Role of BIM+GIS checker for improvement of technology deployment in infrastructure projects

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Abstract. There has been a focus in construction industry, on creating, sharing and reusing digital project information, throughout the project lifecycle, which includes Building Information Modelling (BIM) and Geographical Information Systems (GIS). These co-existed technologies are said to have the ability to improve the efficiency and delivery of the infrastructure projects. Having said that, this can only be achieved through the right strategy, and proper collaborative environment, rather than relying on the cutting-edge technology alone. The involvement of 3rd party experts or “checker” is necessary to ensure the use of technology does not go off on a tangent from its original objectives. This paper will define what constitutes to successful process of infrastructure implementation, and how it helps to improve the use of technology with the correct methodology. Two ongoing mega infrastructure projects in Malaysia were selected as case studies. Comparison is being carried out on both projects to study the effectiveness of the technology that is being utilised during the construction works. Finally, the paper established a conclusion whether there is a need for a 3rd party “BIM+GIS checker” in order to ensure the right processes are being adhered to achieve efficiency in the delivery of linear construction projects.

1. Introduction

Virtual construction implies that it is possible to practice construction, to experiment and to make adjustments in the project before it is constructed [1]. Digital mistakes in the virtual construction generally do not have serious consequences provided that they are identified and addressed early enough so that they can be avoided in the actual construction of the project. When a project is planned and built digitally, most of its relevant aspects can be considered and communicated before the instructions for construction are finalized [2]. It is like running a simulation of a construction project by considering all aspects of the construction life cycle.

With Building Information Modelling (BIM) and Geographic Information Systems (GIS) technologies, one or more accurate digital information will be able to be captured, stored, manipulated, analysed and managed efficiently. GIS applications are tools that allow users to create interactive queries, analyse data, edit in maps and many other functions related to spatial and geographical information [9]. GIS can also be referred to as a number of different technologies, processes and methods deployed for the data capturing. It can be the foundation for a location-enabled horizontal
construction which is attached to many operations and has many applications related to engineering, planning and management of the infrastructure works [3][4][5].

Meanwhile, BIM technology produces three dimensional (3D) virtual model of the construction components with the parametric information [2][3][7]. BIM support the whole construction phases from design, construction, up to the operation of the completed infrastructure. These computer-generated 3D parametric models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the construction is realized [3]. BIM technology also accommodates many of the functions needed to model the lifecycle of a construction, providing the basis for ease of design review and efficient capabilities of error detection. BIM processes will optimize the success of project delivery by introducing changes in the overall methodologies, roles and relationships among project team. When adopted well, the application of BIM, GIS technology and the right processes will facilitate a more integrated design and construction that results in better quality at lower cost and reduced project duration [5].

In terms of the types of data and information that can be derived within BIM and GIS, generally they could provide a 2-D and/or a 3-D data with graphical or non-graphical information including geographical topography, specifications, cost data, scope data, and schedules [4][9][8]. On the other hand, categorised several types of information within Building Information Model based on the nature of the link between information and the model [1]. This pertains to all information that is part of, or connected to the components as well as the physical information inherent in the model itself such as size, location, etc. It is important that all information required in making an actual analysis be available from the BIM+GIS platform.

2. Technology Background
Dealing with a large-scale infrastructure project requires a proper methodology and workflow strategy. This is to ensure the smoothness of project delivery with better coordination and communication among the project team [6]. The deployment of BIM and GIS in the construction of infrastructure provides the tool for creating digital representation of the works for visualization, engineering analysis, code criteria checking, cost engineering, as-built product and many other functions [7]. Producing the proper BIM process could foster better integration, management and communication within the industry. The correct implementation of BIM+GIS processes within the lifecycle of project delivery is important to be strategize correctly since it affects the performance of the overall project. In the context of the whole construction life cycle, the Building Information Modelling processes can be used in every project phase, regardless of the type of project [3]. Hence, BIM methodologies had been utilized in most building projects and mega infrastructure projects in Malaysia.

2.1 Three Dimensional (3D) Model Development
BIM consists of two-facet, the 3D parametric modelling technology and the process of inputting information within the model [3][8]. Hence, at its basic core, deployment of BIM should begin with the production of 3D parametric model from the inception of the project lifecycle (model-based design), failing which, will jeopardize the efficiency and effectiveness of BIM implementation and reducing its benefits [6]. The approach of converting the 2D CAD drawings to 3D model is the lowest form of BIM methodology with the lowest potential benefits, while at the same time potentially creating new contractual disputes and disruption to the work progress [4]. It has been proven as inefficient approach since it was introduced in the early 2008. This method is also known as PseudoBIM and viewed by experts as a “first step to failure”, if it is not handled with due expertise.

The 3D parametric model that is produced from the 2D CAD model introduces some issues relating to its quality and integrity [6]. The fact that the conversion from 2D to 3D model is not carry out by consultant designers, but done by a 3rd party modeller with less project experience or non-AEC background, may result in the models being unsuitable for BIM uses, in fact, such 3D model may only be suitable for visualization and basic clash checking, which are only one-eighth (1/8) of the benefits reaped from BIM implementation. Further to that, the processes that
are created from this approach are neither efficient nor productive thus not reducing the overall cost of the project (in contrary, adding more cost to the project), in which the reduction of cost and time are the essence of BIM. Nevertheless, the PseudoBIM approach is becoming a norm in Malaysia, where the involvement of a 3rd party “checker” or coach is inevitable in ensuring the use of BIM processes and methodology do not go off tangent from its original objectives. Hence, the first and basic criteria to ensure the success of BIM implementation and to reap the maximum BIM benefits is to have the 3D model developed from the inception of the project (model-based design) and use the information within the model for every aspect throughout the project lifecycle [2][3][6][7].

2.2 GIS Data Capture

Geographical Information Systems (GIS) application is a tool that allows users to analyse geospatial data, edit in maps and many other functions related to geographical information [4][9]. These highly accurate & precise Geospatial Datasets are acquired using the advanced surveying and remote sensing technologies such as GNSS, GPS, LiDAR and Photogrammetry [7]. The GIS base map is developed in 2D with the aerial data of the construction site captured using UAS methodology, and the terrestrial data is captured using field survey.

The UAS methodology for capturing GIS Data has been used extensively and proven professionally in many industrial sectors such as Property Development, Highway Construction, Plantation, Forestry, Agriculture, Engineering/Civil Infrastructure, as well as Oil & Gas [7]. Technically, these systems will deliver cost-effective services for the construction monitoring and Project Management of a linear construction. The drones/UAVs are capable of flying hours and covering distances up to 10km. Nevertheless, optimal flying specification must be properly identified for quality orthophoto captured during certain condition. For a focused area which requires high attention and details, the flying method is totally different from the way orthophoto data is captured, where it will require oblique and nadir data acquisition method. The flight altitude will be lesser while camera angle must be manually adjusted during data acquisition period to eliminate as many blind spots as possible [7]. The processed data can be opened using the given freeware viewer for offline viewing purpose.

The utilization of suitable drone platform and its operating procedures is crucial in order to achieve cost-effective operations. The flight path must be thoroughly planned and correctly configured prior to the work execution in order to cover the required area and obtain good set of aerial images. Additionally, potential areas for the ground station should be pre-determined, as it will serve as the take-off and landing location, as well as initial home reference. For the UAV flight planning for orthophoto generation of the linear area with minimal curves, such as road project with corridor width, the flying grid is to be properly determined to ease the image stitching and processing step later on.

In short, the development of 3D parametric model in BIM and capturing high quality GIS data can only be achieved through the right strategy, methodology, processes and proper planning rather than relying on the cutting-edge technology alone. In order to achieve efficiency and highest benefits from the 3D model and GIS data, the collaborative environment is inevitable.

2.3 Collaborative Environment

The collaborative environment in the construction industry originated from one segment of BIM methodology, namely Common Data Environment (CDE) [5]. The use of collaborative environment such as the CDE in BIM process is the segment that is crucial to achieve the highest benefits in deploying technologies [8]. It enables architects, engineers and contractors alike to work on a single platform from anywhere in the world. It condenses a plethora of information about every detail into a workable format.

It facilitates testing and analysis during the design phase and monitoring during construction phase, to find the best answer and solution to a problem [3]. Designing is made easier, and coordination is
made simpler among team members, hence structure maintenance is made seamless too across the entire built environment. Without the proper deployment of CDE, the efficient and effective communication and coordination among the project team members will not be possible, defeating the original intention of BIM implementation [6]. Figure 1 shows the basic arrangement of CDE based on PAS1192-2. It provides a specific guidance for information management requirements associated with projects delivered using BIM process.

This information is to be managed in consistent and structured way to enable efficient and accurate information exchange. Specific details of the standards and processes should be properly adopted to deliver better outcomes. All types of information exchange and management standards between the entire project stakeholders need to be developed based on the specific project requirements. For the avoidance of doubt, all project information, either in GIS, BIM or conventional data formats should be shared using a single source of truth, i.e., the common data environment (CDE).

Nevertheless, not all information on a project will be originated, exchanged or managed in a graphical format. There should also include the non-graphical data, documentation and GIS information into the ecosystem of CDE [8]. Nevertheless, the data that is acquired through GIS acquisition is usually stored in its own geo-database. The geo-database data warehouse applies sophisticated rules and relationships to the data and has the ability to store a rich collection of spatial data in its own centralised location. All data stored in the geo-database is published to a GIS server and accessible via a web-based GIS application [7]. An example of the geo-database system architecture is shown in Figure 2. The geo-database in GIS also has the ability to define advanced geospatial relational models, integrate spatial data with other IT database and capable of leveraging spatial data to its full potential, where the CDE in BIM cannot provide these requirements within its platform. Hence, the interoperability between BIM CDE platform and GIS geo-database is another crucial aspect to be considered prior to implementing BIM+GIS.

![Common Data Environment based on PAS1192-2:2013](image-url)
The key concept of Common Data Environment (CDE) is that the project team works together using the best collaborative tools at their disposal to ensure that the project will meet the owner’s requirements at significantly reduced time and cost [3]. The owner needs to be either part of this team (to help manage the process) or a consultant, to represent the owner’s interests. The trade-offs that are always part of the design process can best be evaluated using BIM—cost, energy, functionality, and constructability [2][3]. Therefore, BIM and project management go together and represent a clear break with current linear processes that are based on paper representation exchange of information. The effective use of BIM requires that changes be made to almost every aspect of project management approach (not just doing the same things in a new way) [3]. It requires some understanding of technology (BIM & GIS) and related processes and its implementation plan before the project may begin. Since, BIM and GIS having their own centralised data platform, they are required to be connected between each other, so that they are able to work as in a single assess point. The connection of two centralised platform (BIM+GIS) is known as the Connected Data Environment (CDE) for infrastructure projects.

3. Hierarchy of BIM Implementation (HBI)
The deployment of the cutting-edge technology alone do not guarantee benefits without a proper process [6]. There are proofs showing that technology can only be benefited so much, but with the correct methodologies and processes, technologies are able to provide up to 33% cost reduction and 50% of overall time savings. The lesser the standard processes being deployed; the lesser benefits will be gained from the technology deployment.

Figure 3 shows the hierarchy of BIM Implementation based on three (3) level of Classes, with 1st Class as the highest hierarchy while 3rd Class being the minimum BIM deployment with the least benefits [6].
As earlier mentioned, conversion of 2D CAD drawings to 3D parametric models is the lowest form of BIM approach which potentially create other contractual disputes within the contract and may disrupts the entire work progress. At this stage, the appointment of 3rd party model checker is inevitable to avoid the potential problems as described in item 2 above.

The 3rd Class implementation, is considered as the beginners of BIM adoption, it begins when the implementers deploying BIM with the use of BIM-related tools from the inception of the project, i.e. the design consultant deploys the BIM-related tools since day one of the project. However, the design consultant developing the models for the purpose of fulfilling their respective roles only (individual discipline) and production of drawings without the overall BIM process. At this condition, the use of 3D parametric models is for the basic purposes such as visualization or animation (3D), authority submission, basic estimation and discipline-based coordination—without the use of CDE while lacking of overall BIM work-process.

Implementation at 2nd Class acknowledges the implementers at higher BIM proficiency level, with the internal workflow being established and the use of some sort of CDE. Federated models and information are shared while collaboration and communication are carried out through this platform. However, the workflow established at this phase is produced based on isolated cases and suits the specific project or organisation only. Having said that, the benefits that are able to be gained at the 2nd Class implementation will be 40% to 60% higher than 3rd Class [6].

The most comprehensive implementation is marked as 1st Class BIM implementation, where the deployment of technology at this stage is by using the available accepted standards, specification and guidelines such as BS8541, BS8536 and the eight (8) pillars of BIM with high competency. The production of documentation is from the information developed through the
BIM process. A full BIM compliance to the 1st Class will potentially reap full benefits from the technology deployment. Hence, we need to move upward from current practices of 3rd Class BIM implementation with very low benefits towards the most efficient 1st Class practices.

4. Comparison of two (2) Mega Infrastructure Projects in Malaysia as Case Study

4.1 Methods

This research relies on an intrinsic case study approach. Two ongoing mega infrastructure projects in Malaysia were selected as the case studies. The first project is called Linear A, and it is a mega highway project in East Malaysia. The second project is a mega rail project in peninsular or West Malaysia, and is referred to as Linear B. These projects varied in size, phase, BIM execution approach and processes. The projects were selected from the authors’ expert involvement.

Data of the study were collected through desk research (i.e., document analysis), observation and direct interviews with the BIM and GIS implementers, team members, and project managers. Comparisons of these two projects were developed to identify the evolving nature of BIM and GIS, and to create a common view of current BIM and GIS effective deployment practice and processes. The comparison constitutes seven (7) key criteria or checklists of the collaborative data environment, i.e., method of 3D model production, BIM modelling tools and coordination tools, BIM model checking tools, BIM CDE tools, GIS data capturing methods, GIS geodatabase accessibility, and availability of BIM Standards. Assessment tools developed by the BIM Institute of Malaysia are also utilized for the purpose of analysis and generalisation. The study period ended in May 2018.

4.2 Findings

Both, Linear A and Linear B projects implemented similar technologies, BIM and GIS, with two different sets of methodologies and processes. Comparison between both projects was carried out to identify the effectiveness of the technologies that are being utilised and the tangible benefits achieved during the construction works, since the GIS+BIM technology deployed in both projects are similar, hence the comparison is being made to their differences in methodology and processes.

The findings show that both projects have different outcomes and results, whereby, Linear B project is reaping more benefits from the technology deployment and achieving the significant saving in terms of time and cost including winning the international award of “Best BIM implementation” in 2017. Meanwhile, Linear A project is yet to show any significant benefits other than deploying a cutting-edge technology and having a detailed 3D parametric model and reality model of the infrastructure works with some clashes function (carried out by outsourced consultant) with a GIS geo-database accessible separately through the web-based application. The significant differences are on the organisational arrangement and CDE setup between both projects as shown in Figure 4 (Linear A) and Figure 5 (Linear B) respectively.
Linear A project providing separate centralised platform for Project and Information Management dashboard, BIM platform and GIS platform. The setting up of each platforms are being sub-contracted to two (2) separate service providers with separate contract to maintain each service. The GIS service, which includes a separate geo-database with a web-based application is a subset from BIM service. The project information management dashboard is a desktop and server application. The BIM centralised storage is in a local network server (Network Attached Server), while GIS is a web-based application. All three (3) platforms are able to be accessed separately with different access points. This creates disruption to the ease of operation and inconvenience to the users. The author did not find any properly established processes for the use of these three (3) storage areas which could streamline the use of these platforms.

**Figure 4.** Centralised Data Storage for Linear A project

**Figure 5.** Connected Data Environment (CDE) for Linear B project
On the other hand, the setup of Linear B project is based on the single access point for BIM CDE, meanwhile the GIS web-based application is being connected through hyperlink in the GIS platform to the BIM CDE. Even though there are two (2) access points (BIM & GIS), it works as a single-entry platform, since both platforms are connected with each other through hyperlink (inter-connected). This approach makes the utilization of the platform much acceptable to site operation personnel. Meanwhile, the appointment of application setup is through software supplier while the operation and control of the system is through the internal experts with one single head of section to manage both aspects of technology. The process of information management for the entire project is established from the globally accepted standards and guidelines, i.e: BS1192: 2007; PAS1192-2:2013; PAS1192-3 and others, with some modification to suit local practice.

| Table 1. Comparison between Linear A and Linear B project |
|----------------------------------------------------------|
| **Technology Deployment** | **Linear A** | **Linear B** |
| 1. Method of 3D model production | Modelling (conversion) from 2D CAD drawing | Model-based design from inception of project |
| 2. BIM modelling tools and coordination tools | Autodesk Revit, Civil 3D, Infraworks and Naviswork | Autodesk Revit, Civil 3D, Naviswork and Bentley Aecosim |
| 3. BIM model checking tools | N/A | Solibri Model Checker |
| 4. BIM CDE | Bentley Projectwise | Bentley Projectwise |
| 5. GIS data capturing | LiDAR, UAS | UAS |
| 6. GIS geodatabase accessibility | WebGIS – view in plain view only | ArcGIS – view in plain and orbit view |
| 7. Availability of Standards / Guides | | |
| a. BEP | √ | √ |
| b. LOD definition specific for the project | x | √ |
| c. Modelling guide | x | √ |
| d. Establishment of internal Standards & operating Process for entire project | Minimal | Detail SOP for every single phase and operation |
| e. Globally accepted guides e.g: BS, PAS etc | some portion of Singapore BCA BIM Guide and BS1192:2007 | BS1192:2007; PAS1192-2 to PAS1192-4 |

Referring to the aforesaid literatures in item 2.0 and the Hierarchy of BIM Implementation (HBI) at item 3.0, the setup of CDE and the processes used in both projects show that the implementation of Linear B project is at 1st Class implementation while Linear A could be at 2nd
Class or 3rd Class. In order to categorized accordingly, further comparison is made between Linear A and Linear B project as listed in Table 1.

From Table 1, it shows another major difference identified between Linear A and Linear B project, which is the method of 3D parametric model development. Linear A project develops the model from the design consultant’s 2D CAD drawings. Which means, the project designers produced the design in accordance to the conventional method (2D CAD), hence, the client had sought the BIM consultant service to ‘convert’ the 2D CAD into 3D parametric model. As described in earlier literature and experiences, this method contributes further to the inefficiency of the project. According to HBI theory, this is the lowest form of BIM implementation approach. Having said that, there are also some elements of 2nd Class implementation that are available in Linear A project, hence the assessment of Linear A project may fall under the 3rd Class implementation.

Based on the assessment tool developed by BIM Institute of Malaysia, the results from the comparison of both projects against the Hierarchy of BIM Implementation (HBI) and Benefits of the technology deployment is shown in Figure 6.

![Figure 6. HBI and BIM benefits](image)

5. BIM+GIS Process Checker
A comparison between the two (2) case studies clearly proves that deployment of technology alone may not provide optimum benefits if it is deployed without a proper process. The technical know how to use the technology will only benefit to certain level. The more important aspect is to have the knowledge to develop efficient and proper processes to suit the project requirements. The development of these processes must be in accordance to the globally accepted standards and guidelines. Therefore, even though having a BIM+GIS consultant is very helpful at certain level, there is still the need to counter check the BIM+GIS consultant. This is to ensure the appointed consultant is doing the correct approach to reap the maximum benefits from the technology implementation. The BIM+GIS checker can be a company or a person who is an...
expert within the client’s organisation or an external 3rd party BIM experienced and proven practitioners. Without the Checker, there will be no parties cross-checking the ‘BIM consultant’ whether they are doing the right BIM and giving benefits to the organization.

It is proven that by deploying technology alone will not reap the whole BIM benefits, hence, the role of the Checker is necessary in ensuring the process developed for the project is able to streamline the entire construction processes and the deployment of technology. In the event the project is forced to begin from the 2D CAD conversion to 3D model, the Checker is required to ensure the conversion is being done correctly and the developed models (from the 2D CAD) by the BIM consultant meet the minimum requirements for further BIM+GIS processes to take place. Therefore, the Checker (either internal or 3rd Party) must be fully equipped with knowledge and have sufficient experiences on what DO’s and DON’Ts on the construction process, particularly relates to BIM implementation. The selection for BIM+GIS checker must be done thoroughly and strictly. They must be a construction-related background and possess both technical and process skills. They need to prove the competencies from the previous successful project and not simply ‘involved’ in project or handled a previously-failed BIM related project. The BIM+GIS Checker can also act as a coach to the client’s BIM+GIS team to enhance their skills to be a process checker and/or hand-hold the appointed BIM+GIS consultants through-out the project life-cycle.

6. Discussion
The findings show that both projects, Linear A and Linear B, have very distinct approaches, but to determine if the implementation is effective, it has been the subject of discussion and reference to the BIM, CDE, and HBI literature.

The significant differences in terms of approach are the strategy, execution, and model development. It can be said that the implementation of the Linear B project is considered state-of-the-art. Linear B was validated through extensive BIM processes and applications, making it one of the most robust and structured BIM-driven projects. Linear A is evolving as a pseudo-BIM project, and it is believed by most practitioners to be a less desirable approach to “disrupt” the BIM best practice.

This study observed the CDE execution, and the reflection is clustered around the processes and technologies used. The Linear B project CDE approach makes the utilization of all data platforms much more acceptable to the site operation personnel. Meanwhile, the CDE of Project A is ineffective, because the appointment of the application setup is through a software supplier while the operation and control of the system is through the internal experts with one single head of section to manage both aspects of the technology. There are also no established processes for the use of these three (3) storage areas, which could link and streamline the use of these platforms. This situation creates a disruption to the operation and an inconvenience to the users.

Client organizations are a complex network of sub-units with individuals with differing agendas and interests. Clients may have their own criteria on project success and perceived benefits. To improve the client’s perceived value and benefits, and therefore the integrity in the BIM delivery, there is a need for client actors or “integrity agents” in the process of BIM. Based on observation, these agents are argued to possess the needed authority and influence to ensure the system integrity and process clarity by other project participants. There is clear merit to BIM and GIS consultants, as a means to deliver the BIM and enhance the project performance; however, alongside the workflow and process, the integrity check is deemed appropriate. This is also to ensure the appointed consultant is utilizing a suitable approach to reap the maximum benefits from the technology implementation as well as checks and balances in the process developed for the project and is able to streamline the entire construction process and the deployment of technology. In the event the project is constrained to take up the pseudoBIM approach, the “Checker” is required to ensure the conversion and data transformation is performed according to standards and the developed models (from the 2D CAD) meet the minimum requirements for further BIM and GIS integration processes to take place.
7. Conclusion
The paper present two realities of BIM+GIS-driven projects. BIM and GIS are cutting-edge technology and best-practice process, and by adopting these technologies, clients can manage mega infrastructure projects in a more effective, integrated, and structured way. The information, documents, and models are systematized in the entire timeline of the project from inception to operation and demolition. Since BIM and GIS are technologies that need specific competencies and experience, the appointment of the right expertise is crucial to ensure the achievement of the project objectives. A comparison of the case studies has proven that having cutting-edge technology alone will not provide much benefit to the project unless it is coupled with the appropriate processes and standards. It is clear to see that the Linear B project is reaping more benefits from the technology deployment and is achieving significant savings for time and cost. Meanwhile, the Linear A project is yet to show any significant benefits other than deploying a cutting-edge technology and having a detailed 3D parametric model and reality model of the infrastructure works with some clashes function.

This paper shows that efforts to integrate BIM and GIS in Malaysia are evolving, and thus a “one-size-fits-all” approach is probably misguided and could hinder BIM diffusion in Malaysia. There is nothing wrong with pseudo-BIM, as despite being less desirable, it can however be improved and reoriented with an integrity checker role. The implementation and execution approach must be strategically planned and properly developed to avoid creating new disputes and conflicts. The Checker, either internal or third party, is appropriate to ensure the BIM execution meets the client’s objectives and requirements.

8. References
[1] Kymmel W 2008 Building Information Modelling, Building Information Modeling Planning and Managing Construction Projects with 4D CAD and Simulations pp11, 47-50, 51-52
[2] Harris M, Irfan A, Haron T and Husairi A 2014 The Way Forward for Building Information Modeling (BIM) for Contractors in Malaysia Malaysia Construction Research Journal 15. No.2
[3] Eastman C, Teicholz P, Sacks R and Liston K 2011 2nd Edition BIM Handbook: A Guide to Building Information Modelling for Owner, Managers, Designers, Engineers, and Contractors John Wiley and Sons., Inc. New Jersey
[4] Esri 2018 What Is GIS Corporate website of Esri https://www.esri.com/en-us/what-is-gis/overview
[5] McPartland R 2016 What is the Common Data Environment (CDE)? Corporate Website of NBS https://www.thenbs.com/knowledge/what-is-the-common-data-environment-cde
[6] Ismail M H 2018 Improvement of BIM Deployment for Construction Project in MY Cubicost, Glodon Ltd, China https://mp.weixin.qq.com/s/B4l-qKpkORqh5sU54AcZiA
[7] Razak A A 2018 Provision of GIS + BIM Solutions to Support Utilities Relocation Works Technical Proposal, RS&GIS Consultancy Sdn. Bhd.
[8] The British Standards Institution (BSI) 2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling. PAS 1192-2:2013 Incorporating Corrigendum No. 1, 25
[9] Wikipedia,GeographicalInformationSystems, https://en.wikipedia.org/wiki/Geographic_information_system