



## Digital Integration of BIM, GIS, and Digital Twins in Structural Health and Infrastructure Monitoring

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### ABSTRACT:

Large physical structures such as city infrastructure, university campuses, farms and buildings, need to be monitored on a regular basis to ensure that they remain safe, efficient, and well-maintained. The traditional method of checking structures is paper clipboards and manual checks by facility managers. This was an older method, was slow, costly and sometimes would miss early signs of structural stress, equipment failure or material losses. Four interconnected digital tools – Building Information Modeling (BIM), Geographical Information Systems (GIS), the Internet of Things (IoT) and Digital Twins – have revolutionized the way we monitor physical assets today. BIM gives detailed 3D images of individual buildings, GIS gives maps of neighbourhoods and areas on a wider scale, IoT contributes with continuous live measurements from small sensors, and Digital Twins are a computer mirror of the world that is created and continuously updated. Combined, these digital tools enable engineers to track how safe a structure is, aid urban planners in locating healthcare clinics where there are elderly residents, automate watering systems for farms, and accelerate emergency fire response at a campus. But there are still some challenges that need to be addressed, such as software compatibility, expensive equipment, poor internet connectivity in rural areas, and data privacy issues. These obstacles can be overcome by making a set of software rules available for all to share, deploying inexpensive wireless sensors and providing simple computer displays. As a summary, the use and implementation of integrated digital twin systems offer a potential opportunity to significantly improve the safety, cleanliness and resilience of our buildings and communities for all.

**KEYWORDS:** Building Information Modeling; Internet of Things; Geographic Information Systems; Digital Twin; Construction Monitoring; Smart Cities.

### 1. INTRODUCTION:

Every day, millions of people live, work and travel within physical spaces like residential buildings, bridges, medical facilities, agricultural land, and school campuses. It takes a significant amount of ongoing effort, time and money to maintain these assets in a safe, efficient and sustainable manner. Engineers and facility managers have been using walkabouts with measuring tapes, paper forms and clipboards for many decades to inspect physical structures.

This was a traditional manual technique, though, which was time-consuming, less effective in identifying slight problems of structural stress, expensive and often resulted in postponing repair until after damage had taken place. With increasing urban population and climate risks, automated and real-time monitoring of building health and physical resources is critical for public safety and conservation of resources. In recent years, four sophisticated computer technologies have come to the fore to assist in the management of physical space: Building Information Modeling (BIM), Geographical Information Systems (GIS), the Internet of Things (IoT), and Digital Twins. BIM generates detailed 3D drawings of structural components, such as walls, beams, pipes and material characteristics. GIS is like a smart street map which depicts the wider neighborhood terrain and roads in the outer view. The Internet of Things is the technology of attaching small electronic sensors to any real-world object to gather real-time data such as vibration, temperature, tilt and water flow. All three tools are connected via a Digital Twin, which is a real-time computer simulation that reflects the actual world in real time.

Although these technologies have definite advantages, most organizations are not using them in clusters. In fact, a construction crew could draw a bridge using 3D graphics, but only have paper records showing what each column of concrete looks like when it is finished years later. Likewise, urban planners could look at a map of the city's streets without making a connection to the real-time indoor air sensors or building health monitors.

This lack of technology connection leads to data silos, loss of data and delays in emergency responses by various sectors. In order to address the above issue, this study aims to combine the latest research conclusions from five key journal papers to offer a synthesis digital integration model. This study aims to uncover and map out the benefits of integrating BIM, GIS, IoT and Digital Twins in the context of structural health and resource tracking, as well

as exploring practical applications on construction sites, healthcare planning, farming and university campuses, while also identifying and analyzing common technical challenges, such as software communication errors, high set-up costs or privacy concerns, and outlining future steps towards safer, smarter and more resilient communities.

## 2. LITERATURE REVIEW

There has been a number of recent studies that have attempted to evaluate the advantages of the use of digital technologies for various fields of reality. A thorough literature search was performed by Liu et al. (2025) by screening 87 related articles. They discovered that by using 3D building drawings, street maps, and tiny wireless sensors, the project leader can track building materials before they are delivered to the site, optimise the use of machinery and avoid collisions between workers and trucks on busy job sites. Dong et al. (2026) conducted a study on one hundred fifteen publications pertaining to smart medical facilities from an urban healthcare planning perspective.

These researchers found that integrating city mapping with hospital floor plans and real-world environmental sensors allows city planners to locate medical clinics closer to elderly and lower-income residents, thereby doubling the access to care for walking residents in neighbourhoods where the study was conducted, without compromising indoor hospital air quality. Digital twin in agriculture and higher education brings significant performance improvements as well. 48 studies were reviewed by Subeesh and Chauhan (2026) on agricultural digital twins.

They showed that by linking the field sensors to artificial intelligence, farmers can identify the disease on crop leaves with a 95 percent accuracy rate and estimate the amount of water required by the crops in the field for the next day with a 95.85 percent accuracy rate, starting automatic drip irrigation and saving water and electricity for the field. In university campuses, Tong and Chen (2025) tested the digital twin platform in four hundred buildings in the campus. University managers could seamlessly link room sensors, 3D building models and campus maps to one main computer display, automatically triggering the creation of repair tickets, monitor energy usage and pinpoint emergency fire alerts in real time in 3D.

Azari et al. (2025) in their technical computer engineering paper, resolved a significant software bottleneck in which they created a 3D building drawing system that would freeze a standard digital city map. They have built a clever algorithm that removes the walls inside the 3D models to make the files smaller, and keep all the room data in graph databases to ensure that the web can be viewed without any issues. The benefits of long-range sensors and collision warnings on construction sites were also pointed out by earlier studies by Teizer et al. (2020) and Jo et al. (2019).

Though these individual advances, there is still a gap in the research: most studies are carried out on a single use, instead of having an easy-to-implement, multi-scalar framework that includes the ease of use, resource tracking, and structural health across various sectors. This paper fills that gap by providing a single synthesis that is easy to understand and follows a unified approach to real-time monitoring.

## 3. CONCLUSION

The paper reviewed and summarized results from five key research studies around Building Information Modeling (BIM), Geographical Information Systems (GIS), the Internet of Things (IoT), and Digital Twins. It explored the potential for a seamless system that integrates 3D building models, larger city maps and real time wireless sensors to monitor building health and physical resources. The key observations reveal that integrated digital twins are as follows: They greatly enhance the efficiency of daily work; They reduce the risk of accidents occurring on construction sites; They expand the access of the elderly to healthcare clinics; They automate crop watering on farms and speed up the response to emergencies in campuses. In addition, the use of technical methods such as projection of the hidden faces of 3D buildings decreases the computer file size by a factor of 24, enabling the smooth display of the 3D building on typical web displays. The importance of these results is that they enable the development of a unified multi-purpose technology framework connecting isolated technology silos. Future research efforts should be directed towards the adoption of simple open standards for software, the creation of more affordable wireless sensor technology, assurance of data privacy, and adaptability of the computer screen for use by non-technical managers to maintain safer, smarter and cleaner infrastructure.

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