4**	0.7	4.1	1.10	1
Strong leadership	138	5.8	12.2	**26.6**	23.0	31.7	0.7	3.6	1.21	2
Risk	138	3.6	18.0	23.7	**30.9**	23.0	0.8	3.5	1.14	3
Logistics	138	3.6	15.8	30.2	**33.1**	16.5	0.8	3.4	1.06	4
Training personnel	138	6.5	17.3	24.5	**29.5**	21.6	0.6	3.4	1.20	5
Lack of knowledge	138	10.8	14.4	23.7	**29.5**	20.9	0.7	3.4	1.27	6
Experimental time	138	4.3	13.7	**45.3**	22.3	13.7	0.7	3.3	1.01	7
Sharing information	138	11.5	16.5	**33.1**	23.0	15.1	0.8	3.1	1.21	8
Technology development	138	8.6	23.0	**39.6**	18.0	10.1	0.7	3.0	1.08	9

Table 4.17: Issues that influence a construction firm's decision to invest or not to invest in new strategic management methods on a construction site

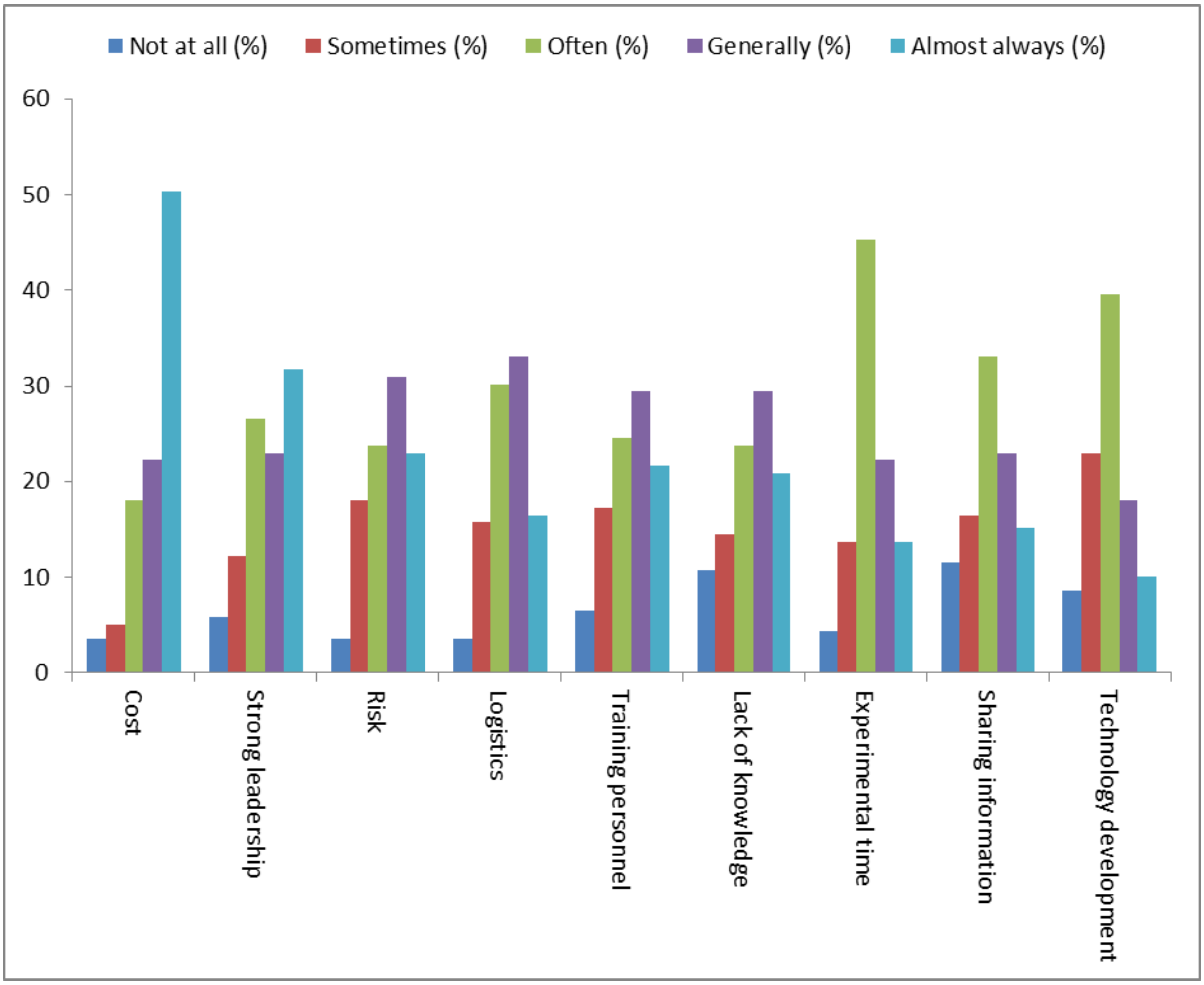

Figure 4.14: Issues that influence a construction firm's decision to invest or not to invest in new strategic management methods on a construction site

4.4.7 Investigation into Individual Perceptions on Current Use of Strategic Management Methods in Urban Centres

Section 6 of the questionnaire explored individual perceptions on the current use of strategic management methods (management of cost, time and quality) in urban centres. Respondents were solicited to agree or disagree with some significant statements regarding the current status of strategic management methods employed in urban centres (Table 4.18).

There is a strong sentiment (70%) that current building production processes in South African are advanced and competitive. However, the study revealed a mixed reaction to whether, or not, current building production processes in South African are internationally aligned (see Table 4.18). Based on the findings there is a robust belief that current building production processes in South Africa need to be modernised. The view that policies are in place to mitigate weaknesses in the current building production processes in South Africa is uncertain. Automation and technology is being used to improve building production workflows in South Africa. Based on the findings, it can be deduced that the construction industry in South Africa is significantly reluctant to explore the benefits of innovative strategic management methods in the urban centres.

Statement	Average (%)	
	Disagree	Agree
Current building production processes in South African are advanced and competitive	30%	70%
Current building production processes in South African are internationally aligned	47%	53%
Current building production process in South Africa need to be modernised	24%	76%
There are policies in place to mitigate weaknesses in the current building production processes in South Africa	43%	57%
Automation and technology is being used to improve building production workflows in South Africa	34%	66%
The construction industry in South Africa is reluctant to use innovative strategic management methods in urban centres	36%	64%

Table 4.18: Response to statements on building production processes in South Africa

4.5 DISCUSSION OF THE FINDINGS

4.5.1 Strategic Building Production Processes in Urban Centres

The first objective of this study investigates what strategic building production processes are currently being employed in urban centres. The preliminary study and literature review revealed that the strategic building production management methods currently being employed in the construction industry include lean construction methods, the use of innovative technology, knowledge management, just-in-time methods and prefabrication. In the study respondents were asked to indicate the usefulness of these strategic management methods and the frequency seen in the management of building projects.

The study revealed that knowledge management and just-in-time methods, as well as lean construction methods are largely being used. The use of technology and prefabrication however is being used occasionally (see Table 4.7). It was found (see Table 4.18) that 66% of respondents felt that automation and innovative technology are currently being used to improve building production workflows in South Africa. Furthermore it was emphasised, during interviews conducted in the preliminary study, that the use of technology in building production processes, along with lean construction management, are the most prominent construction management methods (see Table 4.2).

These findings are consistent with those of Talukhaba and Taiwo (2009:33), Walker (2012:126) and Egbu (2012:236). These authors stated that knowledge management is a crucial part of construction management. There is also extensive evidence in the literature indicating that innovative technology has a significant impact towards improving building production processes (Isikdag et al., 2008; Hardie, 2010:387; Yun-Yi Su, 2010:1; Razavi et al., 2012:239; Zhang et al. 2009).

4.5.2 Problems and Constraints in Building Production Processes in Urban Centres

The second objective of this study was to identify distinctive difficulties and constraints in building production in urban centres, from the initiating to the closing stage of a construction project. The preliminary study and the literature review referred to the nine knowledge areas in project management, and five process groups that make up the duration of a construction project. Time, cost, quality, human resource, communication, risk, procurement, integration and scope management were all discussed during the preliminary investigations. In the main study respondents were asked how effective (based on frequency) do current building production processes address the nine knowledge areas in construction management.

The study revealed that quality management is almost always addressed during construction projects, and cost, time, procurement, communication, risk and scope management are also largely addressed. Human resource and scope management are considered as being only addressed every so often (Table 4.9). During interviews conducted in the preliminary study, time and cost management were the two knowledge areas most referred to (see Table 4.2).

The preliminary study and the literature review highlighted fourteen activities that are affected by construction in urban centres (see Table 4.2). The study revealed that the biggest challenges on congested construction sites in urban centres are the safe movement of materials, and the limited storage place for materials (see Table 4.10). However, the safe movement and limited storage of materials were not identified as a general inconvenience (see Table 4.11). Damage to materials was identified as the biggest inconvenience when working on a congested construction site (see Table 4.11). Generally restricted access for delivery of materials occurs (see Table 4.10). The study by Spillane et al. (2012) of factors impacting on health and safety on confined construction sites revealed that a lack of storage space, the safe movement of materials, and an over-crowded workplace, are the three biggest challenges. These top-ranked factors by Spillane et al. are consistent with the findings of this survey.

The findings of this study	**Rank**	**Findings of Spillane et al. (2012)**
Safe movement of materials	1	Lack of adequate storage space
Restricted access for delivery of materials	2	Difficulty to move materials around site safely
Limited storage of materials	3	Workplace becoming over-crowded
Project program issues	4	Intersections and collisions of personnel in heavily travelled routes during construction operations
Congested space	5	Close proximity of individuals to operation of large plant and machinery
Locating material	6	Difficulty in ensuring site is tidy and all plant and materials are stored safely
Health and safety issues	7	Lack of adequate room for the effective handling of materials
Increased resource management	8	Difficulty in ensuring proper arrangement and collection of waste materials on-site
Damage to material	9	Difficulty in controlling hazardous materials and equipment on-site
Personnel in close proximity to machinery	10	Increased possibility of over-crowding the workplace due to lack of available space
Coordination management issues	11	Difficulty in providing temporary facilities on-site to cater for the needs of the site effectively
Increased personnel management	12	Difficult to account for and manage personnel due to the restricted working conditions
Difficulty communicating	13	Difficulty in positioning temporary facilities to avoid accidents from falling heights
Overcrowding of personnel	14	Difficulty in the management of on-site traffic

Table 4.19: Comparison of factors affecting construction in urban centres

Project program issues, congested space, locating material, health and safety issues, increased resource management, personnel in close proximity to machinery, coordination management issues, and increased personnel management, were all identified as occurring more often than not, however difficulty in communicating and overcrowding of personnel were identified as only occurring sometimes or not at all (see Table 4.10). Communication was identified as not being inconvenient, however, the rest were found to be inconvenient more often than not. The preliminary study showed that communication is important, especially between the design and construction teams. The primary study revealed that communication is in fact important, however, it has no effect on construction in urban centres. Moum (2006) stated that during design there needs to be a high degree of communication and collaboration amongst stakeholders. Hadjimanolis (2010) advocated that innovation should be embedded in communication and feedback.

4.5.3 Alleviation of Weaknesses in Current Building Production Processes

The third objective of this study was to identify influences that help alleviate weakness in current building production processes. In the preliminary pilot study and literature review, LAT and BIM were mentioned extensively. In the main study respondents were asked to what degree innovative technologies enhance building production processes during the five stages of construction management. Results showed that in the initiating and planning stages of a project, BIM technology is almost always used towards enhancement of building production processes, while LAT, barcoding, 3D laser scanning, remote sensing and CCTV cameras were not used at all (Table 4.13). These results were partially expected, considering that none of these technologies can be used at the initiating stage of a project. However, laser scanners, indoor location sensing systems and remote sensing can be useful at the planning stage. Table 4.13 indicates that on average, 13% of respondents did not answer this part of the questionnaire. This suggests the percentage of the respondents that did not know or understand the significance of these technologies.

Results affirm that at execution stage of a construction project BIM and LAT are generally useful, while 3D laser scanning is seldom useful. Rapid information accessibility such as bar code scanners and remote sensing imagery, were considered as not useful at all (see Table 4.14). These results were expected as the preliminary study showed that there is no association between bar code scanners or remote sensing within the initiating or planning phases of a construction project. Space management on a congested construction site is a key issue (Tommelein & Zouein, 1993; Sawacha et al., 1999 cited in Spillane et al., 2011:143). Yun-Yi Su (2010:1) suggested that innovation, using enhanced LAT to improve building processes and to support important decision-making tasks in the field, is very important.

Findings in this research study revealed that at the monitoring stage, CCTV cameras and LAT are useful, but BIM is more useful. Although point cloud scanning was useful more often than not, bar code scanners and remote sensing images were not considered useful (see Table 4.15). Remote sensing and monitoring personnel in real-time can improve construction safety by warning equipment operators and personnel on foot, of a potential risk (Cavanaugh & Amendolare, 2010; Schiffbauer, 2001, Teizer et al., 2008; Zhang et al., 2009 cited in Razavi et al., 2012), Without timely and accurate feedback the accuracy of updating a project database is effected; hence many critical decisions cannot be made in a timely manner.

Results in this investigation ascertain that at closing stage, BIM is almost always useful, more than other technologies (see Table 4.16). It is clear from these results that BIM is an extremely useful technology that can have a big impact on improving current building production processes. The preliminary study respondents were unanimous that BIM is an important technology for building construction projects. Respondents described BIM as a carefully coordinated model that can be used from the design stage, into construction and beyond. The respondents agreed that a database-driven model, such as BIM, would be beneficial on site, where project managers and quantity surveyors can count, cost and order material, based on updated real-time information. Furthermore, respondents felt that BIM would be useful for programming, construction sequencing and would reduce mistakes on site. Although some of the respondents described BIM as a just another documenting system, others felt that its use integrates engineering and facilitates collaboration between professionals. Respondents felt that construction managers see BIM as futuristic, referring to it as 'digital engineering'. Respondents felt that project managers and senior engineers in South Africa are generally older and resist change. However, it was noted that younger engineers believe BIM is rapidly becoming an essential tool that will dictate competitiveness in the future. One respondent stated that South African engineers are up-to-date and are contributing to the development of BIM internationally. The suggestion of incorporating cloud storage in BIM was received enthusiastically and respondents agreed that laser scanners are becoming more practical on construction sites. Respondents felt digital engineering should be encouraged at universities so as to produce industry leaders in this regard.

4.5.4 Investment in New Innovative Building Production Methods

The fourth objective of this study was to investigate why construction firms are reluctant to invest in innovative building production methods. Respondents were asked what influences a construction firm's decision to invest in new strategic management methods on construction sites. The study showed that the cost of implementing new innovative construction methods is almost always a factor (Table 4.17). Risk, logistics, personnel training and a lack of knowledge significantly influenced a firm's decision to invest in new innovative construction methods, whereas experimental time, sharing information and technology development is more often than not a factor. The study also revealed that strong leadership is often needed to adopt innovative methodologies for new strategic management methods on construction sites.

4.5.5 Validation of Findings

The external validity of the findings was tested. Five respondents were selected. The participants were all professional practitioners who have been involved in construction management for at least ten years. The participants included contracts managers (2), a project manager (1) and quantity surveyors (2). The participants were asked to agree, partially agree or disagree with the findings of this study (see Table: 4.20).

The respondents agreed that building production management method most used in Cape Town’s central business district is knowledge management, followed by just-in-time delivery of materials. It was agreed that technology and prefabrication are not extensively used during building construction in Cape Town’s urban centres. Further, the respondents agreed with the findings concerning the most effective building management methods used in Cape Town’s Metropolitan urban centres and agreed that technology, although not extensively used, is an effective way to improve building production processes in urban centres.

Respondents partially agreed with the findings that the most adequately addressed knowledge area in building construction management in Cape Town’s central business district is quality management, cost management and time management. Respondents felt that cost management and time management are not adequately addressed.

The respondents did not feel that the safe movement of materials posed the biggest challenge on congested building construction sites; they felt that restricted access for delivery of materials was the biggest challenge. Furthermore, respondents felt that restricted space on site was more inconvenient than damage to building materials.

Respondents agreed with the order of importance of innovative technologies that enhance building production processes during the initiating, planning, executing, monitoring and closing stages of a construction project, but they disagreed that BIM and LAT are being used to enhance building production processes during the executing stage of a construction project, or that LAT is being used during the monitoring stage of a construction project.

Finally the respondents agreed that the factors that influence a construction firm's decision to invest in innovative building production methods, are cost, weak leadership, risk, logistics and the training of personnel.

4.5 CHAPTER SUMMARY

This chapter presents the analysis of data collected during the qualitative preliminary study and the main quantitative study. The data gathered has been corroborated and summarised (see Table 4.20). The diverse sources of data have resulted in comparable responses giving confidence to the data.

RESEARCH ENQUIRY	FINDINGS (most frequent)	External verification (yes - agree, partially agree, no - disagree)
Currently the most used building production management method in Cape Town's central business district (Table 4.7)	• Knowledge management • Just-in-time management • Use of Technology • Prefabrication	Yes - agree
The most effective building management method in Cape Town's central business district (Table 4.8)	• Knowledge management • Use of Technology • Lean construction • Just-in-time • Prefabrication	Yes - agree
Knowledge areas in building construction project management that are adequately addressed in Cape Town's central business district (Table 4.9)	• Quality management • Cost management • Time management • Procurement management • Communication management	Partially agree – cost and time specifically where not adequately addressed

Factors that pose challenges on building sites in Cape Town's central business district (Table 4.10)	• Safe movement of materials • Restricted access for delivery of materials • Limited storage of materials • Project program issues • Congested space	Partially agree - Restricted access/ delivery of materials the biggest challenge
Most inconvenient factor on building sites in Cape Town's central business district (Table 4.11)	• Damage to material • Congested space • Restricted access for delivery of materials • Limited storage of materials • Health and safety issues	Partially agree – indicated that the most inconvenient is congested space
Innovative technologies that enhance building production processes during the *initiating* stage of a construction project (Table 4.12)	• BIM technology • Point Cloud technology • Remote Imagery technology • LAT technology • Bar Code Scanner technology • CCTV technology	Yes - agree
Innovative technologies that enhance building production processes during the *planning* stage of a construction project (Table 4.13)	• BIM technology • Point Cloud technology • Remote Imagery technology • Bar Code Scanner technology • LAT technology • CCTV technology	Yes - agree
Innovative technologies that enhance building production processes during the *executing* stage of a construction project (Table 4.14)	• BIM technology • LAT technology • CCTV technology • Point Cloud technology • Bar Code Scanner technology • Remote Imagery technology	No – BIM and LAT are not currently being used at executing stage
Innovative technologies that enhance building production processes during the *monitoring* stage of a construction project (Table 4.15)	• BIM technology • CCTV technology • LAT technology • Point Cloud technology • Bar Code Scanner technology • Remote Imagery technology	Partially agree – agree with CCTV Cameras but noted that LAT is not used

Innovative technologies that enhance building production processes during the *closing* stage of a construction project (Table 4.16)	• BIM technology • CCTV technology • LAT technology • Point Cloud technology • Bar Code Scanner technology • Remote Imagery technology	Yes - agree
Factors that influence a construction firms decision to invest in innovative building production methods (Table 4.17)	• Cost • Strong leadership • Risk • Logistics • Training personnel	Yes - agree

Table 4.20: Summary of the research findings

CHAPTER FIVE

CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH

5.1 INTRODUCTION

This chapter provides concluding remarks based on findings of the research, recommendations and future research topics. The problem statement of this study is of concern that construction firms in South Africa are not innovative or dynamic when it comes to improving building production processes. This is problematic as the success of building construction in urban centres hinges upon the ability of the construction firm to be strategic, which is to know better than others, what direction to go in, what risks to take, the available resources and the capabilities to develop in order to fulfil some planned goal.

This research investigates and identifies current building production processes in urban centres and evaluates the success of these processes on a construction firm's competitiveness.

The research objectives:

1. To investigate the strategies that are currently being employed during building production processes in urban centres.
2. To identify problems and constraints on building production processes in urban centres.
3. To identify the factors that help mitigate weakness in current building production processes.
4. To ascertain qualifying ways of improving building production processes in urban centres.
5. To establish effective management systems that would significantly enhance building production in urban centres

A graphical framework for this study is presented in Figure 5.1 outlining the study objectives and the respective outcomes. Summary of the findings are documented within this chapter.

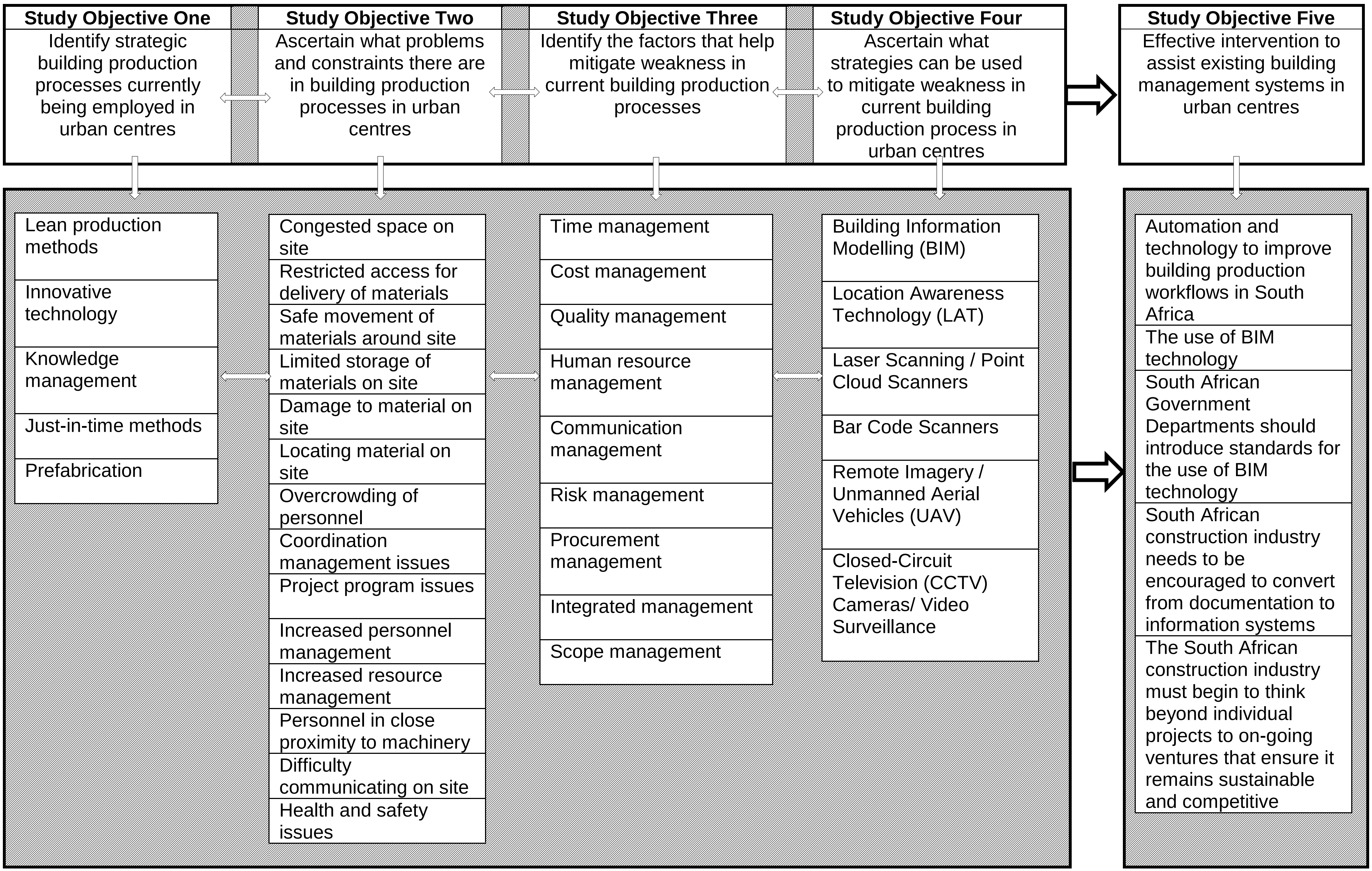

Figure 5.1: Framework for effective management of building production systems in urban centres

5.2 CONCLUSIONS

The conclusions below are derived from the results of data collection analysis and discussion of findings in Chapter 4.

5.2.1 Strategic Building Production Processes

The first objective of this study investigates the strategic building production management methods that are currently being employed in the South African construction industry. This study identifies five methods that are currently being used in building production in the City of Cape Town's urban centres. Furthermore this study has shown that cost and time are the most critical factors in building construction management in the City of Cape Town's urban centres. The most successful strategy to manage cost and time is through lean construction. Just-in-time construction methods, knowledge management and prefabrication, preassembly, modularisation, and off-site fabrication techniques are methods in construction that effectively decrease cost and time of construction in urban centres without compromising quality.

- Lean construction management has been identified as being useful in building production processes and is currently being implemented on the majority of building projects in the City of Cape Town's urban centres.
- This study affirms that knowledge management is a useful method to improve building production processes. Knowledge management ensures the preservation of valuable knowledge and the capturing of creativity of individuals that generate innovation. The efficient management during construction with lean methods enhance the delivery time through quick learning. Time-based competition is a marketing tool that can give a building construction firm a competitive edge. Knowledge management harnesses a web of information that includes innovative thought processes, assumptions and opinions. Hence knowledge management leads to wisdom through the re-use of information for different purposes and in different contexts.
- The use of just-in-time methods in construction has been identified as another strategic management method used in the City of Cape Town's urban centres. Just-in-time delivery of materials is intended to improve the cost and time of a project. The objective of just-in-time approach is to meet project time constraints without any unnecessary schedule improvement. To achieve project time constraints project control is required to monitor progress and to add resources only when it is required.

- The use of prefabrication, preassembly, modularisation, and off-site fabrication techniques and processes have also been identified as a construction method that provides time saving advantages. These activities could significantly increase construction efficiency and improve the quality, time and cost of a project. According to this survey prefabrication, preassembly, modularisation, and off-site fabrication techniques are well established strategies in building construction, however, this method of construction is not as popular in urban centres in the City of Cape Town.
- The use of current innovative technology is being used to address a significant number of issues concerning cost and time on construction projects. BIM technology links all building production processes using one continuous information model. This study indicates that the use of BIM technology is useful from initiating to the closing stage of a building project. BIM integrates all elements and modules, precisely defining function, position and schedule. BIM is an intelligent technology that allows instant updates of information with accuracy.

5.2.2 Problems and Constraints in Building Production Processes in Urban Centres

The second objective of this study identifies problems and constraints in building production processes in urban centres. Problems and constraints accrue in urban centres due to the complex nature of construction within a confined space, congestion and restricted access to the construction site. This creates challenges when reliable and predictable workflow is interrupted. This study identifies some significant factors that affect the alignment of the supply chain on construction site in urban centres (Table 5.2). Three construction sites in the Cape Town central business district were photographed during this research to obtain visual evidence of these factors (Plates 5.3 – 5.8). The increasing number of inner-city developments suggests that congested site construction is rapidly becoming the norm within the industry. The complex nature of construction in urban centres includes confined space, congestion and restricted access to a construction site. The factors that influence supply chains in urban centres are the safe movement of materials, restricted access for delivery of materials, limited storage of materials, project program issues, congested space, locating material, health and safety issues, increased resource management, damage to material, personnel in close proximity to machinery, coordination management issues, increased personnel management, difficulty communicating and overcrowding of personnel.

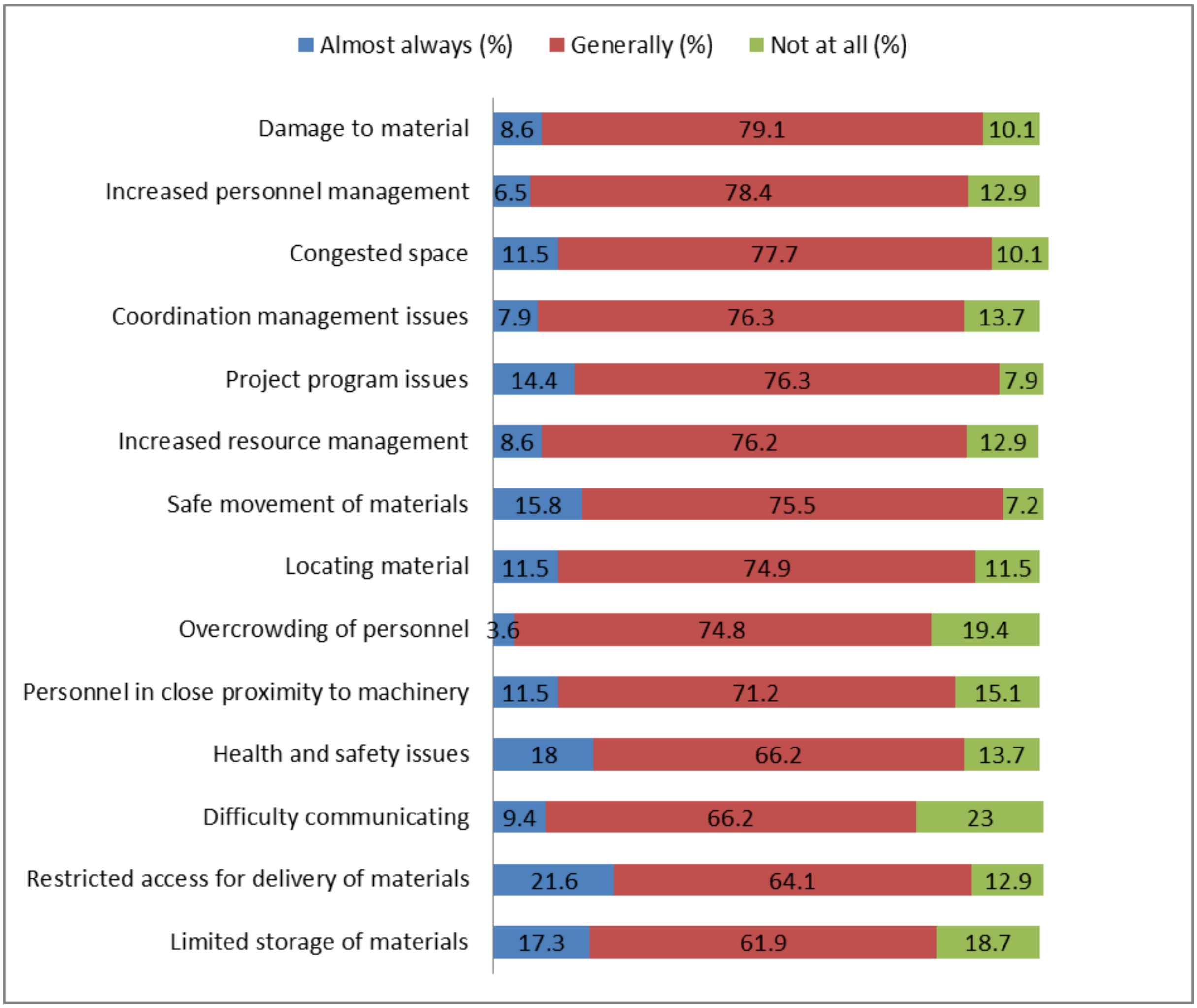

Table 5.1: Problems and constraints on construction sites in Cape Town's urban centres

5.2.3 Qualifying Ways of Improving Building Production Processes in Urban Centres

The third and fourth objectives of this study identifies the factors that help to mitigate the weaknesses in current building production processes and ascertain qualifying ways of improving building production processes in urban centres. This study identifies the use of innovative technologies as a means to address weakness in current building production processes. There is clear indication from this study finding that innovative technology can be used to vastly improve building production in the urban centres and the construction firms that utilise these technologies will have a competitive advantage over others that ignore it.

Innovative Technology	Process groups in building production management				
	(a) Initiating	(b) Planning	(c) Executing	(d) Monitoring	(e) Closing
(1) BIM technology	✓	✓	✓	✓	✓
(2) LAT technology	x	x	✓	✓	x
(3) Point Cloud technology	x	x	✓	✓	x
(4) Bar Code Scanner technology	x	x	✓	x	x
(5) UAV technology	x	x	x	x	x
(6) CCTV technology	x	x	x	✓	x

Table 5.2: Innovative Technologies

- The use of BIM technology will significantly contribute to the success of building management systems such as knowledge management, just-in-time construction methods, lean construction methods and the use of modular prefabrication construction. South African government departments should introduce standards for the use of BIM technology as the United Kingdom and other governments have. Furthermore the South African construction industry needs to be encouraged to convert from documentation to information systems. This will unlock data that can be linked across cities and across the country.
- The production of point cloud information through laser-scanning technology provides a vast pool of information about as-built structures. Laser scanners provide point cloud information that can be used to interpolate information between designs and help structural engineers, architects and construction engineers to process, visualise and synthesise design and construction more clearly.
- The use of remote sensing technology using UAVs, CCTV sensors and bar code scanners can ensure optimum distribution of sensors on a construction site so that future

behaviour and potential responses can be identified. This will allow for a system that can respond appropriately to differing situations and different desired outcomes. UAVs are increasingly being used for civilian use. The use of UAVs in construction can provide management opportunities and innovation that will contribute to a construction firm's competitiveness. Innovative ways of introducing drones onto construction sites include safety and quality management by providing real-time data and analysis so that project teams can act timeously to situations. UAVs can be used to collect environmental information such as air quality and temperature to ensure safe operation of projects. UAVs have been extensively used and developed in South Africa however it was announced in 2014 that the lack of aviation regulations on the use of UAVs deemed them illegal. Draft regulations submitted by the South African Civil Aviation Authority in January 2015 have paved the way for the legalising of this technology. This survey indicates that the construction industry in South Africa has yet to realise the usefulness of this technology however this survey found that in the City of Cape Town 15% of respondents frequently use UAVs in building construction while 42% generally do and 29% not at all.

- LAT uses several radio technologies that supply wireless connectivity. This technology is being explored in shopping malls where retailers are experimenting with achieving deeper customer engagement by helping them find the precise location of products and staff. The construction industry can actively deploy these solutions to address factors that affect construction in urban centres such as the management of congested space, locating materials, managing restricted access for delivery of materials, safe movement of materials, health and safety issues, communicating, coordination management and increased resource and personnel management (see Table 4.11). This survey suggests that the use of LAT is generally used during the executing and monitoring stages in the building production process, however, the true success of implementing LAT on construction sites will only materialise with innovation and the discovery of new applications, which will be either stand-alone applications or in combination with other technologies.

5.3 RECOMMENDATIONS

The final objective of this study is to recommend interventions for more effective management of building construction in urban centres.

5.3.1 Automation and technology

Automation and technology is an effective management system for building production in urban centres to improve building production workflows. The construction industry in South Africa seems to be reluctant to invest in innovative technology for building construction projects. The biggest obstacle a firm faces when making a decision to invest in innovative technology is cost of equipment and training. Furthermore, weak leadership was found to influence a firm's decision to modernise. Risk, logistics and training of personnel are all issues that a firm needs to consider. The lack of technological knowledge, experimental time, sharing of information and technological development are also influential. The use of technology is proving to be useful during all stages of building construction.

5.3.2 The use of BIM technology

BIM is an emerging technology that is globally accepted in the construction industry and is gaining momentum. The BIM trend in African is progressive with building construction firms in Cape Town using BIM extensively during the initiating and planning stages of a project. BIM needs to be utilised to its full potential and be supported through various policy frameworks by different stakeholders of the AEC sectors such as the statutory councils and the government agencies. The staged adoption of BIM and a new policy framework in the South African AEC sector need to be put in place. BIM technology is applicable throughout the process in building construction management (see Table 5.2). BIM technology allows the project to be seen within the context of the system it will operate in. The convergence of building production methodologies and technology is allowing better management of information.

5.3.3 Standards for the Use of BIM Technology

This study indicates that, although current building production processes in South African are advancing and competitive they are not adequately aligned with the construction industry internationally (see Table 4.18). Data standards need to be established so that the different disciplines can take ownership and responsibility for authoring and updating the data. Lessons can be learnt from the implementation of data standards and policy regarding BIM in the United Kingdom.

5.3.4 Documentation and Information Systems

The South African construction industry needs to be encouraged to convert from documentation to information systems. This will unlock data that can be linked across cities and across the country. The construction industry must play its role in the notion of smart cities and the realm of the virtual world that merges with the physical. The South African construction industry must begin to think beyond individual projects to on-going ventures that ensure it remains sustainable and competitive.

5.4 FURTHER RESEARCH

This study has affirmed that the use of technology is proving to be useful during all stages of building construction; importantly BIM is an emerging technology that is globally accepted in the construction industry and is gaining momentum in the South Africa construction industry.

The suggested area of further research involves the use of BIM technology in Building Construction Management. The following topics of research are suggested:

- Management of Building Information Models – Building information models span from initiating a building construction project to its closing and management. Building Information Models can bridge the information loss associated with handling a project from design team, to construction team and to building owner/operator.

- Open Standards for Building Information Modelling Data – How are they developed and what is their role in building and operating built Environments.

- The use of Building Information Modelling on large construction sites for health and safety management.

- Building Information Modelling in construction management – challenges to deliver successful projects despite tight budgets, limited manpower, accelerated schedules, and limited or conflicting information.

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APPENDIX A

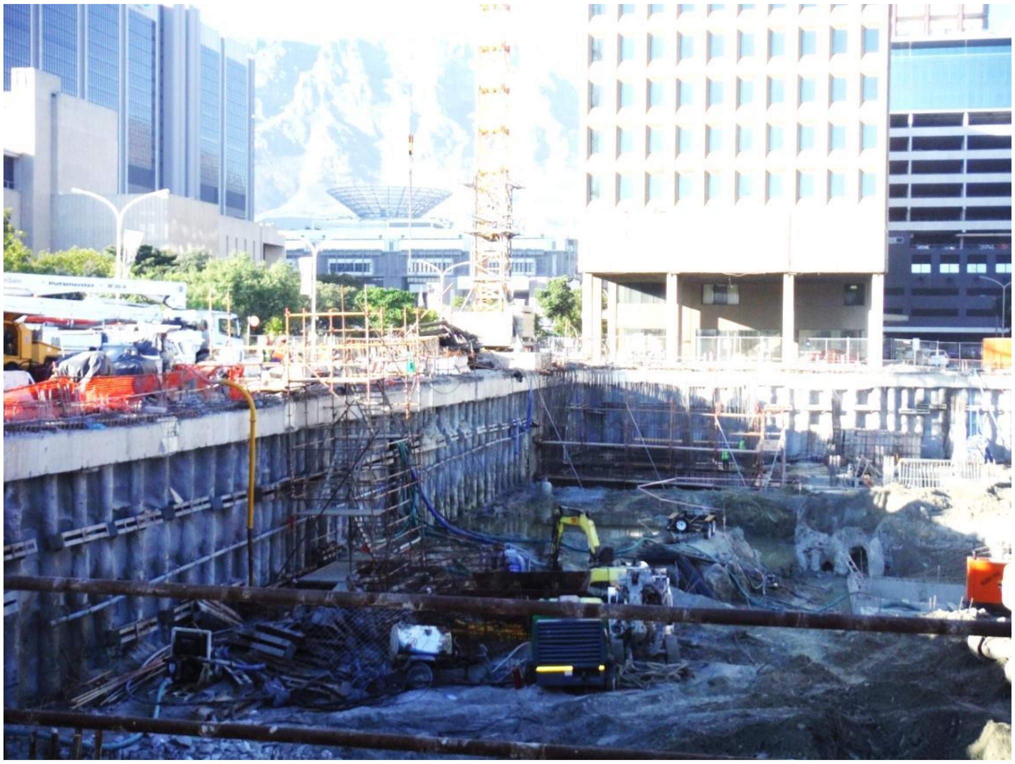

Plate 5.1: Confined space, congestion and restricted access for delivery of materials (Christiaan Barnard Hospital, Cape Town Urban Centre, 2014)

Plate 5.2: The safe movement of material, damage to materials and location of materials (Christiaan Barnard Hospital, Cape Town Urban Centre, 2014)

Plate 5.3: Close proximity of construction to existing buildings (Christiaan Barnard Hospital, Cape Town Urban Centre, March 2014)

Plate 5.4: Close proximity of construction to existing buildings (Christiaan Barnard Hospital, Cape Town Urban Centre, April 2015)

Plate 5.5: Restricted space and personnel in close proximity to machinery (Touchstone Office Development, Cape Town Urban Centre, August 2013)

Plate 5.6: Noise and dust – inconveniance for existing commercial buildings (Touchstone Office Development, Cape Town Urban Centre, August 2013

Plate 5.7: Construction materials and storage containers spill into the adjacent street necessitating road closure (Touchstone Office Development, Cape Town Urban Centre, April 2015)

Plate 5.8: Traffic and pedestrian access restricted due to construction (Touchstone Office Development, Cape Town Urban Centre, April 2015)

Plate 5.9: Incorporating the existing building facade - heritage requirement (Touchstone Office Development, Cape Town Urban Centre, April 2015)

Plate 5.10: Restricted access for delivery of materials (Touchstone Office Development, Cape Town Urban Centre, April 2015)

Plate 5.11: The confined site and limited access has required intricate planning of the positions of cranes and site operations (The Towers, Cape Town Urban Centre, March 2013)

Plate 5.12: The use of BIM technology has allowed the modelling of the layout to ensure clashes are limited and interference with existing buildings and foundations avoided (The Towers, Cape Town Urban Centre, April 2015)

Plate 5.13: The first phase of the project was the demolition of an existing four-story building above a basement that continues to operate as a parking garage with active traffic movement (The Towers, Cape Town Urban Centre, March 2013)

Plate 5.14: Ready-mix concrete delivery (The Towers, Cape Town Urban Centre, March 2013)

APPENDIX B
Questionnaire

Cape
Peninsula
University
of Technology

Dear Sir/Madam,

RE: <u>PARTICIPATION IN A QUESTIONNAIRE SURVEY</u>

I hereby request your assistance in completing the following quantitative research survey. This study is for academic purposes in compliance withthe Master of Technology in Construction Management, from the Department of Construction Management and Quantity Surveying at Cape Peninsula University of Technology. My research topic is **<u>INNOVATIVE PRACTICES FOR EFFECTIVE MANAGEMENT OF BUILDING PRODUCTION PROCESSES WITHIN URBAN CENTRES</u>**.

This research investigates the complex nature of building construction in urban centres. The increasing number of inner city developments suggests that congested site construction is rapidly becoming the norm within the industry. The complex nature of construction in urban centres includes confined space, congestion and restricted access to a construction site. This creates challenges such as personnel in close proximity, increase personnel management, project planning issues, coordination of management and increased resource management.

This contemporary research is exciting and relevant in the context of South Africa's construction industry. Your valued input and support will contribute greatly to the outcome of this research. Please endeavour to answer all the questions. This study will be kept strictly **<u>CONFIDENTIAL</u>** and will only be used for academic research purposes. Thank you for the anticipated help and courtesy in this matter.

Please return to:

Laura Pinfold
P.O.Box 1906
Bellville
7535

Email: **<u>pinfoldl@cput.ac.za</u>**
Cell Phone: 083-4401805

SECTION 1

BIOGRAPHICAL INFORMATION OF RESPONDENT

Kindly answer all questions. Please mark **(x)** the CORRECT box.

1. Kindly specify which of the following categories your company belongs to:

Contractor	
Architectural firm	
Project management firm	
Quantity surveying consultant firm	
Sub-contractor firm	
Others (Please specify)	

2. Kindly indicate your gender:

Male	
Female	

3. Please indicate your age group:

Below 26	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	65 Above

4. Please indicate the highest formal qualification you obtained:

Matric Certificate	
Diploma	
Post Graduate Diploma	
Bachelor degree	
Honors degree	
Master's degree	
Doctorate degree	
Others (Please specify)	

5. In which urban centres have you worked?

Urban Centre	
Cape Town	
Bellville	
Claremont/ Wynberg	
Somerset West	
Philippi Centre	
Other	

6. Kindly indicate your present position in your organisation ……………………………….…

7. How long have you been working in this position? ……………………………………..

SECTION 2:

The objective of this question is to investigate what strategic building production processes are currently being employed in urban centres.

2.1 How often are the following strategic managing practices used during building production?

Kindly tick the appropriate frequency scale from 1 to 5: where; **Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5**

Strategic management methods used in urban centres		How often are they used in current building projects				
1	Lean construction methods	1	2	3	4	5
2	Use of innovative technology	1	2	3	4	5
3	Knowledge management	1	2	3	4	5
4	Just-in-time delivery of materials	1	2	3	4	5
5	Prefabrication	1	2	3	4	5
Other (kindly specify)						
6		1	2	3	4	5
7		1	2	3	4	5
8		1	2	3	4	5

2.2 How effective are the following strategic managing practices in enhancing building production processes?

Kindly tick the appropriate frequency scale from 1 to 5: where; **Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5**

Strategic management methods used in urban centres		How effective are they in enhancing current building projects				
1	Lean construction methods	1	2	3	4	5
2	Use of innovative technology	1	2	3	4	5
3	Knowledge management	1	2	3	4	5
4	Just-in-time delivery of materials	1	2	3	4	5
5	Prefabrication	1	2	3	4	5
Other (kindly specify)						
6		1	2	3	4	5
7		1	2	3	4	5
8		1	2	3	4	5

SECTION 3:

The objective of this question is to identify problems and constraints in building production processes in urban centres.

3.1 How effectively (based on frequency) do current building production processes address the following knowledge areas on a construction site?

Kindly use/write from the scale 1 to 5 to indicate the appropriateness: where;
Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5

	Knowledge areas					
1	Time management	1	2	3	4	5
2	Cost management	1	2	3	4	5
3	Quality management	1	2	3	4	5
4	Human resource management	1	2	3	4	5
5	Communication management	1	2	3	4	5
6	Risk management	1	2	3	4	5
7	Procurement management	1	2	3	4	5
8	Integrated management	1	2	3	4	5
9	Scope management	1	2	3	4	5

3.2 What level of occurrence and what level of inconvenience do the following challenges pose during building production on a building site in an urban centre?

Kindly tick the appropriate frequency scale from 1 to 5: where; **Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5**

	Challenges posed during building production in urban centres	Level of occurrence					Level of inconvenience				
1	Congested space on site	1	2	3	4	5	1	2	3	4	5
2	Restricted access for delivery of materials	1	2	3	4	5	1	2	3	4	5
3	Safe movement of materials around site	1	2	3	4	5	1	2	3	4	5
4	Limited storage of materials on site	1	2	3	4	5	1	2	3	4	5
5	Damage to material on site	1	2	3	4	5	1	2	3	4	5
6	Locating material on site	1	2	3	4	5	1	2	3	4	5
7	Overcrowding of personnel	1	2	3	4	5	1	2	3	4	5
8	Coordination management issues	1	2	3	4	5	1	2	3	4	5
9	Project program issues	1	2	3	4	5	1	2	3	4	5
10	Increased personnel management	1	2	3	4	5	1	2	3	4	5
11	Increased resource management	1	2	3	4	5	1	2	3	4	5
12	Personnel in close proximity to machinery	1	2	3	4	5	1	2	3	4	5
13	Difficulty communicating on site	1	2	3	4	5	1	2	3	4	5
14	Health and safety issues	1	2	3	4	5	1	2	3	4	5
Other (kindly specify)											
15		1	2	3	4	5	1	2	3	4	5
16		1	2	3	4	5	1	2	3	4	5

SECTION 4:

The objective of this question is to identify the factors that help alleviate weakness in current building production processes

4. To what degree do the following innovative technologies enhance building production processes during the five stages of construction management?

Kindly use/write from the scale1 to 5 to indicate the appropriateness: where;
Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5

Innovative Technology		Process groups in building production management				
		Initiating	Planning	Executing	Monitoring	Closing
1	Computer software that facilitates communication of data, knowledge and design solutions between project participants i.e. Building Information Modelling					
2	Indoor location sensing systems i.e. location awareness technology					
3	Computer software that facilitates three dimensional (3D) laser scanning i.e. Point Cloud Scanners					
4	Rapid information accessibility i.e. Bar Code Scanners to build computer databases					
5	Remote imagery for site and layout planning i.e. unmanned aerial vehicles UAV/drone					
6	Closed-circuit television (CCTV) cameras i.e. video surveillance					
Other (kindly specify)						
7						
8						
9						

SECTION 5:

The objective of this question is to investigate why construction firms are reluctant to invest in innovative building production processes.

5. To what degree do the following issues influence a construction firm's decision to invest in new strategic management methods on construction sites?

Kindly use/write from the scale 1 to 5 to indicate the appropriateness: where;
Not at all =1, Sometimes =2, Often = 3, Generally =4, Almost always =5

	Knowledge areas					
1	Money/finance/cost	1	2	3	4	5
2	Logistical difficulties	1	2	3	4	5
3	Risk/comfort zone	1	2	3	4	5
4	Waiting for improvements in the technology/management methods	1	2	3	4	5
5	Lack of knowledge/experience with technology/management methods	1	2	3	4	5
6	Training of personnel	1	2	3	4	5
7	Affording experimental time	1	2	3	4	5
8	Sharing/exchange of information	1	2	3	4	5
9	Strong leadership	1	2	3	4	5
Other (kindly specify)						
10						
11						
12						

SECTION 6:

This section explores individual perspectives on current use of strategic management methods (management of cost, time and quality) in urban centres.

6. Indicate your agreement/disagreement with the following statements regarding the current status of strategic management methods currently employed in urban centres.

Kindly tick one of the following codes **1 = Do not agree or 2 = Agree**

	Individual perspectives on strategic management methods during building production processes		
1	Current building production processes in South African are advanced and competitive	1	2
2	Current building production processes in South African are internationally aligned	1	2
3	Current building production process in South Africa need to be modernised	1	2
4	There are policies in place to mitigate weaknesses in the current building production processes in South Africa	1	2
5	Automation and technology is being used to improve building production workflows in South Africa	1	2
6	The construction industry in South Africa is reluctant to use innovative strategic management methods in urban centres	1	2

THANK YOU

APPENDIX C

CONFERENCE PAPERS ABSTRACTS

USING LOCATION AWARENESS TECHNOLOGIES FOR INNOVATIVE CONSTRUCTION MANAGEMENT IN URBAN CENTRES, CAPE TOWN, SOUTH AFRICA

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The continued growth of inner city construction coupled with the mounting costs of land in the urban centres puts pressure on inner city construction management. The complex nature of construction in urban centres requires innovative methods for site management. Confined space, congestion and overcrowding and the jamming of new buildings within existing structures poses challenges. Construction firms in South Africa tend not to be innovative or dynamic when it comes to improving building production processes. This is problematic as the success of building construction in urban centres hinges upon the ability of the construction firm to be strategic, which is to know better than others, what direction to go in, what risks to take, the available resources and capabilities to develop in order to fulfil some planned goal. Using the latest remote sensing technologies to provide real-time access to the location of materials, equipment and workers on a congested construction site could significantly improve the construction process. The confined characteristic of construction sites in urban centres makes location awareness critical. Location awareness technologies can improve manual processes and support important decision-making tasks in the field. This paper investigates the competitiveness and innovation of construction firms operating in urban centres within the Cape Town metropolis South Africa and whether construction companies find location awareness technologies and geospatial data useful for construction management on confined sites. A sample will be gathered from project managers, registered building contractors as well as building consultants and private owners in the Cape Town Metropolis using structured interviews and questionnaire. Empirical evidence shows that the use of automation and integration technologies improves construction productivity and exhibit tight integration of data and provides a workflow solution that improves production.

USING GEO-SPATIAL TECHNOLOGY TO MANAGE INNER-CITY BUILDING CONSTRUCTION WITH CONFINED SPACE AND CONGESTED ACCESS, CAPE TOWN, SOUTH AFRICA

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This research seeks to examine the shortcomings of current inner-city building production processes in Cape Town, South Africa. Confined space, congested access and the proximity of over crowed public places pose challenges when it comes to inner-city construction. The increasing number of inner city developments in Cape Town suggests that congested site construction is rapidly becoming the norm within the construction industry. This demands innovative ways of improving building construction processes in urban centres for increased competitiveness. The aim of this study is to investigate to what extent construction firms in South Africa are using geo-spatial technology to manage issues such as health and safety of personnel in close proximity to machinery, storage of materials, access to the construction site, and the availability and delivery of construction materials. Empirical studies indicate that construction firms in South Africa are reluctant to employ new technology. The possible cause for this could be financial, logistical difficulties, risk, waiting for improvements in the technology, lack of knowledge of new technology, lack of commitment of top management, training of personnel, affording experimental time, sharing/exchange of information and lack of strong leadership. A causal-comparative approach has been adopted to investigate to what degree innovative technologies such as Building Information Modelling (BIM), Location Awareness Technology (LAT), point cloud scanners, spatial awareness tools (bar code scanners), remote sensing (UAV/Drone) and wireless video surveillance cameras support each of the five management process groups that interact in a project i.e. initiating, planning, executing, monitoring and closing. It is imperative that construction firms realise that intelligent use of data and information is needed to address project constraints such as cost, time and quality.Project management knowledge areas such as risk management, knowledge management, cost management, time management and others need to be addressed.Interviews with engineers, architect and land surveyors involved in the construction industry highlighted the need for accurate data for improving production process on congested construction sites, as well as for better

decision-making about machinery, materials, manpower, cost, time and quality. Management principles and practices i.e. organising, controlling, delegating, forecasting, planning, communication and co-ordination need innovative processes for building production. There was a general interest in BIM technology as a way of integrating and collaborating information. Geo-spatial awareness and the use of high-quality data allow physical assets to be located and documented to facilitate industry regulatory requirements to ensure safe and ongoing operations. These results are discussed and analysed in this paper.