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## **Employee Perspective on the Impact of using GIS on Highway and Transportation Construction Project Success**

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### **Abstract**

This survey research effort investigated the Geographic Information System (GIS) functions in highway and transportation construction-project success based on employee perspective. The population included engineers and IT professionals in the United States. The sample included members of various organizations who are classified under the construction industry.

The high percentage of respondents who reported little knowledge about how to use the GIS functions may cause erroneous conclusions about the use of the GIS. The lack of knowledge was the primary reason that people in the field do not use the GIS appropriately. Moreover, it seems that executives have more skills or knowledge about the 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 the GIS on their construction projects. Recommendations included the following: (a) engineers and managers should consider using GIS functions for highways, streets, roads, or public sidewalk projects; and (b) special attention should be given to ensuring that appropriate GIS training is provided for all levels in an organization.

**Keywords:** GIS; Construction Project Success; Highway, street, and bridge project

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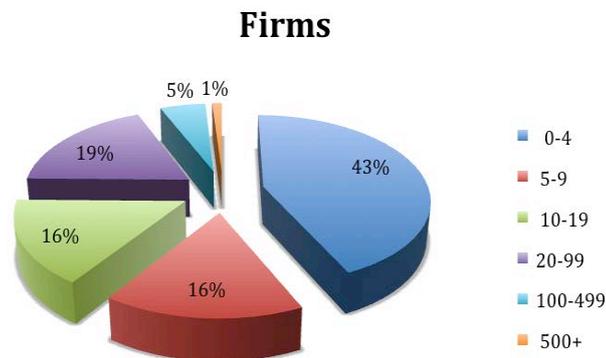
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## 1. Introduction

The construction industry is one of the most important industries in the United States [1]. According to the U.S. Bureau of Labor Statistics 2010-2011 Occupational Handbook, employee numbers in the construction industry will increase 19% between 2008 and 2018. More than 670,000 firms, 11.7% of the total number of U.S. industrial firms, are in the construction industry. According to [2], 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

The construction industry sector is divided into three subsectors: construction of buildings, heavy and civil engineering construction, and specialty trade contractors. In this research, the Highway, Street, and Bridge Construction group, which is under the heavy and civil engineering construction subsectors, was studied.

Approximately 99% 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 1. According to [2], the Highway, Street, and Bridge group includes “streets, roads, airport runways, public sidewalks, or bridges.” As [3] 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 1.** Employment in Highway, Street, and Bridge construction based on enterprise employment size.

Source: U.S. Census Bureau, 2010

The primary focus of this study was an investigation into the impact of using the Geographic Information System (GIS) on the success of construction projects from the perspective of employees in the Highway, Street, and Bridge group.

For this study, 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.

### ***1.1. Project Success***

Regarding the success of the construction industry, the authors in [4:1] reported that “about two-thirds of all projects still fail.” According to this report, only “32% of all projects succeeded, that is, delivered on time, on budget, and with required features and functions” [4:1]. Moreover, one of the authors in [4] 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” [4:1]. Project success is the value for which everyone is looking and reflects the success of the business [5].

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 project management success. 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 [6].

### ***1.2. Construction Project Management Success***

A 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” [7:7]. According to [7], construction project management can be explained in three words: plan, organize, and control. 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” [7:3].

The authors in [8] 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 [9], 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 [10] 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, these authors found that “the project studied was delivered to time, within budget and to the specified quality standards [10:284],” which would be deemed successful when compared to other projects using traditional project performance criteria.

Chan and Chan [11] 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 (Fig. 2). 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” [11:218]. Moreover, other measures, such as safety, functionality, and satisfaction, are important in the industry.



**Figure 2.** KPIs for construction projects. Adapted from: [11]

In an attempt to determine the factors in construction project success, Phua and Rowlinson [12] 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 [13] 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” [13:145].

Li [13] 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” [13:147].

In conclusion, based on a literature review 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).

### **1.3. GIS technology**

According to Chrisman [14], “the term ‘GIS’ has come to symbolize a technology, an industry, a way of doing work” [14:177]. Pine [15] 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” [15: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) [15:A-2].

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 the authors in [16] stated, “The key players in the GIS software market today are Autodesk, Bentley, ESRI Inc. (ArcGIS), GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph” [16:4]. Some of this software is used for business analysis and planning, and some is for management.

### **1.4. GIS uses in construction projects**

Information Systems (IS), including GIS, have gained importance because of the increase in complexity and the globalization of many projects. IS help in:

- Providing an IT backbone,
- Exchange of information and data,
- Managing vast amounts of information, and
- Proving the optimization techniques for the global networks [6].

According to [6], top management support is the most important factor in the success of worldwide IS implementation: “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” [6:57]. One of these systems is called GIS. It has the ability to store and exchange spatial and descriptive data.

The authors in [17] 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” [17:145].

Poku and Arditi [18] 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 authors 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 authors 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” [18:357]. There are three parts in this software:

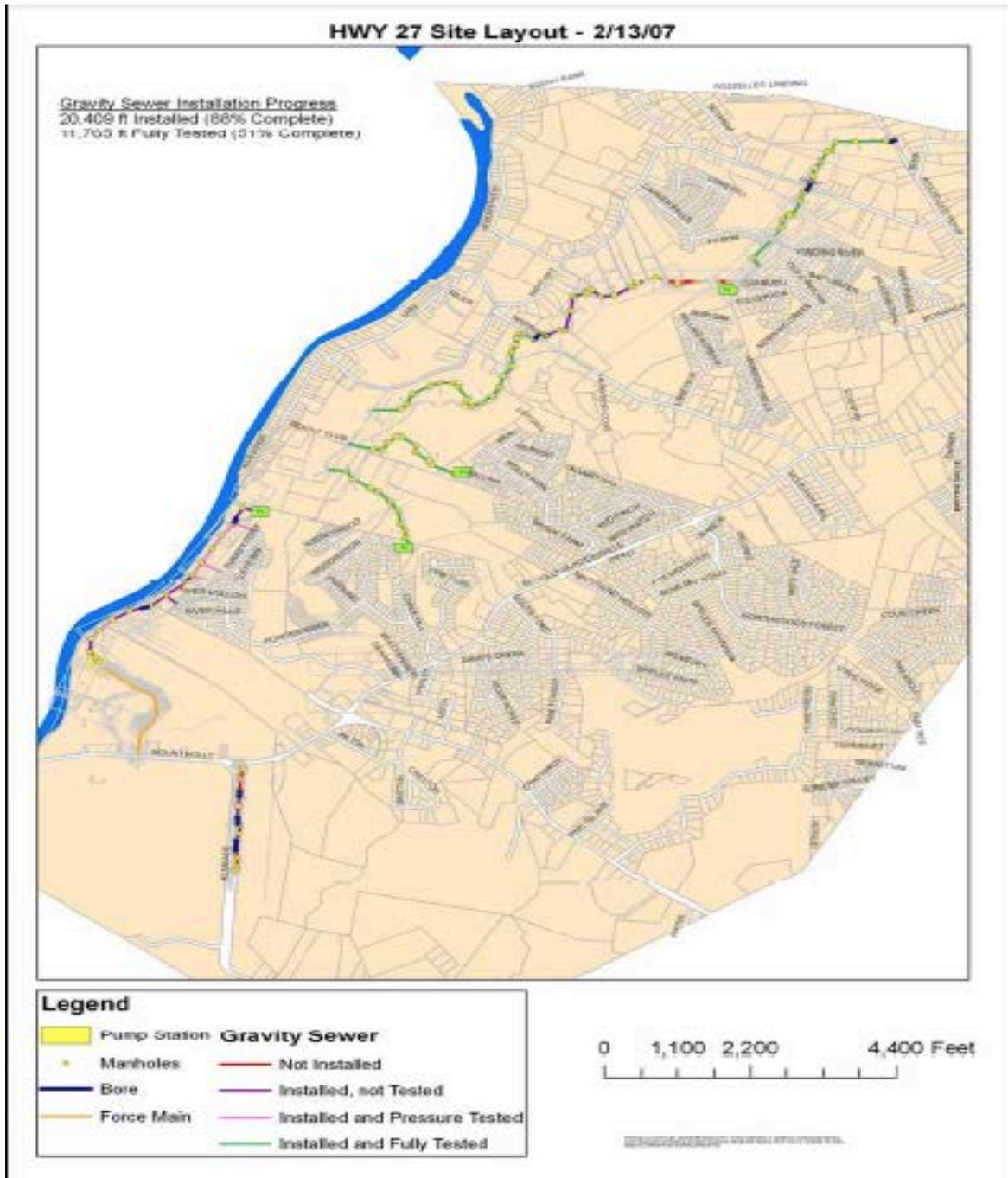
- AutoCAD
- Primavera Project Planner (P3)
- GIS (ArcViewGIS)

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 [18], Cheng and Chen [19] discussed how a 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 [20] 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” [20:2]. The authors [20] 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 [20:2].

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, [20] came up with using GIS to track construction activities (Fig. 3). As they 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” [20:9].



**Figure 3.** Typical update handout. Source: [http://www.ncsafewater.org/Pics/Training/AnnualConference/AC08TechnicalPapers/SpecialTopics/AC08ST\\_Mon0445\\_Dierkes.pdf](http://www.ncsafewater.org/Pics/Training/AnnualConference/AC08TechnicalPapers/SpecialTopics/AC08ST_Mon0445_Dierkes.pdf)

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 [21] 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.

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 [21]'s study were:

- Generation of digital dataset,
- Generation of report, tables, and maps for the study area, and
- Report the areas with appropriate scale maps and assessment of deforestation factors report on causative [21:27].

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, [21] found that “changes such as the reduced vigor of forest vegetation, urbanization, mining, etc. are noticed in the study area” [21:31].

Construction project safety may affect economics, cost, and social life. Good safety practices are an important factor in the construction field. Bansal [22] 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.

### ***1.5. Statement of the problem***

The impact of the utilization of GIS functions on construction project 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 based on employee perspective.

## **2. Research methodology**

For this study, 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 impact of using GIS on construction project success (cost, schedule, and quality), based on employee perspective were investigated. A survey instrument that gathered respondents' perceptions was the primary data-gathering tool.

### ***2.1. 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 subsector. 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).

## **2.2. Instrument design**

The survey questionnaire, developed through the Qualtrics website ([www.qualtrics.com](http://www.qualtrics.com)), was used to collect data on GIS functions and PSC. 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 was to determine employee perspective on the three construction project success criteria. The third section in the survey requested respondents to comment about their experiences with GIS.

## **2.3. Data Collection**

Data were collected through an electronic survey using Qualtrics. An online questionnaire was distributed via email to the targeted individuals:

- A list of people and companies selected by use of the InsideView software.
- Selected construction professionals (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).

## **3. Results**

### **3.1. Organization Characteristics of the Sample**

The respondents' job position levels (Table 1) 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 mean that these results represent high-level perspectives on the use of GIS in construction organizations.

**Table 1:** Demographic Characteristics of the Sample for Level of Position

Classification	Responses	
	Number	Percent
<b>Position Level</b>		
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%
<b>Total</b>	<b>156</b>	<b>100.00%</b>

Regarding job function (Table 2), 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.

**Table 2:** Demographic Characteristics of the Job Function

Classification	Responses	
	Number	Percent
<b>Job function (Multiple answers)</b>		
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 [inspection, surveying, feasibility studies, etc.]	47	16.80%
Other	18	6.40%
<b>Total</b>	<b>280</b>	<b>100.00%</b>

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 3). 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%).

**Table 3:** Demographic Characteristics of the Organization’s Work Focus

Classification	Responses Number	Percent
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%
<b>Total</b>	<b>343</b>	<b>100.00%</b>

The last demographic question dealt with the knowledge respondents’ organizations had about GIS (Table 4). The survey results showed that more than 67.5% had good, very good, or excellent knowledge about GIS in their organizations.

**Table 4:** Demographic Characteristics of the Sample Organization's Knowledge of GIS

Classification	Responses Number	Percent
Organization’s knowledge of GIS		
None	13	8.30%
Fair	38	24.40%
Good	45	28.80%
Very Good	36	23.10%
Excellent	24	15.40%
<b>Total</b>	<b>156</b>	<b>100.00%</b>

**3.2. Descriptive analysis**

Section two of the survey asked the respondents’ opinion about the impact of using the GIS on the project (Table 5). 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).

**Table 5:** Respondents’ Opinions on Level of Impact in Using GIS

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

**3.3. Construction Industry User Experiences with GIS**

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.

**3.4. 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 [23]. 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.

**3.5. 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.

**3.6. 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.

### **3.7. 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 the 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.

### **3.8. 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 employees 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”

### **3.9. 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.

## **4. Conclusion**

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 [24] stated, “GIS is rapidly increasing in its use and importance in many fields and disciplines” [24:8]. Although trend data on the use of GIS in the construction industry were not readily available, it appears 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.

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. 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."

#### **4.1. 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. The authors in [17] 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.

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.

#### **4.2. 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.

- 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 in

future research efforts.

- Since the focus of this study was only on the subsector 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, and so forth, to get a better handle on the special GIS needs or potential applications of this group.
- The sample was drawn from organizations within the Highway, Street, & 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.
- 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.

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