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Original Research Article

THE RELATIONSHIP BETWEEN THE USE OF GIS AND CONSTRUCTION PROJECT SUCCESS

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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.

No significant relationship between GIS function use and construction project success criteria (time and cost) was found. The third success criterion (customer's 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.

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

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(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.

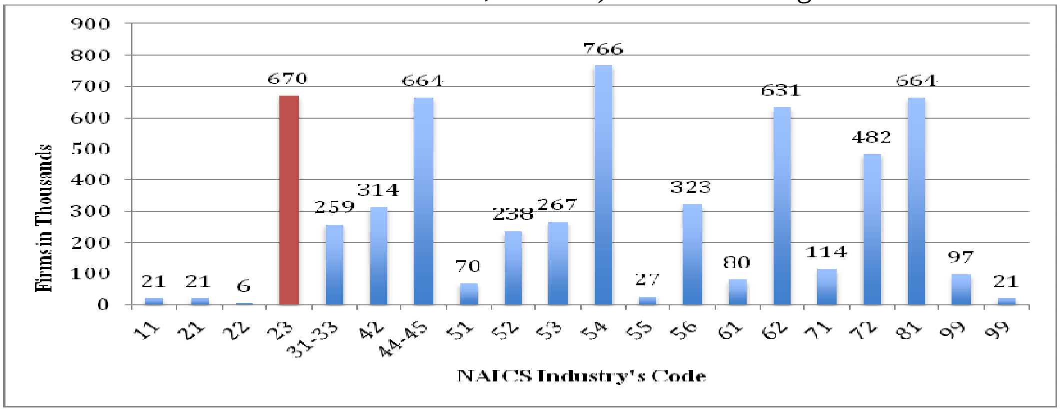

Figure 1. NAICS Industry number of firms (**Source: U.S. Census Bureau, 2010)**

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

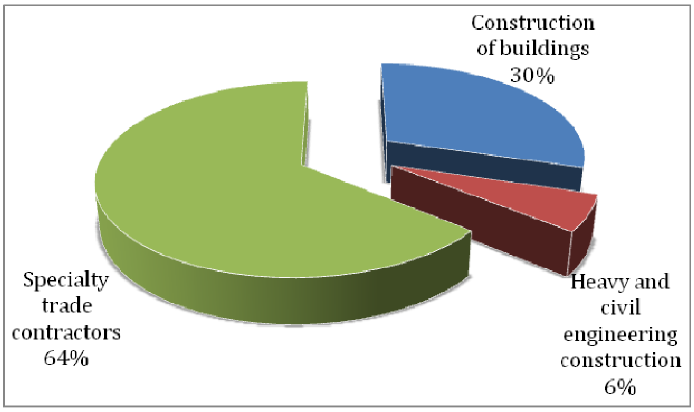

Figure 2. Subsectors of construction industry sector (Source: U.S. Census Bureau, 2010)

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

Construction Project Management

Many researchers have studied the concept of construction management. Ritz (1993) stated, "basic construction project management philosophy is simply in three words: *plan*, *organize*, and *control*" (p. 20). In another definition, Dykstra (2011) said that construction management is "all the processes involved in organizing, monitoring, and controlling a construction project" (p. 81).

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

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 3).

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).

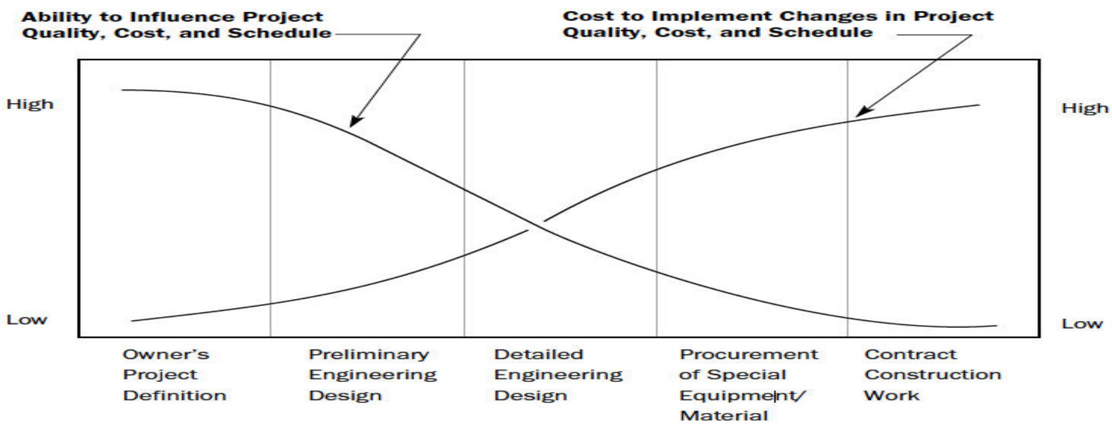

Figure 3. Clear project definition in the early phases of a project, Source: (Oberlender, 1993, p. 21).

GIS Uses in Construction Projects

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 found that using GIS to calculate BOQ for construction projects can deliver an accuracy percentage of 98.85 of BOQ on site surveying.

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).

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.

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.

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.

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.

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 organizations 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.

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 by using appropriate tools to test the Hypothesis . A survey instrument that gathered respondents' perceptions was the primary data-gathering tool. 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

Data Collection

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%.

Data Analysis

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 independentsamples 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 2.

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 2 : *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
	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
	Mann-Whitney U-test
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).	
$H4_{1-11}$ (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.	

Results

A statistical analysis was used to determine the psychometric properties of the survey, generate relevant descriptive statistics, and test the hypotheses

Project success. A descriptive analysis was done for these 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 3).

Table 2 : *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%

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. 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.

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

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 4.

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 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.

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.

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), 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.

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 null hypothesis four has 11 sub-null-hypotheses as is summarized in Table 4. 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. For the Terrain Modeling function, 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, 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 4 **:** *Mann-Whitney U-test of Null Hypotheses 4_{1-11}*

	Null Hypothesis	Sig.	Decision
4_1	The distribution of 2D and 3D visualization of project is the same across categories of organization's focusand ,Roads ,Streets ,Highway/ public sidewalks and otherconstruction 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 focusand ,Roads ,reetsSt ,Highway/ public sidewalks and otherconstruction 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 focusublic and p ,Roads ,Streets ,Highway/ sidewalks and otherconstruction 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 focusand ,Roads ,Streets ,Highway/ public sidewalks and otherconstruction 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 focusand public ,Roads ,Streets ,Highway/ 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/ and public sidewalks and other ,Roads ,Streets 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 focusand public ,oadsR ,Streets ,Highway/ sidewalks and otherconstruction organization's focuses.	.055	Retain the null hypothesis.
4$_8$	The distribution of Monitoring Systems is the same across categories of organization's focusand public ,Roads ,Streets ,Highway/ .ther organization's focusessidewalks and o	.309	Retain the null hypothesis.
4$_9$	The distribution of Organizing Maps and Surveys is the same across categories of organization's focusand public ,Roads ,Streets ,Highway/ sidewalks and otherconstruction organization's focuses.	.202	Retain the null hypothesis.
4$_{10}$	The distribution of Traffic Management is the same across categories of organization's focusand public ,Roads ,Streets ,Highway/ sidewalks and otherconstruction organization's focuses.	.043	Reject the null hypothesis.
4$_{11}$	The distribution of Geocoding is the same across categories of organization's focus ,Highway/ and public sidewalks and other ,Roads ,Streets construction organization's focuses.	.206	Retain the null hypothesis.

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

Discussion and Recommendations

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 results, 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 (2002), 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 results (Table 3). 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. (2012), GIS traffic management can help transportation companies evaluate noise impacts from highway traffic and find a solution.

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 (1993): " 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

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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