INTEGRATION OF GIS AND BIM TECHNIQUES IN CONSTRUCTION PROJECT MANAGEMENT – A REVIEW

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ABSTRACT:

Construction industry has become much more complex due to the large number of people and documentations involved. As a result, the full process of building construction may involve with many different types and format of information that needs to collect, document and share. In order to share this information between architect, contractor, construction manager, etc., there are need to develop a common model that can document and store this information in single platform. BIM represents a series of parametric objects that composed together to form a building model which carries all information includes their physical and functional characteristics and project life cycle information. Since BIM represent the detailed geometrical and semantic information of the building, the application of GIS is needed to manage the construction project's information resources. GIS can use information from many different sources, in many different formats and can link data sets together by common locational data such as coordinate or postal zip code. Besides, GIS can use combinations of data sets to build and analyze integrated information and also can convert the existing digital information into a form that meets the user's need. From this point of view, GIS can complement BIM function in order to develop a systematic platform for construction purpose. Finding of this study, there are some drawbacks in this technique especially in the construction application in term of data sharing, data integration and data management. Furthermore, the integration of GIS in BIM is studied and potential techniques are shown to overcome the drawbacks of the construction application.

1. INTRODUCTION

Construction is a process of work by creating building or infrastructure to support the requirement of society. This process starts from the planning, design, financing and continues until the project is ready for use include problem recognition to the implementation of fully operational solution. Construction can be referring to the several sectors such as building (residential and non-residential), infrastructure (roads, bridges, public utilities, and dams) and industrial (process chemical, power generation, mills and manufacturing plants).

Building construction is a process of adding a new structure to real property whether for existing or new building. This process was involved with complex documentation that call as construction documentations (CDs) that can be divided into several components such as:

i. A graphical representation of the building (which includes 2D floor-plans, elevations and cross-sections, and possibly 3D CAD models)
ii. A set of specifications that dictate the quality of the components and finishes of the building
iii. A legal document that highlights the project expectations.

Through CDs, the construction management team is able to gather information about the building (such as design information, geometric properties, etc.), add information related to constructability, resources, sequence of work, schedule, and document the construction process in fulfilment of the requirements of the legal contract (Dib et al., 2013).

Nowadays, the different level of technology used among users has produced a variety of different information and format that can be documented in the whole process of building construction. Because of that, the project information and documentation is not in a systematic way and it give an effect on the information sharing system among other users.

According to Dib (2007), the construction industry is suffering from "islands of information syndrome" due to the lack of connectivity between various participants and functions which is affect the ability to maximizing the usage of computer technologies. In order to overcome this problem, Industry Foundation Classes – IFC, has been develop. IFC is a standard data structures that allow computer application to exchange project information about construction project. Besides IFC, Object Oriented Computer Aided Architectural Design (OOCAD), and Life Cycle Management (LCM) is also some approaches that can improve building information modeling and communication in Architecture, Engineering and Construction (AEC) industry.

Architects, engineers, contractors, owner, and project manager face many obstacles due to the various type of information and data format used during construction project life cycle. This information can be categorized into graphical and non-graphical information. In order to overcome this obstacles, both graphical and non-graphical information need to be maintained in a single environment. When this happen, all information such as drawing, layouts, routes, blueprints, execution schedules, cost estimation and specifications will be consistent with each other and it make data updating process become much easier and consistent.

Building Information Modeling (BIM) provides capabilities to resolve this problem which contains the integration and analysis of a large volume of graphical and non-graphical construction information. It affords the ability to overcome the existing weakness in construction industry. BIM defines three-dimensional (3D) geometry, attribute information regarding geometry, spatial relationships and semantics. It is facilitating information exchange and interoperability during the entire building lifecycle. Figure 1 show that the process of BIM in construction project application.

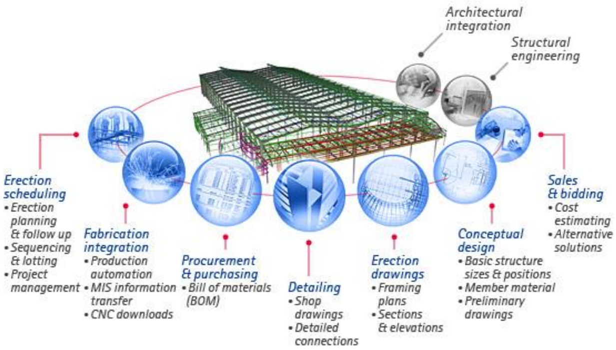


Figure 1. BIM work flow in construction project. (Source: http://www.tekla.com/de/bim-forum-2013/bim.html)

BIM usually used in new building construction but rarely in management on existing building. Bansal (2012) state that the main focus in BIM is on indoor planning tasks such as in relation to space use and energy consumption like heating, ventilation, or air conditioning. While Geographic Information System (GIS) facilitates mainly for outdoor planning tasks such as site selection, jobsite planning, delivery of goods and services, and emergency evacuation operations. BIM represents detailed geometrical and semantic information about building elements and their main emphasis is on interactive 3D graphical modeling to serve the needs of automated drafting and attribute linking with features. On the other hand, GIS has less emphasis on drafting and more on digital terrain modeling that facilitates spatial analyses and used to manage urban management task, disaster management, delivery of good and services, and cityscape visualization. This is because of GIS provide high level and volume of geospatial information and can give the detailed geometrical and semantic information about the building in order to become facilitated through better automation. There are certain functional overlaps between GIS and BIM technologies in the area of spatial information analysis on the other hand, there are many differences such as in term of visualization, geometry information storage, and 3D analysis performance (Bansal, 2011b).

BIM lacks capability in geospatial analyses like: route planning, site selection, planning for delivery of construction material, assure construction safety, and site layout planning. Therefore, the geospatial capability provided by Geographic Information System (GIS) has its own strength for the construction industry (Miles and Ho, 1999). For example, in the construction sequence simulation and schedule review of projects like gravity dams where topography plays a major role could not be done with commercially available construction planning tools because they lack in the geospatial capabilities provided by GIS (Bowman, 1998). Because of data interoperability among BIM and GIS is still a problem, the construction industry is looking for geospatial analysis capabilities in GIS. Figure 2 below show the system architecture for BIM/GIS interoperability platform. In this figure, it shows that a complicated system is required in order to create the function of data interoperability between BIM and GIS.

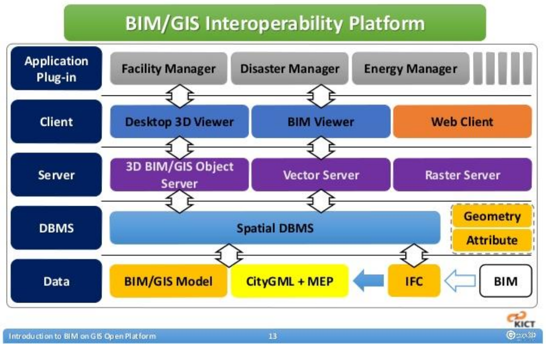


Figure 2. System architecture for BIM/GIS interoperability platform. (Source: http://www.slideshare.net/slhead1/design-and-development-of-bim-on-gis-interoperability-open-platform)

Sustainable construction is an important issue for sustainable development because of the world's population increased. Construction professionals and architects play an important role in sustainable development, for this they need a tool to evaluate environmental impacts of a construction project on urban microclimate and outdoor comfort before final approval (Pham et al., 2007). GIS is a tool for sustainable construction planning and makes it possible to have a better understanding of the urban environment. It also helps urban designers to simulate and evaluate environmental impacts of their project.

The current state of GIS application in construction industry is GIS was used to improve the construction planning by integrating location and thematic information in a single environment. Its capability to store a large database may be utilized to maintain construction data in digital form. Besides, GIS platform also allow the manipulation/updating of schedule, editing components, and topography modeling in a single environment previously the major hurdle in successful use of 4D technologies. Figure 3 show the involvement of GIS application in facility life-cycle management.

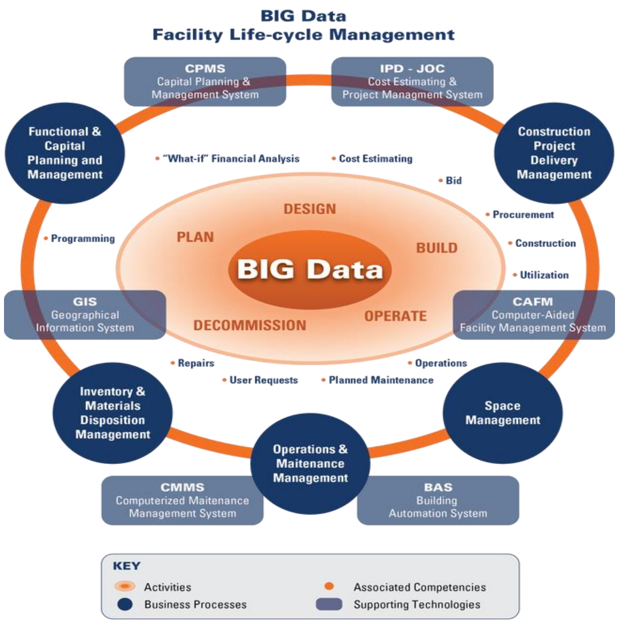


Figure 3. Facility life-cycle management that involve with big data. (Source: https://jobordercontracting.org/tag/cobie/)

2. STATUS OF BIM AND GIS IN CONSTRUCTION INDUSTRY

Along with the development of technology, construction industry also rapidly improved with new technology that helps their currents activity. This technology is included with the improvement of BIM and GIS applications. In this section, reviews on BIM, GIS and integration GIS and BIM application were made in order to show the status of BIM, GIS and their integration in construction industry.

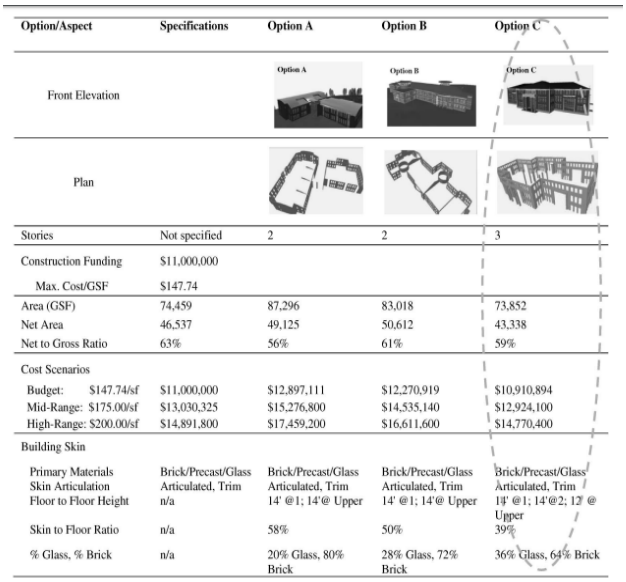
2.1 Reviews of BIM Applications

For the last decade, BIM has been introduced. Eastman et al. (2008; 2009) stated that even through BIM technology is still new, initial experiment shows that the creation of parametric 3D model of BIM can used to improve construction project in order to overcome the problems of design errors, design quality, construction time and construction costs. Due to these initial findings the popularity of BIM has grown extremely in the past decade.

According to AGC (2005), 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 analysed to generate information that can be used to make decisions and to improve the process of delivering the facility.

BIM is more than just a drawing. BIM represent data repository that contained building design (floor plans, sections, and elevations), construction and maintenance information which is combined in a single model that be used as a base for data sharing application with all users. A BIM that contains all information related to the building such as design, material, financial, estimating and legal considerations, and their project life-cycle can be called as "smart object". For example, each facility must contain information about their supplier, operation and maintenance procedures, and clearance requirements. (CRC Construction Innovation, 2007). The use of BIM as a construction management tool is a little slower than expected in the AEC industry even though BIM technology is rapidly growing (Fischer and Kunz, 2004). This because, at the present time, there are still do not has a perfect efficient of BIM.

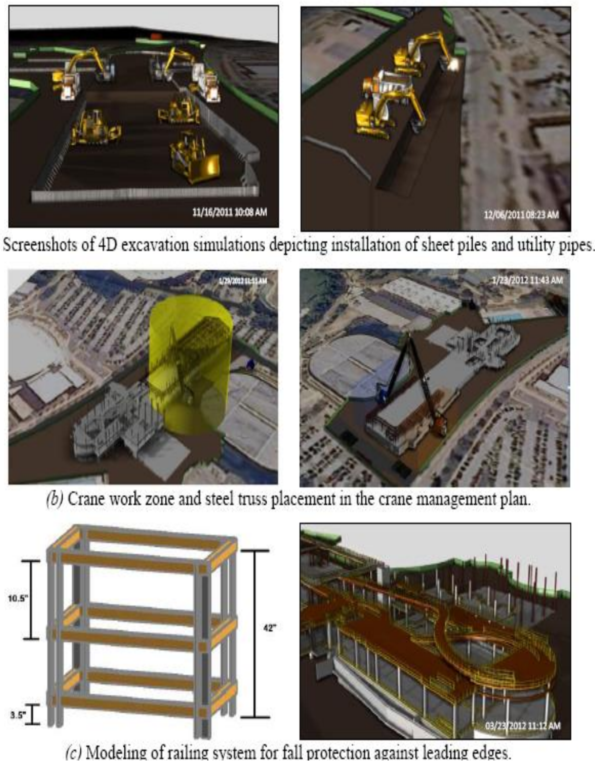
Azhar (2011) studied the use of BIM at the project planning phase to perform options analysis (value analysis) for selecting the most economical and workable building layout. For this study, the General Contractor working together with architect and owner to design three different design options in BIM. Each design options contains BIM-based cost estimation that prepared using three different cost scenarios such as budgeted, midrange and high range. Through BIM-based cost estimation, the owner can make a better decision for cost estimation planning. Figure 4 show the BIM-based cost estimates were also prepared using three different cost scenarios (budgeted, midrange, and high range).



Option/Aspect	Specifications	Option A	Option B	Option C
Front Elevation		Option A	Option B	Option C
Plan				
Stories	Not specified	2	2	3
Construction Funding	$11,000,000			
Max. Cost/GSF	$147.74			
Area (GSF)	74,459	87,296	83,018	73,852
Net Area	46,537	49,125	50,612	43,338
Net to Gross Ratio	63%	56%	61%	59%
Cost Scenarios				
Budget: $147.74/sf	$11,000,000	$12,897,111	$12,270,919	$10,910,894
Mid-Range: $175.00/sf	$13,030,325	$15,276,800	$14,535,140	$12,924,100
High-Range: $200.00/sf	$14,891,800	$17,459,200	$16,611,600	$14,770,400
Building Skin				
Primary Materials	Brick/Precast/Glass	Brick/Precast/Glass	Brick/Precast/Glass	Brick/Precast/Glass
Skin Articulation	Articulated, Trim	Articulated, Trim	Articulated, Trim	Articulated, Trim
Floor to Floor Height	n/a	14' @1; 14'@ Upper	14' @1; 14'@ Upper	14' @1; 14'@2; 12' @ Upper
Skin to Floor Ratio	n/a	58%	50%	39%
% Glass, % Brick	n/a	20% Glass, 80% Brick	28% Glass, 72% Brick	36% Glass, 64% Brick

Figure 4. Scope and budget options for the Savannah State Academic Building: GSF = gross square foot; sf = square foot (Azhar, 2011).

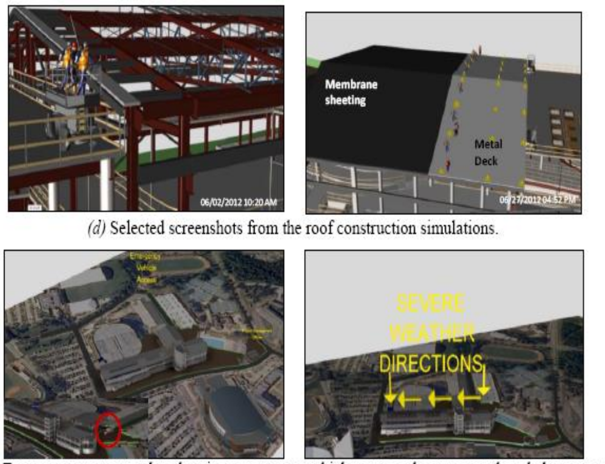
Azhar et al. (2013) illustrates the effectiveness of BIM technology in build and implement a construction site safety plan. The case study is Recreation & Wellness Centre on the campus of Auburn University (AU). BIM model was used to created sheet piling components that consist of sheet pile section and base re-shoring stand made of a steel beam and solid steel tube. These activities were modeled using 4D simulation to coordinate excavation equipment operation at the jobsite. Figure 5 show screenshots of BIM-based safety plans for AU Health & Wellness Center project.



(a) Screenshots of 4D excavation simulations depicting installation of sheet piles and utility pipes.

(b) Crane work zone and steel truss placement in the crane management plan.

(c) Modeling of railing system for fall protection against leading edges.



(d) Selected screenshots from the roof construction simulations.

(e) Emergency response plan showing emergency vehicle route and severe weather shelter areas.

Figure 5. Screenshots of BIM-based safety plans for AU Health & Wellness Center project (Azhar, 2013).

2.2 Reviews of GIS Applications

Willenbacher et al. (2006) studied the potential of GIS as an approach for integrating spatial analysis in building model management in order to identify changes. The objective of this work was to minimize mistakes and inconsistencies during the building lifecycle. This research work focuses on the conception and realization of 3D GIS components as a basis for the identification of relations between elements of different partial models. This component is able to apply the known spatial analyses that are offered by GIS for 3D building objects. On the other hand of the paper, it shows how this component is included in the concept of a descriptive object oriented integrated planning environment for the building lifecycle. With the help of the agent technology, the component is used as a part of an "intelligent building element", to inform about or to recognize changes in its environment. The result is a very flexible building information system, which contributes to an efficient decision making by the improvement of the cooperation and communication.

Shanmugam et al. (2002) studied the information flow on process plant projects, the disruptions to information flow, and the problems faced due to the disruptions. This study identified that an information system that can used to capture the relationships between different deliverables, record the status of deliverables, and process queries from any of the teams regarding status and impact of disruptions can be useful to support the decision-making required for rapid development of pragmatic plans.

Cheng and Chen (2002) focuses on development of automated schedule monitoring system to assist manager to control the erection process building construction. ArcSched was used to improves the data collection efficiency by integrating bar code system with the wireless Radio Frequency transmit technology. ArcSched improves schedule control efficiency by integrating spatial and thematic information into a single environment. The application of the real time schedule monitoring system in this project improve the construction constructability and positively impact the construction efficiency.

Li et al. (2005) studied on integrated Global Position System (GPS) and Geographical Information System (GIS) to reduce the construction waste. A prototype was developed from automatic data capture system such as barcoding system for construction material and equipment (M&E) management onsite, while the integrated GPS and GIS technology was combined with M&E system based on the Wide Area Network (WAN). Experimental results indicate that the proposed system can minimize the amount of onsite material wastage.

Cheng and Yang (2001) developed an automated site layout system for construction materials. MaterialPlan was a system that included with GIS-based cost estimating system integrated with material layout planning, is a new tool to assist manager to identify suitable area to locate construction materials. Based on the information of quantities and location materials' that required in the project, this study can identify the suitable area to store the materials by using the concept of "searching by elimination".

Bansal (2011a) discusses the use of GIS in the development of safety database from which safety information are retrieved and linked with the activities of the schedule or components of a building model. 4D modelling along with topographical conditions and safety database in a single environment assist safety planner in examining what safety measures are required when, where and why.

Bansal and Pal (2007; 2008) conducted a study to explore the potential of GIS for building cost estimation and visualization. The proposed method used ArcView 3.2 to store the data from different tasks and link that data to the corresponding spatial feature in GIS environment. The methodology forms this study utilises the capabilities of GIS to store spatial data in different themes, which can later be manipulated for building cost estimation. New scripts were added to the existing GIS software for cost estimation and easy access to information available in the GIS.

Gopal et al. (2011) demonstrated the understanding of methodology to create 4D-GIS based model for optimization and real time monitoring of the construction project. ArcScene in ArcGIS and Primavera was used for this study. Different stages of the construction process and activities was generated in different layers using ArcGIS software. Primavera P3 software was used to creation schedules and linked with the GIS layers. It is found that actual building information at site and the building simulation model that some overlapping and rework can be avoided.

2.3 Approaches for Integration of BIM and GIS

According to Zhang et al. (2009), BIM and GIS became a powerful platform in construction industry because of their variety individual features and capabilities. But, each platform contains weaknesses. In order to overcome this weaknesses, the integration of BIM and GIS must be obtained. For example, GIS provides topological (georeferenced) data, which allows for 3D analysis, spatial analysis, and queries such as calculating the distance between two different points, calculating routes, and defining the optimal location (Irizarry and Karan, 2012). BIM is incapable of such analysis, but it provides a detailed database of object-oriented parametric information for the building and represents it in a 3D model, a feature that GIS is lacking (El-Mekawy, 2010).

For the sake of successful data integration between BIM and GIS, there is a criteria need to be look up such as data interoperability because both BIM and GIS use different main standard like GIS used CityGML while BIM used IFC standard. Beside data interoperability problem, there are other issues that need to be look up due to the differences between BIM and GIS. This differences are discussed in term of the spatial scale, level of granularity, geometry representation methods, storage and access methods as well as semantic mismatches between them (Isikdag and Zlatanova, 2009b; Karimi and Akinci, 2010; El-Mekawy and Ostman, 2010). Regarding this issue, various approaches have been used to overcome this matter. Amirebrahimi et al. (2015) state that integration BIM with GIS can be generally be classified into three groups: at application level, process level, and data level.

2.3.1 Application Level Method

At the application level, the integration methods generally use reconfiguring or rebuilding (Kamari and Akinci, 2010) where the existing GIS or BIM tool is either modified by software patches or is rebuilt from scratch to include the functions or the other. This method is usually costly and inflexible. Below are examples of works that used application level method.

Irizarry et al. (2013) developed a BIM-GIS integrated model to improve the visual monitoring of construction supply chain management. In this study, BIM-GIS visual module was developed to represent the availability of materials. This application provides real-time quotes on doors and windows from different databases across the Internet. GIS-based spatial analyses such as network analysis and attribute analyses were used to provide an optimal solution to manage costs of supply chain logistics.

Sebastian et al. (2013) presents the multi-disciplinary approach that underpins the collaborative research project. It reviews the state-of-the-art of BIM and GIS for collaborative design, and pin-points the areas where innovations are urgently needed. This study explained the composition of the research consortium and role distribution between the partners, as well as the multilevel research methodology, including the description of the demonstration cases.

2.3.2 Process Level Method (Web Based Integration)

Integration BIM with GIS in term of process level integration method can be refer to the OWS-4 project by OGC (2007) which use Service Oriented Architecture (SOA) to allow the participation of BIM and GIS systems in those tasks that require the capabilities of both while they simultaneously remain live and distinct. This method provides more flexibility rather than application level. But, the challenges of the integration in this method are still not resolved at the fundamental of data level to provide interoperability between these systems.

Kang and Hong (2015) proposed software architecture for the effective data integration of BIM into GIS-based facilities management system. The proposed software will separate the geometrical information from related to relevant properties. The properties required for each use-case perspective is extracted and transformed from information for BIM to GIS using Extract, Transform and Load (ETL) concept, which extracts the homogeneous data from the source systems and load data into warehouse by transforming the data into proper format or structure. A step-by-step description on how to integrate BIM into spatial information model by ETL was demonstrated by Rafiee, Dias, Fruijtier and Scholten (2014).

Ebrahim et al. (2016) studied on the uses of semantic web technology to ensure semantic interoperability between existing BIM and GIS tools. The proposed approach in this study is composed of three main steps which are ontology construction, semantic integration through interoperable data formats and standards, and query of heterogeneous information sources. The contribution from this study are enhance data exchange and integration between BIM and GIS form syntactic level to semantic level by providing semantics of the data and also constructed new ontology based on the EXPRESS schema at the application level. This BIM ontology provides a way for seamless integration of building and construction related data that encompasses all IFC classes with different attributes.

During integration data between BIM and GIS, data sharing and exchanging information between these two domains is still a huge challenge. While, synthetic or semantic approaches do not fully provide exchanging semantic and geometric information of BIM into GIS or vice-versa. Hor et al. (2016) created an approach for integrating BIM and GIS using semantic web technologies and Resources Description Framework (RDF) graphs which produced one unified model, so-called as Integrated Geospatial Information Model (IGIM). This IGIM can access and process datasets from GIS and BIM through RDF graphs without creating direct link between various terminologies. IFC and CityGML were translated into IFC-RDF and GIS-RDF graphs, while the integration of both graphs was done at semantic level. This IGIM system gives an advantage of linked data form building elements to 3D/2D geospatial data into the IGIM unified domain ontology.

Karan and Irizarry (2015) used semantic web Technology to interpretable by both construction project participants as well as BIM and GIS applications processing the transferred data. The methodology from the authors showed that semantic technology can enable semantic interoperability between building and geospatial heterogeneous data. First steps of this works are all spatial and non-spatial data is represented as RDF triple. After that, a set of standardized ontologies for construction and geospatial domains are used to integrate and query the heterogeneous spatial and temporal data in semantic web data format. Lastly, SPARQL query language is used to access and acquire the data.

Deng et al. (2016) used an instance-based method to generate mapping rules between IFC and CityGML based on the inspection of entities representing the same component in the same model. Four basic concepts were developed in the reference ontology which is building object, geometry, property sets, and inverse relationship. The relationship between these four concepts was also developed by studying the schemes of IFC and CityGML. Based on the developed reference ontology, A CityGML scheme extension called Semantic City Model AE was developed in order to store the rich information and inverse relationships.

Mignard and Nicole (2014) extended the platform dedicated to facility management called ACTIVe3D which is to enlarge its scope to take account the management of urban elements contained the building environments, as well as others buildings. In order to solve the heterogeneity problem between BIM and GIS, authors developed a semantic extension to the BIM called UIM (Urban Information Modeling). This extension defines spatial, temporal and multi-representation concepts to build an extensible ontology which allow authors to model all the city information, including urban proxy elements, networks, building, etc.

Lapierre and Cote (2008) used CItyGML, WFS and 3D Viewer to develop a web-based solution to manage city data. The development of the WFS for BIM, and the translation of IFC to CityGML, even if limited to a simple "room" view of the IFC data, proved the feasibility of merging such architectural data in a very beneficial way for a disaster management scenario. The choice of the WFS architecture for the BIM services also enables implementers to minimize the work in design and specification of interfaces.

Wu et al. (2010) discussed on the technical issues of developing a virtual globe-based 3D visualization framework for publicizing urban planning information, using Web Service Oriented Architecture (SOA) to support visual planning model sharing and interoperability. End users can rapidly inspect an urban planning design from macro-vision to micro-detail with their home computers. Based on CityGML, a standard descriptive language for 3D city models, this architecture supports interoperability. End users can select any of the available urban planning designs for visualization. With the architecture's strong capability of integrating distributed resources, other communication platforms, such as dynamic labeling, BBS, forum, and email, are integrated into the system, so that end users can conveniently enter their remarks about any urban planning solution when they are viewing them.

Pauwels et al. (2017) studied on the semantic web technologies in AEC industry. From this study, the authors show that semantic web technologies have a key role to play in logic-based applications and applications that require information from multiple application areas (e.g. BIM + Infra + GIS + Energy). This three keys application area of the semantic web technologies can be categories into interoperability, linking across domains, and logical inference and proofs. In term of interoperability, this paper pinpointed that no solid proposal exists so far for fully resolving interoperability issues in these disciplines using semantic web technologies. At least, there is no proposal that solves it any better than existing approaches. In that regard, most domain professionals currently aim first at providing semantic data exchange rather than full interoperability. Linking across domain refer to the linking data applications. Linked data was hereby explained as a response to the finding that quite some data was being published on the web, seemingly following the semantic web idea but actually never linking to outside data (Berners-Lee, 2006), and thus in fact not realizing the initial core idea behind the semantic web at all, which is *linking data*. When taking a linked data approach, one uses only a subset of the stack of available semantic web technologies. For many researchers and developers, linked data is thus the 'fast track' forward. For the logical inference and proof, it refer to the Applications and use cases that focus on the logical basis of OWL and SWRL are less common than the use cases focusing on linking across domains. OWL and SWRL, but also inference engines and proof engines, are technologies that are not commonly present in linked data-inspired applications and use cases. Since these technologies are the upper parts of the semantic web technology stack, it takes considerably more effort to implement and use them effectively in practical use cases.

2.3.3 Data Level Method

There are various methods that have been developed to integrate BIM with GIS at the data level integration. For example is linking methods such as ESRI ArcSDE facilities data transfer between BIM and GIS software by an Application Programming Interface (API) at either side. Translation/Conversion methods such as FME (Safe, 2013) and work by Nagel et al. (2009) which is introduced directly convert between GIS and BIM formats. This method usually translates the data between IFC and CityGML. The main problems using this method are loss of semantics, limitation in geometric conversion and only focus on the major building elements which neglected the other aspect such as utilities or connections. Li et al. (2006) and Wu et al. (2010) have completed their works on resolving the geometry transformation problem but only partially address on the overall integration.

Research has focused on the unidirectional conversion from IFC to CityGML, however, Isikdag and Zlatanova (2009a) concluded that manipulating data from one system to the other requires a two-part transformation of both the geometric and semantic datasets. Because the two systems are conceptually misaligned, one dataset cannot be transformed without the transformation of the other. Usually, the manual conversion/translation between IFC and CityGML normally involves the steps: (1) semantic filtering; (2) exterior shell computing; (3) incorporation of building installation; (4) geometric refinements; and (5) semantic refinements (Donkers, 2013). This is one of the classic frameworks on IFC and CityGML conversion/translation.

Zlatanova, et al. (2013) stated that one of the limitations of the conversion between IFC and CityGML is the missing semantics. Even if the semantic information is complete after conversion, the original meaning of the attributes does not retain (Kang and Hong, 2015). However, this does not mean the conversion of geometry will always be easy. Transferring from CityGML to IFC is more difficult in terms of both semantic information and building geometry (Mignard and Nicolle, 2014). Two of the possible solutions are a better defined surface type in CityGML and the improvement of the "IfcSpaces" in IFC (Donkers, 2013). "IfcSpaces" and "IfcSlab" are two key layers between the conversion of CityGML and IFC.

Juan et al. (2006) described four approaches for the data integration, i.e. direct data import, shared access to database, formal semantic and integrated data management and file translation. This authors focus on integrate 3D data of 3D GIS and 3D CAD using the last approach; integrated data management and file translation. This approach focuses on two aspects: geometry exchange and the information loss due to file translation. Using this method, this paper implements the geometry translation, including line, surface and solid, between 3D GIS and 3D CAD and resolves largely the technical differences in the geometry. This shows that the file translation is a pragmatic and efficient approach in integrating the two systems. A tight integration will require a combined solution at the data representation level. Currently, CAD-GIS integration projects tend to be project specific and case-by-case. But model conversions are seldom based on pure geometric "translations", so semantics is important. One of the efficient solutions to integrate two different systems is to achieve interoperability between them.

Hijazi et al. (2011) studied an approach for integration interior building utilities in city models by means of semantics mapping. The ideas on this study is how to acquire the information from BIM/IFC and map it on CityGML utility network Application Domain Extension (ADE). The investigation points out that, in most cases, there is a direct one-to-one mapping between IFC schema and UtilityNetworkADE schema, and only in one case there is one-to-many mapping which is related to logical connectivity since there is no exact concept to represent the case in UtilityNetworkADE.

de Laat and van Berlo (2011) investigated the integration of BIM and GIS in the development and implementation of a GeoBIM extension on CityGML for IFC data. To fully integrate BIM and GIS it is obvious that a translation from CityGML to IFC is also necessary. From this research, it is possible to add semantic information from IFC into CityGML using GeoBIM that was developed. The GeoBIM extension works in practice and is implemented in software. In this project, the conversion of IFC data to CityGML files with additional rich IFC semantics is proved to be possible.

The Unified Building Model (UBM) approach was proposed by El-Mekawy and Östman (2010); El-Mekawy, Ostman, and Shahzad (2011); El-Mekawy and Östman (2012); El-Mekawy, Ostman and Hijazi (2012). This was a unique approach that enabled users to fully combine the BIM and GIS features and capabilities into one central model. UBM works as intermediate model to related BIM and GIS. This model is built based on IFC and CityGML, and it can be revised for different applications. The main advantage of the UBM approach is the fact that it allows for bi-directional conversion of data between IFC for BIM and CityGML for GIS. This differs from other unidirectional methods as it implies that the data loss can be minimized during the conversion for the exchange.

The QUASY (Quartierdaten-Managementsystem) project aims to develop a new 3D semantic building model, which is dedicated to urban development (Benner et al., 2005). It has many similar features as CityGML, but becomes more flexible, due to the application of variants (QuVariants). The variants can indicate different things, such as volume, surface, and curve geometry; detailed semantic information on building components; and a parametric description for future instantiation. Part of the objects in IFC were mapping to the QUASY using IfcWallModificator.

In order for IFC and CityGML to be compatible in one system, Geiger, et al. (2015) simplified the complexity of the IFC model in terms of both geometry and semantics. This study was implemented on the IFCExplorer, which is a software package developed to integrate, visualize and analyzes the spatially referenced data at Karlsruhe Institute of Technology (Benner et al., 2010).

From here, it can be said that there a many previous research that have been conducted in field of BIM and GIS. Each of these technologies come with their own strengths and weaknesses. The merging of 3D BIM with 3D GIS can creates a more powerful tool that can be used in Architecture, Engineering, Construction, Operations and Facilities Management (ECO / FM) industry.

3. BARRIERS TO BIM-GIS INTEGRATION

In recent years, implementation of BIM and GIS in construction application has been widely used. This implementation solved many problems in construction application such as reduce error of design, improve design quality, shorten construction time, reduce construction costs, reduce loss of information, facilitating easy updating and transfer activity in 3D CAD environment. Along with these advantages, there are several problems that occur during this implementation such as data sharing, data management, integration of BIM with GIS and topology functions.

In term of data sharing, BIM share their information as drawing files created as views of a building model rather than sharing intelligent object from the model (Dib et al., 2013). Because of this, users are defaulting back to exchanging documents. BIM also cannot share data directly to other users because different users use different applications. User needs to rebuild the model in order to significant with their requirements. This affects the project schedule because of poor information sharing.

On data management, BIM cannot manage "what if" scenarios for engineering design (Ian and Bob, 2005). For example, by using a single BIM model, it's cannot perform Building Performance Modeling (BPM) (energy analysis, sun/shade studies, emergency simulation, etc.) because BIM does not provide the flexibility needed by consulting engineers to conduct a variety of "what if" situation in one environment. BIM need add additional simplified model to perform analysis. This happen because BIM application is more on building design and documentation, rather than BPM. BIM data structure is also not suitable to provide 3D spatial and connectivity information that required by BPM because BIM does not provide topology function that use to link each data in the model to create connection among them. Through topology, 3D spatial and connectivity information that required by BPM can be solve.

Integration between GIS and BIM give many advantages to solve construction problems. But, the main problem during the data integration process is data mismatches. Mismatches data happen because GIS and BIM used different data types and file formats. GIS does not support all primitives of BIM which cause problem when geometry data loss during exporting process. BIM not support semantic information and it becomes a problem when semantic information losses during data export. Transformation semantic information and spatial relationship from building model of BIM to geospatial environment will also be a problem because BIM lack of object-oriented data structure. This also happen because of geospatial information that provide by BIM is insufficient in representing 3D geometry and 3D spatial relationship.

4. SUMMARY

Construction projects are described by several graphical (drawings, layouts, charts, and blueprints) and non-graphical (schedule, specifications, cost estimates, safety and quality control recommendations) documents. In order to control the full-cycle of construction effectively, technology of GIS and BIM can be useful because GIS and BIM can handle graphical and non-graphical documents, which make it easier to collect construction project information in a central repository. Various graphical operations and non-graphical operations in GIS and BIM application can improve and speed up construction planning as well as ensure data integrity and accuracy. By integrating both technology GIS and BIM, they can bring spatial analysis in a real-world spatial reference. Through the integration between GIS and BIM, users will use the advantages of the one element (either in GIS or BIM) to complement the weakness from the other parties (GIS or BIM). From this point of view, the integration of GIS and BIM can improve the interoperability function which means data sharing problem among the users can be completely solve. This data sharing issues' is the critical benchmark in order to evaluate the effectiveness of BIM. In addition, through interoperability function, the function of reused data can be use for different representation by using the same model without recreate back the model. Accessibility of consistent and accurate data by entire project also be improved. In the end, the problems of late project schedule and overrun costs can be resolve.

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