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Building Information Model For Infrastructure: Challenges and Benefits

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Abstract
Infrastructure has a major impact within our economy, from improving our growth to providing jobs for the general public. In the UK, infrastructure is being heavily invested in for the next 20 years as the population is growing and current infrastructure is undergoing wear and tear. Providing efficient and cost effective construction of infrastructure has been an issue for many years now which is why level 2 Building Information Model has been made a minimum requirement to use within the infrastructure sector by the UK government by 2016. The Building Information Model brings a variety of gains within the construction of infrastructure sector from improving collaboration within the entire team before the construction starts to providing better asset management post construction of the asset.

Keywords
Building Information Model; Infrastructure; AutoCAD; 3D

1. Introduction

The production of infrastructure has been at a steady decrease for the past seven years (KPMG, 2015) which has taken a toll on the economy as infrastructure takes a major part in our lives. For the next twenty years, the government has decided to invest on infrastructure, however achieving efficiency and providing a cost effective route of construction has always been an issue within infrastructure production (HM Treasury, 2013). Although technologies have been in use to aid the production of infrastructure, such as AutoCAD, the infrastructure sector still had issues with collaboration, clashes during construction and asset management as maintenances are not well organised, just to name a few. The UK government has made the adoption of level 2 BIM a minimum requirement as of 2016 as it has been proven to improve these issues within the infrastructure sector.

With the adoption of a new technology comes various questions, before investing in such a massive process, clients and consultants would like to know what are the benefits of adopting BIM?; what costs and additional work would be the outcome of adopting BIM?; and what would it add to the organisation, is the cost and additional work worth the adoption of the process?

An investigation into how BIM benefits the infrastructure sector in essential in this paper in order to demonstrate useful information gathered through a literature review and exploratory research. Current studies have provided mostly taken the direction of recommending BIM for the use of infrastructure construction. The Building Information Model provides a 3D model of the asset even before works starts, however it is not just a 3D model, it also contains a number of facilities which can aid in the production of both an efficient and cost effective design and production while providing data management.

2. Overview of the Building Information Model

BIM has become more popular over the past 10 years as it has proven its benefits within the infrastructure sector compared to other software's. In about 1957, Dr. Patrick J Hanratty, the creator of CAM (Computer Aided Manufacturing) took chance to present the AEC (Architecture, Engineering, and Construction) with the Building Information Model and this was the first the model was heard of (Mandhar & Mandhar, 2013). There are four levels of the Building Information Model, level 0, level 1, level 2 and level 3 which are demonstrated below in Figure 1.

Level 0 BIM
This is the simplest of all the levels, it consists of converting paper drawings to 2D CAD drawings and the output is simply distributed along the parties by paper or electronically (NBS, 2014).

Level 1 BIM
Level 1 is a combination of 3D CAD models for concept work and 2D for drafting documents and information about the product. The CAD models are managed with the use of BS 1192:2007 and the data share electronically is obtained by the common data environment (CDE) which is usually managed by the contractor (NBS, 2014).

Level 2 BIM
This level is the level of BIM required by the UK government by 2016. It is operated by collaborative practices, all parties work on their own 3D model which is not necessary a shared model however the design information shared through the same file format allowing the organisations to be able to input data and all check on it. Each party using the CAD software should be able to access the file formats through IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange (NBS, 2014).

Level 3 BIM
Level 3 BIM uses a single shared model and is a fully collaborative process. All of the parties involved and use the same model accessing and changing it if required, this allows the risks to be reduced by reducing the conflict of information. This level is the governments' requirement by 2019 (NBS, 2014).

2.1 BIM Maturity Levels

The maturity level of BIM is based upon quality, repeatability and the degree of superiority with the capability of BIM. The BIM maturity level that was produced was based on BIM's capability, implementation requirements, performance targets and quality management. There are five levels to the maturity of BIM, where the names were formed by comparing terms that were used by maturity models and the easily understood names were chosen to represent the levels, this decision was made by DCO stakeholders (Succar, 2009).

The five maturity levels produced are shown on Table 1:

Level	Name of Level	Textual Rating	Numerical Rating
A	Initial/Ad-hoc	Low Maturity	0-19%
B	Defined	Medium – Low Maturity	20-39%
C	Managed	Medium Maturity	40-59%
D	Integrated	Medium – High Maturity	60-79%
E	Optimised	High Maturity	80-100%

Table 1: Maturity levels of BIM Source: (Succar, 2013)

In order to progress from the lower maturity level to the higher maturity level, organizations should have a better control over having the targets and actual results almost match (acceptable even if little difference) (Succar, 2013), they should also have better predictability which would lead to less risks and a reduction of costs and finally better possibility of reaching their goals and creating new and ambitious ones (Succar, 2013).

2.2 Granularity levels of BIM

Granularity levels can be defined as: "The level of detail within a conceptual model, matrix, tool or document", (AEC, 2015). Granularity levels were introduced in order to enhance BIM capability and maturity assessments to increase their flexibility. Four Glevels were developed and organisations can progress from lower levels to the higher levels. These levels are as follows: (i) assessment breadth; (ii) scoring detail; (iv) formality; and (iv) assessor specialization.

3.0 Challenges of adopting BIM and implementation of BIM

With the Building Information Model being an immense programme, it requires training at the start after implementation which can take some time as with the construction industry being led by older generations which are using processes that have been in practice for years.

Even though BIM enables savings on cost once implemented, it does however cost a lot during implementation, through training and updating system software's to be able to utilise BIM within the organisation.

With BIM containing a mass amount of information, management of this information might cause an issue if not executed in the right manner.

4.0 Benefits of BIM within infrastructure

The BIM process does not only help within the engineering aspects of building infrastructure, it also helps with the budgeting, warranty information, project specification, purchase requests and existing service documents. BIM provides benefits to the owner before construction. For the contractors, it assists with communication be being visual. At the tendering stage, it gives the contractor an opportunity to give the client a display of how they would intend to go on with the project and how he has limited some of the

construction in order to get the best quality as long as best price (Smith, 2012). Implementing the Building Information Model provide a number of benefits, a few of them are; Better predictability, as the model is produced prior the commencement of works, different scenarios can be tested out which the organization can predict which is the best case scenario; Clashes can also be detected early leading to a more efficient design as errors can be minimized during construction leading to a faster production; Reinforcement modelling, complex structures can be difficult when modelling the reinforcement, with the visualization BIM provides, reinforcement in complex structures can become a lot easier visualizing how the reinforcement ties in together.

BIM can be used within all stages of construction, from the pre-construction stage, assisting with planning and making efficient decisions early in the design stage by having the advantage of manipulation the model, bringing in different ideas and testing them out, to the post construction Stage where it assists with managing the asset.
Infrastructure has a long lifespan which would need maintaining and as previously mentioned, BIM is useful for maintaining the asset throughout its lifespan.

4.1 BIM and Data Management

The Building Information Model provides a better way of managing data throughout the life cycle of the asset through the usage of different programmes which are compatible with the process.

Construction Operations Building Information Exchange (COBie)
COBie is described as a data plan which is provided in a spreadsheet data format, and contains a 'subset' of the information in the building model for the purpose of the handover (Lymath, 2014).

IFC Files
IFC's are object-based formats which allow data exchange between different software's (Lymath, 2014). Through the usage of IFC files, which are files that can be generated from excel files and saved in an "all files" format making the file compatible with the programme.

Opening these IFC files in the programme automatically draws up the information that has been fed into the file, which saves time and is very efficient. For example when drawing multiple manholes and catch pits within the design, the diameters, depths, northings and eastings can be saved as an IFC file with the individual Manhole and catch pit names through Excel and that can be opened within BIM automatically drawing these drainage systems. Along with this information, attributes can be added to the spreadsheet which are descriptions of the structure, and once opened in BIM, when clicked on the structure, the attributes are shown as properties of the object drawn which can describe to anyone what the structure actually is. Compared to AutoCAD 2D, these would have had to be drawn up which would take a longer time and cost a lot more.

BIM Execution Plan
The BIM execution plan is used for managing the delivery of the project. There are two stages to this: Pre-contract BIM execution plan; this is a direct answer to the Employer Information Requirements (EIR) which is a document that provides the information that is required by the employer prior the start of the project (Dana K. Smith, 2009).
This may include:

- A project implementation plan;
- Goals for collaboration and information modelling;
- Project milestones and project programme; and
- Deliverable strategy.

Post-contract BIM execution plan; this entails how the Employer's Information Requirements will be provides (Dana K. Smith, 2009). These include:

- Management;
- Planning and documentation;
- Standard method and procedure; and
- IT solutions.

As part of planning and documentation, an MIDP and TIDP are created.
MIDP: Model Information Delivery Plan, this is the primary plan for the preparation of the project information. Following that;
TIDP: Task Information Delivery Plan, is the MIDP but divided in subsections in order to set out the responsibilities for each individual information deliverable.
These are used to manage the delivery of that information provided.

4.2 BIM and Collaboration

With the use of BIM between teams within the organisation, an effective way of communication is produced. BIM can be used as a tool as with the process containing an integrated design strategy, it would go against lone working within the organisation.

Information collect on site by the site team, or information produced by the designers are all integrated within the BIM model, effectively leading to all members of the organisation working within one shared model which can be accessed to extract information which has been integrated into the model by different teams.

4.3 BIM and asset management

The building information model and asset management are both transforming the infrastructure industry and they are both mainly focused on maximising the value of the asset throughout its lifespan, however to attain all of the benefits of BIM with asset management, the collaboration between the different stakeholders must be at maximum level throughout the lifespan of the asset (Ferrovial, 2015).
As mentioned previously, with BIM being used for infrastructure, all documentation can be stored within the model. Infrastructure has a long lifespan and with all this data stored within the model maintaining the asset would become a lot simpler.

Using BIM with the asset management of infrastructure is a complimentary process as they support each other, the assets help in bringing BIM together whereas BIM assists in introducing new assets into the project and also in operating and managing both new and existing assets. Using information collected from BIM will allow asset managers to register assets and also receive topographic data on the assets and the quantities that were derived. The performance of the assets can also be registered, life expectancy details can be recorded and as infrastructure has a long life span, if maintenance is required a description can be obtained from BIM and in this case maintenance details can also be recorded and stored for future references (ICE, 2015).

5.0 Implementation of BIM

The implementation of BIM in an infrastructure project is not thought of as a technical decision but it is more like a business decision, because the building information model gives the parties a better way of communicating and also improves the outcome quality by allowing better decisions to be made while reducing the time and cost of the building process and operation (Smith, 2009). Most business owners choose to implement the building information model mainly for the reason that the competitiveness in the market is rather high. Companies adopting the implementation of BIM only achieve the full benefits if the

implementation is done carefully, however there are many risk areas when implementing the building information model.

The building information model does not only affect the construction and operation of the infrastructure building processes, it also has an impact of the business process. However for this switch to using BIM to be possible, the business owners need to be able to visualize the benefits of implementing the building information model and also see the positivity in the process giving them a better relationship with business partners and clients (Smith, 2009).

The best practice of implementing BIM is to analyse the organisations internal business processes, for example evaluate "whether is it a design, construction or property ownership enterprise" (Smith, 2009), and revise whether these business processes are a part of the system and if the model information which has been created by someone within the system can be of use to another party that is a part of the system. When implementing the building information model there could be a number of drawbacks, implementing the Building Information Model does not mean that all the files have to be compiled together at a single location throughout its lifespan, from the business point of view, this would be a problem.

Pitfalls to be avoided

Storing all data into a single file, the building lifecycle of both the business processes and the workflow is too complicated to be able to function when stored into one file.

Within the industry, business processes and workflow fluctuate a lot throughout the buildings lifespan in order for all of it to fit into one workflow paradigm.

There would be great difficulty for business processes to support changes to existing workflows to new ones with a single building model environment as it would require a big change for the existing information-management infrastructure.

With a single data file, the cost and technical challenges would rise as the software would have to be developed in order to be capable of meeting all the users' requirements throughout the life span of the building process.

Assessing the Fundamental risk of implementing BIM

Even though the implementation of the building information model brings a lot of good to the business, it also has its implementation challenge, the following are a few examples of challenges that may occur;

• New business processes
The building information model is not a process used to improve old technological tools, it re-engineers the internal processes and creates new business processes. The disadvantage with this is that the organisation has to be able to handle this drastic change in processes and if users are not on the maturity level of using BIM, the implementation would not go as planned (Smith, 2009).

• New roles and responsibilities
As new processes are being introduced, new roles within different processes are created. For example, once BIM is implemented, it is a necessity that the right person has the responsibility over the data entries and is also responsible for the inaccuracies. Taking this responsibility can be a major risk as it could lead to legal liability problems (Azhar, 2008).

• Too much work?

More organisations are talking about how BIM can solve all most problems within the building infrastructure industry, answering all coordination, management and procurement problems, however some contractors do struggle with the amount of information that they receive from using BIM (NCE, 2015). It would be a good decision to implement BIM if contractors are ready to handle the information load i.e. implemented in the tight project in the right hands.

6.0 Findings

A number of five case studies were undertaken in order to explore the influence BIM has within the infrastructure sector, the findings are as follows:

The result obtained on how BIM benefits the infrastructure sector is fairly consistent. A number of aspects were affected by BIM which improved the production and construction of the case projects. The value of using the Building Information Model within projects is mainly that it improves savings of construction costs for the owner and also improves efficiency.

The case studies and interviews provided what benefits were gained from implementing BIM. The biggest benefits that were highlighted were cost savings and efficiency. With clashes being detected early, casts repairing these damages would be improved and would also lead to an efficient design as these potential clashes would not need to be rectified which would waste time. Visualization is one of the benefits that also assist with clash detection and also during the pre-construction phase, clients can view the proposed design and be comfortable with design.

And improved collaboration was also a key benefit as with BIM having a shared environment, changes to design are easily picked up on by all teams of the organization. All data is also inputted into the program which provides better data management and assists in the asset maintenance post construction.

The major outcome of BIM that was identified within the case projects and interviews is the visuals it provides. With the model being 3D, the visual does not only assist within designing but also helps when it comes to saving costs as cost effective solutions can be tested out to see if practical and used. In addition, BIM enhances the collaboration within the organisation which makes it easier to work during all three construction stages

7.0 Conclusion

There has been a fall in production within the infrastructure sector which is why the UK government has invested up to £40 billion to improve the infrastructure in the UK for the next 20 years (KPMG, 2015).

Before this investment, the UK government was hesitant as infrastructure production was not executed in a cost effective and efficient way in the past which is why the government has made the adoption of level 2 BIM a compulsory step by this year of 2016.

The Building Information Model can be used for a number of effects within the infrastructure sector as it would benefit the project from its prime during the design stage to after the project through asset management (AutoDesk, 2012). BIM is a process that provides a 3D model of the project, unlike AutoCAD which provides 2D drawings, which can be a shared model between the organisations and can be used by architects, engineers, contractors and even the client.

The Building Information Model has to be implemented in the right way in order for its full benefits to be possible. Training and updating software's are two of the main drawbacks which come with the implementation of BIM. With the civil engineering infrastructure sector containing older generation civil engineers, the training process takes longer as the upskilling of the staff would be difficult because the

staff would be tempted to use techniques that they have been using for over 20 years. These claims have been supported through the interviews conducted within the case studies and the opinion of people utilising BIM.

References

AEC, 2015. *BIM Dictionary.* [Online]
Available at: http://bimexcellence.com/dictionary/granularity-level
[Accessed 08 October 2016].

AutoDesk, 2012. *BIM for Infrastructure: A vehicle.* [Online]
Available at: http://thebuildingcoder.typepad.com/files/bim_for_infrastructure_november_2012.pdf
[Accessed 09 October 2016].

Azhar, S., 2008. *Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects.* [Online]
Available at: http://www.neduet.edu.pk/Civil/ICCIDC-I/Conference%20Proceedings/Papers/045.pdf
[Accessed 10 October 2016].

Ferrovial, 2015. *BIM and Asset Management revolutionize the way we manage projects in Ferrovial.* [Online]
Available at: http://www.ferrovial.com/en/press-room/news/asset-management-and-bim-revolutionize-the-way-we-manage-projects-in-ferrovial/
[Accessed 16 October 2016].

HM Treasury, 2013. *National Infrastructure Plan 2013.* [Online]
Available at:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263159/national_infrastructure_plan_2013.pdf
[Accessed 16 October 2016].

ICE, T. I. o. A. M., 2015. BIM and Asset Management. *ICE,* pp. 1-2.

KPMG, 2015. *Infrastructure, building and construction.* [Online]
Available at: http://www.kpmg.com/uk/en/industry/buildingandconstruction/pages/default.aspx
[Accessed 08 October 2016].

Mandhar, M. & Mandhar, M., 2013. BIMING THE ARCHITECTURAL CURRICULA – INTEGRATING BUILDING INFORMATION MODELLING (BIM) IN ARCHITECTURAL EDUCATION. *International Journal Of Architecture (IJA),* 1(1), pp. 1-20.

NBS, 2014. *The NBS.* [Online]
Available at: http://www.thenbs.com/pdfs/NBS-National-BIM-Report-2014.pdf
[Accessed 10 October 2016].

Smith, D. K., 2009. *Building Information Modeling.* New Jersey: John Wiley & Sons.
Succar, B., 2009. *The Five Components of BIM Performance Mesurement.* [Online] Available at: http://www.hetnationaalbimplatform.nl/files/pages/the-five-components-of-bim-performance-measurement.pdf
[Accessed 15 October 2016].
Succar, B., 2013. *BIM framework.* [Online]
Available at: http://www.bimframework.info/2013/12/bim-stages.html [Accessed 19 October 2016].