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# IMPLEMENTATION OF BUILDING INFORMATION MODELLING (BIM) FOR ROAD INFRASTRUCTURE IN THE DESIGN PHASE

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## Info Artikel

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## Abstrak

Pemanfaatan Building Information Modelling telah banyak diterapkan pada struktur bangunan gedung, namun masih relatif baru diterapkan pada struktur jalan raya. Dengan berbagai tuntutan yang dihadapi oleh struktur jalan raya seperti keamanan, kenyamanan serta anggaran pemeliharaan, cara-cara tradisional untuk mengelola infrastruktur jalan raya dirasakan sudah tidak mencukupi lagi. Menurut UNECE (United Nation Economic Commission for Europe), dengan lebih dari 50% modifikasi kontrak disebabkan oleh berbagai kelemahan, BIM menawarkan solusi untuk mengatasi berbagai kelemahan dengan jalan menyatukan peran semua pihak-pihak yang terlibat dari tahap desain hingga tahap pemeliharaan. Artikel ini membahas penerapan BIM pada proyek infrastuktur jalan raya, khususnya pada tahap desain. Metodologi yang digunakan adalah membahas beberapa jurnal yang membahas penerapan BIM pada proyek jalan raya.

## *Abstract*

*The implementation of BIM has long been known to building but is still relatively new to road infrastructure. With various demands such as safety, comfort and maintenance budget, the traditional way of managing road infrastructure is considered inadequate. According to UNECE (United Nation Economic Commission for Europe), in large-scale of infrastructure project, more than 50 percent of contract modification - which is considered inefficient - are related to deficiencies, BIM provides an effective way to overcome this by integrating all the stakeholder since the design phase to post construction phase. This article reviews the implementation of Building Information Modelling (BIM) in road infrastructure, particularly in the design phase. The methodology used is by reviewing some journals discussing implementation of BIM in road infrastructure.*

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## INTRODUCTION

Road infrastructures are subjected to various requirements such as safety, comfort and maintenance budget. Traditional ways of managing this sector are inadequate of managing the challenges of today. Managing road's quality for its entire life is a big concern for all the parties involved. Many problems are the result of inadequate communication within the contracting parties or with the other design parties.

The amount of information of a project from start to finish is massive. Various types of information are required by different stakeholders within the project at any stage of the project. According to UNECE (United Nation Economic Commission for Europe) in its report, many problems are triggered from the design stage or communication about the design, and more than 50% of contract modification are caused of design deficiencies. This suggests all the parties involved to identify and resolve potential problems as early as possible to make sure the delivery of complete and correct design and construction documentation.Therefore, road authorities need to adopt a more efficient measure as inefficiency is not tolerated, i.e., the authorities need to plan, build, maintain and operate road infrastructure properly to create an appropriate value for the customers. As stated by UNECE, to achieve this goal, road authorities must adopt an appropriate system to achieve:

Greater transparency and consistent workflow throughout the design, construction and maintenance process.

Reduction in error and change order.

Increased productivity.

Better collaboration among stakeholders.

Cost saving.

These days, digital technologies influence the way of creating, delivering and managing projects, e.g., Building Information Modelling (BIM), robotics, artificial intelligent, 3D printing, the internet of things, drones, etc. In recent years, the adoption of BIM has been widely spread in a construction of a building to boost productivity, on the other hand the adoption of BIM still waiting to be more adopted in infrastructure construction. Nevertheless, the application of BIM in infrastructure is accelerating as infrastructure stakeholders increasingly recognize the benefit of 3D modelling and the use of intelligent objects.

Creating virtual model in 3D not only benefits designer and builder, but also mostly benefit the client, as the client can monitor the performance-based cash flow, supervise the project, analyse performance and safety aspect and manage work in a coordinated manner. Having a digital platform also helps client seeking information and mapping their assets.

## METHODOLOGY

The methodology used in this article is by reviewing some journals discussing BIM implementation in road infrastructure, particularly in the design phase.

### BIM Origins

According to Lenart et al., Building Information Modelling (BIM) is a model-based process for generation and managing building data during building life cycle. The concept of BIM was first introduced by Eastman et al. and explained in detail by Van Nederveen and Tolman in the journal Automation in Construction in 1992. Moreover, still according to Lenart et al., real implementation and popularity of BIM started at the end of the millennium with various commercially available solutions, from traditionally two-dimensional drawing to 3D modelling. Now, BIM appends spatial dimension with time as the fourth dimension and cost as the fifth dimension, thus nowadays BIM is known as a digital representation of physical and functional characteristic of a facility. BIM is also a shared-knowledge platform of a facility that can form a reliable basis for decision making during the life cycle of a facility.

Autodesk introduced Civil 3D 2006 in 2005 to make BIM more applicable for infrastructure project. Civil 3D 2006 applied parametric modelling to the definition of a road model. The early version of Civil 3D did not have BIM capabilities, but nowadays significant changes and development has been made so that it is more powerful in performing BIM capabilities. The concept of the creation of 3D model corridor of a road was later adopted by other major software vendors such as Bentley with the Open Road application.

**Comparison of the Traditional Process and the BIM**

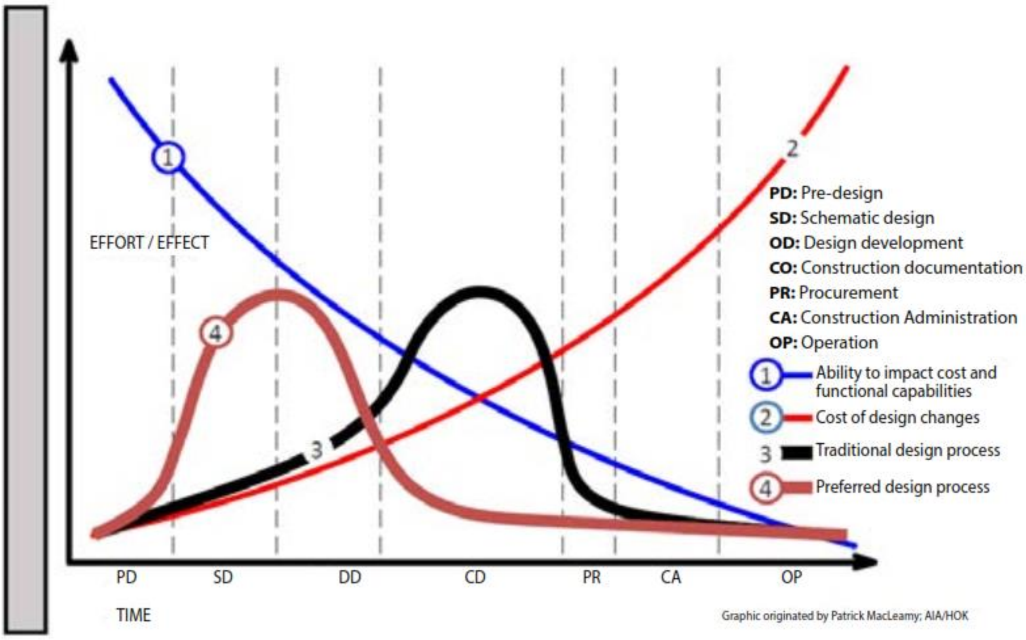
Typically, a construction process is described as a client orders engineering services to facilitate a project's implementation to a designer. The selected designer refines the project's requirement and communicate it to the consultant. Together as a design team, they develop a design as a solution to meet the client's requirement. The design is developed through several stages, i.e., concept design, feasibility study, and preliminary and detailed design. In this approach (traditional approach), documents related to the technical specification, its cost and construction duration are produced at each of these stages.

The communication between the project's team sometimes does not work well for example when exchange of 2D drawing, thus many technical data can be lost when switching to subsequent stage and must be re-created. In this kind of working environment, it is difficult to coordinate between the profession because it is lack of review procedure. Typical and common errors occur with this process, e.g., working with non-up to date files, mismatching of different parts of the project and lack of data describing the technical characteristics and functioning of individual elements.

According to UNECE, in road project, there are lots of data that cannot be presented and verified during the design stage in traditional approach, so that error in design is not detected in time. The result of transferring incorrect and incomplete data to the next phase resulting in identified error in the construction stage that caused delays and additional cost.

On the other hand, BIM has a systematic manner to overcome the drawbacks in the traditional approach. In BIM system, it is necessary to ensure uninterrupted flow data and tools for communication and coordination. According to UNECE, the basic concept of BIM is to develop a model through all stages using the component of the building that contains information. In the conceptual design, the project communicates in a way that depicts spatial relationship using shapes and more general component.

This kind of system is very helpful for the road authorities in making decision about a new project. The earlier a decision is made, the greater the impact to the project's variable such as time and cost, as can be seen in MacLeamy diagram (Figure 1). For example, reviewing a planned motorway route in a 3D environment, with the necessary indicators such as intersections and structures, can have a decisive impact on preventing costly and complex changes during the construction stage.




*Source*: Bob Springer, as shown in "Thoughts inspired by the ABA Forum on Construction Law", The Division 4 Triclinium, 28 June 2013.
Available at http://division4triclinium.blogspot.com/2013/06/of-macleamy-curve-efficient-design-and.html

**Figure 1**. MacLeamy curves, cost/time reduction potential versus cost/time of making changes

The designer should maintain the balance of the scope of the project, schedule and cost in line with the client's budget and requirements during the further design process. Any change can trigger cost overruns and delay. Traditional method usually needs longer time to produce cost estimates and schedule information. On the opposite, BIM provides all the design documents, schedule, quantities and other important information are all in a single source. This simplification puts the design and other construction team in a better communication and collaboration which in turn eliminates painstaking of manual verification and improves cost efficiency.

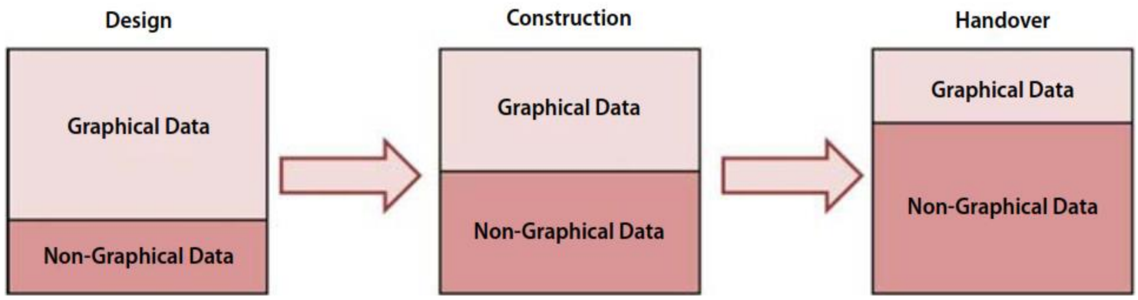
As the design process goes into the detailed design, the information on component throughout the model will increase and allow the engineering analysis in support of the design. At the completion of the design, all graphical model, performed analysis, simulation, as well as non-graphical data will form Design Intent Model.

Upon completion of the design process, the digital model is forwarded to the contractor. The transfer of data between the designer and contractor is better in this way than using standard CAD project documentation printed on paper. The level of detail of the component supports the accuracy of cost estimation, procurement, constructability and installation, leading to Virtual Construction Model. Moreover, direct import and export data (e.g., a design subgrade surface can be loaded directly into a GPS-guided machine control) eliminates misreading and misinterpretation.

BIM technology enables a better communication between the designer team and the contractor in construction process as there will be more likely modifications and updates which is often necessary in motorway project due to various reasons.

When construction works completes, there will be a large amount of data generated throughout the process and systematically linked to the BIM model. The next step is to transfer this data to asset management which in turn will be used in life cycle management. This is important because operation and maintenance is the biggest proportion of the life cycle of a road.

As stated by UNECE, based on all project information and modification during the construction process, this model then serves as an Operation and Maintenance Model. At this stage, the amount of non-graphic data begins to dominate into the asset management and maintenance system, 3D models are no longer appropriate for this system (Fig. 2)




*Source*: Yusuf Arayici, Building Information Modelling (n.p., Bookboon, 2015), e-book.

**Figure 2**. Changes to BIM model in project phases according to data type

**BIM Tools**

BIM requires many cross functional processes that involve many software solutions, BIM is not a single process brought through by a single piece of software. Each piece of software has its functional ability to perform work related task relevant to its purposes. In other words, BIM model is generated by varieties of BIM software. Although the history of BIM implementation in infrastructure is shorter than in building architecture, a valuable set of tools are already available today. Software tools are used at different stage to achieve each outcome, no one application can be ideal for any project and task, so BIM uses several applications with a clear data change protocol. Today there are two major software vendors in architecture, engineering and construction (AEC), Autodesk and Bentley. Both offer complete solution for the application of BIM in Civil Engineering projects.

**Autodesk Platform**

In terms of Civil Engineering and Architecture, the main application is Civil 3D. Civil 3D is based on CAD tool, AUTOCAD. There are advantage and disadvantage, the advantage is AUTOCAD is widely spread. The disadvantage is that AUTOCAD is not an ideal platform to work in 3D environment, the complexity and the size of the model should be considered when the model will be stored in a single drawing file. AUTOCAD also supports parametric modelling by creating so called Corridor Road Model.

Autodesk also includes Infraworks and Naviswork Manage application. Infraworks is responsible for planning and designing the analysis in the conceptual design phase, while Naviswork Manage is used to perform project review and make 4D and 5D BIM analyses.

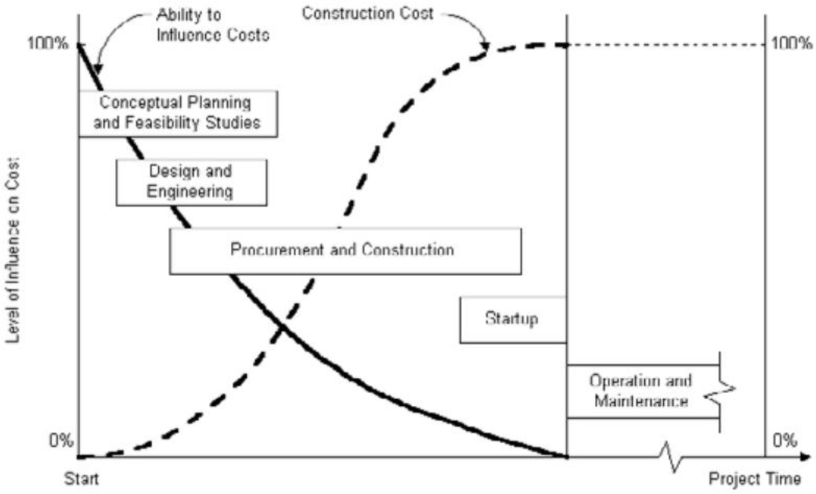
The significant and powerful of the Autodesk application is Revit. Although primarily intended for architectural application, Revit is also used for structural project, often for detailed reinforcement design.

**Bentley**

There are no predefined collections in Bentley, but the user has different tool grouped by brand, product line or discipline. There are four applications for road design, InRoads, GEOPAK, MX and PowerCivil. According to UNECE, as of 2016, these products has been replaced by the more modern OpenRoad application with strong BIM features. The basic concept is similar to Civil 3D, with a corridor model consisting of functional component that allow the placement of intelligent, modifiable compound element. Similar to how Civil 3D works in AutoCAD environment, OpenRoad works in Microstation environment.

**BIM Uses in the Design Processes**

BIM influences design phase more than in any other phases. Design phase is the crucial phase where considerable amount of data and information are generated by stakeholders to satisfy the client and code requirement. Problems that occur in design phase due to poor decision making can cause a high-cost impact on the project. As illustrated in Fig. 3, changes made earlier in project life cycle can have a greater influence on the project outcomes. Whenever a change is made, the consequences are coordinated throughout the project. The change can be introduced in the design phase. In addition, the project teams can offer solutions or ideas to overcome problems that occur in the process.




*Source*: Chris Hendrickson, "Project Management for Construction", summer 2008. Available at https://www.cmu.edu/cee/projects/PMbook/02_Organizing_For_Project_Management.html

**Figure 3.** Level of Influence of Decision in Project

**BIM Uses in the Design Phase**

Because there are so many activities happening during the design phase, the application of BIM is more obvious there than it is during the building and operation phases. The subsections below provide more details on certain BIM applications.

**Site modelling-establishing and analysing a 3D real world environment**

Before launching a project, the designer can use variety of tool to capture the existing condition to better understand the terrain and the environment. To make the environment more realistic, things like trees, houses, water areas, etc can be added to the model. Once established, the environment is ready for topographic analysis of the elevation or slope of the terrain.

The BIM model can show the optimal location of the project or for optimal route selection by properly analysed with available tool. Mapping tools and website that allow the user to view topography in a variety of way, for example displaying the project on Google Earth platform are incorporated in BIM tools.

**Site/route analysis**

BIM and GIS are used to evaluate properties in a specific area to determine the most optimal site for future project. Condition at a future construction site can affect developments and construction costs, and it is important for the client to realize this potential, before an investment is made.

A 3D model of a motorway site or a corridor can used to evaluate the advantage and the disadvantage of a selected location based on selected criteria, including environmental impacts-on water, noise, propagation, surrounding structures, historical objects, forests, etc.

### Visualization

A 3D project model embedded in a realistic environment helps each party to better understand the design concept and details. Infrastructure project generally affect the stakeholder-including the general public and they have an interest to understand the proposed project.

For the project team, project visualization leads to a more precise and detailed design and an improvement in the design as a whole. Furthermore, visualization helps in many situations where the client and the designers must choose one of several solution.

### Design authoring

Design authoring is a procedure that creates an information model for a specific element or object in a highway project using BIM tools. It is crucial to remember that the BIM model should be created concurrently with the design since doing so would result in a major waste of resources and a BIM model that is fundamentally faulty because it is based on a project that was finished using traditional methods (2D drawings).

### Surface analysis

BIM's surface analysis tools are used to perform in-depth study on model objects, like volume analysis. On planned surfaces, all analyses that have been done on the existing surface can be repeated. It is possible to evaluate the suggested design interventions in terms of elevation, slope, aspect, and hydrology. Cut and fill calculations can also be done to balance the need for earthworks.

### Design review

A BIM model is used during the design review process to assess the project schedule and a list of desired criteria, such as layout, lighting, or road safety. For instance, a highly detailed virtual mock-up can be created to analyse design options and research constructability in an interactive setting. These reviews will then result in the early elimination of any potential building issues.

### Design changes

The dynamic architecture of 3D modelling software allows it to cross-examine surface data with pipe networks, roadway alignments, vertical profiles, and site grading to quickly react to design changes. Modifications to a vertical curve, the removal of nearby walkways in favour of landscaping, changes to pipe sizes, or adjustments to pavement depths are all immediately reflected in the model and recalculated to accommodate site conditions.

### Engineering analysis

An engineering analysis is a process that uses a BIM model using intelligent modelling tools to identify the best engineering approach based on the design requirements. The performance of designed structures (such bridges and tunnels) is simulated and analysed using specialist analytic tools in BIM in a variety of methods, including structural analysis.

To ascertain the behaviour of a certain structural system, BIM data is used. The optimization process for structural design and analysis uses modelling to meet minimum requirements. Based on this study, the structural design is further developed and refined to produce functional, cost-effective, and constructible structural systems. The acquisition of this knowledge serves as the foundation for the phases of digital manufacturing and building system design.

### 3D, 4D and 5D analysis

A 4D/5D analysis and simulations can be run to assess project specifics, timetables, and logistics once a BIM model has been finished and verified. Stakeholders can envision construction throughout the project's lifespan using 4D modelling to spot any potential spatial or temporal scheduling problems. A fifth dimension is added to the process by including a cost component. Stakeholders can assess expenses and estimate cash flows for each stage of construction using 5D designed models.

**Code validation**

BIM software uses a procedure called "code validation" to check model parameters against project-specific codes and standards. These codes serve as fundamental regulatory specifications for the safety, level of service, and road design.

**Cost estimation**

The procedure for calculating the quantity of supplies and the number of items needed in a certain building project is known as quantity take-off. BIM may be used to predict project costs and automatically extract quantities from models. Additionally, using BIM in this way can help compare the costs of various designs so that adjustments can be made early in the design phase, preventing budget overruns.

Compared to a quantity take-off that is manually extracted using conventional methods, which rely on the estimator to calculate quantities from 2D drawings, a quantity take-off generated by a BIM tool from the model is significantly more accurate and reliable.

**Clash detection**

Tools for validation are utilized for the process of clash detection, which is analogous to 3D coordination. Most investigations examine how one profession affects another; hence these analyses are carried out on a complicated, aggregated model. The project team may better identify and address any design difficulties using this kind of study before construction begins.

Conflicts are typically found manually by superimposing 2D drawings. However, with BIM technology, systems from all the disciplines can be compared and incompatibilities can be found before they are discovered on the construction site. Identifying design flaws or omissions involves the automatic detection of incompatibilities. A soft clash occurs when two items are too close to one another, but a hard clash occurs when two objects overlap or occupy the same space.

## CONCLUSION

Implementation of BIM in road infrastructure, particularly in the design stage is expected to decrease the contract modification caused by design deficiencies. In order to comply with today's economic realities, where inefficiency is not tolerated, BIM is expected to improve productivity, business processes, and transparency. For example, authorities must properly plan, construct, maintain, and operate road infrastructure in order to provide their customers with value that is appropriate (in this context meaning individual road users, logistic companies or public transportation agencies).

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