Application of GIS-BIM Integration for Mega Project Construction Equipment Management

With the advances in the field of information technologies, construction industry has started taking advantages some of these developments. GIS & BIM are the tools used to manage construction projects and can improve the construction planning and design efficiency by integrating locational and thematic information in a single environment. There is huge potentials of using 3D-GIS and BIM by integrating together in managing construction project activities. All mega construction equipments can be optimally used and controlled using integrated GIS-BIM technology.

About GIS and 3D GIS & BIM

Geographic Information Systems (GIS) is an appropriate technology for managing construction projects and can improve the construction planning and design efficiency by integrating locational and thematic information in a single environment. It provides capabilities to solve problems, involving creation and management of data, integration of information, visualization and cost estimation to which most of the construction management software is lacking. In construction management, GIS leads to the improvement in collective decision-making among planners, designers and contractors. A large number of data involve in planning and design phases of construction projects are usually stored in various forms such as drawings, tables, and charts. These data need to be sorted out properly to ensure it can be retrieved and manipulated by related parties when needed. Database in GIS environment can provide a wide range of information to construction industry with a mechanism for
rapid retrieval and manipulation capabilities. Integration of schedule and design information makes it easier for the project manager to monitor and control the construction progress. Several tools for construction industry using GIS as suggested in many literatures and their applicability has been demonstrated with suitable case study. However, the practical usefulness of these developed tools in construction industry is still doubtful and the implementation on real world project in the industry is rare. Further, most of the reported works uses different software in combination with GIS software. Although, CAD technologies provide visualization capabilities, but three dimensional (3D) GIS technologies could not only provide advance visualization techniques (e.g. fly-through with query on-demand and way-finding) but also stores geometry’s topological information and being able to perform true 3D analysis, which is not yet possible in CAD technologies.

Whereas, Building Information Modeling (BIM) represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users’ needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility. Refer Figure 1 for BIM modeling.

![3D Architectural Model](image1.jpg) ![Integrated Structural and MEP Model](image2.jpg)
![Site Logistic Planning Model](image3.jpg) ![Quantity Estimates](image4.jpg)

**Figure 1: Different Components of a Building Information Model**

**Why 3d-Gis and BIM integrationin Construction Management**

To-date, two dimensional (2D) GIS is still being utilized in various engineering projects especially in managing construction industry but its complete potential to expand into another dimension, the 3D-GIS for better data manipulation, analysis and visualization using 3D data sets has not been realized yet. 3D-GIS, known as an ideal tool for representing 3D geometry, semantic as well as topology, has been gradually utilized in many disciplines. 3D-GIS provide several benefits to the construction industry, in which most of the construction management software are lacking. It may improve the construction planning and design efficiency by the integration of 3D spatial and attribute information in single environment. In general, managing construction is quite demanding and needs rapid spatial information on the spot even using the conventional 2D GIS. It would be great if a construction project is managed by decision makers using 3D-GIS where the required information is in the form of 3D display of a dynamic 3D spatial query and analysis. Geographic information systems (GIS) facilitate the analysis of large amounts of spatial data used in the process of location optimization for various construction equipments such as tower cranes. In addition, integrating analysis results from GIS with 3D visual models enables managers to visualize the potential conflicts with all such mega equipments in great detail. Building Information Modeling (BIM) helps managers to visualize buildings before implementation takes place through a digitally constructed virtual model. Hence, the integrated GIS-BIM model starts with the identification of feasible locations for defined mega construction equipments. The method presented is based on previous works using “geometric closeness” and coverage of all demand and supply points as key criteria for locating a group of mega equipments. Once the geometry of the construction site is generated by the BIM tool, the model determines the proper combination of tower cranes in order to optimize location. The output of the GIS model includes one or more feasible areas that cover all demand and supply points, which is then linked to the BIM tool and generates 3D models to visualize the optimum location of all the mega construction equipments. As a result, potential conflicts are detected in different 3D views in order to identify optimal location.

**Use of GIS and BIM technology in managing Tower Crane-A mega construction equipment**

Tower cranes are considered as the centerpiece of construction equipment in building projects. They play a key role in transporting a variety of materials vertically and horizontally. The efficiency of tower cranes largely depends on their type, number and location. As the number of work tasks and the demand for tower cranes increase, planners may experience difficulties in making an appropriate decision about the optimum layout of tower cranes. A poor decision, however, is likely to have significant negative effects, which will lead to additional costs and possible delays.

On typical construction projects, the selection of the appropriate crane can have a significant influence on the cost, time and safety of construction operations. Due to this role, many models have been developed over the past 20 years for solving tower crane problems, generally
related to financial and operational efficiency. Some of the literature addresses safety issues associated with tower cranes, whereas others rely on improving the crane operation, or involve cost forecasting models. Most crane location-related studies relied on the use of mathematical programming formulations. Some of these methods were designed to minimize the total crane transportation cost. Researchers have also developed mathematical models in an attempt to decrease total crane transportation time.

The location and type of tower cranes are closely related to the shape, position and spatial characteristics of the loads and obstacles. This spatial data is mainly used in the process of location optimization for tower crane(s), which is possible to be analyzed in large amounts by geographic information systems (GIS). The optimal number of tower cranes is a function of their locations and the geometric layout of loads. On the other hand, GIS support the wide range of spatial data that can be used to support location problems. The advantage of GIS-based methods is that they directly use spatial aspects of the construction site and display output in a suitable form to the user. For these reasons, GIS is found to be useful for such purposes. In addition, visualization techniques can be used to further enhance the functionality and integrity of GIS models.

However, due to the limitation of GIS tools in automated drafting and lack of semantic information about building elements, one can utilize different visualization tools. Regarding the distance between the crane’s cab and load location, finding an optimal place for the tower crane plays an important role in improving operator’s view. To respond to this need, it is appropriate to model the operator’s viewpoint through the use of Building Information Modeling (BIM). Furthermore, visual representation can be extended to monitor the crane’s movements and to prevent the collision of tower cranes operating in a shared work zone. In reality, the number of structural elements (obstacles) increases with construction progress. Cranes must not only avoid collisions with these elements that have previously been installed but also need a collision-free path for each subsequent element to be installed. The snapshots generated by BIM are capable of appropriately representing the changing construction environment.

Integration Of GIS And BIM

While BIM systems focused on developing objects with the maximum level of detail in geometry, GIS are applied to analyze the objects, which already exist around us, in most abstract way. Therefore, to visualize existing topography and a new facility to be developed together we need more research on integrating the data models of BIM and GIS. Several studies have been conducted to explore the application of GIS technology in BIM environments and BIM models in the geospatial domain. For instance, some researchers investigated the application of BIM in a geospatial context in order to improve the transfer and representation of information between these two domains. Another research established a prototype system to demonstrate the feasibility of BIM models to support indoor GIS applications. Researchers on the other hand, recognized the need to integrate different IT technologies, such as GIS, RFID and digital building information, in one reliable platform for emergency response management.

However, aforementioned research efforts have focused on either BIM or GIS. Real integration of BIM and GIS is achieved by using the strengths from both the BIM and GIS world in the context of the other, which has been recently proposed. Before integration approach is developed, the advantages and differences between BIM and GIS should be considered. To develop a BIM-GIS model, it is essential to bring the benefits of both technologies together into a single comprehensive model. GIS builds upon existing information and objects; so, BIM should be used to create the building information. On the other hand, the lack of spatial analysis capabilities in BIM underlines the need for utilizing GIS. The major incompatibilities that exist between the technologies have been provided in Figure 2. Integrating these two technologies depends on the assumption that there are applications from both domains, which can maximize the value of both.

<table>
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<tr>
<th>Modeling Environment</th>
<th>GIS</th>
<th>BIM</th>
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<tr>
<td>Mainly focus on outdoor environment. An outdoor activity may need to be positioned in GIS.</td>
<td>Focused mainly on indoor environment. Outdoors applications are limited to the outside of buildings. 3D modeling of site utilities and terrain modeling are also available in BIM.</td>
<td></td>
</tr>
<tr>
<td>Reference System</td>
<td>Geospatial data is always georeferenced. Objects are defined in a physical world with global coordinate systems or map projections.</td>
<td>BIM objects have their own local coordinate system, for example at the left corner of the building.</td>
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<tr>
<td>Details of Drafting</td>
<td>GIS builds upon existing information and objects. It covers a large area with less detail and in smaller scales.</td>
<td>Drafting capabilities of BIM are utilized to develop large scales with higher level of details.</td>
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<tr>
<td>Application Area</td>
<td>GIS is focused on urban and city areas.</td>
<td>BIM is rooted in the building and its attributes.</td>
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<tr>
<td>3D Modeling</td>
<td>GIS capabilities are limited to simple 2D shapes, Experimentation with 3D in GIS is in an early stage.</td>
<td>BIM is unique in its ability to work in full 3D environment. BIM has a rich set of spatial features and attributes.</td>
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Figure 2: Incompatibilities between BIM and GIS
Figure 3: Flowchart of GIS-BIM optimization location model
Enabling interoperability at the semantic level is an important issue for the link between BIM and GIS. The key to conducting interoperability at the semantic level is to make sure that the relationship between two different disciplines is maintained during data transfer. To solve this problem, one researcher suggested a mechanism that automatically transforms the relationship from one discipline to the other.

Efforts to enhance interoperability within the AEC industry and GISs have been made during the last two decades. Among the most prominent of these models are the Geographic Markup Language, GML, and the Industry Foundation Classes, IFC. The Open Geospatial Consortium (OGC) introduced the GML for data interoperability in the geospatial community. GML allows complete data transfer between different databases and application software, which results in application scheme.

An Approach for Optimised GIS-BIM Model- A Case Study

The methodology outlined above was employed to determine the needed tower cranes and their optimal locations for a commercial building project. The project is a commercial complex located in Tehran, Iran, consisting of 6-story shopping mall, entertainment complex, underground parking, and recreational facilities with a site area of 8 acres (32000 m2) and a total gross floor area of 128,200 m2. The location in an urban area with limited workspace and its proximity to congested throughways are factors that require the contractor to utilize tower cranes. In order to demonstrate the model’s capabilities, three different types of tower cranes are taken into account when identifying the optimal locations. Although the crane’s prices are not included in the table, the model is capable of considering different combinations of tower cranes to minimize the total cost. In this case, after grouping the tasks based on different types of cranes, the process starts with assigning a tower crane to a task group and generates the remaining task groups based on different types of cranes. The process is repeated for all tower cranes, until the best crane combination that has the minimal cost is reached. Figure 3 shows the flow chart for the model and Figure 4 shows the optimal location of tower cranes achieved through integration of GIS-BIM concept vis a vis with the proposed one. It can be seen that how application of this technology helped in efficient management of the mega construction equipments in this case it is tower cranes. Figure 5 gives a general view of the case study project under construction.

Conclusion

This article shows the new approach for integrating GIS and BIM that enables managers to visualize the 3D model of tower cranes and other mega construction equipments in their optimal locations. Identifying minimal number and optimal location of such mega equipments, especially when they operate with overlapping work zones, can create a challenge for managers. This process comprises a variety of spatial data that can be presented in the 3D visualization model. Thus, there is a need for a new tool with spatial analysis and visualization capabilities within a single environment. Integrating GIS with BIM seems to be an appropriate approach to solve such problems. The implementation of the proposed model reveals the feasibility and practicality of using GIS for managers who have access to a BIM model with the full range of material information. This model can be applied as part of a site layout process and, using scheduling functionality provided by many BIM tools, allowing visualization of the sequential construction of the building. The practical application of the model will become even more useful in the future, as software applications support data standards and various information exchange efforts such as IFC. Integration of GIS and BIM, however, still comes with some limitations. The developed method suffers from a certain lack of interoperability between GIS and BIM. Although the use of commercially available tools in the model enables the user to exchange data between the BIM and GIS domains, it still requires him or her to have knowledge about both systems and their functionalities. In order to fully integrate GIS and BIM, future work should focus on providing more interoperability at the semantic level. The employment of mobile computing technologies is another potential area for future studies. This will extend the applicability of the model to real projects.
Reference