AN EXPLORATORY STUDY OF AWARENESS AND PERCEIVED RELEVANCE OF GIS AMONG GENERAL CONTRACTORS IN THE USA

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SUMMARY: *This document analyzes the awareness and perceived relevance of geographic information systems and related technologies by construction industry general contractors via an exploratory survey of individuals in the field. A quantitative survey was developed based on an extensive literature review and meta-analysis. The survey was then administered at the Association of General Contractors (AGC) 2018 convention in New Orleans, LA. Eighty-eight construction industry related individuals participated. When asked if they were familiar with GIS, a tool for organizing data so it can be displayed and analyzed based on its geospatial characteristics, 32.95% (n=29) said they were not, 57.95% (n=51) said they were, and 9.09% (n=8) did not respond to the question. The researchers further assessed respondents who stated yes to familiarity with GIS or left it blank in depth. Within this group, the greatest perceived relevance was in property and site survey maps (4.37 average), digital mapping (4.22 average), engineering surveys (3.95 average), and topographic or planimetric mapping (3.95 average). This article proposes consideration of broader use of GIS for geovisualization in the construction industry as in many ways it is an untapped resource. GIS use could play a more important role in design and planning, site location selection, materials management, market analysis, monitoring, logistics, and decision making.*

KEYWORDS: *Geographic Information Systems, Building Information Modeling, Construction Management, GIS, BIM*

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1. INTRODUCTION

Maps are often used in construction to convey information because some information is more easily understood graphically (Seo & Kang, 2006; Kumar & Bansal, 2016) This includes surveying, mapping, and the use of Geographic Information Systems (GIS). With construction surveying, for example, the goal is to mark the location of structures or proposed structures with reference points. This is accomplished with precise measurement, defined boundaries, and documented, often visual, depictions. Tools and techniques that support analysis of geospatial data, known as geovisualization, help in analysis, pattern identification, and approaches to problems. In this realm, GIS is a collection of data that is mapped on to physical locations, giving the data a spatial context. All too often, spatial and temporal components are overlooked or underrepresented in cases where the information could be beneficial. Traditional construction methods, such as construction scheduling which lacks illustration of spatial requirements for construction resources, are still mainstream and comprehensive data-driven spatio-temporal modeling is minimally utilized although it could play a significant role in analysis of real time and dynamic progress as well as in analysis of multiple factors impacting productivity or outcomes (Song et al, 2017). As the Environmental Systems Research Institute (ESRI) (2008) points out, "GIS provides tools for modeling information to support more intelligent, faster decisions; discover and characterize geographic patterns; optimize network and resource allocation; and automate workflows through a visual modeling environment" (p 1). GIS use could play a more important role in design and planning, site location selection, materials management, market analysis, monitoring, logistics, and decision making. The purpose of this analysis is to perform an exploratory meta-analysis and survey that evaluates current awareness and perceived value of GIS in the construction industry. The survey inquiries about various potential GIS use areas based on categories identified in the meta-analysis.

2. LITERATURE REVIEW

2.1 Geographic Information Systems

Geospatial technologies such as GIS combine key data and visual information from multiple sources and integrate them in to intelligent maps (Chen, Peng, Rowlinson, & Huang, 2015). This ability to collect, overlay, and analyze disparate data can reveal patterns, relationships, and trends that might otherwise be overlooked. "Generally, the GIS is defined as the skills, processes, and tools to store, query, modify, and analyze geographic-spatial data and related information to refine pertinent information and to aid in decision making" (Seo & Kang, 2006, p 509). Often, solutions become more apparent through visualization. As a broad field, GIS covers geovisualization-based decision making and geospatial modeling (Song et al, 2017). The technology used in GIS provides tools for acquiring or creating, managing, analyzing, storing, and visualizing data, whether spatial or the accompanying descriptive information, associated with developing and managing infrastructure (Mitka and Pluta, 2015, ESRI, 2008). GIS are commonly used for mapping of property, parcels or utilities. They are also used for platting (planning via mapping) in areas such as right of way planning, land use planning, or road and structure design surveys (reference?). They are additionally used for topographic or planimetric surveys or mapping. This might include environmental areas such as wetlands or mudslide areas.

GIS is a digital form of managing data that has a geographic location component. The data is related not just to the project at hand but to a broader geographic context and may include information from sources such as Light Detection and Ranging (LiDAR) remote sensing, photogrammetry (measurement and determination of exact positions from photographs), surveys, Computer Aided Design (CAD), and standard imagery. GIS work using statistical modeling. Song et al (2017) note, "Spatial or spatio-temporal statistical modeling for the analysis of patterns and exploration of relationships is regarded as the central function of GIS" (p 2). Objects of interest can be identified in relation to the earth by use of spatial assessment coordinates in an adopted reference system, geometric properties, and geographical relationships (Mitka and Pluta, 2015). It is used "for accurate modeling of spatial and temporal patterns, explorations of relationships and potential statistical factors, prediction of future distribution scenarios and statistics-based decision making" (Song et al, 2017, p 12). GIS scanning of the earth via remote sensing satellites and other geospatial data and tools have come into play as a significant potential contributor to improved public services, policy and planning activities, and community development / community participation (Caldwell, 2009).

2.2 GIS for Construction Site Surveying

One might expect GIS to be used by land surveyors since surveying provides the critical link between exact design engineering and precise on-the-ground layout of facilities (Parkinson, 2017). Property and site survey maps include items such as boundary and property line surveys or a site survey of surface and sub-surface features. One example is the American Land Title Association (ALTA) American Congress on Surveying and Mapping (ASCM) Land Title Survey, which is a survey of physical property boundaries used by title ensuring agencies. GIS is also used by professional surveyors for easement exhibits, topographic and planimetric surveys and mapping, construction staking and surveys. Surveys may include engineering surveys used for obtaining locations on or above ground of features that may impact design of improvements; construction surveys used for locating planned features on the ground at locations noted by designer, or laser scanning surveys. Lastly, professional surveyors use GIS and related technologies for platting. Platting is the generation of maps and similar which are used to help ensure compliance with governmental regulations. It includes items such as right-of-way platting, road and structure design survey, or subdivision and condominium platting. Overall, GIS integration into construction surveying enhances data management, project management, quality control, and cost reduction (Parkinson, 2017).

2.3 GIS for Design and Planning

GIS has many areas of use within design and planning, regardless of the type or site of the construction project. This includes site selection, climate adaptation, construction safety planning, construction space planning, design, pre-construction operations, and energy design to name a few (Song et al, 2017, Seo and Kang, 2006). As ESRI (2008) describes, GIS has "specific functions to collect precise site data used for predesign analysis; design; and calculations including field survey, topography, soils, subsurface geology, traffic, LiDAR, photogrammetry, imaging, sensitive environmental areas, wetlands, hydrology, and other site specific design-grade data" (p 2). Through its use, information can be presented in a visual manner which can be useful in all types of design and planning including new civil works. "It allows creation of new infrastructure data for new civil works including grading, contouring, specifications, cross sections, design calculations, mass haul plans, environmental mitigation plans, and equipment staging. This includes integration with traditional design tools such as CAD" (ESRI, 2008, p 2). An example of such use is demonstrated in a case study of GIS-based visualization of integrated highway maintenance and construction planning in Fort Worth, Texas. GIS tools integrate data from many disparate sources and projects in to one visual interface, helping identification of opportunities or challenges far more straight-forward at a district level (France-Mensah, O'Brien, Khwaja, & Bussell, 2017).

The ability to assist in logical errors or inconsistencies could be of monumental value in relation to cost, time, effectiveness, and reputation. Using a GIS-based visual simulation system can offer "powerful planning, visualizing, and querying capabilities that facilitate the detection of logic errors in simulation models" (Zhong et al, 2004, p 742). As one example, "an optimum equipment set scheme [can be] determined by simulating a variety of scenarios taking place under different construction conditions" (Zhong et al, 2004, p. 742).

When it comes to site location selection, GIS can help with spatial analysis and design, natural environment analysis, and engineering surveys. For environmental areas it can help in assessment of issues such as steep slopes, wetlands, flood prone areas, riparian corridors, liquefaction, and slide areas (Kumar & Bansal, 2016, ArcGIS, n.d.). Or for water quality and service it could help assess watershed and wetlands data as well as assist in locating contamination (Prasad, Marfai, & Jatmiko, 2017; Dai, Guo, Tan, & Ren, 2016). GIS systems contain "high-level planning functions for site location including environmental impact mitigation, economic analysis, regulatory permitting, alternative siting analysis, routing utilities, what-if scenarios, visualization of concept options, data overlay, modeling, and benefit/cost alternatives analysis" (ESRI, 2008, p 2). For environmental analysis, "It provides analysis to support design including hydrology analysis, volume calculations, soil load analysis, traffic capacity, environmental impact, slope stability, materials consumption, runoff, erosion control, and air emissions" (ESRI, 2008, p 2). Part of the power of GIS systems is the capability to overlay information. "The basemap can include parcel maps, zoning and city designations, environmental protection areas, aerial photos, and topographic and soil maps. Overlays of relevant data on population growth, commercial activity, and traffic flow combine to rapidly paint a meaningful picture of a site's opportunities and constraints" (ESRI, 2008, p 6).

2.4 GIS for Materials Management

GIS can be used to support a wide range of spatial analyses used in logistics of warehousing and transportation or similar. Consider quantity take offs as a case in point. Quantity take offs are a detailed measurement of materials and labor necessary on a specific project. "The spatial data generated for the purpose of visualization in GIS can also be utilized for quantity take offs" (Bansal and Pal, 2008, p 241). GIS can be helpful with cost estimates by helping identify options and solutions regarding materials layout and the like. This can include cost estimation as well as supply chain management and materials tracking. As Irizarry et al (2013) note, "when GIS data is linked with three-dimensional (3D) site models, the whole material circulation path in the site can be vividly simulated" (p 242).

GIS can interact with methods for data acquisition that are already in place (Chen, Peng, Rowlinson, & Huang, 2015). “An automated system that integrates radio frequency identification (RFID) and global positioning system (GPS) technologies with GIS for tracking resources can eliminate labor-intensive data collection and limitation of distance of line of sight” (Irizarry et al, 2013, p 242). Identification and tracking technologies might include manual tracking, barcodes, RFID, or GPS which are then utilized by GIS. An integrated Building Information Modeling (BIM) and GIS system could help in visualizing the supply chain process and visually monitoring material availability and flow.

GIS can help with inventory management. For example, as Irizarry et al (2013) explain, “we can reduce costs due to reduction in inventory costs and aggregate different demands into one pool for storage, or by trade-off between inbound and outbound transportation costs. Movement of materials among different parties is a critical consideration in cost analysis, which is closely related to location, or spatial information of the suppliers. Due to its significant impact on the overall expenditure, cost of transportation is considered as one of the deterministic factors in choosing suppliers” (p 245). In addition, GIS can help improve efficiencies and reduce costs in areas such as transportation of supplies. “In the traditional way of managing the supply chain, the focus may be on the site activities (e.g. reduce costs or duration of site activities), or on the supply chain itself (e.g. reduce logistics costs, lead time and inventory). The main objective of logistic analysis is to minimize the combination of vehicles, hours, or miles required to deliver the product. It is estimated that transportation costs accounts for 10-20% of construction costs” (Irizarry et al, 2013, p 242). GIS can actually be used to evaluate all steps in materials delivery. “To evaluate logistics constraints involved in the material delivery process, GIS is used to map the entire supply chain process, e.g., location of suppliers, transportation, value adding, and nonvalue adding activities. In this sense, the GIS module of the system uses descriptive information (e.g. transportation network) and geographical location of suppliers in order to provide an ideal solution to manage costs of transportation” (Irizarry et al, 2013, p 243)

2.5 GIS for Building Construction

GIS offer situational awareness. “GIS can be used to maintain different types of information regarding the building, such as the site plan, drawings, subsurface details, component specifications, building evacuation plans, safety plans, and landscaping plans” (Ebrahim et al, 2016, p 3829). It offers management and key stakeholders’ visualization of construction progress as well as visualization of construction supply chain management (Song et al, 2017). One component found in literature is the use of GIS as a tie in to scheduling as an alternative or supplement to other methods in use. This can be accomplished by synchronizing spatial and non-spatial data into a single environment so it can be queried and analyzed. The GIS-based system then uses themes or layers to extract and display targeted information, giving it the potential to be not just a visualization tool but a project management tool (Bansal and Pal, 2008). As Bansal and Pal (2008) see it, GIS based methodologies can be used to “represent and integrate spatial and nonspatial information, like drawing, specifications, resources, and construction schedule in a single environment” (p 241). They continue, “nonspatial schedules can only convey what is built ‘when’, whereas the schedule in GIS conveys what is built ‘when and where’” (Bansal and Pal, 2008, p 242). Ebrahim et al (2016) agree, “Planners can visualize 2D drawings and three-dimensional (3D) models using a GIS model that logically links their components with the activities in the schedule to establish the construction sequence” (p 3827). Some companies have customized systems that allow progress monitoring with the use of GIS. These allow for more visual and understanding of critical path items which are driving project schedules (Poku and Arditi, 2006).

Operational level planning and management of buildings emphasizes current and tactical goals which relate to the overall strategic goals of the project. “Operation level planning, as opposed to activity level planning, involves the selection of resources such as equipment, labor, and material to perform construction activities that take into account construction site conditions and other factors that could affect construction activity” (Seo & Kang, 2006, p 508). Relevant types of information might include design, resource, or site level items obtained from sources such as CAD files, estimating references, geological reports, and historic databases.

GIS can play a role in operation level planning such as earthwork and the equipment combination costs and duration therein (Seo & Kang, 2006). Some examples of areas where GIS use could have an impact include fire or other emergency response, disaster scenarios, indoor navigation, heritage protection, facility management, hazard identification and prevention, ecological assessment, and management of property interests (Song et al, 2017). After all, “Spatial selection and display tools allow you to visualize scheduled work, ongoing activities, recurring maintenance problems, and historical information. The topological characteristics of a GIS database can support network tracing and can be used to analyze specific properties or services that may be impacted by such events as stoppages, main breaks, and drainage defects” (ESRI, 2008, p 2). When it comes to building demolition, there is also a role for GIS. It can be used for waste estimation and planning by optimizing transport and distribution processes, environmental assessment, environmental assessment, energy cost estimation, and reuse and recycling planning (Song et al, 2017).

2.6 GIS for Facilities Management

GIS offers the ability to visualize change over time and space to identify patterns and trends. "It provides the mechanics and management for building new infrastructure including takeoffs; machine control; earth movement; intermediate construction, volume and material, and payment calculations; materials tracking; logistics; schedules; and traffic management" (ESRI, 2007, p 2).

All in all, its uses are many as they relate to on site management of facilities. "Geoinformation can be used, for instance, to improve the management of buildings, mobile pedestrian navigation, and emergency services" (Mitka and Pluta, 2015, p 20). In considering emergency services as one example, "Emergency managers use the enterprise GIS database to: identify critical infrastructure and hazards within affected areas; identify medical resources and route patients to nearest facilities; prepare evacuation routes for at-risk populations; provide accurate damage estimates; identify priorities for short-term recovery needs; and assess long-term recovery needs" (ESRI, 2007, p 7).

Monitoring of events and items is a key function of facilities management. GIS is useful for maintenance and renewal of existing buildings (Song et al, 2017) as well as for monitoring for disaster situations, its potential mitigation, and response. This can include evacuation route information, or specific information such as locating chemical spills and contamination sources in hydrography and sewers. It can also be used for monitoring important resources. Continuing with the water source example, GIS can assist with hydrologic (below ground) and hydrographic (above ground) surveys and profiling, watershed studies, groundwater monitoring, or even flood insurance elevation certificates. For that matter, it could even be used for drain management whether local or across larger areas.

2.7 Building Information Modeling and GIS Integration

Building information modeling (BIM) is the use of software to develop three dimensional models that give architecture, engineering, and construction professionals the ability to better plan, design, construct, and manage buildings and infrastructure (Autodesk, 2018; Deng, Cheng, & Anumba, 2016). These models, sometimes also referred to as BIM, are often intelligent and interactive, permitting professionals to use them in decision making throughout the project. Combining the strengths of GIS and BIM permit detailed representations of construction projects, both internal and external, via 3d models (Kang & Hong, 2015). This modeling method and the resulting models can integrate and synchronize data from multiple sources to improve decision making (Chen, Peng, Rowlinson, & Huang, 2015). Applications of BIM-GIS integration for planning and design include numerous aspects including site selection, space planning, climate adaptation, safety planning, building design and preconstruction operations, energy design, and planning of disassembly processes (Song et al, 2017).

The industrial practices of BIM and GIS in construction management fields have been increasing rapidly in recent years and are likely to continue in areas of architecture, engineering, and construction (Song et al, 2017; Kang & Hong, 2015). "BIM has advantages on rich geometric and semantic information through the building life cycle, while GIS is a broad field covering geovisualization-based decision making and geospatial modeling" (Song et al, 2017, p 1). BIM-GIS can be useful whether planning a city or a single building. It can be used in every construction phase, whether planning and design, construction, facilities management, or demolition (Song et al, 2017; Kang & Hong, 2015).

BIM-GIS integration capabilities include data integration, quantitative analysis, application of technologies, and visualization of construction supply chain management for emergency response, urban energy assessment and management, heritage protection, climate adoption, and ecological assessment (Song et al, 2017). Based on the circumstances, these integrations can be schema-based, service-based, ontology-based, process-based, or system-based (Kang & Hong, 2015). Some popular uses of BIM-GIS integration for single buildings include building modeling, indoor navigation, heritage protection, supply chain management, project management, and ecological assessment. At the urban planning level, the integrated systems can be used for urban/city modeling and representation, facilities management, emergency response, traffic planning and analysis, walkability analysis, and energy assessment and management (Song et al, 2017).

The integration of BIM and GIS is actually a demonstration of the continuing improvement and capabilities of construction technologies. "GIS and BIM are the products of digitization of two subdisciplines of surveying and mapping, geodesy and engineering survey" (Song et al, 2017, p 9). Geodesy is the mathematical side of understanding the earths geometric shape, orientation in space, and gravity field over time using technologies such as GPS, remote sensing, and GIS. Topographical maps with terrain characteristics, infrastructure, buildings and land cover are commonly developed and converted to digital formats using multiple data layers. Engineering surveying provides geospatial information for construction projects. In this subdiscipline, engineering drawings using CAD and BIM are common for model visualization, data exchange, and analysis. Integration of these two subdisciplines is now occurring in platforms and systems, theories and methods, and analysis and products, as we move increasingly toward geosciences-based architecture and a melded engineering and construction industry (Song et al, 2017; Miller & Wentz, 2003; Rafiee, Dias, Fruijtier, & Scholten, 2014).

2.8 GIS in Construction Project Management and Predictive Decision Making

As alluded to in the content above, GIS can be used in all levels of construction project management from conception to close out as well as in a vast array of construction types including residential, commercial, and civil. Projects that use GIS run the gamut, from road design such as highway construction projects in hilly terrain (Sharma & Bansal, 2018) to assessing urban sustainability and potential value-add for adoption of green standards such as Leadership in Energy and Environmental Design (Son, Choi, Woods, & Park, 2012). The use of GIS assists in comprehensive in-depth planning, project execution, monitoring and control, performance tracking, and even documentation at project closure (Kaushal & Srivastava, 2009).

GIS add data visualization and assessment capabilities that can play a strong role in project management and decision making whether via digital mapping, logistics, reporting, data combination, or analysis. It is useful for both short-term and long-term planning from informal facilities management to formal legal assessment. It helps with local decision making or broad competitive analysis or even utility coordination. "GIS allows you to integrate satellite images, CAD drawings, and parcel maps to create a visual overview of a project and turn it into easily understood reports. It accepts CAD data without conversion and includes it as a layer in a geodatabase. A GIS geodatabase gives you the ability to handle rich data types and apply sophisticated rules and relationships. In addition to managing large volumes of geographic data, it also implements sophisticated business logic that, for example, builds relationships between data types such as topologies and geometric networks, validates data, and controls access" (ESRI, 2007, p 4). One example can be seen in the study of abandoned residential developments using GIS in the southeastern United States. This study evaluated 153 sites and ultimately determined that unfinished developments in Upstate South Carolina are likely a major source of sediment pollution in streams via visual evidence of site sediment erosion. They were also able to identify misclassified sites as well as offer recommendations for remediation, which include erosion control and ground cover (Werts, Mikhailova, Post, & Sharp, 2013).

Predictive modeling is the use of statistics and related information to predict outcomes. Geoprocessing or manipulation and assessment of data via GIS, is a "framework for modeling and analysis. Some of the common modeling applications include: Composite overlay models for assessing suitability, sensitivity, capacity, and risk; evaluation models for comparing alternatives; growth models for assessing future conditions; and statistical models for assessing trends and generating predictive surfaces" (ESRI, 2008, p 3). GIS systems could be used for environmental threat and damage assessment and monitoring. As an example, the technology has been used to study changes in groundwater quality and soil salinity over time (Abd El-Aziz et al, 2018). GIS, in combination with BIM, is also useful for emergency and disaster simulation, response, and management. In these situations, the problem should be addressed from both a large spatial scale down to detail considerations of specific construction components (Song et al, 2017). GIS systems offer easy access to combined information from a variety of sources. "The base map contains layers such as streets, parcels, districts, and constructed schools. The database of each site can be linked to the GIS model, including the type of soil, the groundwater level, the contour lines and the bearing capacity" (Ebrahim et al, 2016, p 3830).

Market analysis and demographic profiling is another area where GIS can add benefits. "Predictive modeling can also be applied to sales forecasting in areas such as real estate and retail. A common application in market analysis is site selection or retail location analysis… Data from public sources such as traffic patterns, major roadways, and demographics may be added to custom data such as daytime population of business districts, customer preferences and buying patterns" (Brody, 1999, p 11). It can even play a role in city planning including urban renewal projects, urban design, urban crisis response, human activity and land use, urban representation, urban facility management, energy assessment and management, district modeling, traffic analysis (tunnels, noise, etc.), and utility compliance checking (Yongze et al, 2017).

3. METHODOLOGY

The goal of this study was to analyze the awareness and perceived relevance of GIS and related technologies by construction industry general contractors via an exploratory survey of a limited group of individuals working in the field. Our proposition was that individuals in the construction industry would identify GIS technology use in survey mapping and platting but might not consider other areas where it could be beneficial. General contractors, who are responsible for the materials and services necessary for the construction of a project on a day-to-day basis are distinctly relevant. They make a projects design and planning a reality. They are the direct implementors of strategies created by the architects and engineers. Thus, a quantitative survey was developed based on an extensive literature review and meta-analysis. The survey was then administered at the Association of General Contractors (AGC) 2018 convention in New Orleans, LA, USA. Eighty-eight construction industry professionals participated. While general contractors have the focus just mentioned, they are also likely at least somewhat familiar with tools and resources used in construction design and planning in both the short term and the long term.

For the purposes of assessing the awareness and perceived relevance of GIS by construction contractors in the United States, the largest known general contractor conference, the AGC convention held in New Orleans on February 26 to 28, 2018, became our target. Attendees at this conference were mostly those in commercial and civil construction. With cooperation from the AGC association who held the event, we were able to acquire a table adjacent to registration. The authors surveyed the participants while the registration area was open.

A quantitative survey, as seen in Appendix A, was developed based on an extensive literature review and theme identification. Based on our proposition above, we reviewed over sixty academic journal articles that relate to the use of spatial planning, GIS, or BIM in construction. These were then divided in to major subtopic areas including location selection, design and planning, supply chain management, facilities management, threat or damage monitoring, GIS use, and BIM use. We ensured we had multiple articles to review for each subtopic to minimize bias, while also performing a critical appraisal and removing articles that seemed to have limited quality or relation to our topic. Next, we synthesized our findings in the literature. Specifically, major areas where GIS is used were identified and categorized using the reviewed literature. Categories that came to light included the expected construction related areas, but also areas such as materials management, design and planning, choosing of building sites and locations, digital mapping, business decision making, facilities management, risk assessment, and logistics. From the results, measurable Likert scale questions were created, and a beta survey was finalized. The questions on the survey were listed in a fixed order for all respondents and contained clear and concise language for the population being studied. The survey contained a series of content items, written as semi-structured questions which ask about the respondents' opinions, attitudes, knowledge and behavior (Graziano and Raulin, 2003, McMillan and Schumacher, 1997).

The survey was then distributed to four local individuals with both academic and construction contractor experience who analyzed it and provided feedback for improvement. Changes made based on pilot test included breaking out or rephrasing specific questions to encourage more targeted responses or to increase clarity. Two open ended questions were also added to give opportunities to address items the survey may have missed and to communicate the role participants felt integration between GIS and BIM might play.

Next, a letter of consent was written, as seen in Appendix B, which explained the intention of the survey, how it would be administered, and how the information would be dispersed. To encourage participation, it was determined that survey participants would be given a pair of work gloves as a reward for their time and effort. Using the survey and the letter of consent, Human Studies Review Board approval was then obtained.

4. RESULTS

Eighty-eight construction industry related individuals who were at the 2018 Association of General Contractors conference completed the survey. 37.50% (n=33) of respondents were executive level, 18.18% (n=16) were mid-level, 12.5% (n=11) were current college-level students studying in the field, 11.36% (n=10) were in entry level positions, 6.82% (n=6) were in sales, and 13.64% (n=12) had other titles that did not fit into one of the above categories. A list of job titles that fall into the job title categories can be seen in Appendix C. Of those who completed the survey, the greatest number were from Louisiana (n=15) where the convention was held, Arizona (n=6), Texas (n=6), Utah (n=6), Ohio (n=5), Oregon (n=5) and Pennsylvania (n=5). Overall, 33 states are represented in the results.

When participants were asked if they were familiar with GIS, a tool for organizing data so it can be displayed and analyzed based on its geospatial characteristics, 32.95% (n=29) said they were not, 57.95% (n=51) said they were, and 9.09% (n=8) did not respond to the question. Of those who were familiar with GIS, the majority were executive level individuals (n=20), followed by mid-level individuals (n=11). Table 1 shows a summary of the results by job title category.

TABLE 1: Familiarity with GIS by Job Title Categories

	Count				Percent			
Job Title Category	No	Yes	Blank	Total	No	Yes	Blank	Total
Construction Student	5	6	-	11	5.68%	6.82%	0.00%	12.50%
Entry Level	6	4	-	10	6.82%	4.55%	0.00%	11.36%
Executive	7	20	6	33	7.95%	22.73%	6.82%	37.50%
Mid-level	4	11	1	16	4.55%	12.50%	1.14%	18.18%
Other Titles	4	7	1	12	4.55%	7.95%	1.14%	13.64%
Sales	3	3	-	6	3.41%	3.41%	0.00%	6.82%
Grand Total	29	51	8	88	32.95%	57.95%	9.09%	100.00%

As can be seen from the above, 32.95% of the surveyed population, all active in the construction industry, were not familiar with GIS. This number was higher than we anticipated since GIS is used with fair frequency in survey mapping.

For analysis of the remaining aspects of the survey which followed this initial question, the researchers assessed only those respondents who stated yes to familiarity with GIS (n=51) or left it blank (n=8). They excluded further responses of those who said no (n=29) even if the respondent answered additional questions (n=24). The researchers felt that only those familiar with the technology would be able to give informed responses to the questions that followed. This means that feedback from mostly executive and mid-level management was assessed as can be seen in the Table 2.

TABLE 2: Summary of Respondents Familiar with GIS

Job title category	Count	Percent of total
Construction Student	6	10.17%
Entry Level	4	6.78%
Executive	26	44.07%
Mid-level	12	20.34%
Other Titles	8	13.56%
Sales	3	5.08%
Grand Total	59	100.00%

The survey, as can be seen in Appendix B, asked five-point Likert scale questions with five being very important, one being very unimportant, and zero being "not sure" to assess to what degree the participant felt GIS could help in a variety of construction management and planning areas. These areas were divided into the following major categories: construction surveying, materials management, design and planning, choosing building sites and locations, and other areas.

The averages of the responses (n=59) to these questions can be seen in Table 3.

The highest results cross multiple major category areas including construction surveying, choosing building sites or locations, and other areas. This demonstrates that GIS is used in multiple stages of project management. If one considers the lean six sigma project management model which consists of a) defining the problem, b) measuring relevant data, c) analyzing cause and effect relationships between input and outputs, d) improving process inputs, and e) controlling to sustain improvements (American Society for Quality, n.d.), the results show usage for each stage.

As can be seen in Fig. 1, the greatest potential for usefulness was seen in property and site survey maps (4.37 average). We did not find this surprising since this is the area of construction management in which GIS already has a longstanding foothold. Next, was digital mapping (4.22 average). Digital mapping is the process by which a collection of data is compiled and formatted into a virtual image. It is used to provide imagery and street-level map data throughout much of the world. If one has tried Google Maps, then one has used a digital mapping system. Based on its broad potential this indeed has potentially high impact. One example is the collecting, processing, and digital mapping of information related to land use and inaccessible areas for decision making in land management (Ramos and Hernandez, 2018).

TABLE 3: Average Scores for Likert Scale Question Responses

Construction Management and Planning Areas	Average Score
Construction surveying	3.94*
Property/site survey maps	4.37
Parcel/utility mapping	3.81
Platting	3.64
Topographic/planimetric mapping	3.95
Materials management	3.14*
Quantity take-offs	3.26
Cost estimation	3.26
Supply chain/material tracking	2.96
Design and planning	3.70*
Proposals	3.60
Traffic and transportation	3.70
City/urban design and planning	3.77
Choosing building sites/locations	3.69*
Spatial analysis and design	3.63
Natural environment analysis	3.48
Engineering surveys	3.95
Other Areas	3.40*
Digital mapping	4.22
Environmental threat and damage monitoring	3.41
Facilities management	3.00
Market analysis / demographic profiling	2.92
Logistics	3.31
Long term planning and decision making	3.60

* Group averages.

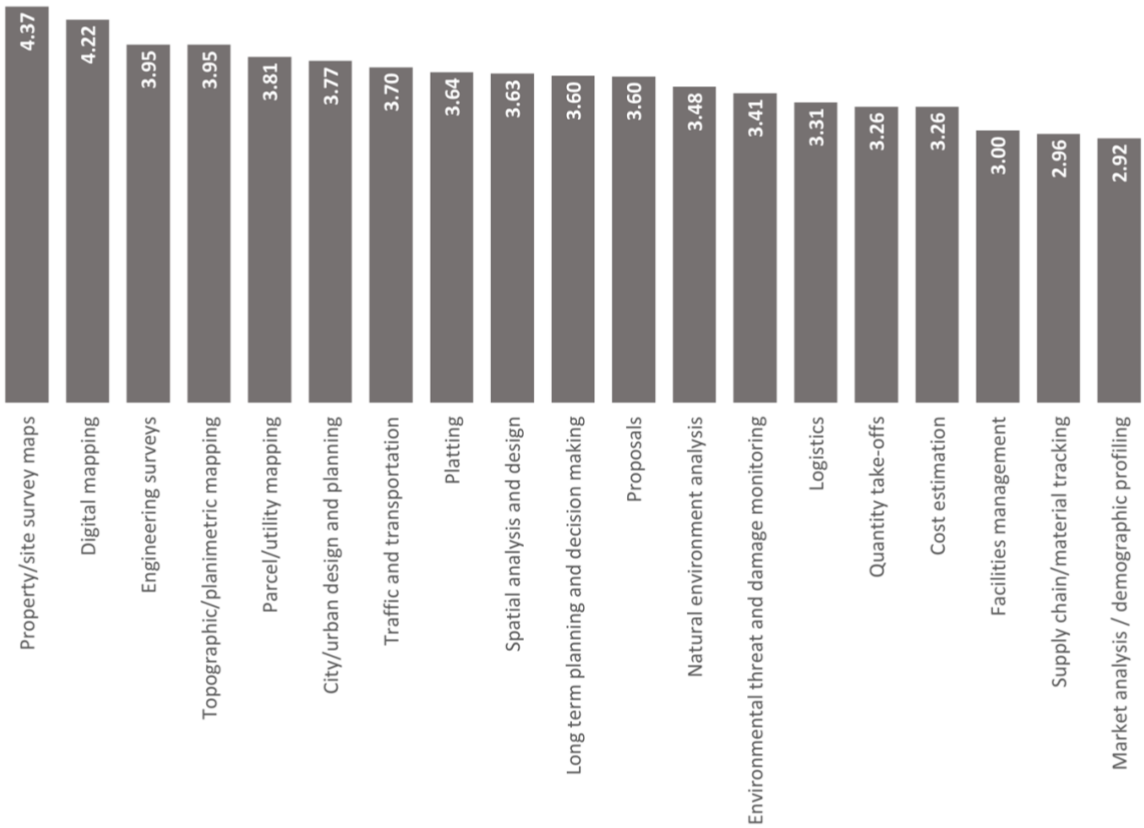

FIG. 1: Average Score for Each Construction Management and Planning Area in Descending Order

This was followed by engineering surveys (3.95 average). These are often used by civil engineers in design and development and frequently include geodetic components. Geodesy deals with accurate measurement and understanding of the earths shape, orientation in space, and gravity field. Engineering surveys often result in topographic maps or digital terrain models. An example is the use of GIS to assist in investigation of pavement distress classifications and maintenance priorities (Obaidat et al, 2018). Topographic or planimetric mapping (3.95 average) followed next. With topographic maps the object is displayed with the configuration of the earth's surface, including both horizontal and vertical positions. A planimetric or line map, on the other hand, presents only the horizontal positions and omits vertical positions that are often represented by contour lines.

Two other items that ranked above 3.75 are parcel and utility mapping (3.81) and city and urban design and planning (3.77). These are both areas in which we anticipate GIS usage growth based on recent literature which demonstrates its use in location selection and planning (Dudko et al, 2018, Lu et al, 2018, Milz et al, 2018). It may even be used it increase public participation in discussions in these areas (Haklay et al, 2018).

In considering what was deemed least important, market analysis and demographic profiling was on the bottom of the list at 2.92. These were followed by supply chain and material tracking at 2.96 and facilities management at 3.00. Regarding overall survey categories, materials management scored lowest at 3.14, for which supply chain and material tracking was a part, followed by other areas in which marketing analysis and demographic profiling as well as facilities management was a part.

4.1 Variance across Employee Types

Based on individual roles within the construction industry, some individuals are likely to identify or prioritize different potential uses of GIS. Indeed, there is some variance in responses based on the type of employee as can be seen in Table 4.

TABLE 4: Average Score Variance Across Employee Types.

Construction Management and Planning Areas	All	Executive	Mid-Level	Entry Level	Students	Sales	Other	Variance (max-min)
Property/site survey maps	4.37	4.04	4.64	4.75	4.50	4.00	4.88	0.71
Parcel/utility mapping	3.81	3.62	3.50	4.50	4.17	4.67	4.00	1.00
Platting	3.64	3.32	3.45	4.50	4.20	3.67	4.13	1.18
Topographic/planimetric	3.95	3.78	3.75	4.75	4.50	3.67	4.00	1.00
Quantity take-offs	3.26	3.44	3.18	2.50	3.67	2.33	3.25	1.17
Cost estimation	3.26	3.40	3.08	2.50	3.67	2.33	3.57	1.17
Supply chain/materials	2.96	2.67	2.92	3.00	3.50	3.33	3.29	0.83
Proposals	3.60	3.56	3.50	4.00	4.00	4.00	3.25	0.50
Traffic and transportation	3.70	3.46	3.50	4.00	4.50	4.00	3.88	1.04
City/urban design/planning	3.77	3.56	3.67	4.50	4.67	4.50	3.29	1.11
Spatial analysis and design	3.63	3.58	3.17	4.25	4.33	3.00	3.88	1.17
Engineering surveys	3.95	3.69	4.00	4.25	4.50	2.33	4.75	0.81
Natural environment analysis	3.48	3.28	3.00	4.25	4.17	3.33	4.00	1.25
Digital mapping	4.22	3.77	4.42	4.50	4.83	4.67	4.71	1.06
Environmental threat	3.41	2.96	3.67	3.75	3.67	5.00	3.57	0.79
Facilities management	3.00	2.96	3.25	2.75	3.33	2.67	2.75	0.58
Market analysis	2.92	2.54	2.92	4.00	3.50	3.33	3.00	1.46
Logistics	3.31	3.04	3.42	3.75	4.00	1.67	4.00	0.96
Long term planning	3.60	3.27	3.67	3.75	4.33	3.00	4.29	1.06

Interestingly, when the results are filtered to only include individuals involved in sales (n=3), environmental threat and damage monitoring tops the list with a perfect 5.00 score. However, for all 59 respondents who are familiar with GIS, environmental threat and damage monitoring only received a 3.41 score. When the results are filtered to only include construction students (n=6), digital mapping tops the list at 4.83 and city and urban design and planning comes in with a high 4.67 score, although for the larger group they received 4.22 and 3.77 respectively. For executive management (n=26), the top items largely match the overall results: property and site survey maps scored 4.04, topographic and planimetric mapping scored 3.78, digital mapping scored 3.77, and engineering surveys scored 3.69.

4.2 Open Ended Question Related to GIS and BIM integration

The final question on the survey asked, “What role do you see GIS playing in Building Information Modeling (BIM)?” A surprising 43 of 59 participants responded. Of those who responded to this question, 11 simply stated it has or will have a large or important role. Five stated they were not sure and four said the question was not applicable to them. Four participants said it has or will have a role in design and planning. One response was unreadable. The other 16 responses were unique and are as follow:

- Basis for site layout
- Business Development and Marketing
- Conceptual pre-con[struction]
- Increasing effectiveness of BIM
- It is both an input for building models and an output for other GIS tools (layout, etc.)
- Link vertical and horizontal building perspectives
- merger with larger inroads via augmented reality enabled by GIS
- Plays a huge part in the foundation
- Point cloud scans
- Somewhat important if they can be linked successfully.
- Surveying / civil is the start to all projects and simplifying this process would be great.
- The main data stream for BIM to pull from to make future decisions
- They are merging. USACE is working on combining SDSFIE with BIM.
- Use in more logistics in BIM making it more "useful"
- Utilities and Horizontal construction for underground construction.
- Very useful. It helped us with relocating a building (tech college) on the project site. We were only bidder to do so. Saved owner money and got us the job.
- You can use the imaging to use as a site for the model, giving a more accurate understandable model.

See Appendix D for a full list of the open-ended responses and their categorization.

5. LIMITATIONS OF THE STUDY

We acknowledge that our survey results reached only a limited number of applicable individuals who attended the Association of General Contractors (AGC) 2018 convention in New Orleans, Louisiana and excluded those who were not in attendance. Therefore, the results cannot be generalized to areas outside the surveyed group. Our primary concern, however, was doing an exploratory study to assess potential areas of further study or inquiry.

One point that became apparent upon review of the responses is that the survey should have done more to delineate the participant’s familiarity with GIS. In some cases, some individuals started out the survey by stating they were not familiar with the technology but then proceeded with assessing its usefulness in various areas of construction. The authors felt this information could not be included in our assessment if the participant was not familiar with the technology in the first place. Equally, there could have been cases when the terminology “are you familiar with” could have been interpreted in various ways. The survey did not specify if the familiarity was in relation to direct active use in the field, awareness of the technology and its capabilities, or ability to formulate and create GIS materials.

Another point that became apparent was the necessity of further research in to the relationships and relevance of GIS to BIM. Some perceive the two technologies as merging in to one. Others see them as inter-twined. Twenty-five percent of those who responded to the question saw the role of GIS in BIM to be large or important.

6. DISCUSSION

Items that received the highest scores already play a role in the construction industry as described above. These include survey maps (4.37), digital mapping (4.22), engineering surveys (3.95), topographic or planimetric mapping (3.95), parcel and utility mapping (3.81), and city and urban planning (3.77). It is likely GIS use in these areas will remain steady or grow. It is also likely, though, that items that ranked in the middle of the overall scoring will begin to play an increasingly relevant role. These include traffic and transportation design and planning (3.70), platting (3.64), spatial analysis and design for building sites and locations (3.63), proposal development (3.60), and long-term planning and decision-making (3.60) as found in Table 4.

There are areas of industry in which other specific functionalities of GIS play a stronger part in other fields, perhaps foreshadowing areas where GIS could play an increasing role in construction industries as well. One such area is market analysis and demographic profiling. While it is not seen as important in construction management at this time based on the survey results, GIS plays an active role in marketing research and geodemographics in areas such as tourism (Chmielarz and Szumski, 2016, Supak et al, 2014) or tax valuation appraisal (O'connor, 2013). Demographic profiling is also a common use for GIS, even if it is seen as less relevant in construction. It is used, for example, to assess areas most in need of healthcare services (Dudko et al, 2018).

GIS has also become a resource for assessing where there are gaps in fulfilling community needs from banks to charter schools. A socio-spatial analysis study was done in Chicago with the use of GIS, for example, in relation to the location of charter schools (LaFleur, 2016). This research argued that there is a ceiling effect where the highest need areas are not being amply serviced. In another study, commercial bank locations were analyzed with the use of GIS in Milwaukee and Buffalo (Hegerty, 2016). In this case, the researchers found inner-city cold spots where bank density and distance were significantly correlated with income and other economic variables. In these studies, recommendations are made to make access to resources more equitable primarily via the use of GIS.

One reason for the results we received, however, may be that we primarily surveyed commercial and civil contractors. It is possible that the residential sector would utilize demographic data more frequently. It should be relevant to contractors, regardless, since it is used by other industries to determine community demographics, building and facility needs, and site locations. Often GIS helps determine when and where buildings are developed, along with other business management decision making.

As with many technologies, different industry and service sectors incorporate their use in a variety of ways. The use of GIS in facilities management, for example, could be more important to business management throughout the life of the building even if it is less relevant to many in the construction industry. A literature review completed by Wong et al (2018) found that digital technologies such GIS and BIM can play an active role in the digitization of facilities management. They note,

> The application of GIS technology in FM is not something new. The early application of GIS in FM focused on managing the external works (e.g. pavements) of various infrastructures (e.g. airports, municipal water and wastewater, electricity supply infrastructures). The geospatial data collected from the GIS helps to support different business processes and information systems for managing facilities inside buildings. For example, facility managers can analyse space use, space availability and space optimisation across a large area, like a university campus. (p 319)

GIS, when used in cooperation with other technologies such as BIM, hold promise for continuing to improve processes, practices, and business decisions in many areas.

Some areas of construction management may be served by either different technology than GIS or by a combination of GIS with other technologies. Supply chain and materials tracking may be more dependent on RFID, for example (Chen, Peng, Rowlinson, & Huang, 2015). RFID uses tags on physical items such as equipment or processed materials. The tags permit identification and tracking via wireless communication and electromagnetic fields. While information obtained from the RFID could potentially end up in GIS, the primary technology is the prior.

Although GIS use did not score high as a priority for materials management, several vendors at the convention promoted its usage in relation to materials management. One such company was Nektar, which uses GIS based maps to track assets as well as task data. With their software, complete asset management can occur from anywhere via the use of mobile devices. Another theme from GIS-related vendors was the use of GIS for business decision making. Trimble, for example, had multiple booths that discussed their many BuildingPoint solutions that improve productivity, schedule adherence, and cost discipline. A number of their construction industry products make use of GIS, along with other technologies. Trimble is well known in industries that use geospatial information, ranging from earth science to forensics. Earl Dudley's Sensefly unmanned aerial systems (UAS) also had multiple booths and presented products such as their eBee autonomous mapping drone. With Sensefly, companies can collect geospatial data to monitor a sites evolution, measure cut and fill volumes, and support infrastructure inspection. The UAS systems work in cooperation with GIS and other technologies. In some ways, these vendor priorities may indicate how GIS is trending in the construction industry.

7. CONCLUSION

GIS offer visualization-based analysis which can be used for more effective and efficient planning and site location assessment, environmental analysis, infrastructure design review, construction management, data collection and as-built surveying, and operations and maintenance (ESRI, 2007). As ESRI (2007) notes, "having an accurate, clear picture of the project helps you better understand needs, reduce problems, and mitigate costs and environmental impacts. These processes are improved when GIS is the core system for data management and visualization" (p 5). Work must be done, however, on awareness and implementation. "The challenge with GIS is in determining what new value the more rapid, consistent, intelligent and overall more powerful mapping systems bring to age-old problems in your business" (Brody, 1999, p 17).

We propose consideration of broader use of GIS for geovisualization in the construction industry as in many ways it is an untapped resource. GIS use could play a more important role in design and planning, site location selection, materials management, market analysis, monitoring, logistics, and decision making as described above. Based on the results of this exploratory study, it seems additional research could be done on specific segments of GIS technology and the role it might play in the construction industry overall.

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APPENDIX A: SURVEY

Use of Geographic Information Systems (GIS) in Construction Management and Planning

1. Your job/title: ____

   (Examples: construction manager, superintendent, project engineer, construction worker)

2. Your primary city/state: ____

3. Are you familiar with Geographic Information System (GIS), a tool for organizing data so it can be displayed and analyzed based on its geospatial characteristics? Yes / No

4. Regarding construction management and planning, to what degree do GIS assist the following areas?

	Very Important	Important	Neutral	Unimportant	Very Unimportant	Not Sure
Construction surveying	(5)	(4)	(3)	(2)	(1)	( )
Property/site survey maps	(5)	(4)	(3)	(2)	(1)	( )
Parcel/utility mapping	(5)	(4)	(3)	(2)	(1)	( )
Platting	(5)	(4)	(3)	(2)	(1)	( )
Topographic/planimetric mapping	(5)	(4)	(3)	(2)	(1)	( )
Materials management	(5)	(4)	(3)	(2)	(1)	( )
Quantity take-offs	(5)	(4)	(3)	(2)	(1)	( )
Cost estimation	(5)	(4)	(3)	(2)	(1)	( )
Supply chain/material tracking	(5)	(4)	(3)	(2)	(1)	( )
Design and planning	(5)	(4)	(3)	(2)	(1)	( )
Proposals	(5)	(4)	(3)	(2)	(1)	( )
Traffic and transportation	(5)	(4)	(3)	(2)	(1)	( )
City/urban design and planning	(5)	(4)	(3)	(2)	(1)	( )
Choosing building sites/locations	(5)	(4)	(3)	(2)	(1)	( )
Spatial analysis and design	(5)	(4)	(3)	(2)	(1)	( )
Natural environment analysis	(5)	(4)	(3)	(2)	(1)	( )
Engineering surveys	(5)	(4)	(3)	(2)	(1)	( )
Digital mapping	(5)	(4)	(3)	(2)	(1)	( )
Environmental threat and damage monitoring	(5)	(4)	(3)	(2)	(1)	( )
Facilities management	(5)	(4)	(3)	(2)	(1)	( )
Market analysis / demographic profiling	(5)	(4)	(3)	(2)	(1)	( )
Logistics	(5)	(4)	(3)	(2)	(1)	( )
Long term planning and decision making	(5)	(4)	(3)	(2)	(1)	( )

5. Do you have any other uses of GIS in construction management that are not listed above? If, so please list them here.

6. What role do you see GIS playing in Building Information Modeling (BIM)?

APPENDIX B: LETTER OF CONSENT

Subject title: Use of Geographic Information Systems (GIS) in Construction Management and Planning.

We are inviting you to participate in a research project to study the awareness and use of geographic information systems (GIS) in construction management and planning in the United States.

You are being given a short questionnaire that asks about your perspective on GIS use in construction management. We are asking you to complete the anonymous questionnaire. It should take you about 3-5 minutes to complete. The results of this project will be used by construction management professionals nationally and globally to access and improve their use of GIS technologies. We hope to share the results by publishing in a scholarly journal and by making them publicly available on the Web ([institutional URL]). We know of no risks to you if you decide to participate in this survey and we guarantee that your responses will not be identified with you personally. Your response will remain anonymous and confidential.

We hope you will take the time to complete this questionnaire. By completing the survey, you certify that you are 18 years of age or older. Your participation is voluntary and there is no penalty if you do not participate.

This project has been approved by the Institutional Review Board at XXX University (IRB # 01844). If you have any questions or concerns about the research, please contact a member of our research team below.

Research team:

[authors and author contact information]

APPENDIX C: COUNT OF PARTICIPANTS BY JOB CATEGORY AND TITLE

Job Title and Category		Count
Construction Student		11
	Student	10
	Student (Civil Engineering Major/GIS Minor)	1
Entry Level		10
	Construction Intern	2
	Construction Worker	1
	Construction Worker, Student	1
	Estimating Intern	1
	Estimator	1
	Intern, Student	2
	Junior Account Manager	1
	Worker	1
Executive		33
	CFO	1
	Contractor, Owner	1
	Contractor, President	1
	COO	2
	Director of Construction	1
	Executive Board Member	1
	Executive Vice President	1
	Owner	4
	President	4
	President, CEO	1
	President, COO	1
	President, MEP Contractor	1
	President, owner	1
	Principal	1
	Vice President	10
	Vice President - Operations	1
	Vice President, Project Manager	1
Mid-Level		16
	Area Manager	1
	Branch Manager (Engineering Firm)	1
	Chief Estimator	1
	Construction Manager	3
	Director of Programs	1
	Director of Risk Management	1
	Lead Estimator	1
	Project Controls	1
	Project Manager	1
	Quality Control Manager	2
	Safety Director	1
	Strategic Account Manager	1
	Test Manager	1
Other Titles		12
	APM	1
	Bond Broker	1
	Consultant	1
	Director of IT	1
	HR Director	1
	IT Manager	1
	Professor	3
	Surety Broker	1
	VDC App Developer	1
	Virtual Construction Engineer	1
Sales		6
	Outside Sales Rep	1
	Outside Salesman	1
	Sales	1
	Sales Engineer	2
	Sales Manager	1
Grand Total		88

APPENDIX D: FULL LIST OF THE OPEN-ENDED RESPONSES AND THEIR CATEGORIZATION

What role do you see GIS playing in Building Information Modeling (BIM)?
Design and Planning Responses:
Design and planning
Design Phase & Layout
Help designing
Helps design
Responses Stating Large or Important Role:
A very key role in connecting the existing data
Big one in the future
Big role
Big role with coordination
Important
Important for revuse
It will be the future standard for the construction industry
Large
Significant
Significant
Very helpful
N/A Responses:
N/A
N/A
N/A
Not applicable to us.
Not Sure Responses:
Don't have enough knowledge
I am learning
Interesting, would like to learn more
Not sure, need to learn more
Not sure.
Unique Responses:
Basis for site layout
Business Development and Marketing
conceptual pre con
Increasing effectiveness of BIM
It is both an input for building models and an output for other GIS tools (layout, etc.)
Link vertical and horizontal building perspectives
merger with larger inroads via augmented reality enabled by GIS
Plays a huge part in the foundation
Point cloud scans
Somewhat important if they can be linked successfully.
Surveying / civil is the start to all projects and simplifying this process would be great.
The main data stream for BIM to pull from to make future decisions
They are merging. USACE is working on combining SDSFIE with BIM.
Use in more logistics in BIM making it more "useful"
Utilities and Horizontal construction for underground construction.
Very useful. It helped us with relocating a building (tech college) on the project site. We were only bidder to do so. Saved owner money and got us the job.
You can use the imaging to use as a site for the model, giving a more accurate understandable model.
Unreadable Response:
Unreadable