3-2014

A study of the relationship between the use of GIS and project success in selected construction organizations

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A Study of the Relationship between the Use of GIS and Project Success in Selected Construction Organizations

by

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Dissertation

Submitted to the College of Technology

Eastern Michigan University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN TECHNOLOGY

Area of concentration: Engineering Management

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March 2014

Ypsilanti, Michigan

Acknowledgements

"قُلْ إِنَّ صَلاَتِي وَنُسُكِي وَمَحْيَايَ وَمَمَاتِي لِلّهِ رَبِّ الْعَالَمِينَ، لاَ شَرِيكَ لَهُ وَبِذَلِكَ أُمِرْتُ وَأَنَا أَوَّلُ الْمُسْلِمِينَ"

Say, "Indeed, my prayer, my rites of sacrifice, my living and my dying are for Allah, Lord of the worlds. No partner has He. And this I have been commanded, and I am the first [among you] of the Muslims."

I would like to thank my parents, my wife, and my three kids for their patience, encouragement, and support. I will not forget their help.

A special thanks and appreciation to my advisers, Professor John C. Dugger, Chair of my Ph.D. research committee and Professor Hugh Semple, Co-Chair of my Ph.D. research committee, for being flexible and supportive during my study. I appreciate their guidance and encouragement. I would also like to thank the other members of the research committee, Professor William Moylan, Construction & Project Management representative, and Professor William Welsh, Graduate School & GIS representative for their valuable advice and support throughout this study. I would like to thank all faculty members at the College of Technology who taught me during my Ph.D. program, and a special thanks to Tracy Rush-Byers for her support.

More thanks go to all the students in Eastern Michigan University’s Construction Management graduate class (CNST630, Research on Construction Process) for participating in the pilot study. I also want to thank Mr. Walt Norko, Vice President of Professional Practice in the Construction Management Association of America (CMAA), for reviewing the design survey contents and providing feedback.

A very special thanks and appreciation go to Professor Tom Bowlin, Faculty Professor at The University of Kansas department of Engineering Management, for his efforts in teaching me courses in engineering management and research skills during the work on my master's degree, which was the first step toward the Ph.D. Also, thanks to Julie Banhart, the editor for the research, for being flexible and patient. General thanks to all participants in this research.

Abstract

This survey research effort investigated the relationship between 11 selected Geographic Information System (GIS) functions and three (time, cost, and quality) highway and transportation construction-project success criteria. The population included engineers and information technology professionals in the United States who worked in the highway and transportation area. The sample included members of various appropriate email groups.

No significant relationship between GIS function use and construction project success criteria (time and cost) was found. The third success criterion (customers specification–quality) was not tested because of the lack of variability of the responses. There were significant differences between organizations that focused on highway, street, road, and public sidewalk jobs and other construction organizations that focused on different construction jobs as related to the following two GIS functions: Terrain Modeling and Traffic Management. Some functions that were very close to the .05 level of significance included Estimating Project Costs, Terrain Analysis, 2D and 3D Visualization, and Route/Site Selection.

Recommendations included the following: (a) Engineers and managers should consider using GIS functions for highways, streets, roads, or public sidewalk projects; (b) Special attention should be given to ensuring that appropriate GIS training is provided for all levels in the organization.

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CHAPTER ONE: INTRODUCTION

The construction industry is one of the most important industries in the United States (Nguyen, Ogunlana, & Lan, 2004). According to the U.S. Bureau of Labor Statistics 2010–2011 Occupational Handbook, employee numbers in the construction industry will increase 19 percent between 2008 and 2018. The construction industry is made up of approximately 670,000 firms, which is 11.7 percent of the total number of U.S. industrial firms. According to the U.S. Census Bureau (2010) the construction industry employed 5,389,271 individuals, with an annual payroll of $260,959,445,000. Based on the North American Industry Classification System (NAICS), the construction industry (code 23) is ranked second in size after the Professional, Scientific, and Technical Services Sector (Code 54) as shown in Figure 1.

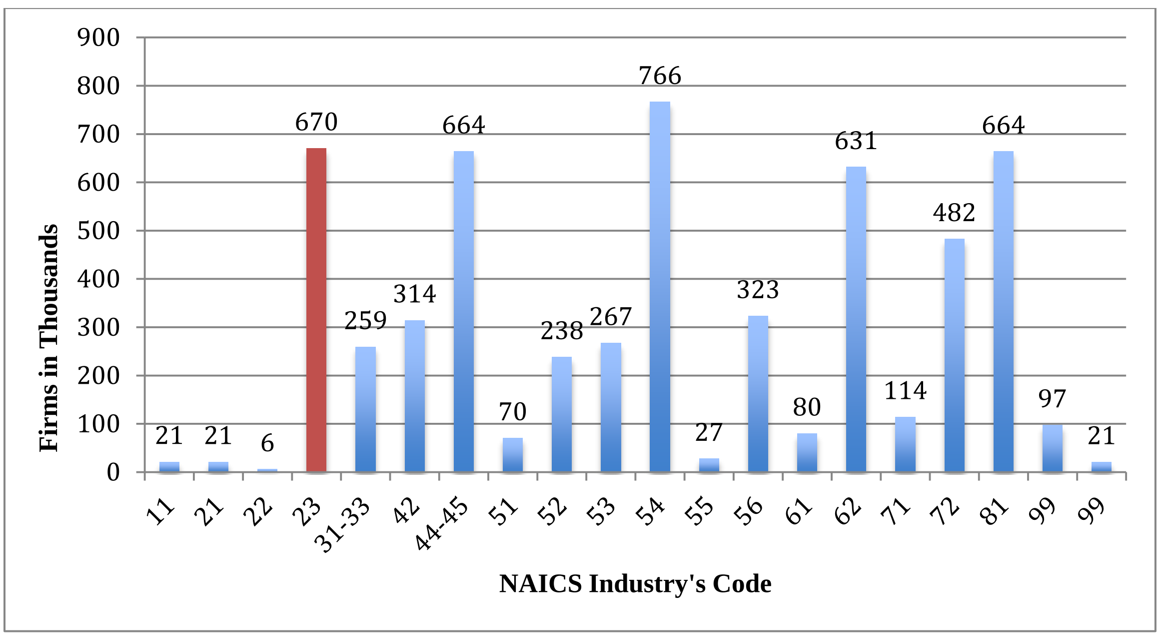

Figure 1. NAICS Industry number of firms
Source: U.S. Census Bureau, 2010

The construction industry sector is divided into three subsectors: construction of buildings, heavy and civil engineering construction, and specialty trade contractors (Figure 2).

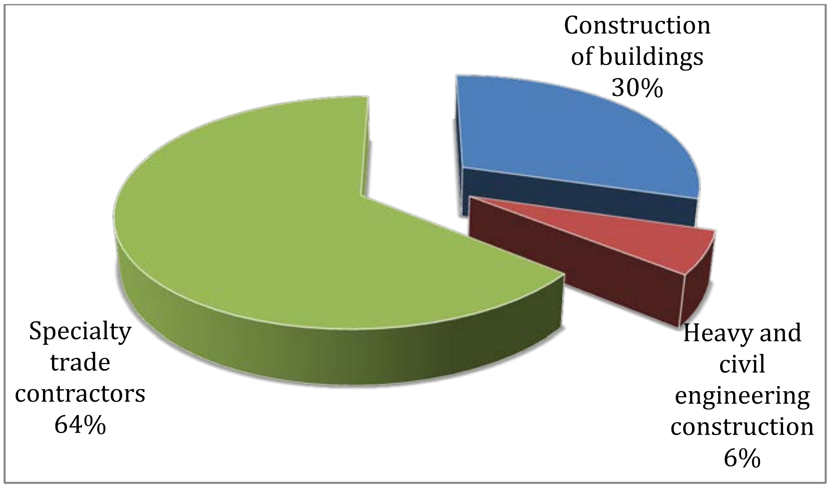

Figure 2. Subsectors of construction industry sector
Source: U.S. Census Bureau, 2010

Each subsector contains several industry groups, and each group has many other subgroups. Table 1 explains the levels of the construction industry based on the U.S. Census Bureau, 2010 classification.

Table 1
Construction Industry Sector (23) Classification Source: U.S. Census Bureau, 2010

Construction Industry sectors:
1-Construction of Buildings
- Residential Building Construction
- Nonresidential Building Construction
- Industrial building construction
- Commercial and institutional building construction
2-Heavy and Civil Engineering Construction
- Utility System Construction
- Land Subdivision
- **Highway, Street, and Bridge Construction**
- Other Heavy and Civil Engineering Construction
3-Specialty Trade Contractors
- Foundation, Structure, and Building Exterior Contractors
- Building Equipment Contractors
- Building Finishing Contractors

The Heavy and Civil Engineering Construction subsector has four main groups: (a) Utility System Construction, which captured 45 percent of the total Heavy and Civil Engineering Construction subsector firms; (b) Land Subdivision, which accounted for 19 percent of the total Heavy and Civil Engineering Construction subsector firms; (c) Highway, Street, and Bridge Construction (25 percent); and (d) Other Heavy and Civil Engineering Construction (11 percent).

This research was focused on Highway, Street, and Bridge Construction, which includes construction of highways, streets, roads, bridges, public sidewalks, and airport runways. These make up 25% of the heavy and civil engineering construction subsector with 273,685 employees and an annual payroll of $17.587 million (see Figure 3).

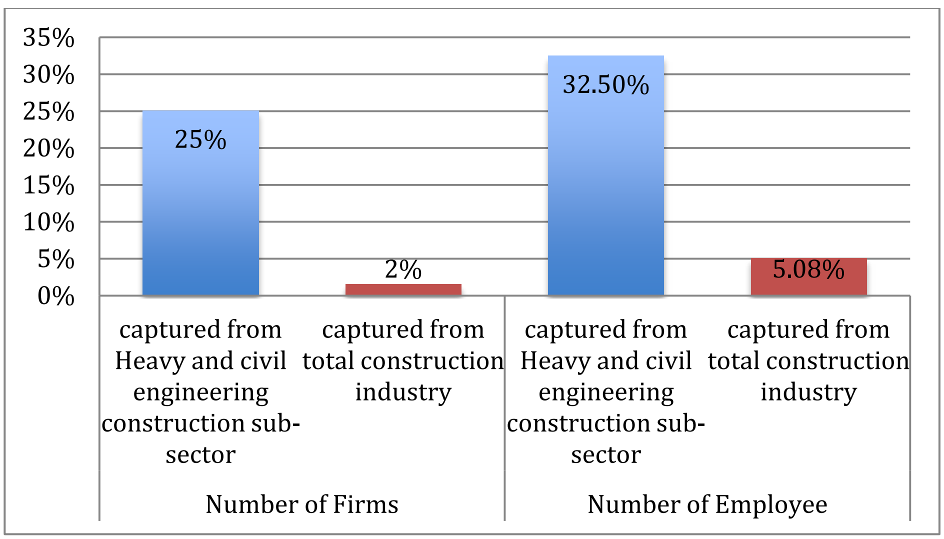

Figure 3, Percentage of firms and employees of Highway, Street, and Bridge construction.
Source: U.S. Census Bureau, 2010

Approximately 99 percent of the companies in this target group in the construction industry (Highway, Street, & Bridge) had fewer than 500 employees, as can be seen in Figure 4. According to the U.S. Census Bureau (2007), the Highway, Street, and Bridge group, includes “streets, roads, airport runways, public sidewalks, or bridges”

(U.S. Census Bureau, 2007, para. 1). As Vincenzo (2012, para. 2) pointed out, “small companies for the most part are struggling because of the sluggish economy, increased competition, rising insurance costs, and a shortage of excellent workers.”

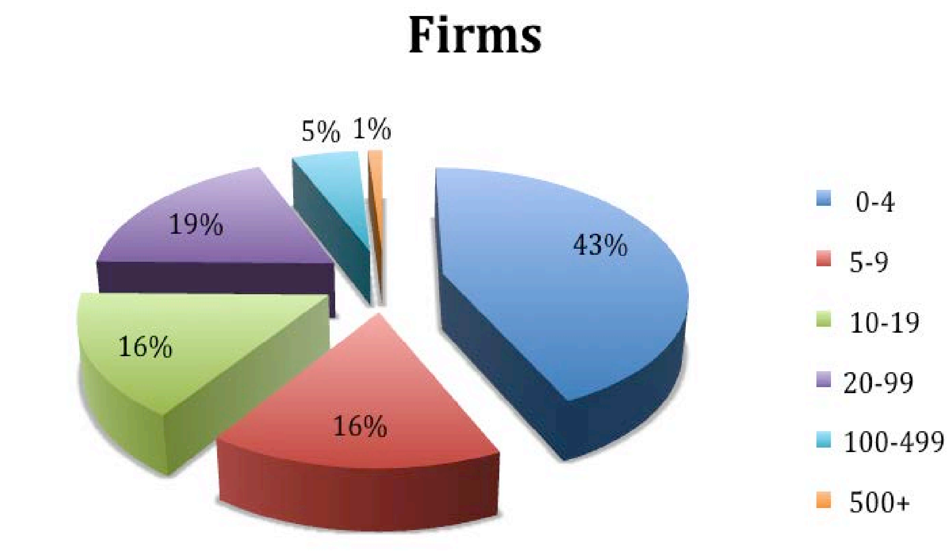

Figure 4. Employment in Highway, Street, and Bridge construction based on enterprise employment size Source: U.S. Census Bureau, 2010

Regarding the success of the construction industry, the Standish Group (2009) reported, “about two-thirds of all projects still fail” (p. 1). According to this report, only “32% of all projects succeeded that is, delivered on time, on budget, and with required features and functions” (p. 1). Moreover, Jim Johnson, chairman of the Standish Group, stated “44% were challenged as late, over budget, and/or with less than the required features and functions, and 24% failed which are cancelled prior to completion or delivered and never used” (p. 1). Project success is the value everyone is looking for, which reflects the success of the business (U.S. Census Bureau, 2007).

Integrated project tools may help the success of a project in the construction field. Before the information technology (IT) revolution, the handwritten planning method was the only way to accomplish success in project management. Now, after the huge growth of available IT tools (e.g., Microsoft project management, AutoCAD, and GIS), leading or managing projects is easier and more reliable (Biehl, 2007).

What is GIS? According to Bhargava, Bhargava, and Sharma (2012), "A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information" (p. 38). GIS provides a useful tool for managing and coordinating many project elements such as, project tracking, cost estimating, project cortical path method (CPM), and site selection. In pipeline construction, project inspection and management duties "include tracking of construction and testing throughout the life of the project, as well as coordination with individuals who may be unfamiliar with the project or who are managing many projects" (Dierkes & Howard, n.d., para. 3). GIS has not been widely used in managing projects, but recently engineers have started to think about the GIS concept. The GIS can generate graphic maps, which could be very useful for engineers, including charts, bar charts, histograms, and scatter plots (Jeljeli, Russell, Meyer, & Vonderohe, 1993).

For the purposes of this study, the use of various GIS functions, which include GIS tools, applications, and custom applications were investigated. A GIS function has been defined as "Tools that allow you to create address-lookup searches, and edit data and maps. The results of these operations can be displayed in the software suite." (Mentor Engineering, n.d.).

An investigation into the relationship between the use of GIS functions by the Highway, Street, and Bridge group and project success was the primary focus of this study. In addition, for the purposes of this study, success criteria for construction project management were operationalized.

Statement of the Problem

The relationship between the utilization of GIS functions and construction project management success in the Highway, Street, and Bridge construction category has not been adequately explored. There are insufficient data regarding the use of GIS functions and success in this construction group category.

Theoretical Framework

A construction project is considered successful when it is completed on time, within budget, and in accordance with specifications (Takim & Akintoye, 2002). In this study, GIS functions that are used in Highway, Street, and Bridge construction activities to increase project success rates were investigated. The independent variable is the use of GIS functions for the purposes of Highway, Street, and Bridge construction group tasks. Using GIS functions could help reduce the amount of administrative time (Dierkes & Howard, 2008). Figure 5 depicts the possible relationship between the GIS functions, the target construction area and the key elements of success of the construction activity.

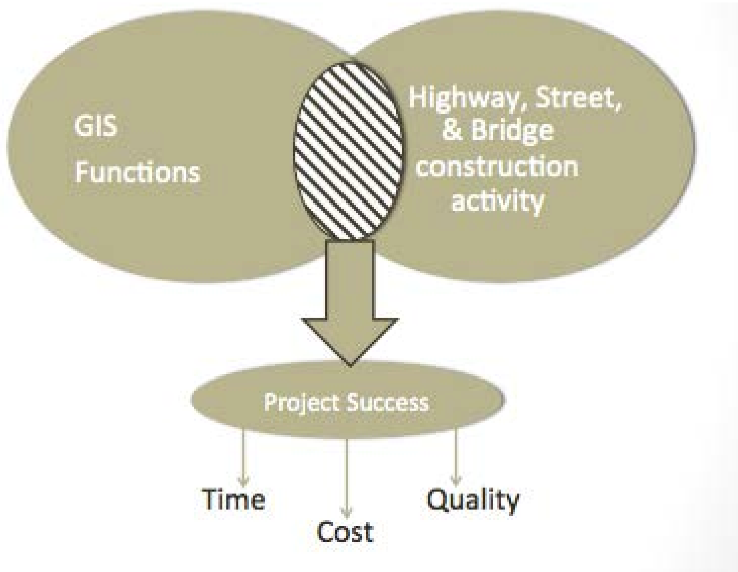

Figure 5. The Theoretical framework

Nature and Significance of the Problem

The concept of project management was first used in the 1950s for managing the complex weapons systems of the Department of Defense (Taylor, 2006). According to Taylor, “Project management is the art and science of managing relatively short-term efforts having finite beginning and ending points, usually with a specific budget, and with customer-specified performance criteria” (p. 3). The meaning of “short-term” differs from industry to industry. In the construction industry, projects may take from a few weeks to a few years (e.g., building a room or constructing a hospital or highway). Defining “short term” is one of the first things to consider when planning how to manage projects.

The use of computer systems, such as a computerized construction project management scheduling system, is the new way to manage construction projects with many applications, such as scheduling, cost, and resources. In the 1980s, the microchip and personal computer caused a major revolution in the computer industry, which caused a major revolution in the construction industry. Since that time, construction managers in many companies have become computer literate (Ritz, 1993).

Design documentation is produced using a computer application, Computer Aided Drafting/Design (CAD) to help construction managers design their projects. The most popular software for scheduling and management is Microsoft Project management software. It provides many functions, such as network analysis, scheduling, data sorting, cortical path, resource scheduling, and cost calculation, among others (Ritz, 1993). The following sections will discuss two areas of the proposed research: (a) Construction Project Management Success, (b) GIS Uses in Construction Projects.

Construction project management success. Construction project “means different things to different people. It can mean building a house, a high-rise building, a dam, an industrial plant, an airport, or even remodeling or upgrading a facility” (Ritz, 1993, p. 7). According to Ritz, construction project management can be explained in three words: plan, organize, and control. Recently, and after the IT revolution, the new computer technology affected the construction field. Construction payroll and accounting have been simplified, and “scheduling and cost-control applications were developed and proven out in the field” (Ritz, 1993, p. 3)

Al-Tmeemy, Abdul-Rahman, and Hauron, (2010), developed a framework to categorize project success from the contractor’s perspective for construction projects in Malaysia. They asserted that cost, time, and quality are the basic criteria for success in construction project management. Atkinson (1999), in his study of the criteria for project success, referred to the three criteria of cost, time, and quality as the “iron triangle.”

Moore and Dainty (1999) studied the performance of integrated project teams in managing unexpected change events in construction projects. They used an integrated procurement approach known as “design and build” (D&B). After applying this approach to the UK construction industry, Moore and Dainty found that “the project studied was delivered to time, within budget and to the specified quality standards” (p. 284) which would be deemed successful when compared to other projects using traditional project performance criteria.

In conclusion, based on the Moore and Dainty (1999) study and the definition of construction project management success, the three most important success criteria for construction project management are:

- Cost (budget),
- Time (schedule), and
- Quality (specification).

GIS uses in construction projects. Information Systems, including GIS, have gained importance because of the increase in complexity and the globalization of many projects. IS helps in:

- Providing an IT backbone,
- Exchange of information and data,
- Managing vast amounts of information, and
- Proving the optimization techniques for the global networks. (Biehl, 2007)

According to Biehl, (2007) top management support is the most important factor in the success of worldwide IS implementation. As Biehl said, “The importance of top management’s understanding is more essential to the success of Global IS projects, as it leads to greater support and better change management throughout implementation” (p. 57). One of these systems is called GIS. It has the ability to store and exchange spatial and descriptive data.

Miles and Ho’s (1999) work covered research about the application of GIS as a tool for civil engineering modeling. They found some misuse of GIS in the context of engineering modeling in spatial data, outputs, and operations. They stated that GIS can help engineers to “capture, store, and manage spatially referenced data such as points, lines, and polygons” (p. 145).

Celeritas Technologies (n.d.) is a consulting firm that helps solve business problems using technology solutions. It recommends the use of GIS for the construction management industry. It designed the “construction management cartridge” application for engineering and construction firms. This application helps companies manage and organize their information by:

- locating, displaying and monitoring construction management,
- visualizing and mapping business assets,
- linking database tables dynamically,
- linking documents and other data, and
- accessing a company’s document repository (Celeritas Technologies, n.d)

In conclusion, based on previous studies, the 11 most important application “functions” for construction project management are covered and summarized in Chapter Two.

Objective of the Research

The overall purpose of this study was to determine whether a relationship exists between the use of GIS functions and construction projects in the Highway, Street, and Bridge group. A related second purpose was to determine the differences between organizations' focuses (types) in the use of GIS functions. This research should be helpful in the study of any construction organization or company. It should also lead to improved processes of construction project management in the work of different organizations. This research should be useful to any researcher in understanding the effectiveness of the GIS in construction project management in both the United States and other countries.

Research Questions

The following questions helped inform the research and resolve the problem identified above.

RQ 1: What relationship, if any, exists between the degree of utilization of GIS functions by the Highway, Street, and Bridge group and each of the three project success criteria (Schedule, Cost, and Quality)?

RQ2: What differences if any, exist between the construction organization categories (highway, street, roads, and public sidewalks as compared to other construction categories) in the frequency of usage of each of the eleven GIS functions within the Highway, Street, and Bridge group?

Research Hypotheses

H1 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved budget (Cost).

H2 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and owner specified requirements (Quality).

H3 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved schedule (Time).

The following null hypothesis has eleven null sub-hypotheses. Each null sub-hypothesis represents one function:

H4 (Null Hypothesis) There are no significant differences between respondents from different construction categories regarding the frequency of usage of each of the eleven GIS functions.

Limitation and Delimitation

This study focused on the construction sub-sector group of Highways, Streets and Bridges, as classified by the North American Industry Classification System (NAICS), and any related project type within the heavy and civil engineering sub-sector. The scope of this study was on both business and government organizations inside the United States that do construction management. Many organizations, such as architectural and engineering design firms and construction services use GIS functions as they complete their projects.

Assumptions

It was assumed that the respondents in the survey:

- Provided accurate and honest data.
- Had a basic understanding of the GIS functions available for use in the construction industry.

Definition of Terms

Project management: the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. This application of knowledge requires the effective management of appropriate processes (Program Management Institute, 2008).

Project success: is measured both in terms of product success (goal and purpose) and project management success (output and input) (Baccarini, 1999).

Project cost: the quantitative estimate of the likely resources required to complete project activities, generally expressed in units of currency (Program Management Institute, 2008).

Project schedule: planned dates for performing activities and the planned dates for meeting milestones (Program Management Institute, 2008).

Project performance: Whether the project has the functionality and works according to established requirements or defined objectives (Karlsen et al., 2005).

Construction project success: a construction project is acknowledged as successful when it is completed on time, within budget, in accordance with specifications, and the stakeholders are satisfied (Takim & Akintoye, 2002).

GIS application: According to the Borton-Lawson website, these "are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data, create maps, and present the results of all these operations" (*What is GIS?*, n.d., para. 2). For example, traffic analysis, transportation analysis, and many interfaces in ArcView software; among other things, can be used in construction projects.

GIS function: According to Mentor Engineering (n.d.), GIS function is, "Tools that allow you to create address-lookup searches, and edit data and maps. The results of these operations can be displayed in the software suite."

Success factors: A success factor is any knowledge, skill, trait, motive, attitude, value, or other personal characteristic that is essential to perform the job or role and that differentiates solid from superior performance. (Human Resource Management, 2004)

Success criteria: "A criterion can be defined as a principle or standard by which something may be judged or decided" (Oxford Dictionaries, 2010)

CHAPTER TWO: LITERATURE REVIEW

Introduction

This chapter provides a review of relevant literature about success in construction project management and GIS functions for construction projects. This review is divided into four sections. First is a general review of project, construction projects, and construction project management, including definitions of their elements and a consideration of the criteria necessary for successful construction project management. Next, because GIS technology is playing an ever larger role in construction project management, its history and uses in construction projects, as reflected in the relevant literature, is discussed. This is followed by a discussion of the literature related to previous surveys and assessment tools. Finally, a summary of what was found in the literature about construction success criteria and factors and about useful GIS functions in the construction industry is presented.

What is a Project?

According to the Federal Transit Administration (2006), “a project is made up of a group of interrelated work activities constrained by a specific scope, budget, and schedule to deliver capital assets needed to achieve the strategic goals of an Agency” (pp. 1-3). Shenhar and Dvir (2007) defined a project as “a temporary organization and process set up to achieve a specified goal under the constraints of time, budget, and other resources” (p. 94). Moreover, the Project Management Institute (PMI) (2013) defined a project as “a temporary endeavor undertaken to create a unique product, service, or result” (p. 3). As can be seen, the term “temporary” is mentioned in the definitions of both Shenhar and Dvir and PMI, which indicates that a project is different from ordinary production work. It does not mean something that takes less time or is of shorter duration. It means the duration of the project from start to end. According to the PMI (2013), “the temporary nature of projects indicates a definite beginning and end” (p. 3).

What is Project Management?

According to PMI (2013), project management is defined as “the application of knowledge, skills, tools, and techniques to project activities to meet project requirements” (p. 5). Shenhar and Dvir (2007) defined project management as “the managerial activities needed to lead a project to a successful end” (p. 94). This term became well known and was used widely in the 20th century, as many different organizations began to notice the benefits of project management (Shenhar & Dvir, 2007).

Project Management has been used since the 15th through 17th centuries in many large projects. This method became more fully developed in the 1950s, when the U.S. Navy used project management methodologies in the Polaris project (Kwak, 2003). Between 1960 and 1985, project management became mandatory for all companies that had complex tasks and operate in a dynamic environment. During that time, the construction industry was one of the most important industries in which the concept of project management was used. During the early 1980s, more companies moved from informal project management to formalized project management (Kerzner, 2005). Table 2 summarizes the key points in the history of the development and some sample uses of the project management method.

Table 2

History of the Development and Uses of the Project Management Method

Period	**Development and/or Use**
15^{th}- 17^{th} centuries	Large projects were increased on emerging concepts such as, Wren and Hawksmore projects “Architects worked not just as designers but as estimators, purchasers, organizers, inspectors, and paymasters.”(Morris, 1997, p.5).
1796	Hwaseong Fortress Project built between 1794 and 1796 by King of the Joseon Dynasty, Jeongio. This project was very well organized and detailed construction plan (American Society of Civil Engineers, ASCE, n.d)
1857	The project for construction of the Pacific Railroad through the USA, (*Judah, 1857.)*
1931-1936	Construction of the Hoover Dam was a project comprised of six companies that were assigned to it, one of them acting as general contractor. These companies developed a project plan that was both controlling, and coordinating. (Kwak, 2003).
1942-1945	The Manhattan project (Kwak, 2003).
1955	The U.S. Navy created the Special Projects Office (SPO), which used the following techniques later: - Program Evaluation and Review Technique, 1957 (PERT) - Reliability Management Indicator (RMI) - Project Management - Project Management Plans (PMPs) - Technical Development Plans (TDPs) - Program Management Center (PMC) - Weekly Program Review Meetings - Management Graphics (Sapolsky, 1972).
1958	“The beginning of the age of the giant project” (Snyder & Kline, 1987, p. 28).
1956-1961	Polaris project to deliver nuclear missiles “Fleet Ballistic Missile” (Sapolsky, 1972).
1969	Project Management Institute (PMI) founded as a professional association. (Shenhar & Dvir, 2007.)
1980s-1990s	“The revolution of IT/IS sector shifted people from using mainframe computer to multitasking personal computer that had high efficiency in managing and controlling complex project schedules” (Kwak, 2003, p. 5).
1985	The implementation of total quality management (TQM) (Kerzner, 2005).

(continued)

Table 2

History of the Development and Uses of the Project Management Method (continued)

Period	**Development and/or Use**
1990	Beginning of modern project management. (Kerzner, 2005)
1991-1992	"Executives recognize control that can still be achieved at the top by functioning as project sponsors" (Kerzner, 2004, p.6)
1994	Cost control system recognized. (Kerzner, 2005).
1995-2000	"The project management community adopted Internet technology to become more efficient in controlling and managing various aspects of projects" (Kwak, 2003, p. 7).
1996	Risk management plans were now included in the project plans (Kerzner, 2005).
1997-1998	Project Management recognized as a professional career (Kerzner, 2005).
1999	Dedicated resource for the duration of the project (Kerzner, 2005).
2003	The Internet comes of age and helps in the exchange of information and data. (Kerzner, 2005).
2005	Six sigma is being applied to project management (Kerzner, 2005).
2006	Virtual project management (Kerzner, 2005).

Project management consists of two main parts, project planning and project monitoring. Project planning includes the definition of requirements, quality of work, and resources. On other hand, project monitoring includes tracking progress, actual outcome versus predicted outcome, making adjustments, and analyzing impact (Kerzner, 2005).

The project manager is the individual who is assigned by the company and given both the responsibility and the authority to manage the team, the project, or both. Without a project manager, the company or organization may face many challenges in its attempt to complete the project. Figure 6 illustrates how a project without a manager works. Lang (2007) stated, “project managers must have a keen understanding of how the organization defines success” (p. 2). Cost, time, and quality are the basic three criteria that determine how project mangers lead the project to success (Litsikakis, 2006).

Changes in technology and global competition have made doing business more complex, with tighter constraints, more integrated activities, dynamic environmental considerations, and functional boundaries. This has led to the need to formalize project management (Kerzner, 2003). Large companies, such as AT&T, IBM, Bell South, and Citibank, put their project managers through training for Project Management Professional (PMP) certification. PMP is certified by the Project Management Institute (Talye, 2006).

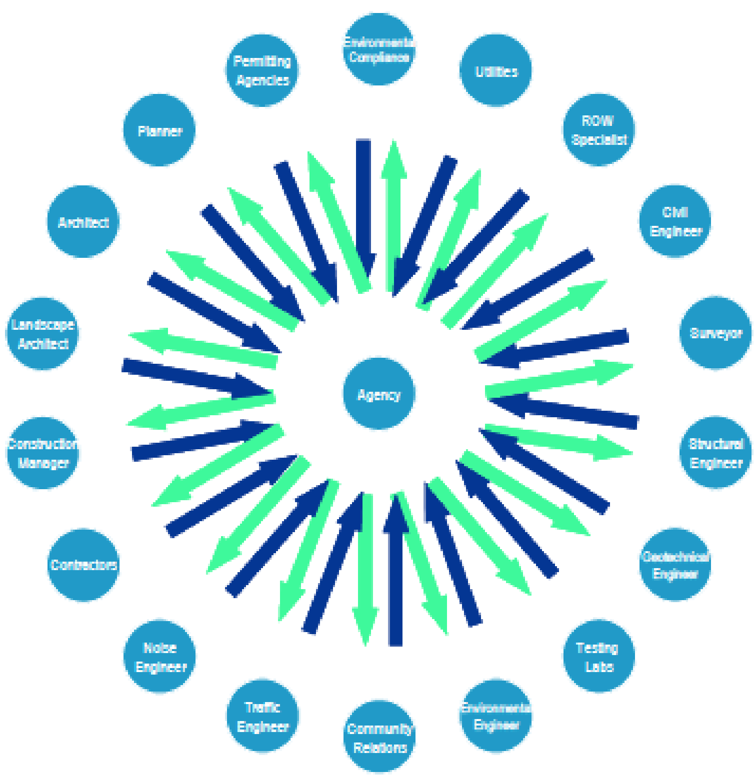

Figure 6. A Project without a project manager.
Source: (Federal Transit Administration, 2006, 1- 4)

Any project should have specific stages to start the project. According to the Federal Transit Administration (2006), "the project management process begins with identification of the user requirement, project constraints, resource needs, and establishment of realistic objectives to meet the strategic goals" (p. 1-9). Project development, project initiation, project planning, and project design are all common steps in starting any project, whether it is construction, IT, a product, or a general project (Federal Transit Administration, 2006)

Project Management Process Groups and Project Phases

According to the standards provided in the Project Management Body of Knowledge (PMBOK) Guide (PMI, 2013), any project or any project phase may be impacted by all or some of the five process groups: (a) initiating, (b) planning, (c) executing, (d) controlling, and (e) closing (Figure 7). Project life cycle phases for a construction project are: (a) initiation, (b) planning, (c) design, (d) construction, (e) commissioning, and (f) closeout (Federal Transit Administration, 2006).

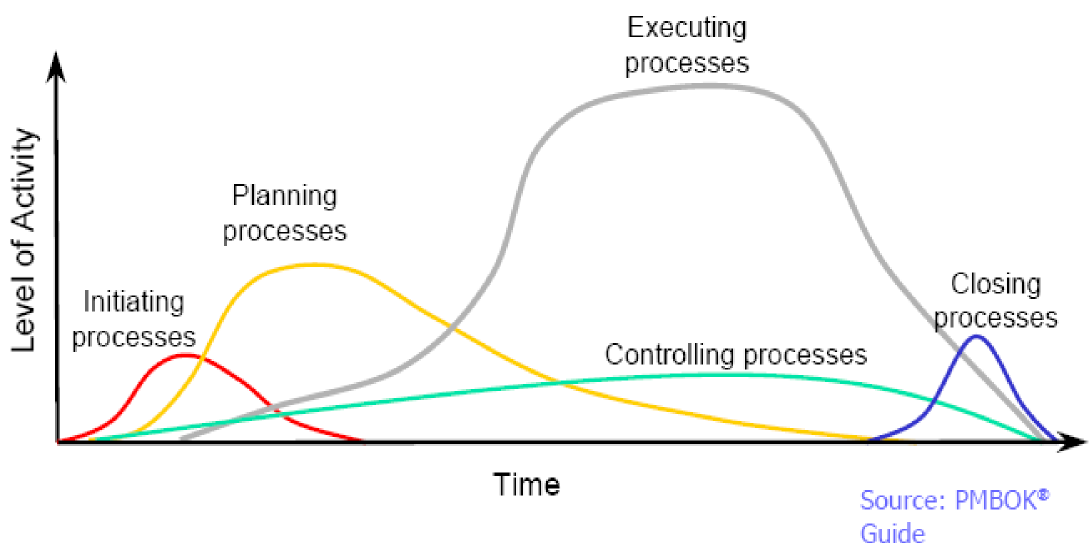

Figure 7. Process groups interact in a phase or project
Source: (A guide to the project Management Body of Knowledge, 2013, p 51)

Successful Project

The related literature suggests that success criteria are different from success factors. Litsikakis (2006) stated that success criteria are “the standards by which a project will be judged” (para. 15). On the other hand, success factors are “the facts that shape the result of projects” (para. 15). Cooke-Davies (2002) mentioned that "success factors are those inputs to the management system that lead directly or indirectly to the success of the project or business" (p. 185). According to Litsikakis (2006), cost, time, and quality are the three criteria that determine project success and are considered the standards for any project. Moreover, when Atkinson (1999) studied and investigated success criteria in project management. He referred to the three criteria (cost, time and quality) as The Iron Triangle. On other hand, project management researchers have found many project factors, but top management support is the common factor mentioned by many authors (Litsikakis, 2006; Tinnirello, 2002, p. 14; Tukel & Rom, 1998, Table 5, p. 48).

According to Kerzner (2005), successful project management is defined as having achieved the project objectives: (a) within time, (b) within cost, (c) at the desired performance technology level, (d) utilizing the assigned resources effectively and efficiently, and (e) accepted by the customer (p. 3).

According to KPMG, (2001) a professional services network for audit, tax, and advisory services, they have advised many businesses on the risks that may affect the successful outcome of their IT projects. After doing a survey of 256 United Kingdom (UK) IT companies, they found the following common causes of project failure:

- 32% - Poor project management.

- 20% - Lack of communication.
- 17% - Failure to properly define objectives.
- 17% - Unfamiliar project scope or complexity.
- 14% - Inability to cope with new technology (KPMG, 2001, p.2).

Other reasons for project failure were found by ProjTech, Inc. (2003), a technical project expert. They found that there was a high percentage of project failure, especially for IT-related projects. In 2002, the investment in IT projects in the United States was around $100 billion. "Roughly 60% of those projects failed to meet technical objectives at an estimated cost of over $70 billion" (ProjTech, Inc., 2003, para. 2). According to ProjTech Inc., there are four main reasons projects fail:

- Incorrect requirements
- Insufficient planning
- Poor risk mitigation
- Wrong technical solution (ProjTech,Inc., 2003).

Moreover, another survey was conducted by Standing, Guilfyle, Chad, and Love (2006). Results of that survey showed that there were five top reasons IT projects fail:

- Lack of user support and involvement
- Lack of properly defined project scope
- Lack of executive management support and commitment
- Imprecise defined objectives and knowledge of the IT project
- Poor project management and leadership. (Standing et al., 2006, p. 1153)

In reviewing the relevant literature, it became apparent that many researchers considered project criteria and project factors to be two different things. The next section will focus on the concept and definition of a construction project, construction project management, success criteria, and factors in construction management.

Construction/Construction Project

Construction means “different things to different people. It can mean building a house, a high-rise building, a dam, an industrial plant, an airport, or even remodeling or upgrading a facility” (Ritz, 1993, p. 7). There are different delivery method types available in the construction industry. As Dykster (2011) stated, “the three basic types are Design-bid-build (traditional), Design-build, and construction management” (p. 74). Each of the delivery methods has specific types of activities. In the Design-bid-build (DBB) method, also known as the traditional method, the owner hires a designer to design the project and finish the construction document. Then, after calling for bids and selecting one, the owner hires a contractor. This method costs money and time. In the Design-build (DB) method, the fast-growth delivery method, the designer and design builder are hired under one contract and they work as one team. This method has better communication between the designer and contractor. On other hand, with this method, the price cannot be estimated early, and the owner is less involved. In the Construction Management (CM) delivery method, the construction manager is hired by the owner to assist the owner, in organizations or companies, it is known as the “agency CM method.” The architect, general contractor, and owner are working as a team. The construction manager offers advice to the owner and works as the agent of the project. In this method, the construction manager assists the owner and manages the general contractor through all the construction processes (Dykster, 2011).

Construction Project Management

Many researchers have studied the concept of construction management. Ritz (1994) stated, “basic construction project management philosophy is simply in three words: *plan*, *organize*, and *control*” (p. 20). In another definition, Dykster (2011) said that construction management is “all the processes involved in organizing, monitoring, and controlling a construction project” (p. 81).

The construction industry is one of the important fields that use project management knowledge. Carrillo, Robinson, Al-Ghassani, and Anumba (2004), who studied knowledge management in the UK construction industry, said that “the construction industry delivers large, expensive, custom-built facilities at the end of a construction process” (p. 47). The authors reviewed the construction process and the impact of knowledge management practices on the construction industry by conducting a survey among UK consulting and contracting firms. They found the following:

- 75% of organizations expect to have knowledge management strategy.
- The lack of standard work processes and the lack of time are the most important barrier to KM.
- 45% of the organizations have appointed a person or group with responsibility for knowledge management. (p. 55)

What drives construction project success has been a hot topic in the last few years and has attracted many researchers (Nguyen, Ogunlana & Lan, 2004). Yates and Eskander (2002) used a survey to analyze the causes of delays that affect the planning and scope development phase in construction projects. In their survey, which included 27 types of delay, the participants were asked to rank these types-of-delay factors. The results showed that the three highest-ranked factors were "(a) constant changes in project requirement, (b) developing multiple projects at the same time, and (c) lack of communication among various divisions" (p. 47). Moreover, these three factors received the most modification suggestions.

Success of Construction Project Management

Ashley, Lurie, and Jaselskis (1987), studied and determined construction project success, obtaining more than 200 factors from both a study of the literature and information from construction project personnel. These factors were reduced to 46 factors and separated into five groups as follows:

- Management, organization, and communication
- Scope and planning
- Controls
- Environmental, economic, political, and social
- Technical (p. 69).

Ashley et al. (1987) conducted a survey to find, from the contractors' and owners' perspectives, the top factors in construction success. They found 15 factors rated as the top. They then chose 11 from the top 15 to analyze further. The authors also conducted interviews to collect data. A total of 16 project samples were gathered from eight companies, each company contributing two projects (an average project and an outstanding project). The authors focused on individuals who had experience in different types of projects. The interview questions included 90 subjective and objective questions relating to the 11 factors. Various measures of success were used as success criteria. Based on the separation between average and outstanding projects, the authors found seven factors to be the most significant in determining project success: “planning effort, scope and work definition, project manager goal commitment, project team motivation, goal orientation, project manager capabilities and experience, safety, and control systems” (p. 72). The authors found six significantly important criteria to use to measure construction project success: “budget, schedule, functionality, contractor satisfaction, client satisfaction, and project manager/team satisfaction” (p. 72).

Moreover, Ashley et al., 1987 continued to analyze this research to find the correlations between factors and success criteria by using regression analysis (Figure 8). They found strong relationships between the following:

- construction planning effort and functionality
- project management technical capabilities and end user satisfaction
- technical uncertainty and end user satisfaction
- project management administrative capabilities and budget
- legal political environment and follow-on work.

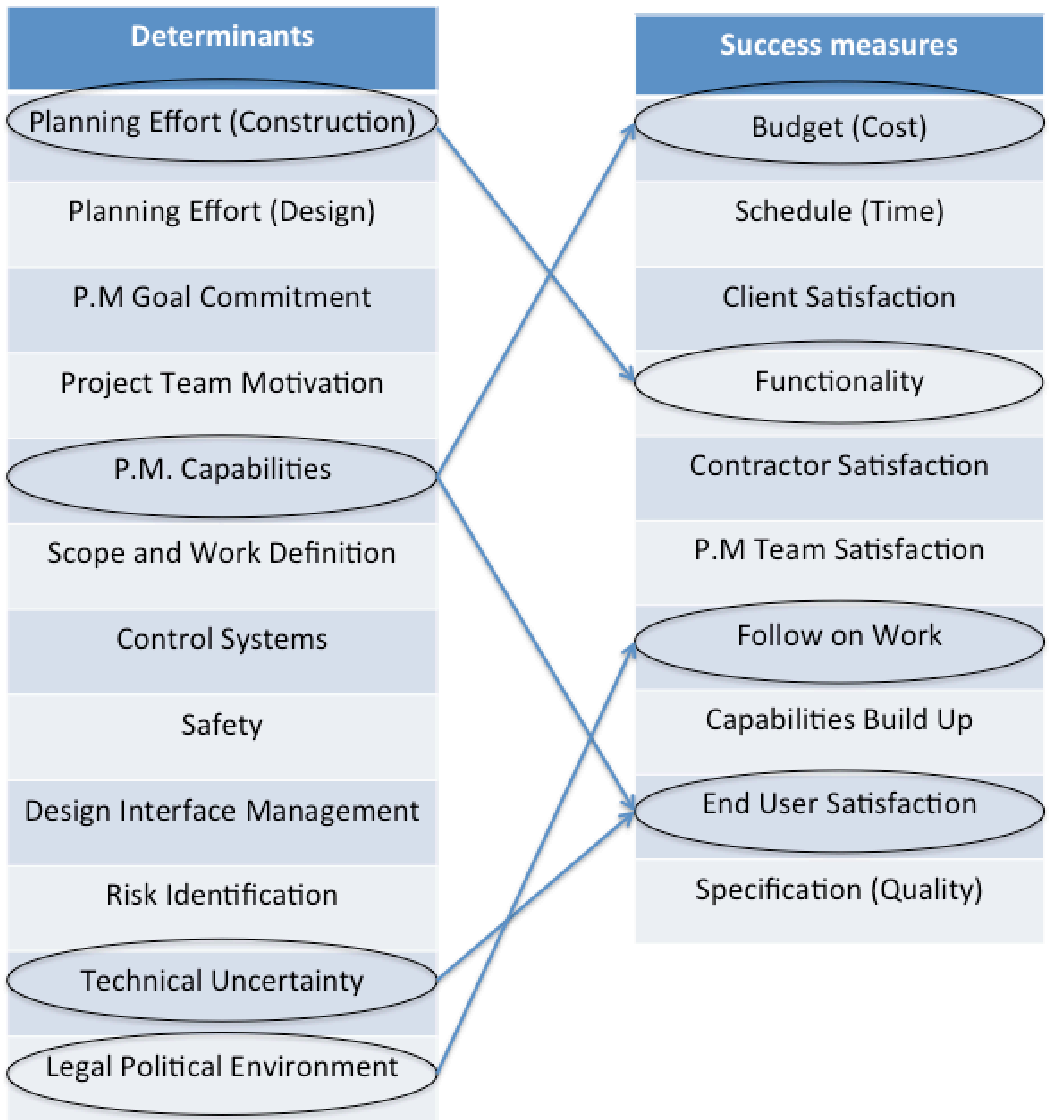

Figure 8. Project success influence diagram
Source: (Ashley, Lurie, & Jaselskis, 1987, p. 76)

Albert and Ada (2004) provided an overview of success measures for construction projects. After reviewing the literature from the last decade, they developed a set of key performance indicators (KPIs) for measuring construction success (Figure 9). After that, the authors applied the KPIs to three cases studies. They found that “in the construction industry, time, cost, and quality have long been defined as the basic criteria of measuring success" (p. 218). Moreover, other measures become important in the industry, such as, safety, functionality, and satisfaction.

Figure 9. KPIs for construction projects
Adapted from: (Albert and Ada, 2004)

In an attempt to determine the factors in construction project success, Phua and Rowlinson (2004) studied the importance of cooperation. They used data from 29 interviews and 398 quantitative responses from construction firms in Hong Kong. They found a link between cooperation and project success and discovered that personal friendship between project participants is a factor that can affect the success of a construction project.

Cost could have an effect on construction projects and the life cycle of construction projects. Li (2009) stated,

> According to analysis of some western countries, usually design cost only amounts to less than 1% of life cycle of construction project. However, it is the cost of less than 1% that accounts for more than 75% of influences on construction cost. (p. 145)

Li analyzed the cost of construction projects through a study of the theoretical methods and practice of construction cost management in China. He developed a list of factors that have an effect on construction cost, and stated, “bidding of a project, contract signing and management, examination of a construction management plan, and management of materials all have decisive effects upon formation of construction cost” (p. 147).

Oberlender (1993) pointed out that defending the goals of a project in the early phase of a construction project is important. In addition, having a high engineering design will help to reduce the cost and time and assure good quality (Figure 10).

Nguyen et al. (2004) identified and studied relationships between success factors in the Vietnamese construction industry. Based on previous research, the authors included 20 success factors, but did not include time, cost, and quality as general factors. They went into more detail, such as commitment to project, frequent progress meetings, absence of bureaucracy, multidisciplinary project team, and so forth. Then, after conducting a survey of contractors, owners, and consultants, Nguyen et al. found that the top critical success factors for construction projects in Vietnam were:

- competent project manager
- adequate funding throughout the project
- multidisciplinary project team
- commitment to project
- availability of resources (p. 411).

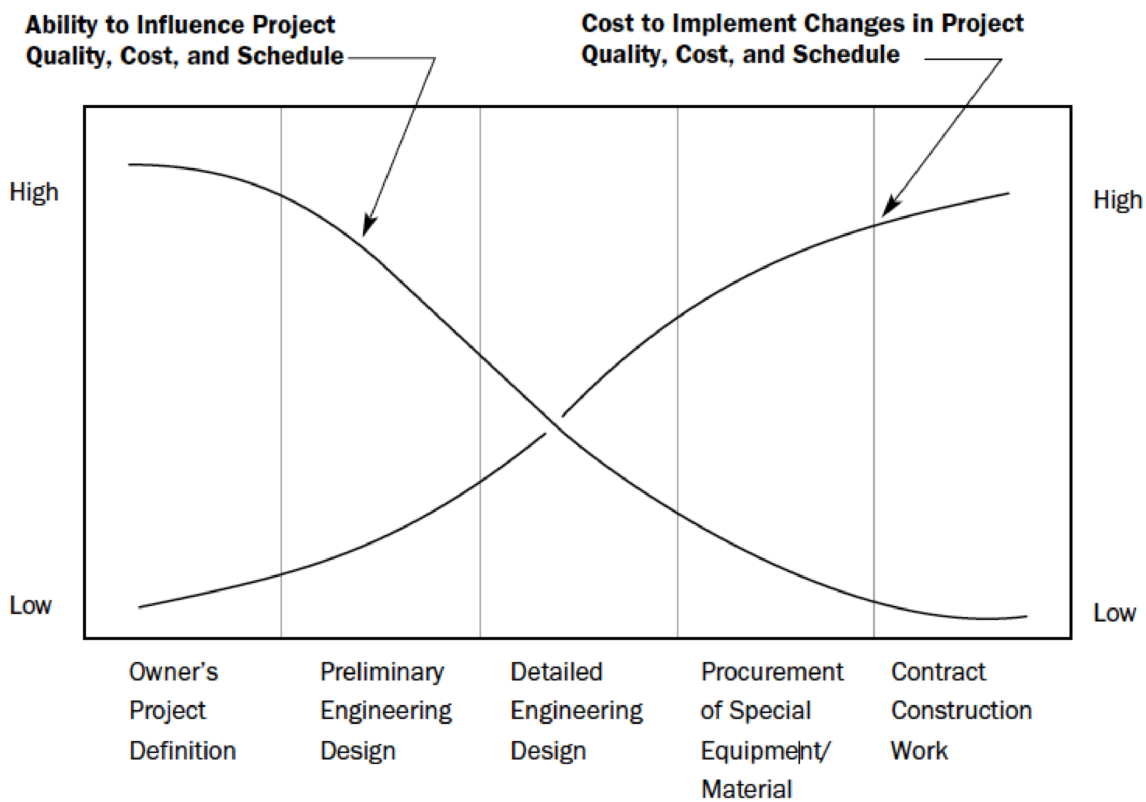

Figure 10. Clear project definition in the early phases of a project
Source: (Oberlender, 1993, p. 21).

Other researchers started to think about new success criteria, not just quality, time, and cost. Al-Tmeemy, Abdul-Rahman. and Harun (2011) stated, "The building project is most successful when it is capable in integrating the three success dimensions" (p. 347). These three-dimensions are project management success, product success, and market success, as shown in Figure 11. Moreover, Atkinson (1999) suggested that it is time to think about success criteria other than "The Iron Triangle," such as stakeholder benefits.

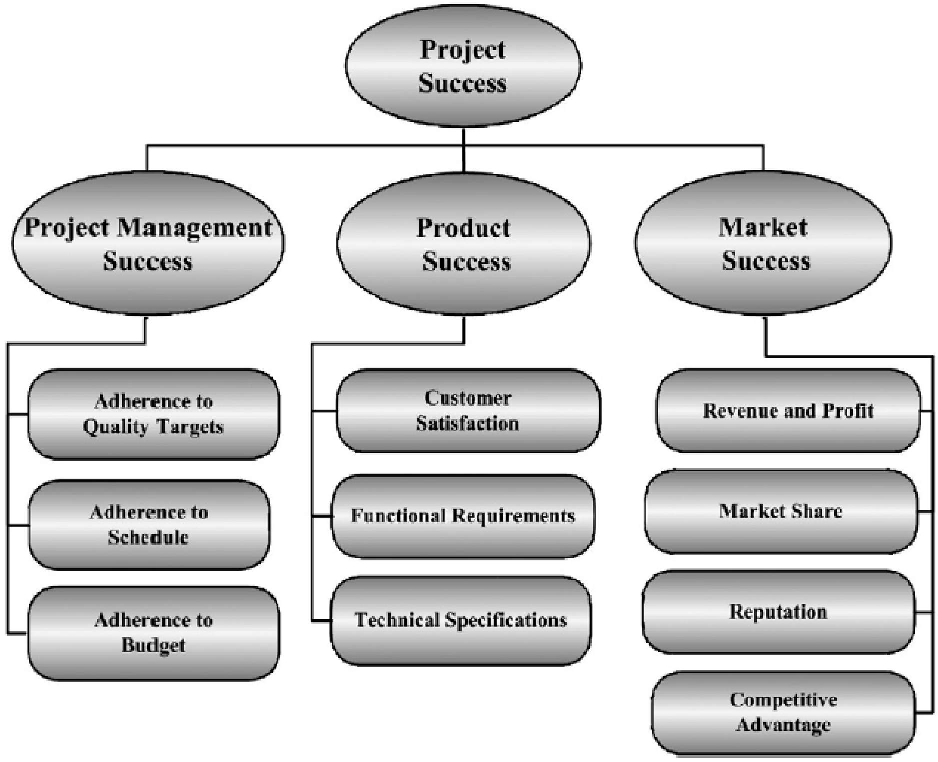

Figure 11. Success criteria for construction building projects.
.Source: Al-Tmeemy, Abdul-Rahman. and Harun, 2011, (p. 346).

Jha and Iyer (2007) studied the impacts of different factors/attributes on project performance. They suggested that there could be two categories of criteria: (a) objective criteria, "which are tangible and measurable, are schedule; cost; quality; safety, and dispute" (p. 527); and (b) subjective criteria, which "include client satisfaction; contractor satisfaction; and project management team satisfaction" (p. 527). The result shows that three factors (commitment, coordination, and competence) are important for achievement of cost, time (schedule), and quality objectives.

Finally, after reviewing project and construction project management that covered some history and the success criteria and factors, the researcher found many different criteria could be considered as the most common criteria for a successful construction project. In the next section; GIS technology, GIS history, and uses of GIS in construction management are covered.

GIS Technology

According to Chrisman (1999), “the term `GIS' has come to symbolize a technology, an industry, a way of doing work” (p. 177). Pine (1998) offered a similar definition when he wrote that a “Geographic information system is an organized collection of computer hardware and software designed to efficiently create, manipulate, analyze, and display all types of geographically or spatially referenced data” (p. A-1). In addition, the GIS can be used as a decision support system by using spatial data to solve environmental problems. Pine defined three elements in using spatial data:

- Input (encoding)
- Data Management (storage and retrieval)
- Output (Maps) (p. A-2)

Chrisman (1999) studied the literature and reviewed a sampling of definitions of GIS that discuss its different aspects. He found that GIS has been defined as Geographic Information Science, Geographic Information Studies, and Geographic Information System. Chrisman then examined the definitions to determine how GIS works and has been adapted and, after studying these, concluded that a reformulated definition would help promote a better understanding of how GIS can be used in everyday practices. Chrisman’s proposed new definition of GIS is “organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures” (p. 183).

Pine (1998) studied the use of GIS in emergency management and how to achieve effective results in that situation by using GIS. In his study, Pine reviewed GIS elements, GIS as a system, and the benefits of GIS. Moreover, he found that developing a GIS system involves an investment in five areas:

- computer hardware
- computer software
- geographic data
- procedures
- trained staff. (p. A-13)

Pine concluded, "GIS can be an excellent tool for the emergency management community in hazards analysis and risk assessment [and] in making operational decisions concerning evacuation routes or street closings" (p. A-13).

According to Sutton, Dassau, and Sutton (2009), a GIS consists of:

- Digital Data – the geographical information that you will view and analyze using computer hardware and software.
- Computer Hardware – computers used for storing data, displaying graphics and processing data.
- Computer Software – computer programs that run on the computer hardware and allow you to work with digital data. A software program that forms part of the GIS is called a GIS Application. (p. 2)

Many researchers studied different aspects of the GIS, such as its history, development, and applications. Sutton, Dassau, and Sutton (2009) defined GIS applications as "normally programs with a graphical user interface that can be manipulated using the mouse and keyboard" (p. 4). There are many different applications, which provide big or small functions, but "the common function of GIS applications is to display map layers" (p. 4).

In addition, GIS has data that consist of geographic and nongeographic data. In the GIS, these data allow users to associate information with places. Moreover, there are two different types of data–vector data and raster data. Raster data could help users show where the impacted or important areas are. Vector data consist of three features (Figure 12): (a) point feature, (b) polyline feature, and (c) polygon feature (Sutton, Dassau, & Sutton, 2009).

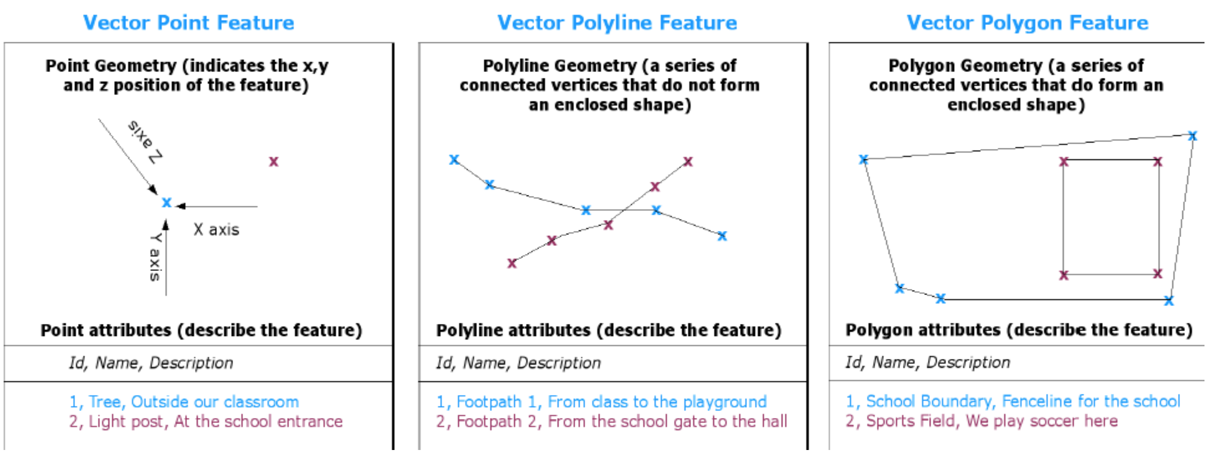

Figure 12. Vector point, polyline, and polygon feature.
Source: (Sutton, Dassau, and Sutton, 2009, p. 11)

There are many GIS software programs and customized applications available for use in different industries. Some of these are free and open sourced and usually are focused on a single category. Various companies sell software and applications that include multiple categories. As Steiniger and Weibel (2009) stated, "The key players in the GIS software market today are Autodesk, Bentley, ESRI Inc. (ArcGIS), GE

(Smallworld), Pitney Bowes (MapInfo), and Intergraph" (p. 4). Some of this software is used for business analysis and planning, and some is for management.

GIS History Overview

Coppock and Rhind (1991) stated that "computer-based GIS have been used since at least the late 1960s" (p. 21). However, during the 1840s, the procedure was used manually when, in London, Dr. John Snow used a map of London (Figure 13) to determine the location of the most deaths caused by cholera and then to pinpoint the location of the contaminated water pump from which the cholera was spread. He found that water from the Broad Street pump was contaminated and the source of cholera (Stolley & Lasky, 1995). If Snow's methodology was transferred to the modern use of the GIS, it could be explained as three layers of maps; one is the map of London, the second is the location of deaths from cholera, and the last is the water pump.

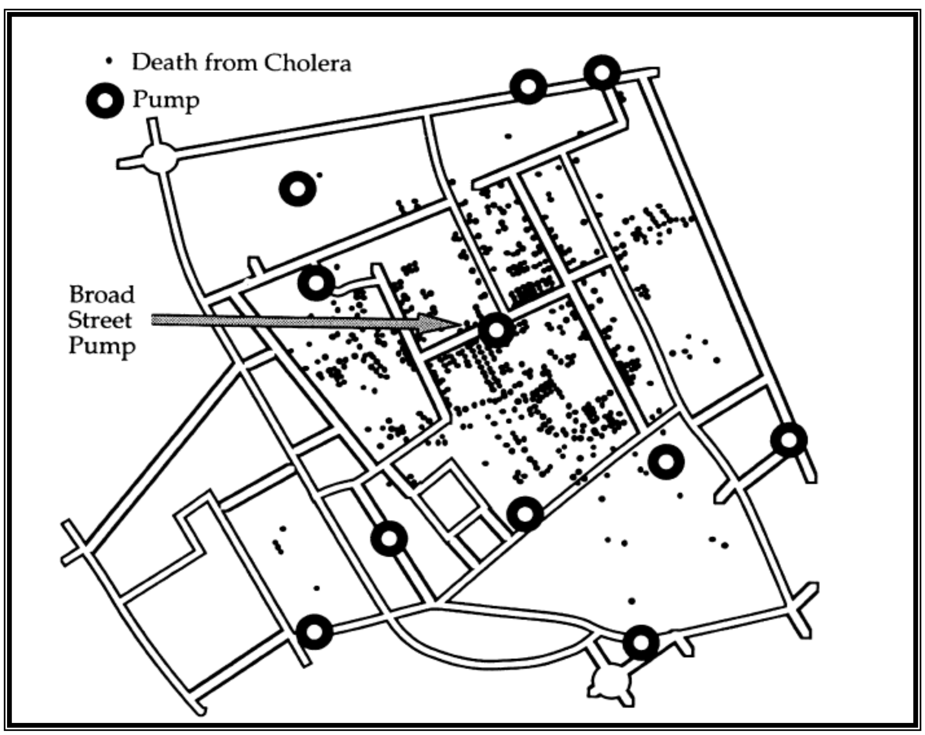

Figure 13. A map of Cholera deaths in London in the 1840s.
Source: Monmonier's (1991, p. 142) recreation of Snow's dot-map.

According to Coppock and Rhind's (1991) study, GIS Technology has been used since the 1960s, in four phases. The first phase was from the 1960s to 1975 and is known as the pioneering age. During this phase, there were limited international contacts and little data. The second phase, from 1973 until the early 1980s was marked by government-funded research. The third phase, from 1982 to the late 1980s, was the commercial phase. The last phase began in the late 1980s and continues to the early 1990s. It is known as the period of user dominance (p. 39).

GIS Uses in Construction Projects

In 2003, the Oregon Department of Transportation (DOT) found that 365 of Oregon's bridges had problems. This meant that a bridge repair plan had to be established. The Oregon DOT used GIS in this big project, which included infrastructure and integration of a new traffic model. The Oregon DOT plans and manages roadway projects by collecting comprehensive environmental data for around 400 of its bridge sites. DOT staff draw a box around the bridge site and identify all the resources inside the box. After collecting all the data for the site, engineers design work for the project (DeMeritt, 2012).

In Malaysia, Jusoff (2008), studied how the GIS, based on a decision support system, can be used to select a suitable new forest road. He considered three things in his research: (a) timber volume, (b) slope, and (c) ground condition. With this information, values were assigned to each area, and then the Raster Calculator function was used to find the best route with less timber harvesting impact.

Rezouki and Rasheed (2012) developed an application system that used GIS to report a Bill of Quantities (BOQ) for construction projects. This application has been implemented at the Al Khawrizmy College of Baghdad University. Researchers used AutoCAD to draw spatial data and ArcGIS, which provided some functions such as extract, query, and spatial analysis. Several processes were done to reach a result that included creating a breakdown structure, creating AutoCAD, transferring the AutoCAD to ArcMap, data integration, and creating a database and analysis. Rezouki and Rasheed found that using GIS to calculate BOQ for construction projects can deliver an accuracy percentage of 98.85 of BOQ on site surveying.

Work zone traffic analysis is the sheet that will come up with the DOT system. It includes all environmental features and spatial data. In addition, economic benefits and costs are included in this system. From this case, it can be said that use of the GIS can help to minimize the impact on the surrounding environment and decrease costs for the bridge repair project (DeMeritt, 2012).

Poku and Arditi (2006) studied construction scheduling and progress control with the GIS. Bar charts and critical path are the best known tools for scheduling and moving project tasks ahead. The researchers noted that the information provided in this traditional way, is not enough. For example, start and end time, duration, date, and next tasks are the traditional way, and more advanced tools are needed. The researchers developed a system called PMS-GIS (Progress Monitoring System with GIS). They stated that this system "allows project planners and managers to see in detail the spatial characteristics of a project by showing on the same screen a bar-chart schedule and a 3D rendering of the project marked" (p. 357). There are three parts in this software:

- AutoCAD
- Primavera Project Planner (P3)

- GIS (ArcViewGIS)

With these elements, every update will provide 3D progress tasks. This can help engineers and managers to see the work in detail with the 3D picture. Similar to this work, Cheng and Chen (2000) discussed how barcode and GIS could help monitor construction progress. They discussed how the ArcSched application was developed to assist engineers in controlling and monitoring the construction process.

Moreover, Dierkes and Howard (2008) used GIS technology to provide construction-tracking tools and digital project data for a construction project and then shared it with customer “stakeholders.” They studied GIS integration into pipeline construction inspection, and management. There were 27 highway pumping stations and one Force Main Project for Charlotte Mecklenburg Utilities in this project. “GIS was used to track and manage construction progress so that project-related data could be queried and analyzed” (p. 2). Dierkes and Howard also used the GIS to track the following;

- gravity sewer installation
- force main installation
- acceptance testing
- compaction tests
- soil and erosion control issues
- punch list items for substantial completion
- warranty follow-up
- Compiled data for the project (Dierkes and Howard, 2008, p.2)

This information helped to calculate accurate progress reports. Even the construction specifications, which require testing on manhole installation, can be uploaded on GIS software to produce the information spatially instead of on paper. Finally, Dierkes and Howard (2008) came up with using GIS to track construction activities (Figure 14). As Dierkes and Howard said,

> The most important benefit of digital tracking of pipeline construction projects is that integration of GIS and GPS technology will reduce the amount of administrative time spent by inspectors and management on the project and better communication will be provided to stakeholders. (p. 9)

Bansal and Pal (2006) studied the GIS uses for building cost and visualization. They came up with a methodology for using GIS to calculate cost and visualize the project. AutoCAD was used in this methodology to draw the construction plan. GIS was used to store spatial and descriptive data, such as construction materials, labor, equipment, and cost. They also added new scripts to GIS software, which can be used for cost estimation. By using all these information and scripts, bills of materials, bills of quantities, and labor requirements can be generated (p. 321).

Increasing pollution and natural disasters have become a challenge in our world. Many areas, like India and western Africa, face pollution, deforestation, and natural disasters. Manjula, Jyothi., Varma. and Kumar, (2011) used the Geographical Decision Support System to make decisions for developing a specific area. Three parts are used in this system:

- Remote sensing.
- Computer cartography.
- Environmental assessment and planning.

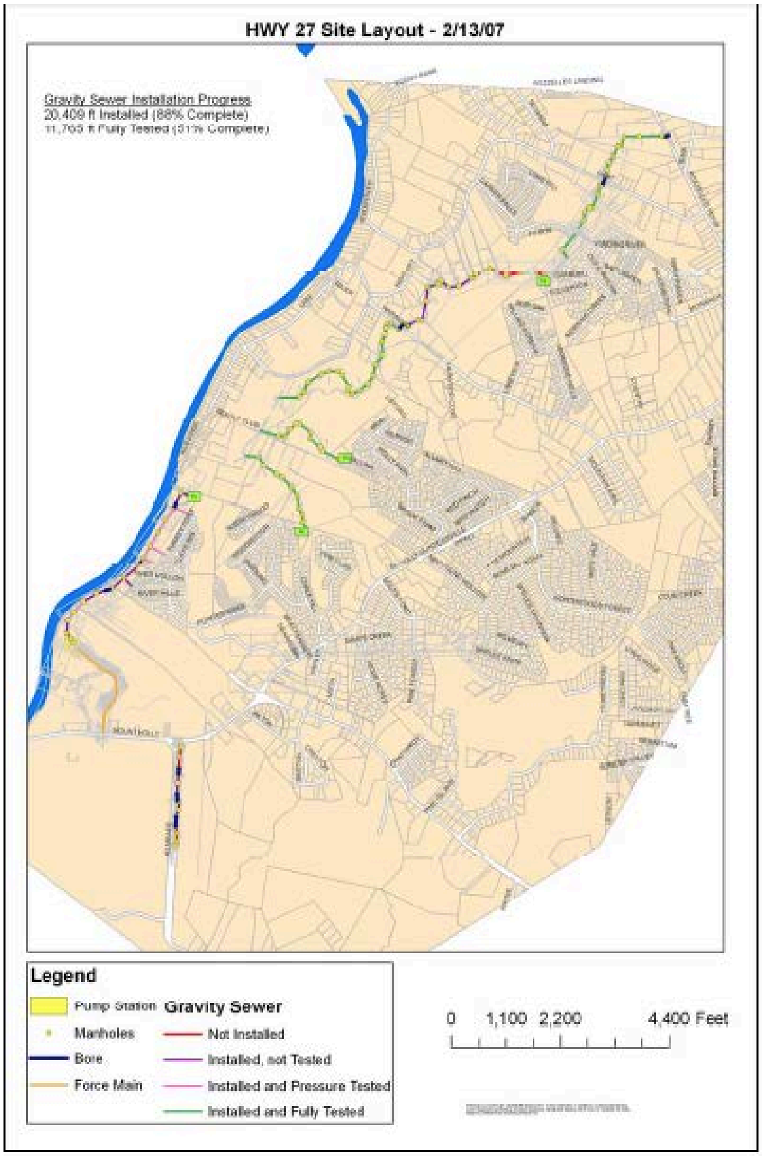

Figure 14. Typical update handout
Source: http://www.ncsafewater.org/Pics/Training/AnnualConference/
AC08TechnicalPapers/SpecialTopics/AC08ST_Mon0445_Dierkes.pdf

After that, the GIS was used to integrate information about an area to reach a solution that would solve complicated problems. The main objectives of Manjula et al.'s (2011) study is:

- Generation of digital dataset
- Generation of report, tables, and maps for the study area

- Report the areas with appropriate scale maps and assessment of deforestation factors report on causative (p. 27).

Data were collected from two methods: satellite and collateral. Also, image classification was used to identify the changes in the study area. Finally, after collecting data from different sources and calculating the change, Manjula et al. (2011) found that "changes such as the reduced vigor of forest vegetation, urbanization, mining, etc. are noticed in the study area" (p. 31),

Construction project safety may affect economics, cost, and social life. Good safety practices are an important factor in the construction field. Bansal (2011) suggested that creating a simulation of the construction process and its environment, through the use of four-dimensional modeling or building-information modeling (BIM) by linking the schedule with the 3D model, would be useful. This can help identify if a hazardous situation is possible and, if so, the GIS can correct it before the start of actual implementation.

Safety measures and simulation can help the safety planner define what is required to ensure the project has high level of safety. These can be obtained from:

- 4D modeling
- Topographical conditions
- Safety database

As pointed out by Bansal (2011), "safety planning of gravity dam construction where topography plays a major role could not be simulated without the geospatial capabilities" (p. 86). This can be done using the GIS, which "improves execution planning and safety planning by integrating geospatial-editing with spatial and nonspatial information” (p. 68). “The GIS approach allows the safety planner to manipulate the schedule, components, and sequence on a single platform” (p .76).

Construction of a new dam could affect the environment and natural resources. Al-Shangiti (2009) studied how the GIS can be used to evaluate environmental impacts of dam construction. A case study was used to test the successful use of GIS in dam construction. The area selected was at the Man River in the west of India. Many information layers, such as physiography and drainage; geology and structure; and climate, soil, and land use/land cover were integrated in the GIS software, and a suitable site selection tool was used. By using all these information layers, Al-Shangiti determined the soil, land use, slope, and land irrigability, among other things, for the area. The finding was that the Man River Dam could cause submergence of 17.55 square km, which included five villages.

The uniqueness of GIS software is the tools that can be used to facilitate both construction and importation of data. Miles and Ho (1999) discussed how GIS could help construction and civil engineering. For example, digital elevation models (DEMs) can be used in many engineering projects, especially those in civil and construction engineering, to represent the terrain's surface at the site or location. In addition, triangulated irregular networks (TINs), which can help construction managers read a physical land surface in 3D view, is another GIS tool that can be used in construction projects. These two tools can drive much other useful information, for instance *slope*, which can show the incline of a surface, and *aspect*, which, according to the GIS Dictionary, means “the compass direction that a topographic slope faces.” As can be seen, use of the GIS provides the ability to present analysis results in map form.

Jeljeli, Russell, Meyer, and Vonderohe (1993) identified potential applications for GIS in the construction industry and explored the benefits of using GIS technology. They found that GIS technology could be used in the contractor prequalification process, the design phases, the bidding phase, and the construction phase.

In the contractor prequalification process, the process owner and contractors have the capability to find the information they need by using the massive amount of data stored in the GIS software as layers, which contain spatial and descriptive data. Once the data layer is constructed, spatial and descriptive queries can be done through the GIS. For example, owners can select a contractor based on specific criteria, such as the contractor's office location, labor type, and number of engineers. In the design phases, topological overlay and proximity functions are very important in optimizing the construction site. In addition, site investigation in GIS can be done by finding "where geological structure needs to be examined" (Jeljeli et al., 1993, p. 77). In the bidding phase, the contractor needs information about such things as water, access roadways, utilities, and soil. All this information can be stored in the GIS, ready to be queried. Therefore, use of the GIS makes it possible for the contractor to gather the information needed to estimate his/her bid on the project easily and at a lower cost than if the GIS was not used.

As can be seen from previous paragraph, the GIS tools and techniques can be used in the construction phase. The GIS network analysis function can provide assistance with many tools or methods, for example, the critical-path method in scheduling. Jeljeli et al. (1993) pointed out that "different GIS techniques such as classification, measurement, retrieval, proximity, and overlay operations, can be used to assess the suitability of particular equipment to a construction site" (p. 87).

GIS also has an affect on asset management. The GIS-centric Computerized Maintenance Management System company produced a system called GIS-centric public asset management. This system "is a system design approach for managing public assets that leverages the investment local governments continue to make in GIS and provides a common framework for sharing useful data from disparate systems" (ESRI, 2011). This kind of system also helps companies share and exchange geospatial data and descriptive data.

Some construction projects, especially highway and street projects, use the geocoding process to manage the project. Geocoding is a GIS analysis tool that can be defined as "the mechanism that allows you to use addresses to identify locations on a map" (Pine, 1998, p. A-10). This tool helps to create maps to show locations, query features, and search for the target group. This helps organizations with large databases locate their customers, projects, or suppliers.

In construction management, maps and surveys are important for any project. Maps provide information about locations, environmental features, routes, and so forth.. Use of surveys (surveying) ensures accuracy of the maps, whether land maps or boundaries. According to ESRI, "you can use GIS to support initial planning and environmental studies; organize map, survey, and design documents; and share information with personnel in the office or the field" (para. 2). Recently, many construction companies and municipalities have been using GIS to organize maps and surveys.

The relevant literature about projects, construction projects, success factors for construction projects, GIS technology, GIS history, and the use of GIS in construction projects have been discussed. The next section covers some previous surveys and assessment tools found in the literature that is relevant to this research.

Literature Related to Previous Surveys and Assessment Tools

This section presents an overview of tools and surveys used in previous research studies. The first part of this section identifies and reviews a summary of five construction project management research methods (Table 3). The second part identifies and reviews five GIS research methods (Table 4).

Table 3

Review of Research Methods of Using GIS in Construction Projects

Methodology Identification	Description
Bansal and Pal, 2006	Authors used applications in GIS ArcView 3.2 to store data. They used also GIS to store spatial data. Then they used a case study to provide 3-D and cost estimation by using a residential building.
Dierkes, and Howard, 2008	Authors use experimental method (one shot experimental case study). They tracked and installed data by using GIS/GPS and tested the procedure. Finally, they came up with a report update for the project.
Poku & Arditi, 2006	Authors designed a new system called Progress Monitoring System with Geographic Information Systems (PMS-GIS). AutoCAD, project management software, and ArcView GIS were used in this system to generate a 3D schedule and progress.
Shangiti 2009	A Case study was used about Man River in the west of India. Data were then collected from Physiography, Geology, Climate, Soil, and Land use/ Land cover. Then, tools from ArcInfo were used to generate soil, land use, slope, land irrigability, and so forth. Finally, site selection was used to find if the location was appropriate or not.
Jeljeli, Russell, Meyer, and Vonderohe (1993)	The authors identified potential applications for GIS to explore the benefits in the construction industry. These applications were applied in the contractor prequalification process, design phases, bidding phase, and construction phase.

Table 4

Review of Research Methods into Success in Construction Project Management

Survey Identification	Description
Nguyen, Ogunlana & Lan, 2004	Based on literature reviews, the authors designed a questionnaire to gather information about success factors. Participants were from 42 large projects in Vietnam construction industry. The respondents were contractors, owners, and consultants
Al-Tmeemy, Abdul-Rahman, & Harun, 2011	Based on the literature, the authors found 13 significant success factors related to construction building. Then, 151 participants, from the building construction industry, filled out a survey to rank these 13 factors.
Yates & Eskander, 2002	The authors collected data about types of delay during planning and the scope of the development of projects' phases. Twenty-seven delay types were found. Then a 45-item questionnaire was developed and sent to 500 E&C industry professionals to rank the delay factors; 101 returned the surveys.
Phua, and Rowlinson, (2004)	Qualitative data were collected from a sample of 2,005 construction firms. Twenty-nine interviews conducted. The authors used telephone interviews, which were tape-recorded. Three factors were found by interviewees as the basic criteria, namely budget, time, and quality. Moreover, cooperation was considered as a secondary factor for project success. Then, a questionnaire was designed that contained 20 factors from the interviews. After two mailings of the questionnaires, a total of 398 responses were received.
Jha and Iyer, 2007	From previous research, case studies, and interviews, 55 factors were identified. After that, a two-stage questionnaire survey was designed. Out of a total of 450 sent out, 114 first-stage questionnaire responses were received. This helped identify factors responsible for success or failure of a project. Ninety responses to the second-stage questionnaire were received out of a total of 300 sent out. These evaluated the impact of factors, identified from the first-stage questionnaire, on project performance. Respondents included senior officials from government, the public sector, multinational, and private companies in India.

Summary

In conclusion, in Chapter Two, based on the relevant literature, construction projects, construction project management and its history and development, and success criteria or factors for construction projects and project management were discussed. Also discussed were GIS and its history, technology, and role in construction projects. The literature related to construction surveys and assessment tools were also part of the discussion. Based on the information found in the relevant literature, two tables were prepared. Table 5 presented a summary of construction project management success factors and criteria. In Table 6 the GIS applications and functions that are used in construction projects were presented.

Table 5

Summary of Construction Project Management Success Factors and Criteria

Author	**Success factors**	**Success criteria**
Jha and Iyer, 2007	commitment, coordination, and competence	Cost, schedule, and quality
Yates and Eskander (2002) (Affect of the planning and scope development phase in construction projects)	constant changes in project requirement, (b) developing multiple projects at the same time, and (c) lack of communication among various divisions	
Ashley, Lurie, and Jaselskis (1987)	planning effort, scope and work definition, project manager goal commitment, project team motivation, goal orientation, project manager capabilities and experience, safety, and control systems	budget, schedule, functionality, contractor satisfaction, client satisfaction, and project manager/team satisfaction
Albert and Ada (2004)		Time, cost, and quality. Other measures become important in the industry, such as, safety, functionality, and satisfaction.
Phua and Rowlinson (2004)	Cooperation: Personal friendship between project participants	
Li (2009)	Cost	

(continued)

Table 5

Summary of Construction Project Management Success Factors and Criteria (continued)

Author	**Success factors**	**Success criteria**
Al-Tmeemy, Abdul-Rahman. and Harun (2011)	when it is capable in integrating the three success dimensions (three-dimensions are project management success, product success, and market success,)	
Jha and Iyer, 2007		Objectives, which are schedule; cost; quality; safety; and dispute. Subjective criteria include client satisfaction; contractor satisfaction; and project management team satisfaction
Oberlender (1993)	Cost and time and assure good quality	
Nguyen, Ogunlana and Lan (2004) Note “they did not include time, cost, and quality as factors”	-competent project manager -adequate funding throughout the project -multidisciplinary project team -commitment to project -availability of resources	

Table 6

Summary of GIS Functions that were Used in Construction Projects In Research

Author	**GIS functions**
Steiniger and Weibel, 2009	Autodesk, Bentley, ESRI Inc. (ArcGIS), GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph
Oregon Department of Transportation (DOT) 2003	Traffic analysis
Poku and Arditi (2006)	The Progress Monitoring System
Dierkes and Howard (2008)	Construction-tracking tools
Bansal and Pal (2006)	Calculate cost and visualize the project.
Manjula, Jyothi., Varma. & Kumar, (2011)	Geographical Decision Support System
Bansal(2011)	Creating a simulation of the construction process and its environment, safety planning
Al-Shangiti (2009)	Evaluate environmental impacts for Dams construction
Jeljeli, Russell, Meyer, and Vonderohe (1993), Miles and Ho (1999)	Spatial and descriptive queries Site selection Terrain modeling: for displaying and interpolating Digital elevation models (DEMs) and Triangulated irregular networks (TINs)
Jusoff (2008)	Terrain analysis: Aspect and Slope
Rezouki and Rasheed (2012)	Bill of Quantities

This research was focused on the most important criteria, which are related to GIS projects. Table 6 covered GIS applications and functions that were used in construction projects as discovered in the review of the relevant literature. In this literature review, many GIS tools, applications, or functions have been covered. As mentioned earlier, all of these were called GIS functions to simplify the research. However, after consulting with the panel of experts, some functions have been grouped under one main function. For example, tools for displaying and interpolating TINs and DEM, which represent surfaces, are grouped under Terrain Modeling, while tools for calculating slope, aspect, plan curvature, profile curvature, etc are grouped under Terrain Analysis. The 11 main functions used in the survey that sent to the population are:

- Data Visualization
- Construction Analysis (Simulation of the construction process)
- Route/ Site selection analysis
- Terrain modeling
- Terrain analysis
- Asset Management
- Construction Cost Estimation Support
- Monitoring Systems
- Organizing of maps and surveys
- Traffic Analysis/Management
- Geocoding

CHAPTER THREE: RESEARCH METHODOLOGY

Descriptive methodology was used to collect data from employees in construction organizations or construction consulting firms that fall under the target categories of the Highway Construction Group. The success criteria for construction projects (cost, time, and quality) were used as dependent variables. The relationship between project success criteria (PSC) and GIS functions in construction projects were investigated. A survey instrument that gathered respondents' perceptions was the primary data-gathering tool.

Research Design

Descriptive methodology may be used to find the correlation or relationships between several variables (Leedy & Ormrod, 2010). In this research study, a survey instrument was utilized to gather data to investigate the relationship between PSC (cost, schedule, and quality), which are the dependent variables, and the use of a set GIS functions (independent variables). Project success criteria and GIS functions were based on the perceptions of the respondent.

Study Population

The research was focused on that part of the construction industry listed under the Highway, Street, & Bridge group category and any related project type within the heavy and civil engineering sub-sector. The organizations studied were either construction companies or construction-and-project-consulting companies in the private or government sector, both of which employ some of the selected job titles used in this research. This group of the population was specified from the North American Industry Classification System (NAICS). Following is a list of the sources from which respondents were selected and the number of surveys sent based on the information gathered:

- InsideView: is a software used to help the researcher find the list of construction companies in the Highway, Street, & Bridge group, which is coded as 237310 in NAICS. InsideView is a service company (www.insideview.com) with database information on more than 50 million companies worldwide. Using InsideView software, a sample was drawn of individuals with fall within the category of job functions (Engineering; IT and IS; Director; Manager; CEO; Vice President; Board Member; and Operations and Administration) in the construction industry who are employed by companies in the Highway, Street, and Bridge construction group. The survey was sent to 978 individuals identified from this source.
- The Google search engine was used to find professionals in this field. The researcher then emailed the survey to 33 of these professionals and asked them to complete the survey.
- The Associated General Contractors of America (AGC) (www.agc.org) is an association that serves construction professionals in the United States. The survey was emailed to 1,000 of its members in the Highway and Transportation Division.
- The American Association of State Highway and Transportation Officials' website (www.transportation.org) contains contact information about individuals working in the Highway and Transportation departments (including the Bridge and Structure, Design, Construction, Maintenance, and Highway Transport subdivisions) of state agencies in the United States. Email surveys were sent to all 491 Highway committee members listed on the site.

- The Michigan Society of Professional Engineers (MSPE) (www.michiganspe.org) provided contact information about professional engineers in different engineering disciplines. The survey was emailed to all 1,266 of its members working in construction, government, higher education, and private practice.
- The National Society of Professional Engineers (www.nspe.org) provided contact information on more than 35,000 members who are licensed professional engineers (PEs) and engineer interns (EIs). The survey was emailed to all 5,610 professional engineer members listed under construction, private practice, and government groups.

Vaske (2008) stated that “email surveys can have low response rates because using the delete key makes disposing of the questionnaire easy” (p. 167). It is common to have 20% or lower email response rate (Witmer, et al., as cited in Jones, 1999) A breakdown of the organizations providing contact information, the number of surveys that were sent, and the total number received are found in Table 7.

Table 7

Number of Survey Sent and Received

	Population	Sent	Received
1	InsideView	978	
2	Organizations available online	33	
3	AGC of America	1,000	
4	The American Association of State Highway and Transportation Officials (AASHTO) Committees	317	
5	Michigan Society of Professional Engineers	1,266	
6	National Society of Professional Engineers	5,610	
	Total	9204	189

Instrumentation Development

Four steps related to instrument development are covered in this section: (a) literature review, (b) instrument design, (c) expert review, and (d) pilot study. A short description of each of these sections follows.

Literature review. A review of key journals revealed the most important criteria in construction project success. Also determined through the review of the literature were the common applications (functions) of GIS in the construction industry that were analyzed in this study. The GIS applications and functions chosen for construction projects that were analyzed in this study were:

- Data Visualization
- Construction Analysis (Simulation of the construction process)
- Route/ Site selection analysis
- Terrain modeling

- Terrain analysis
- Asset Management
- Construction Cost Estimation Support
- Monitoring Systems
- Organizing of maps and surveys
- Traffic Analysis/Management
- Geocoding

Instrument design. The survey questionnaire, developed through the Qualtrics website (www.qualtrics.com), was used to collected data on GIS functions and PSC (Appendix B). Fifteen questions were used to gather the data, fourteen of which were close-ended and one was open-ended. Information on business factors, such as position level, job function, organization's focus (type), and project budget was gathered. The construct validity of the tools was determined by consultation with a panel of experts from both the construction-industry and GIS.

The survey consisted of three sections. The first section contained questions to gather business and general information. The second section consisted of questions to determine the level of success of the company project. The third section consisted of two parts. The first part was to determine the GIS knowledge base of the company while the second part included a list of GIS functions and tools, which helped determine the most and least frequent uses of GIS functions in construction projects. This third section used a 5-point Likert-type scale (see Appendix A for the survey).

Experts. For this study, a panel of experts reviewed the content for validity. The research committee and two experts in the field, i.e., an individual from the construction industry and another individual from the GIS industry, reviewed the literature review, the survey instrument, and the research steps. In addition, the survey was sent to the Construction Management Association of America (CMAA) to gain their feedback. Walt Norko, Vice President of Professional Practice of the CMAA, reviewed the design survey contents and provided feedback. The researcher reviewed Mr. Norko's feedback with that of the committee members and considered it.

Pilot study. After the construct validity was established and confirmed by the experts, a pilot study was conducted in Eastern Michigan University's construction management graduate class (CNST630 Research on Construction Process) during September 2013. This helped validate the accuracy of the survey instructions and ensured readability. An estimate of the reliability of the instrument was calculated as well. Graduate students in this program completed the online survey and provided feedback to the researcher with comments on each question and on the overall survey. All comments and feedback from the pilot study were considered.

Safety, Confidentiality, and Anonymity for Human Subjects

There were no conflicts with privacy. The identities of the participants were kept anonymous, which insured privacy and confidentiality of the outcomes. Participants were not asked to provide name, age, company's name, or gender.

Human Subjects Approval

Following Eastern Michigan University requirements, as stated by the Office of Research and Development, an application was completed and submitted to the Graduate School for human subjects approval.

Data Collection

Data were collected through an electronic survey using Qualtrics, after gaining Human Subjects Approval from Eastern Michigan University. An online questionnaire was distributed via email to the targeted individuals:

- The list of people and companies selected by use of the InsideView software.
- Selected construction professional (by Google search engine).
- The Associated General Contractors of America (AGC).
- American Association of State Highway and Transportation Officials.
- The Michigan Society of Professional Engineers.
- National Society of Professional Engineers.

Data collection began on September 14, 2013, and concluded on November 7, 2013. Out of 9,204 potential respondents, 189 surveys were returned. Of this number, 35 were either incomplete or the individuals were outside of the research target demographic. A total of 156 returned surveys were usable. The return rate was 2.04%. All of the completed surveys were analyzed using the Statistical Package for the Social Sciences (SPSS), version 22 for Mac.

One initial email and two follow-up emails were sent to help ensure a good response. A statement that the results would be shared with the respondents was included in the email messages to help encourage recipients to complete the survey. In addition, the first 50 completed surveys got a Starbucks card "eGift". When participants completed the survey and submitted it, their responses were stored on the Qualtrics website. After that, all data were transferred into the Statistical Package for Social Science (SPSS) software for data analysis.

Data Analysis

Cronbach's alpha coefficients were calculated to measure internal consistency and to estimate the reliability of each item that used a Likert-scale. In addition; means, modes, and standard deviations were computed for some questions that required them. To test the hypotheses, it was necessary to understand the data and which kinds of variables were contained in the data. The first three null hypotheses have two variables, which are nominal/dichotomous, two groups in each variable. A Chi-square test was used to compare the relative frequencies in various categories (Leedy & Ormrod, 2010, p. 26). It works with frequency data. "A Chi-square test of independence is a nonparametric test designed to determine whether two variables are independents or related" (Cunningham & Aldrich, 2012, p. 202). A Chi-square test for association between usage of the GIS and success criteria (budget, scheduled, and quality) was used.

A Mann-Whitney U-test was used to test various hypotheses that dealt with the use of GIS functions in different types of construction organizations. A Mann-Whitney U-test is a "nonparametric test that may be used when the data assumptions required of the independent-samples t-test cannot be met." (Cunningham & Aldrich, 2012, p. 105). This test required ranking the values in ordinal level. The main purpose of the Mann-Whitney U test is to provide statistical evidence that two sample populations are significantly different (Cunningham & Aldrich, 2012). In this case, for null hypothesis four, the frequency of using GIS functions is the dependent variable and the organization's focus (type) is the independent variable. The highway, streets, roads, and public sidewalks group was chosen to test null hypothesis four to examine each of eleven GIS functions and compare their extent of use in this construction area with the grouped remaining construction organization's focuses (types). Techniques used to test the various null hypotheses are summarized in Table 8.

In each section of the survey, data were analyzed to determine the following:

- The most and least uses of GIS functions in construction management.
- The relationship between each GIS function and each success criterion (quality, schedule, cost).
- What type of construction function uses the most, and what type of construction function uses the least, GIS functions.
- Which employee job function uses the most, and which uses the least GIS applications or functions

Table 8

Summary of Tools to Test the Hypotheses

Null Hypothesis	**Tools to test the Hypothesis**
H1 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved budget (Cost).	Cross tabulation / Chi-Square tests
H2 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and owner specified requirements (Quality).	Cross tabulation / Chi-Square tests
H3 (Null Hypothesis) There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved schedule (Time).	Cross tabulation / Chi-Square tests
$H4_{1-11}$ (Null Hypothesis) There are no significant differences between respondents from different construction categories regarding the frequency of usage of each of the eleven GIS functions.	*Mann-Whitney U-test*

Resources

1- Resources were comprised of computer software programs, including MS Word, MS Excel, InsideView, and SPSS.

2- Qualtrics was used to design the survey and collect the information.

3- Survey design experts will be consulted.

Budget

Most of the resources were provided through Eastern Michigan University. The survey was developed by Qualtrics, which was free. InsideView cost $100/month.

Summary

This chapter described the research population, the research sampling frame procedure, research design, data collection, and data analysis methods. It also described the instrumentation development, which includes the literature review, instrument design, experts, and a pilot study. Safety and anonymity for human subjects was explained in this chapter.

CHAPTER FOUR: RESULTS

This chapter provides the analysis and results of the research. A statistical analysis was used to determine the psychometric properties of the survey, generate relevant descriptive statistics, and test the hypotheses. In the first section, a reliability analysis, conducted by alpha coefficient, is discussed. Then, sample demographics are discussed. Next, a descriptive analysis, including cross tabulation, means, standard deviations, and frequency tables is provided. The last section covers hypothesis testing.

Reliability Analysis

After carefully examining the responses, 156 were found to be usable. Any survey in which all of the first 10 questions (except Question 6, the project's budget) were answered was considered a completed survey. A Cronbach's alpha coefficient was calculated to assess the reliability and internal consistency of the Likert-scale type questions by utilizing the SPSS software. An alpha was developed to provide a measure of the internal consistency of the scale. The lowest acceptable value of alpha is 0.70 (Tavakol, 2011). The results indicated a high level of internal consistency for the three scales, with 0.829, 0.813, and 0.876 (see Table 9 for details). This means these are considered to have very good reliability.

Table 9

Reliability Analysis

Variable	Cases Number	Excluded	Valid	Number of Items	Cronbach's alpha
Degree of knowledge of GIS (Q4, Q12, and Q13)	156	33	123	3	0.829
Impact of using the GIS on project (Q11)	156	68	88	3	0.813
Organizations use the GIS applications and functions (Q14)	156	36	120	13	0.876

Organization Characteristics of the Sample

The respondents' job position levels (Table 10) were: (a) middle management (32.47%); (b) executive (25.97%); (c) design/engineering (24.68%); (d) consultant (9.09%); (e) field construction (2.60%); (f) support service (2.60%); and (g) other (2.60%), which included estimator/project manager, small civil/survey firm owner, and city engineer. More than half of the respondents were in executive and middle management positions, which means that these results represent high-level perspectives on the use of GIS in construction organizations.

Table 10

Demographic Characteristics of the Sample for Level of Position

Classification	Responses	
	Number	Percent
The level of position		
Executive	42	26.90%
Middle Management	50	32.10%
Design/Engineering	38	24.40%
Field Construction	4	2.60%
Consultant	14	9.00%
Support Service	4	2.60%
Other	4	2.60%
Total	**156**	**100.00%**

Regarding job function (Table 11), since individuals may have more than one job function, the total number of responses was 278. The highest-ranking job functions were planning and design (25.70%), consulting/support services (16.80%), and management of construction (16.40%). The lowest ranking job functions were company management (13.20%,) contract bidding and administration (11.40%), facility owner/representative (10%,) and other job functions that related to the Highway, Street, and Bridge group construction (6.40%). This result indicated that all job functions are close to each other, ranging from 10% to 25% among the participants.

There were 338 responses from 154 respondents about the focus of their organization's work, which meant that many organizations have more than one focus (Table 11). The survey results showed that the focus of 33.50% of the total respondents was on highways, streets, roads, or public sidewalks. In addition, 25.40% of the total respondents focused on bridges, and 15.50% focused on other heavy and civil engineering construction. Lower percentages of respondents focused on water resources (9.90%), airport runways (8.70%), and other work related to the highway construction group (7%).

The last demographic question was about the knowledge respondents' organizations had about GIS (Table 12). The survey results showed that more than 67.5% had good, very good, or excellent knowledge about GIS in their organizations.

Table 11

Demographic Characteristics of the Job Function and Organization's Work Focus

Classification	Responses	
	Number	Percent
Job function (Multiple answers)		
Company Management	37	13.20%
Facility Owner / Representative	28	10.00%
Planning & Design	72	25.70%
Contract Bidding & Administration	32	11.40%
Management of Construction	46	16.40%
Consulting / Support Services [i.e., inspection, surveying, feasibility studies, etc.]	47	16.80%
Other	18	6.40%
Total	**280**	**100.00%**
Organization's work focus (Multiple answers)		
Highway, Streets, Roads, or public sidewalks	115	33.50%
Bridges	87	25.40%
Airport runways	30	8.70%
Water resources (e.g Levees, Dams, Locks)	34	9.90%
Heavy and Civil Engineering Construction/ Others	53	15.50%
Other	24	7.00%
Total	**343**	**100.00%**

Table 12

Demographic Characteristics of the Sample Organization's Knowledge of GIS

Classification	Responses	
	Number	Percent
Organization's knowledge with GIS		
None	13	8.30%
Fair	38	24.40%
Good	45	28.80%
Very Good	36	23.10%
Excellent	24	15.40%
Total	**156**	**100.00%**

Descriptive Analysis

The next three sections provide details about Section 2; and Section 3, parts 1 and 2; of the survey. Cross tabulation, means, standard deviations, and frequency tables are provided.

Project success. Questions 5 through 9 of the survey examined of project success, based on a recently completed project. A descriptive analysis was done for each of these five questions. Almost half the total responses (103 or 46.4%), dealt with highways, streets, roads, or public sidewalks. The second highest number was bridges, with 48 responses (21.6%) (Table 13).

A total of 126 respondents provided data on the approved budget for the last completed project. Small project budget can affect the result because there is large range between minimum and maximum budget, therefore any budget less than $100,000 was excluded from the study in order to address threats to internal validity. Out of the 156 respondents, 120 cases were usable for this question. The mean for the sample was $62,681,448. The result also reveals that the mode is $2,000,000 and median is $5,000,000 (Table 14 and Figure 15). As can be seen, the figure has some outliers that affect the results and the histogram confirmed that the overall, Approved Project Budget, is non-normal distribution. It was felt that the reason for this was that some of the participants were executives in the federal or state government, and they manage very large projects. For this reason, as shown in Figure 15, the responses to this question were not normally distributed.

Table 13

Type of Recent Completed Project

A recent project completed (Multiple answers)	Responses N	Responses Percent
1- Highway, Streets, Roads, or public sidewalks	104	46.2%
2- Bridges	49	21.8%
3- Airport runways	8	3.6%
4- Water resources (e.g., Levees, Dams, Locks)	17	7.6%
5- Heavy and Civil Engineering Construction	25	11.1%
6- Other	22	9.8%
Total	225	100.0%

Table 14

Approved Budget Amount

N	Valid	120
	Missing	36
Mean		$62,681,448
Median		$5,000,000
Mode		$2,000,000
Std. Deviation		$241,764,906
Minimum		$100,000
Maximum		$1,700,000,000
Percentiles	25	$1,400,000
	50	$5,000,000
	75	$20,000,000

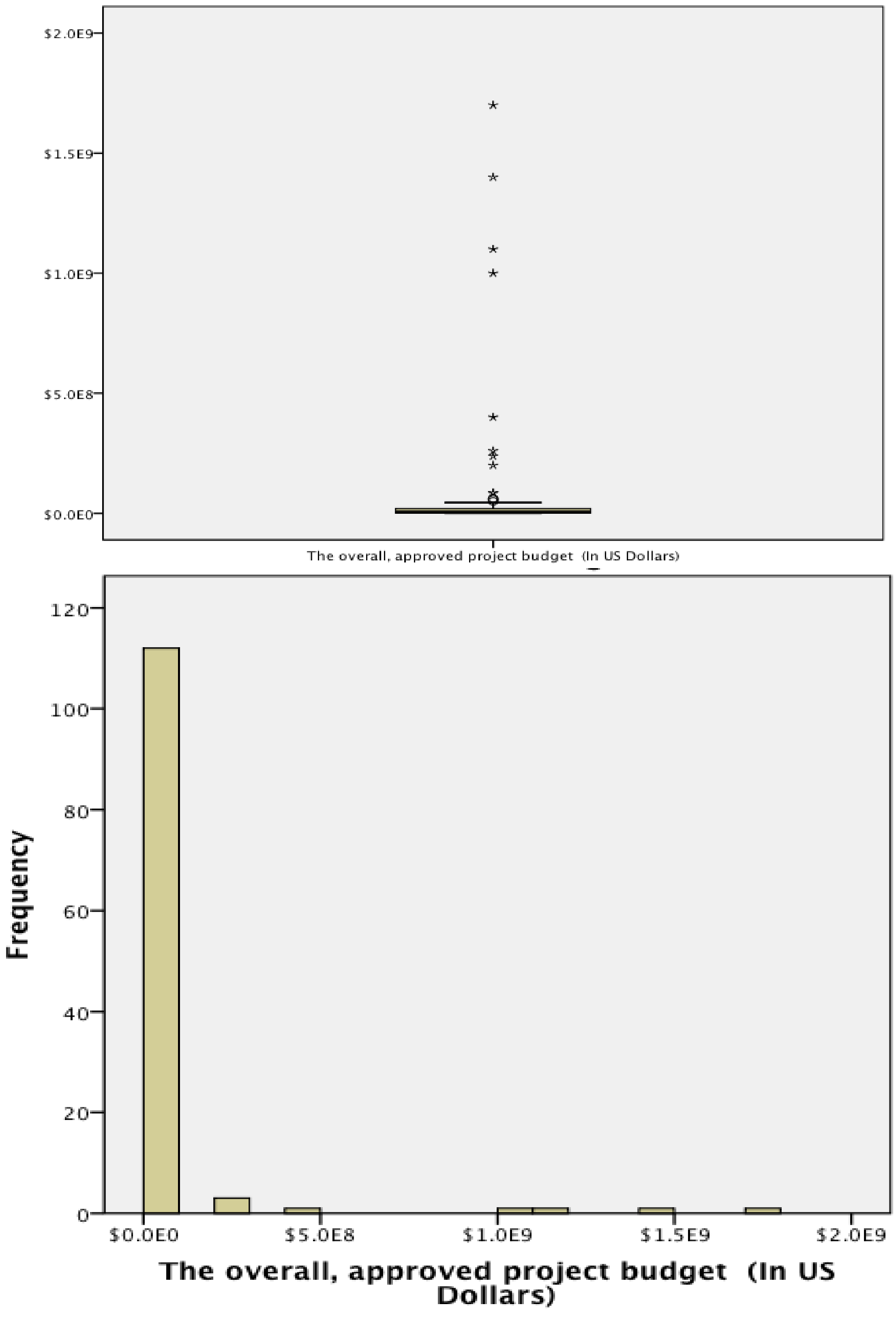

Figure 15. Box Plot and histogram of the overall, approved project budget.

Out of the 156 total respondents, 138 (88%) reported that their last completed project was within approved budget, 154 (99%) completed the overall project to owner's specifications, and 135 (86%) completed the project within the approved schedule (see Figure 16). These results show that project management considered the three criteria were being met very well. The quality criteria had a very high successful rate. After some investigation, it was discovered that project managers did not start any project before the owner's requirements or expectations had been approved by the owners, so the high percentage of success regarding quality was expected.

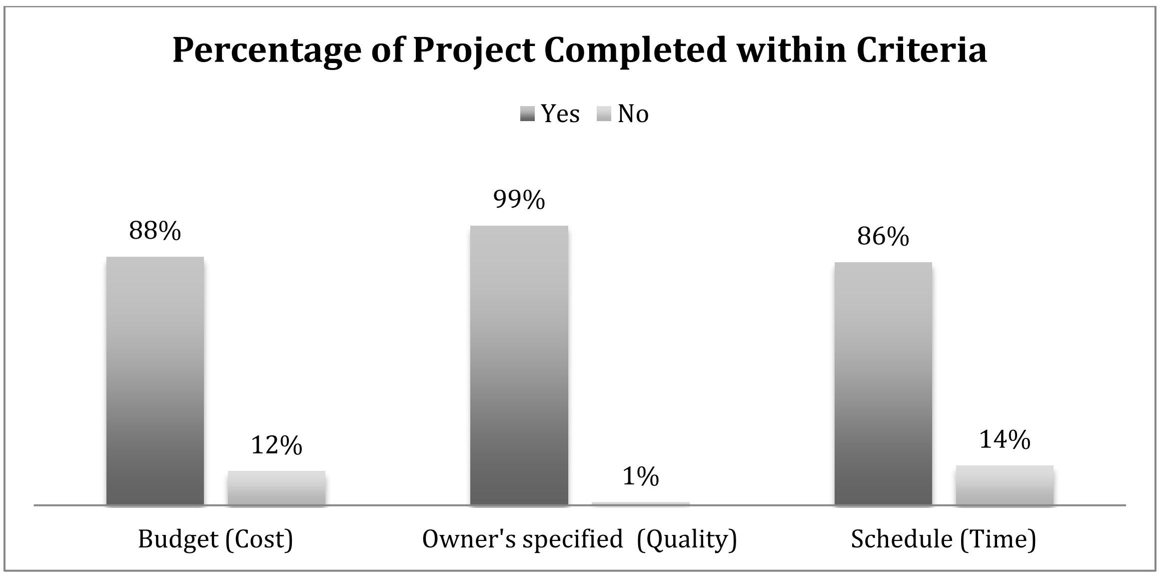

Figure 16. Projects completed within criteria

Moreover, a cross tabulation was developed to determine the relationship between project type and each success criterion (Table 15). The highway, streets, roads, or public sidewalks type of project was the highest recently completed project type, with 47% of the total respondents completing the project within budget, and 46% completing the project within quality and schedule. The second highest recent completed project was bridges, with 22% of the total respondents completing the project within budget, and 21%

completing the project within quality and schedule. The results showed that about two thirds of the total projects involved in this survey came from highway, street, roads, public sidewalks, or bridges types of project.

Table 15

Cross Tabulation for the Type of the Recently Completed Project and Success Criteria (Budget, Quality, and Schedule)

	Completed within the approved budget?			**The owner's specified requirements (Quality)**			**Completed within the final approved schedule**		
	Yes	**No**	Total	**Yes**	**No**	Total	**Yes**	**No**	Total
Highway, Streets, Roads, or public sidewalks	93	11	104	102	2	104	89	15	104
	47%	41%	46%	46%	50%	46%	46%	47%	46%
Bridges	45	4	49	47	2	49	41	8	49
	22%	15%	22%	21%	50%	22%	21%	25%	22%
Airport runways	6	2	8	8	0	8	7	1	8
	3%	7%	4%	4%	0%	4%	4%	3%	4%
Water resources (e.g., Levees, Dams, Locks)	13	4	17	17	0	17	11	6	17
	7%	15%	8%	8%	0%	8%	6%	19%	8%
Heavy and Civil Engineering Construction	22	3	25	25	0	25	23	2	25
	11%	11%	11%	11%	0%	11%	12%	6%	11%
Other	19	3	22	22	0	22	22	0	22
	10%	11%	10%	10%	0%	10%	12%	0%	10%
Total	198	27	225	221	4	225	193	32	225
	100%	100%	100%	100%	100%	100%	100%	100%	100%

GIS and the level of project success. Of the 156 respondents who completed the surveys, 93 (60%) used GIS in their most recently completed project and 63 (40%) did not use the GIS (Figure 17). Question 11 asked the respondents' opinion about the impact of using the GIS on the project. There was a total of 98 responses to this question. Five respondents provided their opinion based on their previous experiences with GIS, and 93 answered the question based on their last completed project. The five cases where GIS was not used in the last completed project were included for this analysis (Table 16). Forty-five percent of the total respondents felt that GIS has a moderate to significant impact on budget, 59% felt that GIS has a moderate to significant impact on quality, and 44% felt GIS has a moderate to significant impact on schedule (time).

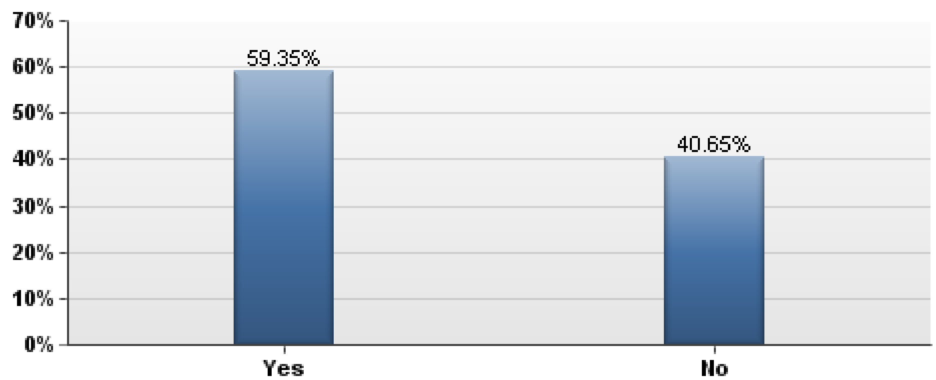

Figure 17. Using GIS on the last completed project.

Table 16

Respondents Opinions on Level of Impact in Using GIS

Question	Slight		Minor		Moderate		Significant		Critical		Total Responses		Mean
Cost (Budget)	21	21%	32	32%	31	31%	14	14%	1	1%	99	100%	2.4
Quality of Project's Requirements	17	18%	17	18%	31	32%	26	27%	5	5%	96	100%	2.83
Approved Schedule (Time)	25	26%	25	26%	27	28%	15	16%	4	4%	96	100%	2.44

GIS usage in the organizations. Out of the 156 persons surveyed, 123 respondents answered questions Q12 and Q13. Of the total respondents, 56.10% had between good and excellent personal knowledge regarding the use of GIS for general purposes. On other hand, 36.58% of the total respondents had between good and excellent personal knowledge regarding the use of GIS for construction purpose (Table 17). As can be seen, the respondents' reported less knowledge regarding the use of the GIS in construction when compared to general GIS usage. From this result, it can be stated that the use of GIS in constructions industry was low (36.58%). This is a clear indication that respondents in this field need to increase their knowledge of GIS for construction purposes in order to take better advantage of this technology.

Table 17

Personal GIS knowledge

Personal GIS knowledge	None	Fair	Good	Very Good	Excellent	Total
General usage	11	43	34	17	18	123
	8.94%	34.96%	27.64%	13.82%	14.64%	100.00%
Construction usage	35	43	27	8	10	123
	28.46%	34.96%	21.95%	6.50%	8.13%	100.00%

The survey requested that respondents provide their personal frequency of use of GIS functions. The number of responses to the various items in this question ranged from 113 to 120. In this question, the mean was used to represent the results, which range between 1 and 5, where 1 is never used, and 5 is always used. As can be seen in Table 18, organizing maps and surveys had the highest usage with an average of 3.14 on the Likert scale, with 120 total responses. The second highest usage was 2D/3D visualization of project with an average of (2.83) on the Likert scale, with 119 responses. The third highest usage was site selection analysis, with an average of 2.77 on the Likert scale with a total of 120 responses. Respondents reported using GIS for such tasks as generating figures for reports, reference to as-Builts, pole location, locating properties with FEMA data, equipment control, project scoping, public notifications, and pull up tension.

Table 18

Use of GIS Among Construction Functions

Question	Never	Rarely	Sometimes	Most of the Time	Always	Total Responses	Likert Average
2D and 3D visualization of project	25	17	42	23	12	119	2.83
Simulation of the construction process	55	38	17	6	2	118	1.83
Route / Site selection analysis	27	21	37	23	12	120	2.77
Terrain Modeling to create digital elevation model (DEMs) and Triangular Irregular Networks (TINs)	34	13	39	20	13	119	2.71
Terrain Analysis (e.g., slope, aspect, profile, cut and fill analysis, interpolation etc.)	37	14	37	16	13	117	2.61
Asset Management	37	25	29	19	8	118	2.46
Estimating Project Costs	46	27	27	14	4	118	2.18
Monitoring Systems	52	32	21	7	5	117	1.98
Organizing Maps and Surveys	25	11	26	37	21	120	3.15
Traffic Management	52	19	26	16	4	117	2.15
Geocoding	40	18	32	14	9	113	2.42
Other	4	0	0	4	2	10	3

Construction industry user experiences with GIS. Question 15, the last question in the survey, requested respondents to comment on their experiences as they used GIS in the construction industry. Out of the 156 respondents, 72 provided responses to the last question, and 67 were usable. Qualitative analysis was used for this question. After grouping the responses into categories, the responses were divided into six main areas: (a) contractor interface, (b) equipment utilization, (c) operational performance, (d) management process, (e) other benefits, and (f) why they had not yet used GIS.

***Contractor interface*.** Contractor interface provides a structured communication process to control the exchange of information (detailed drawings and documents) between the contractors and the designers (Emmitt, & Gorse, 2003, p. 140). One respondent said that, “A contractor is much more confident with valid visible information available during his selection.” The contractor’s effort is much easier and clearer, which helps in proper utilization of resources. On the other hand, contractors in some organizations do not focus on GIS efforts at this time; and this technology is only used to establish the location and condition of organization assets, planning, and design phases.

***Equipment utilization*.** Light detection and ranging “LIDAR” is used to gather data for some projects. This technology is a remote sensing tool that measures distance by using a laser and analyzing the reflected light. One respondent said, “We have developed a system we call UPLAN which has been very helpful and are gathering LIDAR Data to enhance the information that we work with.” Others used LIDAR to survey rock-fall sites in maps. In addition, GIS and GPS are extensively used by some organizations to geocode all of the organization’s assets.

Operational performance. Visualization of construction areas helps inexperienced operators manage operational processes. The traffic impacts of adjacent development projects can be monitored. The 3D modeling adds a dimension to scheduling and improves the estimating process. Some operations used GIS to verify items missed by surveyors. GIS information provides a great tool to ensure project locations for geotechnical drillers. Some respondents have negative opinions about GIS in operational management, and they do not trust GIS data in their projects. One respondent said, “We cannot trust GIS data for excavation and grading application in our area.” Another respondent said,

> The intersection of two pipelines, in a cross pattern. Each leg of the cross has a valve for isolation purposes. If you locate these valves accurately in the GIS, the image generated on the document shows an illegible blob. If you space them away from the intersection, the location is inaccurate.

Based on these comments, it seems some respondents have less knowledge about using tools, functions, or features in the GIS. In fact, many features can be located accurately, by defining the coordinate system to all layers. One may connect the leg of the cross with a valve too. It seems that this lack of knowledge causes some issues in using GIS. Most of the operational people in highway and transportation use GIS primarily to manage project assets along the highway system.

Management process. In project management, GIS has been used in initiating, planning and designing, executing, and monitoring and controlling processes. Based on the respondents’ comments, both the initial phase and the execution phases involve using GIS. Some organizations use aerial images to gather data for the initial project phase. GIS also helps speed up the process from initiation to execution. As one respondent wrote, “GIS helps speed up this process and add value to the service we provide. Then take forward for executing with almost no loss of study done during initiating stage." GIS maps can include information about organization assets, location, distances, and stakeholders' information, which helps the project manager and owner, when meeting in the initial phase, to make decisions. Based on the respondents' comments, GIS is very helpful in the planning and design phase. It provides maps for analysis/design for the construction department. One respondent wrote, "GIS is very useful in the early planning stages of a project." Another wrote, "mostly for planning and environmental documentation." Another comment pointed out that GIS "seems to provide the most benefit during planning and scheduling of the project work tasks." These comments seem to reveal that most of the respondents involved GIS in planning phases. It appears that respondents knew how to use GIS tools in planning and design by employing a few features, such as map locations, elevations, and aerial photographs.

For project monitoring phase, the respondents, especially in bridge maintenance activities, made different comments. As one of the respondents mentioned, "GIS has been most useful in structural health monitoring of bridges and asset management programming for maintenance activities." Another respondent said, "GIS helps us monitor the traffic impacts of adjacent development projects." There are positive views about using GIS in the monitoring phase.

In general, the survey found that GIS helps construction management processes in many different ways, such as providing maps for the construction department in the company by integrating data into a third-party software for asset management. GIS can link geographic location to archived plans. As one respondent wrote, when reporting a project, "It is critical when working on projects such as landfills, where side slopes and incremental fill amounts must be reported" GIS tools help with respect to understanding and representing surrounding features, such as streets, hills, lakes, water sources, and so forth.

Other benefits of the GIS. Some respondents reported different uses of GIS that were outside management and operational processes. One respondent mentioned that GIS helps to check information on a map. He said, "We use Auditors' GIS systems to look up info on projects." GIS helps communicate with the public about upcoming closures, as some respondents mentioned. Moreover, this system helps employees feel they are organized and the job is simplified. Also, it motivates employee to get the job done on time and within the customers' specifications. One respondent wrote, "GIS is the tool they are given that makes them want to get a job done on time and of better quality." Some other benefits mentioned were: saves time, more accurate, less errors, archiving project details, and visible information. Some responses included:

- "GIS with superior results and significant savings to the agency."
- "Allows least cost routes to be selected," and
- "We also utilize GIS to track past project locations to quickly retrieve information previously used or collected"

Why GIS had not yet been used. Some respondents had little knowledge about GIS, especially senior engineers, and they do not yet incorporate GIS into projects. Some companies are working to further integrate GIS into their processes. A few respondents mentioned that although their organizations did not use GIS; they used other software to gather their needed information. One respondent said, "as an engineer, I am a CAD user." It appears that some respondents do not know how to integrate CAD into GIS.

Another respondent said, “The GIS, up to now, has been in asset management and geospatial data, such as property boundaries.” This is further confirmation that some engineers or construction personnel are still unfamiliar with GIS tools and capabilities.

Using GIS based on project type. What construction project category was perceived to have the highest percentage of GIS function use? In considering the last completed project, it was found that Highway, Street, Road, or public sidewalk construction had the highest percentage (42.25%) of the total sample (Table 19). Bridge construction was the second highest percentage of project type (19.72%). The results showed that GIS is used far more with highway and transportation projects than with other projects.

Table 19

Use of GIS Based on Last Completed Project

Project type	**Using GIS**	**%**
Highway, Streets, Roads, or public sidewalks	60	42.25%
Bridges	28	19.72%
Airport runways	6	4.23%
Water resources (e.g., Levees, Dams, Locks)	15	10.56%
Heavy and Civil Engineering Construction	17	11.97%
Other	16	11.27%
Total	142	100%

Knowledge of using GIS in construction project based on position level. Based on the survey results, it was found that the executive position level reported better knowledge than other position levels about using GIS in construction projects. Out of 33 executive-level responses, 30% had good knowledge and 12% has very good and excellent knowledge about using GIS for construction projects. The design/engineering position level had 26% of respondents with good knowledge and 13% with very good and excellent knowledge about using GIS for construction projects (Table 20). It was not expected that individuals in executive-level positions would have better knowledge of GIS use. This means that higher level executives within the construction company were knowledgeable about this kind of technology.

Table 20

Knowledge About Using GIS in Construction Project Based on Position Level

	Degree of familiarity (knowledge) of using GIS in construction project					
Position's Level	**None**	**Fair**	**Good**	**Very Good**	**Excellent**	**Total**
Executive	11 33.33%	8 24.24%	10 30.30%	2 6.06%	2 6.06%	33 100%
Middle Management	11 30.56%	17 47.22%	4 11.11%	3 8.33%	1 2.78%	36 100%
Design/Engineering	7 23.33%	11 36.67%	8 26.67%	1 3.33%	3 10%	30 100%
Field Construction	2 50%	1 25%	1 25%	0 0%	0 0%	4 100%
Consultant	3 25%	3 25%	2 16.67%	1 8.33%	3 25%	12 100%
Support Service	1 25%	2 50%	1 25%	0 0%	0 0%	4 100%
Other	0 0%	1 25%	1 25%	1 25%	1 25%	4 100%
Total	35 28.46%	43 34.96%	27 21.95%	8 6.50%	10 8.13%	123 100%

Hypotheses Testing

Moreover, since this study has 11 GIS functions, the frequency of use of each function was compared based on the organization’s focus (organization’s type). The null hypothesis four has 11 sub-null-hypotheses as is summarized in Table 24.

Since the job functions, organizations' work focus, and type of recently completed project are multiple answers, the highest selected answers were chosen. To test null hypothesis four, the choice was highway, streets, roads, or public sidewalks (115 responses out of 156) for organizations' work focus. The following is a review of the null hypotheses and the results.

H1 (Null hypothesis). *There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved budget (Cost).*

No statistically significant relationship was found between the use of GIS and meeting the approved budget (Tables 21 and 22) provided cross tabulation and chi-square test. This analysis failed to reject the null hypothesis because it ($\chi^2(1) = .139$, p = .709) did not meet the threshold for a p-value of 0.05.

Table 21

Cross Tabulation Null Hypothesis 1

		Usage of the GIS		
		Yes	**No**	Total
Was the overall project completed within the approved budget?	**Yes**	83 89.25%	55 87.3%	138 88.46%
	No	10 10.75%	8 12.7	18 11.54%
	Total	93 100%	63 100%	156 100%

Table 22

Chi-Square Test for Null Hypothesis 1

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.139	1	.709
N of Valid Cases	156		

H2 (Null hypothesis). There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and owner specified requirements (Quality).

Owner-specified requirements or quality could not be tested since, in the total response to this question, 99% chose the "yes" option. Of the 156 respondents, 154 met the quality criteria, which meant the data could not be used to test the significance of the relationship between quality and use of the GIS. After some investigation, it was found that organizations would not start a project before the customer approved, and they keep tracking the project. That means the organization's project manager or engineer will believe they met the customers' expectations, which could be right. More discussion about this result can be found in the discussion part of Chapter Five.

H3 (Null hypothesis). *There is no significant relationship between the use of GIS functions by Highway, Street, and Bridge organizations and meeting the final approved schedule (Time).*

There is no statistically significant association between the use of GIS and meeting the final approved schedule (Time), (Tables 23 and 24) provided cross tabulation and chi-square test. This analysis failed to reject the null hypothesis because it ($\chi^2(1)$ = .053, p = .818) did not meet the threshold for a p-value of 0.05.

Table 23

Cross Tabulation for Null Hypothesis 3

		Usage of the GIS		
		Yes	**No**	Total
Was the overall project completed within the final approved schedule?	**Yes**	80 86.02%	55 87.30%	135 86.54%
	No	13 13.98%	8 12.70%	21 13.46%
	Total	93 100%	63 100%	156 100%

Table 24

Chi-Square Test for Null Hypothesis 3

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.053	1	.818
N of Valid Cases	156		

H4 (Null hypothesis). *There are no significant differences between respondents from different construction categories regarding the frequency of usage of each of the eleven GIS functions.*

The result of the Mann-Whitney U-test showed that there is no statistically significant difference between the type of construction companies studied and the frequency of use of GIS functions in these companies, except in the case of the terrain modeling and traffic analysis functions.

The analysis failed to reject the null hypotheses for 9 functions, and rejected the null hypothesis for the following functions: Terrain Modeling and Traffic Management (Table 27). For the Terrain Modeling function (Table 25), it can be said that the scores for organizations' that focus on highways, streets, roads, or public sidewalks (mean rank = 63.86) were significantly higher than the scores other construction categories (mean rank= 49.50), U=1,056, z = 2.08, p = .037). For the traffic analysis function (Table 26), it can be said that the scores for organizations that focus on highway, streets, roads, or public sidewalks (mean rank = 62.68) had a higher score than organizations that focus on other works (mean rank= 49.22), (U=1,047, z = 2.024, p = .043). The results also indicated that the test for one null hypothesis was very close to significance, which is Estimating Project Costs function (U=1,709, z = 1.92, p = .055). Moreover there were three null hypotheses that were close to the .05 level. These functions were 2D and 3D visualization of project (U=1,652, z = 1.61, p = .107), Site selection analysis (U=1,702, z = 1.61, p = .107), Terrain Analysis (U=1,594, z = 1.67, p = .094).

Table 25

Mann-Whitney U-test for Terrain Modeling Function in Organization's Focus on Highway, Streets, Roads, or Public Sidewalks Group vs Other construction focuses.

	Highway, streets, roads, and public sidewalks focus	Other construction focuses
Total N	87	32
Sum of Ranks	5556	1584
Mean Rank	63.86	49.50
Man-Whitney U	1056	
Wilcoxon W	1584	
Z	2.083	
P-Value	.037	

Table 26

Mann-Whitney U-test for Traffic Management Function in Organization's Focus on Highway, Streets, Roads, or Public Sidewalks Group vs other focuses

	Highway, streets, roads, and public sidewalks focus	Other construction focuses
Total N	85	32
Sum of Ranks	5328	11575
Mean Rank	62.68	49.22
Man-Whitney U	1047	
Wilcoxon W	1575	
Z	2.024	
P-Value	.043	

Table 27

Mann-Whitney U-test of Null Hypotheses $4_{1\text{-}11}$

	Null Hypothesis	Sig.	Decision
4_1	The distribution of 2D and 3D visualization of project is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses	.107	Retain the null hypothesis.
4_2	The distribution of Simulation of the construction process is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.250	Retain the null hypothesis.
4_3	The distribution of Route / Site selection analysis is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.107	Retain the null hypothesis.
4_4	The distribution of Terrain Modeling using digital elevation model (DEMs) and Triangular Irregular Networks (TINs) is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.037	Reject the null hypothesis.
4_5	The distribution of Terrain Analysis (e.g., slope, aspect, profile, cut and fill analysis, interpolation etc) is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.094	Retain the null hypothesis.
4_6	The distribution of Asset Management is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.256	Retain the null hypothesis.
4_7	The distribution of Estimating Project Costs is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.055	Retain the null hypothesis.
4_8	The distribution of Monitoring Systems is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other organization's focuses.	.309	Retain the null hypothesis.
4_9	The distribution of Organizing Maps and Surveys is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.202	Retain the null hypothesis.
4_{10}	The distribution of Traffic Management is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.043	Reject the null hypothesis.
4_{11}	The distribution of Geocoding is the same across categories of organization's focus/Highway, Streets, Roads, and public sidewalks and other construction organization's focuses.	.206	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Summary

Chapter Four provided a statistical analysis of the collected data, including reliability, descriptive analysis, and testing of hypotheses. The Cronbach's alpha coefficient provided strong evidence that each of the three scales of the instrument possessed a high level of internal consistency, with more than a 0.7 alpha value for each scale. An analysis was completed for all questions, such as cross tabulation, means, standard deviations, and frequency tables. The results show that:

- 59.6% of the total respondents used GIS functions in the last recent completed project.
- 45% of the total respondents felt that GIS has a moderate to significant impact on budget, 59% felt that GIS has a moderate to significant impact on quality, and 44% felt GIS has a moderate to significant impact on schedule (time) (Table 16).
- The results indicated that 36.58% of the total respondents had between good and excellent personal knowledge regarding the use of GIS for construction purposes (Table 17).
- The project types that used the GIS most were highway, streets, roads, or public sidewalks, with 42.25%, and bridges, with 19.72% (Table 19).
- Out of 33 responses from those in executive-level positions, 30% had good knowledge and 12% had very good and excellent knowledge in using GIS for construction project.

In summary, two sub null hypotheses, $NH4_4$ and $NH4_{10}$, were rejected. The study failed to reject all other null hypotheses as summarized in Table 28. On the other hand, one sub null hypothesis ($NH4_7$) was very close to the .05 level of significance. Also, three sub null hypotheses ($NH4_1$, $NH4_3$, $NH4_5$) were close to the .05 level of significance. Further discussion and recommendations based on the results are presented in Chapter Five.

Table 28

Null Hypotheses Results

#	Null Hypotheses	P-Value	Decision
1	There is no significant relationship between the usage of GIS functions by the Highway, Street, and Bridge organization and meeting budget.	.709	Retain the null hypothesis.
2	There is no significant relationship between the usage of GIS functions by the Highway, Street, and Bridge organization and meeting customers' requirements.	N/A*	N/A
3	There is no significant relationship between the usage of GIS functions by the Highway, Street, and Bridge organization and meeting schedule.	.818	Retain the null hypothesis.
4_1	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the 2D and 3D visualization GIS function by the Highway, Street, and Bridge construction group.	.107**	Retain the null hypothesis.
4_2	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Simulation of the construction process GIS function by the Highway, Street, and Bridge construction group.	.250	Retain the null hypothesis.

Table 28

Null Hypotheses Results (continued)

#	Null Hypotheses	P-Value	Decision
4_3	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Route / Site selection analysis GIS function by the Highway, Street, and Bridge construction group.	.107**	Retain the null hypothesis.
4_4	There are no significant differences between an organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other organizations' focus with frequency of using the Terrain Modeling GIS function by the Highway, Street, and Bridge construction group.	.037	Rejected
4_5	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other organization's focus with frequently of using the Terrain Analysis GIS function by the Highway, Street, and Bridge construction group.	.094**	Retain the null hypothesis.
4_6	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction construction organization's focus with frequently of using the Asset Management GIS function by the Highway, Street, and Bridge construction group.	.256	Retain the null hypothesis.
4_7	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Estimating Project Costs GIS function by the Highway, Street, and Bridge construction group.	.055***	Retain the null hypothesis. (close to significant)

Table 28

Null Hypotheses Results (continued)

#	Null Hypotheses	P-Value	Decision
4_8	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Monitoring Systems GIS function by the Highway, Street, and Bridge construction group.	.309	Retain the null hypothesis.
4_9	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Organizing Maps and Surveys GIS function by the Highway, Street, and Bridge construction group.	.202	Retain the null hypothesis.
4_{10}	There are no significant differences between an organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organizations' focus with frequency of using the Traffic Management GIS function by the Highway, Street, and Bridge construction group.	.043	Rejected.
4_{11}	There are no significant differences between organization's focus (organization's type) in Highway, Streets, Roads, or public sidewalks and other construction organization's focus with frequently of using the Geocoding GIS function by the Highway, Street, and Bridge construction group.	.206	Retain the null hypothesis.

* The lowest became unnecessary
** Close to
*** Very close to

CHAPTER FIVE: SUMMARY, DISCUSSION, AND RECOMMENDATIONS

This chapter provides a summary of the quality of the instrument, nature of data, and return rate. The limitations of the study are also discussed and suggestions are made regarding future research in this area. The findings and discussion regarding each of the two research questions and other related answers are included. The two research questions investigated were:

RQ 1: What relationship, if any, exists between the degree of utilization of GIS functions by the Highway, Street, and Bridge group and each of the three project success criteria?

RQ2: What differences if any, exist between the construction organization categories (highway, street, roads, and public sidewalks as compared to other construction categories) in the frequency of usage of each of the 11 GIS functions within the Highway, Street, and Bridge group?

A discussion of other issues, recommendations for future research and suggestions for practitioners are included as well.

Instrument, Nature of the Data, and Return Rate

The reliability of the instrument was estimated using the Cronbach's alpha coefficient and ranged between 0.82 and 0.87 which indicated that the instrument is significantly above the recommended minimum acceptable reliability value of 0.7. Based on the results in Chapter Four, there are many outliers on the data, as can be seen in Figure 15. The Man-Whitney U test was used since the data were not normally distributed. Different possible reasons that caused the low response rate include:

- The lack of ability to follow up with many societies, such as the AGC and the National Society of Professional Engineers.
- Redistribution of some questionnaire may not have occurred as multiple parent organizations were contacted and some may not have effective control over the response rate of their members.
- Emails are easy to delete.
- Many project managers or engineers were busy working at the project site with little time or access to electronic surveys.

Answer to Research Question 1

"What relationship, if any, exists between the degree of utilization of GIS functions by the Highway, Street, and Bridge group and each of the three project success criteria?"

Findings. The first three null hypotheses addressed this research question. As mentioned in the previous chapter, an analysis of the data failed to reject two of the three hypotheses which means, based on the perceptions of the respondents, a significant relationship was not found between the schedule success criteria and use of the GIS functions. In addition, a relationship between meeting budget targets and the use of the GIS functions was not found. The "meets owner specification" (quality) criterion was dropped and was not tested since 99 percent of the respondents revealed that the project performance met their owner's specification, which provided insufficient variability to use an appropriate statistical test.

Discussion. Construction project success may be defined as: "completed on time, within budget, in accordance with specifications, and the stakeholders are satisfied"

(Takim & Akintoye, 2002). For the purposes of this research, the various project success criteria were investigated separately. For budget (null hypothesis 1) and schedule (null hypothesis 3), there were no significant relationships between the overall use of GIS functions and project success based on the test used.

The findings for hypotheses 1 and 3 were not consistent with results from other studies, such as DeMeritt (2012), who concluded that GIS can help to decrease costs for bridge repair projects, and Cheng and Chen (2000), who reported that the ArcSched (GIS) application could be used to assist engineers in controlling and monitoring the construction process. Findings similar to DeMeritt (2012) and Cheng and Chen (2000) were expected in this study, but the study data did not support these expectations.

A number of reasons may have contributed to this result:

1. The sampling may not have been fully representative of the population since the respondents from the multiple organizations surveyed may not have fully met the desired characteristics of ideal respondents.
2. Different project sizes may have affected these results. No account was taken of variations in project size in this study as, initially, there was no evidence that size made any difference in the project success variable.
3. The dependent variables (quality, cost, and time) may not have been effectively operationalized. The dependent variable could have been set up in a different way, for example, by using categorical scaling rather than dichotomous scaling to measure the quality level. Alternatively, the dependent variable could have used actual company data rather than respondents' perceptions.

4. Finally, the parameters of the projects on which the respondents were directed to report may have skewed the result. Since only completed projects were considered, those that failed completely and those that were only partially successful were not considered for the purposes of this research.

As mentioned earlier, the third success criterion, customer specification (quality), was dropped from the results section because 99% of the respondents said “yes, we met the owner’s specification (quality),” and this lack of variability of responses did not allow Hypothesis 3 to be tested. At least two different causes could have produced this result. The first is that those respondents whose client was a specific owner (company, individual, or organization), would not start the project without customer approval. In those cases, the owners’ specifications were designed to be met. The second cause could be attributed to respondents reporting jobs that did not have a specific owner (e.g., public works for residential areas), in which case, the respondent simply reported what the company felt was the level of quality of the job. It is recommended that the item that addressed “meeting owner specifications” should be modified in future research efforts.

Answer to Research Question 2

RQ2: What differences if any, exist between the construction organization categories (highway, street, roads, and public sidewalks as compared to other construction categories) in the frequency of usage of each of the 11 GIS functions within the Highway, Street, and Bridge group?

Findings. Null hypothesis 4 addressed Research Question 2. This null hypothesis had 11 sub hypotheses, as mentioned in the Chapter 4 (Table 25). The main finding was that most construction companies used a similar range of GIS functions. However, it appears that companies that focus on highway, streets, roads, or public sidewalks used terrain modeling and traffic management functions more frequently than other types of construction companies.

Moreover, the results for the null hypothesis regarding the Estimating of Project Costs GIS function (0.055) were very close to the 0.05 level of significance. Three null hypotheses were close to the 0.10 level of significance (if we consider a 10% level of significance). They are:

- Terrain Analysis (0.094) was not far from the 5% confidence level and under the 10% confidence level.
- 2D and 3D visualization (0.107) was very close to the 10% confidence level.
- Route/Site selection (0.107) was very close to the 10% confidence level.

Discussion. As the results showed, there are differences in the use of GIS between the organizations that focus (type) on highway, streets, roads, or public sidewalks (higher mean), and those construction organizations that focus (type) on other construction categories in using two GIS functions (Terrain Modeling and Traffic Management). This means that these two functions were particularly relevant to the work of these types of companies. Any new organization or company focused on highway, streets, roads, or public sidewalks should consider these functions. Additional functions that could be considered are 3D visualization, Estimating Project Costs, Terrain Analysis, and Route/Site Selection analyses.

Highway and road construction groups use terrain models such as TINs and DEM, which are tools for displaying and interpolating surfaces in the construction industry, to represent elevation of the terrain over a specified area. Moreover, construction work often disrupts traffic, so GIS traffic management tools enable project managers to manage and analyze various traffic scenarios more easily. Also, based on Fine et al. (2011), GIS traffic management can help transportation companies evaluate noise impacts from highway traffic and find a solution.

Other Issues Related to the Results

This section discusses items not addressed by the hypotheses and reports findings and discussion regarding the level of GIS knowledge reported by the respondents and addresses some comments provided by the respondents.

Findings. Many respondents stated that they did not possess much knowledge about the use of GIS in construction projects. Interestingly, based on respondent comments, it is clear that GIS has gained importance in the construction field.

Sixty percent of the respondents reported using GIS at least one time during their project. When these responses were examined more closely, it was discovered that organizations that focused on highway, streets, roads, and public sidewalks had the highest proportion (42%) of the reported use of GIS functions. As Smith (n.d) stated, “GIS is rapidly increasing in its use and importance in many fields and disciplines” (p. 8). Although trend data on the use of GIS in the construction industry were not readily available, it appear that that GIS is becoming more widely used in the construction industry The results indicate that the GIS functions had a good percentage of use in construction projects, especially in organizations focused on the highway, streets, roads, and public sidewalks. Many respondents indicated that they frequently used GIS functions during the project being described, (Table 18).

Analysis of the respondents' comments also revealed that contractors in some organizations do not focus on GIS use at this time. Also, the respondents used some equipment and software during their last completed project, such as GPS and UPLAN software. When considering operational performance, respondents have less knowledge about using tools, functions, or features in GIS. Three management processes (initial, planning, and monitoring) have involved some GIS activities (Appendix F). For example aerial images are used to gather data for the initial project phase. GIS also provides maps for analysis/design for the construction department. Finally, GIS is used to track and monitor activities of projects such as bridges. Regarding knowledge of how to use GIS, it appears that the project management executives are more knowledgeable about using GIS with 42% rating their knowledge between "good" and "excellent."

Discussion. The high percentage of respondents reporting little respondent knowledge about how to use the GIS functions may cause erroneous conclusions about the use of GIS. Miles and Ho (1999) found some misuse of the GIS in the context of engineering modeling in spatial data, outputs, and operations. Even though respondents reported little GIS knowledge, they reported using GIS at least one time during their last completed project, which suggests that they have started to become more involved with this technology. It may be assumed that increasing the knowledge of GIS uses and more involvement with this technology will likely produce different results with high quality. Based on the responses about the frequency of their use of the 11 GIS functions, the results (Table 18) showed frequent uses of these functions during the projects. This means these 11 functions are commonly used in the construction industry, especially in highway and transportation projects. This provides evidence of good construct validity for the independent variable (section of the instrument) related to GIS functions.

Many respondents provided comments about using the GIS functions in construction projects for contractor interface, management processes, operational performance, and other benefits. It seems that the lack of knowledge was the primary reason that people in the field do not use GIS appropriately. Based on the comments, many engineers still do not know how to integrate CAD with the GIS software. They also do not know how to find GIS data or how to use these data.

Finally, based on the results, a high percentage of executive-level respondents reported using GIS. It seems that executives report having more skills or knowledge about GIS than those in lower level positions. The reason could be that executives received the chance to train on GIS software and started to apply GIS on their construction projects or that they learned via other channels such as reading or attending conferences.

Limitations and Suggestions for Future Studies

It is important to discuss the limitations of this study to ensure that the context is understood and any recommendations can be carefully crafted. Several items are discussed below.

1. The population selected for this study was limited to U.S. highway and transportation construction groups. Since there is a need to vary the construction techniques based on weather and terrain conditions, it may be useful to narrow down to regions with very cold temperatures and states with mountains or no mountains with future research efforts.

2. Since the focus of this study was only on the sub-sector of the construction industry that produces highways, streets and bridges, further research should focus more on homogeneous groups in the construction industry. For example, future studies should narrow the focus to only one group of contractors such as those involved with highways or airports or walking services, etc to get a better handle on the special GIS needs or potential applications of this group.
3. The sample was drawn from organizations within the Highway Street, or Bridge group regardless of whether those organizations were government organizations or private businesses. Future studies should consider narrowing the focus to only one sector, either private business or government.
4. The research methodology used for the purposes of this study was descriptive in nature. It is suggested that future studies consider experimental or qualitative tools. An experimental study could help to draw cause and effect conclusions. Also, qualitative studies provide more details, validity, and explanations of the ambiguities, which can be recognized in the analysis.

General Suggestions for Future Studies

Researchers conducting further investigation into the question of how GIS could affect the construction industry may want to consider modifying the items about the customer's specifications (quality) by conducting interviews with customers or changing the research method to qualitative or experimental. Researchers should also consider retesting the success criteria with only one company focus—highways, streets, roads, and public sidewalks—since the Terrain Modeling and Traffic Management GIS functions have significant levels of frequent use in this construction group. Moreover, instead of success criteria, future studies should consider the basic construction project management philosophy as stated in Ritz (1994): " plan, organize, and control" (p. 20). Simply, instead of cost, time, and quality, future research should consider plan, organize and control as the three elements. The research should then test to see if there is any relationship between these three elements and use of the GIS functions during the projects.

Suggestions for the Construction Field

As can be seen in past research (reviewed in Chapter Two) and from the results of this research, several suggestions can be formulated for leaders of the construction industry, especially those who work in the Highway, Street, and Bridge group of the heavy and civil engineering subsector. The important suggestions that emerged from this and past research for the construction can be seen below.

Using GIS in construction projects could help improve the output of the projects. Some basic steps, which should be considered to ensure using GIS appropriately, are having good training on GIS functions and tools, using appropriate data when employing GIS tools, and ensuring that GIS tools are used for the appropriate purpose. Then, the construction industry, especially the Highway, Street, and Bridge group may consider Terrain Modeling and Traffic Management functions as they indicated significant differences between an organization's focuses. These functions help to display and interpolate surfaces in the construction projects and enable project managers to manage and analyze different traffic scenarios. Moreover, when choosing a suitable location; calculating cost; and calculating slope, aspect, plan curvature, profile curvature, and so forth, users in the construction industry can use the following functions in GIS: Visualization, Estimating Project Costs, Terrain Analysis, and Site Selection analyses.

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Appendix A: Student Informed Consent Agreement

Project Title: A Study of the Relationship Between the Use of GIS and Project Success in Selected Construction Organizations.

Investigator: Hamad Altuwaijri, Eastern Michigan University

Purpose of the Study: The overall purpose of this study is to determine whether a relationship exists between the use of GIS functions and the success of construction projects in the Highway, Street, and Bridge group. A related second purpose is to determine the relationship between business factors (such as job function, construction functions, project budget) and use of GIS functions.

Procedure: After reading this section, you will be asked to complete a series of questions that you will be asked to answer using the a five-point Likert-type scale along with indicating the correct response from several options. The approximate time to complete the questionnaire should be between 6 to 12 minutes to complete.

Please answer all questions, since incomplete questions create problems during data analysis and are often rendered non-usable. If you would like a copy of the survey, please contact the investigator and he will provide a copy for you.

Confidentiality: Only a code number will identify your questionnaire response. The results will be stored separately from the consent form. You will not be asked to provide your name, name of your company, your age, or gender. All information will be kept in password-protected personal computer accessed by the research investigator. The responses will be confidential and summarized as input for articles, conferences, and other academic-related events.

Expected Risks: There are no foreseeable risks to you by completing this survey, as all results will be kept completely confidential.

Expected Benefits: Those who complete the survey will be eligible to obtain a copy of the research results. Please indicate whether you would like to receive a copy of the results in the question provided at the end of the survey. Your participation will contribute to our understanding of the importance of GIS applications in the construction field. Also, it may be used as foundation for further studies.

Voluntary Participation: Participation in this study is voluntary. You may choose not to participate. If you do decide to participate, you can change your mind at any time and withdraw from the study without negative consequences.

Use of Research Results: Results will be presented in aggregate form only. No names or individually identifying information will be revealed. Results may be presented at research meetings and conferences, and in scientific publications, and as part of a doctoral dissertation being completed by the principal investigator.

Future Questions: If you have any questions concerning your participation in this study now or in the future, you can contact the researcher:

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This research protocol and informed consent document has been reviewed and approved by the Eastern Michigan University Human Subjects Review Committee for use from September 2013 to December 2013.

If you have questions about the approval process, please contact UHSCR (734.487.0042) or, mailto: human.subjects@emich.edu

Consent to Participate: I have read all of the above information about this research study, including the research procedures, possible risks, side effects, and the likelihood of any benefit to me. The content and meaning of this information has been explained and I understand. All my questions, at this time, have been answered. By clicking on the 'Next' button bellow, I hereby consent and do voluntarily offer to follow the study requirements and take part in the study.

Appendix B: Data Gathering Instrument

A Survey of Selected Construction Practices and Project Success

Construction and Information Technology Professionals are being surveyed to help identify the most useful Geographic Information System (GIS) functions for the Highway, Street and Bridge group of the Heavy Civil Engineering Sub-sector of the construction industry. This survey should only take from 6 to 12 minutes of your time. Your answers will be completely anonymous. All survey results will be shared with you if you provide your email address in the last question.

If you have any questions about the survey, please contact me at hm.ku@hotmail.com or call 785-979-6695. Thank you for taking the time to complete this survey. Your feedback is important to me and for the construction industry.

Hamad Altuwaijri, PhD Candidate

Section 1: Demographic (Business)

Q1: What is the level of your position?

- Executive
- Middle Management
- Design/Engineering
- Field Construction
- Consultant
- Support Service
- Other ____________________

Q2: What is your job function? (Select all that apply)

- Company Management
- Facility Owner / Representative
- Planning & Design
- Contract Bidding & Administration
- Management of Construction
- Consulting / Support Services [i.e., inspection, surveying, feasibility studies, etc.]
- Other ____________________

Q3: Within the Highway, Street, and Bridge Construction group, what is your company's focus in the heavy and civil engineering construction sub-sector? (Select all that apply)

- Highway, Streets, Roads, or public sidewalks
- Bridges
- Airport runways
- Water resources (e.g., Levees, Dams, Locks)
- Heavy and Civil Engineering Construction/ Others
- Other ____________________

Q4: What degree of familiarity (knowledge) does your firm have with Geographic Information System (GIS) functions (applications) for construction projects?

- o None
- o Fair
- o Good
- o Very Good
- o Excellent

Section 2: Instructions: Please respond to each question in this section based on a recent project completed by your company/organization.

Q5: What was the type of the project?

- o Highway, Streets, Roads, or public sidewalks
- o Bridges
- o Airport runways
- o Water resources (e.g., Levees, Dams, Locks)
- o Heavy and Civil Engineering Construction
- o Other ____________________

Q6: What was the overall, approved project budget? (In US Dollars)

$-------------

Q7: Was the overall project completed within the approved budget?

- o Yes
- o No

Q8: Was the overall project constructed to the owner's specified requirements?

- o Yes
- o No

Q9: Was the overall project completed within the final approved schedule?

- o Yes
- o No

Section 3: The following questions address the use of GIS and the level of success of the project. Part 1: Project Success:

Q10: Did your firm utilize GIS during any phase of this recently completed project? If "No" please move to the last question of the survey.

- o Yes
- o No

Q11: In your opinion, what was the impact of using the GIS on your project?

	Slight	Minor	Moderate	Significant	Critical
Cost (Budget)	o	o	o	o	o
Quality of Project's Requirements	o	o	o	o	o
Approved Schedule (Time)	o	o	o	o	o

Part 2: Please rate the following research questions:

Q12: What degree of familiarity (knowledge) do you personally have with the use of Geographic Information System (GIS) for any purpose?

- o None
- o Fair
- o Good
- o Very Good
- o Excellent

Q13: What degree of familiarity (knowledge) do you have with the use of Geographic Information System (GIS) (functions, tools, or applications) for managing construction projects?

- o None
- o Fair
- o Good
- o Very Good
- o Excellent

Q14: How often did your firm/organization use the following GIS applications and functions to manage your project?

	Never	Rarely	Sometimes	Most of the Time	Always
2D and 3D visualization of project[1]	o	o	o	o	o
Simulation of the construction process[2]	o	o	o	o	o
Route / Site selection analysis[3]	o	o	o	o	o
Terrain Modeling using digital elevation model (DEMs) and Triangular Irregular Networks (TINs)[4]	o	o	o	o	o
Terrain Analysis (e.g., slope, aspect, profile, cut and fill analysis, interpolation etc.)[5]	o	o	o	o	o
Asset Management6	o	o	o	o	o
Estimating Project Costs[7]	o	o	o	o	o
Monitoring Systems[8]	o	o	o	o	o
Organizing Maps and Surveys[9]	o	o	o	o	o
Traffic Management[10]	o	o	o	o	o
Geocoding[11]	o	o	o	o	o
Other	o	o	o	o	o
Other	o	o	o	o	o

Definitions/ Term explanation
Visualization of project[1]: visual representations of information and data.
Simulation of the construction process[2]: is the imitation of the operation of a real-world process of construction over time
Site selection:[3] indicates the practice of new facility location, both for business and government Terrain Modeling
Terrain Modeling[4]: terrain is used to refer to an area of land or a type of land when you are considering its physical features.
Terrain Analysis[5]: the collection, analysis, evaluation, and interpretation of geographic information on the natural and man-made features of the terrain,
Asset Management[6]: Refers to any system that monitors and maintains things of value to an entity or group. It may apply to both tangible assets such as buildings and to intangible concepts such as intellectual property Estimating Project Costs[7]: is the approximation of the cost of a project or operation.
Monitoring system[8]: a set of tools that help administrators monitor
Organizing Maps and Surveys[9]: manage, reuse, share, and analyze your survey data
Traffic Management[10]: involves directing vehicular and pedestrian traffic around a construction zone
Geo-coding[11]: is the process of finding associated geographic coordinates (often expressed as latitude and longitude) from other geographic data, such as street or addresses

Q15: Please comment on how GIS helps improve your organization's performance as to contractor interface, equipment utilization, operational performance, management process, etc.

Q16: Please provide your email address if you would like to see a summary of the results of this survey.

Appendix C: Initial Invitation Email

Date: September 14, 2013

Dear construction or information technology professional:

Your assistance is being requested as I conduct a study entitled "A Study of the Relationship Between the Use of Geographic Information System (GIS) and Project Success in Selected Construction Organizations." You have been selected to participate based on your expertise and job position within the construction industry. Please read the informed consent attachment to this email.

The overall purpose of this study is to determine whether a relationship exists between the use of GIS functions and construction projects in the Highway, Street, and Bridge group. A second purpose is to determine if a relationship exists between business factors (such as job function, construction functions, annual revenue) and the use of GIS functions on one of your recently completed construction projects.

Please complete the online questionnaire entitled "Selected Construction Practices and Project Success Survey" accessed at the URL below, or copy and paste the URL into the address bar of your browser window. Based on the pilot study, it is anticipated that the questionnaire will take between 6 to 12 minutes to complete.

URL:
https://qtrial.qualtrics.com/SE/?SID=SV_1FFqCIGs2Iq9aDP

Those who complete the survey will be eligible to obtain a copy of the research results, also (the first 50 completed survey will get Starbucks card "eGift"). Please indicate whether you would like to receive a copy of the results of this study and eGift by providing your email address in the last question.

If you have any questions/concerns about this study, please do not hesitate to contact me. Thank you for your help as I try to identify the most effective GIS tools for use in the construction industry.

Hamad Altuwaijri
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School of Technology
Eastern Michigan University
111 Sill Hall
Ypsilanti, MI, USA 48197
Telephone: (785) 9796695
E-mail: hm.ku@hotmail.com

Appendix D: Reminder Email

Dear construction or information technology professional:

This is a follow up to an email that was sent on Sep 12, 2013, in which we requested your participation in an important research entitled "A Study of the Relationship Between the Use of Geographic Information System (GIS) and Project Success in Selected Construction Organizations." You have been selected to participate based on your expertise and job position within the construction industry. Please read the informed consent attachment to this email.

If you have already responded, please ignore this reminder. If you did not have the chance to complete the online questionnaire yet, we would highly appreciate your insight. The survey is scheduled to close by Oct 19, 2013 and it would be very helpful if you could respond as soon as possible.

Please complete the online questionnaire entitled "Selected Construction Practices and Project Success Survey" accessed at the URL below, or copy and paste the URL into the address bar of your browser window. Based on the pilot study, it is anticipated that the questionnaire will take between 8 to 15 minutes to complete.

URL:

https://qtrial.qualtrics.com/SE/?SID=SV_1FFqCIGs2Iq9aDP

Those who complete the survey will be eligible to obtain a copy of the research results, also (the first 50 completed survey will get Starbucks card "eGift"). Please indicate whether you would like to receive a copy of the results of this study and eGift by providing your email address in the last question.

If you have any questions/concerns about this study, please do not hesitate to contact me. Thank you for your help as I try to identify the most effective GIS tools for use in the construction industry.

Hamad Altuwaijri
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Eastern Michigan University
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Telephone: (785) 9796695

Appendix E: EMU Human Subjects Approval Letter

EASTERN MICHIGAN UNIVERSITY

Education First

University Human Subjects Review Committee · Eastern Michigan University · 200 Boone Hall
Ypsilanti, Michigan 48197
Phone: 734.487.0042 Fax: 734.487.0050
E-mail: human.subjects@emich.edu
www.ord.emich.edu (see Federal Compliance)

Appendix F: Responses Answers

1. Section 1: Demographic (Business) Questions1- What is the level of your position?

#	Answer		Response	%
1	Executive		42	26.9%
2	Middle Management		50	32.1%
3	Design/Engineering		38	24.4%
4	Field Construction		4	2.6%
5	Consultant		14	9.0%
6	Support Service		4	2.6%
7	Other		4	2.6%
	Total		156	100.0%

Other
Estimator / Project Manager
Project Manager
Owner- Small Civil/Survey Firm
City Engineer

2. What is your job function? (Select all that apply)

#	Answer		Response	%
1	Company Management		37	24%
2	Facility Owner / Representative		28	18%
3	Planning & Design		72	46%
4	Contract Bidding & Administration		32	21%
5	Management of Construction		46	29%
6	Consulting / Support Services [i.e., inspection, surveying, feasibility studies, etc.]		47	30%
7	Other		18	12%

Other
Project Delivery - Design Consultant
DATA MANAGEMENT
Client Manager for Technology and GIS services
Project Management
Highway Asset Management
Operations Manager
GOV ADMINISTRATION
Quality Assurance (Post Const. Reviews, Constructability Reviews, Value Engineering)
Government Department of Public Works
Information Technology
In service inspection and management
State Agency
Roadway Maintenance
Operations of the highway system
GIS Specialist at Airport
Field support
Consulting engineering

3. Within the Highway, Street, and Bridge Construction group, what is your company's focus in the heavy and civil engineering construction sub-sector? (Select all that apply)

#	Answer		Response	%
1	Highway, Streets, Roads, or public sidewalks		115	73.7%
2	Bridges		87	55.8%
3	Airport runways		30	19.2%
4	Water resources (e.g Levees, Dams, Locks)		34	21.8%
5	Heavy and Civil Engineering Construction/ Others		53	34.0%
6	Other		24	15.4%

Other
Site Preparation
Rail
utilities
government
DOT
Landfills
ADA Compliance
Wastewater
Design and Construction Oversight
Pipe Lines up to 12"
Railroad
Does not apply - do no design or direct construction work
geotehcnial
forensic engineering
natural gas utility
water and wastewater mains
Solid Waste
Water & Wastewater, Collection, Treatment & distribution
telecommunications
DOT

4. What degree of familiarity (knowledge) does your firm have with Geographic Information System (GIS) functions (applications) for construction projects?

#	Answer		Response	%
1	None		13	8.3%
2	Fair		38	24.4%
3	Good		45	28.8%
4	Very Good		36	23.1%
5	Excellent		24	15.4%
	Total		156	100.0%

5. Section 2: Instructions: Please respond to each question in this section based on a recent project completed by your company/organization. 5- What was the type of the project?				
#	Answer		Response	%
1	Highway, Streets, Roads, or public sidewalks		104	67%
2	Bridges		49	31%
5	Heavy and Civil Engineering Construction		25	16%
6	Other		22	14%
4	Water resources (e.g Levees, Dams, Locks)		17	11%
3	Airport runways		8	5%

Other
Site Preparation
management of multiple developments
Network level asset management for state highway agency
Over-dimensional Permitting
Overhead Electric Construction
Retaining Walls
wastewater
pipe lines up to 12"
Sandy Damage Analysis - consulting - in process
subsidence investigation
church
Soil reports for building foundation systems in Texas.
Buildings and Schools
Natural gas pipe relocation in conjunction with state highway work
new development
Same as before
telecommunications infrastructure
Maintaining the highway system

6. What was the overall, approved project budget? (In US Dollars)

Text Response
$1,019,000
1.7 billion
$10,000,000
$4,600,000.00
1,000,000
varies from $100k to over $2million
General Public Works approved budget for the 2013 fiscal year was $ 9,817,082.00
GIS IS NOT ON A PER-PROJECT BASIS
$300,000.00
1.8 billion
200000
36,000,000
Varies
4 million
1.5 Billion
5mm
greater than$50 million
300,000
9.2mm
6.9M
$25M
3,000,000
varies 100 k +
$400,000
1.4M
Don't know
9 million and 11 million
n/a
1 million
20000000
$260 million
$2.0 million
20Million
$1 million
$1.2 million
$30 million
$30M
$200,000,000
60 million

$1B is our annual program depending on funding in a specific fiscal year
$11,800,000
$2,900,000
CR Design and Construction completes 20-40 projects per year between $1 and $50 million.
3,000,000
1.1B
7,000,000.00
3,000,000.00
400,000,000.00
$20,000,000
2M
$20 million
11.8 million
$73,000
$1,075,000
$1,940,000
$1,300,000
200000
2000000
$2 million
$12 million
$1,400,000,000
1'600.000
$7.5M
60 million
$2.1
5,000,000
8,000,000.00
N/A
700,000
$500,000
20
?
1,000,000
30,000,000
$325,000
5 million
10,000
$12.5 M

n/a
Ranges from $500, 000 to $10,000,000
$30-$50M
6000000
$4,000,000
7500
185,000
$ 3 TO 7 MILLION PER PROJECT
$3 million
Most GIS uses in our consulting firm are for presentations, planning studies for water and sewer projects and environmental reviews for all types of projects and water right work
32,000,000
38 M
$2.6M
Geotechnical Engineering Reports that include field borings, laboratory soil tests, and GIS information such as USGS Maps & Aerial Photographs. $1500 to $8,000
$45M
$2.5 million
1000000
$25 million
$6m
$85,000,000
multiple million dollar projects
22.6 M
$1,047,727

Statistic	Value
Total Responses	138

7. Was the overall project completed within the approved budget?

#	Answer		Response	%
1	Yes		138	88%
2	No		18	12%
	Total		156	100%

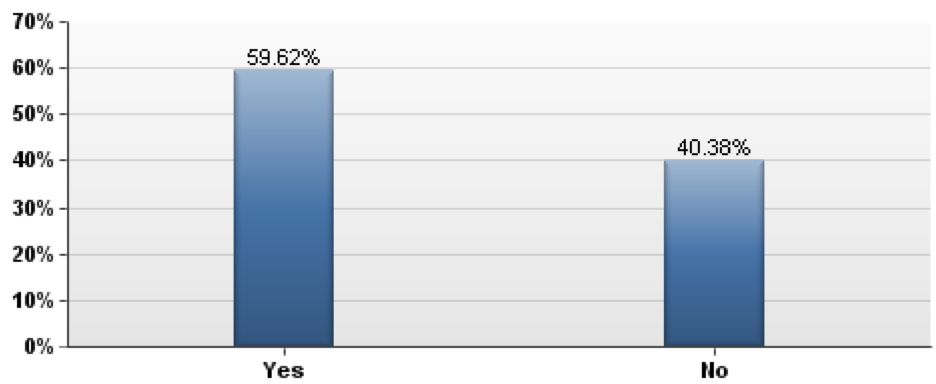
8. Was the overall project constructed to the owner's specified requirements?

#	Answer		Response	%
1	Yes		154	99%
2	No		2	1%
	Total		156	100%

9. Was the overall project completed within the final approved schedule?

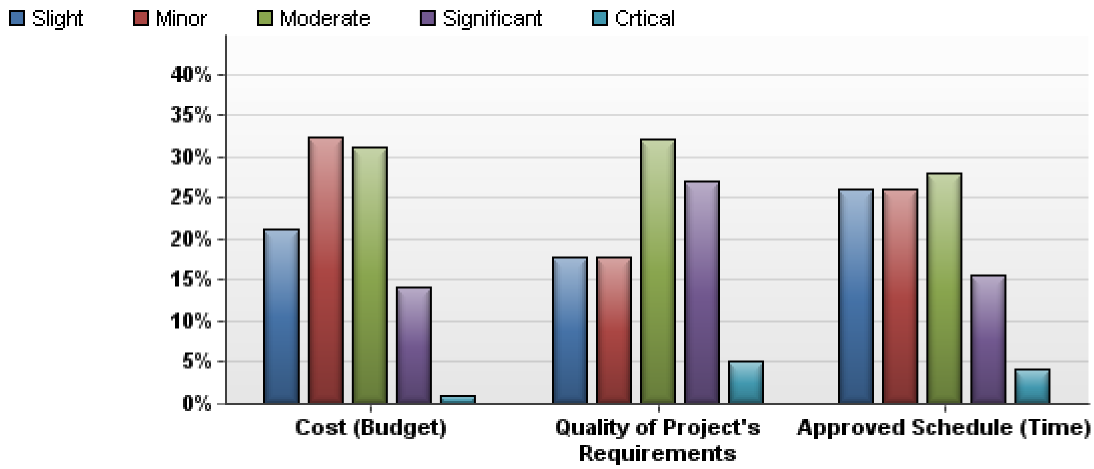
#	Answer		Response	%
1	Yes		135	87%
2	No		21	13%
	Total		156	100%

10. Section 3: The following questions address the use of GIS and the level of success of the project.Part 1: project success 10- Did your firm utilize GIS during any phase of this recently completed project? If "No" please move to the last question of the survey.



#	Answer		Response	%
1	Yes		93	60%
2	No		63	40%
	Total		156	100%

11. In your opinion, what was the impact of using the GIS on your project?



#	Question	Slight	Minor	Moderate	Significant	Crtical	Total Responses	Mean
1	Cost (Budget)	21	32	31	14	1	99	2.41
2	Quality of Project's Requirements	17	17	31	26	5	96	2.84
3	Approved Schedule (Time)	25	25	27	15	4	96	2.46

12. Sections 3: Part 2: Please rate the following research questions?12- What degree of familiarity (knowledge) do you personally have with the use of Geographic Information System (GIS) for any purpose?

#	Answer		Response	%
1	None		11	9%
2	Fair		43	35%
3	Good		34	28%
4	Very Good		17	14%
5	Excellent		18	15%
	Total		123	100%

13. What degree of familiarity (knowledge) do you have with the use of Geographic Information System (GIS) (functions, tools, or applications) for managing construction projects?

#	Answer		Response	%
1	None		35	28.46%
2	Fair		43	34.96%
3	Good		27	21.95%
4	Very Good		8	6.50%
5	Excellent		10	8.13%
	Total		123	100.00%

14. How often did your firm/organization use the following GIS applications and functions to manage your project?

#	Question	Never	Rarely	Sometimes	Most of the Time	Always	Total Responses	Mean
1	2D and 3D visualization of project1	25	17	42	23	12	119	2.83
2	Simulation of the construction process2	55	38	17	6	2	118	1.83
3	Route / Site selection analysis3	27	21	37	23	12	120	2.77
4	Terrain Modeling using digital elevation model (DEMs) and Triangular Irregular Networks (TINs)4	34	13	39	20	13	119	2.71
5	Terrain Analysis (e.g., slope, aspect, profile, cut and fill analysis,interpolation etc.)5	37	14	37	16	13	117	2.61
6	Asset Management6	37	25	29	19	8	118	2.46
7	Estimating Project Costs7	46	27	27	14	4	118	2.18
8	Monitoring Systems8	52	32	21	7	5	117	1.98
9	Organizing Maps and Surveys9	25	11	26	37	21	120	3.15
10	Traffic Management10	52	19	26	16	4	117	2.15
11	Geocoding11	40	18	32	14	9	113	2.42
12	Other	4	0	0	4	2	10	3.00
13	Other	2	0	2	1	3	8	3.38

Other	Other
Generating figures for reports	Project scoping
Reference to As-Builts	Public Notifications
Pole Location	Pull Up Tension
locate properties with FEMA data	
Equipment Control	
review of third party designs	

15. Please comment on how GIS helps improve your organization's performance as to contractor interface, equipment utilization, operational performance, management process, etc.

Text Response
GIS has been most useful in structural health monitoring of bridges and asset management programming for maintenance activities.
Not an integral part at this time. We are working to further integrate GIS into our processes
We use aerial images on a daily basis to scout jobsites for bidding purposes. We also plan job execution on gathering data from aerial images. We also produce our own cut to fill maps for civil projects. We have topo maps made to accurately estimate dirt quantities.
Early stage development uses GIS data to examine existing structure, utilities, parcels and land ownership to locate a desirable site. This GIS data on existing as-builts allows the planner/engineer to quickly gather information pertaining to design based on what is currently in the field. Although GIS is not accurate enough to directly design from, it is of great benefit to quickly establish a general overview of existing conditions, a rough dtm for surface analysis and a source of compiling all other relative information so it6 can be easily and efficiently accessed.
GIS HELPS OUR DEPARTMENT BY PROVIDING MAPS FOR ANALYSIS/DESIGN, AS WELL AS INTEGRATING OUR DATA INTO A 3RD PARTY SOFTWARE FOR ASSET MANAGEMENT AND PRODUCING WORK ORDERS (CITIWORKS).
We are a detailed design firm that uses online GIS information to help develop a project, then a more detail survey is required to complete the design.
Large Spread Projects mostly from Government come in short period for study. GIS helps speed up this process and add value to the service we provide. Then take forward for execution with almost no loss of study done during initial stage. Contractor is much more confident with valid visible information available during his selection. The extent of efforts involved is much more clear and hence help in proper utilization of resources.
Used for spatial information and better visualization of construction areas that are densely populated.
Have not used yet.

All of our earthwork takeoff are implemented into the field operations along with 2d & 3d. Earthwork quantities our arrived at to the shortest distance along with confirmed dirt management for both onsite and offsite locations.
In my view GIS should play a larger role in these projects however the Project Engineers are responsible for identifying and assigning roles. On many large projects the senior engineers have little or no familiarity with GIS. Therefore they do not incorporate GIS into the project. I believe this reveals an automatic bias in the survey which will affect the accuracy of your results.
I think it empowers your employees, you spent the money on the equipment, the time to train them and they have the whole job lay out in front of them. Not just this is what I need you to do today, but here is what we are trying to build. I have noticed many operators leading without being pushed and wanting to do a good job in the long run, not just there to collect a pay check. So it falls back to happy employee want do a better job type of thing. So the GIS system is the tool they are given that make them want to get a job done on time and of better quality.
We use Modeling based on "Real" topo data on all projects having more than 10,000 CY of excavation and grading. We cannot trust GIS data for this application in our area. Our data must be within +/- 1/10'. GIS has not proven to be accurate enough to use for the machine control and quantity estimating.
None used
Monitoring progress, asset management
GIS many times adds to the helpful information in the management process. We can also inventory critical elements and determine if we need to survey verify accuracy of existing elements prior or during construction. We don't always rely on GIS, but we use software that allows it as supplemental information.
Seems to provide the most benefit during planning and scheduling of the project work tasks
Production and covering for inexperienced operators.
GIS helps us monitor the traffic impacts of adjacent development projects. We also use it as a tool to communicate to the public about upcoming closures
Line and grade, equipment grade control, and quantity computation are invaluable going to project completion.
Saves time, more accurate, less errors, facilitates archiving project details
One use is to link post construction review information (lessons learned) to geographic location. We also use GIS to link geographic location to archived plans.
Our agency uses GIS to manage the inventory of highway assets, for planning and budgeting of highway maintenance, to display highway construction and maintenance locations to the public on GIS maps, to survey rockfall sites (lidar), for 2D and 3D visualization of high profile projects, for flood mapping, terrain modeling and analysis, tracking mobile assets, and reporting highway maintenance activities. These

technologies improve overall efficiency of our workforce, provide simple and effective means of communication of information to the traveling public, and allow for sophisticated analysis of data quicker and more accurately.
GIS has helped our organization become more efficient in a number of ways.
We do not use GIS
We have developed a system we call UPLAN which has been very helpful and are gathering LIDAR Data to enhance the information that we work with.
We use it now to the point where we do not like to work without it. It has improved efficiency with better personal use and time savings
We haven't used it much but can see how you can benefit from it
GIS Data used in bridge placement.
GIS data has made it easier to track existing areas of concern during construction, particularly existing utilities. It is critical when working on projects such as landfills where side slopes and incremental fill amounts must be reported for permitting.
When developing RUS plans and specifications for overhead (and underground) medium and high voltage lines, the exactness of our plans increases to a great degree. It also allows us to perform the work at less expense since we do not involve a surveyor. This use of GIS is maybe a little away from what you are performing the survey for but that is how we use it. Give us a call at 734/222-9951 if you want to see an example of how it is utilized.
I work primarily on highway and bridge projects for the Michigan Department of Transportation and other municipalities. I have not worked on any construction projects yet where GIS applications were used extensively; however, I do expect that GIS will be used more on construction projects in the near future. My primary use of GIS up to now has been in asset management and geospatial data such as property boundaries.
GIS allows us to visualize actual location of our work and provides quality control feedback that data is accurate with respect to surrounding features.
Currently, our organization primarily uses GIS to establish the location and condition of its assets. This includes facilities and the highway network. Construction work is mainly handled by Contractors and is not a focus of our GIS efforts at this time.
GIS is a great tool to help the public understand the scope and impacts of a project.
We use GIS to analyze airspace during construction and to collect as-built data,
I do not see a current benefit relative to the construction projects we are doing. N/A
My agency does not use GIS. Our Civil Engineering and Surveying consultants use GIS with superior results and significant savings to the agency.
GIS helps improve my organization's performance by clearly documenting our assets located throughout our service territory.
Allowed confirmation of locations within the FEMA map system
Location of underground utilities prevents early change orders caused by unforeseen

conditions, 3D modeling adds a dimension to scheduling and improves estimating process.
I need to learn more about GIS before I can comment
I use Google Maps on every project - to verify items missed by surveyors, look at signs, buildings, etc. To check approximate elevations and other things. I also make use of each counties Auditors' GIS systems to look up info on projects. Recently in Ohio, the TIMS system by ODOT gives traffic counts, bridge data, etc. that is very helpful.
We do not use GIS to support contractor interface. We only use GIS for planning and design.
Primarily in the location of existing utilities and property lines, generally obtained from local utility agencies and pva offices.
It provided visualization for non-technical stakeholders. It assisted in conflict identification by speeding up that process to a degree. Unfortunately, the data in the data base was less than accurate for engineering concerns. There appears to be a conflict between preparing documents for a pleasing reading and assisting the non-technical users and the accuracy required by design and construction reality. Example. Imagine the intersection of two pipelines, in a cross pattern. Each leg of the cross has a valve for isolation purposes. If you locate these valves accurately in the GIS. The image generated on the document shows an illegible blob. If you space them away from the intersection, the location is inaccurate.
GIS information provides me with a great tool to ensure project locations for geotechnical drillers. On site coordinates obtained and given to me by drillers verify site locations and provide USGS map locations, elevations, and aerial photographs. Being 76 years of age, I seldom ever have to go out to sites. GIS saves me a lot of time and provides me with great tools that were not efficiently available 10 to 20 years ago.
Our experience is that GIS stands for "General" Information System, and can be handy in the preliminary scoping and gathering of unreliable, but basic characteristics of a site/corridor. We engineer solutions that rely on accuracy and precision that the GIS applications we have seen cannot offer in the design or delivery of our projects. Unless, of course, one considers a product like Land Desktop a "GIS" tool these days. We don't, but the line seems to be increasingly thin between say (AutoCAD and ArcGIS). Engineers are CAD guys- Planners and Architects are GIS guys!
it helps a lot in planning but is not accurate enough for design, at least in our area
It helps our firm plan more efficient preliminary layouts, survey needs, and potential regulatory or geological obstacles. We also utilize GIS to track past project locations to quickly retrieve information previously used or collected.
Significantly improved speed or stakeout and final grading while significantly reducing costs
We use GIS for Asset Management, Tracking of permit activity, project location mapping and impact review, route planning for public facilities (streets, sidewalks, paths, transit,

utilities)
GIS is very useful in the early planning stages of a project, however during detailed design and construction I see that it becomes less useful. In our company, when doing detailed design, we use a different software from GIS to prepare the construction document. While we do use some GIS data for plan creation, oftentimes the data received from the local municipality or county is not as accurate as the actual survey data received from the field. During our construction observation projects, I have seen GIS utilized on larger grading projects, but not that much on smaller project.
Do not use GIS as a construction tool. Mostly for planning and environmental documentation.
allows least cost routes to be selected
beginning to utilize GIS more as we gain understanding
not being used at this time
Not applicable
GIS is used more in the planning and initial budgeting stages of a project.
Used to collect data and get information out to the public, this is mainly internal to the agency and does not involve contractor interaction.
Increased and more widespread usage of available applications would be an asset if incorporated into the process
We don't generally use GIS outside of the initial scoping/planning stages of a project, and then on the completion end for asset management of built structures (roads, water and waste water)
We use GIS and GPS in our section to mainly manage our assets along the highway system since our section deals with operations and not construction. We use GIS and GPS extensively to geocode all of our assets. This has led to the establishment of a Feature Inventory System that contains all of our highway assets.
We use GIS to manage assets and help with Capital Improvement Project forecasting, field Utility verification, exhibiting various maps, QA/QC final project deliverables.
Mainly governmental interface requirements.

Statistic	Value
Total Responses	67