Study on Implementation of Building Information Modelling (BIM) in the Architecture, Engineering and Construction (AEC) Industry (AEC)

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Abstract. Technical requirements regarding sustainable development guidelines, especially for the building sector, have been implemented based on Law no. 28 of 2002 concerning Buildings, Government Regulation no. 16 of 2021 concerning the Implementation of Law no. 28 of 2002 and Regulation of the Minister of Public Works and Public Housing No. 9 of 2021 concerning Guidelines for Sustainable Development. This research is initial research as a form of response to the legislation in the AEC industry which is still very new in Indonesia.

The type of research used is survey research. The population and sample are the parties involved in the AEC industry, especially in the process of procuring goods and services in Indonesia. This research is to obtain a critical study of the expectations and constraints faced by consultants, contractors and planning consultants who specifically are the individuals involved in it, such as architects, site engineers, drafters, construction management consultants and others. The data collection technique was carried out using a questionnaire technique distributed through the google-form platform.

The results show that the implementation of BIM in the Indonesian AEC industry is still in the low category. The low level of BIM implementation can be seen from indicators such as the type of BIM-based software which shows that more than 40% have never used BIM-based software. The implementation of BIM in Indonesia still revolves around 3D modelling problems (30%). The implementation of BIM in Indonesia has not been developed to solve problems such as budget planning analysis (37.8%), construction implementation management (53.4%), energy analysis (86.6%), infrastructure management (71.1%). The conclusion of this study is that the problems of BIM implementation in Indonesia in response to the enactment of legislation are still very open and challenging, such as the adequacy of BIM experts, compatibility and availability of BIM-based hardware and software, both in terms of quantity and quality.

Keywords: Building information modelling (BIM) · Architecture · Engineering and construction industry (AEC industry) · Implementation

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1 Preliminary

Law 28 of 2002 concerning Buildings stipulates provisions regarding buildings which include functions, requirements, implementation, community roles, and development. Building regulations in Law 28 of 2002 concerning Buildings have the objectives of 1) realizing buildings that are functional and in accordance with building codes that are harmonious and in harmony with their environment, 2) realizing orderly building operations that guarantee the technical reliability of buildings from a safety perspective., health, comfort, and convenience, and 3) realizing legal certainty in the administration of buildings. While PP No. 16 of 2021 concerning the Implementation of Law no. 28 of 2002 regulates matters of a basic and normative nature regarding the management of buildings.

The implementing regulations of the two laws are one of the Regulations of the Minister of Public Works and Public Housing No. 9 of 2021 concerning Guidelines for Sustainable Development. Article 6 paragraph 3 requires that the implementation of sustainable construction must be carried out in an integrated and efficient manner by taking into account the use of building information modelling (BIM) technology. The implementation of sustainable construction by adopting BIM technology includes general planning, programming, implementation of construction consulting and/or implementation of construction work.

As a new technical requirement in the modern architecture, engineering and construction (Architecture, Engineering and Construction/AEC) industry, BIM is a demand that must be met by the implementing components of service providers in the construction sector, especially buildings. This demand must not only be met by service providers as institutional institutions, but also target individuals who are involved in this service industry. The provision of AEC services requires technology that is integrated with one another. The provision of AEC services requires increasingly complex individual competencies. Individual competence recognized in the form of certification is a must. In addition, the quality of the products produced must meet standards that are globally accepted and general in nature. The consequences of the provisions for the implementation of BIM implementation in the AEC industry broadly of course have consequences in various fields which do not only have implications as a response to the implementation of BIM itself. The basic problems of implementing BIM in the AEC industry, especially in Indonesia, clearly have wider consequences such as the availability of software and hardware, resource readiness, certification issues and others.

The objectives of this study are 1) to obtain a critical study of the level of use and mastery of BIM in the sustainable AEC industry in Indonesia, especially buildings, and 2) to obtain a critical study related to the expectations of the use of BIM in the AEC industry in Indonesia that must be met by components -components involved in the field of implementing sustainable AEC work, both as institutions and as individuals.

2 Method

This type of research is a survey research type with a quantitative research approach. The reason for choosing this type of research is because this research is basic research so that initial data is obtained for critical studies of similar research in the future related to the response of the legislation in 8 AEC industries which is still very new, namely the Regulation of the Minister of Employment. Public and Public Housing No. 9 year 2021.

The population of this study is all parties involved in AEC activities, including planning consultants, contractors, supervisory consultants and practitioners in the field of education (academics). The research sample is divided into several elements of personnel involved in the AEC, which consists of architects, site engineers, implementers, surveyors, estimators, drafters, quality assurance and other individuals who are directly involved in project implementation. The time of data collection was carried out in the period from June 2021 to August 2021. The number of samples obtained after data reduction was 45 people, with details as in Tables 1, 2 and 3. In relation to respondents who have taken professional education at the engineer level, the main requirement is that the respondent must have passed undergraduate or diploma level program.

The descriptive data analysis technique used is to compare each data item collected to the total items obtained. Furthermore, the results of the comparison of these data items are changed by using measures of central tendency, such as the technique of percentage,

Table 1. Samples by type of work

Type of work	Percentage
Contractor	33.3
Consultant (Construction management, architectural and MEP)	17.8
Drafter	11.1
Academics	13.3
Others	24.4

Table 2. Sample based on education

Type of education	Percentage
Doctoral level	3.2
Master's level (post-graduate	20.0
Graduate level	68.9
Diploma level (D1/D2/D3)	5.1
Others (high school level)	2.8

Table 3. Sample by age group

Age group (years)	Percentage
20 – 30	44.4
30 – 40	31.1
40 – 50	13.3
>50	11.1

mean, median, mode, standard deviation and others. This descriptive data analysis technique was used for data using observation data collection techniques, questionnaires and interviews.

The research instrument is in the form of a questionnaire or a questionnaire, either physical or non-physical. Physical instruments are paper-based instruments that are circulated directly to parties involved in the AEC industry. Meanwhile, non-physical instruments are instruments created through digital applications, such as google-form.

The research variables were grouped into 7 groups of variables, namely the level of BIM mastery, the type of BIM software used, building elements made using BIM, projects made using BIM, reasons for using BIM, problems using BIM, and expectations of using BIM.

Data collection techniques related to data sources. The data collection techniques used were questionnaires and interviews. The interview technique was carried out to sharpen the results of data analysis. Techniques Interviews were conducted randomly on the sample who filled out the questionnaire.

The descriptive data analysis technique used is to compare each data item collected to the total items obtained. Furthermore, the results of the comparison of these data items are changed by using measures of central tendency, such as the technique of percentage, mean, median, mode, standard deviation and others. This descriptive data analysis technique was used for data using observation data collection techniques, questionnaires and interviews.

3 Results

The level of use of BIM is divided into 6 levels, including conceptual design (3D), construction details (plans, sections and views), calculation of the budget plan (RAB) (4D), construction schedule creation (5D), energy analysis (6D) and management infrastructure and building facilities (7D). The results showed that the level of BIM usage for all levels of BIM usage was still very low, namely in the never and very rarely categories. The BIM usage level profile for each category is shown in Figs. 1, 2, 3, 4, 5 and 6.

Although the level of use of BIM is still in the very low category, there are still respondents who use BIM software in completing their project designs. The BIM-based software frequently used by respondents are Archicad, Revit, Tekla, Civil 3D and Bentley. Table 4 shows the ratio of respondents using BIM-based software (Tables 5 and 6).

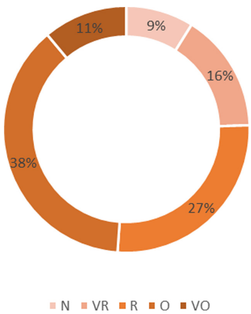

Fig. 1. BIM usage rate ratio: Conceptual design (3D)

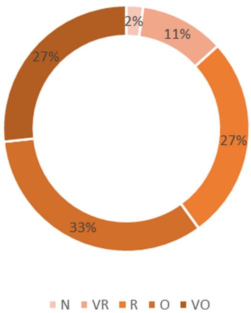

Fig. 2. BIM usage rate ratio: construction details (plan, cut and view)

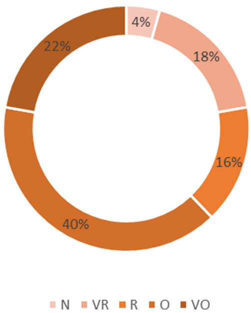

Fig. 3. BIM usage rate ratio: Budget Plan Calculation (4D)

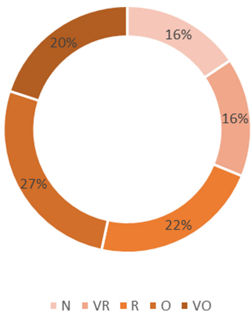

Fig. 4. BIM usage rate ratio: construction schedule generation (5D)

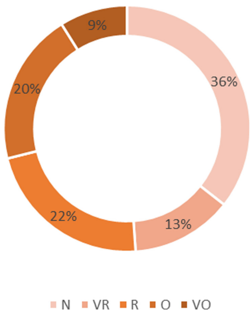

Fig. 5. BIM usage rate ratio: Energy analysis (6D)

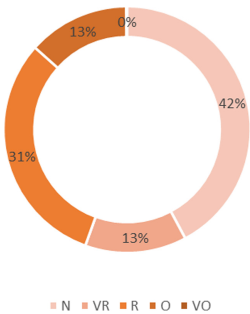

Fig. 6. BIM usage rate ratio: Infrastructure and building facilities management (7D)

Table 4. Software used

Software	**Intensity (%)**				
	N	**VR**	**R**	**O**	**VO**
Archicad	55.6	13.3	17.8	7.2	6.1
Revit	44.4	13.3	31.1	11.1	0.1
Tekla	40.0	11.1	20.0	20.0	8.9
Civil 3D	40.0	11.1	20.0	29	8,9
Bentley	73.3	5.6	13.3	4.2	3.6

Table 5. Building elements using BIM

Building elements	**Intensity (%)**				
	N	**VR**	**R**	**O**	**VO**
Architectural components	11.1	15.6	15.6	46.7	11.1
Structure (column, beam, plate/slab, foundation)	9,65	5,95	13.3	48.9	22.2
Double skin facade	26.7	13.3	42.2	6.7	11.1
MEP *(Mechanical, electrical and electrical)*	28.8	11.3	24.4	24.4	11.1

Table 6. Frequently created projects using BIM

Project	**Frequently (%)**				
	N	**VR**	**R**	**O**	**VO**
Residential	42.2	8.9	35.6	11.1	2.2
Mid-risk building (5 to 10 floors)	44.4	7.6	28.9	13.3	5.8
High-risk building	46.7	11.1	28.9	9.3	4.0
Mixed use building	40.0	17.8	20.0	13.3	8.9
Infrastructure facilities and infrastructure	17.8	8.9	22.2	33.3	17.8
Industrial building	33.3	11.1	26.7	11.1	17.8
Public building	24.4	4.5	26.7	31.1	13.3

4 Discussion

BIM is one of the big leaps in the Architecture, Engineering and Construction (AEC) industry after previously using computer-aided drawing technology (Computer Aided Design/CAD). BIM is the development and use of computer software data, not only to document building designs, but also to simulate the construction and use of new and refurbished facilities (Administration, 2009). The BIM process produces a building information model that has characteristics in the form of building components (elements) along with behavioral data that can be calculated and are consistent and irreducible so that building information becomes more coordinated. BIM is a digital representation of the physical and functional characteristics of a building that serves as a source of knowledge about building information that forms the basis for reliable decision-making from the design process over the life of the building (Eastman, Teicholz, Sacks, & Liston, 2011). Based on these several definitions of BIM, BIM is a tool as well as a process that cannot be separated from one another, namely from the planning process to when the building is "destroyed".

BIM applications are based on CAD applications, which generate digital data or files. However, this BIM application is more than just operating CAD. The BIM process can be said to be the opposite of the design and documentation process using CAD. Previously, old CAD systems only generated geometry data based on vectors associated with line types in the form of layers. While the BIM process depends on parameter models (parametric modelling) to produce coordinated, consistent and quantifiable information on 4 projects (Borrman, Konig, Koch, & Beetz, 2015).

In parametric modelling, it produces parameters with several criteria such as: a) Geometry contains data and related properties; b) geometry is integrated and consistently informed in all directions of view (view); c) the geometry will adjust automatically when it is interconnected or inserted with other interrelated elements; d) the property has a consistent change in value across all sub-element levels; e) element properties can detect conflicts if there is a change in the properties of the elements on them or related to them; and f) element properties can be linked (linked) or extracted for further and complex analysis using the same or different applications. BIM is also more than just 2-dimensional and 3-dimensional modelling of CAD methods. Some of the basic differences between 2-dimensional CAD, 3-dimensional CAD and BIM modelling are as shown in Table 7.

BIM functions like the work process of architects and engineers in designing buildings and loading their construction methods. This design stage is a back and forth process every time (iteration). BIM also has the ability to simultaneously enter data covering all elements from the conceptual design stage to the final construction. In this context, if a change occurs at an early stage in an element, it will also affect the next stage.

BIM integrates 3D drawing and 4D animation to dramatically improve communication, coordination, and planning of construction projects, while reducing risk, errors, and costs. BIM is an in-depth resource that shows architects and building professionals how to utilize BIM concepts, tools, and techniques for their own building projects. In-depth explanation of BIM concepts, tools and techniques.

Guidance on applying BIM to new buildings and retrofitting construction projects. More than 200 photos, charts, diagrams and details BIM integrates 3D drawing and 4D animation to dramatically improve communication, coordination, and planning of construction projects, while reducing risk, error and cost. Building Information Modelling is an in-depth resource showing architects and building professionals how to leverage BIM concepts, tools, and techniques for their own building projects. In-depth explanation of BIM concepts, tools and techniques. Guide to applying BIM to new buildings and retrofit construction projects. More than 200 photos, charts, diagrams and details of

Table 7. Comparison of modelling concepts

	2D CAD	3D CAD	BIM
Files required for project completion	More than 1 file	More than 1 file	1 file
File size	Small	Medium	Large
Standard working drawing annotation	Manual	N/A	Otomatic
Calculation of non-graphical data	Manual	N/A	Automatic
Design visualization	N/A	Yes	Yes
Architectural behaviour	N/A	N/A	Yes
Spatial understanding	N/A	Yes	Yes
Project documentation	Manual and relatively easy	Manual and difficult	Automatic
Difficulty level in training/training	Simple	Moderate	Complicated

the detailed BIM case study process. Models generated from BIM are used for analysis and design of buildings and other infrastructure. The ability to integrate schedule and cost data with analysis and design processes makes BIM a very useful tool. The use of BIM is examined as a framework for structural design; in cost estimation; in adaptive cyber-physical systems; in construction progress monitoring and project management; in the delivery of green building projects; in commissioning and facility management; in military construction; in model assessment; and in integration with augmented reality. Engineers, architects, contractors, building owners, facility managers, and researchers will find this publication a valuable resource (Nawari, 2018). Building Information Modelling: Framework for Structural Design outlines one of the most promising new developments in architecture, engineering, and construction (AEC).

BIM is an information management and analysis technology that is changing the role of computing in the architecture and engineering industry. The innovative process of building a database that collects all the objects needed to build a particular structure. Instead of using a computer to produce a series of images that together depict a building, BIM creates a single illustration that represents the building as a whole. This book highlights BIM technology and explains how to redefine structural analysis and design of building structures (Krygiel & Nies, 2008).

Standardization is the process of implementing and developing technical standards based on the consensus of various parties including companies, users, interest groups, standards organizations, and governments (Xie, Hall, McCarthy, Skitmore, & Shen, 2016). Standardization can help maximize compatibility, interoperability, security, repeatability, or quality, both in the social sciences including in the field of economics (Blind, 2004). As a process of implementing and developing these technical standards, standardization plays an important role in a series of work, starting from the planning process, the production process to post-production. From these two statements, it can be

Table 8. Comparison of modelling concepts (LoD)

LoD	Description	Phase
LoD 100	Model elements can be represented by basic geometries, symbols, or other generic representations	Schematic design
LoD 200	Model elements are represented as generic systems, objects, or assemblies that represent approximate numbers, sizes, shapes, locations, and orientations	Design development, design drawing
LoD 300	Model elements are represented as specific systems, objects or assemblies in terms of number, size, shape, location, and orientation.	DED, construction documents
LoD 350	Model elements are represented as specific systems, objects, or assemblies in terms of number, size, shape, location, orientation, and other system interfaces.	Bidding and procurement documents, sub-contractors and sub-consultants
LoD 400	The model elements are complete with detailed information, manufacturing, assembly, and installation	Construction phase, fabrication phase
LoD 500	An as-built model, according to field conditions after being built	Operational and maintenance phase

concluded that product standardization is the minimum benchmark that must be met in a production process. This standardization also covers the work process in the production process itself up to post-production. In the context of BIM, standardization plays an important global role. British Standards is an institution that seeks to implement the BIM standardization. The product produced by British Standards related to BIM is ISO 19560–2020. In Indonesia, standardization is carried out by the Indonesian National Standardization Agency. This body formulates various standards or codes that are generally applicable and technical in nature. This standardization product is compiled in the format of the Indonesian National Standard, abbreviated as SNI.

Certification is the formal attestation or confirmation of certain characteristics of an object, person, or organization. While the definition of a certification test provided by the U.S. National Council on Measurement in Education, certification tests are tests that are credential and are used to determine the adequacy of a person's knowledge in a particular field of work, so that the individual can be labeled "competent to practice" in that field (Glossary1). Competence is defined as a set of knowledge, abilities, skills, experience and behavior, which leads to the effective performance of individual activities. Competence can be measured and can be developed through training. It can also be broken down into smaller criteria (Maaleki, 2019). The maturity level of competence in the adoption of BIM consists of 3 (three) levels, namely level 0, level 1 and level 2.

The level of development of BIM is known as the Level of Detail or Level of Development (LoD) (Architect, 2013). The six levels of LoD known in BIM are known as LoD 100, LoD 200, LoD 300, LoD 350, LoD 400 and LoD 500. The different descriptions of each LoD can be seen in Table 8. Maturity level level 0 is indicated that the construction implementation has not used BIM technology. This maturity level is only a design product in 2-dimensional form that is not organized even though it already uses CAD technology (unmanaged 2D CAD design). Maturity level level 1 is a mixed combination of 2-dimensional and 3-dimensional technology based in integrated 2D and 3D file-based design. While the maturity level level 2 is an integration between 2 dimensions and 3 dimensions in the data environment and the combined model (mixed 2d and 3d with a common data environment and federated model). The use of BIM is not just a design modelling in the form of a 2-dimensional format. The use of BIM includes up to 8D, namely modelling (modelling/3D), scheduling (scheduling/4D), financing (cost/5D), sustainable design (sustainability/6D), infrastructure management (facility management/7D) and security aspects (safety/ 8D).

5 Conclusion

The conclusion of this study is that the development and implementation of BIM in Indonesia is still relatively low, which is indicated by the mastery of computer software to support the implementation of BIM-based projects. This is an obstacle as well as a challenge in the future, considering that the development of BIM in Indonesia requires experts, which are currently still dominated by workers who are not yet competent in the field of BIM. The biggest obstacle going forward in the development of BIM in Indonesia also includes standardization and certification which are still seen as aspects of high (very expensive) economic costs. This must be resolved by various stakeholders who are interested in the implementation of BIM in Indonesia.

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