INTEGRATING BIM AND GIS IN RAILWAY PROJECTS: A CRITICAL REVIEW

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The railway plays a significant role in human life by providing safe, reliable, cost-effective services, which are environmental and drive economic growth. Significant decisions are taken at early stage of rail projects which need effective tools to avoid rework and save time, cost and increase work efficiency. Indeed, the continuous upgrading of this sector is needed to respond to technological advances, environmental change and increased customer demands. Integrating Building Information Modelling (BIM) and Geographic Information systems (GIS) is promising since the scope of BIM usually does not extend beyond the footprint of the "building"; it does not provide geospatial data. Therefore, integrating BIM with GIS provides a complete picture of the project. However, this integration is challenging especially in rail projects as they are amongst the most complicated projects and numerous parties are involved in making important decisions. This paper reviews the literature regarding integrating BIM with GIS systematically, with the aim of analysing the need for this integration and its benefits. The paper highlights a lack of a clear guideline for collaboration in the railway project lifecycle and indicates the need for research to focus on this issue as well as the possibility of applying integrated BIM with GIS as a potential solution to improve collaboration for better decision among project participants.

Keywords: railway, collaboration, BIM, GIS, integration

INTRODUCTION

Railway transport is considered a mature industry in the developed world. It is showing a remarkable comeback after a period of decline. The obvious rediscovering of railways is boosted through its ability to move enormous amounts of freight or passengers efficiently from one place to another with minimum energy and emissions. However, railways in many countries are still struggling to be more efficient and commercially viable; rather they still depend on, government subsidy and legacy companies (Bank, 2015). To achieve such efficiency, there is a need for a continuous upgrade in different operational activity in response to technological advances, environmental changes and increasing customer demands. Railway infrastructure has greatly contributed to society in terms of safety, reliability, sufficient capacity and availability over its lifecycle (Patra, 2009).

BIM and GIS as recent technologies can realise the huge benefits of infrastructure through its lifecycle. BIM has the ability to improve efficiency and effectiveness through providing a different process of collaboration and a new working approach to transform current Architecture, Engineering, Construction industry structure and practice (Bradley

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et al., 2016). BIM has been used to facilitate the integration, interoperability, collaboration and automation of processes in the construction industry (Isikdag and Zlatanova, 2009).

Although BIM has significant features, it has been restricted to building information (indoor environment). Therefore, to integrate interior and exterior information to provide a complete picture of the built environment, attempts have been made to integrate it with GIS. The core theme of the UK government strategy is working collaboratively using integrating BIM with GIS in projects such HS2 and Crossrail, which are considered amongst Europe's largest infrastructure projects. Would assist in ensuring that the right information is available at the right time in the right format for the right person (May, Taylor and Irwin, 2017). Combining BIM with GIS would provide a complete picture for the project because of the complementary nature of the information that each technology can provide (Fosu *et al*., 2015).

RAILWAY

Rail is considered as a safe, efficient, environmental transport mode. However, recently, there has been a decline in the publics' perception of railway (Berrado, Cherkaoui and Khaddour, 2011). According to a report by Network Rail, collaboration is one of the most effective factors to deliver better railway in terms of safety, reliability, capacity, cost-effectiveness, quality and productivity (Network Rail, 2014). Collaboration, however, needs effective tools. BIM enables participants to collaborate in a shared software platform to share information, enabling better decision making throughout the project lifecycle (AGC, 2006). However, it lacks the ability to analyse spatial data. GIS tools have the ability to deal with spatial and geographic information (Karan *et al*., 2015). Therefore, integrating BIM with GIS can provide a complete toolset to support collaboration between participants for better collaborative decision making throughout the lifecycle of the railway project. Despite this potential merit, data on the application of BIM and GIS integration in infrastructure is rather lacking when compared with buildings. This is expected to change as countries such as the UK are now mandating that heir public sector projects use BIM, with other countries expected to follow suit (Karan *et al*., 2015).

Building Information Modelling (BIM)

Building Information Modelling is facilitates the decision making (Utiome, 2010). It can be defined as a process of creating, sharing, exchanging and managing information in an effective way through the whole lifecycle of the building (Isikdag *et al*., 2007). The fundamental concept of BIM is the use of a single repository of data which all team members share. This single model or database or group of databases can be linked together, thereby, easing accessing and sharing information (Autodesk, 2011).

Thompson and Miner (2007) clarified the basic theory of Building Information Modelling as the execution of the project in a virtual environment where it is possible to store all project-related data in a single (central) online system. Furthermore, the time (schedule) and cost dimensions can be added to the model which in turn allows an immediate analysis of the benefits of various cost-time options. Thompson and Miner (2007) developed BIM models for all phases of the project which enables more stakeholders to be involved practically in the early project stages. These stakeholders can use their knowledge (business- and engineering) in the facility design, scheduling and organising which would lead to improved coordination in all project stages (Fischer and Kunz, 2004). Thus, the BIM model will act as a repository of data to serve the project throughout its lifecycle.

BIM will become a source of reliable information. It becomes possible to bridge the gap between the world scale and detailed data through linking BIM and GIS platform, which offers a high level of information from GIS to detailed information in BIM. Furthermore, BIM in the long term will provide high efficiency from knowledge capture, stimulating communication, and continuous analysis of work, which will result in increased productivity.

Geographic Information System (GIS)

During the last few decades and with the rapid development of technology, the demand for more efficient construction has increased. Doing more with less is the target that all relevant parties are keen to achieve. New approaches are needed to cope with these current requirements. Geospatial technologies are one of the interesting approaches to meet the current needs. GIS is used as a platform to manage and present spatially referenced information, (Amirebrahimi *et al*., 2015).

GIS is defined as "a system for capturing, storing, checking, integrating, manipulating, analysing, and displaying data which are spatially referenced to the Earth", (Fazal, 2008, p7). Consequently, GIS depends on geographic coordinate systems and projections of the world map, whilst BIM coordinates depend on modelling objects not relative to a specific place on the earth (Fosu *et al*., 2015). Ebright-mckeehan *et al*., (2009) used GIS to assess rail corridors in terms of their proximity to the intermodal services and their importance to the traffic. Wiltshire Council uses solutions from mobile GIS to deliver public services cost-effectively. In Ireland, a mobile ArcGIS app is used to identify leaks, manage repair teams, handle data and maintain the water network more efficiently, helping Ireland's national utility to provide 1.8 million households with clean drinking water.

GIS has many applications in civil engineering fields, to which it offers spatial solutions. For example, transportation, water resources, facilities management, urban planning, construction and E-business. Moreover, GIS can be used as an effective visualisation tool for construction site topographical conditions (Palve, 2013).

Over the years, continuous attempts have been made to integrate BIM and GIS for different purposes which it can provide a project with an inclusive picture and highly detailed in terms of information from building information models and related geographical data (Fosu *et al*., 2015).

BIM and GIS Integration

Integrating BIM with GIS is not a novel idea (Fosu *et al*., 2015). Several methods have been used to achieve complete integration of BIM/GIS. For example, various authors have proposed different methods and developed new tools by using available standards. As a result, extensions were created that may offer a needed functionality to be added to one or other platforms such as the extension of Geo BIM (Laat and Berlo, 2011), or the extension of urban information modelling for facility management (Mignard and Nicolle, 2014).In order to integrate BIM into GIS, Amirebrahimi *et al*., (2015) suggest the use of a data model. Hjelseth and Thiis, (2008) propose an IFC-based (Industry Foundation Classes) tool.

El-Mekawy, Östman and Hijazi (2012) proposed an approach called Unified Building Model (UBM) which allows users to combine the features and abilities for both BIM and

GIS into one central mode. UBM allows bi-directional data to be transferred between IFC for BIM and CityGML for GIS. This minimises the loss of data through the conversion for the exchange. Integration BIM and GIS has been applied to address many issues as illustrated in next section, but not specifically to collaborative decision making. Integration for this study aims to provide updated information for more accurate collaborative decision making.

APPLICATIONS OF BIM/GIS INTEGRATION

Integrating BIM with GIS offers huge advantages; Kolbe, König and Nagel (2011) argued that using BIM and GIS allows planning questions to be addressed. Targeted application areas of integrated BIM and GIS clearly include urban planning and landscaping, architectural design, tourism and leisure, 3D cadastre, simulation of environments, mobile telecommunications, disaster management, homeland security, vehicle and pedestrian navigation, training simulators, and mobile robotics (Kolbe, König and Nagel, 2011). Table (1) illustrates the applications of BIM/GIS integration throughout the project lifecycle.

Table 1: Application of integration BIM/GIS

Project stage	Application
Planning and Design	Select the site and manage fire response (Isikdag, Underwood and Aouad, 2008).
	Easiest collaboration between planning (Niu, Pan and Zhao, 2015).
	Effective traffic planning (Wang, Hou, *et al*., 2014).
	Plan and make a decision of low- disturbance bridge construction bridge (Sebastian, Böhms and Helm, 2013).
	Identify optimal number and location of tower cranes (Irizarry and Karan, 2012).
	4D topology and use novel IFC in planning a path for 3D indoor spaces respectively (Lin *et al*., 2013).
	Indoor geovisual analytics (Wu and Zhang, 2016).
Construction	Speed up the work (Shiu and Sar, 2014).
	Managing construction supply chain, green design, construction and sustainable consequences (Irizarry, Karan and Jalaei, 2013).
	Metro construction project (Wang, Li, *et al*., 2014).
Operation and Facility management	Facility management, facility analysing, visualising and assess damage in buildings such as flood (Karan and Irizarry, 2014).
	Emphasise the materials delivered by enabling tracking the status of the supply chain (Irizarry, Karan and Jalaei, 2013).
	Flood damage assessment (Amirebrahimi *et al*., 2015).
	Evaluate the performance of construction (Elbeltagi and Dawood, 2011).
	Managing the processes of maintenance and repair of facility management (Karan and Irizarry, 2014).
	Detect and map the information for pipe networks (Liu and Issa, 2012).
	Manage the maintenance using a UML (unified modelling language) in Taiwan railway (Shr and Liu, 2016).

There are several researchers addressing similar areas by using integrated BIM and GIS such as facility management, utility visualisation, analysis, assessed damage and natural disasters. (Liu and Issa, 2012)

On the other hand, the most important area that stands to benefit from the integration of BIM/GIS to provide a collaborative environment. Through collaboration, large problems can be tackled and huge benefits can be gained. Collaboration includes facilitating sharing knowledge, risks, skills and reducing cost (Prahalad and Hamel, 1990a).

Integrating BIM and GIS for Collaboration

The importance of collaboration has increased with advances in Information and Communication Technologies. Collaboration improves decision making, exchange of knowledge and skills, access to information and sharing of risks and responsibilities (Prahalad and Hamel, 1990b). As Gerges *et al.*, (2016) concluded, based on interviews, collaboration leads to reducing risks. Collaboration is considered as a solution to many issues such as social challenges, environmental issues, and economic recessions. Moreover, Moon *et al.*, (2004) noted that effective collaboration requires integrating models for the whole life of railway construction from planning to the maintenance.

There is various research into using different techniques and methods to achieve collaboration for several purposes. BIM and GIS are among the two most important technologies that might be used for providing a collaborative environment for rail projects. Although integration of BIM with GIS has the potential to produce a powerful tool for collaboration in railway projects, there are just few studies around this topic.

Several studies have been conducted in order to determine the success in collaboration whether using BIM and GIS separately. Shim *et al.*, (2008) suggested using a RIIM (Railway Infrastructure Information Model) model to provide integration and interoperability during the whole lifecycle of the railway infrastructure from planning until maintenance.

BIM can offer a high level of efficiency in communication and collaboration (Bryde, Broquetas and Volm, 2013). Sebastian (2011) emphasises that using BIM optimally could lead to achieving a multi-disciplinary collaboration.

Similarly, GIS has also used alone in railway projects. Guler, Akad and Ergun (2004) found that through GIS, better decisions could be made by using it to identify the event or asset to another event or asset and determining if the relationship between them may be considered as a crucial factor in deciding the design, construction and maintenance. For the same purpose, in selecting an optimum railway line, Wei (1996) developed a new RGIS technology (Railway Geographic Information System) to select a new railway line. He found that there is the insufficient difference in results between using a computer and using a traditional method, even though the computer was more efficient.

Nyerges and Jankowski (1997) suggested a theoretical framework for human decision making collaboratively based on GIS. One of the practical aspects of integrating BIM and GIS explored by Kim *et al.*, in 2015 was to provide a program for a safe path for pupils travelling to school called Safe Routes to School (SRTS). The purpose of this program was to reduce consumption of energy and CO2 emissions, resulting in improving the safety and health of children. This program consists of integrating BIM with GIS in providing a visualisation for the weather and monitoring this information via participants.

There are many ongoing studies of collaboration in the railway sector using techniques such as BIM and GIS. However, there is a lack of integration of BIM and GIS for collaboration in this sector. Combining them may provide a significant role in every lifecycle stage of railway projects especially for better decision making and more efficiency. Therefore, to bridge this gap an attention is needed to be take in order consider this issue.

DISCUSSION

From the literature review, it is appearing that railway projects are very crucial and need collaboration for safety, reliability capacity, cost-effectiveness, quality, and productivity. For example, improving collaboration can result in saving time, cost, improving quality, reducing carbon emissions, increasing efficiency, productivity and availability of information throughout the project lifecycle. Collaboration can be supported through integrating BIM with GIS, on which several studies have been conducted focusing on different aspects of this issue. Integration of BIM and GIS can provide a platform for collaboration for better decision making.

Wognum and Faber (2002) argued that there is a lack of understanding of collaboration among organisations. Consequently, there are few techniques to facilitate and manage collaboration. This may be because collaboration needs several factors to succeed. To illustrate that, Eriksson and Pesämaa (2007) pointed out that moving towards collaboration in construction projects, relationships and delivery methods require a comprehensive change in structures, processes and attitudes. Moon *et al*., (2004) stated that to provide an active collaboration environment, a single integrated model would be required for the design, construction and maintenance process.

CONCLUSIONS

This paper reviewed literature and provided evidence around integrating BIM and GIS in the railway industry, and explored the potential benefits applying BIM and GIS integration in the railway sector. The railway sector needs to keep up to date with technological developments to realise the potential benefits of BIM and GIS. There is a possibility to bridge the gap between the world scale and detailed data through linking BIM and GIS platforms. The literature has revealed that collaboration may play a crucial role in railway projects and may solve existing problems; thus, providing huge opportunities and better decision making. However, it was found that despite the importance of collaboration and even with using BIM and GIS separately in railway projects, there is a lack of research focusing on using them in an integrated manner. Therefore, serious attention should be considered to tackle this issue, through developing a framework for integrating them to improve collaboration for better decision making which it will be the next step for this study.

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