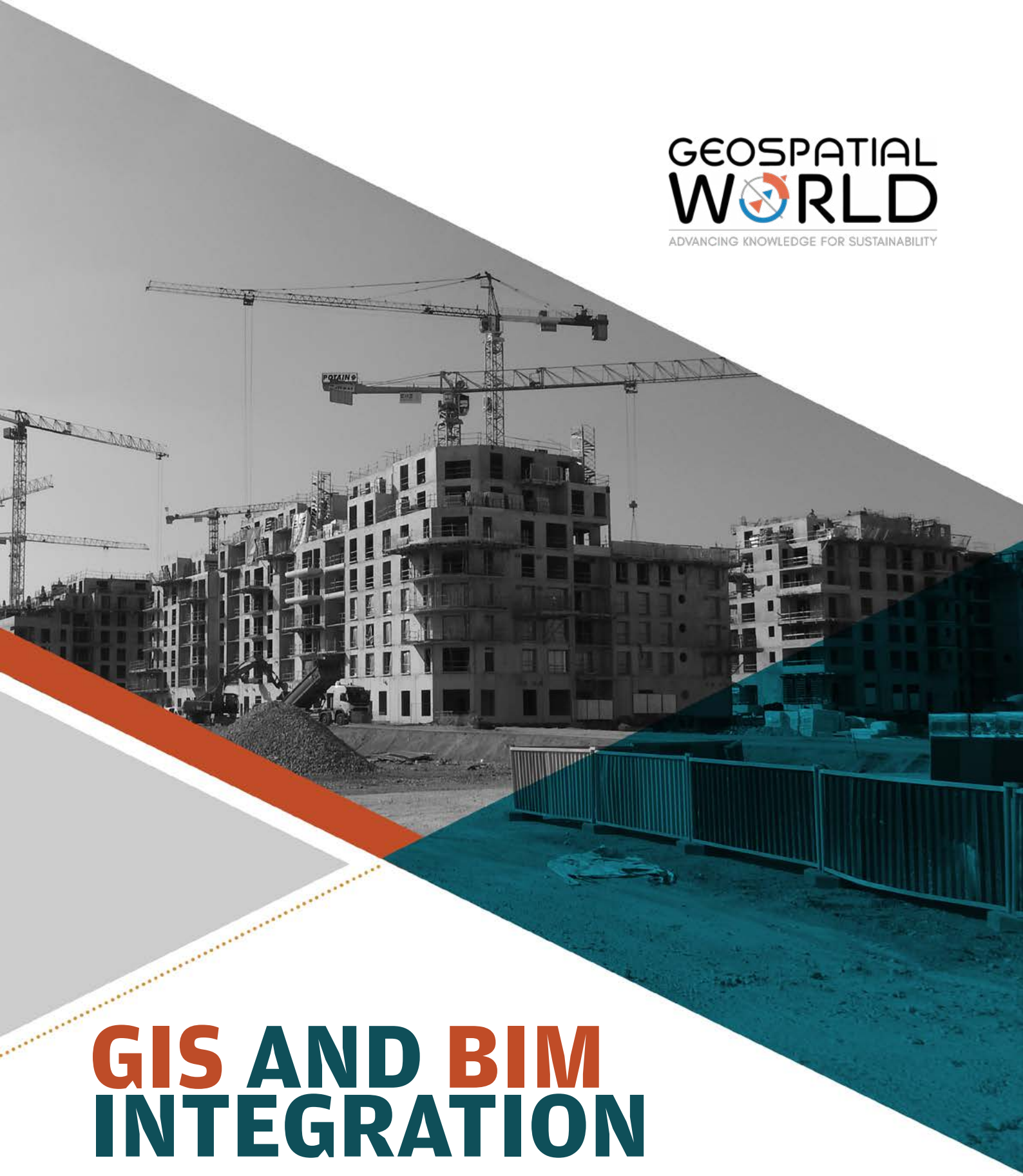
GEOSPATIAL WORLD

ADVANCING KNOWLEDGE FOR SUSTAINABILITY



GIS AND BIM INTEGRATION

A High Level Global Report

AUTODESK esri

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Executive Summary

Rapid urbanization and industrialization – exacerbated by increasing investments in infrastructure development by governments worldwide, increasing intensity and frequency of extreme weather events – demonstrate the need for sustainability in the architecture, engineering, and construction (AEC) industry. The importance of sustainability in the AEC industry in today's time is critical as it is classified as one of the huge consumers of natural resources. Studies show that the AEC industry consumes 50% of natural material resources and 40% of energy and is responsible for 50% of total waste. Subsequently, even though an intangible concept, today, the AEC industry is oriented around sustainability, and stakeholders worldwide are adopting a new systems-thinking approach to achieve circular economy objectives and goals.

The COVID-19 pandemic has enabled a digital transformation to address project delivery performance issues and bolster sustainability across projects. The deployment of data-driven solutions, particularly geospatial technologies, building information modeling (BIM), digital twin, and robotics across projects, has provided varied benefits to stakeholders to deliver project goals per social, environmental, and economic performances. And the role of integrated GIS (Geographic information systems) and BIM solutions in this process-based approach is significant!

GIS and BIM integration is not new to the AEC industry – it is the process of blending the BIM model into layers of geospatial context, leading to effective and efficient design, project management, and improved coordination and collaboration among stakeholders. Providing long-term benefits, integrated GIS and BIM solutions address sustainability at its core – reducing material usage and increasing project resiliency. Studies find that the application of such integrated platforms in construction workflows results in a 25% improvement in inefficient consumption of fuel on-site and a 15% increase in productivity, enabling project stakeholders to achieve a sustainable outcome. In this regard, technology roadmaps by stakeholders must include incremental approaches – wherein both GIS and BIM data are treated and managed as critical assets.

GIS and BIM Integration is a high-level global report, prepared by Geospatial World, in association with Autodesk and Esri, includes insights from design consultants, construction professionals and owners and operators on their use of GIS and BIM for project delivery with sustainability in focus.

KEY FINDINGS:

- Improved interoperability between GIS, BIM, and other technologies; and supporting standards will drive the demand and application of integrated GIS and BIM solutions across AEC workflows.

- **Perspective of Stakeholders with respect to Benefits of integrating GIS and BIM**

  - Design consultants perceive increased project resiliency as the prime benefit of deploying integrated GIS and BIM solutions for sustainable project delivery. At the same time, construction professionals, owners, and operators believe the enhanced ability to consider environmental and social impacts is the main benefit.

  - For improved processes and outcomes, both design consultants and construction professionals state that integrated GIS and BIM solutions lead to faster plan approval and permits, which saves significant time. However, the owners and operators foresee the reduced construction cost as the primary benefit.

  - For risk reduction, design consultants state that the enhanced ability to manage project complexity due to improved coordination and collaboration is the single-most-important benefit of integrating GIS and BIM in their workflows. On the other hand, construction professionals state that reduced conflicts on project sites and ease in field coordination reduce maximum project risks for them. Enhanced, improved budget forecasting is the primary benefit of utilizing integrated GIS and BIM solutions for owners and operations.

- **Perspective of Stakeholders with respect to Return on Investment on integrating GIS and BIM**
  Return on Investment at the project level includes reduced waste and risk, improved design quality, improved safety, reduction in errors, and improved and timely project delivery.

- **Workflow perspective-**
  In the plan and design stage – 65% of design professionals foresee positive RoI in deploying integrated GIS and BIM solutions to design the structure of the buildings taking into consideration the site and its attributes such as wind force, temperature, etc. At the same time, 60% of construction services professionals currently see positive RoI in integrating GIS and BIM to improve construction progress, track assets, and improve logistics management to eliminate approximately 10-30% of errors in the construction phase. Given that the awareness and adoption of integrated GIS and BIM solutions are comparatively less amongst the owners and operators, nearly half of the respondents, i.e., 48%, believe integrated GIS and BIM solution provides them with Positive RoI.

- **Regional perspective –**
  Integrated GIS and BIM solution adoption across countries, by way of mandate and otherwise drives data-driven technology implementation. In America, 90% of the stakeholders (all groups) see positive RoI when deploying GIS and BIM solutions, with 50% indicating a positive RoI between 10%-24%. In Europe, 58% of stakeholders see positive RoI when deploying GIS and BIM solutions, with almost 14% demonstrating RoI of above 100%. In this region United Kingdom has been at the forefront of integrated GIS and BIM implementation, closely followed by Germany, Netherlands, and Denmark. Alternatively, in Asia-Pacific and the Middle East, only 48% of the respondents believe positive RoI is achieved through the integration of GIS and BIM solutions, with 30% indicating a positive RoI between 10%-24%. The adoption of technology, per se, is slow and uneven across Asia-Pacific and the Middle East due to a lack of awareness and mandates in most countries.

- **Adoption of GIS in construction project delivery by non-GIS users**

  - **Approximately 35% of non-GIS users – both design consultants and construction services professionals have not used GIS in their workflows but are open to exploring its potential value. On the other hand, 55% of owners and operators who have not used GIS in construction projects are already evaluating its need in project workflows.**

  - Design consultants believe the challenge of adopting integrated GIS and BIM solutions for construction projects is the lack of real application and the unavailability of objective-based benefit documentation of the solution alternatively. In contrast, construction professionals and owners, and operations state that the lack of demand from clients is a primary reason for the slow adoption of integrated GIS and BIM solutions in organizations.

- Non-GIS users (across all stakeholder groups) believe that the scope of using integrated GIS and BIM solutions in their workflows is tremendous – particularly to achieve improved collaboration across multi-disciplinary project teams. Subsequently, enhanced and high-level client satisfaction is also one of the benefits the non-GIS users foresee driving integrated GIS and BIM solutions in their workflows.

Undoubtedly, the integration of GIS and BIM is a critical component for the end-to-end digitalization of the AEC industry's value chain. Globally stakeholders realize that the application of GIS and BIM solutions enables stakeholders to monitor infrastructure development at a structured level carefully and frequently – so much as in real-time. The time has come for stakeholders to assess integrated GIS and BIM maturity across project workflows to mitigate siloed project data and help project delivery teams collaborate and efficiently deliver sustainable project outcomes.

Chapter 1: Integrated GIS and BIM Solutions for 'Sustainable Design and Construction' Practices

"Recent studies on efficient project delivery performance indicate the role of digitalization in reducing actual project cost and duration by 30 percent to 50 percent, and in doubling project returns."

The architecture, engineering, and construction (AEC) industry's contribution towards natural-resource extraction is estimated to be about 30 percent of the global consumption. The built environment has also been found to be the primary contributor to global emissions, with about 36 percent contribution to global energy use and 39 percent contribution to CO2 emissions, as per the World Green Building Council[1]. The AEC industry also faces significant project delivery performance issues that often result in increased project costs and time, which subsequently results in mismanaged resource utilization and increased waste. Recent studies[2] on efficient project delivery performance are indicative of the role of digitalization in reduction of actual project costs and duration by 30 percent to 50 percent, and in doubling project returns.

An integrated digital platform can help meet project delivery goals with easy user interface (UI) capabilities and features aimed at overcoming challenges in stakeholders' coordination. For instance, using clash or change detection in the pre-construction stage of the project significantly reduces reworks and wastage in the construction stage of the project. Digitalization practices in the AEC industry have witnessed increased demand since the onset of the pandemic. Integrated geographic information system (GIS) and building information modelling (BIM) solutions are becoming inevitable in the industry for their ability to provide interoperable data in an efficient, holistic, and user-friendly manner.

1.1. Definition

Building information modeling (BIM) has been globally accepted by the AEC industry since 1992 and has been playing a crucial role in guiding energy efficient building modeling since then. According to ISO 19650:20193[3], BIM is defined as "use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions."

Sustainability in construction projects

Sustainability in construction projects typically revolves around project management measures that are focused on prevention, reuse, and management of waste, and which can lead to reduced impact on the surrounding environment. However, these strategies are mutually exclusive due to the difference in long-term environmental benefits and short-term economic objectives. Sustainable project delivery is a process-driven approach that provides a structured workflow and brings together the project goals in terms of social, environmental, and economic performance.

Sustainable construction outcomes require an updated project delivery model, with a framework capable of addressing decades-old industry challenges, including lack of integrated systems, prioritization of short-term cost management over long-term outcomes, poor stakeholder communication, and rigid planning and design systems that are unable to adapt to dynamic project demands. Industry experts have introduced digitalized project quality management to overcome such challenges, aimed at focused interventions in a project's lifecycle: predicting outcomes, having a unified platform for project innovation, and achieving sustainability goals.

Scope of integrated GIS and BIM solutions for construction infrastructure management

Sustainable construction outcomes are tied to a process-driven approach in project management. Integrated digital solutions like GIS and BIM can drive such a process-oriented approach with rich project data, for construction and coordination planning development. An integrated GIS and BIM solution supports infrastructure delivery with project controls progress for large-scale transportation or industrial infrastructure projects, and comprehensive master planning for city-level development. These solutions promise efficient design delivery, real-time project progress tracking, and sustainable asset inventory management. An integrated solution also helps users to perform comprehensive project assessment and quality inspection.

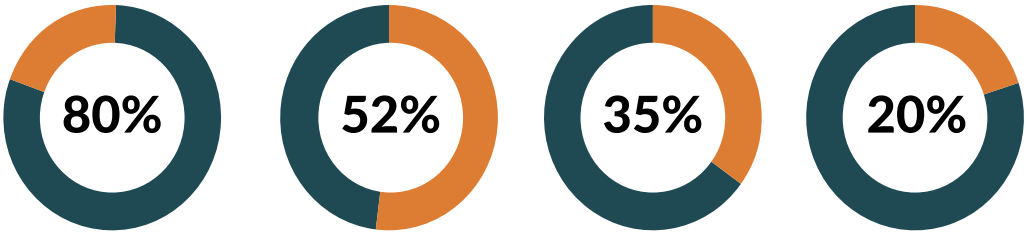
On the other hand, GIS can be defined as a frame- work for gathering, managing, and analyzing data that organizes layers of information into visualizations using maps and 3D scenes. GIS was originally considered a tool to be used mainly by urban planners and geologists for carrying out spatial and sub-surface-related analyses. However, over the last decade, a considerable number of AEC firms have started using GIS solutions to design within a geographic context, update field inventory and make maintenance updates.

Integrated GIS and BIM solutions can seamlessly interconnect data between worksites, workers, and equipment, thus creating a free flow of information across the project's lifecycle. This integration can also take advantage of data to gain more insight into the natural conditions impacting a site, such as understanding how the flood sensitivity of an area can impact decisions about the location, orientation, and construction materials required for a particular infrastructure project.

1.2. Need for integrated GIS and BIM solutions for sustainable project delivery

Successful delivery and management of sustainable projects require the integration of GIS and BIM, providing for a more holistic view of a project that can be efficiently shared, managed, and accessed by different stake-holders. There is an increasing need for the application of advanced digitalization solutions that facilitate collaborative workflow, which subsequently results in integrated digital systems. Based on a recent report[4], figure 1 captures and quantifies the major problems associated with poor data interoperability in construction projects:

Figure 1: Major problems in construction projects



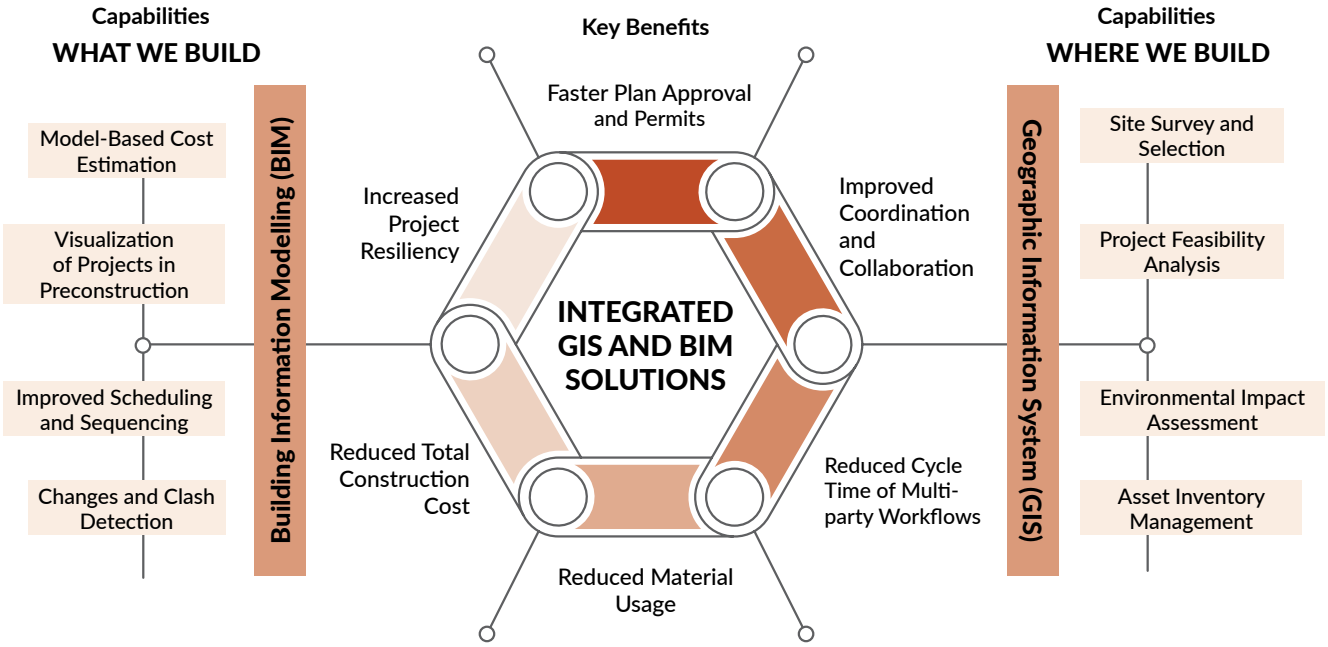
Source: Construction Disconnected: The High Cost of Poor Data and Miscommunication

The majority of these challenges (related to decision-making, resource management, waste reduction, scheduling, and project management) mainly occur in those construction organizations, including small and medium-sized enterprises (SMEs), that are yet to adopt enterprise-level integration of GIS and BIM solutions.

Project assessment

Integrated GIS and BIM solutions provide digital support for design compliance evaluation, with an array of solutions in the form of non-intrusive measures. Additionally, with the help of BIM solutions, **project design assessment and structural load distribution and calculations** are becoming both cost effective and time efficient **Monitoring of technical installations and tracking of energy consumption** using spatial data help deliver sustainable and energy efficient built infrastructure. Integrated GIS and BIM solutions also guide construction and general contracting companies in the **assessment of health and safety on-site**, and thus help them achieve risk reduction benefits in project deliveries. GIS solutions-in terms of a different geographic and geologic context-make it easier to understand the impact of infrastructural developments on the natural environment. Subsequently, an integrated solution helps users perform environmental impact assessment for large-scale infrastructure and for industrial projects, which is gradually becoming mandatory in most countries.

Figure 2: GIS and BIM integration



Source: GW Consulting Analysis

Quality inspection

Project monitoring is important for sustainable project delivery, and it is crucial to incorporate quality inspection and identify quality tolerance during the early stages of a project's lifecycle. Quality inspection is the process of checking planned work against actual work on-site, as well as the inspection of as-built elements during the design-to-execution stage. Project stakeholders need to frequently conduct inspections on jobsites to ensure compliance with quality standards and to drive sustainable project delivery. Construction and engineering companies have embraced digitalization solutions to conduct virtual inspections, which help monitor the quality of project execution.

1.3. Digital twins for project delivery

Geospatial data from GPS devices, satellites, 3D scanning tools, and sensors have enabled GIS platforms to create, render, and analyze construction data at a temporal scale. Similarly, project collaboration platforms (Autodesk Construction Cloud, Primavera, MS Project, etc.) integrate BIM models with 4D-temporal data involving sequencing and scheduling related to the 3D building model construction processes. These datasets help develop a Live 4D model, which can be leveraged from preconstruction to construction execution project handover. The convergence of BIM and geospatial data, among other project data, enables the **digital twin** and helps deliver sustainable project outcomes.

Digital twins have taken the role of an integrated, centralized platform or nerve-center capable of hosting a diverse set of project information, and are multi-disciplinary. They accommodate virtual representation of equipment, processes, workflow information, and digital data of building assets extracted from multiple sensors and synchronized in real time. Integration of digital twins with artificial intelligence (AI) & big data helps optimize infrastructure operations, and lower costs and time associated with operations and maintenance (O&M) through implementation of predictive maintenance in project delivery.

The role of digital twins for project delivery has evolved in recent years, owing to the advancement of the fourth industrial revolution (4IR) transformative solutions like AI-enhanced data analytics, the cloud, and the internet of things (IoT). This enables

"Digital twins have taken the role of an integrated, centralized platform or a 'nerve center' capable of hosting a diverse set of project information, and are multi-disciplinary."

Prime benefits of project digital twins

- **Cost savings:** The data collected from the site with sensors will update the as-built models frequently. Digital twins can store, analyze, and visualize this data, which helps the contractors avoid expensive mistakes/ reworks.
- **Improved collaboration:** Digital twins facilitate a two-way flow of information from on-site to the digital twin and vice versa; this supports a single source of data for all the stakeholders involved in the project. Digital twin facilitate users to virtually and visually plan, schedule, and control the engineering and construction process of the project by enabling a seamless flow of project information. This increases stakeholder collaboration and drives decision-making based on data.
- **Safety and security:** Real-time tracking is a crucial feature of digital twins. This can map the workers in hazardous zones and prevent the use of unsafe methods on-site. Digital twins can use sensor data in a critical area: for example, scaffolding areas have to be constantly monitored for high stress to avoid the failure of the scaffolding platforms.
- **Structural integrity:** After the project is handed over, digital twins can be used for comprehensive assessment of the built asset. Sensors installed to monitor the cracks and stresses in a live structure can transmit the data to the digital twin. This helps assess structural health by closely monitoring vibrational and cyclic loads, which can cause stresses and compromise structural integrity.
- **Model slicing:** Digital twins allow construction stakeholders to break design models into linear pieces and develop a project management schedule accordingly for efficient project delivery. For instance, by slicing the project into linear design models, construction stakeholders can accurately estimate and assign human resources to specific project deliverables and define the raw materials required.

digital twins to provide construction management solutions across all phases of the lifecycle, including the design to-execution phase, and O&M. Digital twins help benchmark optimal performance levels of construction-related activities; this can help identify best practices related to different types of projects to help reach sustainable construction performance.

Recent advancements in digital twins include enhanced AI/ machine learning (ML) capabilities along side cloud-based analytics. These solutions support advanced predictive modeling for engineers to perform a virtual stress-test built structures. Such tests enable the project stakeholders to plan preemptive measures and identify weaknesses in their assets to strengthen project sustainability and improve structural resiliency.

“Application of integrated digital platforms to monitor and inspect project workflows has resulted in 25 percent improvement in efficient consumption of fuel on-site, 15 percent increase in productivity, and 10 percent increase in machine productivity, enabling project stakeholders to achieve sustainable outcomes.”

Chapter 2: Market Drivers for Increased Use of Integrated GIS and BIM Solutions

"As countries worldwide start adopting digitalization in the overall process of construction, the quality of construction and infrastructure development helps achieve returns on investment in terms of time, cost, and productivity."

Construction companies worldwide are increasingly adopting data-driven decision-making with digital tools to improve their project workflows. This phenomenon has helped increase the application of integrated digital solutions in the AEC industry. In this context, a vast array of project solutions associated with integrated GIS and BIM solutions are being widely adopted beyond the surveying and designing stages of construction projects. Additionally, the introduction of the digital twins framework in the AEC industry and the initiation of dynamic digital cities programs across many regions of the world are playing a significant role in advancing integration of GIS and BIM solutions.

Other factors driving use of integrated digital solutions include a rise in the use of frontier technologies — advanced sensors, augmented reality (AR)/virtual reality (VR), IoT, etc., which require conducive digital platforms that can accommodate large streams of data in different formats. Secondary factors include national construction and infrastructure policies that encourage the application of integrated digital solutions in projects of varying scale. For instance, half of the $1 trillion US infrastructure bill has been set aside for upgrading roads, bridges, airports, waterways, broadband, water systems, and the power grid. Such infrastructure policies subsequently result in an uptake of digitalization solutions like integrated GIS and BIM. Thus, integratation of GIS and BIM solutions is critical for end-to-end digitalization of the AEC industry's value chain.

2.1. Government initiatives and policies

The rapid increase in urbanization leading to a rise in smart cities programs has created worldwide interest in comprehensive digital solutions. Mega-cities are in the process of developing and updating policies and digital mandates to digitalize systems and processes associated with infrastructure development and operations. The construction industry is a major provider of services effecting the digital improvements sought by development authorities. Globally, stakeholders are realizing that the application of GIS and BIM solutions enables a nation's infrastructure to be carefully monitored at a structural level and at a geographic scale, which is imperative for regular upgrades and expansion. Digitalization of construction workflows with GIS and BIM can help resolve the loss of raw material, budgetary constraints, and other uncertainties , which may inadvertently result in significant economic loss to governments. The quality of infrastructure and longevity of assets can also improve through near real-time monitoring, virtual inspections, and predictive maintenance, thanks to integrated GIS and BIM solutions.

The **United States** is at the forefront of mandating policy related to the use of BIM, GIS, and other digital solutions in the construction industry. The US introduced the National 3D-4D-BIM Program in 2003. The program guidelines focus on providing support and resources for ongoing capital projects. The digitalization measures of the program promote value-added digital visualization, simulation, and optimization technologies to increase quality and efficiency through General Services Administration (GSA) project lifecycles and beyond.

The **United Kingdom's Centre for Digital Built Britain (CDBB)** pioneered the national BIM framework and is assisting USA in developing the United States' National BIM Program . The "Government Construction Strategy 2016-2020"[5] of the UK gave a major boost to implementing fully collaborative 3D BIM on centrally procured government construction projects. Apart from that, the CDBB a UK

Figure 3: Timeline of government initiatives, policies and mandates

Source: GW Consulting Analysis

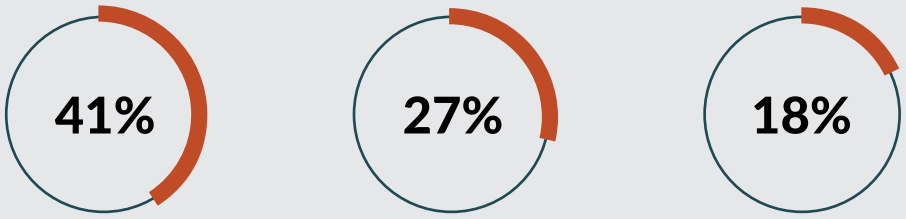
government-funded body, has been working closely with the National Institute of Building Sciences (NIBS) a non profit and nongovernmental organization established in the USA. This is a key step in the digital transformation of the infrastructure and construction sectors for both countries.

Other countries are also following the footstep of UK and USA, and there has been an increased effort by national building construction organizations and government agencies to facilitate a collaborative and coordinated effort among stakeholders to develop national digital standards for construction processes, digital information management, and technology implementation.

2.2. User demand

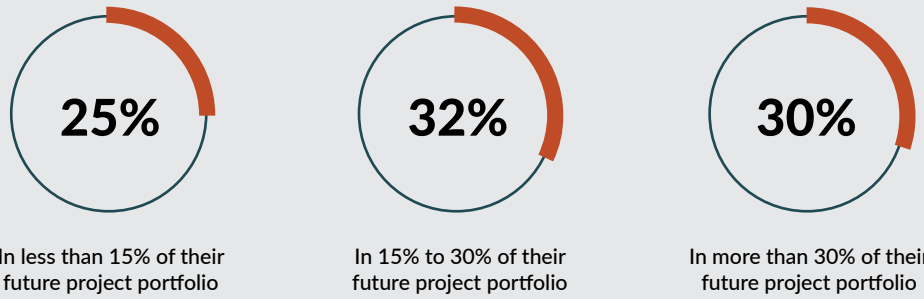
Integrated GIS and BIM solutions provide enhanced functionalities that are often unavailable to multi-disciplinary groups of project stakeholders in the AEC industry. This has increased user demand for such solutions among all stakeholders associated with construction services such as design, construction, and owners or operators of construction projects.

Organizations believe their competitors are using GIS and BIM



Geospatial World surveyed the stakeholders mentioned above, wherein 27 percent of the respondents believed that their competitors were using some form of integrated GIS and BIM solutions in 15 percent to 30 percent of their design and construction projects, while 18% of the respondents believed the same for more than 30 percent of their projects.

Organizations believe their clients might mandate GIS and BIM

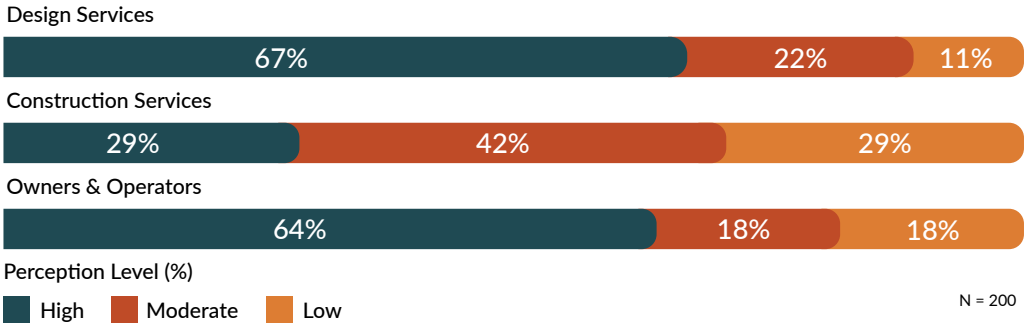


Further, 30 percent of the respondents believed that their current or prospective clients might mandate integrated GIS and BIM solutions in more than 30 percent of their design and construction projects.

Geospatial World conducted user surveys to understand the major drivers of Integrated GIS and BIM application in project workflows.

Figure 4: Drivers of integrated GIS and BIM collaborative workflows

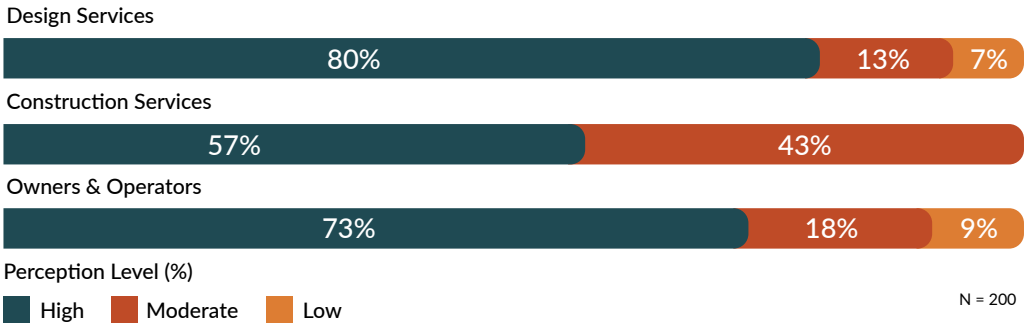
Team members understanding the value of integration



Source: Geospatial World Survey, 2021

67 percent of respondents from design services and 64 percent of the respondents from owners and operators indicate that team members understanding the value of integration is one of the primary drivers of integrated GIS- and BIM- collaborative workflows.

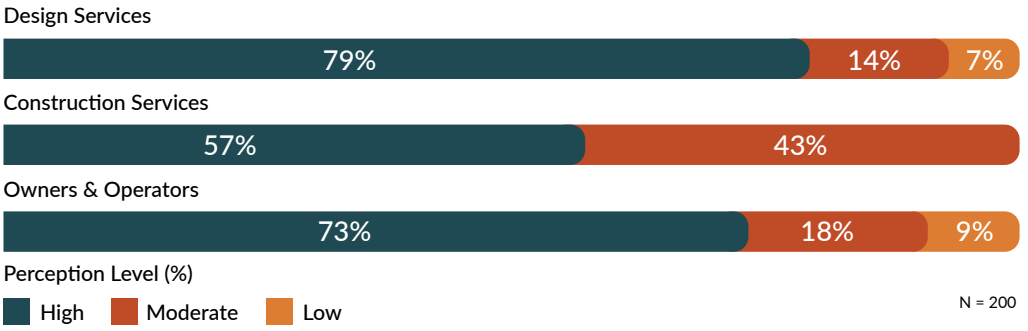
More standards for integrated GIS- and BIM-based workflows



Source: Geospatial World Survey, 2021

Majority of the respondents from design and construction services, as well as owners and operators believe that more standards for integrated GIS-and BIM-based workflows should be another important driver for integrated GIS and BIM collaborative workflows.

Better interoperability between GIS, BIM, and other technologies



Source: Geospatial World Survey, 2021

Similarly, majority of the responses across all different types of stakeholders suggest that better interoperability between GIS, BIM, and other technologies is one of the major drivers of integrated GIS and BIM collaborative workflows.

Stakeholders associated with design services perceived “more standards for integrated GIS and BIM-based workflows” and “better interoperability between GIS, BIM and other technologies” as the leading reasons bound to drive the application of integrated GIS and BIM solutions. Similarly, respondents from the owners and operators category found these two reasons to be the primary drivers of the demand. On the other hand, respondents from the construction services found these reasons to be partial drivers of the demand.

Construction services stakeholders had mixed opinions on the contribution of “team members understanding the value of integration” toward the demand for integrated GIS and BIM solutions. In contrast, the respondents from design services and owners and operators perceived the “team members understanding of the value of integration” of GIS and BIM as equally important for driving the application of an integrated solution.

“Stakeholders associated with design services perceived ‘more standards for integrated GIS- and BIM-based workflows’ and ‘better interoperability between GIS, BIM, and other technologies’ as the leading reasons bound to drive the application of integrated GIS and BIM solutions.”

THOUGHT LEADERS INTERVIEW

Integrated GIS and BIM Solutions for GeoDesign to GEOBIM Digital Transformation

Prof. Henk Scholten

Spatial Informatics - Vrije Universiteit Amsterdam, Director Innovation at Geodan

"The government has to play a role in providing a mandate wherein BIM model along with Geo, would encourage the adoption of GIS and BIM technologies together in the infrastructure projects"

With over 42 years of research & academia experience, Prof. Henk Scholten is a leading scientist and CEO of GEODAN - a location intelligence company based in the Netherlands. In his interview with Geospatial World, Prof. Henk Scholten emphasized the role of a holistic data-driven collaborative approach to achieve sustainable development in the infrastructure industry. "We need to put all the effort together in coming up with solutions," said Prof. Henk. Citing the example of the surge in traffic in the bridges of the Netherlands, Prof. Henk explained the role of integration of GIS and BIM in connecting workflows and processes and to tackle the siloed approach. "The bridges in the Netherlands and also in many other places are often congested with traffic– the design and maintenance of the bridges are being taken care of by different offices, instead of the office responsible for mobility." Such offices functioning in silos often face challenges in mapping the asset data required for their engineering and modeling work. Such projects require data-driven project management solutions such as integrated GIS and BIM solutions. Integrated technology solutions help to connect these offices and integrate their workflow and data efficiently bringing in efficiency and improving productivity.

Need for integrated solutions: Transition from GeoDesign to GEOBIM

GeoDesign is a design framework to support technology professionals to leverage GIS across the infrastructure lifecycle of the industry. "Today, GeoDesign can be considered across the lifecycle of GEOBIM solutions," said Prof. Henk. As per Prof. Henk, the role of GeoDesign is crucial during the pre-construction phase, which helps provide accurate project information for the next phase. "I think, Geo-design is a part of the whole cycle of Geo-BIM, and there is freedom in the first phase to come up with all the ideas and plans for the future development," he added. However, he believes some stakeholders are only interested in the planning & design capabilities of integrated solutions like GIS and BIM and are not as keen on applying the integrated solution in the O&M phase. The limitation of integrated GIS and BIM to specific project lifecycle phases results in different workflows, and Prof. Henk considers this as the primary difference between GEOBIM and Geo-design. He concluded that BIM performs a vital role across the project lifecycle; however, an integrated GIS and BIM solutions will play an equally important role.

National Digital Twin Strategy and GEOBIM standards

The Netherlands has developed a National Digital Twin Strategy with a significant budget allocated for the purpose. The significant increase in the Field labs over the years has helped evolve the Digital Twin capabilities in the country. "Field labs are the practical exercises that will be part of the solution at the end and are much required," added Prof. Henk. For instance, there is a scope in the Ministry of Transport, Public Works and Water Management of Netherlands, also responsible for traffic management to undertake practical solutions utilizing the Digital Twin system. There is an existing opportunity to develop a digital twin for the southern tunnel of Rotterdam using a BIM model and further to integrate it with the digital twin of the Netherlands. "Applications on real-world projects, i.e., the Field Labs are thus, required for expanded approach and evaluation of the true value of Digital Twin capabilities," adds Prof. Henk.

Another important aspect of digital twins' development is the understanding and recognition of the value of GEOBIM standards associated with them. Standards are critical for the development of digital twins, and according to Prof. Henk, there is a need for a more significant awareness among the stakeholders involved in the process. Citing the example of water barriers and dikes in the Netherlands, he comments, "It's unbelievable that many stakeholders still don't understand the value of geospatial infrastructure, and the standards associated with it. There is a need to change the contracts and include standards as necessary, otherwise, we cannot make the necessary progress. At present, the whole Netherlands is under a 'Geo' perspective in a digital twin, and as per the OGC standards and we now need to get to GEOBIM standards and processes," he added.

Importance of integrated GIS and BIM for sub-surface infrastructure

Present-day infrastructure asset project information and data serve as historical data for future engineers and asset managers. Hence, the preservation of built-asset data is critical for the expansion, maintenance, and repair of infrastructure. "When we talk about a bridge, a 100 years ago, the estimations that a civil engineer might have made and built, but the structures may not be able to bear the traffic load that travels on that bridge today," said Prof. Henk. The integration of traffic models within the BIM environment is a good start towards developing advanced Digital Twin systems. Such integrated technology solutions are crucial for the long-term resilience of sub-surface infrastructure.

For instance, an integrated GIS and BIM platform helps visualize the location data alongside structural data. This enables asset managers to monitor infrastructure operations and develop predictive maintenance systems. "It's clear that we need to make sure to know how strong the sub-surface is. In 2021, we received the best Governmental Solution Award for sub-surface that we developed for BRO – the Dutch Key Register of the Subsurface, wherein we integrated the 'Geo' aspect with the 'BIM' aspect." he added. The BRO mandated sub-surface data to be assessed in a GEOBIM model before the commencement of building projects. "And of course, looking means you must use it. This is one of the most wonderful examples of integration of the BIM and Geo" concluded Prof. Henk.

Advancement of integrated GIS and BIM: Government and academia

"The government has to play a role in providing a mandate wherein BIM model along with Geo, would encourage the adoption of GIS and BIM technologies together in the infrastructure projects" said Prof. Henk. He added that the government needs to initiate a cloud environment for BIM models, which can help organize and provide access to built-asset information. From an academia standpoint of view, Prof. Henk considers renowned institutions like TU Delft and TU Eindhoven at the forefront of the research and application of BIM solutions. "They are willing to integrate their solutions into a large environment, using digital twins," he said. However, the components of GEOBIM focused on mobility, accessibility, and the energy transition are yet to take importance, he was quick to add. Prof. Henk believes the present focus of integrating GIS and BIM solutions for large-scale construction, environmental issues, mobility, traffic, and transportation will gradually shift in a positive direction in the next few years to come.

Chapter 3: Benefits of Integrating GIS and BIM Solutions

"Integration of GIS and BIM allows users to visualize a digitally designed project in context of its actual geographic location, thus reducing the risks and uncertainties associated with complex infrastructure projects."

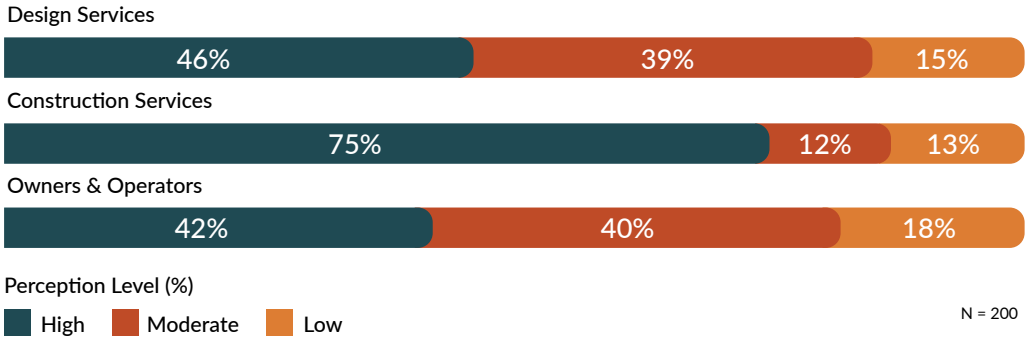
Using an integrated GIS and BIM solution provides a user-specific platform to professionals from design and construction services and owners and operators of construction projects. The benefits of an integrated platform include optimized designs, accelerated project approvals, reduced costs, smart inspections and maintenance, and sustainable facilities management. The integration of GIS and BIM solutions allows users to visualize a digitally designed construction project in the context of its actual geographic location, thus reducing the risks and uncertainties associated with designing and building complex infrastructure projects. The geographic information thus gathered helps users prepare for the project uncertainties emerging from economic, social, and environmental conditions, especially for large-scale infrastructure projects. This chapter discusses the prime benefits associated with stakeholders through an integrated GIS and BIM solution for project delivery.

3.1. Sustainable project delivery

Stakeholders participating in the Geospatial World Survey had the opportunity to earmark the benefits their organizations experienced using integrated GIS and BIM solutions for sustainability. According to the respondents, the prime benefits included enhanced ability to consider environmental and social impacts, reduced material usage, and increased project resiliency.

Figure 5: Prime benefits in terms of sustainable project delivery

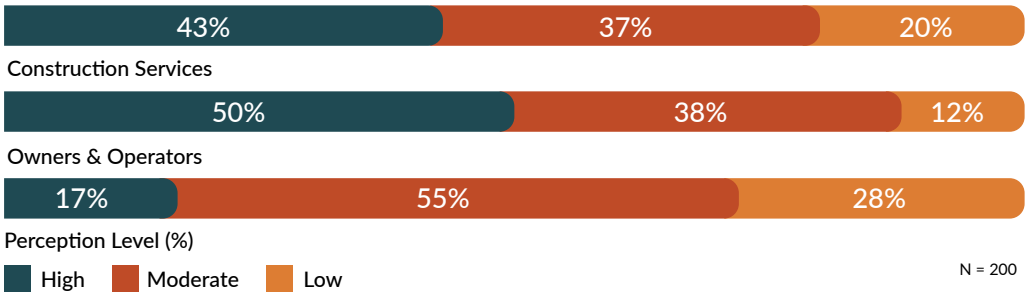
Enhanced ability to consider environmental and social impacts



Source: Geospatial World Survey, 2021

75 percent of the respondents among construction services indicate that a high level of benefits can be achieved by integrating GIS and BIM solutions in terms of enhanced ability to consider environmental and social impacts.

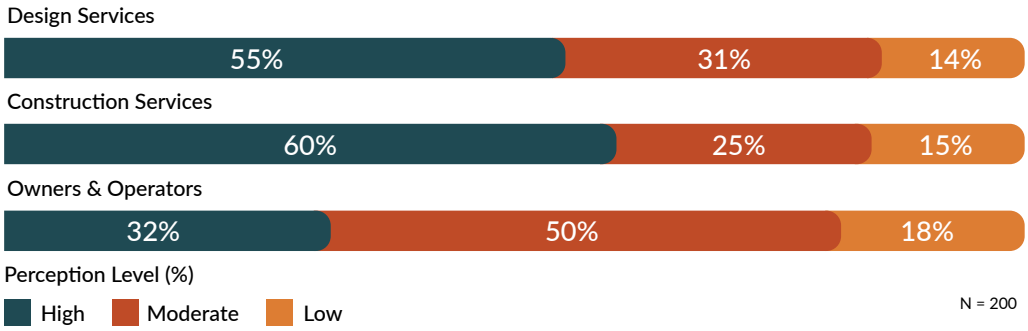
Reduced material usage



Source: Geospatial World Survey, 2021

50 percent of the responses coming from construction services professionals indicate that integrated GIS and BIM solutions can help achieve a high level of benefits in terms of reduced material wastage.

Increased project resiliency



Source: Geospatial World Survey, 2021

60 percent of the respondents among construction services indicate that integrated GIS and BIM solutions can help achieve a high level of benefits in terms of increased project resiliency.

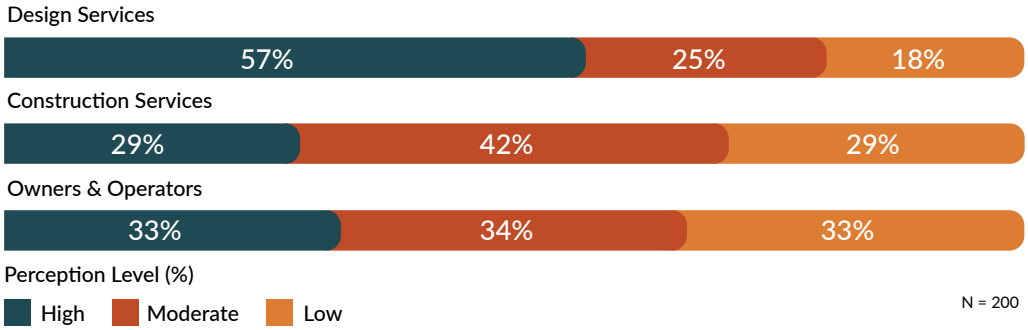
Design services professionals indicated "increased project resiliency" and "enhanced ability to consider environmental and social impacts" as the leading benefits of using integrated GIS and BIM solutions in their workflow. Respondents from this category had mixed responses about the contribution of integrated GIS and BIM solutions in "reduced material usage". Respondents associated with construction services overwhelmingly voted for "enhanced ability to consider environmental and social impacts" as the prime benefit of utilization.

3.2. Improved processes and outcomes

In the Geospatial World survey, respondents ranked project workflow benefits associated with utilizing integrated GIS and BIM solutions. These workflow benefits were extrapolated from the sustainable project delivery outcomes. According to the stakeholders, the prime benefits of using integrated GIS and BIM solutions in construction workflow processes included reduction in overall project duration, reduced total construction costs, and faster plan approval and permits.

Figure 6: Prime benefits of integrated GIS and BIM solutions in improved processes and outcomes

Reduced overall project duration



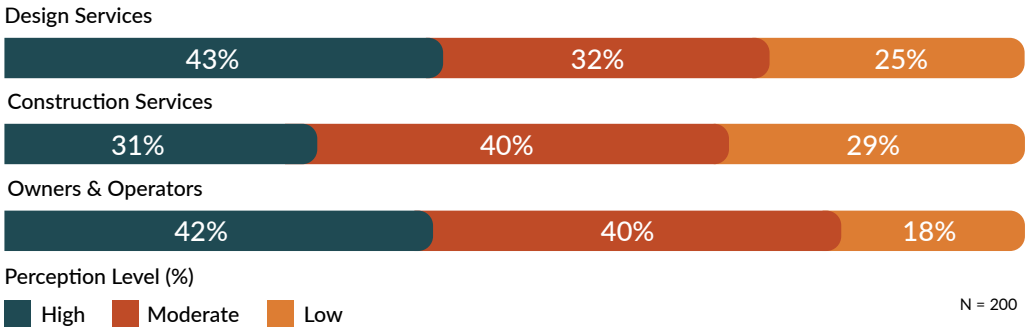
Source: Geospatial World Survey, 2021

57 percent of the respondents among design services professionals indicate that a high level of benefits in terms of reduced overall project duration can be achieved using integrated GIS and BIM solutions.

"Integrated GIS and BIM solutions eliminate issues like wrong measurements and clashes, allowing construction to go on a lot quicker, and also eliminate a lot of waste production. It helps avoid ordering of wrong or extra materials to a large extent, and thus lowers the downtime of the entire project as well."

Zachary Jaffe, GIS Analyst, LandTech Consultants Inc.

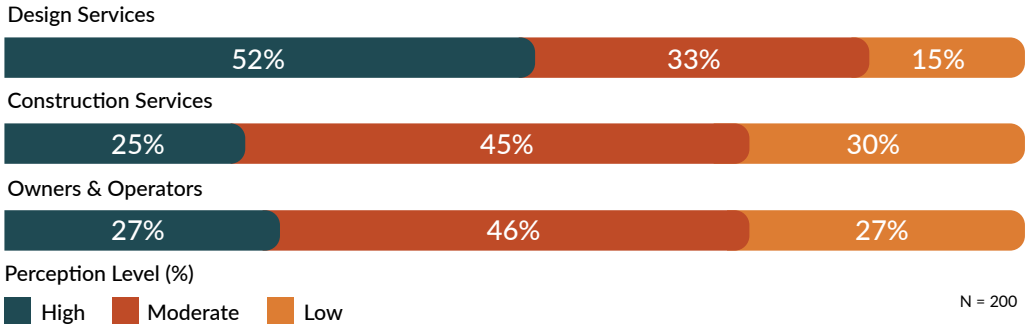
Reduced total construction cost



Source: Geospatial World Survey, 2021

Around 40 percent of respondents among design services professionals as well as owners and operators suggest that a high level of benefits in terms of reduced total construction cost can be achieved using integrated GIS and BIM solutions.

Faster plan approval and permits



Source: Geospatial World Survey, 2021

52 percent of the respondents among design services professionals indicate that a high level of benefits can be achieved in terms of faster plan approval and permits by using integrated GIS and BIM solutions.

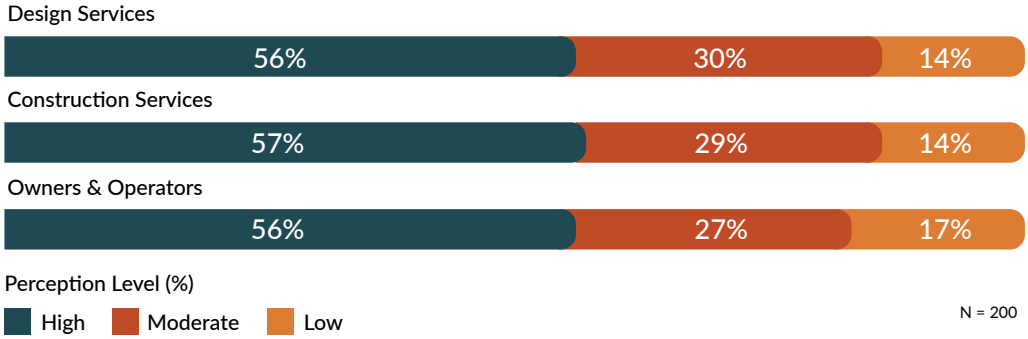
Respondents from the design services chose “faster plan approval and permits” as the leading process-based benefit from an integrated GIS and BIM solution. Design services professionals designated “reduced overall project duration” as another prime benefit. Construction services professionals, and owners and operators, perceived the process-centric benefits as moderate in terms of project duration, construction cost, and plan approvals and permits.

3.3. Project risk reduction

Integrated GIS and BIM solutions can reduce project risks and increase on-site safety for construction projects. These solutions enable successful identification of unsafe practices and optimal workflows for improved productivity. In this case, the prime benefits perceived by respondents included improved project budget forecasting: enhanced ability to manage project complexity: and reduced conflicts, changes, and field coordination problems.

Figure 7: Prime benefits of integrated GIS and BIM solutions in project risk reduction

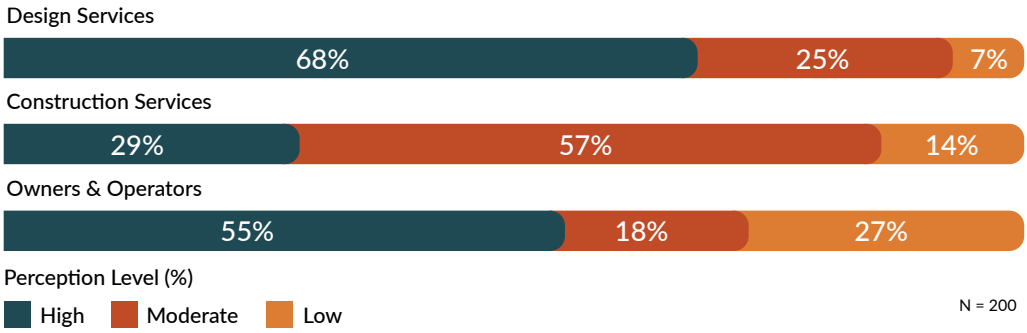
Improved project budget forecasting



Source: Geospatial World Survey, 2021

Around 56 percent of the responses coming from design and construction services professionals as well as owners and operatorss indicate a high level of benefits in terms of improved project budget forecasting using integrated GIS and BIM solutions.

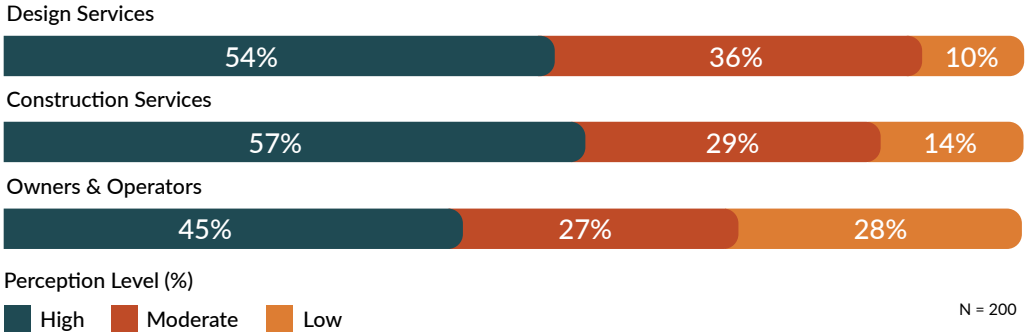
Enhanced ability to manage project complexity



Source: Geospatial World Survey, 2021

68 percent of the respondents among design services professionals indicate that a high level of benefits can be achieved in terms of enhanced ability to manage project complexity.

Reduced conflicts, changes & field coordination problems



Source: Geospatial World Survey, 2021

Around 55 percent of responses coming from design and construction services professionals indicate that a high level of benefits can be achieved using integrated GIS and BIM solutions in terms of reducing conflicts, changes, and field coordination problems.

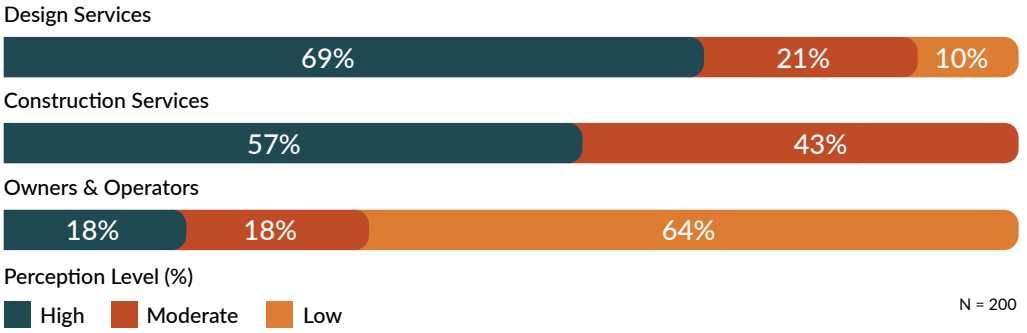
Respondents from design services perceived “enhanced ability to manage project complexity” as the prime benefit of integrated GIS and BIM solutions in reducing project risks. Construction services professionals earmarked “reduced conflicts, changes, and field coordination problems” and “improved project budget forecasting” as the leading benefits. Owners and operators perceived “enhanced ability to manage project complexity” as the prime benefit, while “improved project budget forecasting” received moderate benefits with an integrated GIS and BIM solution.

3.4. Organizational benefits

Organizational benefits are two-fold, namely, short-term economic objectives and long- term environmental benefits for sustainability. According to the respondents, the three prime benefits in this respect included increased win rates for pursuit of new work, improved client satisfaction, and additional services.

Figure 8: Prime organizational benefits

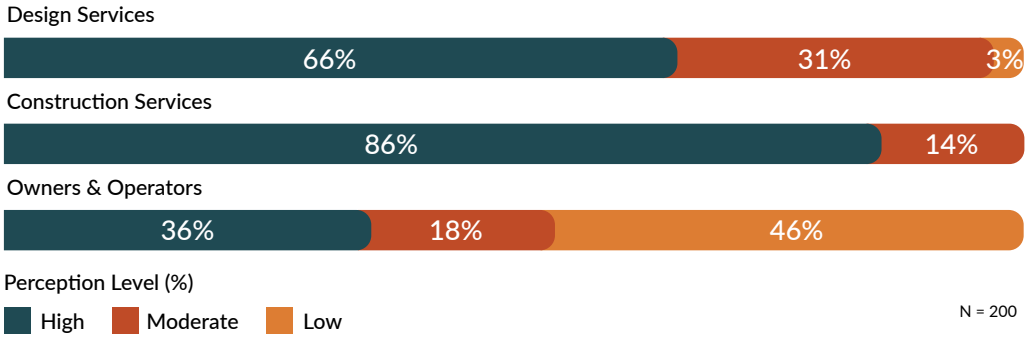
Increased win rates for pursuit of new work



Source: Geospatial World Survey, 2021

69 percent of the responses coming from design services professionals indicate that a high level of organizational benefits can be achieved in terms of increased win rates for pursuit of new work by using integrated GIS and BIM solutions.

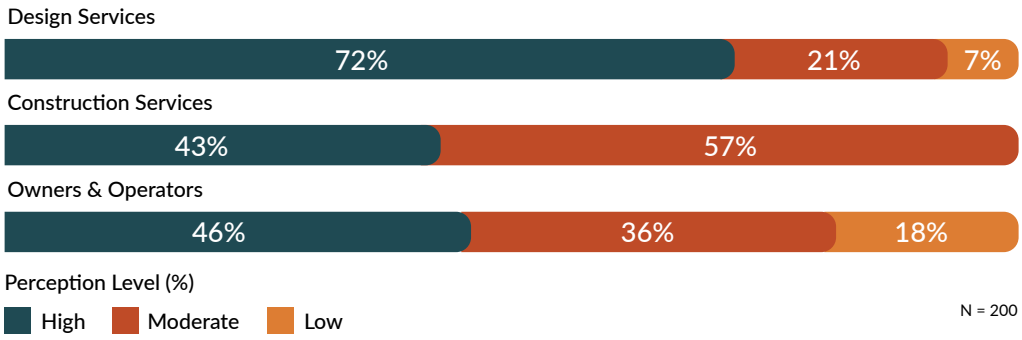
Improved client satisfaction



Source: Geospatial World Survey, 2021

86 percent of the respondents among construction services professionals indicate that a high level of benefits in terms of improved client satisfaction can be achieved by using integrated GIS and BIM solutions.

Additional services (Customer support and training)



Source: Geospatial World Survey, 2021

72% of the respondents among design services professionals indicate that a high level of organizational benefits with regard to additional services in terms of customer support and training can be achieved using integrated GIS and BIM solutions.

Respondents from construction services overwhelmingly indicated "improved client satisfaction" as the major benefit at an organizational level. Design services professionals said that the major benefits were "increased win rates for new work," "client satisfaction," and "additional services" in terms of customer support and training. Owners and operators saw moderate benefits in "additional services" at an organizational level.

"Design services professionals indicated 'increased project resiliency' and 'enhanced ability to consider environmental and social impacts' as the leading benefits of using integrated GIS and BIM solutions in their workflow."

THOUGHT LEADERS INTERVIEW

Digitalization of Construction Workflows with an Integrated GIS and BIM System or Sustainable Project Outcomes

Marc Goldman
Director - AEC Industry Solutions
Esri

Stephen Brockwell
Senior Product Owner
Esri

Steven Santovasi
Sr. Product Manager
Esri

"There is multi-stakeholder benefit associated with the application of integrated GIS and BIM systems in the project lifecycle. Your construction management crew, project controls, the team that does the RFIs and similar kind of things such as scheduling, construction safety and field reporting crews who tend to benefit due to this integration."

Mega projects require some form of construction project delivery digital twins, this is developed with the help of BIM and GIS platforms which multiple teams can leverage during the project duration. Such digital twins of the project delivery system hold capabilities associate with environmental monitoring, daily reporting, stake-holder, and real estate management. Integrated BIM and GIS helps incorporate advanced technologies like reality capture, which enables project stakeholders to assess progress in a spatial-temporal aspect.

Value proposition of an integrated GIS and BIM system

Major project stakeholders (for ex: VPs of EPC firms) prefer macro-view of the project portfolio, and rarely indulge in granular detail of project information, says Steven. However, multi-disciplinary teams working together on the different facets of the construction workflow require micro-level details affiliated to the project progress. An integrated GIS and BIM acts as a holistic platform capable of providing both macro and micro view in this regard. This multi-dimensional nature of the integrated solution helps vast array of stake-holders in their project workflow including (but not limited to): real estate stakeholder management, land surveying, environmental permits and approvals, and every aspect of pre-construction stage.

I. Pre-construction: Environmental permitting and approvals

Infrastructure development projects require multiple permits and seek the approval of appropriate governing bodies and development agencies. Steven emphasized the role of technologies in overcoming challenges faced during the approval stages of the project. For instance, electric transmission project requires presidential permit followed by approvals and permits from USAPE, DET and local governing bodies, he said. Such processes take up to two years or more of environmental permitting prior to construction of the project. Other stages during the permit approval process include public hearing in every municipality (under project geography). In such circumstances, the project stakeholders generally utilize 3D CAD models for visualization of electric transmission infrastructure and help the public stakeholders to interact with the virtual elements and understand the impact of the infrastructure.

II. Construction: Progress monitoring, control, and tracking

There is multi-stakeholder benefit associated with the application of integrated GIS and BIM systems in the project lifecycle, commented Steven. He added, "your construction management crew, project controls, the

team that does the RFIs and similar kind of things such as scheduling, construction safety and field reporting crews who tend to benefit due to this integration." Although, people working on-site in physical components of the project may not receive direct benefits from the integrated GIS and BIM system, Steven suggested there are significant indirect benefits such as project documentation, reporting, and estimations. However, project management team, project controls team and construction management team remain the predominant group of stakeholders who stand to benefit from the integrated solution.

Role of integrated GIS and BIM systems in project workflow challenges

Project stakeholders often find themselves in dire situations due to technical mix-up, inaccurate cost/ time estimation, and loss of data during the project lifecycle. An integrated GIS and BIM ecosystem provides micro-level monitoring of project workflows, which helps alleviate major project disruptions and uncertainties. For instance, the City of Ottawa had a broken rail system for 14 days due to derailment incidence in the network. However, they were left facing a basic problem in terms of the project information data, they didn't have insight onto what was built and the way in which they were built in the initial stages of the project. The as-built data of the project holds significance in this case, and the lack of which resulted in loss of time and money to the asset owners.

Integrated GIS and BIM system enables advanced project modelling to help aggregate building information from conceptualization stage to project handover. The integrated system devises a unique as-operating model (in GeoBIM terms) which subsequently facilitates the project stakeholders to track, trace and monitor multiple projects in the portfolio. Owners can adopt this form of project portfolio monitoring, wherein the integrated system becomes a single source of truth for work in progress and as-built models. Integration of GIS and BIM enables project view in the form of as-operating alongside activities undergoing changes in near real-time. Furthermore, the integrated GIS and BIM system has capabilities of paired project monitoring in the form of both as-operating and as-designed.

Project data: Exchange, conversion, and interoperability

"Integration of the system or a part of it is not necessarily about conversion," said Steven. This is potentially a huge liability from the process point of view from the beginning must be avoided, he added. Presently, the engineering information associated with construction projects can be accessed completely without conversion. This is possible due to the updated platforms which enable project stakeholders to view and exchange data as per their requirements. For instance, projects like the Toronto Light Rail had their project stakeholders (HDR etc.,) had only resorted dynamic data exchange, conversion, and update due to the nature of the project, which demanded the stakeholders to update project information every week or every few days. However, the pre-requisites for project data conversion depends on different timescales and their respective volatility associated with intelligent pragmatic conversion to keep information available.

Sustainable project outcomes

"An integrated GIS and BIM product uses less servers. It allows us to have less people on site. It enables remote work," indicated Marc. Delivering projects that have various types of digital information requires trustworthy features associated with access to information, cybersecurity, and dynamic workflow monitoring capabilities when it comes to large scale projects and infrastructure. Also, its equally important to consider the digital solution's business capability in terms of repeatability, scalability, delivery, and solution that allows the organization to have a sustainable business model. Steven added, "there's also an additional angle to that - It stops organization/firms from making excuses about for example, the integration, IT costs of getting this setup, are too high and we can't afford to know (eg. USGS data). Yeah, we can't afford that, while the project is in flight because that can be a construction and delivery costs."

Chapter 4: Return on Investment of Integrated GIS and BIM Solutions

The integration of GIS and BIM solutions supports efficient management of on-site activities across the construction lifecycle, from preconstruction to O&M after project hand over. An integrated GIS and BIM solution improves on-site engineering accuracy (precision engineering), operational efficiency, and workforce productivity. The integrated solution helps overcome project uncertainties, resulting in sustainable practices.

The Returns on Investment (ROI) at the project level include reduced waste and risk, improved design quality, improved safety, reduction in errors, and improved and timely project delivery through efficient use of resources and strategic action plans. AEC companies can decide on the scope of integrated GIS and BIM solutions they want to use, based on the targeted interventions required in the project lifecycle for monitoring project costs and measuring returns.

Figure 9: Returns on Investment on small- and large-scale construction projects

	Average Design Time Saved	Average Construction Time Saved	Average Project Cost Saved
Small projects (Length <= 10 km & Area <= 100 sq. km.) *No of projects-50*	22.2%	45 days	5.9%
Large projects (Length > 10 km & Area: > 100 sq. km.) *No of projects-30*	28.3%	90 days	13.1%

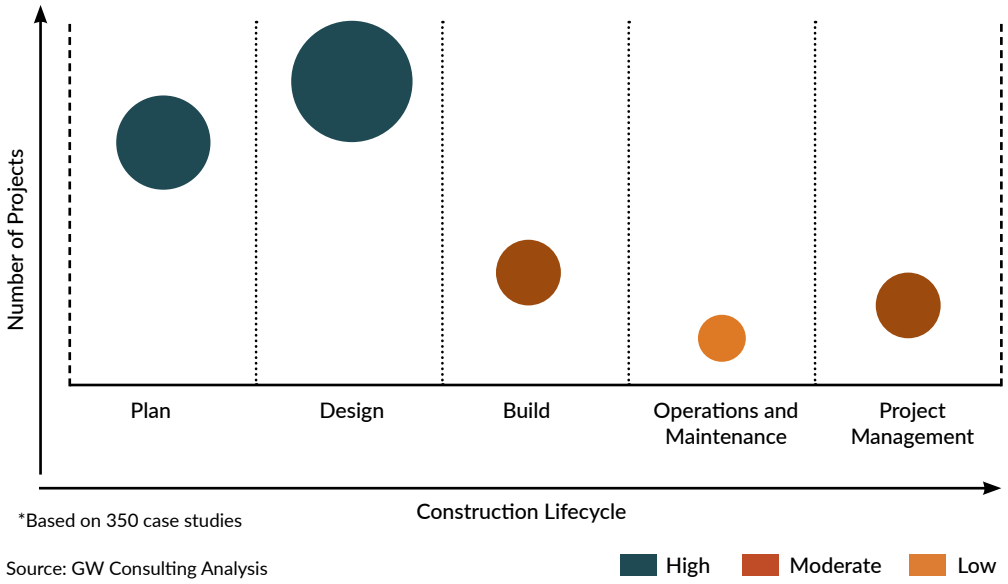
Source: GEOBIM Market in AEC Industry Report 2020, Geospatial World

4.1. Project workflows and ROI

Geospatial World's **GEOBIM Market in AEC Industry**[6] report finds the application of GEOBIM solutions to be much higher in the planning and design phase of the construction lifecycle (see figure 10). This increased application of integrated GIS and BIM solutions can be attributed to their higher usage by architects, urban planners, and BIM/CAD modelers. These project stakeholders adopt integrated GIS and BIM solutions for 3D design and simulation capabilities (made possible only by integrating geospatial data and information). Such integrated digital solutions enable stakeholders to assess design complexities and project uncertainties for higher project returns. For instance, in the preconstruction process, the contractor and design team can provide the owner with higher accuracy in terms of cost estimates, which can reduce expenses across the entire project duration.

"Digitalization of surveying techniques has resulted in precision mapping. Integration of this on-site survey data with GIS and BIM has improved return on investment (ROI) across the project lifecycle."

Figure 10: Integrated GIS and BIM adoption across the construction lifecycle

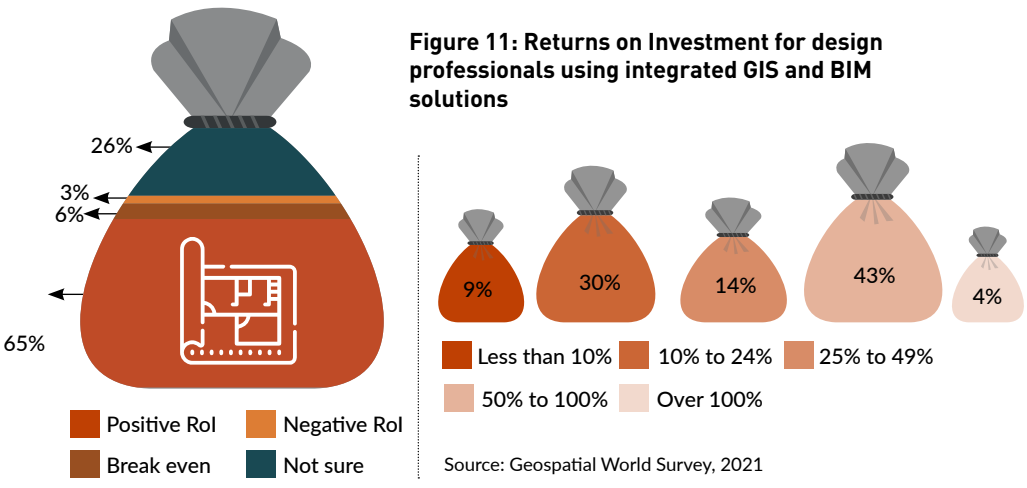


4.1.1. Plan and design stage

In the plan and design stage, stakeholders must analyze geospatial data to determine the project prerequisite of the built structure. For instance, the determination of height and floor-area ratio of buildings requires a comprehensive analysis of the geologic conditions of the project site, including wind force and direction and light conditions. Integration of GIS and BIM solutions can also help planners and designers design the structure of the buildings based on data like temperature, wind force, and land subsidence in the project site, alongside the characteristics of building materials. These analyses are crucial to forecasting raw material requirements, project cost estimates, and duration.

In Geospatial World's survey (see figure 11), the majority of design professionals indicated positive ROI on using integrated GIS and BIM solutions. However, 26 percent of the respondents are "not sure" and are yet to quantify returns on investment, whereas six percent perceive that their organizations are able to break even on project costs using integrated GIS and BIM solutions. Among the respondents who believe their organizations get positive ROI, 43 percent believe that using integrated GIS and BIM solutions helps them achieve an ROI above 50 percent, whereas 30 percent say that the ROI generated is between 10 percent and 24 percent.

Figure 11: Returns on Investment for design professionals using integrated GIS and BIM solutions



4.1.2 Construction stage

In the construction phase of a project lifecycle, the application of integrated GIS and BIM solutions improves construction progress, tracking, and assets and logistics management. This helps in sustainable project management and data-driven decision support. GIS has made asset tracking and management easier by incorporating real-time data into the BIM models, saving contractors and subcontractors both time and cost. Further, integrated GIS and BIM solutions also enhance other construction workflow activities such as monitoring equipment, energy consumption, and raw materials waste. Figure 12 shows the breakdown of the ROI as perceived by construction professionals in design-to-execution tasks when integrated GIS and BIM solutions are applied.

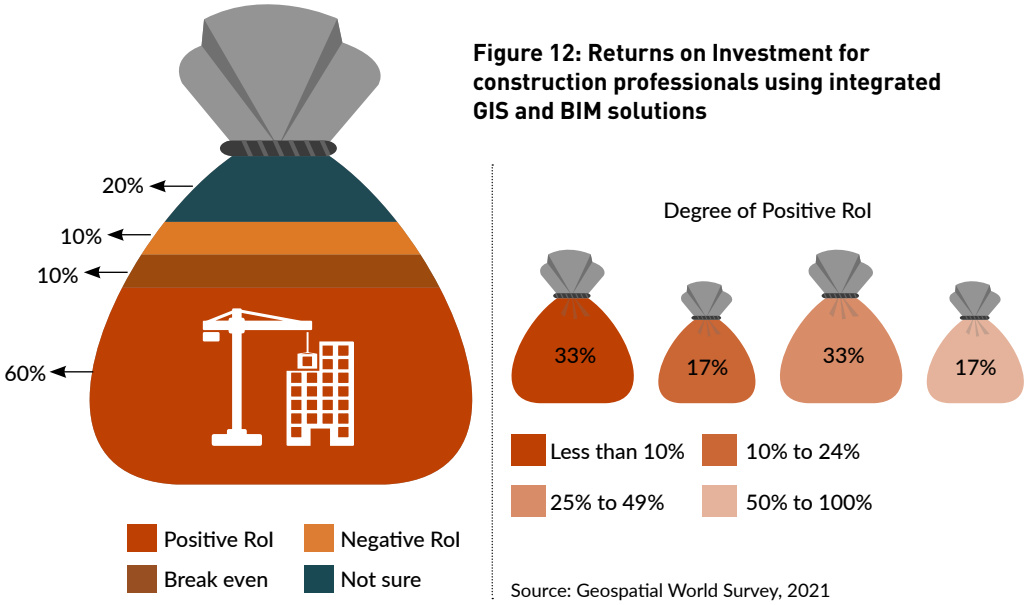


Figure 12: Returns on Investment for construction professionals using integrated GIS and BIM solutions

Source: Geospatial World Survey, 2021

Most of the respondents from construction services perceive that integrated GIS and BIM solutions yield positive ROI for their organizations. 33 percent of respondents indicated positive ROI of between 25 percent and 49 percent. While 17 percent of the respondents from large construction firms believe their ROI is above 50 percent; about 20 percent indicate they are unsure about the ROI, and 10 percent believe their organizations are able to break even using integrated GIS and BIM solutions.

CONSTRUCTION WORKFLOW ROI—USER PERCEPTIONS

"With the integration of geospatial data (like point clouds) and BIM during the construction phase, projects are able to eliminate a huge percentage of errors, approximately 10–30 percent. It has allowed faster completion of the construction process and eliminated a lot of waste of cost."

Zachary Jaffe, GIS Analyst, LandTech Consultants Inc.

(Excerpts from user interviews conducted by Geospatial World)

4.2. Returns on investment for owners and operators using integrated GIS and BIM solutions

Integrated GIS and BIM solutions can support progress tracking and monitoring and targeted interventions across an AEC project lifecycle. Project monitoring supported by integrated GIS and BIM solutions enables quality inspection and quality tolerance identification in the early stages of a project lifecycle. This helps owners and operators evaluate task status, productivity, challenges, and bottlenecks. Integrated GIS and BIM solutions help check planned work against actual work on-site and inspection of as-built elements during the design-to-execution stage, which facilitates early identification of project errors by owners and operators. Furthermore, this helps project stakeholders frequently conduct virtual inspections on sites to ensure compliance with quality standards and drive sustainable project delivery. Integrated GIS and BIM solutions enable nonintrusive measures for the following:

- Architectural assessment (design evaluation, optimization, etc.)
- Assessment of technical installations (dimensions, energy consumption, etc.)
- Assessment of health and safety on-site, and
- Environmental impact assessments.

Figure 13 shows the breakdown of RoI, as perceived by owners and operators, in the entire lifecycle of a project using integrated GIS and BIM solutions.

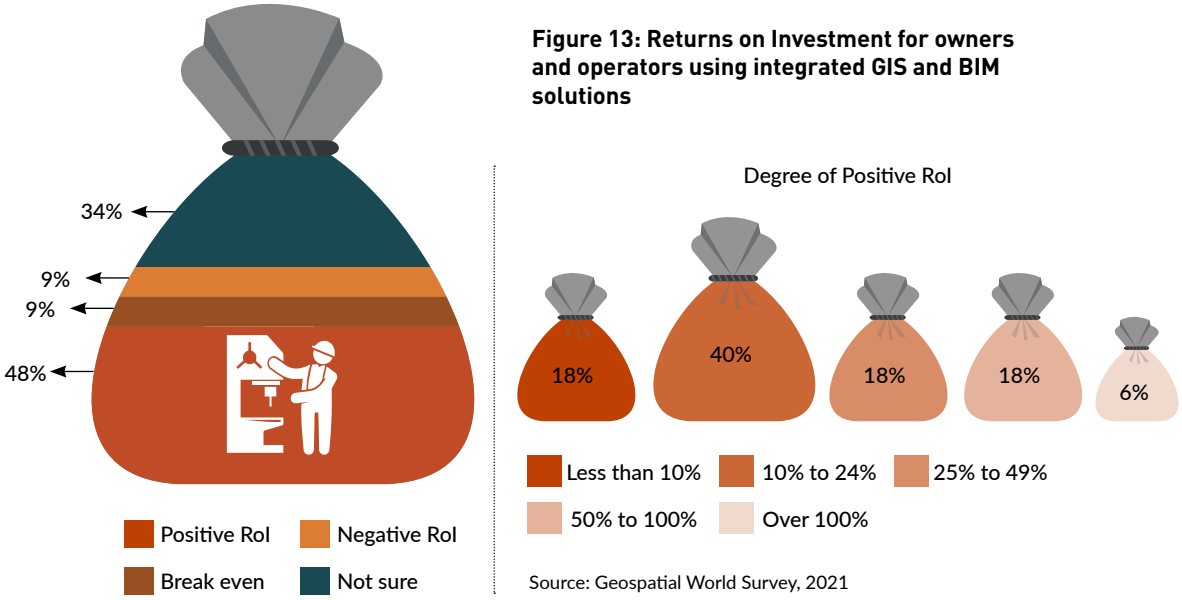


Figure 13: Returns on Investment for owners and operators using integrated GIS and BIM solutions

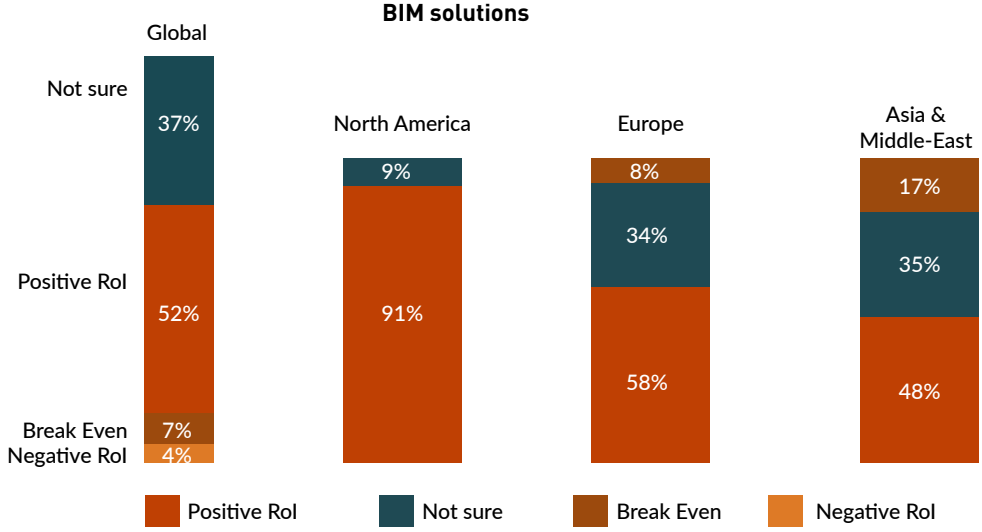
About 48 percent of respondents perceive positive ROI, while 34 percent of respondents are yet to assess the ROI they receive from using integrated GIS and BIM solutions. This is indicative of the level of awareness of digital transformation among the AEC stakeholders and increased understanding of integrated GIS and BIM solutions among owners and operators. Among the respondents who perceived positive ROI, 40 percent believed that integrated GIS and BIM solutions helped them achieve ROI between 10 percent and 24 percent.

4.3. Returns on investment using integrated GIS and BIM solutions—Regional perception

Integrated GIS and BIM solutions give positive ROI globally, as indicated by more than 52 percent of the survey respondents. Interestingly, about 37 percent of the

respondents are unaware of the ROI they generate from using integrated GIS and BIM solutions, which indicates that there is a need to help project stakeholders, particularly owners and operators, quantify ROI. Regionally, more than 90 percent of respondents from the North America region believe integrated GIS and BIM solutions have helped them achieve a positive ROI, while the rest are "not sure." In the case of respondents from the European region, about 58 percent believe integrated GIS and BIM have

Figure 14: Region-wise comparison of Returns on Investments using integrated GIS and BIM solutions



Source: Geospatial World Survey, 2021

helped them achieve positive ROI, whereas 34 percent of respondents are "not sure." About 48 percent of respondents from Asia and the Middle East also selected positive ROI, but their numbers were relatively fewer than their counterparts from North America and Europe. RoI, whereas 34 percent of respondents are 'not sure'. About 48 percent respondents from Asia and the Middle East also selected positive RoI, but their numbers were relatively fewer than their counterparts from North America and Europe.

4.3.1. North America

About 50 percent of respondents in North America indicated a positive ROI of between 10 percent and 24 percent, whereas 30 percent perceived the range of ROI being between 50 percent and 100 percent. In North America, the United States has over the years led the way where application of GIS and BIM solutions in industry is concerned, and this is reflected

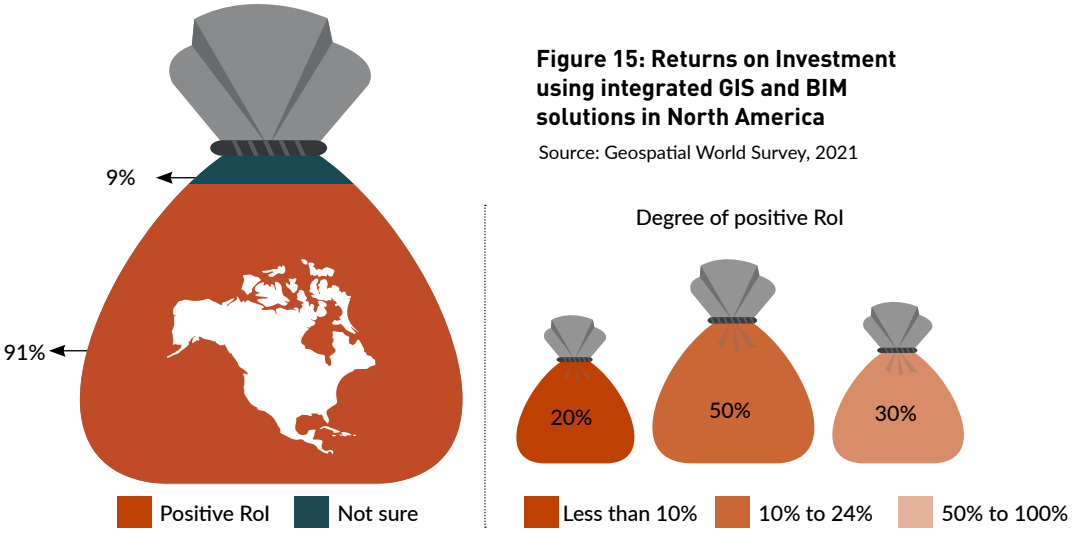


Figure 15: Returns on Investment using integrated GIS and BIM solutions in North America

Source: Geospatial World Survey, 2021

in the user perceptions of GIS and BIM solutions. In the last decade, the United States has seen a surge in the number of companies offering innovative construction software solutions (inclusive of BIM and 4IR technologies) owing to its strong ecosystem of fostering new ventures in the construction technology industry. Such technology firms have gained the attention of venture capitalists and received significant funding. In terms of a policy framework related to the application of GIS and BIM, the United States is one of the first countries to have implemented guidelines on this—National 3D-4D-BIM Program in 2003. These activities have helped create awareness and impart and advance the scope of integrated GIS and BIM solutions among AEC professionals.

4.3.2 Europe

In Europe, 43 percent of the respondents believed integrated GIS and BIM solutions could help their organization achieve positive ROI of above 50 percent. Interestingly, about 14 percent of the respondents indicated ROI of above 100 percent. In this region, the United Kingdom has been in the forefront of using integrated GIS and BIM solutions in the construction industry. "The Government Construction Strategy

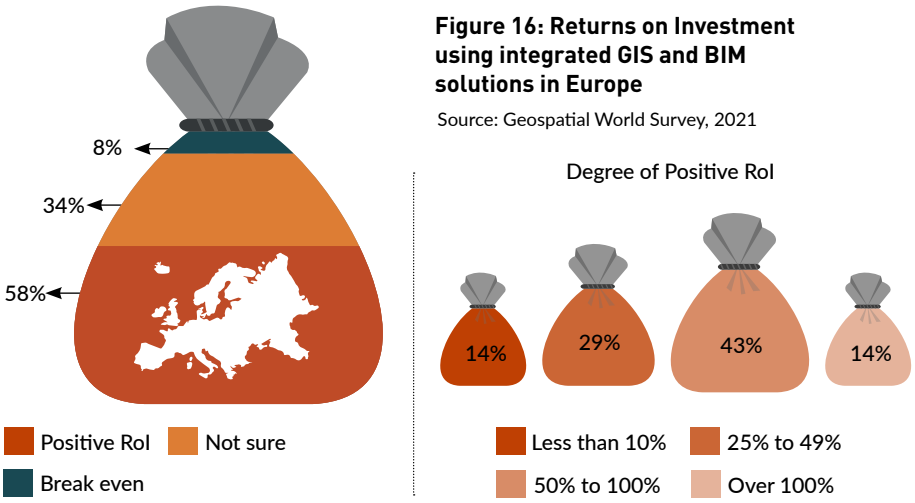


Figure 16: Returns on Investment using integrated GIS and BIM solutions in Europe

Source: Geospatial World Survey, 2021

2016–2020" of the United Kingdom sets out its requirement for implementing fully collaborative 3D BIM on centrally procured government construction projects, along with the implementation of BIM Level 2 in design and construction. According to the GEOBIM Market in AEC Industry report of Geospatial World, Germany is gradually transitioning from Level 2 to Level 3 of the GIS and BIM maturity model owing to significant solution offerings for the industry and subsequent policy mandates. Other European countries, such as the Netherlands, Finland, and Denmark, have also made commendable progress in terms of utilizing and integrating GIS and BIM solutions, thanks to their programs and national initiatives in favor of mandating the use of GIS and BIM at different stages of construction activities.

4.3.3. Asia Pacific and Middle East

In Asia and the Middle East, the number of respondents in favor of positive ROI are relatively fewer compared to North America and Europe. Among the respondents who

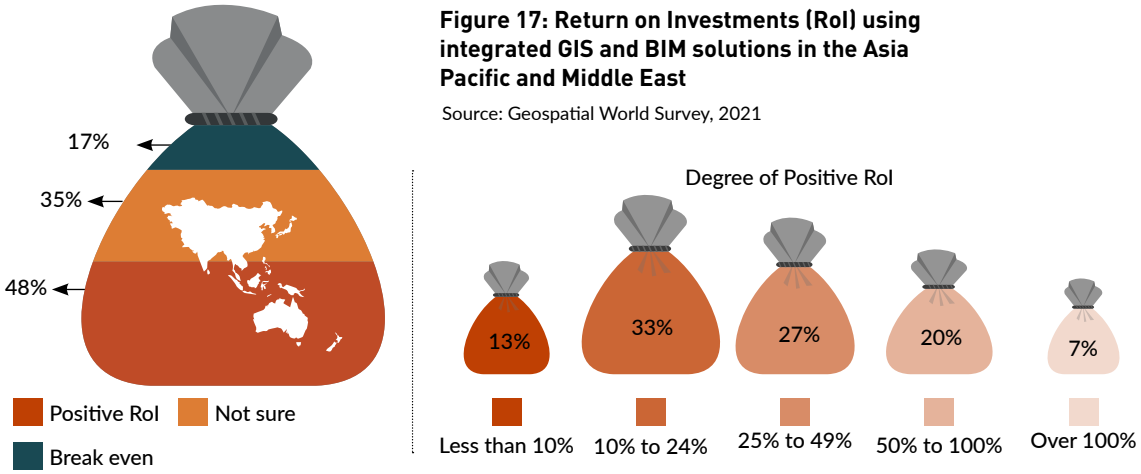


Figure 17: Return on Investments (RoI) using integrated GIS and BIM solutions in the Asia Pacific and Middle East

Source: Geospatial World Survey, 2021

believe their organizations are receiving positive ROI with integrated GIS and BIM solutions, more than 30 percent perceive positive ROI between 10 percent and 24 percent, whereas 27 percent perceive ROI between 25 percent and 49 percent. Only seven percent of the respondents from this region indicated ROI above 100 percent. Recently, countries like China and South Korea have increased adoption of integrated technologies in construction projects, which can be considered one of the major drivers of GIS and BIM applications in this region. .

As per Geospatial World's GEOBIM Market in AEC Industry report, advanced technologies have shown a steady uptake in developed countries like Singapore, Japan, Australia, and New Zealand, wherein national governments and construction companies are utilizing digital twin systems regularly, and more than 55 percent of the projects have used emerging technologies like immersive solutions (AR/VR). Both Australia and New Zealand have mandated BIM Execution Plans (BEPs) and given instructions for using geospatial technologies in the construction sector. Other emerging economies, such as Indonesia, Malaysia, and Hong Kong, have recently mandated the use of BIM in public utility and housing projects, which has encouraged the integration of GIS and other frontier technologies in this region.

Integrated GIS and BIM solutions facilitate unified common data environment, help assess long-term environmental impact alongside short-term objectives (including efficient cost management and higher returns) outcomes, improve stakeholder communication, and help develop flexible planning and design systems.

"Design service professionals indicated 'increased project resiliency' and 'enhanced ability to consider environmental and social impacts' as the leading benefits of using integrated GIS and BIM solutions in their workflow."

Chapter 5: GIS Users' Perspectives on Opportunities and Challenges of Integrated GIS and BIM Solutions

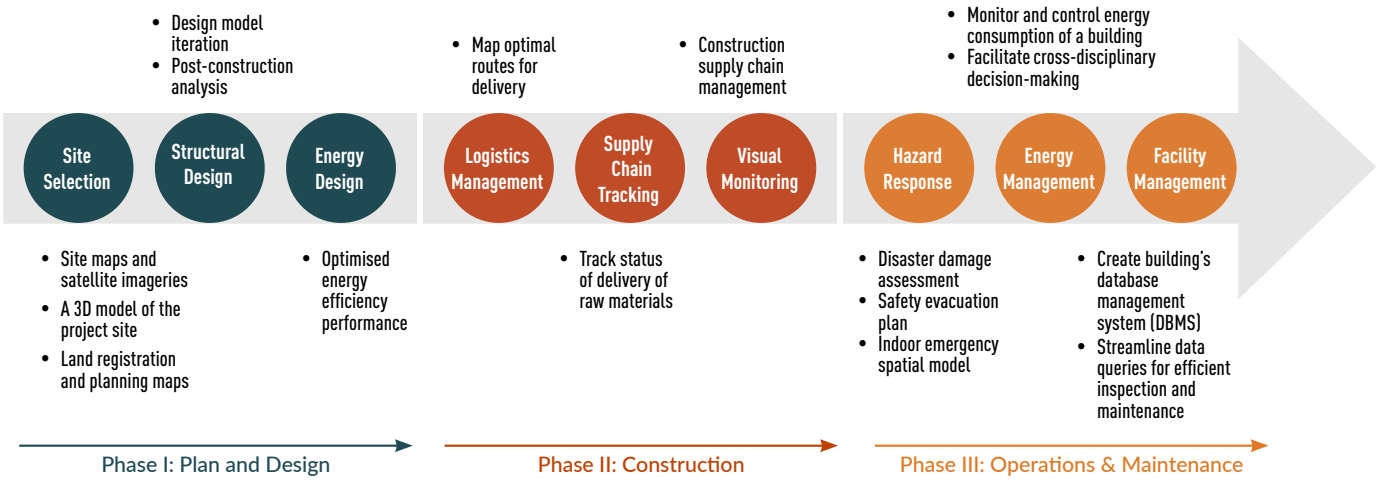
"Geographic data helps project stakeholders leverage real-time project information to resolve workflow obstacles before the project is underway and identify an optimal solution at the planning and specification stage itself."

Historically, preconstruction activities, which include site suitability and preproject planning, have used geospatial solutions such as remote sensing, scanning. and image analytics extensively. The use of drone-based surveys and GIS-based apps for faster data collection and processing, and ground truthing, has increased significantly in project workflows like construction planning and monitoring. In addition, GIS users can now integrate spatiotemporal information with BIM, which facilitates project data exchange and communication at any given time in the design, construction, and O&M phases of a project's lifecycle. However, the integration of spatiotemporal project data with BIM comes with its own set of challenges. Some of these challenges include data sharing and the management and integration of BIM and GIS topology functions.

5.1. Opportunities

The plan and design stage of a project's lifecycle holds enormous potential for applying integrated GIS and BIM solutions to different project parameters such as site selection, energy design, structural design, and performance evaluation, among other things. GIS has proven to be beneficial to assess site conditions to identify and derive optimal design solutions. In the construction phase, application of integrated GIS and BIM solutions can be seen to yield benefits in different tasks such as clash detection, site logistics, and 4D planning and schedule management. Aside from finding them useful in preconstruction, GIS users also perceive integrated GIS and BIM solutions to be helpful in the postconstruction phase of a project lifecycle. After the project has been handed over, owners and operators can use integrated GIS and BIM solutions to extract and analyze stage-wise project lifecycle data. The following figure attempts to capture the different project activities under different phases of a construction project lifecycle where integrated GIS and BIM solutions have an opportunity to be utilized to streamline the workflow and enhance value proposition of the project.

Figure 18: Project activities under different phases of project lifecycle



Source: GW Consulting Analysis

5.2. Challenges

An integrated GIS and BIM solution plays an important role in the planning and management of the construction lifecycle, particularly during the design and build stages. These stages require data exchange among the stakeholders of the project (architect, planner, engineer, etc.) within which GIS users are faced with implementation challenges by aspects like common data environment (CDE), lifecycle information management, and BIM component orientation.

PRECONSTRUCTION—USER PERCEPTIONS

"The first thing that we do in order to reduce the amount of change orders and time spent is utilize geospatial solutions like reality capturing technology from the very beginning of the project lifecycle. Generally these solutions were applied by designers, but these days, this has been adopted by contractors to avoid expensive rework."

Christopher Allen, VDC/BIM Manager and Laser Scanning Expert, Reis Contracting, USA. Inc., USA.

(Excerpts from user interviews conducted by Geospatial World)

POSTCONSTRUCTION—USER PERCEPTIONS

"Integrating GIS and BIM together gives the owners and operators the opportunity to develop an internavigable system for monitoring their assets in an infrastructure project. It is extremely important to not only capture the real-time location data but also to identify a network that will allow stakeholders to make decisions in case of emergencies by following a specific path, which takes into consideration the MEP, potential hazards around the site, creating evacuation plans, etc."

George Floros, GIS Lead - Infrastructure, Skanska, UK.

(Excerpts from user interviews conducted by Geospatial World)

"Currently, GIS and BIM data are integrated by different professionals using different software packages for different purposes. This results in many challenges, including data interoperability, mismatch, and loss of semantic information during the process of integration."

THOUGHT LEADERS INTERVIEW

Digital Transformation of Construction Industry and the Role of Integrated GIS and BIM Solutions

Prof. Dr. Jantien Stoter

Chair of 3D Geoinformation - Delft University of Technology and Francesca Noardo, Postdoctoral Researcher - Delft University of Technology

"The roadmap should deploy down-to-earth, incremental approaches starting with existing data to support realistic and feasible growth paths for a wide variety of organizations that can be adjusted and aligned along the way in all its aspects and that allows organizations to gradually introduce the required changes."

There is no doubt that advancements in GIS and BIM have opened new avenues in academic institutions. Initially, the research domain of GIS and BIM were focused on the technical potentials of integration. But ever since the added value and technical feasibility of the integrated solution have been proven, the role of academic institutions has extended beyond research and transitioned into facilitation of the technology across data, processes, and systems. Prof. Dr. Jantien Stoter, Chair of 3D Geoinformation – Delft University of Technology, co-leader of several project on GeoBIM in Europe, and the EuroSDR GeoBIM project remarked in the interview with Geospatial World, "there is a need to facilitate the advancement of GIS and BIM integration in the AEC industry by revealing and addressing the challenges to scale up the results obtained in research, individual projects and pilots. There is no other way."

Digital transformation with integrated GIS and BIM Solutions

Prof. Jantien believes "realistic" and "feasible" are key terms to devise any digital transformation roadmap to enhance the adoption of integrated GIS and BIM solution in the AEC ecosystem. Digital transformation today, requires a well-defined framework to address the inter-connected challenges faced by the infrastructure industry. The framework should encompass key facets of digital interventions to overcome both technical and non-technical issues related to workflows, establishment of data infrastructure, development of standards and stakeholder coordination. Prof. Jantien adds, "The roadmap should deploy down-to-earth, incremental approaches starting with existing data to support realistic and feasible growth paths for a wide variety of organizations that can be adjusted and aligned along the way in all its aspects and that allows organizations to gradually introduce the required changes."
The success of a digital transformation strategy with integrated solutions plays a crucial role in achieving sustainable project delivery outcomes. Prof. Jantien highlights, "Integration of GIS and BIM for sustainable project delivery requires both BIM and GIS data to be treated and managed as critical assets themselves. An integration like this involves consideration of all aspects concerning data sharing (maintenance, interoperability, accountability, privacy, copyright, validation, ethical issues, work processes, etc.) to ensure the quality and trustworthiness of the data".

Although the data models of GIS and BIM represents the same real-world entities, they tend to serve different disciplines, which results in considerable

differences in their respective data semantics and geometric contents. However, Prof. Jantien believes the challenges associated with sustainable project delivery can be resolved by acknowledging these differences in the GIS and BIM environment, "by linking and synchronizing the models to each other (and with their real-world counterparts) and developing meaningful conversions solutions for specific use cases," she said.

EuroSDR GEOBIM project - Opportunities and challenges in integration of GIS and BIM

The EuroSDR GEOBIM project, a multi-stakeholder project, details the needs and issues of GeoBIM integration in Europe. Dr. Francesca Noardo, who leads the project, explains, "The project examines the opportunities and challenges for GeoBIM in Europe by developing two use cases to raise awareness and examine technical interoperability challenges." The project, completed in 2020, undertook an approach of compiling use cases to study the workflows involved in digital building permits and asset management using integrated GIS and BIM solutions.

The project developed over the period of three years includes specific case studies and interviews with operators and other stakeholders of the infrastructure lifecycle. Access to data from the design and construction phase enabled the project stakeholders and researchers to highlight the practice-related issues which hinder the uptake of GeoBIM solutions to address the multi-disciplinary challenges of the built environment. "The findings showed that use cases that required integration of GIS and BIM data are wide and complex, and the many components (including human and process-related) and data involved often contain many sub-issues and uncertainities," said Dr. Francesca.

The challenges discovered during the project highlight the need and requirement for further developments in the integration of GIS and BIM solutions, - for downstream applications. "This requires among others: the need of defining clear data requirements, for both GIS and BIM data, as most useful for the use and analysis of the models; their formal representation within the standardized model, most likely by means of a specific Model View Definition in case of IFC," added Dr. Francesca. The project ultimately helped the broader stakeholders to understand the coordination required between the stakeholders and users (multidisciplinary) and showcases the data requirements necessary for effective GeoBIM integrations.

GEOBIM, Digital Twins, and the Way Forward

"Digital Twin is a catch-all term that is used in many ways. The risk of this variety in used definitions is that implementation efforts are limited to solving technical sub-issues," said Prof. Jantien. However, this approach doesn't address the implementation, organization, coordination processes in the entire Digital Twin-data chain. "The GeoBIM domain has a lot to offer since this domain has already studied fundamental issues of data sharing and integration of data across domains," added Prof. Jantien.

Integrated GeoBIM solutions will help the construction industry overcome the existing fundamental issues of data sharing and integration of multi-disciplinary workflows, i.e., accurate spatial representation of the as-built data and dynamic project information updates for the stakeholders involved. These capabilities of GeoBIM solutions can lead to integration of data from extremely heterogeneous and dynamic sources and help standardize their respective geometry and attributes, which will subsequently improve productivity and efficiency.

Chapter 6: Non-GIS Users Perspective

The application of integrated technology solutions among non-GIS users is determined by the need for data-driven capabilities for project delivery , wherein different project data can be successfully integrated with minimal loss of information.

Traditionally, construction technology (ConTech) enterprises have released their unique platform solutions with functionalities aimed at specific industry challenges in different stages of the project lifecycle. Such solutions can be seen in the form of a project design and delivery software collection created for the development of 3D building models, visualization and analysis of drone data for topographic surveys, etc. Most of these platforms are mutually exclusive and require manual conversion of data to exchange and share among different project stakeholders. One key challenge that the non-GIS users face in construction project delivery is to manually feed location data into their project model. For instance, topographic survey data, like spot elevation, have to be physically entered in a BIM model to create a 3D representation of the project site.

Application of different platforms devoid of functionalities aimed at the integration of project information can cause workflow inefficiencies. Non-GIS users of such applications find it difficult to integrate siloed project information. This restricts the data-driven decision-making capabilities of construction companies and reduces the analytical capability of an individual platform. The need for data-driven capabilities for project delivery drives the application of integrated technology solutions (including GIS and BIM) among non-GIS users, wherein different project data (topographic, building information, etc.) can be successfully integrated with minimal loss of information.

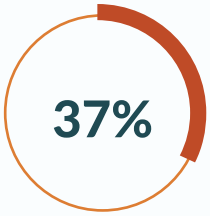
6.1. Integrated GIS and BIM workflow challenges

The aim of the integrated GIS and BIM solutions is to increase data—quantity, exchange, and conversion speed and advanced analytics. Industry-defined data standards for information exchange among stakeholders improve the quality, interoperability, and security of the project information, which is often sensitive. There is a scope for the development of a single source of truth (SSOT) for construction companies, which can support transparent project delivery. This requires a single platform capable of collection, analysis, and dissemination of project data. Such platforms require functionalities that can address workflow challenges across the project lifecycle.

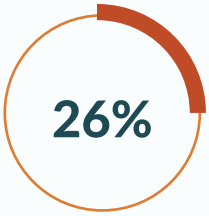
GIS and BIM integration involves technical workflow challenges that include transformation accuracy, semantic simplification, geometric information filtering, etc. One of the other core challenges is the lack of norms and standardization currently available for integrating GIS and BIM. Presently, such integration is conducted in project-specific scenarios, resulting in a lack of standardized integrated data management practices. Therefore, technical specifications of GIS and BIM data integration are yet to be unified, and the standardized practice remains to be developed. Despite new standards appearing in the industry for such data transformation and standardization (e.g., IndoorGML and InfraGML/LandInfra), these standards are at a nascent stage. For instance, LandInfra is much closer to 3D GIS models than to BIM models during implementation of the integration, while it can limit interoperability with BIM format.

Implementation of integrated GIS & BIM in project workflows

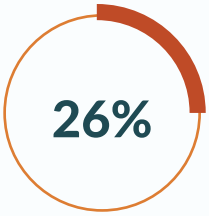
Design services professionals



Not used it but open to exploring its potential value



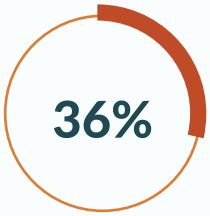
Not used it and not yet begun evaluating it



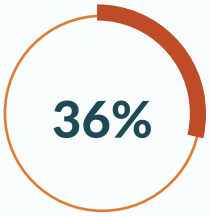
Not used it but are actively evaluating it

37 percent of the respondents related to design services said that they have not used integrated GIS and BIM solutions in their project workflows but are open to exploring its value

Construction services professioanls



Not used it but open to exploring its potential value



Not used it and not yet begun evaluating it

Not used it butare actively evaluating it

36 percent of the respondents representing design services professionals stated that they have not used integrated GIS and BIM solutions in their project workflows but are open to exploring its value. Alternatively, the remaining 36 percent said that they have not used/integrated GIS and BIM in their project workflows and have yet not evaluated the value proposition of using the solution in their project workflows. 18 percent of the respondents, on the other hand, have not yet used the solution but are actively evaluating the value proposition, the key benefits, and the challenges associated with using an integrated solution.

Owners and Operators

Not used it but open to exploring potential value

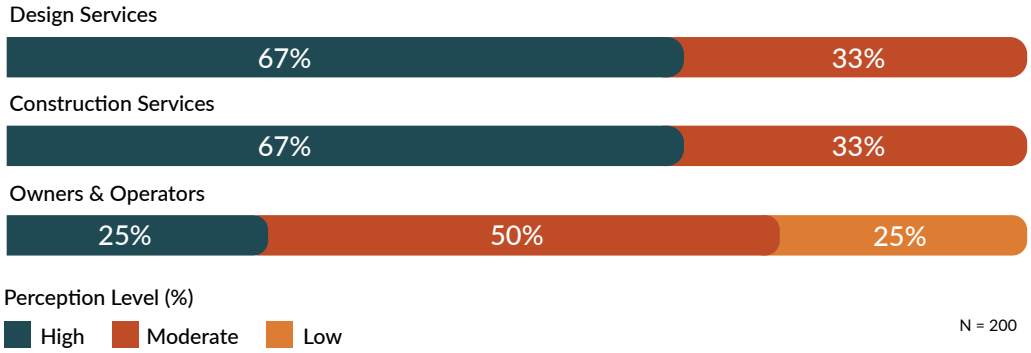
Not used it and not yet begun evaluating it

Not used it but are actively evaluating it

When it comes to owners and operators of construction projects, 56 percent of the respondents replied that they are not using integrated GIS and BIM solutions in their project workflows but are actively evaluating the value proposition of using it.

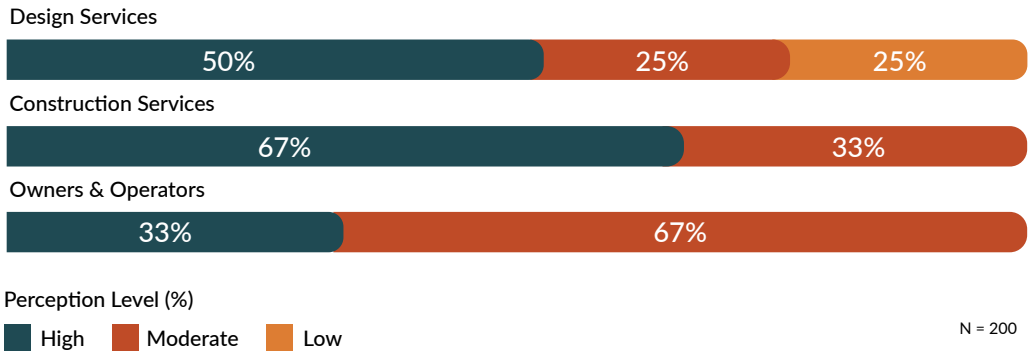
Figure 19: Primary challenges of integrated GIS and BIM workflows for organizations

No real applicaton



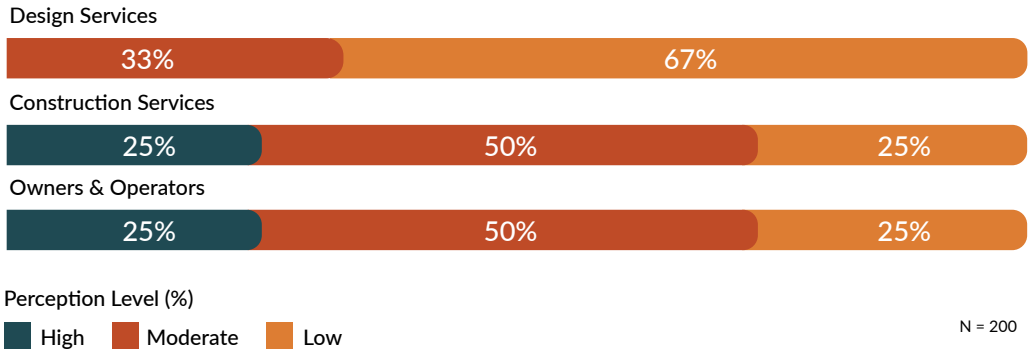
67 percent of non-GIS user respondents belonging to construction and design services perceive that the highest level of challenge in adopting integrated GIS and BIM workflows for construction projects is the lack of real application of the same. Digital solutions in construction projects turn out to be one-of-a-kind endeavors, aimed toward unique requirements for design and delivery approaches. However, these solutions are rarely repeated, and it's difficult to adopt them across many projects for complete digital transformation. This partially results in stakeholders perceiving no real application of advanced digital transformation solutions like an integrated GIS and BIM system, and instead, the stakeholders resort to traditional solutions.

Not enough demand from clients or other stakeholders



67 percent of non-GIS user respondents belonging to construction services perceive that the highest level of challenge in adopting integrated GIS and BIM workflows for construction projects is the lack of demand from clients or other stakeholders. Construction projects predominantly involve new sets of stakeholders/ organizations partnering together, and project teams in this regard are inconsistent. Contractors and subcontractors under construction services are more prone to these challenges. Survey respondents perceive the composition of project teams and demand from other stakeholders/organizations play a crucial role in the adoption of a digital transformation solution (including integrated GIS and BIM).

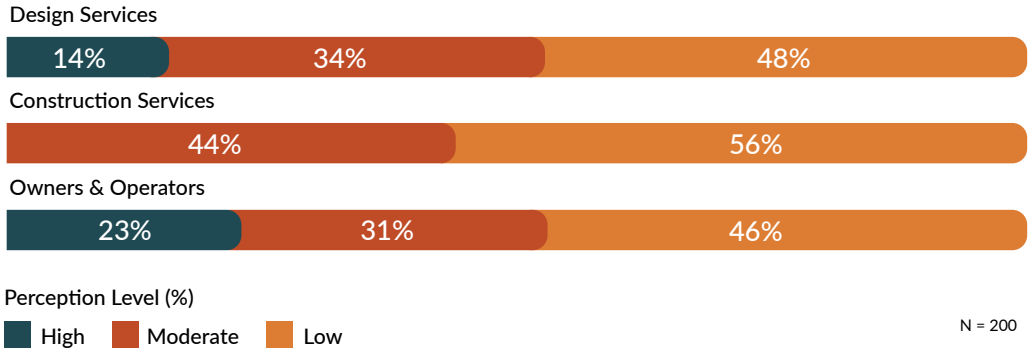
Poor interoperbility between GIS and BIM



33 percent of non-GIS users' responses from design services professionals believe that the highest level of challenge in adopting integrated GIS and BIM workflows for construction projects is poor interoperability between GIS and BIM platforms. Due to the difference in the platforms used by GIS and BIM, there are many challenges arising out of data interoperability, which includes data exchange/conversion, mismatch, and loss of semantic information, which are also bound to occur during the process of integration. The survey respondents who have design services often face such interoperability challenges in their project workflows.

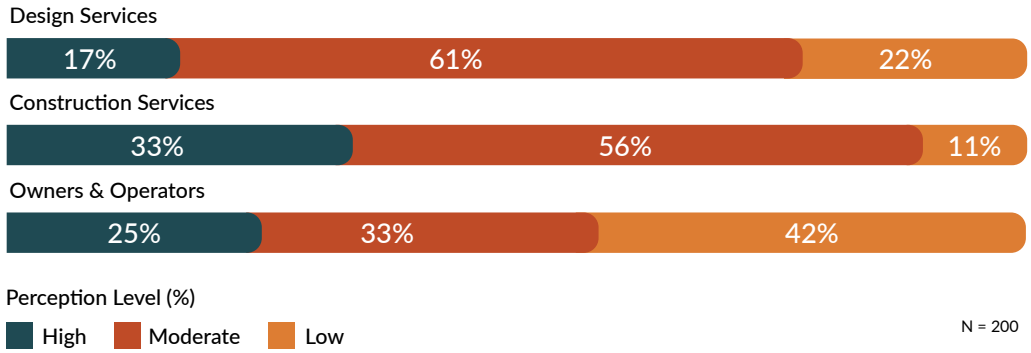
Figure 20: Primary impacts delaying adoption of integrated GIS and BIM workflows for organizations

Less necessity for smaller projects



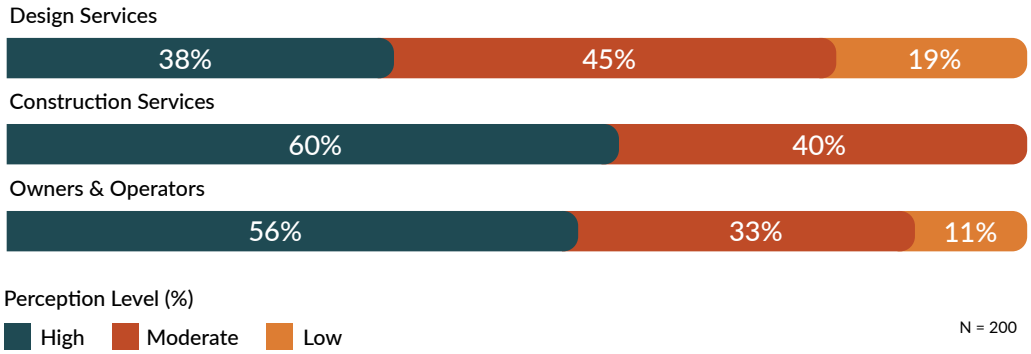
Among the respondents from construction services, 44 percent of non-GIS users perceive less necessity for smaller projects as the leading reason delaying adoption of integrated GIS and BIM workflows for their organizations. Many small and medium-sized project owners and other stakeholders are comfortable in 2D CAD/3D BIM solutions to overcome project challenges and improvise with these platforms to inspect project workflows and monitor project progress.

Lack of objective documentation of benefits



Only 33 percent of non-GIS user responses coming from construction services professionals perceive a lack of objective documentation of benefits to be the primary factor delaying adoption of integrated GIS and BIM workflows for their organizations. The understanding of return on investment for advanced solutions like integrated GIS and BIM remains scarce, and there are no studies in place to calculate initial investment, long-term outlays, and benefits. Stakeholders require documentation of benefits and ROI to quantify the impact of integrated GIS and BIM solutions for project workflows.

No demand from clients and owners



Among the respondents from construction services, 60 percent of non-GIS users believe that no real demand from clients and owners is the primary factor delaying adoption of integrated GIS and BIM workflows for their organizations. The demand from clients and owners remains low due to the lack of understanding of the economic value of integrated GIS and BIM solutions. Clients and owners seek a nuanced view of the integrated solutions' ROI to help them decide their strategy of investment in technologies.

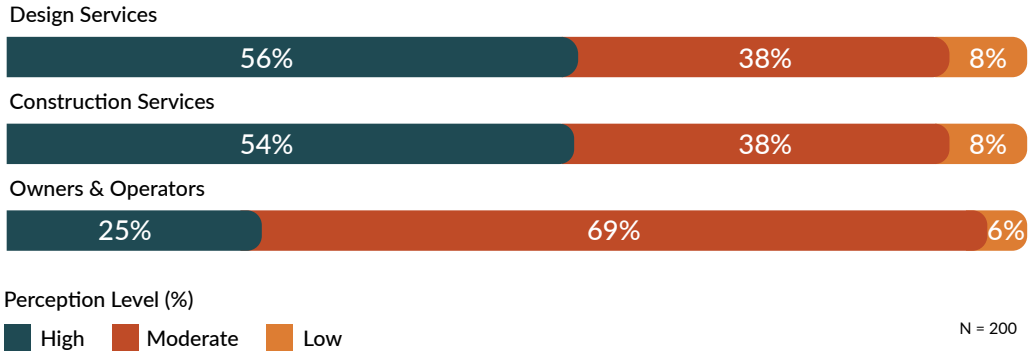
6.2 Scope for integrated GIS and BIM workflows

The scope of integration of GIS and BIM workflows is focused on data interoperability and information exchange between geospatial and building information data. An integrated workflow of GIS and BIM appears to have moderate to significant effects of ownership and competition in individuals. Such effects are precursors to design collaboration and have important implications for enabling benefits across the project lifecycle and value chain. Integrated GIS and BIM workflows include a process field for delivering constructed facilities with enhanced collaboration, coordination, visualization, project forecasting, and clash detection. The following survey responses indicate such benefits at the project and business levels of the project stakeholders.

6.2.1 Project-based benefits

Figure 21: Project-based benefits which might influence adoption of integrated GIS and BIM workflows

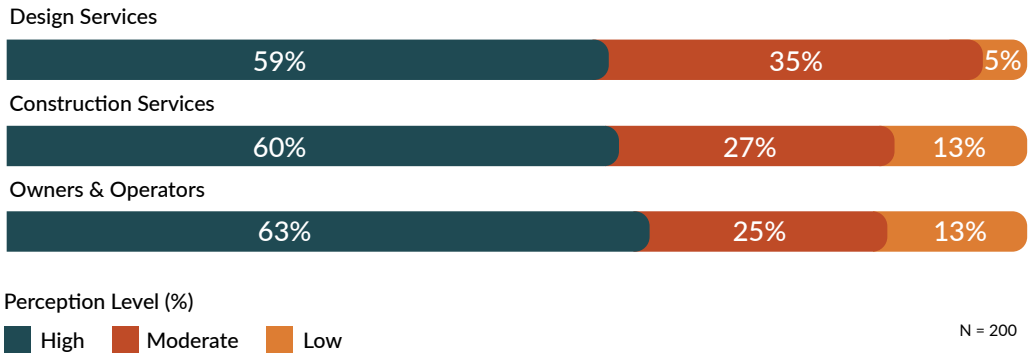
Improved project forecasting



Source: Geospatial World Survey, 2021

Among respondents from design services, 56 percent of non-GIS users perceive that improved project forecasting can be the highest level of project-based benefit. They believe such forecasting of capabilities helps plan project management based on prevalent uncertainties and increase project resilience. Addition of cost data to integrated digital solutions (like GIS and BIM) as the project progresses helps collect historical cost information on a granular level, which is difficult to achieve using 2D drawing methods. Integrated digital solutions have the ability to generate automated lists, such as volumetric information, and this helps achieve accurate project forecasting.

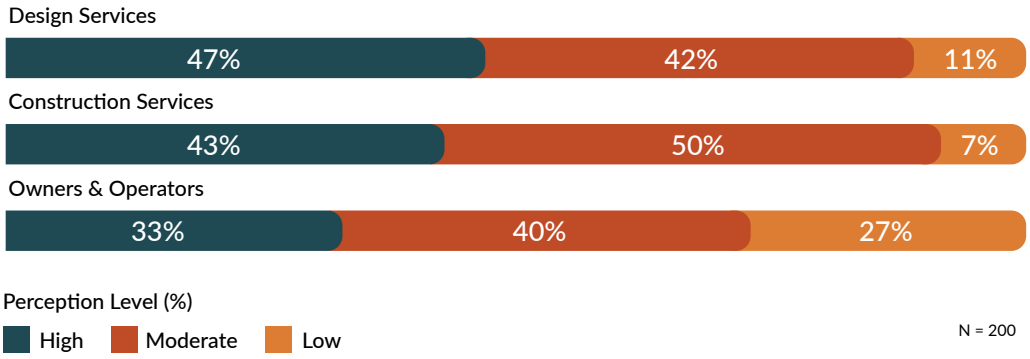
Improved collaboration across and within teams



Source: Geospatial World Survey, 2021

Responses from owners and operators suggest that 65 percent of the non-GIS users believe the highest level of project-based benefits can be achieved in the form of improved collaboration across multidisciplinary project teams.

Reduced number and need for RFIs and change orders

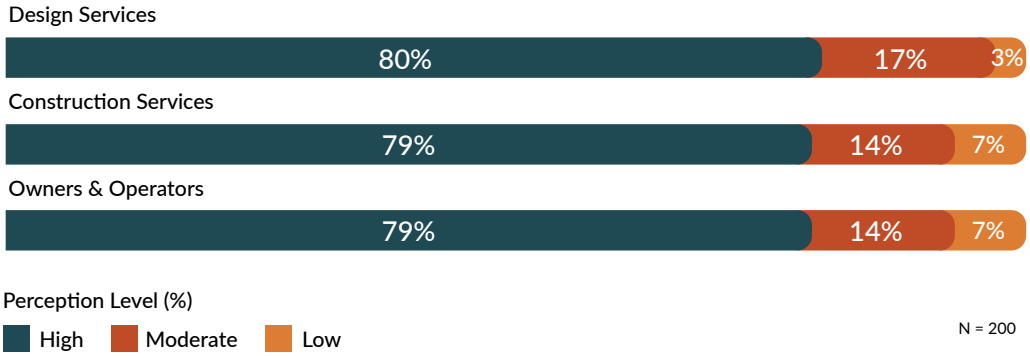


About 45 percent of non-GIS user respondents from construction and design services perceive that the highest level of project-based benefits can be achieved in the form of reduced number and need for RFIs and change orders. Construction professionals (including contractors & subcontractors) benefit the most with reduced change orders, resulting in avoidance of project delays and increased project cost.

6.2.2 Business-related benefits

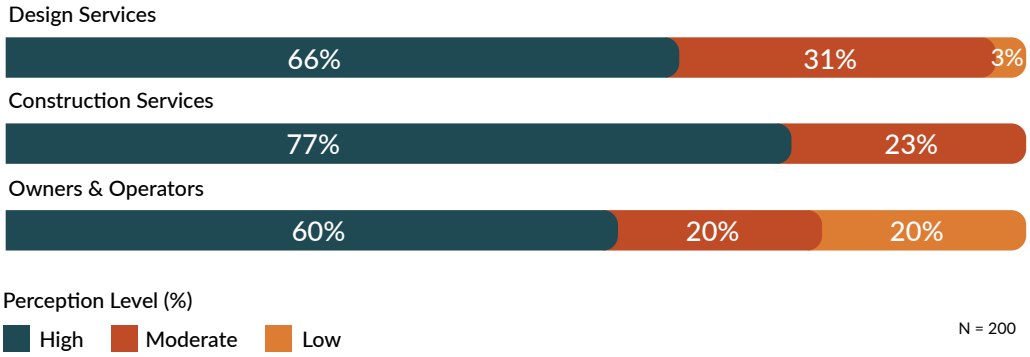
Figure 22: Business-related benefits which might influence adoption of integrated GIS and BIM workflows

Improved clients satifaction



Around 80 percent of non-GIS user respondents from both design and construction services, as well as owners and operators, indicate a high level of client satisfaction using integrated GIS and BIM solutions under business-related benefits.

Improved repeat business from existing clients



77 percent of non-GIS user respondents among construction services professionals perceive that the highest level of business-related benefits can be achieved in the form of improved repeat business from existing clients. This can influence adoption of integrated GIS and BIM workflows in their organizations in the future.

Improved productivity

Source: Geospatial World Survey, 2021

About 70 percent of non-GIS user respondents perceive that the highest level of business-related benefits can be achieved in terms of improved productivity. An integrated GIS and BIM solution for project delivery is associated with productivity across all project stakeholders. This is achieved through a common data environment in the form of an integrated GIS and BIM platform capable of construction information management that streamlines project management, from task coordination to team workflows.

The survey responses highlight various benefits of GIS and BIM integration. For instance, collaboration enables clash detection for all the project stakeholders involved to work on the same plan and design blueprint simultaneously. Moreover, using enhanced collaboration with integrated GIS and BIM, the process of decision-making becomes effective, and project stakeholders undertake timely decisions. Collaboration with integrated GIS and BIM unifies the project information, which drives all the stakeholders to utilize the same file format and project tools to exchange information, minimizing information loss.

In conclusion, non-GIS users predominantly believe that an integrated GIS and BIM solution leads to better project outcomes in terms of time, reducing the project cost by avoiding rework, and enabling an effective decision-making process. However, there are significant challenges outlined by non-GIS users in the application of integrated GIS and BIM solutions despite the major benefits. Some of the significant challenges include lack of process and standardization on collaborative techniques, data prerequisites, roles of technicians, and appropriate time to exchange information.

An integrated GIS and BIM solution enables collaboration and unifies the project information, which drives all the stakeholders to utilize the same file format and project tools to exchange information and minimize information loss.

THOUGHT LEADERS INTERVIEW

Integration of GIS and BIM Systems for Digital Project Delivery of AEC Project Lifecycle

Eric DesRoche

Senior Manager Infrastructure Strategy, AEC Design, Autodesk

"The legacy of GIS in engineering involves GIS being an informational layer, typically an aerial photograph or base map. While the engineers didn't necessarily understand the metadata and the rich information in the backend, such metadata often helped them make decisions and choose optimal solutions."

The AEC industry has gradually ramped up the digitalization of project information and workflows. The present-day conversation has changed despite the industry being historically slow in adopting technologies and digital solutions. Previously, the focus was on adding value to the project stakeholders and adopting BIM processes. However, with the advent of technology companies across the AEC value chain, the need for the preservation of accurate project information is now understood by project owners. The pandemic has positively impacted the degree of digitalization in construction projects, and it has accelerated the digital transformation in various construction processes.

Digital Project Delivery with an Integrated GIS and BIM Systems

'The conversation is changing now to Digital project delivery. The project stakeholders are convinced that ensuring proper implementation of BIM processes helps data flow across the entire life cycle for efficient project management,' says Eric DesRoche. Digital project delivery supports multiple use cases in infrastructure development and asset management depending on the kind of information you need - if you are an urban planner or a more detailed design data for an engineer or into the construction of that asset.

The legacy of GIS in engineering involves GIS being an informational layer, typically an aerial photograph or base map. While the engineers didn't necessarily understand the metadata and the rich information in the backend, such metadata often helped them make decisions and choose optimal solutions. 'Often, surveyors got stuck between the engineering and GIS worlds. They were the ones who figured out how the asset gets placed or how this information gets used when we take a BIM model and we go out in the field and start to build an asset,' indicated Eric.

The complexity of projects has been a primary driver of integrating technologies like GIS and BIM. 'How do we message it to the AEC industry? I feel it still remains a big challenge. And I think digital project delivery is part of this conversation,' he added. The industry has acknowledged the importance of making the right level of information available to the right stakeholder at the right part or phase of the life cycle. Nonetheless, there are many challenges in developing a capable system of providing seamless data across the project lifecycle. 'I think both Esri and Autodesk are trying to solve, and it leads us to many conversations around collaboration,' said Eric.

Role of Digital Project Delivery for Project Resilience and Sustainability

Sustainability in construction is the preparation of assets to be resilient in the face of project adversities and uncertainties. 'At present, we are struggling to find the resources to build these assets, let alone have to repair them or replace them in a short period,' said Eric. Historically, infrastructure asset longevity has been limited and required frequent monitoring and inspection for safety and repair, which resulted in the expensive upkeep of assets. 'I don't think people think that way anymore. We all want these assets to live much longer in terms of their lifespan,' he added. This requires careful preservation of project construction data alongside asset operation data to perform data-based decision-making for sustainable infrastructure asset management.

Infrastructure scenarios, including built-asset management (for instance, commercialization and repurposing of existing buildings), expansion of existing transport networks, etc., are today driven by the importance of sustainability. 'And how we deal with existing assets, as well as how we build new assets and how we make them more resilient to these natural hazards that we seem to occur more frequently?' asks Eric. 'The challenge to both Autodesk and Esri in this conversation is, what do you sell that you call sustainability? It's not like the other company has a product - sitting on the shelf, its a concept. ' he added. Sustainability, thus, requires project managers and asset operators to find a common core with which they can utilize tools or data sets for sound decision-making practices, which can help achieve sustainability goals.

Need for Common Language - Digital Project Delivery with Digital Twins

The advent of digital twins has been prevalent in other industries such as manufacturing, aerospace, etc. The AEC industry has only recently witnessed the adoption of digital twins solutions, and today the need for a common language and definition of digital twins has become critical. 'Worldwide, people are trying to ride this digital twin conversation, as though they invented it or it's something brand new because we all know, it's been here for a long, long time it's been in manufacturing for decades,' said Eric. Integrating the physical world with the digital world requires the significant application of frontier technologies such as IoT, sensors, scanning technologies, etc., for real-time data. This has increased the demand for a common data environment capable of collecting, hosting, and analysing datasets from these diverse technologies.

'Fundamentally, I think if we take a step back, whether we call it a digital twin or a metaverse, and at whatever scale, the ability for us (in future) is to be able to visualize the real world in a digital environment, and this is necessary,' emphasized Eric. Integration of GIS and BIM environment is a form of digital twin system that enables stakeholders to interoperate project data captured from different technologies across the project lifecycle. 'If it is necessary for AEC and we decided to call it a digital twin, so be it; but it needs to be understood that integration of technologies like GIS and BIM form the foundation of digital twin solutions,' he added. The role of accurate, up-to-date GIS information, an accurate BIM model, and the seamless integration facilitates project data to interact with each other helping stakeholders achieve their project goals.

Traditional Project Delivery Practices and the Way Forward

The application of geospatial and GIS-based solutions has traditionally been affiliated to geodetic sciences fields wherein the prevalence and importance of geographic elements of project site include coordinates, datum, etc. The advancement of digital solutions in construction practices and the surge in digitalization measures indicate the need to keep track of the technological evolution and frame appropriate project mandates by relevant government authorities and agencies. 'Be it the evolution of a digital twin, be it a metaverse, be it a convergence of BIM and GIS and other different data involved in the AEC industry -the government and authorities associated with the industry have to be steadfast in understanding and mandating the role of these technological transitions for the AEC players and its impact in the industry' concluded Eric.

Chapter 7: Integrated GIS and BIM Maturity Model for Project Workflow

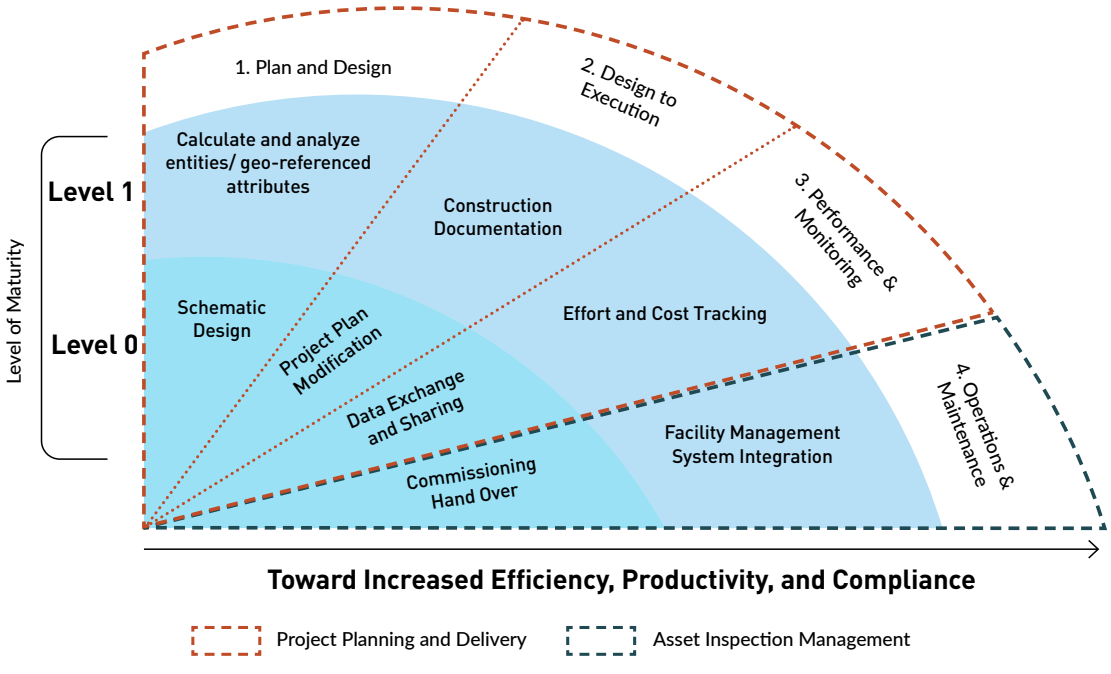
Assessment of integrated GIS and BIM maturity is critical for mitigation of siloed project data. Benchmarking and evaluation of maturity will help project delivery teams to efficiently meet project requirements.

Conventional project workflows in the construction industry reserve GIS for survey data and keep BIM solutions for planning and designing activities. Such siloed application of GIS and BIM data restricts project stakeholders' situational awareness, speed of reporting, and value derived from project inspection. Limited data flow between GIS and BIM solutions across the project lifecycle can inadvertently result in increased project costs for stakeholders to deliver and manage assets and facilities. The siloed approach by industry stakeholders across the project lifecycle has necessitated a benchmark to assess the level of integration of GIS and BIM solutions in project delivery. Today, assessment of integrated GIS and BIM maturity is critical to evaluate the ability of the project delivery team to perform and meet sustainable project outcomes efficiently. The maturity model as presented in figure 25 has been classified in ranges from Level 0 to 3, based on the application of integrated GIS and BIM solutions in terms of the advanced project workflows.

Level 0: Siloed project data | Level 1: Foundation project data integration

Maturity at Level 0 and Level 1 indicates the application of GIS and BIM solutions at a nascent stage. At this level, GIS and BIM data (mostly in silos) are utilized to assess project feasibility, assess on-site conditions, and strategize project plan. There is a lack of spatial data integration with BIM, but 2D CAD drafting (or drawing/ sketches) is utilized to generate schematic designs in the planning phase. Traditional project planning software used in the construction phase enables resource allocation and modification of project plans. However, at this level, the synergy between geospatial and BIM solutions during the construction phase of the workflow remains nonexistent. Performance and project progress monitoring includes tracking of effort and cost, which is taken care of through 4D/5D BIM solutions. In the operations and maintenance stage, basic project data is shared with owners and operators during hand over.

Figure 23: Integrated GIS and BIM Maturity Model (Level 0-1)



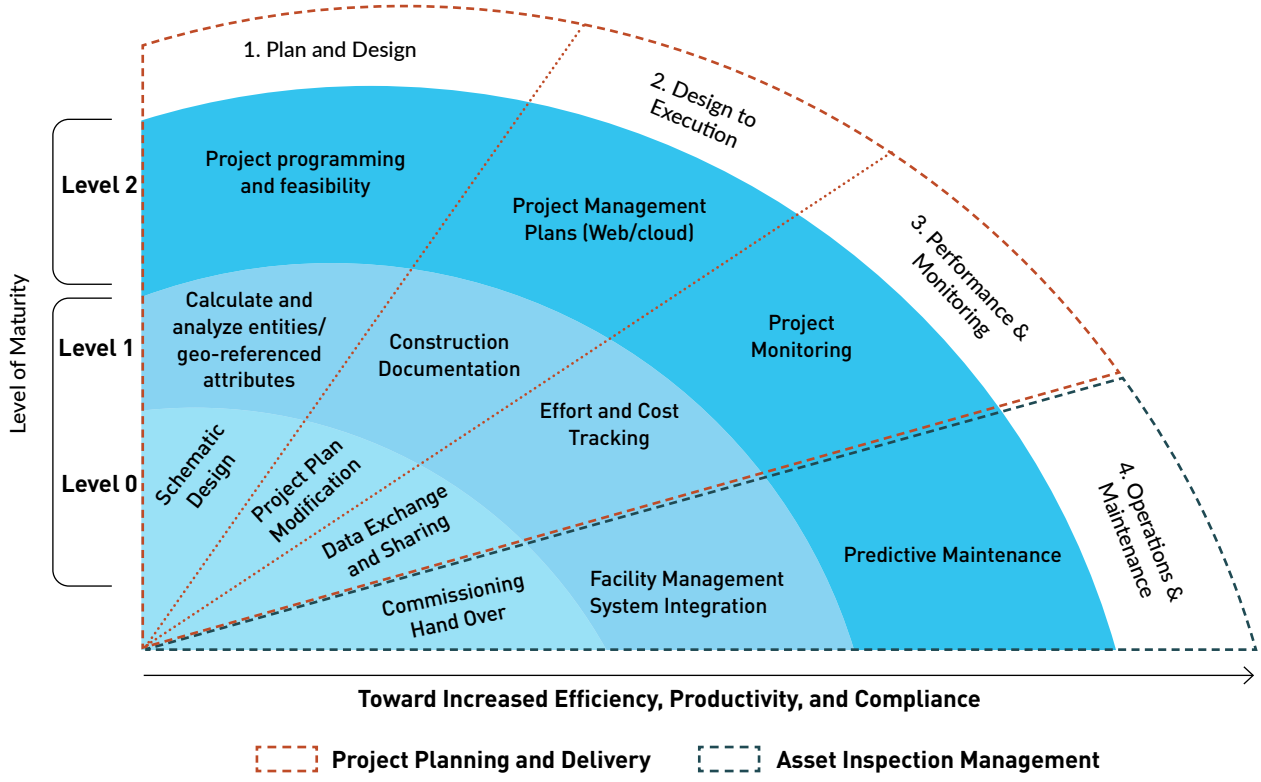
Source: GW Consulting Analysis

Level 2: Intermediate project data integration

Level 2 of the integrated GIS and BIM maturity model focuses on project delivery management, wherein information is exchanged between stakeholders and a suitable information hierarchy is developed (such as the Common Data Environment) for project coordination among various systems and project participants.

At Level 2, there is significant integration of geospatial data and application of GIS with BIM solutions across the construction lifecycle process. Project management plans are hosted in cloud/web platforms to facilitate multidisciplinary teams' real-time access to project data. Integrated technologies facilitate better collaboration, monitor/control the value chain, and transition toward more data-driven decision-making. Subsequently, companies can adopt 5D/6D BIM, advanced analytics, and digital procurement and supply chain management for advanced project management. An integrated GIS and BIM solution helps achieve quality inspection of on-site conditions (materials, work-force efficiency, and project management).

Figure 24: Integrated GIS and BIM Maturity Model (Level 0-2)

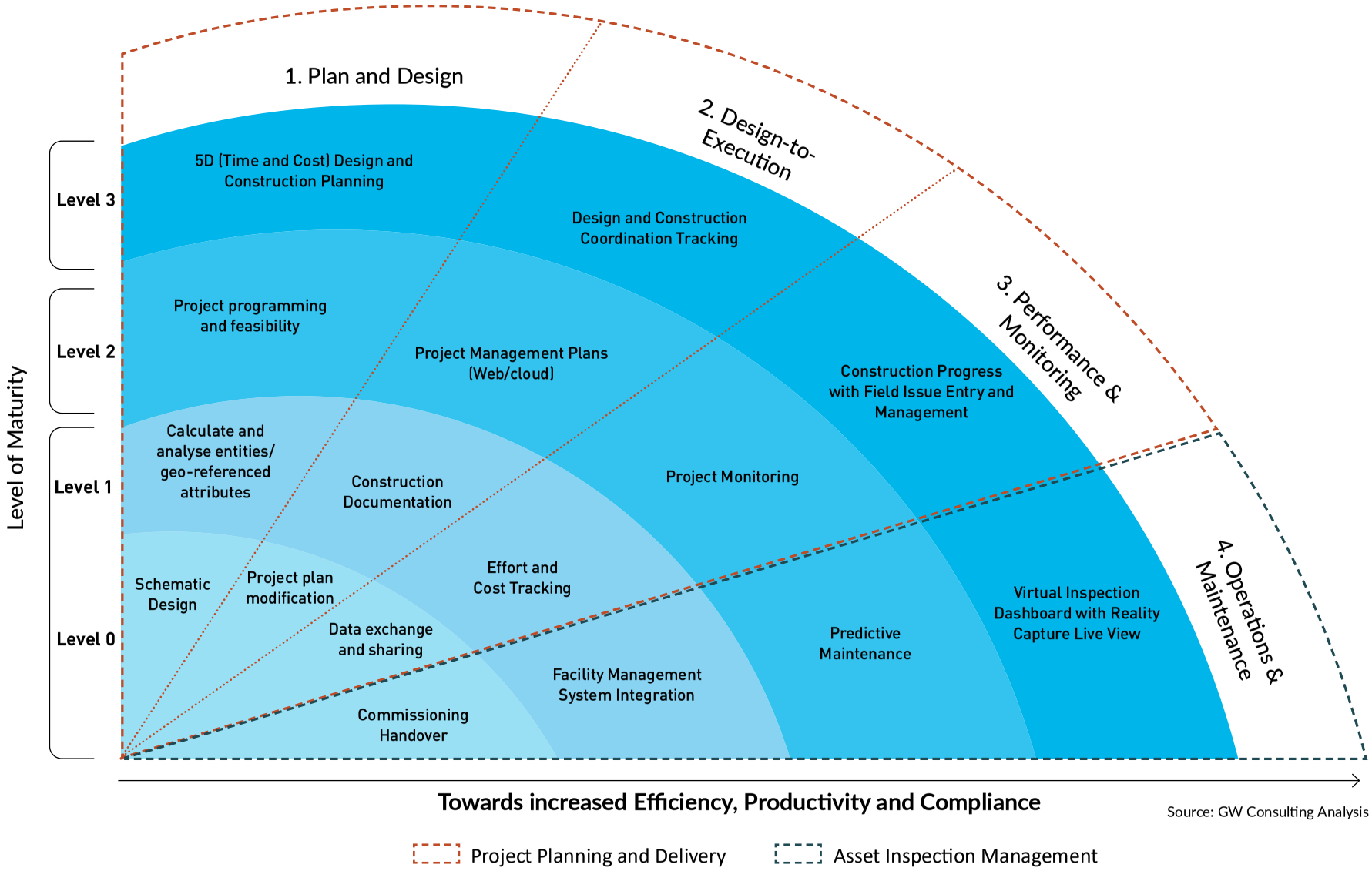


Level 3: Advanced project data integration

Level 3 is the advanced model of an integrated GIS and BIM solution. At this level, the project team can control, track, and monitor multiple projects from project conceptualization to hand over. Advanced BIM (5D/6D) is used alongside GIS for integrated project delivery and to achieve sustainable project outcomes including reduced project cost and duration and increased productivity. At this level, owners and operators and other team members can create an efficient flow of data for a collaborative approach using integrated GIS and BIM solutions. Stakeholders can simulate project strategizing, sequencing and scheduling, and risk assessment in the form of a common dashboard and manage their project portfolio.

Source: GW Consulting Analysis

Figure 25: Integrated GIS and BIM Maturity Model (Level 0-3)



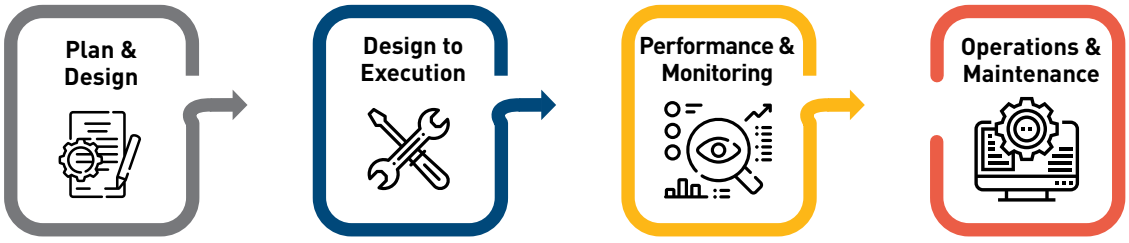
Source: GW Consulting Analysis

7.1. . Integrated GIS and BIM Maturity Model for project workflows

Project planning and design with integrated GIS and BIM solutions help users make optimal utilization of project data. With an increase in the application of collaborative project delivery models like Integrated Project Delivery (IPD), the risk of project execution is uniformly spread among the different teams. The traditional method of planning and executing work results in increased project duration and can lead to data loss during interchange of project information. Integrated GIS and BIM creates a center point for project information to support the process for smart design and execution. Also, contractors tend to work efficiently with precise data and details that 3D models offer, which can be facilitated through an integrated GIS and BIM platform.

In the post-contruction phase, the hand over of the completed project data to the owner and operator plays a crucial role in smooth handling of the facility management process. An integrated GIS and BIM model shared with owners can help them understand the locational attributes of the infrastructure asset, its properties, and its associated metadata. This consolidated data can be used to devise strategic operations and maintenance processes in the form of predictive maintenance and virtual inspection. The Figure 26 indicates the role of an intermediate to advanced level of application of integrated GIS and BIM across other project workflows.

Figure 26: Integrated GIS and BIM Maturity Model for project workflows



- Informed decision-making based on accurate geo-referenced information
- Integration of 2D CAD drawings and schedules
- Development of linkage between scheduled activities and respective drawings

- Simulate different scenarios based on project managements input
- Communicate project scheduling at varying levels of project execution
- Validate design and ensure robust and practical design to execution compliance

- Quality inspection and identification of the quality tolerance at early stages of project lifecycle
- Establish quality workflows for successful completion of stagewise project deliverables
- Track construction progress in near real-time and enable frequent risk assessments

- Enable advanced predictive modeling for engineers to perform a virtual stress test on infrastructure assets
- Identify weaknesses in their assets in order to strengthen resilience
- Data-driven decisions on expansion and/ or retrofitting measures

Source: GW Consulting Analysis

Project portfolio management with integrated GIS and BIM solutions enable project owners to manage data and documents from different project teams and accurately map risks and costs.

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List of Abbreviations

4IR	Fourth Industrial Revolution
AEC	Architecture Engineering and Construction
AI	Artificial Intelligence
AR/VR	Augmented Reality/Virtual Reality
BEP	BIM Execution Plans
BIM	Building Information Modelling
CAD	Computer Aided Design
CDBB	Centre for Digital Built Britain
CDE	Common Data Environment
DBMS	Database Management System
GIM	Generalized Information Management
GIS	Geographic Information System
GML	Geography Markup Language
GPS	Geographic Positioning System
GSA	General Service Administration
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical and Plumbing
ML	Machine Learning
NIBS	National Institute of Building Sciences
RFI	Request for Information
RoI	Return on Investment
SME	Small and Medium Enterprises
SSOT	Single Source of Truth
UI	User Interface
VDC	Virtual Design and Construction

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