UNIVERSITY OF NAIROBI

SCHOOL OF BUILT ENVIROMENT

APPLICABILITY OF SITE AUTOMATION IN MONITORING PROJECT PERFOMANCE IN KENYA:

A Case Study of Construction Firms in Nairobi

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B53/68408/2013

Research Project Presented in Partial Fulfillment of Master of Arts Degree in Construction Management in the Department of Real Estate and Construction Management

JULY 2016

DECLARATION

DECLARATION BY THE CANDIDATE

I, John Njoroge Kimani declare that this research project is my original work and has not presented for the award of a degree in any other university.

Signature: ……………………………………….. Date: ……………..……………

DECLARATION BY THE SUPERVISOR

This research project has been submitted for examination with my approval as the university supervisor.

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ACKNOWLEDGEMENT

To the *Heavenly Father* who has been so gracious by enabling me to complete this research and my studies. I give all adoration and praise to his Holy name and pray that may his grace continue carrying me through as I seek to excel in all I do.

I appreciate the work and guidance of my supervisor, *Qs. Thomas Ng'olua* and all the lecturers from School of Built environment for dedicating their time throughout this research. I thank you all.

To all my colleagues, at the State Department of Housing and Urban Development, starting with the Director of Housing *Mrs. Jane Mwangi* and my immediate supervisor *Arch. Raphael Owoko* for their encouragement and support. I thank you.

I wish to acknowledge my longtime friend and data analyst, *Mr. Joshua Kinyua ('Dagitari')* for his guidance and support during my studies. Your comments and support were highly appreciated.

To all my classmates, you were the best class I ever had. May God bless you for your contributions during in this study. Thank you for your encouragement. You kept me on my toes and dedicated your time in my studies.

Finally, my appreciation goes to all construction firms that participated in this research and took time to fill and return the questionnaires. May God bless you.

DEDICATION

I wish to dedicate this work to my dear wife, *Naomi*, and daughter *Tiffany* for their encouragement and unwavering support. I treasure you so much.

ABSTRACT

In modern construction management, site automation has been used to improve on project performance. This study sought to evaluate factors affecting site automation levels in construction firms and identify their impact on project performance. The study identified seven factors affecting site automation levels. The study hypothesized that, site automation levels varies significantly with the size of a firm, complexity of a project and cost of site automation technologies. Further, sought to find out whether there is significant difference in project performance by construction firms that have high automation levels than those with minimal automation levels. The study employed two conceptual models to establish the factors affecting site automation levels on construction sites and further explore the influence of site automation on project performance. Higher project performance was measured in terms impact of site automation on project time, budget, quality, scope, and safety.

The study employed descriptive research design and structured questionnaires were used in data collection from a sample size of 277 construction firms registered under NCA 1-3. The impact of factors affecting adoption of site automation technologies and evaluation of the impact of automation on project performance was measured using a five-point likert scale. Correlation analysis was undertaken to determine the strength and significance of association between factors influencing automation and levels of site automation while to explain the variance in levels of site automation and to generate a predictive model, standard multiple regression was undertaken. Finally, to establish whether the level of site automation significantly varies with the theorized factors of site automation, a chi-square test for independence was undertaken.

The results showed that the level of site automation is strongly and significantly associated with costs of automation, size of the firm, project magnitude, and staff capacity. The results showed that majority of the firms (96 percent) were using partial automation. The results further indicated that automation of labour, materials, plant and equipment; construction processes can be associated with improved project performance up to 41.9 percent. The study established that there is significant difference in project performance by construction firms that have high levels of site automation than those with minimal levels of automation. In this regard, 76.7 percent of the firms indicated that use of site automation technologies had a major influence on project performance with greater influence on improved quality, better health and safety, and reduction in completion time and thus recommended that firms be sensitized in the adoption of site automation technologies. The study further recommends that, the National Construction Authority to formulate legal framework that construction firms that can be used to use site automation to improve project performance.

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ABBREVIATIONS AND ACRONYMS

3D	-	3-Dimensional
4D	-	4-Dimensional
ACMS	-	Advanced Computer based Management Systems
AEC	-	Architecture, Engineering & Construction
ADC	-	Automatic Data Collection
ASCE	-	American Society of Civil Engineers
ANOVA	-	Analysis of Variance
CMAA	-	Construction Management Association of America
EDM	-	Electronic Data Management
GDP	-	Gross Domestic Product
GNP	-	Gross National Product
GPS	-	Global Position Systems
GIS	-	Geographic Information System
ICT	-	Information Communication Technology
IT	-	Information Technology
FCC	-	Federal Communications Commission
LADAR	-	Laser Detection and Range tracking
NCA	-	National Construction Authority
PMI	-	Project Management Institute
RFID	-	Radio Frequency Identification Device
RFID-QIM	-	RFID-based Quality Inspection and Management
UWB	-	Ultra Wide Band
WPMS	-	Web-based Project Management Systems
VRS	-	Virtual Reality Systems
MW	-	Mega Watts
IPD	-	Immersive Projection Display

CHAPTER ONE

1.1 Introduction

Construction is the activity of creating physical infrastructure, super structure and related facilities such as buildings, manufacturing plants, roads, and bridges. According to Project Management Institute (PMI), sound project management ensures efficient utilization of construction resources such as labour, materials, plant, and equipment in a construction site throughout the project life cycle. The use of advanced automation technologies in project delivery has resulted into a paradigm shift in recent decades with the construction achieving great strides as a result (PMI 2014).

Khoshnevis (2004) noted that the construction industry has been slow in adoption of automation as compared to the manufacturing industry. In addition, Balguer (2003) noted that, the construction firms utilize site automation technologies on projects as a way of improving project performance due to the associated benefits such as: costs savings, quality improvement, safety and health improvement, reduction in time of a project among others. Unfortunately, the construction sector has been slow in the adoption and use of site automation technologies compared to other sectors in the economy, therefore making the construction process to be a labor-intensive, tiresome in monitoring project performance (Balguer 2003).

The construction industry forms one of the largest and most fragmented industries that bring together various stakeholders in a project thus requiring great co-ordination to achieve the set objectives (Isikdag et al. 2007). Johnson and Laepple (2003) argued that advancement in information and communication technologies (ICT) is a key tool in the co-ordination of construction projects with a view of facilitating improved productivity and performance in construction sites. Bridgewater (1993) further pointed out that, experience from other sectors showed that the principles of design for automation of construction tasks was a key consideration in automating task and process levels.

According to Sardroud (2012a), construction projects are dynamic, multi-faceted comprising of different life cycle phases and are undertaken in unique environments' that are often complex and thus requires greater co-ordination efforts for successful delivery. Modern construction management requires real-time and accurate information, which can be utilized and shared by all parties involved in the project for efficiency planning and execution of construction projects (Sardroud 2012a).

Elsewhere, Bohn (2009) noted that, monitoring and tracking of project performance in a construction site is important in attaining efficient project delivery, regardless of projects complexity due to the constantly changing job site environment. Further, though the majority of the construction sites employs manual task monitoring (i.e. visual inspection and paper-based checklists), most of the site managers, project managers, architects and engineers largely relies on available technologies to update projects' data when collecting site performance information (Bohn 2009).

In a construction site, the impact of management decisions on construction works and processes is often limited because of delays in provision of accurate reports thus affecting project performance parameters (Sacks et al. 2002). Sacks et al (2002) further points out that the available information and control systems of monitoring project performance are inadequate with progress reports being delivered late , thus leading to reactive approach to correction of wrong trends. On the other hand, Sacks et al. (2002) argued that monitoring of indirect parameters of a construction project and processing of the data obtained could provide insightful indicators that could determine project progress.

Researchers have identified automation technologies that can provide real and objective information to project teams that may otherwise would be difficult or time consuming to obtain (Bohn, 2009). Further, Bohn (2009) argues that, to satisfy owner specified requirements and to maintain competitive advantage, construction firms often have access to a pool of technologies for adoption in construction projects.

Construction firms in Kenya faces a myriad of challenges in delivery of construction project as projects continues to be complex. Statistics obtained from the Kenya National Bureau of Statistics') showed that, the building and construction sector contributed approximate 11.1 percent of the country's GDP (KNBS 2015). The building and construction sector registered an accelerated growth of 13.1 percent in

2014 compared to 5.8 percent in 2013 (KNBS, 2015). This growth was attributed to an increase of funds allocated to construction of infrastructure projects coupled with rehabilitation of existing road networks (ibid).

According to Wachira (1999), Kenya, as a developing country is not exception to the trends in other countries, which continues to experience myriad of challenges with the projects being delivered with time lags. Zubeah et al. (2006) observed that, there were little efforts made to address the challenges of project progress monitoring and control. Research on construction site automation has progressed well in developed countries in comparison with developing countries.

In a recent interview, Dr. Macharia, the chairperson of Kenya Private Developers Association (KPDA) pointed limited capital is a major challenge that most construction firms' encounters in an effort to improve project performance, leading to poor project delivery (Onsare, 2011). Further, the sector's management neither promotes innovativeness and merit, hence impeding the perceived development skills and ideas in the sector. In this regard, it is therefore critical to address the challenges in construction sites through site automation to ensure improved project performance.

1.2 Problem statement

The construction industry is complex in nature because it comprises of a large number of stakeholders whose main objective is to deliver construction projects successfully. However, the industry contributes approximately 10 percent of the Gross National Product (GNP) in developed countries (Navon 2007). The complex nature of construction tasks and processes calls for a more streamlined processes that can enhance delivery of high quality and economical projects (Bohn 2009).

Warszawski and Navon (1998) identified challenges of labour inefficiency, increased accident rates at construction sites, poor quality of workmanship and difficulty in controlling the construction sites as critical concerns faced by construction site managers. A study by the Stichiting Bouw Research Center (2000) showed that 6 to 7 percent of contract expenses results from inefficient processes and tasks that do not meet the agreed and set specifications of the project.

Wamelink, Stoffelem & Der (2002) observed that inadequate management of the construction processes was the major cause of project failure. Further, these challenges necessitated for radical changes in traditional project management and communications methods. One of the early innovations in measuring project performance was the golden triangle concept, which earlier referred to quality, time, and cost and which was further expanded to include sustainable project , project stakeholders satisfaction, and finally health and safety issues (Atkinson 1999).

Sidawi (2012a) observed that several issues continued to affect performance of construction projects despite rapid progress in the project-management field. In another study, Sidawi and Alsudairi (2014) observed that, some of the project management and communications issues were triggered by the use of unsuitable tools and methods of communication, co-ordination, and management. Sidawi (2012a) recommended for the need of having project information and effective communications by the project team. However, this could only be achieved through conventional methods, which had limitations and thus could not be effective in monitoring performance of construction projects (Sidawi and Alsudairi, 2014).

According to Teizer, Lao and Sofer (2007), monitoring of construction site activities has become an important element to the project participants (contractors, architects, engineers, suppliers). Successful projects are evaluated based on the level of awareness of project progress status site tasks status. Consequently, obtaining the right information at the right time information is important for real-time or near real-time decision-making. Good resource procurement and resource allocation of workforce, material, and equipment comes in play when job site conditions can therefore be monitored. Teizer, Lao, and Sofer (2007) further argues that, site automation technologies have been used to enable real time data collection and assessment processes can assist in making timely decisions.

In another study, Wang (2008) observed that, the existing methods for tracking and managing performance in construction sites utilizes the traditional manual recording methods that involve a lot of paper work. Further, information collected using such labour intensive methods is unreliable and ineffective while inputting, retrieving, analyzing, and disseminating the resulting site information requiring more time and effort leading to inadequacies since every project is time bound (Wang 2008). In recent times and in large and complex construction projects, construction managers have integrated different web-based monitoring systems that integrate wireless technologies, network cameras and a web platform have been utilized. Leung et al. (2008) presented a cost-effective construction site monitoring system by integrating a long-range wireless network, network cameras, and a web-based collaborative platform.

Monitoring and evaluation of the construction project tasks and processes are a critical task that can help in monitoring overall project performance. Project stakeholders require timely and accurate project progress reports with indications on compliance with the set budget, time, quality, and safety (Hastak, Halpin and Vanegas 1996). Tatum (1989) introduced site automation in an effort of improving project performance.

Elsewhere, Arditi, Sundareswaran, and Gutierrez (1990) examined the advantages of automation in construction by use of survey questionnaires. Ninety five percent (95 percent) of the respondents' indicated that automation in construction projects could help improve the performance of the project. The researchers have therefore shown great interest in the usage of new innovative methods of site automation in progress monitoring and control. (Navon (2007) further adds that, the most economical solution that can enable site managers to determine the actual performance of a project is by automation.

Some of the site automation technologies available includes: Global Position Systems (Navon 2007), Radio Frequency Identification (Jaselskis and Gao 2003; Song, Haas & Caldas 2006), and Ultra Wideband technology (Teizer, Lao & Sofer 2007).These automation technologies systems uses wireless, satellite, internet-based or mobile tools and networks in construction sites which can be useful in management of complex construction projects. Arslan, et al. (2006) points out that automating construction sites can reduce construction sites challenges and thus increase faster decision making that will lead to efficiency in overall timely decision making.

Studies have shown that project performance in Kenya is inadequate and faces challenges (Gwaya, Masu & Wanyona 2014).Time and cost performance of projects in Kenya are poor to the extent that, over 70 percent of the projects initiated are likely to escalate in time with a magnitude of over 50 percent. In addition, over 50 percent of the projects are likely to escalate in cost with a magnitude of over 20 percent (ibid). Masu (2006) points out that, although cost performance was not better, time performance was comparatively the worst. This points out to serious deficiencies in the management of construction projects, which results to project delays, cost escalation, and even unsafe site practices, poor quality leading to inefficiencies in project delivery. This has made the sector to experience inefficiency in the delivery of construction projects. The study postulated that adoption of site automation technologies could enhance site automation levels thus increasing project performance by construction firms in Kenya.

As indicated in the literature review, the benefits of site automation includes: enable real-time or near real-time decision-making, improving site health and safety, project costs control, improving quality, and time saving, project scope control thus improving the overall project performance.

The construction sector in Kenya is fast growing due to innovations and new technologies. The study established factors affecting site automation adoption levels and the extent of their effect. In addition, the study established the impact of site automation on project performance.

1.3 Objectives of the study

This study was guided by the following objectives:

i). To explore factors that determines site automation adoption levels by construction firms in Kenya

ii). To find out site automation technologies used by construction firms in Kenya

iii). To identify barriers affecting adoption of site automation technologies in Kenya

iv). To assess the impact of site automation on project performance in Kenya

1.4 Research hypothesis

1.4.1 Model I-Null and alternative hypothesis

Null hypothesis

i). Site automation levels do not vary significantly with the size of a firm, complexity of a project and cost of site automation technologies.

Alternative hypothesis

ii). Site automation levels vary significantly with the size of a firm, complexity of a project and cost of site automation technologies.

1.4.2 Model II –Null and alternative hypothesis

Null hypothesis

i). There is no significant difference in project performance by construction firms that have high levels of site automation than those that have minimal levels of site automation

Alternative hypothesis

ii). There is a significant difference in project performance by construction firms that have high levels of site automation than those with minimal levels of automation

1.5 Research Questions

i). What factors significantly determines the implementation levels of site automation technologies by construction firms in Kenya and to what extent?

ii). Which site automation technologies are construction firms using in Kenya and to what extent?

iii). To what extent have the major barriers of site automation affected adoption of site automation technologies in the Kenyan construction industry?

iv). How significant is the impact of site automation on project performance in Kenya?

1.6 Research Methodology

The study adopted a descriptive research design and structured survey questionnaires were used to obtain raw data. The sample was drawn from 277 construction firms registered under NCA 1-3 for building and civil engineering works. A five point likert scale was adopted to enable measure the extent of impact of factors on site automation levels and further evaluate the impact of automation on project performance. The significance of factors affecting site automation adoption levels and the impact of site automation technologies on project performance was measured using a five point likert scale ranging from 'not at all, slightly, moderately, majorly, and extremely' respectively. Site automation levels was measured based on a similar five point likert scale ranging from 'no automation, partial, moderate, major and full automation' respectively.

In order to address these research questions, the study employed two conceptual models. Firstly, the study established the factors affecting site automation levels in construction sites. Secondly, the study explored the significant impacts of adoption of site automation technologies on project performance in the Kenya. In this regard, the study first established the extent to which factors influencing adoption of site automation technologies (the independent variables) affect site automation levels (the dependent variable). In addition, the significant impact of site automation (the independent variables) on project performance (the dependent variable), was established.

The independent variables in the first model comprised seven factors affecting site automation levels. These variables were costs of automation, construction firm's size, firms' strategy, project scope, technology availability, construction site characteristics, and human resource capacity. The dependent variable was site automation levels.

In the second model, independent variables that determined higher or increased project performance was dependent on the level of automation employed on labor management, materials management, plant and equipment management and construction site monitoring.

Correlation analysis was undertaken to determine the strength and significance of association between factors influencing automation and levels of site automation. In order to explain the variance in levels of site automation and to generate a predictive model, standard multiple regression was undertaken. Finally, to establish whether the level of site automation significantly varies with the theorized factors of site automation, a chi-square test for independence was undertaken.

Increased project performance because of adoption site automation technologies was measured in relation to its impact on time, budget, quality, scope, and safety in a project. Model linear equations for the two models were then provided using coefficient established in the study. The results of the statistical analysis formed the basis of discussion and the formulation of possible conclusions and recommendations.

1.7 Scope of the Study

The study was undertaken amongst construction firms in Nairobi County. This was because, the distribution of these construction firms in Kenya are largely biased towards the city capital with more than 67 percent of the registered Building and Civil engineering firms. The research focused on construction firms approaches to site automation. The study was limited to building and civil engineering firms registered under NCA 1-3 in Nairobi. This was because such firms were capable to undertake large volumes of work employing qualified professionals' hence had the capacity to engage and appreciate site automation technologies in their projects.

A sample size of two hundred and seventy seven (277) construction firms formed the sample size of the study. The scope of site automation technologies in the study was limited to technologies applicable during the construction phase.

In addition, this study evaluated specific factors that affected site automation levels identified through literature review and further established the impact of site automation adoption on project performance.

1.8 Significance of the study

Construction site automation is essential for the success of construction firms because it enables a site manager to properly prepare resources and make plans for the remaining part of the construction activities. Adoption of site automation in construction sites reduces the challenges, which construction managers encounter as they undertake construction site management.

The study evaluated the factors that affected site automation levels and barriers to site automation. Further, the study established the impact of site automation levels on project performance. The recommendations' have been made on areas of further research to enable construction firms to improve on project performance. The study contributes to the construction sector and encourages adoption of site automation technologies by construction firms in Kenya.

1.9 Limitations

The study limitation was on the area to be covered. The study was limited to construction firms registered under NCA 1-3 operating in Nairobi County since most major firms in these categories are biased towards the capital city. As per the NCA register, 67 percent of the firms in NCA 1-3 were found to be domiciled in Nairobi with only a few spread over the other major towns. In addition, there was limitation on information available in regards to site automation in Kenya. The researcher thus relied on information available from other developing countries who were undertaking site automation in their projects.

1.10 Assumptions

The study assumptions were that the target construction firms were reflective and adequately representative of similar firms in Kenya thus adding value to the results. The study assumed that the respondents answered the questions truthfully and objectively and were knowledgeable on the area of the study. In addition, the predictive study models assumed a linear relationship among the variables under study and thus are only applicable to that extent.

1.11 Organization of the study

The study was organized in five chapters as follows:

Chapter One, introduces the whole project, highlighting in general site automation technology and problem statement; research objectives, research questions, study hypothesis, research methodology, scope of the study, significance of the study, assumptions and finally the study limitation.

Chapter Two, focuses on literature review exploring the theoretical concepts relating to the area of automation. The chapter begins with a review of site automation concepts highlighting principles and use of on-site information. Other areas highlighted includes: factors affecting site automation implementation levels, conventional site monitoring versus modern site monitoring technologies, Site automation technologies used in construction sites, benefits of site automation and applicability and use of site automation technologies in monitoring project performance. Finally, the chapter shows two conceptual models used in the study with dependent and independent variables respectively.

Chapter Three, covers research methodology. Descriptive research design was used with the survey questionnaire as the data collection instrument. The target population was also identified with a sample size of 277 firms distributed according to their registration category in NCA 1-3.The chapter indicates levels of measurement, and method of data analysis. In summary, chapter three consists of the research design, target population, sample size and sampling procedure, research instrument and its reliability and validity, data collection procedure, methods of data analysis and a summary.

Chapter Four, presents the analysis of data obtained, discussions, and interpretation of the findings of the survey. The data collected was entered into MS Excel 2010 and statistical analysis done using SPSS (Statistical Package for Social Sciences 20.This chapter contains the results and discussions of statistical analysis of data collected for this study through mailed survey questionnaires. The statistical analysis and interpretation, was guided by the study hypothesis and research questions. The study model equations are finally presented showing the relationships of factors affecting site automation and site automations levels and the impact of site automation on project performance.

Chapter Five, summarizes the conclusions of the study and recommendations based on the findings of the study. This chapter summarizes the whole study, provides the key findings of the study, and provides areas of further research. ***Finally***, the report also contains a list of references of the study's scholarly literature sources and appendices relevant to the study.

1.13 Operational definition of terms

Construction site: Defined as "an environment where activities such as erection of physical infrastructure, superstructure, and related facilities such as buildings, manufacturing plants, roads, and bridges are done" (CII 2001–2003).

Automation: Automation has been defined as "the usage of control systems and information technologies to reduce the need for or change the type of human work in the production of goods and services." (CII 2001–2003). This study adopted site automation as the use of automated technologies on construction sites that enables monitoring and tracking of construction progress on-site.

Site automation technologies: Defined as the "technologies concerned with the application of electronic, mechanical and computer based systems to operate and control construction production" (Castro-Locouture 2009).

Components of site automation: In this study, this will mean labor, materials, and equipment and construction processes where automation is done for effective site management.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Construction automation is a field of research and development, which focuses on automating construction processes. In other terms, construction automation deals with application the principles of tested industrial automation to the construction sector i.e. in building construction and civil engineering (Saidi et al. 2008).

In the construction industry, site and operations monitoring and inspection is one of the indispensable procedures for construction performance. Due to advancement in technologies and affordable price of equipment in recent years, the use of automation technologies in site monitoring has become more common (Ahuja, Yang & Shankar 2009). By integrating heterogeneous information and communication technologies (ICT) such as environment condition sensing, wireless networking, video streaming, stereoscopic imaging and artificial intelligence the implementation of intelligent construction site visual surveillance systems has become feasible. In this regard, such systems of automatic data collection (ADC) could collect valuable site information automatically, which is useful for workforce productivity analysis, workforce training, and safety monitoring (Yang, Ahuja & Shankar 2007).

Recent research has shown the effectiveness of applying site automation technologies in site monitoring and inspection. Integration of wireless network technologies, network cameras, and collaborative systems has been has achieved towards monitoring construction site environment where project team members could monitor project progress and behaviors of site workers as they undertake their tasks (Leung, mark & Lee 2008). In addition, radio frequency identification technology has been employed to track the movement and location of materials (Song, Haas & Caldas 2006). Further, global positioning system and a hand-held computing device have also been used to improve materials-locating processes (Song, Caldas & Haas 2006).

2.2 Construction performance monitoring

In the last two decades, researchers have narrowed down on measurement of projects success in construction management, which has led to a wide variety of innovative management approaches, and techniques that has resulted in considerable improvements in construction (Akkoyun and Dikbas 2008). Research further points out that that performance monitoring is so important in the site management and thus has necessitated a lot of research in construction management (Akkoyun and Dikbas, 2008). Project performance can be evaluated using indicators such as delivery time, cost or budget, quality of the final product, health and safety concerns in the project, scope control among others (Cheung, Suen & Cheung, 2004).

Warszawski and Navon, (1998) observed that implementation of site automation has been slow due to ‘‘unsuitability of the available automated technologies , unsuitable conventional design approaches, smaller ratio of production type of final products as compared with other industries, limitations in the materials that could be employed by an automated system, economic unattractiveness of expensive automated equipment, and managerial issues.’’

Since early 1990’s information communication, technology (ICT) has shown increasing importance for its possible applications in construction industry (Amor and Bett 2002). Complex systems have been developed to cater for efficient planning and management of construction sites (Tarun & Barai, 2007). System’s involving visual techniques to obtain a bird’s eye view of the construction site as the construction progress has been developed (Chau et al. cited in Tarun & Barai, 2007).

According to Tatjana (2008a), monitoring and controlling construction works is a difficult task that involves undertaking monitoring of the construction site, processing of workflow data, and transferring the information to the related personnel. Sacks et al. (2002) observed that indicators of project progress could be compared with required project set targets to deduce the project performance variance levels and thus ensure a corrective action is formulated. In addition, the project information obtained can be interpreted using knowledge-based software.

2.3 Monitoring construction site processes

According to Tatjana (2008a), the quality control of a construction project is critical to the project team in addition to project costs and completion time. Further, Leung, Mak, & Lee 2008 explains that, "the aim of all control procedures is to provide a quality product that is satisfactory to the stakeholders of different parties, compliant with the statutory and industry standards, completion on schedule, within budget and so on. Obviously, the quicker and more information of site activities and worker behaviors the project stakeholders know, the higher the possibility to avoid undesirable outcomes."

Monitoring of construction site processes provides information that guides in preparation of contingency plans by the construction manager. Tatjana (2008b) points out a scenario where the rate of defects in a project can be drastically reduced through daily monitoring of the construction processes and further taking corrective action. According to research reports, construction sites have high wastage and higher costs because of re-work on defective components that were detected late in the project execution phase thus leading to massive waste of time and resources (Josephson and Hammarlund 1999).

The likelihood of accident occurrence in a construction site is determined by the characteristics of the construction sites and the systems put in place. Sulkys (2004) points out that, due to the interactions of different workers and site personnel, plant and equipment in a construction site there are likelihood that these can pose different challenges resulting into high accident rates.

Monitoring construction quality control in a given site helps to minimize construction defects and human errors and further supports project team members in making strategic decisions at critical times throughout the construction phase (Leung, Mak, & Lee 2008).

2.4 Information Communication Technology (ICT) in construction management

The use of ICT for construction project management provides real time access of information and improves coordination and collaboration among the project team members. The benefits pointed out includes: "richer information to aid decision making, project information is obtained quicker, improved communication, closer relationships, improved information flow, greater management control and getting geographically dispersed groups to work together" (Skibniewski and Nitithamyong 2004).

Researchers are in the process of developing project management information systems using ICT for the industry (Yang, Ahuja & Shankar 2007). Faraj and Alshawi (1999) provided an object-oriented implementation of a rapid prototyping environment that supported construction life cycle activities. Peansupap (2004) observed that integration of ICT automation in construction is could drive construction projects to efficient and effective levels.

2.5 Information flow in Construction Projects

The construction site is an intricate rich information area, which produces daily information, and reports that require transferring and analyzing regularly throughout construction phase. The time sensitivity and accuracy of the information is important in ensuring that the project is delivered as envisaged. A good example of such information generated in the construction site includes; project agreements, project drawings, project specification documents, requests for information by project team members, variation orders, project appraisal reports, plant and equipment reports, , daily reports, personnel safety and injury reports, method statements reports, materials procurement reports, payments requests among other (Haas et al. 2000.

The project team members continually and often exchange information electronically but must dispatch the same information manually to the field. At the field level, the site manager collects information and reports manually either on a daily basis, weekly basis, Fortnight basis or/and monthly basis. The field information processed and analyzed by the construction managers to enable timely decision-making. As a result, the high-level project managers then provide automated instructions for transmission and action at the field levels. (Haas et al., 2000).This means that site automation is critical and greatly improve communication on site since the progress on site can obtained by all team members at the same time thus making the decision chain to be shorter.

2.6 Principles of construction site automation

2.6.1 Introduction

The management of construction sites is a very complex task, it requires a large number of controllers, who inspects the site on a daily basis and collect progress information that can be used by the project managers and other team members (Girreti 2012).

Recently, some low cost and easy to use technologies such as global positioning systems, wireless networks, and radio frequency identification, ultra wide band, mobile computing, virtual reality, LADAR have provided the technological background for the development of innovative management scenarios for highly automated construction sites (Girreti 2012).

2.6.2 Concept of site automation

Construction sites are characterized by being dynamic working environments, which changes their organizational regularly. They are affected by unpredictable and uncontrollable external events such as weather, the availability of local resources, etc. (Behzadan et al., 2008). The main goal of the project stakeholders is to deliver the project at minimal cost, within time and with desirable and agreed quality standards while maintaining safe working environment free of hazards (Maalek and Sadeghpour, 2011).

Furthermore, in large and complex construction projects there are many of parts and components while changes to design plans during construction phase is a common practice. The design changes are often made on construction sites without updating the initial plans (Giretti, Carbonari, & Vaccarini 2012).

Traditionally the site data is collected manually, a time consuming and labor intensive (costly and error-prone) task especially in large-scale construction projects (Maleek et al. 2014). Although continuous manual on-site monitoring helps with collecting the necessary data, it is not justifiable in modern construction management. Therefore in practice, a limited number (or frequency) of on-site data are collected to justify the time and cost associated with such manual approaches. In current practices, the most commonly collected quantitative key performance indicators of a project are time of completion and cost of completion of an activity (Cox, Issa & Ahrens 2003).

In order to minimize discrepancies in monitoring construction sites, an effective system is necessary. Monitoring the actual tasks in construction sites can help the project managers, site supervisors, owners and other stakeholders to assess, evaluate, and compare the variances of the actual from the as-planned state of a project and to timely remedy the deviations (Maalek and Sadeghpour, 2012).

2.6.3 General requirements for site automation

Sandround (2012), points out that several factors have to be dealt with when planning and designing automated site management systems. Initially, they should have the ability to automatically identify and track progress with no, or minimum, human input, and to make this information readily and easily available.

Besides being affordable and small, there are some general requirements that any automated site management system must fulfill. According to Sandround (2012), an automated site management system should meet the following requirements:

1. **"Safety:** Technology must work at any location and time and should not harm people.
2. **Cost:** It must have reasonable set-up cost. The running cost for any site automation technology should be minimal, and, in this manner, re-using tags will help the system to keep minimum variable inventory.
3. **Accuracy:** Technology-aided tracking and locating processes should result in more accurate locations than those from manual localization practices.
4. **Network:** Network coverage should be the most suitable for small device communication, capable of scaling to meet the eventual needs of an application. The selection criteria are a mix of the following: coverage, wireless link distance, and data bandwidth.

5. **Flexibility and scalability:** To integrate successfully with other project management systems, the site automation technology must be flexible in terms of its implementation, and have minimum infrastructure requirements for setting up the system. The system must be portable, so that the functionality can be transferred to new projects.
6. **Ease of use:** It should be easy to mobilize, be simple and user friendly in its operations, and, at the same time, reduce errors associated with human roles.
7. **Ambient environment:** Technology must work well when natural illumination is low, obstructions are present, and the likelihood of signal multipath is high.
8. **Ruggedness:** The technology must be rugged enough to withstand harsh construction environments, which are fundamentally exposed to adverse conditions, such as dust, rain, mud, and snow.
9. **Time:** It should take minimal time for initial set up. The effortless data collection processes must require less time for identifying and locating materials and equipment than manual searching."

2.7 Conventional project performance monitoring on construction sites

Harris and McCaffer (2001) defined monitoring "as the act of determining actual progress and resource usage in reference to planned and undertaking decisions that influences future outcome." In this regard, the site manager must collect information on the actual project site progress, updates the computer models the progress, and enable further monitor any deviations. In the conventional site management, this information is collected from daily site progress reports and minutes of site meetings, and updated to computer by analyzing these reports.

Construction sector is an has a lot of information exchange among different project participants since many information pieces need to be transferred and exchanged during the life of a project and to some extent in post construction phase (Chen and Kamara, 2011). The traditional manual delivery methods are insufficient in delivery of timely information (Chen and Kamara, 2011). Singhvi and Terk (2011) observed that, lack of effective communication in construction sites leads to delays in making timely decisions that could offer timely solutions to the ongoing concerns.

2.8 Modern site automation technologies

Different position location systems are applicable in a construction site. Some available technologies are global positioning systems (GPS), radio frequency identification device (RFID), vision cameras, Laser detection, and range tracking (LADAR), ultra wide-band (UWB), mobile computing technologies, and virtual reality systems. These technologies have been used in improving on-site monitoring and have yielded excellent results in project delivery.

2.8.1 Radio Frequency Identification Technology

"RFID is a branch of automatic identification technologies, which uses radio frequencies to capture and transmit data" (Jaseleskis and El- Misalami, 2003. Jaselskis and Gao (2003) published one of the earliest research papers on RFID applications in construction. Wide ranges of applications were covered from a visionary perspective, and this resource was used as an inspirational starting point for many other publications. It took several other years for more research work to appear in the literature and they all took a part of the problem and expanded it.

In recent years, this technology has been used successful in the construction industry in supply chain management, site safety and personnel management, equipment and tool management, maintenance management, asset location and tracking (Jaseleskis and El-Misalami, 2003.

Research shows that the technology is applicable in different knowledge as follows:

a. **Time management**

The project life cycle is long and timely bound which has many factors that influence project delivery. Chin et al. (2003) proposed integration of RFID and 4D CAD in managing processes that could provide logistics and progress management thus reducing materials and project schedules overruns. This system provided a 17 percent time reduction in comparison to the conventional methods applied in practical high-rise construction sites. In another research by Jeselskis and El- Misalami (2003), application of RFID reduced the time used in locating and tracking welded pipe pieces by approximately 30 percent.

b. Quality management

Wang (2007) points out that, 'RFID technology is applicable in improvement of quality in construction through two ways. Firstly, in concrete and asphalt pavement maturity monitoring which involves early formwork removal, accelerated schedules from time saving, and accelerated pre-stressed release times, determination of precise sawing times for joints, hydration rate, and identification of weak spots in the concrete and the appropriate remedial actions. Secondly, RFID can be used in quality inspection and management for enhancing construction quality inspection and management.' Wang (2007) used an RFID based quality management application that integrated web and RFID technology in automatic data collection of concrete specimen inspection and management.

c. Materials management

Material tracking in a construction site is useful because of associated benefits that can reduce the cost of the project. This is because the materials and procurement costs accounts for more than 50 percent of overall project costs (Jing et al. 2013).

In construction sites, the site managers are required to track thousands of components and materials individually after received at the site and stored at the yard (Torrent and Caldas 2009). Missing the required components and raw materials required to undertake certain tasks can have a heavy bearing to construction workers thus increasing working hours by 16–18 percent due to idleness or being non-productive (Torrent and Caldas 2009).

By employing RFID technology, information on materials is stored in RFID tags, which are posted on the materials, where locations of materials are tracked by combining RFID with GPS and GIS. The RFID reader identifies tagged components and materials in the storage yard and the GPS receiver can then localize them and report to a host computer (Song, Haas & Caldas 2006).

d. Site safety and health management

Recent research undertaken on RFID tag shows technology has successfully enhanced the security and site safety management. RFID technology can realize the information automatic identification and remote monitoring in order to achieve accurate collection of various types of risk diversification, real-time monitoring and dynamic tracking, improve the construction workers health and safety (Jing et al. 2013).

e. Progress monitoring

The project manager has to be informed on the daily progress of the construction project. By tracking the status of the components, project managers are then able to monitor the progress of the project, which is crucial to early detection of delays and timely decisions on corrective measures. Chin et al. (2008) made such a trial, integrating both RFID technology with four-dimensional (4D), CAD to manage the logistics and progress of structural steel works from design to manufacture, delivery, and finally erection.

2.8.2 Ultra wide band technology (UWB)

According to the Federal communications commission (FCC), an UWB signal is defined as any signal with a relative bandwidth larger than 20 percent or absolute bandwidths greater than 500 MHz (Breed 2005; Siwiak and McKeown, 2004). The origin of UWB technology dates back to the 1960's, when its application was restricted to United States government and military programs. The Federal communications commission (FCC) approved the unrestricted use of low-powered UWB systems and tags (5 MW) in 2002; therefore, non- government-related research has increased in the last decade (Tiezer et al. 2008).

With the extreme wide bandwidth, UWB positioning system is capable of covering a large area and co-exists with other wave frequencies at low or no interferences (Teizer et al. 2008). Embedded ICT systems for improved information management and the automated control of project performances are currently the foremost frontier of construction project management (Giretti, Carbonari & Vaccarini 2012).

Giretti, Carbonari, & Vaccarini 2012 argue that, UWB location tracking data can be effectively applied to automated work sampling. Location tracking data can be used to decompose the presence of workers and equipment in the different working area zones versus time and in relation to the trajectories of workers and material and can, in principle, be used to argue the work progress.

2.8.3 Mobile computing technologies

Construction organizations have intensively used information and communication technologies to improve the results of projects, with a growing use of mobile technologies. Electronic mobile communication normally includes three features; mobile device, mobile networks and mobile services (Rebolj, Magdic & Cus-Babic 2002). Integration of these features has accelerated development of mobile computing in construction. Mobile devices range from laptop computers, personal digital assistants (PDA), portable data terminals (PDT), and tablet personal computers, to smart phones (Ozumba and Shakantu 2008a).

Many research efforts have been geared towards design, development, and practices of construction information management systems. These include electronic data management (EDM), knowledge management systems, web-based project management systems, and collaborative systems (Chen and Kamara, 2011). Mobile computing technologies have been implemented in many construction processes.

The emergence of mobile computing technology has the potential to extend the boundary of information systems from site offices to actual work sites and ensures real time flow of information to and from work sites. Mobile computing systems for data transfer between construction managers and different websites have been implemented. The progress monitoring wireless mobile system permits to check the progress of the work. At the same time field, note system is used to note unacceptable parts of works. Inspection system is also used for inspect the result of construction. This soft technology is very useful and has a low cost, which make it candidate for massive introduction in the site environment (Balaguer and Abderrahim 2008).

2.8.4 Global positioning system

GPS is a global navigation satellite system that requires an unobstructed line of sight to four or more GPS satellites to provide location information. Its widespread availability is an advantage for this technology. In the case that very accurate positioning data is needed, higher installation and maintenance costs are involved. GPS application is limited to outdoors, because in an indoor environment, excess loss of signals and multipath effect decrease the accuracy of the system. Therefore, GPS could be a cost effective option for tracking the position of larger resources such as heavy equipment fleets (Teizer et al. 2008).

2.8.5 Laser scanning technology/ Laser detection and range tracking

Three-dimensional (3D) Laser scanning, also known as LADAR (laser detection and ranging), is an advanced imaging technology which has been used in the industry since the late 1970's. Because of the high cost and poor reliability of early devices, they were not widely utilized until the early 1990s (Turkan et al., 2012). Cheok, Leigh & Rukhin (2002) observed that technological developments related to computers, optics, and microchip lasers made it possible to capture comprehensive and very accurate 3D data for an entire construction site using a few scans. Shih et al. (2004) investigated the use of 3D laser scanning data to monitor project progress. They concluded that schedule-based scanning facilitates a detailed definition for partially completed construction work and provides as-built proof for geometric measurement and visualization.

LADAR technology is applicable in a construction site in order to get 3-Dimensional (3D) data for the entire site. The requirement for line of site is unfavorable for using this technology in construction environment. As well, 3D models taken from LADAR need to be processed to assist project manager efficiently (Teizer et al., 2008).

Studies by Greaves and Jenkins (2007) indicates that the 3D laser scanning hardware, software, and services market in construction sector has grown exponentially in the last decade. This shows that owners and contractors are aware of the potential of using this technology for sensing the 3D as-built status of construction projects.

Further studies by Brilakis et al. (2010), emphasized that having access to an as-built model of an existing facility can enhance project planning improve data management, support decision making, and increase the productivity, profitability and accuracy of a construction project. This is because as-built data can be collected automatically by using laser scanners, but interpretation and merging of point clouds, stitching, and object fitting are all performed manually.

2.8.6 Vision cameras

Vision camera is a cost-effective technology, which covers a large field of view of job sites remotely; however, it requires line of sight. A source of illumination is also required when working at night. Since the video or images from the camera need to be processed, it is not well suited to automated tracking of materials in complex environments of construction job sites (Golparvar and Pena-mora 2007; Teizer et al. 2008).

Cameras are useful in monitoring the progress of construction activities, especially from a distance and at a standardized viewpoint (Bohn, 2009). Further Bohn notes that camera users can log into a web user interface and see if building sections or components have been completed or if re-work is needed, allowing for early detection of issues or problems while still performing the same construction tasks. This ability to follow the progress of activities allows users to predict upcoming roadblocks and better plan for the immediate next or following work task(s).

In this regard, digital images can also reduce time needed for inspection by allowing this task to be done remotely (Brilakis 2007, cited in Bohn 2009). Therefore, by surveillance through on-site cameras real-time weather can help project managers to plan and schedule accordingly.

2.8.7 Virtual reality systems

The virtual reality (VR) is an immersive projection display (IPD) that allows construction managers to enter and interact with the contents of a full-scale building, before start of the construction or during the execution of the project (Balaguer and Abderrahim 2008).

Using VR system for simulation and training is another software and IT technology (designated soft robotics by some authors) area. For complex machines like excavators, the VR system needs not only to simulate the geometry and kinematics of the machine but also the terrain and the interaction between the machine and terrain (Lipman and Reed, 2000).

2.9 Factors affecting construction site automation implementation levels

2.9.1 Cost of automation

Cost of automating a construction site is key in determining the level of implementation. Mahbub (2008) pointed out that in the construction sector; the main reason of adopting new technologies is the prospect of gaining a competitive advantage through lower input costs. Firms' turnover determines the ability and available financial resources that a firm can allocate towards site automation. Associated costs of automation include acquisition, maintenance, and updating costs.

Strukova and Liska (n.d.) also cited the cost of incorporating site automation technologies as a major impediment. From their research, 74% of the respondents indicated the high costs of acquiring, maintenance, and updating site automation technologies as the most significant barrier. Mistri1 and Rathod (n.d.) cited costs as a tremendous barrier to site automation especially in relation to project variability visa-a-viz. technology variability.

2.9.2 Construction firm's size

Globally constructions firms have been classified according to their financial turn over and capability. In Kenya, firms are categorized according to the kinds of works they undertake and their financial capability. According to National Construction Authority registration categories, construction firms are classified from NCA 1-8 in different fields of specialization. This study assumes that the level of site automation implementation on firms with huge turnovers is greater than firms in lower categories and thus the study will concentrate on firms in higher categories of registration.

Due to the associated high costs of automation both in initial outlay and maintenance, large construction firms are more likely to adopt these technologies as a result of their huge turnovers (Strukova and Liska, n.d.; Mahbub, 2008).

2.9.3 Firms strategy

"A strategy is a unified, comprehensive, and integrated plan relating the strategic advantages of the firm to the challenges of the environment, designed to achieve the basic objectives of the enterprise" (Glueck, 1980). Consequently, Andrew (1989) defined technology strategy "as a pattern of decisions that sets the technological goals and the principle technological means for achieving both those technological goals and the business goals of the organization'.

Hampson et al. (1999) in their study observed that technology strategy guides the construction firm's reengineering approach in the consideration and implementation of technologies within the context of the overall competitive and business goals of the organization. In addition, automation technology could provide construction firms with a number of competitive advantages. Therefore, technology strategy guides a firm's approach to technology, including site automation.

2.9.4 Project scope

A project scope is a document that details the performance specifications of a project deliverables and defines the boundaries of the project. It states what will be done and what will not be done (Wysocki and McGary, 2003). In this research project, scope will refer to the nature of projects in terms of size, location, single or multiple, complexity, construction period.

The scope of the project in terms of size, location, construction period and complexity is also an influencing factor in site automation. According to a study by Strukova and Liska (n.d.), 33 percent of their respondents indicated that the scope of a project could render site automation un-effective to use.

2.9.5 Technology availability

Availability of site automation technologies is a great factor that determines the kinds of site automation technologies to be used. The availability and ease of use of technology necessary for site automation is widely acknowledged as a barrier to its adoption construction management and site monitoring. According to a study by Strukova and Liska (n.d.), 68 percent of the respondents cited availability of site automation technologies as a barrier while 21 percent found their complex nature an impediment to their adoption.

Some of the technology may be available locally while others have to be imported. Researchers have indicated that availability of site automation technologies determines the implementation levels that a construction firm can undertake.

2.9.6 Human resource capacity (Knowledge and skills)

Human resource capacity in this study refers to the available knowledge and skills in the use of site automation technologies. Whereas site automation seeks to reduce human element in construction implementation and management, highly competent staff are required to operate and manage these technologies. Strukova and Liska (n.d.) indicate that the difficulty in the deployment, use and maintenance of these technologies as not only the barrier from human resources point of view but also the general reluctance of staff to adopt new methods of working is also a barrier.

In this study, having knowledge of site automation technologies and skills in operating these devices is key for a construction firm success. Knowledge is attained through theoretical study and training whereas skills are gained through on site experience.

2.9.7 Construction site characteristics

The nature of construction works varies from one project to the other. The type of construction site also determines the applicable technology to be used i.e. single or multiple site, sloppy or flat sites etc. Complex sites require a clear strategy in terms of site automation technologies to be used and the magnitude of investment required. According to Strukova and Liska (n.d.) construction sites are so dynamic and unstructured that site automation construction methods are rendered ineffective and uneconomical to install and operate. In addition, construction sites are usually unique and do not present the similar set of problems (Strukova and Liska, n.d.).

2.10 Construction automation in other countries

In Japan, construction process designers have up scaled the worker-equipment system into a cohesive building production system to find solutions to problems such as the aging of workers, a higher training level for employees, and the low numbers of young people looking for jobs in construction (Obayashi, 1999).

The primary technology drivers for introducing robotics to construction sites in the U.S. were health and safety hazards to workers from chemical or radioactive contamination. In extreme cases, where human access to the jobsite is impossible due to excessive levels of contamination, performance of the required work tasks can only be accomplished using robots regardless of the associated cost. On-site experience with robotics in these environments, as well as in underwater and outer space tasks, has provided the developers of robotic systems with valuable lessons with respect to the practicality of certain robot design and task implementation solution (Mirostaw and Skibniewsk 1992).

Studies by Mahbub (2008) indicated that, majority 90 percent of Japanese companies uses automation and robotics, whilst for Australia 65 percent uses the technology. In Malaysia, half the number of companies, 50 percent uses the technology.

2.11 Current trends in site automation

Project monitoring and control, including progress tracking and resource utilization tracking, constitute distinct components of measurements. Specifically, progress tracking measures quantities installed while resource utilization tracking measures consumed work hours as well as the way by which such work hours were spent (Zhai et al. 2009).

Current approaches to site operation analysis, as described by Zhai et al. (2009) focus on the monitoring of construction progress and the measurement of work task productivity, but are heavily based on manual efforts or at best partially automated.

Similar (manual) steps are taken to analyze for lean principles, including for site safety and security control (Zhai et al. 2009).

Wireless and vision based sensing of site operations have been applied on several jobsites today, and come at low, medium, and high cost, each has distinct benefits (Bohn and Teizer, 2010). Once geospatially registered, wireless and vision based sensing can link to existing project level information (Golpavar 2009), such as pre-existing CAD models. Several case studies have demonstrated the success of these technologies in construction applications, i.e. tracking construction productivity using radio frequency (RF) tagging of construction resources (Grau, Caldas & Haas 2009).

In more recent years, attention to development of site automation technologies technology in the construction industry seems to have been growing, since the industry is becoming more complex and is facing new challenges (Raymond and Choy, 2005). In addition, analysis of current trends suggests that there has been an increased awareness of the potential benefits of site automation technological development and that the industry has ramped up its level of research and development in order to sharpen its competitive position (Yamazaki 2004). The advantages of automation and robotics technology include enhanced productivity, a reduced need for labor, benefits to society, and a lessening of harmful effects on the environment Zhai, Goodrum & Haas 2009).

2.12 Applicability and use of site automation monitoring project performance

The application of sensors for data acquisition and processing is growing rapidly, and numerous types of sensors and communication devices, such as LADAR, global positioning systems (GPS), and RFID devices, are already in use on construction sites (Cheok, Leigh & Rukhin 2002; Balaguer 2003). Some of the applications of site automation includes:

2.12.1 Project controls and management

Having an adequately maintained project controls and management is vital to minimize unnecessary cost on construction projects. Data collected at random times and in a non-standardized fashion is not as helpful for project management as data collected regularly. Standardization will make identifying problems and deviations more obvious (Bohn, 2009). Site automation technologies, enables the construction manager to monitor project progress thus identifying areas for remedial action since this information is obtained on time.

2.12.2 Communication and documentation

Bohn (2009) observed that delays due to poor communication or documentation forms one of the most significant challenges in managing construction projects with company executives or project managers often encountering huge costs on travel time to and from a construction site. When meetings are held, meeting participants can instantly learn about the project status, thus eliminating waiting periods to retrieve information. The need for short answer emails or telephone calls is reduced as well for questions involving project progress or site conditions. Site visits can thus be optimized and condensed as well documentation since site automation technologies stores data e.g. photographs which can be used later (Bohn, 2009).

2.12.3 Optimal resource utilization (labor, plant and equipment and materials)

Site automation technologies are useful in tracking workforce, materials and inventory, and equipment across a site thus being able show imbalances on a given project. Time wasting, task completion time, and inefficiencies can be recognized and adjusted for better optimization of project resources (Senior and Swanber-Mee 1997, cited in Bohn, 2009). Inventory and control of large equipment and bulk materials can be quickly located if they are in the view of the automated technologies i.e. camera. Presence and location of project workforce personnel can effortlessly be identified as well (Bohn, 2009).

2.12.4 Travel and safety

Travel can become a large cost for project managers, executives, and owners if they work directly on project sites, which can be located hundreds of miles away from their main office (Bohn, 2009). Bohn (2009), further notes that project participants can access the website that hosts an image library of the project thus reducing the frequency of trips, expenses, and wear-and-tear on company vehicles i.e. Cameras can become a useful tool in scheduling site visits, since managers are able predict when certain stages may be completed or need input, thus scheduling their trips accordingly.

Safety and health on construction sites is a key issue that site automation technologies can address. Jobsite hazards can be recognized remotely and the safety staff on duty can be informed to remove the hazard. Unsafe methods being used on-site can be identified and stopped if captured by the site automation technologies i.e. cameras. Theft and vandalism to site equipment and materials can also be minimized (Bohn, 2009).

In their study, Abderrahim et al. (2003) described safety security devices that includes; bidirectional voice channel, portable GPS, and micro camera with video link have been integrated in the security the helmet. The position and ID of each worker is communicated periodically via radio link to a monitoring station. This information is compared with a dynamics database containing the tasks and processes to be perform in the site. If a given worker is at what the system considers a hazard source it acts according to the nature of source (Balaguer and Abderrahim 2008).

The strategy to adopt is in the definition of different safe and prohibited zones around the workers and the sources of danger, so that in the moment in which these areas comes into contact a danger situation is triggered and warning is generated. There are several actions to be done in this situation such as advising the worker thought the voice instructions, halting a machine movement via central computer among others. The proposed prototype systems records all the detected risk situations for later examination and is able to be used for monitoring of some activities of the site as it records the position of workers and automated machines continuously. (Balaguer and Abderrahim 2008).

2.13 Benefits of site automation in project performance

Information about the location of construction resources such as workforce, equipment, and materials is highly beneficial to a construction manager enabling delivery of the project on time, safer, within scope and budget. Having a real-time positioning system can be a useful tool as part of construction management (Teizer et al. 2008).

According to Strukova and Liska (n.d. p.5), the major benefits of site automation in construction projects include the following:

i). "Less dependency on direct labor – this means fewer problems related to quality and the repetitiveness of work carried out, as well as costs may be reduced by reducing labor, whereas fewer operators are needed for the automated system.

ii). Construction site productivity increase – besides the speed of production increasing, the productivity is improved by disengaging the operation of the limitations of the human factor.

iii). Occupational safety increase – the automated systems may carry out their work in dangerous zones for humans, this makes it possible to reduce labor injuries.

iv). Quality increase – operations with automated and robotized systems are typically carried out with less variability in quality than human workers.

v). Greater control over the construction process – problems may be detected in an easier way as each stage of the process is controlled in order to verify the correct functioning of the system and the result of each one.

vi). Greater control over the final result of the construction process – the final result may be controlled in a more efficient way by controlling the result of each step of the aforementioned process."

Construction site tasks such as inspection and progress monitoring requires access to a wide range of information. While working on construction sites, site managers, site inspectors, site engineers and other site personnel currently spends a lot of time manually searching into piles of papers, documents and drawings to access important information that is needed in making site decisions (Aziz et al. 2005). In particular, monitoring the progress of construction activities helps decision makers identify causes of delay and productivity-loss early in the project lifecycle (Maleek, Janaka & Kamal 2014).

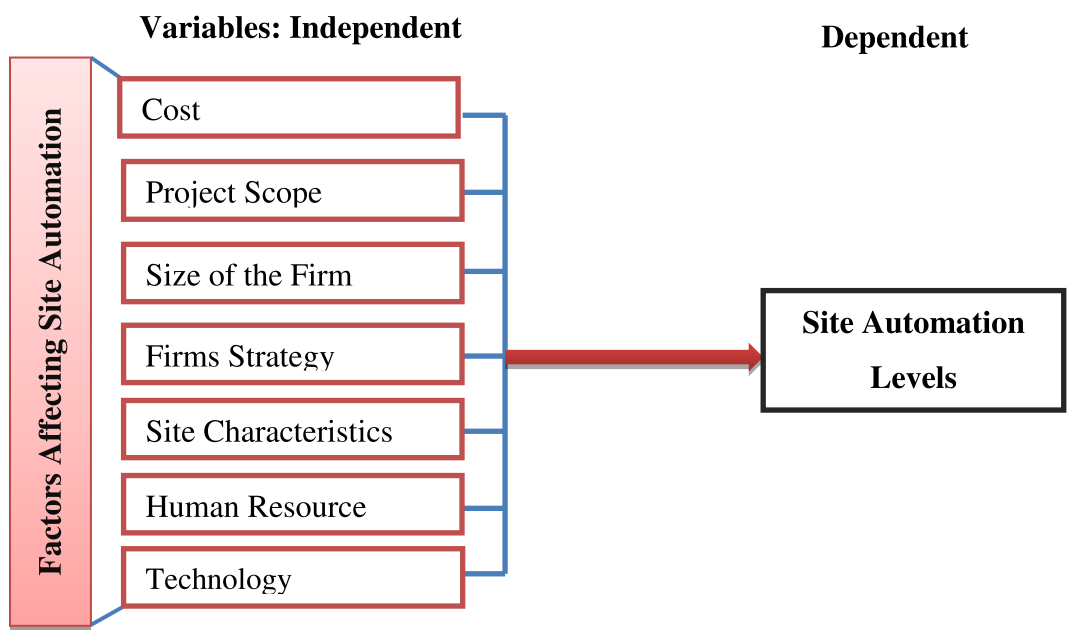
2.14 Conceptual Framework of the Study

The study comprised of two conceptual framework models that determined the factors affecting site automation levels in Kenya construction firms. The first model comprised of seven independent variables that included costs of automation, project scope, size of construction firm, firms' strategy, site characteristics, human resource and technology availability that influenced site automation levels (dependent variable).

The second model showed the impact of site automation on project performance. In addition, the usage of site automation technologies in construction management has been cited to have a significant impact on project performance by reducing dependency on direct labor, increasing output, improving quality, enhancing site monitoring, and greatly improving safety (Strukova and Liska, n.d, p.5).

Figure 2.1 illustrates the relationship between factors that affect site automation (independent variables) and levels of site automation (dependent variable).

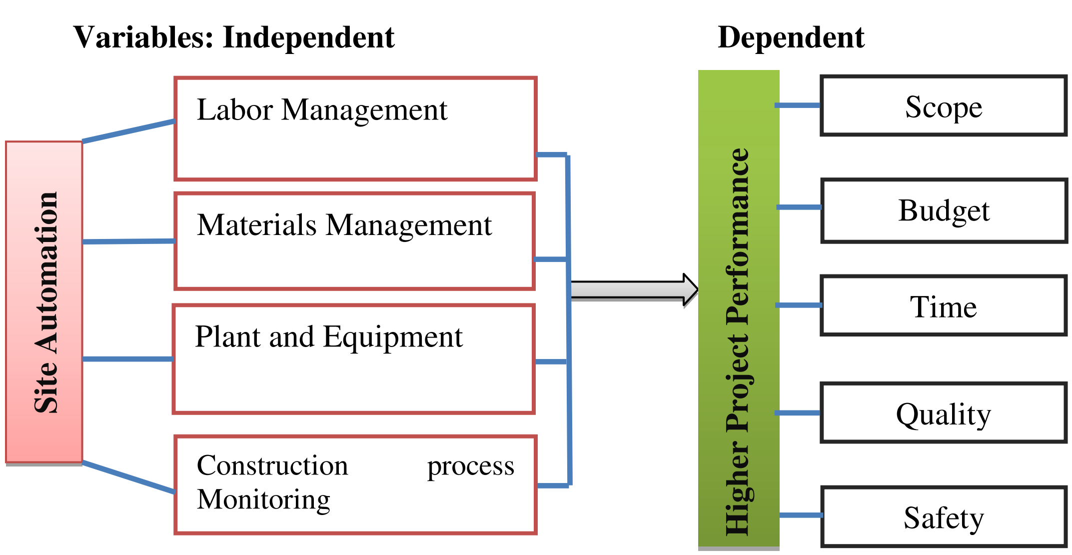
Figure 2.1: Conceptual framework: Model I



Source: *Author,* 2015

Figure 2.2 illustrates the relationship between site automation (independent variables) and project performance (dependent variables

Figure 2.2: Conceptual framework: Model II



Source: *Author,* 2015

2.14.1 Study Model I- research variables

I. Independent variables

From the literature review, major factors influencing adoption and use of site automation technologies identified constituted the independent variables in the study. Mahbub (2008) employed a seven point likert scale to investigate the significance of barriers of adoption of site automation technologies ranging from insignificant, little significant, minor significant, moderate significant, major significant, very significant to totally significant. This study adopted a five point likert scale that measured the extent of influence of factors affecting site automation level and project ranging from "not at all, slightly, moderately, majorly, and extremely" and some of the variables will be broken into ranges e.g. (1-100 employees, turnover of Less than 0.5 billion etc. The independent variables in the first model were factors that influenced site automation levels in construction sites. These were:

i). **Cost** – This included all associated costs of site automation i.e. acquisition costs, maintenance costs and updating costs (Mahbub, 2008).

ii). **Project magnitude-**This was measured in terms of the cost of the project, physical size of the project (spatial coverage and size of the structure), construction period**,** and construction environment (Strukova and Liska, n.d).

iii). **Size of the construction firm**-The size of the construction firm was determined by the category of registration (NCA1-3) measured by the annual turnover and number of employees. The research established that the size of the firm influenced the site automation levels (Mahbub, 2008).

iv). **Firm's strategy**- This included written plan that the firm had in regards to site automation. Different firms employ different strategies' that influences site automation levels (Hampson et al., 2009). Firms' strategy was measured in terms of whether a firm had an implementation plan, availability of budget allocation, availability of strategy steering team.

v). **Site characteristics**- The nature of a site may influence the choice of automation technologies applicable (Strukova and Liska, n.d. p. 5). This was measured in terms of project location, size of construction site and stakeholders involved.

vi). **Human resource capacity**-This refers to the availability of personnel with relevant expertise in the targeted site automation technologies (Mahbub, 2008). This was measured number of employees and ability of the available staff to operate and manage the technology.

vii). **Technology availability**- This was measured in terms of availability of site automation technology locally, ease of use, compatibility with the existing practices and operations, existing regulatory framework and acceptability by project stakeholders as per Strukova and Liska (n.d p.7).

II. Dependent variable (Site automation levels**)**

Site automation levels on (labor management, materials management, plant and equipment, and construction monitoring) was evaluated based on a five point likert scale ranging from no automation, partial, moderate, major and full automation respectively. Correlation analysis was then undertaken to determine the strength and significance of association between factors influencing automation and levels of site automation. In order to explain the variance in levels of site automation and to generate a predictive model, standard multiple regression was undertaken. In addition, analysis of variance was undertaken to establish whether the variance observed in the dependent variable was by chance or not. Finally, to establish whether the level of site automation significantly varies with the with theorized factors of site automation, a chi-square test for independence was undertaken.

2.14.2 Study Model II- research variables

I. Independent variables (site automation levels)

The study established the impact of site automation levels on project performance that was determined by establishing the association between automation of construction monitoring, labor, materials, plant and equipment management and project performance. Site automation levels were measured using a five point likert scale in order to measure the extent of this relationship.

II. **Dependent Variable (**Higher project performance)

The dependent variable higher project performance is related to the successful completion of a project. A successful project is one that is completed and the objectives achieved within scope, budget, time, and quality (Kerzner, 2001). According to Strukova and Liska (n.d.), site automation can lead to significant increase in quality, productivity, and improved occupational safety, greater control in the implementation process and reduction in implementation period thus majorly affecting project performance. Correlation was undertaken to establish the association between site automation levels and project performance. A chi-square test for independence was undertaken to determine whether the theorized factors of project performance varied significantly with the use of site automation technologies.

To model the association established, standard multiple regression was undertaken to establish whether there was significant difference in project performance by construction firms that had higher levels of site automation as compared to those with minimal levels of site automation.

The relationship between the independent variables and the dependent variable identified in the study was theorized in a standard multiple regression equation as follows:

i). Study Model I

$$S_{al} = A + B_1X_1 + B_2X_2 + B_qX_n + \varepsilon_i$$

ii). Study Model II

$$H_{pp} = A + B_1X_1 + B_2X_2 + B_qX_n + \varepsilon_i$$

Where:

S_{al} - Site automation level on model 1;

H_{pp} - Higher project performance on model 2

A - is a constant,

$B_1, B_2 \ldots B_q$ - are the independent variables;

$X_1, X_2, \ldots X_n$ - are the response parameters;

n - is the number of independent variables;

q - is the number of sample size and

ε_i - is the residual error (adopted from Tabachnick and Fidell 2013, p.118).

2.15 Summary

This chapter explored the principle and concept of site automation in construction implementation and management, reviewed site automation technologies and factors affecting site automation implementation levels. Further, it reviewed applicability of site automation technologies in construction sites. Finally, the site automation technology models were developed and dependent variable (site automation levels) independent variables (factors affecting of site automation levels) in model 1identified. In addition, the dependent variable (higher project performance) and independent variables (levels of site automation determined by automation levels on labor, material, plant and equipment and construction monitoring) were also identified. The determinants and measurement of the respective independent and dependent variables were also established.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology used. It describes research design, target population, sampling technique, data collection instruments chosen, data cleaning and methods of data analysis. It clearly shows the methodology the study employed to answer the research objectives

3.2 Research Design

The study adopted a cross-sectional descriptive research survey design. Descriptive design describes the characteristics of a particular individual, or a group, and goes further to determine the frequency with which characteristics of the variables occur (Kothari 2004). This design uses description as a tool to organize data into patterns that emerge during analysis and further identify hypothetical constructs and it can acquire a lot of information through description.

There are two categories of descriptive designs: surveys and observational studies. The study employed a survey design where structured questionnaires were administered to respondents. According to Neuman (2003), this approach is often used in descriptive or explanatory research where a researcher asks respondents questions in a written self-administered questionnaire or during interview where answers are recorded.

Descriptive research design gives a representation of the whole with minimum bias and therefore the findings can be generalized (Kothari 2004). The study employed this approach mainly to obtain accurate and factual data from systematic descriptions from the respondents. The descriptive research design outlines a situation in respect to the variables under study. This method made it possible for data to be collected effectively without any manipulation on the research context.

This research design was appropriate for this study due to the nature of the data required which will be collected through qualitative and quantitative approach. In addition, application of this method was informed by the study objectives and research questions that sought to evaluate the factors affecting site automation levels and the impact of site automation on project performance. This research design has been used in related studies where the sample was drawn from construction firms' i.e. professional teamwork and project performance in the building construction industry in Kenya (Mugeria 2012).

3.2 Target population

The target population for the study was construction firms registered under National Construction Authority. The data on contractors registered was obtained from National Construction Authority (NCA) database. The target population provided adequate information that helped make conclusions and recommendations. The study identified construction firms registered in Nairobi, which were in NCA category 1-3. This was because firms in these categories had huge turn over and were able to invest in automation technologies. The total number of construction firms registered by National Construction Authority (NCA1-8) as of 18th March 2015 for both building and civil works are 10,031 and 9,809 respectively as tabulated below:

Table 3.1: Population of building and civil engineering construction firms

Classification of construction firms (NCA1-8)	**Total in Kenya**
Building works contractors'	10,031
Civil engineering contractors'	9,809
Total no. of registered firms	**19,840**

Source: *Adapted from NCA list of registered contractors, 2015*

Contractors registered under NCA 1-3 in Kenya were 792 for building works and 809 for civil engineering works. The table below shows the classification of all construction firms registered under NCA 1-3 for building and civil engineering works in Kenya:

Table 3.2: Classification of NCA 1-3 contractors in Kenya

Firms classification (operation area)	Category	No. registered in Kenya	Totals population
Building works	NCA 1	227	792
	NCA 2	218	
	NCA 3	347	
Civil engineering works	NCA 1	231	809
	NCA 2	174	
	NCA 3	404	

Source: *Adapted from NCA website, 18th March 2015*

The study sampled construction firms registered under NCA 1-3 for building and civil engineering works. This was also because construction firms in these categories had higher turnovers that enabled them to undertake massive projects. Therefore, these firms had the ability use site automation in their projects. The target population was drawn from 534 construction firms registered under NCA 1-3 for building works and 552 registered under civil works. The total target population was 1086 firms. This represented 67 percent of all construction firms registered in these categories in Kenya.

Table 3.3: Target population

Category of Registration in Nairobi	Target population	Sub-totals
A. Building firms		534
NCA 1	179	
NCA 2	142	
NCA 3	213	
B. Civil engineering firms		552
NCA 1	173	
NCA 2	123	
NCA 3	256	
	Total target population	**1086**

Source: *Adapted from NCA website, 18th March 2015*

3.3 Sampling

Sampling refers to the selection of people or entities to participate in a research study in order to make inference to the rest of the population (Mugenda and Mugenda 2003).

3.3.1 Sample size

According to Gay (cited in Mugenda and Mugenda 2003), for descriptive studies a sample size of 10 percent of the accessible population is enough to give valid data. However, a researcher depending on the availability of resources may study more than 10 percent of the population. In addition, Neuman (2003) pointed out that a sampling ratio should range from 30 percent for small populations (under 1000) to 0.025 per cent for large population (Over 10 Million). The study adapted a sample size of 277 firms (26 percent of the accessible population) as per the table 3.4 with a confidence level of 95 percent and margin error of 5 percent. This sample size gave a representation of the target population under study.

Table 3.4: Sample size computation table

Population size	Tolerable margin error			
	5%	**4%**	**3%**	**2%**
100	79	85	91	96
500	217	272	340	413
1,000	**277**	375	516	705
5,000	356	535	897	1622
50,000	381	593	1044	2290
100,000	382	596	1055	2344
1,000,000	384	599	1065	2344
25,000,000	384	600	1067	2400

Source: *Adapted from Anderson (1996 p.202)*

The sample size was then calculated to get representation from every category as follows:

Table 3.5: Sample size of construction firms

Category of Registration	Target population	26% Sample size	Sample sub-totals
A. Building firms			
NCA 1	179	46	136
NCA 2	142	36	
NCA 3	213	54	
B. Civil engineering firms			
NCA 1	173	44	141
NCA 2	123	31	
NCA 3	256	65	
Total sample size			**277**

Source: *Author, 2015*

3.3.2 Sampling technique

The study used stratified random sampling technique to identify the 277 firms among the target population. The goal of stratified random sampling was to achieve desired representation from various NCA categories in the target population. The study identified the target population and sample size after which stratified sampling was done to achieve the desired sample size.

Stratified sampling was used because of its advantage over other methods of ensuring inclusion of the sample of NCA1-3 categories, which would have been omitted entirely because of the small numbers among the target population. In this regard, the following steps were followed:

i). The construction firms to be studied were first identified.

ii). The criteria for stratification on firms registered under building and civil engineering in Nairobi County was done. This was done as per the NCA register, which categorized firms as per the type of works undertaken.

iii). The study population identified was then listed according to class and categories of registration. The sample size of 277 and subsequent representation for each category under NCA 1-3 for building and civil engineering firms was determined.

iv). Selection by using random numbers for each category was done and representative sample achieved as required.

v). The firms selected randomly were then issued with the final questionnaires after a pilot study had been undertaken and proposed changes incorporated.

3.4 Sources of data

The study used both secondary and primary data sources. Secondary sources were key in obtaining findings from similar studies conducted previously, while the respondents' provided primary data that was analysed to provide findings of the study. Some of the secondary data on the past studies was obtained from journals, archival records of past studies that focused on the automation in construction.

3.5 Data collection instrument

The study employed questionnaires to collect data from selected construction firms. The questionnaires were sent by email and some hand delivered. The study used structured questionnaires because they were appropriate for such a study due to the quantitative nature of data required from respondents'. This was to ensure uniformity in answering the formulated questions. The questionnaire was designed based on literature review to collect information from selected firms on the site automation levels of implementation.

Questionnaires were found to be cost effective way of obtaining data due to the size of the sample size selected. Questionnaire administered allowed the respondents to respond at their own free time due to the busy nature of respondents' in the construction firms. After mailing the questionnaire the respondents' were called to confirm receipt of the questionnaire and to provide the person whom to follow up with thereafter. Respondents were given three weeks to fill the questionnaire after which they were supposed to email them back. A follow up was done after three weeks on the status of the questionnaires.

3.6 Organization of the questionnaire

In the organization of the questionnaire, definition of site automation was provided in the front page with a short introduction of site automation technologies. This prevented misinterpretation and confusion among the respondents. Contact details of the researcher were provided to enable respondents to contact the researcher in case of any query while filling the questionnaire.

a. Basic information on construction firm

This section provided basic information of the firm including registration category, type and number of projects, annual turnover and number of employees. The respondents' were required to tick in the questions areas where applicable.

b. Site automation implementation levels

This section provided questions on the components where automation is applied and extent to which the automation has been undertaken. A five–point likert scale was provided ranging from "*No automation*" to "*Full automation*" that measured site automation levels.

c. Adoption of site automation

This section provided questions that seek the respondents' opinion on how different factors identified affects site automation levels. A likert scale of five-point scale was provided for each factor, ranging from "*Not at all*" to "*Extremely*" that measured the level of impact.

d. Perceived barriers to site automation and solutions to barriers

This section sought the respondents' opinion on barriers to site automation and how they could be minimised. A likert scale of five-point scale was provided for each barrier factor, ranging from "*Not at all*" to "*Extremely*".

e. Impact of site automation on project performance

The section focused on questions sought the respondents' opinion on whether site automation affected project performance and to what extent. A likert scale of five-point scale is provided for each barrier factor, ranging from "*Not at all*" to "*Extremely*"

3.7 Levels of measurement

Parameters to measure levels of implementation of site automation, significance of site automation on project performance was informed by similar studies by Mahbub (2008). The researcher used a seven point likert scale ranging from insignificant, little significant, minor significant, moderate significant, major significant, and very significant to totally significant (Mahbub 2008).

A five point likert scale questions was adopted in this study in order to obtain responses indicating a certain characteristics and the extent to which it was evident. The significance of factors affecting site automation levels and the impact of site automation on project performance was measured using a five point likert scale. In regards to levels of site automation a five point likert scale ranging from no automation, partial, moderate, major and full automation respectively while factors affecting site automation levels and impact of site automation on project performance were be measured based on a similar five point likert scale ranging from 'not at all, slightly, moderately, majorly to extremely.

3.8 Pilot study

Pilot study refers to a replica and rehearsal of the main research and done to establish any gaps or weaknesses of the questionnaires and survey techniques (Kothari, (2004). The pilot study helped in testing the wording of the questionnaire, identifying ambiguous questions and provided an indication of the time required to complete the questionnaire. Pre-testing helped to ensure reliability of the instrument used to collect data and thus measuring the respondents' understanding on the subject under study. A pre-test sample should be between 1 and 10 percent depending on the sample size (ibid).

In this study, 25 questionnaires were administered to construction firms in NCA1-3, drawn from the same target population. 12 questionnaires were received back providing a response rate of 48 percept. This was a good response rate for the pilot study compared to similar studies by Mahbub (2008) which had a response rate of 38 percent.

Comments and suggested amendments from the pilot study were used to amend the questionnaire prior to its final distribution. These amendments included the following:

i). The respondents indicated that there was need to define clearly what the researcher meant by ‘site automation’ in regards to construction projects e.g. question on future of automation in Kenya was removed.

ii). The questions pointed out as ambiguous and that were not answering the stated research questions were removed from the questionnaire.

iii). Participants indicated that the questionnaire was too long and suggested the questionnaire to be amended to allow time taken to be 15-20 minutes at most and this was incorporated and tested.

iv). The respondents indicated that the question on the annual turnover was to be revised to band the turnovers as per NCA requirements. The researcher provided a representative band since the firms were registered for different categories of works, which required different annual turnover for registration.

3.9 Data analysis

The data collected was entered into MS Excel 2010 and statistical analysis done using SPSS (Statistical Package for Social Sciences) 20. Initial analysis focused on providing general findings through descriptive measures such as mode and frequency. To explore the strength and significance of association between factors affecting site automation and site automation levels (independent variables), chi-Square test for independence and correlation analysis were undertaken. To establish the strength and significance of the relationship between site automation and project performance, correlation analysis was undertaken.

To test the hypothesis of the study analysis of variance was undertaken. Mugenda and Mugenda (2003), defines regression analysis as an analysis used when a researcher is interested in finding out whether an independent variable predicts a given dependent variable. On the other hand multiple regression analysis attempts to determine whether a group of variables together predict a given dependent variables (Mugenda and Mugenda, 2003).

In order to validate the associations identified in the chi-square and correlation analysis, standard multiple regression analysis was undertaken. This was to establish the impacts of factors affecting site automation levels by evaluating the strength of the predictors and the variance explained by the predictors from the regression model. Similar analysis is undertaken to explore the impact of site automation on project performance. To establish the individual effect of each independent variable on the dependent variable for both study models, correlation and regression analysis was undertaken. Conclusion and recommendations were then done based on the findings from the study.

3.10 Data Presentation

The data collected is presented in form of frequency tables and bar graphs depending on the analysis undertaken.

3.11 Reliability and Validity

Reliability is the degree to which a research instrument yields consistent results or data after repeated trials whereas validity is the extent to which results obtained from the analysis of the data actually represent the phenomenon under study (Mugenda and Mugenda 2003).

The pilot study was used in testing for reliability. Reliability was tested through the internal consistency technique, whereby scores obtained from one item was correlated with scores obtained from other items in the questionnaire. Cronchbach’s coefficient was then computed to determine how items correlate among themselves. The Cronbach’s Alpha values for all the variables bar solution to barriers of site automation showed that the scale used was internally consistent i.e. (values =>0.70) as shown in table 4.1.

The researcher ensured that the instrument at face value was reasonable way to obtain the information required through in order to meaningfully and accurately reflect a theoretical concept. This established criterion-related validity by including representative indicators of the concepts measured and further checked by evaluating correlations among the independent variables.

3.12 Summary

The chapter describes the entire research methodology centred on the overall objectives of the study. The chapter describes in details the research design, the sampling method, the sample size, techniques for obtaining the relevant data, measurement scale and data analysis is described. A pilot study was undertaken to test the clarity and appropriateness of the questionnaire and the reliability test results provided in the next chapter.

CHAPTER FOUR

DATA ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter contains the results and discussions of statistical analysis of data collected for this study through mailed survey questionnaires. The statistical analysis and therefore desired results, was guided by the study hypothesis and research questions. The data collected was entered into MS Excel 2010 and statistical analysis done using SPSS (Statistical Package for Social Sciences) 20.

Various statistical analysis were undertaken to explore factors influencing adoption of site automation and the significance of site automation on project performance for firms registered under NCA 1, NCA 2 and NCA 3 categories. Initially, reliability analysis was done to test for internal consistency of the various items in each scale for the independent and dependent variables.

To explore the significance of factors influencing site automation levels, frequency and mode were computed to obtain descriptive statistics for factors posited from the literature review against a five point likert scale of no automation, partial, moderate, major and full automation respectively. Correlation analysis was then undertaken to determine the strength and significance of association between factors influencing automation and levels of site automation. In order to explain the variance in levels of site automation and to generate a predictive model, standard multiple regression was undertaken.

Finally, to establish whether the level of site automation significantly varies with theorized factors of site automation, a chi-square test for independence was undertaken. Similar statistical analysis and tests were also undertaken to explore the extent to which theorized site automation technologies were being used in the Kenyan construction industry and the extent to which their use influenced project performance.

4.2 Pilot Study results

Table 4.1: Reliability test analysis

Scale	Cronbach 's Alpha	Cronbach 's Alpha	N of Ite ms
Components of construction site automation	.936	.939	4
Factors that affect site automation	.859	.858	7
Barriers of site automation	.671	.695	6
Solutions to barriers of site automation	.376	.439	7
Benefits of site automation on project performance	.796	.788	5

Source: *Fieldwork, 2015*

The reliability test was undertaken after the pilot study to test the internal consistency of the scales chosen in the data collection instrument for the various study variables. The Cronbach's Alpha values for all the variables bar solution to barriers of site automation showed that the scale used was internally consistent i.e. (values =>0.70) meaning the items in the scale used measured the same underlying construct.

The scale for the solution to barriers of site automation was not expected to meet the threshold since the items used in this scale were not necessarily related.

4.3 Response rate

The questionnaires received back were 146 from 277 questionnaires sent by either mail or physical delivery that represented 53 percent response rate. This was a good response rate given similar studies in site automation e.g. Mahbub, (2008) reported a response rate of 44 percent. In addition, Fellow and Liu (2003) posit that for self-administered questionnaire, a response rate of 25 to 35 percent is acceptable. Furthermore, Mugenda and Mugenda (2003) argues that a response rate 50 percent is adequate for analysis and reporting.

4.4 General information on construction firms

4.4.1: Response by type of work undertaken

Table 4.2: Registration by type of works

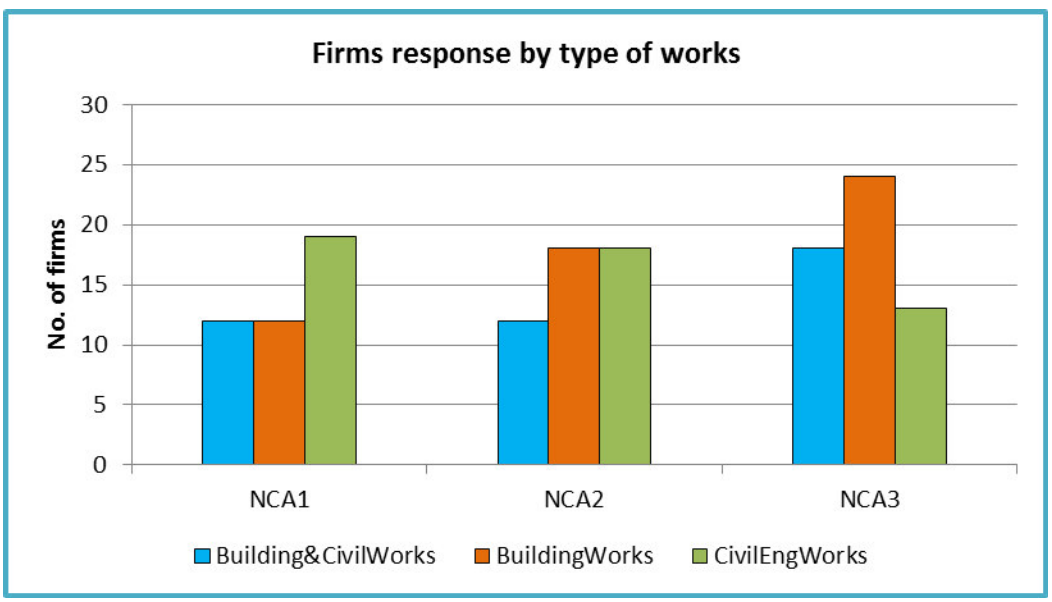
Category	Building & Civil Works	Building Works	Civil Engineering Works	Grand Total
NCA1	12	12	19	43
NCA2	12	18	18	48
NCA3	18	24	13	55
Grand Total	42	54	50	146

Source: *Fieldwork, 2015*

There were more responses from firms in the NCA3 category and most of the firms were mostly engaged in either building or civil engineering projects.It was noted that a good number of the firms in these categories reported to be undertaking both civil and building works since they were registered in both categories.

Figure 4.1 shows a graphical representation of the response by the type of works undertaken:

Figure 4.1: Registration by the type of works



Source: *Fieldwork, 2015*

4.4.2: Firm's average annual turnover

Table 4.3: Firm's response by average turnover

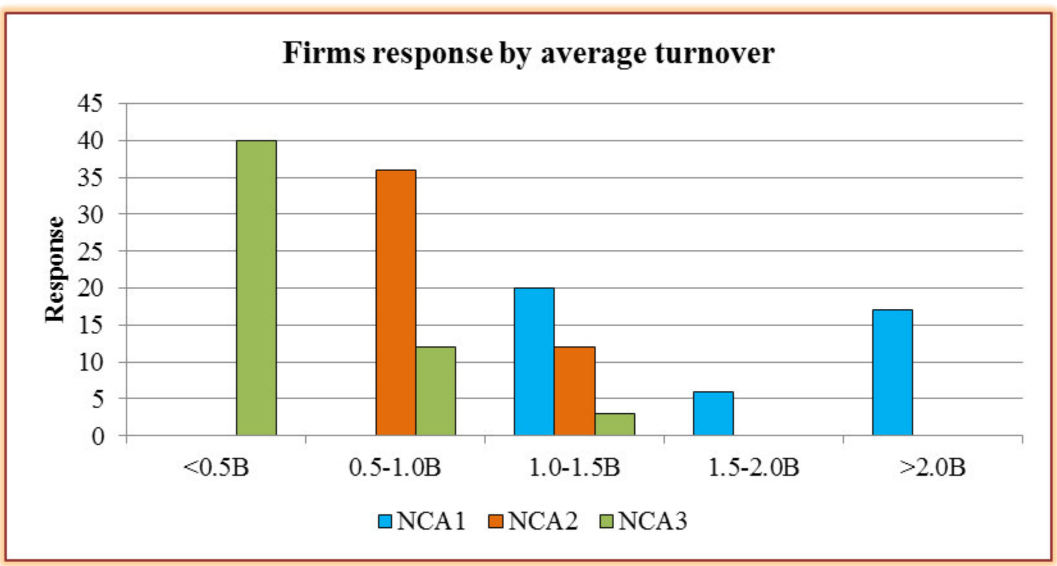
Category of registration	<0.5 B	0.5-1.0B	1.0-1.5B	1.5-2.0B	>2.0B
NCA1	0	7	15	6	14
NCA2	0	36	12	0	0
NCA3	40	12	3	0	0

Source: *Fieldwork, 2015*

The turnovers for the three categories of the firms studied were as expected based on the registration requirements with all three having firms with annual turnover ranging from less than 0.5 billion to more than 2 billion. There were more firms registered under NCA 3 whose turnovers were less than 0.5 billion. Firms registered under NCA 2 had majority of firms with turnover in the range of 0.5 billion to 1.0 billion whereas firms registered under NCA 1 category had more firms whose turnover were in the the range of 1 billion to 1.5 billion.

Figure 4.2 shows a graphical representation on firm's response as per their average annual turnover:

Figure 3.2: Response by average firm's turnover



Source: *Fieldwork, 2015*

4.4.3: Type of projects undertaken by the firm

Table 4.4: Response on type of projects undertaken

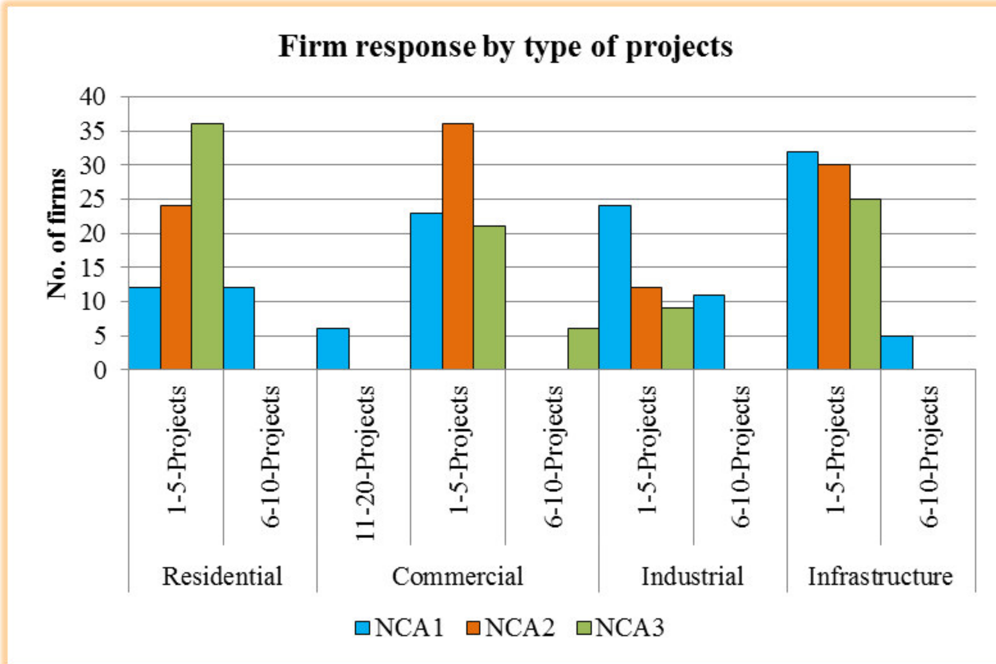
Projects	Number of projects	NCA1	NCA2	NCA3	Totals
Residential	1-5-Projects	12	24	36	72
	6-10-Projects	12	0	0	12
Commercial	11-20-Projects	6	0	0	6
	1-5-Projects	23	36	21	80
	6-10-Projects	0	0	6	6
Industrial	1-5-Projects	24	12	9	45
	6-10-Projects	11	0	0	11
Infrastructure	1-5-Projects	32	30	25	87
	6-10-Projects	5	0	0	5
Grand Totals		125	102	97	324

Source: *Fieldwork, 2015*

The results showed that all of the firms in NCA1-3 had 1-5 projects for residential, commercial, industrial, and infrastructure. Under residential projects, NCA3 firms had more projects compared to NCA1 and NCA2.Under commercial projects, NCA2 had more projects in comparison with NCA1and NCA3.In industrial, and infrastructure projects NCA had more projects compared to the rest respectively.

Figure 4.3 shows a graphical representation firms' response by the type of projects they undertake:

Figure 4.3: Response by type of projects undertaken



Source: *Fieldwork, 2015*

4.4.4: Firm's number of employees

Table 4.5: Response by Number of employees

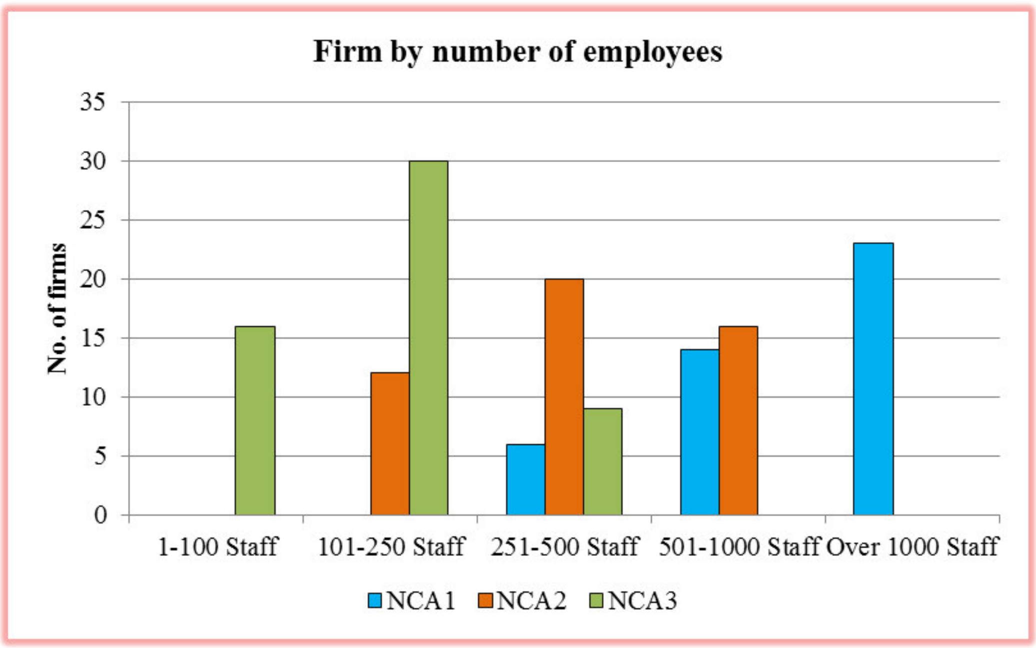
Firm Registration Category * No Employees Cross tabulation						
Firm Registration Category	No Employees					Total
	1-100 Staff	101-250 Staff	251-500 Staff	501-1000 Staff	Over 1000 Staff	
NCA1	0	0	6	14	23	43
NCA2	0	12	20	16	0	48
NCA3	16	30	9	0	0	55
Total	16	42	35	30	23	146

Source: *Fieldwork, 2015*

The results showed that number of staff was related on the firms' registration category and the amount of work the firm was handling. Majority of responses from firms in NCA 1 showed that they had majority of staff exceeding 1000. NCA 2 and NCA 3 had majority of staff between 251-500 and 101-250 respectively. This can be explained by the fact that as the major firms in the higher categories have major projects thus the need for more staff in their firms.

Figure 4.4 shows a graphical representation firms' response by the type of projects they undertake:

Figure 4.4: Response on firms' employees



Source: *Fieldwork, 2015*

4.5 Site automation implementation

4.5.1 Site automation levels

Table 4.6: Site automation levels

Category	No Automation	Partial Automation	Grand Total	% usage
NCA1	0	43	43	100%
NCA2	0	48	48	100%
NCA3	6	49	55	89%
Grand Total	**6**	**140**	**146**	**96%**

Source: *Fieldwork, 2015*

The descriptive statistics showed that all firms registered in NCA1 and NCA2 category used partial automation while only 89 percent of firms in NCA3 reported using site automation technologies. In summary, 96 percent of the firms in NCA 1-3 used partial automation. However, none of the firms reported using site automation technologies to a major or full extent while undertaking their construction projects.

4.5.2 Factors affecting site automation levels

Table 4.7: Cross tabulation on factors affecting site automation levels

Site automation level	Effect on site automation	Cost of automation	Firm size	Having an automation strategy	Project magnitude	Availability of the technology	Human resource capacity	Construction site characteristics
No Automation	None	4%	4%	8%	4%	4%	4%	12%
Partial Automation	Slight to Moderate	0%	19%	45%	13%	20%	67%	51%
	Major to Extreme	96%	77%	47%	83%	76%	29%	37%
Full Automation		0	0	0	0	0	0	0
Grand Totals		100%	100%	100%	100%	100%	100%	100%

Source: *Fieldwork, 2015*

Cost of automation, project magnitude, firm size, availability of automation technology and having an automation strategy were cited to have major to extreme effect on the adoption of site automation technologies by majority of respondents (i.e. 96, 83, 77, 76 and 47 percent respectively) while human resource capacity and construction site characteristics had slight to moderate effect (i.e. 67 and 51 percent respectively). The respondents indicated major to extreme effect scale with 96 percent of the respondents indicating cost of automation was a significant factor influencing automation levels, 77 percent respondents indicating firm size, 83 percent indicating project magnitude, and 76 percent indicating availability of automation technology, 47 percent indicating automation strategy, 37 percent indicating site characteristics and finally 29 percent indicating human resource capacity as factors affecting site automation levels.

4.5.3: Test for association –correlation analysis

Table 4.8: Correlation analysis

Correlations								
		Cost	**Firm Size**	**Strategy**	**Project Magnitude**	**Technology Availability**	**Human R. Capacity**	**Site Characteristi**
Level of Site Automation	Pearson Correlation	.867**	.643**	.430**	.601**	.508**	.610**	.407**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000
	N	146	146	146	146	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).								

Source: *Fieldwork, 2015*

The results showed strong and significant correlations between site automation level and cost of automation, firm size, project magnitude, and staff capacity. Having an automation strategy, availability of automation technology and construction site characteristics all had significant correlations but weaker with level of site automation. In summary, costs of automation (acquisition, maintenance and updating costs) was highly correlated to level of site automation with a Pearson correlation coefficient of 0.867 significant at p=0.000 which means cost has a great influence on level of automation among construction firms in Kenya.

4.6 Modeling the association of site automation levels and factors affecting automation

4.6.1 Regression analysis

Table 4.9: Model Summary

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.919[a]	.845	.837	.080	.845	107.605	7	138	.000
a. Predictors: (Constant), Construction Site characteristics, Automation Technology Available , Human Resource Capacity, Project Magnitude, Automation Costs, Firm Size, Automation Strategy									

Source: *Fieldwork, 2015*

The standard multiple regression analysis results showed that the independent variables (cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics) were excellent predictors of the dependent variable (level of site automation). The independent variables returned a strong model fit of R equal to 0.919, which is equivalent to 91.9 percent quality of prediction.

In addition, the R square obtained of 0.845 which is the coefficient of determination or rather the proportion of variance in the dependent variable that can be explained by the independent variables represented a significant explanation of 84.5 percent at p=0.000. This means that the variance observed in the levels of adoption of site automation technology can be explained by the independent variables (cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics) up to 84.5 percent.

4.6.2 Analysis of variance

Table 4.10: ANOVA results

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.863	7	.695	107.605	.000[b]
	Residual	.891	138	.006		
	Total	5.753	145			
a. Dependent Variable: Uses Site Automation						
b. Predictors: (Constant), Construction Site characteristics, Automation Technology Available , Human Resource Capacity, Project Magnitude, Automation Costs, Firm Size, Automation Strategy						

Source: *Fieldwork, 2015*

The F-test statistic ($F(7,138) = 107.605$, $p = 0.000$) from the ANOVA results showed that the variance observed in the dependent variable level of site automation was not by chance. As a result this confirmed that the alternative hypothesis that site automation is influenced significantly by cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics as posited in the literature review. The null hypothesis was thus rejected and alternative hypothesis accepted.

4.6.3 Model I equation

From the literature review and theoretical concept, this study theorized that the relation between factors affecting site automation and level of site automation could be expressed in the following equation.

$$S_{al} = A + B_1X_1 + B_2X_2 + B_qX_n + \varepsilon_i$$

Table 4.11: Coefficients for model 1

From standard multiple regression analysis, the following coefficients were generated for the model below:

Coefficients[a]							
Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	.883	.043		20.734	.000	.799	.967
Automation Cost	.155	.014	.668	11.018	.000	.127	.182
Firm Size	.055	.013	.267	4.288	.000	.030	.080
Automation Strategy	.018	.010	.108	1.731	.086	-.003	.039
Project Magnitude	.017	.010	.087	1.688	.094	-.003	.036
Availability of Automation Technology	.022	.011	.085	2.020	.045	.000	.043
HR Capacity	.035	.015	.128	2.428	.016	.007	.064
Construction Site Characteristics	-.057	.012	-.308	-4.869	.000	-.080	-.034
a. Dependent Variable: Uses Site Automation							

Source: *Fieldwork, 2015*

The association between factors affecting level of site automation could therefore be presented in a linear equation as follows:

$$S_{al} = 0.883 + 0.155_{AC}X_i + 0.055_{FS}X_2 + 0.018_{AS}X_i + 0.017_{PM}X_i + 0.022_{TA}X_i + 0.035_{HR}X_i - 0.057_{CC}X_i + 0.043$$

Where S_{al} is level of site automation,

AC is automation costs,

FS is firm size,

AS is automation strategy,

PM is project magnitude,

TA is technology availability,

HR is human resource capacity,

CC is construction site characteristics and

X_i is the response variable

4.6.4 Testing for association-Chi square and effect size

4.6.4.1 Chi square test

Table 4.12: Chi-square test

Independent Variable	Pearson Chi-Square value	df	Asymp. Sig. (2-sided)
Cost of Automation	146.000[a]	2	.000
Firm size	146.000[a]	4	.000
Having an automation strategy	69.871[a]	4	.000
Project magnitude	146.000[a]	4	.000
Availability of automation technology	76.792[a]	3	.000
Human resource capacity	146.000[a]	3	.000
Construction site characteristics	44.495[a]	4	.000

Source: *Fieldwork, 2015*

The chi-square test for independence showed that there was a strong and significant association between the independent variables and the dependent variable, level of site automation. The cost of automation, firm size, project magnitude, and human resource capacity had stronger association to level of site automation closely followed by availability of the technology, having a site automation strategy and the characteristics of a construction site respectively.

4.6.4.2: Effect size

Table 4.13: Effect size of the association between independent and dependent variables

Independent Variable	Phi Value	Approx. Sig.
Cost of automation	1.000	.000
Firm size	1.000	.000
Having an automation strategy	.692	.000
Project magnitude	1.000	.000
Availability of automation technology	.725	.000
Human resource capacity	1.000	.000
Construction site characteristics	.552	.000

Source: *Fieldwork, 2015*

As shown by the correlation and chi-square values, the cost of automation, firm size, project magnitude and human resource capacity had a very strong (perfect) association with the level of site automation with all their effect size Phi values equal to one (1).

4.6 Site automation technologies used by construction firms in Kenya

Table 4.14: Site automation technologies used by construction firms

Statistics								
		GPS	Mobile Based	Vision Cameras	UWB	RFID	LADAR	Virtual Reality
N	Valid	140	146	146	146	146	146	146
	Missing	6	0	0	0	0	0	0
Mode		2	3	3	1	1	1	1

Source: *Fieldwork, 2015*

The mode showed that majority of construction firms in NCA1, NCA2 and NCA3 categories respectively were using GPS, mobile based and vision cameras technologies in site automation while a few firms were using UWB, RFID, LADAR and virtual reality technologies.

4.6.1 GPS technologies

Table 4.15: Global Positioning System

GPS					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	4	2.7	2.9	2.9
	Slightly	48	32.9	34.3	37.1
	Moderately	45	30.8	32.1	69.3
	Majorly	36	24.7	25.7	95.0
	Extremely	7	4.8	5.0	100.0
	Total	140	95.9	100.0	
Missing	System	6	4.1		
Total		146	100.0		

Source: *Fieldwork, 2015*

The results showed that 97.1 percent of the firms were using GPS technology in site automation with the level of use ranging between minor and major use.

4.6.2 Mobile based technologies

Table 4.16: Mobile based technologies

Mobile Based					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	4	2.7	2.7	2.7
	Slightly	6	4.1	4.1	6.8
	Moderately	75	51.4	51.4	58.2
	Majorly	48	32.9	32.9	91.1
	Extremely	13	8.9	8.9	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The frequency results showed that all the firms studied used mobile-based site automation technologies with 84.3 percent indicating a moderate to major use of this technology in construction site automation.

4.6.3 Vision cameras

Table 4.17: Vision cameras

Vision Cameras					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	42	28.8	28.8	28.8
	Slightly	21	14.4	14.4	43.2
	Moderately	66	45.2	45.2	88.4
	Majorly	17	11.6	11.6	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that 71.2 percent of the firms studied were using vision cameras in their construction sites with the majority indicating a moderate use of this technology in construction site automation.

4.6.4 UWB technology

Table 4.18: Ultra wide band technology

UWB Technology					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	138	94.5	94.5	94.5
	Slightly	8	5.5	5.5	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that only a minimal 5.5 percent of the respondents were using ultra wide band technology in construction site automation and at a minor extent.

4.6.5 RFID technology

Table 4.19: Radio frequency identification

RFID Technology					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	142	97.3	97.3	97.3
	Slightly	4	2.7	2.7	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that only 2.7 percent of the firms studied were using RFID technology in construction site automation and to a minor extent.

4.6.6 LADAR technology

Table 4.20: Laser detection and range tracking

LADAR Technology					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	142	97.3	97.3	97.3
	Slightly	4	2.7	2.7	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that only 2.7 percent of the firms studied were using LADAR technology in construction site automation and to a minor extent.

4.6.7 Virtual reality technology

Table 4.21: Virtual reality technology

Virtual Reality Technology					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	138	94.5	94.5	94.5
	Slightly	8	5.5	5.5	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that only 5.5 percent of the firms studied were using virtual reality technology in construction site automation and to a minor extent. These results show that GPS, mobile based and vision cameras technologies are used largely in construction site automation in Kenya compared to UWB, RFID and LADAR technologies, which are rarely used.

4.7 Barrier's influencing site automation adoption of site automation technologies

Table 4.22: Barriers of site automation

Statistics						
	High acquisition, maintenance & upgrading costs	Incompatible technology	Low knowledge in technology	Technology acceptability	Technology unavailability	Lack of stakeholder support
N	146	146	146	146	146	146
Mode	5	2	2	1	2	2

Source: *Fieldwork, 2015*

The results showed that high costs of automation i.e. acquisition, maintenance and upgrading costs respectively to be the most significant barrier to adoption of site automation. The other barrier factors i.e. incompatibility, unavailability and acceptability of the technology respectively as well as human resource capacity and lack of adequate stakeholder support were considered to be minor barriers to adoption of site automation.

4.7.1 High costs of automation

Table 4.23: High costs of acquisition, maintenance, and upgrading

High Acquisition and Maintenance Costs * UsesSiteAutom					
Count					
		Uses Site Automation			
		No Automati on	Partial Automatio n	Percen t	Tot al
High Acquisition, Maintenance & Upgrading Costs	Moder ately	6	1	1%	7
	Majorl y	0	12	8%	12
	Extre mely	0	127	87%	127
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The results showed that 87 percent of the firms who reported employing partial automation in construction sites also considered cost of automation i.e. acquisition, maintenance and upgrading costs respectively to be the most significant barrier to adoption of site automation technologies.

4.7.1.1 Test for association between adoption of site automation technologies and of costs

Table 4.24: Correlation of use of site automation technologies and costs

Correlations				
		Acquisition Cost	Maintenance Cost	Upgrading Cost
Uses Site Automation	Pearson Correlation	.842**	.754**	.832**
	Sig. (2-tailed)	.000	.000	.000
	N	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).				

Source: *Fieldwork, 2015*

The correlation result showed that adoption of site automation technologies was strongly and significantly associated to cost of automation i.e. acquisition, maintenance and upgrading costs respectively. In addition, cost of acquisition and upgrading had strong correlation to adoption of site automation technologies signifying that they had more influence on adoption of site automation technologies than the cost of maintenance.

Table 4.25: Chi-square test

Chi-Square Tests			
Cost	Pearson Chi-Square value	df	Asymp. Sig. (2-sided)
Acquisition	146.000[a]	2	.000
Maintenance	114.280[a]	4	.000
Upgrading	146.000[a]	2	.000

Source: *Fieldwork, 2015*

The chi-square test for independence showed that adoption of site automation technologies varied with cost factors i.e. acquisition (χ=146.00 at p=0.000), maintenance (χ=114.28 at p=0.000) and upgrading (χ=146.00 at p=0.000) costs respectively.

Table 4.26: Association effect size

Effective size		
Cost	Phi Value	Approx. Sig.
Acquisition	1.000	.000
Maintenance	0.885	.000
Upgrading	1.000	.000

Source: *Fieldwork, 2015*

The effect size result showed that acquisition and upgrading costs had a perfect effect size e=1 while cost of maintenance had an effect size of e=0.885 which signify that the former had more influence in the adoption of site automation technologies.

4.7.2 Incompatibility of automation technologies

Table 4.27: Incompatibility of technology

Incompatibility of technology * Uses site automation					
Count					
		Uses site automation			
		No Automation	Partial Automation	Percent	Total
Incompatibility of technologies	Not at All	6	2	1%	8
	Slightly	0	102	70%	102
	Moderately	0	36	25%	36
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The result showed that 70 percent of the firms studied did not consider compatibility of automation technologies with other technologies to be a barrier to adoption of these technologies while 25 percent of the respondents indicated that it had minor influence.

4.7.3 Literacy of project participants

Table 4.28: Low literacy levels among project participants

Low knowledge in technology * Uses site automation					
Count					
		Uses site automation		Percent	Total
		No Automation	Partial Automation		
Low knowledge in technology	Not at All	6	29	20%	35
	Slightly	0	105	72%	105
	Moderately	0	6	4%	6
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The results showed that 72 percent of the respondents considered lack of capable human capacity to be a minor barrier to adoption of site automation technologies in the Kenyan construction industry while 20 percent did not see it as a barrier at all.

4.7.4 Acceptability of the technology

Table 4.29: Technology acceptability

Technology acceptability * Uses site automation					
Count					
		Uses site automation		Percent	Total
		No Automation	Partial Automation		
Technology acceptability	Not at All	6	110	75%	116
	Slightly	0	30	21%	30
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The results showed that acceptability of site automation technology was not a significant barrier to adoption of these technologies with 75 percent of the respondents indicating this factor not a barrier while 21 percent reported to have minor influence.

4.7.5 Availability of the automation technology

Table 4.30: Technology availability

Technology unavailability * Uses site automation					
Count					
		Uses site automation			
		No Automation	Partial Automation	Percent	Total
Technology unavailability	Not at All	6	10	7%	16
	Slightly	0	68	47%	68
	Moderately	0	62	42%	62
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The results showed that local availability of site automation technologies to be a significant barrier to adoption of site automation with 42 percent of firms studied indicating this factor to have moderate influence and 47 percent reporting it to have minor influence in the adoption of site automation technologies in the Kenyan construction industry.

4.7.6 Lack of adequate stakeholder support

Table 4.31: Lack of adequate Stakeholder support

Lack of stakeholder **support * Uses site automation**					
Count					
		Uses site automation			
		No Automation	Partial Automation	Percent	Total
Lack of stakeholder support	Not at All	3	0	0%	3
	Slightly	3	116	79%	119
	Moderately	0	24	16%	24
Total		6	140	96%	146

Source: *Fieldwork, 2015*

The results showed that 79 percent of the respondents indicated that lack of adequate stakeholder support in the adoption of site automation technologies was only a minor barrier but still an important factor given this huge consensus.

4.8 Test for association of barrier factors

4.8.1 Correlation analysis

Table 4.32: Correlation analysis of barrier factors with site automation

Correlations							
		High acquisition maintenance costs	Incompatible technology	Low technology knowledge	Technology acceptability	Technology unavailability	Lack of stakeholder support
Uses site automation	Correlation	.766**	.480**	.338**	.105	.413**	.329**
	Sig.	.000	.000	.000	.206	.000	.000
	N	146	146	146	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).							

Source: Fieldwork, 2015

The correlation analysis showed that the high costs of automation technologies was the greatest and most significant barrier to adoption of site automation technology with a correlation of 0.766 significant at p<0.000. Incompatible technologies and unavailability of site automation technologies were also observed to have significant influence on the uptake of these technologies with correlations of 0.480 and 0.413 respectively at p<0.000.4.8.2: Chi-square test for independence.

Table 4.33: Chi-square test for independence

Barriers	Pearson Chi-Square value	df	Asymp. Sig. (2-sided)
High Acquisition & maintenance costs	124.249[a]	2	.000
Incompatible technology	107.936[a]	2	.000
Low technology knowledge	19.844[a]	2	.000
Tech acceptability	1.618[a]	1	.203
Technology unavailability	50.839[a]	2	.000
Lack of stakeholder support	71.791[a]	2	.000

Source: *Fieldwork, 2015*

The results showed that automation costs had the strongest association with the level of site automation closely followed by incompatibility of site automation technologies with existing technologies.

Table 4.34: Effect size of barriers of site automation

Barriers	Phi value	Approx. Sig.
High acquisition & maintenance costs	.923	.000
Incompatible technology	.860	.000
Low technology knowledge	.369	.000
Technology acceptability	.105	.203
Technology unavailability	.590	.000
Lack of stakeholder support	.701	.000

Source: *Fieldwork, 2015*

The effect size also showed that cost of site automation had the most effect on level of site automation followed by issues related to compatibility of these technologies while acceptability of the technologies had the least effect, which was also not significant.

4.9 Minimizing barriers of site automation-Testing for association between automation levels and solutions to barriers of site automation

Table 4.35: Correlation analysis solution of barriers of site automation

Correlations								
		Reduce acquisition & maintenance costs	Encourage technology fusion	Training	Marketing	Enhance technology availability	Supporting Legal Framework	User friendly technology
Uses site automation	Pearson Correlation	.750**	.390**	.436**	.043	.302**	.021	.268**
	Sig. (2-tailed)	.000	.000	.000	.608	.000	.801	.001
	N	146	146	146	146	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).								

Source: *Fieldwork, 2015*

The results showed that reduction in cost of automation, having capable human capacity and having compatible automation technologies to be the most significant factors that require attention in order to increase the adoption levels of site automation.

Table 4.36: Chi-square test for independence

Solution to barriers of automation	**Pearson Chi-Square value**	**df**	**Asymp. Sig. (2-sided)**
Reduce acquisition & maintenance costs	146.000[a]	2	.000
Encourage technology fusion	96.154[a]	2	.000
Training	71.538[a]	2	.000
Marketing	.268[a]	1	.605
Enhance technology availability	71.986[a]	2	.000
Support legal framework	34.345[a]	2	.000
User friendly technology	96.912[a]	3	.000

Source: *Fieldwork, 2015*

The results showed that reducing cost of site automation technologies had the greatest association with adoption of site automation technologies followed by encouraging development of compatible and user-friendly technologies.

Table 4.37: Effect size of solution to barriers of site automation

Solution to barriers of automation	Phi Value	Approx. Sig.
Reduce acquisition & maintenance costs	1.000	.000
Encourage technology fusion	.812	.000
Training	.700	.000
Marketing	.043	.605
Enhance technology availability	.702	.000
Support legal framework	.485	.000
User friendly technology	.815	.000

Source: *Fieldwork, 2015*

The effect size analysis showed that reduction in cost of automation had a perfect score indicating that it had the greatest influence in regards to improving the uptake of site automation technologies. Further, encouraging development of compatible and user friendly technologies also had significant influence closely followed by provision of training and enhancing availability of site automation technologies.

4.10 Significance of site automation on project performance in Kenya

Table 4.38: Impact of site automation on project performance

Site automation affect project performance					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slightly	6	4.1	4.1	4.1
	Moderately	28	19.2	19.2	23.3
	Majorly	112	76.7	76.7	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that 76.7 percent of the firms studied considered use of site automation technologies to have a major influence on project performance with 19.2 percent considering it have just but a minor effect on performance.

4.11 Influence of site automation on project performance parameters

Table 4.39: Level of influence of site automation on project performance

Statistics			
Measure of project performance	N		Mode
	Valid	Missing	
Site automation affect project performance	146	0	4
Reduces completion time	146	0	4
Improves quality	146	0	5
Project cost control	146	0	2
Improves health safety	146	0	5
Project scope control	146	0	3

Source: *Fieldwork, 2015*

The results for the mode showed that use of site automation technologies influences project performance to a major extent in general terms but more specifically, it extremely influences completion time, quality, health and safety. Further, majority of the respondents indicated that use of site automation technology minor effect on cost control and moderate effect on scope control.

4.11.1 Reduction in completion time

Table 4.40: Influence on project completion time

Reduces completion time					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slightly	7	4.8	4.8	4.8
	Moderately	6	4.1	4.1	8.9
	Majorly	133	91.1	91.1	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that 91.1 percent of the respondents considered use of site automation technology in construction site automation to have a major influence on reduction of project completion time with the 8.9 percent considered site automation technology to have minor or no influence at all.

4.11.2 Improvement in quality

Table 4.41: Quality improvement in a project

Improves quality					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slightly	6	4.1	4.1	4.1
	Moderately	16	11.0	11.0	15.1
	Majorly	29	19.9	19.9	34.9
	Extremely	95	65.1	65.1	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that 85 percent of the respondents considered use of site automation technology in construction site automation to have a major to extreme influence on quality improvement while 15 percent reported a minor to moderate influence on quality.

4.11.3 Project cost control

Table 4.42: Control of project costs

Project cost control					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slightly	127	87.0	87.0	87.0
	Moderately	19	13.0	13.0	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that majority (87 percent) of the firms considered use of site automation technology to have only minor influence towards improvement of project cost control. The rest (13 percent) considered use of site automation technology to have moderate influence towards improvement of project cost control.

4.11.4 Improvement in health and safety

Table 4.43: Improvement in site health and safety

Improvement in health and safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Slightly	7	4.8	4.8	4.8
	Moderately	29	19.9	19.9	24.7
	Majorly	27	18.5	18.5	43.2
	Extremely	83	56.8	56.8	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that majority of the firms (75.3 percent) considered use of site automation technologies to have major to extreme influence on improvement in construction quality with 24.7 percent reporting minor to moderate influence.

4.11.5 Project scope control

Table 4.44: Control of project scope

Project scope control					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at All	12	8.2	8.2	8.2
	Slightly	51	34.9	34.9	43.2
	Moderately	83	56.8	56.8	100.0
	Total	146	100.0	100.0	

Source: *Fieldwork, 2015*

The results showed that 91.8 percent of the firms felt that use of site automation technologies improves project scope control while 8.2 percent indicated it to have no effect.

4. 12 Test association of site automation and project performance

4.12.1: Correlation analysis

Table 4.45: Correlation of site automation and project performance

Correlations						
		Reduces Comp Time	Improves Quality	Project Cost Control	Improve Health Safety	Project Scope Control
Site automation affect project performance	Pearson Correlation	.573**	.693**	.200*	.714**	.491**
	Sig. (2-tailed)	.000	.000	.016	.000	.000
	N	146	146	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Source: *Fieldwork, 2015*

The results showed that site automation technologies was strongly and significantly associated with performance in terms of reduction in completion time, improvement in quality, improvement in health and safety and to some extent greater control of the project scope. This therefore means that use of site automation technologies was more significant in the improvement of health and safety, improvement in quality and reduction of completion time required in a construction project.

4.12.2: Chi Square test for independence and effect size

Table 4.46: Chi-square test for independence

Chi-Square Tests			
Measures of Performance	Pearson Chi-Square	df	Asymp. Sig. (2-sided)
Reduces completion time	124.999	4	.000
Improves quality	211.262	6	.000
Project cost control	6.631	2	.036
Improves health safety	181.689	6	.000
Project scope control	62.015	4	.000

Source: *Fieldwork, 2015*

The results of chi-square test for independence showed that theorized factors of project performance vary significantly with the use of site automation technologies.

Table 4.47: Effect size

Effect Size		
Measures of Performance	Phi Value	Approx. Sig.
Reduces completion time	.654	.000
Improves quality	.851	.000
Project cost control	.213	.036
Improves health safety	.789	.000
Project scope control	.461	.000

Source: *Fieldwork, 2015*

As observed with correlation analysis results, the effect size showed that use of site automation technologies had more influence on quality (e=0.851), health and safety (e=0.789), reduction in completion time (e=0.6540 and to a small extent better control of the project scope (e=0.461).

4.13 Modeling association on site automation levels and project performance

Principal component analysis was done to combine the project performance elements into one factor through SPSS factor analysis method. Correlation and standard multiple regression were then undertaken to establish the association between the components of a construction site automation and project performance.

4.13.1 Correlation analysis

Table 4.48: Test for association: Correlation analysis

Correlations					
		Labor	Construction materials	Construction plant equipment	Construction processes
Project Performance	Pearson Correlation	.604**	.517**	.625**	.574**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	146	146	146	146
**. Correlation is significant at the 0.01 level (2-tailed).					

Source: *Fieldwork, 2015*

The results showed that use of construction plant and equipment in site automation, and automation of labor were strongly and significantly correlated with project performance followed closely by automation of construction processes and construction materials management respectively.

4.13.2 Regression model

Table 4.49: Model summary

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.647[a]	.419	.402	.77317674	.419	25.389	4	141	.000
a. Predictors: (Constant), Construction Processes, Construction Materials, Labor, Construction Plant and Equipment									

Source: *Fieldwork, 2015*

The results showed that automation of labor, construction materials, plant and equipment, and construction processes were good predictors of project performance with a model fit of R equal to 64.7 percent. In addition, automation of labor, construction materials, plant and equipment, and construction processes can be associated with an improvement in project performance up to 41.9 percent (R square) at p<0.000.

4.13.3 Analysis of variance

Table 4.50: ANOVA results

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.710	4	15.177	25.389	.000[b]
	Residual	84.290	141	.598		
	Total	145.000	145			
a. Dependent Variable: REGR factor score 1 for analysis 1						
b. Predictors: (Constant), Construction Processes, Construction Materials, Labor, Construction Plant and Equipment						

Source: *Fieldwork 2015*

The F-test for the null hypothesis that there is no significant difference in project performance with adoption of site automation technologies in construction management i.e. R square is zero showed that the variance (41.9 percent) in project performance explained by the independent variables (automation of labor, construction materials, plant and equipment, and construction processes) was not by chance given F (4,141) = 25.389 and a p<0.000. With this result, the null hypothesis that there is no significant difference in project performance from use of site automation technology was rejected.

4.13.4: Model II equation for association.

Table 4.51: Model II equation for the association

Coefficients[a]								
		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model II		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
I	(Constant)	-2.064	.233	0.00	-8.864	.000	-2.524	-1.604
	Labor	.280	.141	.257	1.978	.050	.000	.559
	Construction materials	-.038	.108	-.040	-.347	.729	-.251	.176
	Construction plant equipment	.383	.148	.342	2.587	.011	.090	.675
	Construction processes	.115	.118	.122	.974	.332	-.118	.347
a. Dependent Variable: REGR factor score 1 for analysis 1								

Source: *Fieldwork, 2015*

The study posited the association between components of construction site automation and project performance to be given by the following equation:

$$\boldsymbol{H_{pp} = A + B_1X_1 + B_2X_2 + B_qX_n + \varepsilon_i}$$

By introducing the coefficients from the computed model, the equation was summed up as:

$$H_{pp} = -2.064 + 0.28_{L}X_i - 0.038_{CM}X_i + 0.383_{CPE}X_i + 0.115_{CP}X_i + 0.233$$

Where H_{pp} is the increase in project performance,

L is labor,

CM is construction materials,

CPE is construction plant and equipment,

CP is construction processes and

X_i is the response variable.

4.14 Summary of the results

This chapter explored factors that influence level of site automation, site automation technologies used in the Kenyan construction industry and the influence of site automation technologies on project performance.

The results showed that the level of site automation was strongly and significantly associated with cost of automation (acquisition, maintenance, and updating costs respectively), size of the firm, project magnitude, and staff capacity. In addition, among the elements of costs, the cost of acquisition had more influence followed by updating and maintenance costs respectively. It was also established that the variance in the level of adoption of site automation technology by Kenyan construction firms could be explained by the cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics by up to 84.5 percent.

The results showed that relationship between level of site automation and factors affecting site automation could be predicted using the following equation:

$$S_{al} = 0.883 + 0.155_{AC}X_i + 0.055_{FS}X_2 + 0.018_{AS}X_i + 0.017_{PM}X_i + 0.022_{TA}X_i + 0.035_{HR}X_i - 0.057_{CC}X_i + 0.043$$

Where S_{al} is level of site automation,

AC is automation costs,

FS is firm size,

AS is automation strategy,

PM is project magnitude,

TA is technology availability,

HR is human resource capacity,

CC is construction site characteristics and

X_i is the response variable.

The results also indicated that majority of the firms in NCA1, NCA2, and NCA3 were using GPS, mobile based and vision cameras technologies in site automation between minor to moderate extents while none were using UWB, RFID, LADAR, and virtual reality technologies.

Further, the results showed that high cost of automation technologies was the greatest and most significant barrier to adoption of site automation technology closely followed by incompatibility in the technologies and unavailability of site automation technologies respectively. In addition, automation of components of construction site was found to have significant influence on project performance. Automation of these components was found to influence the variance in project performance up to 41.9 percent.

Finally, the association between site automation and project performance could be predicted by the following equation.

$$H_{pp} = -2.064 + 0.28_{L}X_i - 0.038_{CM}X_i + 0.383_{CPE}X_i + 0.115_{CP}X_i + 0.233$$

Where H_{pp} is the increase in project performance,

L is labor,

CM is construction materials,

CPE is construction plant and equipment,

CP is construction processes and

X_i is the response variable

Following the analysis of the results presented the conclusion and recommendations on areas of further research are described in next chapter.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter contains a summary, discussion, conclusions and recommendations made in regards to the applicability of site automation technologies in monitoring construction project performance in Kenya. The objectives of this study were; to explore factors that determine site automation adoption levels in monitoring project performance Kenya; to find out site automation technologies used by construction firms in Kenya; to identify barriers affecting adoption of site automation technologies in Kenya and to assess the impact of site automation on project performance in Kenya.

Descriptive research design was employed in this study and firms registered under NCA 1, NCA 2 and NCA 3 categories were targeted. Data was collected using a questionnaire that predominantly used a five point likert scale ranging from No automation to Full automation and No effect to extreme effect. The firms targeted were those within the Nairobi County and the questionnaires were either sent by email or hand delivery.

The study population was 1,086 firms and a sample size of 277 firms was used in this study where 146 questionnaires were returned from 277 questionnaires sent by either mail or physical delivery that represented 53 percent response rate.

The data analysis approach employed involved computing descriptive statistics and statistical analysis to explore associations (correlations, chi-square, and regression). The results were presented in tabular and graphical formats.

5.2 Summary and discussion of major findings

The study summarized the findings as according to the set objectives as follows:

5.2.1 Factors affecting site automation adoption levels

As pointed out in the literature review the factors studied included; cost of automation, size of the firm, project magnitude, staff capacity, having an automation strategy, availability of site automation technology and construction site characteristics.

The results showed that the level of site automation was strongly and significantly associated with cost of automation with an r=0.867 at p=0.000 (acquisition, maintenance, and updating costs respectively), size of the firm with an r=0.643 at p=0.000, project magnitude with an r=0.601 at p=0.000, and staff capacity with an r=0.610. Among the elements of costs, the cost of acquisition with an r=0.842 at p=0.000 had more influence followed by updating with an r=0.832 at p=0.000 and maintenance costs with an r=0.754 at p=0.000 respectively.

Further, that the variance in the level of adoption of site automation technology in the Kenyan construction industry could be explained by the cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics by up to 84.5 percent.

This means that if these factors are addressed there will be significant increase in site automation levels. These technologies must therefore be affordable to enable increase in adoption levels by construction firms at a reasonable cost.

5.2.2 Site automation technologies usage in Kenya

The results showed firms employing automation were partially automated and with no construction firm indicating to have fully employed automation. Further the results revealed that GPS, mobile based and vision cameras technologies were the most predominant automation technologies in site automation while very few firms were using UWB, RFID, LADAR and virtual reality technologies. A majority equal to 97.1

percent of the firms were using GPS technology in site automation from minor to major extent while 84.3 percent indicated a moderate to major use of mobile-based site automation technologies. This means that most of the firms have not fully embraced automation in site management. Embracing site automation could be the game changer in our projects.

5.2.3 Barriers affecting site automation technologies adoption

The study found out that high costs of automation i.e. acquisition, maintenance and upgrading was cited as the most significant barrier to adoption of site automation technologies in the construction industry in Kenya. The other barriers theorized in the literature review i.e. incompatibility, unavailability and acceptability of the technology respectively as well as human resource capacity and lack of adequate stakeholder support were considered to have minor influence on the adoption of site automation technologies.

These findings resonated with a study by Mahbub (2008, pp. 253) which ranked high cost of automation as the most significant barrier to adoption of site automation technologies with least influence from; fragmented nature of construction industry, difficult to use or not easily understood, incompatibility with existing practices and current construction operations, low technology literacy of project participants or need for re-training of workers, unavailable locally and difficult to acquire and not accepted by workers. Encouraging technology transfer through training and capacity building will enrich the construction firms to increase adoption levels.

5.2.4 Impact of site automation on project performance

Majority of the firms studied i.e. 76.7 percent indicated that use of site automation technologies had a major influence on project performance with 19.2 percent considering it have just but a minor effect on performance. It was also established that project performance varied significantly with the use of site automation technologies with greater influence seen on quality (effect size e=0.851), health and safety (effect size e=0.789), reduction in completion time (effect size e=0.6540 and to a small extent better control of the project scope (effect size e=0.461).

Further, use of site automation technologies in automation of labor, construction materials, plant and equipment, and construction processes was found to influence the variance in project performance up to 41.9 percent.

5.3 Conclusions

The level of site automation was found to have strong and significant association with cost of automation (acquisition, maintenance, and updating costs respectively), size of the firm, project magnitude, and staff capacity.

The site automation technologies used in the Kenyan construction industry to a major extent were GPS, mobile-based and vision cameras. The high cost of automation was found to be the most significant barrier to adoption of site automation technologies.

In regards to project performance, 76.7 percent of the firms indicated that use of site automation technologies had a major influence on project performance with greater influence on improved quality, better health and safety, and reduction in completion time.

The results also showed that 84.5 percent of the variance in the level of adoption of site automation technology in the Kenyan construction industry could be explained by cost of automation, firm size, having an automation strategy, project magnitude, availability of automation technology, human resource capacity, and construction site characteristics.

Finally, use of site automation technology could explain the variance in project performance by up to 41.9 percent. The study revealed that use of site automation in construction components (labour, materials, plant and equipment and construction process) leads to higher project performance. Construction firms can improve their performance in by employing site automation technologies in their projects.

5.4 Recommendations

With the cost of automation remaining the most significant barrier to adoption of site automation technologies in the Kenyan construction industry and elsewhere, considerations for development of more affordable but effective technologies should be explored. Construction firms could also explore getting into partnerships in order to pull resources necessary for acquiring essential site automation technologies. The National Construction Authority could explore establishment of automation financing frameworks for the most essential site automation technologies.

Further, the study revealed that use of site automation in managing on construction components (labor, materials, plant and equipment and construction process) leads to higher project performance. Construction firms in Kenya should therefore be sensitized in the use of site automation technologies to enjoy the benefits of reduced completion time in projects, quality improvement, project cost control, project scope control as well as improved occupation health and safety on sites. The construction firms should benchmark on the best practices in automation from the successful firms, which have employed site automation technologies.

The study revealed that most firms use site automation technologies to enhance their site performance and the decision of using was dependent on the firms strategy in project implementation. It therefore critical, to encourage the formulation of legal framework that requires that makes it a pre-requisite for constructions firms to adopt automation in their projects. The National Construction Authority could ensure that construction firms undertaking projects complies with the set minimum automation requirements.

5.5 Areas for further study

Further studies should be undertaken in order to:

1. Explore whether the observed increase in project performance because of adopting site automation technologies is viable enough for construction firms to seek substantial long-term financing in the acquisition of these technologies in the future.
2. Determine significant level of savings that could be obtained by automating construction components of labor, materials, plant and equipment and construction processes.

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APPENDICES

APPENDIX I: QUESTIONNAIRE **NO** | | | |

Introduction:

The purpose of this study is to evaluate the "**Applicability and use of site automation in monitoring project performance in Kenya (A case study of construction firms in Nairobi, Kenya)".** Site automation refers to technologies that construction firms employ in order to monitor progress of construction projects thus facilitating timely decision-making on sites.

This research is conducted with the authority of University of Nairobi, School of Built Environment in fulfillment of Masters of Arts degree in Construction Management (introductory letter from the University attached).

Instructions to the Respondent:

As a reputable construction firm in Nairobi, your firm has been selected to participate in this study. The questionnaire is divided into five sections. Kindly respond to all questions as guided in the questionnaire.

All the information gathered will be treated as confidential and will only be used for academic purposes. A copy of the final report will be availed to your firm upon request.

Your assistance and co-operation is highly appreciated

Yours Sincerely,

……………………………………………………………

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SECTION I: BASIC INFORMATION ON CONSTRUCTION FIRM

1. What is the firm registration category?

NCA CATEGORY (Tick appropriately)	Building works	Civil Engineering works
NCA 1	☐	☐
NCA 2	☐	☐
NCA 3	☐	☐

2. How many projects are you currently handling as a construction firm in Kenya?

Project type(Tick all applicable)	1 - 5 Projects	5 -10 Projects	11 - 20 Projects	Over 20 Projects
Residential development	☐	☐	☐	☐
Commercial development	☐	☐	☐	☐
Industrial development	☐	☐	☐	☐
Infrastructure development	☐	☐	☐	☐
Other(Please, specify)				
…………………………………...	☐	☐	☐	☐
…………………………………...	☐	☐	☐	☐

3. What is the firm's average annual turnover over?

Turnover (In Kshs)	Tick appropriately
Less than 0.5 Billion	☐
0.5 – 1.0 Billion	☐
1.0 - 1.5Billion	☐
1.5 – 2.0Billion	☐
Above 2.0	☐

4. How many employees do you have in your construction firm (both in construction sites and offices)?

Number of employees	**Tick one**
1-100 employees	☐
101-250 employees	☐
251-500 employees	☐
501-1000 employees	☐
Over 1000 employees	☐

SECTION II: SITE AUTOMATION IMPLEMENTATION LEVELS

5. To what extent does your firm use site automation technology in construction projects?

KEY: **1=** No Automation, **2=**Partial Automation, **3=**Moderate Automation, **4=**Major Automation, **5=**Full Automation

	Level of Site Automation				
	1	**2**	**3**	**4**	**5**
Extent of site automation	☐	☐	☐	☐	☐

6. Which of the following components have you automated in your construction sites?

KEY: **1=** No Automation, **2=**Partial Automation, **3=**Moderate Automation, **4=**Major Automation, **5=**Full Automation

Components	**Level of Site Automation**				
	1	**2**	**3**	**4**	**5**
Labour	☐	☐	☐	☐	☐
Construction Materials	☐	☐	☐	☐	☐
Construction plant and equipment	☐	☐	☐	☐	☐
Construction Processes	☐	☐	☐	☐	☐
Other; (Please specify)	☐	☐	☐	☐	☐
…………………………………...	☐	☐	☐	☐	☐

SECTION III: ADOPTION OF SITE AUTOMATION

7. To what extent do the following factors influence the adoption level of site automation in your construction project(s)?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Factors affecting adoption of site automation	**Level of influence on Site Automation**				
	1	**2**	**3**	**4**	**5**
a) Costs of automation i.e. acquisition, maintenance and updating costs	☐	☐	☐	☐	☐
b) Size of the firm	☐	☐	☐	☐	☐
c) Firms site automation strategy	☐	☐	☐	☐	☐
d) Project magnitude i.e. size, location, single or multiple, complexity, construction period	☐	☐	☐	☐	☐
e) Availability of site automation technologies	☐	☐	☐	☐	☐
f) Human resource capacity (Knowledge and skills)	☐	☐	☐	☐	☐
g) Construction site characteristics	☐	☐	☐	☐	☐
Other (Please specify): …………………………………………………………………	☐	☐	☐	☐	☐

8. Level of influence on Site Automation

(i) To what extent do the following **cost factors** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Associated costs of site automation technologies	**Level of influence on Site Automation**				
	1	**2**	**3**	**4**	**5**
i. Acquisition costs	☐	☐	☐	☐	☐
ii. Maintenance costs	☐	☐	☐	☐	☐
iii. Upgrading costs	☐	☐	☐	☐	☐
iv. (Other, specify)…………………………………………	☐	☐	☐	☐	☐

i. To what extent do the following **project magnitude parameters** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Project magnitude parameters	**Level of influence on Site Automation level**				
	1	**2**	**3**	**4**	**5**
i. Cost of the project (budget)	☐	☐	☐	☐	☐
ii. Spatial coverage of the project	☐	☐	☐	☐	☐
iii. Size of the structures under construction	☐	☐	☐	☐	☐
iv. Construction period	☐	☐	☐	☐	☐
v. Construction environment	☐	☐	☐	☐	☐
vi. (Other, specify)……………………………………	☐	☐	☐	☐	☐

ii. To what extent do the following **aspects of a firm** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Firms size aspects	**Level of influence on Site Automation levels**				
	1	**2**	**3**	**4**	**5**
i. Annual turnover	☐	☐	☐	☐	☐
ii. Number of employees	☐	☐	☐	☐	☐
iii. Staff capacity to operate and manage the technology	☐	☐	☐	☐	☐
iv. (Other, specify)……………………………………	☐	☐	☐	☐	☐

iii. To what extent does having an automation strategy influence adoption of site automation technology?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
	Level of influence				
	1	**2**	**3**	**4**	**5**
Having Firms automation stratergy	☐	☐	☐	☐	☐

iv. To what extent do the following **aspects of a firm's strategy** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Constructions firm's automation strategy	**Level of influence on Site Automation levels** 1	2	3	4	5
i. Having an implementation plan	☐	☐	☐	☐	☐
ii. Budget allocation	☐	☐	☐	☐	☐
iii. Having a strategy steering team	☐	☐	☐	☐	☐
iv. (Other, specify)……………………………………	☐	☐	☐	☐	☐

v. To what extent do the following **characteristics of a construction site** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Construction site characteristics	**Level of influence on Site Automation** 1	2	3	4	5
i. Size of the construction site	☐	☐	☐	☐	☐
ii. Project location (rural/urban, regulatory frameworks etc.)	☐	☐	☐	☐	☐
iii. Stakeholders involved	☐	☐	☐	☐	☐
iv. Other (Specify)……………………………………	☐	☐	☐	☐	☐

vi. To what extent do the following **aspects of site automation technologies** influence the level of site automation in your construction projects?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Site automation technologies adaptability	**Level of influence on Site Automation levels** 1	2	3	4	5
i. Local availability or importation only	☐	☐	☐	☐	☐
ii. Ease of use	☐	☐	☐	☐	☐
iii. Compatibility with existing construction operations	☐	☐	☐	☐	☐
iv. Existing regulatory frameworks	☐	☐	☐	☐	☐
v. Acceptability by project stakeholders	☐	☐	☐	☐	☐
Other (Specify)…………………………………………………	☐	☐	☐	☐	☐

9. Which site automation technology does the firm use in monitoring construction site performance?

KEY: **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Automation Technologies	**Level of Usage**				
	1	**2**	**3**	**4**	**5**
a) Global Positioning Systems	☐	☐	☐	☐	☐
b) Mobile based project monitoring	☐	☐	☐	☐	☐
c) Vision cameras	☐	☐	☐	☐	☐
d) Ultra Wide Band (UWB) technology	☐	☐	☐	☐	☐
e) Radio Frequency identification(RFID) technology	☐	☐	☐	☐	☐
f) Laser Detection and Range tracking technology	☐	☐	☐	☐	☐
g) Virtual reality systems	☐	☐	☐	☐	☐
Other:……………………………………………	☐	☐	☐	☐	☐

SECTION IV: PERCEIVED BARRIERS TO SITE AUTOMATION

10. How do the following barriers affect the implementation levels of site automation?

KEY: **KEY:** **1**=Not at All, **2**= Slightly, **3**= Moderately, **4**= Majorly, **5**= Extremely					
Barriers to site automation	**Impact of barriers to site automation**				
	1	**2**	**3**	**4**	**5**
i. High costs of acquisition and maintenance of these technologies	☐	☐	☐	☐	☐
ii. Incompatibility of the technologies with existing practices and current construction operations	☐	☐	☐	☐	☐
iii. Low technology literacy of project participants	☐	☐	☐	☐	☐
iv. The technologies are not easily accepted due to wrong perception among construction professionals(acceptability)	☐	☐	☐	☐	☐
v. Non- availability of automated technologies locally or difficult to acquire	☐	☐	☐	☐	☐
vi. Lack of support from the project stakeholders in promoting use of automation technologies	☐	☐	☐	☐	☐
Others(please state) …………………………………………………………………	☐	☐	☐	☐	☐

11. In your opinion, how can the barriers to site automation can be minimized?

KEY: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree						
Interventions to address barriers to site automation		**Extent of agreement** 1	2	3	4	5
i.	Reducing costs of acquisition and maintenance	☐	☐	☐	☐	☐
ii.	Encouraging technological fusion with existing construction practices and operations	☐	☐	☐	☐	☐
iii.	Improving training programmes on automation	☐	☐	☐	☐	☐
iv.	Better marketing strategies' of the technologies to encourage acceptance by project stakeholders	☐	☐	☐	☐	☐
v.	Enhancing availability of the automation technologies	☐	☐	☐	☐	☐
vi.	Developing legal framework that encourages use of automated technologies	☐	☐	☐	☐	☐
vii.	Developing technologies that are user friendly	☐	☐	☐	☐	☐
Other (Please state): viii.	…………………………………………………………	☐	☐	☐	☐	☐

SECTION V: IMPACT OF SITE AUTOMATION ON PROJECT PERFOMANCE

12. To what extent does site automation affect project performance?

KEY: 1=Not at All, 2= Slightly, 3= Moderately, 4= Majorly, 5= Extremely					
	Level of impact 1	2	3	4	5
Site automation implementation level	☐	☐	☐	☐	☐

13. To what extent does site automation influence project performance in the following aspects?

Key: 1= Not at All, 2= Slightly, 3= Moderately, 4=Majorly, 5= Extremely						
Benefits of site automation on project performance		**Level of influence** 1	2	3	4	5
i.	Reduced project completion time	☐	☐	☐	☐	☐
ii.	Quality improvement	☐	☐	☐	☐	☐
iii.	Costs controls in the project	☐	☐	☐	☐	☐
iv.	Improvement of occupational health and safety	☐	☐	☐	☐	☐
v.	Control of project scope	☐	☐	☐	☐	☐

Thank you for your participation