Development of system information of building code checking in planning and permitting phase to improve building code compliance based on work breakdown structure (WBS) using building information modeling (BIM)

Endiq Yogana, Yusuf Latief

Civil Engineering, Department of Civil Engineering Faculty of Engineering, University of Indonesia Jakarta, Indonesia.

E-mail: endiqyogana@gmail.com

Abstract. *Purpose*: Audit of the requirements for construction project regulations in DKI Jakarta is still conducted conventionally (paper and CAD based) which requires a long time, resource intensive, different interpretations of the regulations, the process of revised repetitive, the process of tracking difficult requirements, inaccurate and not transparent, and has significant time and cost implications. Examination of conventional requirements causes that there are still many buildings in DKI Jakarta that have not yet met the technical requirements requested for building completion and public dissatisfaction. Automatic requirements checking is possible when the computer representation of the product data model (Product Data Model (PDM)) is integrated with the Legal Knowledge Model (LKM) as input for data processing systems or machines with algorithmic procedures as Compliant Design Processes (CDP) to produce an accurate automatic regulatory check report. *Methodology*: The Building Model developed in Building Information Making (BIM) is made as a building representation. The scope of building technical requirements based on BIM is managed dynamically using Work Breakdown Structure (WBS) in one database that is validated by the Government and can be applied by planners in any planning. This research uses the BIM model and develops a WBS-based Information System with a BIM application. *Results*: The scope of requirements can be managed by decomposition of work known as Work Breakdown Structure to produce a BIM component that will be subject to regulatory requirements checking. The ability of the BIM can produce building models that can be subject to audit of regulatory requirements. Examination of regulatory requirements can be carried out at each stage of developing the BIM model according to the level of detail of the BIM object. Examination of regulatory requirements can be carried out independently by planners at each stage by using a Web-based Information System developed in the BIM format that has been validated by the Government. *Applications/Originality/Value*: By grouping requirements based on the stages of development of the BIM model, it will maximize the fulfillment of the requirements at each stage so as to reduce the risk of redesign while at the same time increasing the fulfillment of the technical requirements of the building.

1. Introduction
In accordance with the mandate of Law No. 28 Year 2002 about Buildings (2002). (article 7 paragraph 1) each building must meet the technical requirements set by the government.
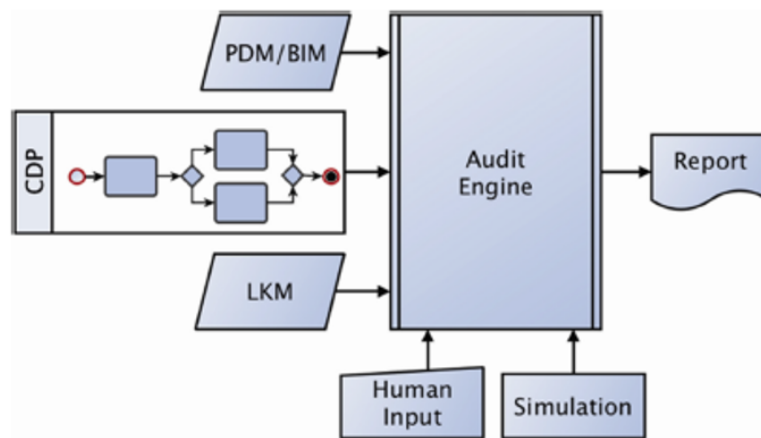
Figure 1: Automated compliance audit framework [4].

Obligation to meet the requirements aims to realize buildings that are functional and in accordance with building structures that are harmonious and in harmony with their environment, to realize an orderly administration of buildings that guarantees the technical reliability of buildings in terms of safety, health, comfort, and convenience, and to realize legal certainty in operation of buildings (*Undang-undang No. 28 Tahun 2002 tentang Bangunan Gedung*). Even though the requirements have been regulated, there is a phenomenon that many buildings and buildings in DKI Jakarta have not yet met the technical requirements. The results of the research index fulfillment of accessibility or convenience requirements conducted by the Jakarta Legal Aid Institute. The results of 38 (thirty four) buildings that were the object of research observation, as many as 26 (twenty four) buildings were categorized as not meeting the requirements, 12 (two) buildings did not meet the requirements, and none were categorized as meeting the requirements.

The work of checking requirements by the Government of the DKI Jakarta Provincial Technical Office is still carried out conventionally and manually, namely checks based on 2-dimensional (2D) drawing documents, both soft-copy and paper-based. The planning documents that are entered are examined manually by the examiner. While the number of documents examined is not proportional to the number of examining personnel, it is not able to thoroughly examine requirements.

Previous studies found that the problem of fulfilling requirements was categorized into 3 (three) factors: identification of requirements, management of requirements and traceability of requirements. [1, 2]. The process of identifying, managing and tracking requirements in a conventional manner (manually) requires a long time, resource intensive, repetitive revision process, the process of tracking requirements is difficult, inaccurate and transparent, and has significant time and cost implications [3].

Automation of requirements checking is possible when the computer representation of the product data model Product Data Model (PDM) is integrated with the Legal Knowledge Model (LKM) as input for data processing systems / machines with algorithmic procedures Compliant Design Processes (CDP) to produce accurate auto-fulfillment reports [4–8], as shown in Figure 1.

The planning stage has the highest decision complexity that demands a match between meeting client requirements, location, construction and regulations. Success in the planning process has a high influence in determining project performance, where the more effective and efficient planning process will reduce redesign while also minimizing the occurrence of cost overrun and delays due to design changes [9–11]. At this stage there is a briefing process
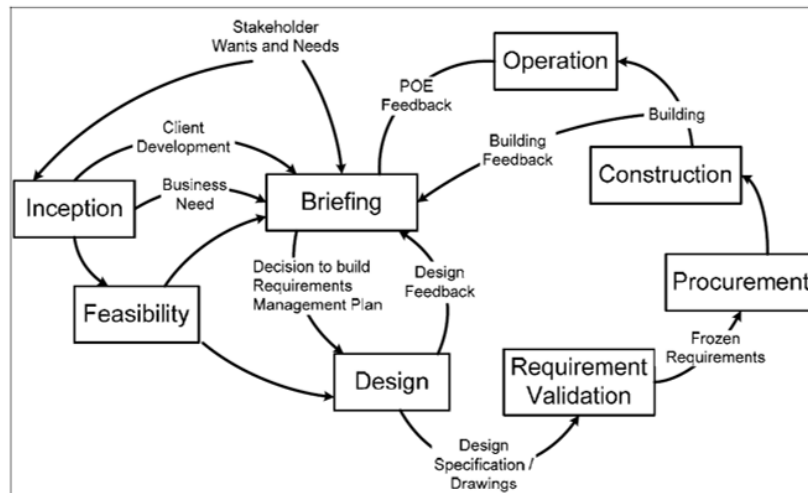
Figure 2: Framework of Requirements Management in Construction Projects [13].

that elaborates on many aspects [12, 13], shown in Figure 2. In the briefing process, owner requirements and location limitations can reduce compliance with regulatory requirements [14, 15].

The product of this research focuses on checking automatic requirements at each stage of developing the BIM model in the planning phase. The legal language in the regulation is validated by the government which has the authority to give permission and then it is translated into the BIM-based automated requirements checking information system procedure that can be applied at every stage of the development of the BIM model. With the increasing use of BIM in Indonesia, the integration of planning and licensing processes with BIM is expected to be a solution to solve problems and phenomena that occur, particularly meeting the technical requirements of buildings aimed at increasing building reliability.

2. Literature Review
2.1. Requirements Management
Definition of requirements   Requirements are the basis for each project, defining what is needed by the stakeholders from it and also what the final product must meet to meet those needs [13]. A requirement is a statement that identifies the ability, physical characteristics, or quality factors that limit a product or process need to be sought for a solution. Good requirements are complete, unambiguous, consistent, feasible, neutral solutions, traceable, needed, concise, correct, verifiable and should not be used for wrong purposes [16].

Requirements in the AEC (Architecture, Engineering, Construction) industry   In the architecture, engineering and construction industries, there are various types of project requirements, namely client requirements, site requirements, environmental requirements, regulatory requirements, design requirements, and construction requirements which are related as shown in Figure 3 [12, 13, 17, 18].

2.2. Information System
The information system is a combination of software, hardware, telecommunications networks and brainware that was developed to collect, create and distribute data and information that is useful in an organizational context. Key elements in Information Systems include Objectives, Work Procedures, Data and Information, People, and Information Technology.
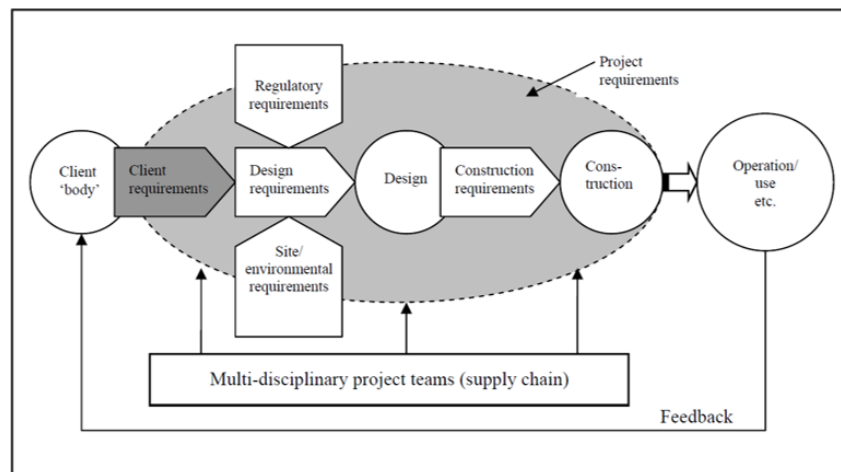
Figure 3: Interrelationship between construction project requirements [12].

Information systems can overcome data and information problems, improve resource efficiency, optimization, monitoring, improve service quality and can be used in lifecycle management [19]. The informatization function can strengthen the role of humans in terms of accurately informing data and information related to requirements [20]. The automation function can reduce operational costs by replacing expensive human resources in managing and processing data and information related to requirements automatically [21]. The transformation function can restructure HR workloads in managing requirements [20].

Automation compliance checks were first introduced by the Singapore Government in 1995 based on 2-dimensional images, which then developed with the BIM-IFC-based "CORENET BP Expert" platform in 1998. Followed by Norway with "Statsbyg", Australia with "CRC" for "CI", and the United States with "ICC & GSA" which focuses on the automation of checking accessibility regulations, building elements, circulation and security [21]. The BIM-IFC-based application was also developed by the private sector, namely Express Data Manager (EDM), SOLIBRI Model Checker (SMC), FORNAX Plan Checking Tool, Avolve Plans Review, Design Data System (DDS) and other data related [22, 23].

2.3. Work Breakdown Structure

Work Breakdown Structure (WBS) is a hierarchical decomposition of work oriented to the total deliverable to be carried out by the project team in order to achieve project objectives and produce the required deliverable. WBS is a decomposition process that structures the scope of work into smaller elements. The goal is that the management of the project scope can be done better. The smallest scope of work elements are usually structured to the level of resources. This level describes the material elements, tools and resources needed to manage the project and produce the required deliverable [24].

2.4. Building Information Modeling

Building Information Modeling (BIM is one of the biggest leaps in the Architecture, Engineering and Construction (AEC) industry after the previous technology, Computer Aided Design (CAD). According to US General Services, BIM is the development and use of computer software data, not just to document building design, but also to simulate the construction and use of new and updated facilities [25].

BIM relies on so-called parametric modeling to produce project information that is coordinated, consistent, and can be calculated [21]. BIM parametric models have the following

Table 1: Comparison of 2D CAD, 3D CAD, and BIM

	2D CAD	**3D CAD**	**BIM**
File needed	More than 1	More than 1	1
File Size	Small	Big	Very large
Standard notation of working drawings	Manual		Automatic
Non graphical data calculation	Manual		Automatic
Design visualization	-	Yes	Yes
Architectural behavior	-	-	Yes
Spatial understanding	-	Yes	Yes
Project Documentation	Manual / easy	Manual / Difficult	Automatic
Difficulty level of training	Easy	Intermediate	Difficult

criteria:

 (i) Geometry contains data and related properties

 (ii) Geometry is integrated and consistently informed on all views

(iii) Geometry will be adjusted automatically when connected or inserted with other related elements.

(iv) Properties have consistent value changes at all levels of sub-elements

 (v) Element properties can detect conflicts if changes are made to them.

(vi) Element properties can be linked or extracted for further analysis using the same or different applications

Comparison between CAD (2 dimensions and 3 dimensions) and BIM can be seen in the Table 1.

3. Material and Method

This qualitative study was conducted in a case studio in the DKI Jakarta Province by validating regulations related to the technical requirements of buildings there. Standard Operating Procedures that have been implemented previously using CAD are translated into Information Systems that have used BIM object databases as inspection objects. The building technical requirements that have been collected by the authors of the existing regulations are validated by the government, to answer the question whether these requirements are indeed applied in the building permit process. Validated components are then matched with building elements in BIM according to the development phase of the BIM model in the planning phase. Development of the BIM Model in one of the BIM development project studio cases. The requirements in this regulation are translated into simple programming logic which is then validated by IT Experts to understand whether it can analyze BIM elements automatically. The Information System Framework is then developed to obtain a database relationship so that automatic Operation Procedure Checks can be performed with communication facilities between engineers and the government.

4. Result and Discussion

The study found that the process of checking requirements that were carried out manually took a very long way with various regulations that had to be reviewed. The findings in the study are WBS standards of building technical requirements that are translated into BIM components and

Table 2: Standard WBS of Automatic Building Code Checking Using BIM

| Level 1 Project Name	Level 2 Task	Level 3 Subtask	Level 4 Sub Sub Task	Level 5 Indicator	Level 6 Requirements Regulation	Level 7 BIM Component	Level 8 Algorithm
High Rise Building Jakarta	Architectural	Door	Main Door	Horizontal Relations between Spaces / Between Buildings	The main entrance / exit of the Public Building Building has an effective width of openings of at least 90 cm, and other doors have an effective width of openings of at least 80 cm.	Door_exterior, Door_accessible, Door_type, Door_width, Space Accessible, Space_Identification, Space_area	{Check Door_width of Door_exterior if more than 90 cm is TRUE}
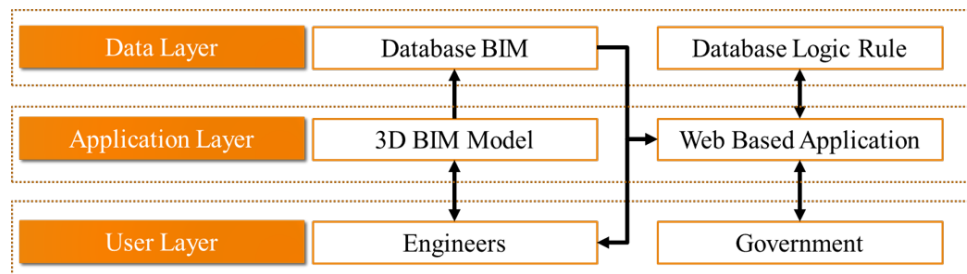
Figure 4: Architecture Scheme of Information System

Programming Logic. The results of this study also describe the Information System procedure for examining the technical requirements of buildings wherein there is an information system architecture scheme and a database diagram.

4.1. Standard WBS of Automatic Building Code Checking Using BIM

This study found WBS standards for Automatic Building Code Checking Using BIM which can be seen in Table 2. WBS Standards Starting from the name of the project, project discipline (task), Components (Subtask), Sub Components (Sub-Task), Indicator of requirements checking, Requirements (Requirements Regulation), BIM Elements, (BIM Component), and programming rules (algorithm). The WBS standard is useful as a checklist of the scope of requirements checking for high rise building projects that use BIM in the DKI Jakarta area. The WBS standard will make it easier for engineers to check what requirements are applied in DKI and can be checked automatically in BIM objects.

4.2. Architecture Scheme of Information System

The use of the system can be divided into 3 layers, namely the Data Layer, Application Layer and User Layer. Engineers designed the 3D Model BIM then extracted it into a database format. The database format in BIM is inputted into a Web Based Application which has a logic logic database embedded from the regulatory requirements which then generates a report on compliance with the requirements automatically. Web Based Application is managed by the government and updated according to the development of regulations, as in the Figure 4.
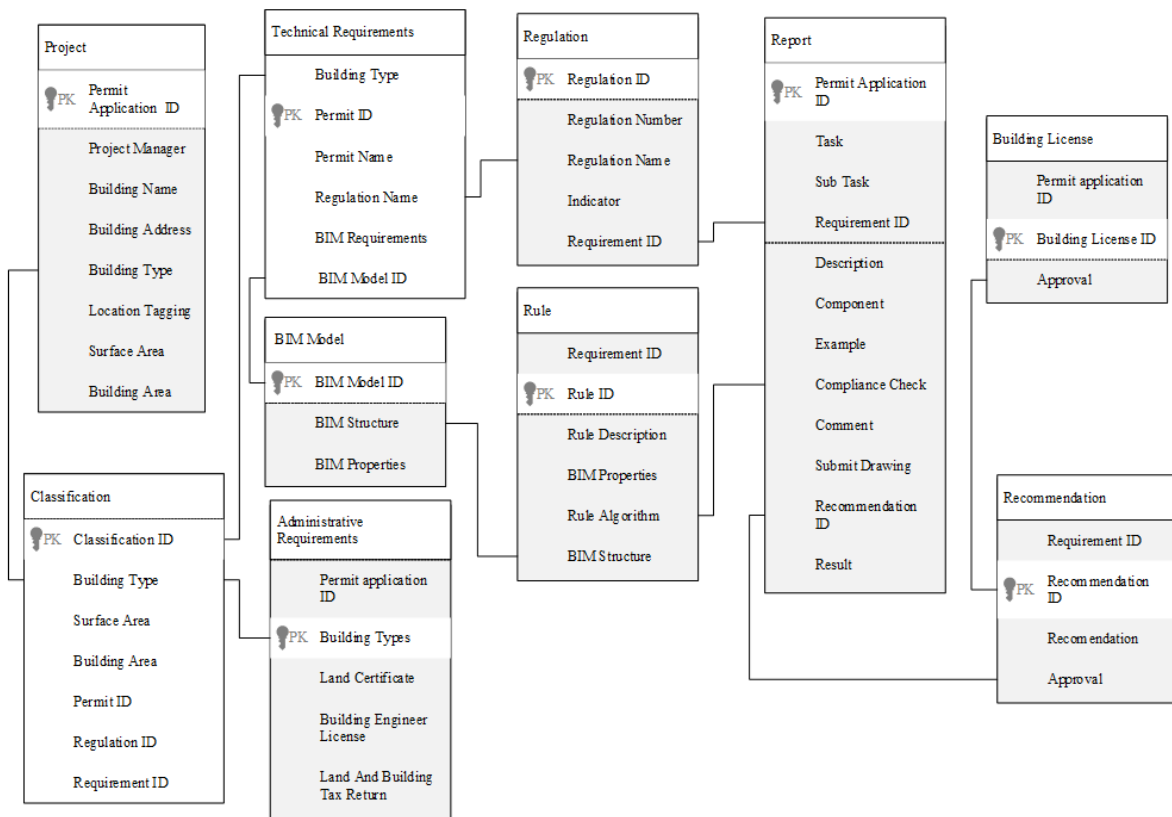
Figure 5: Database Scheme of Information System

4.3. Database Diagram of Information System

The initial database is the description of the project by the project administrator then classified according to existing regulations divided into administrative requirements and technical requirements. Existing technical requirements are then verified for compliance through the BIM model object database. BIM object models are classified by information systems according to the programming logic of the existing regulatory requirements, as in Figure 5.

4.4. Building Code Compliance Automatic Result

One of the advantages of building automated inspection of technical requirements is that it automatically generates inspection reports. BIM objects that have been exported into a database format that are available in each BIM application, are then submitted and read by programming rules in a web-based information system that has been included in the translation of computers from existing regulations. if in accordance with the rules applied, it will automatically give success results with a "pass" code. This system still provides manual procedures that can be used if there are obstacles or errors in reading BIM objects. If the model cannot meet the regulations in the information system, there is a comment facility from the engineer to answer the problem. Engineers can provide evidence of adjustments to non-compliance with these regulations in the form of detailed working drawings explaining the fulfillment of the relevant requirements. Government officials then verify the answers and evidence from engineers and can pour comments in the same column, as shown in Table 3.

Table 3: Building Code Compliance Automatic Result

Project	Discipline	Component
High Rise Building Jakarta, Pejompongan Street	Arsitektural	Doors

Requirements ID	Requirements	Result	Engineer's Comment	Submit Evidence	Government Recommendation	Recommendations Result
2.1.1.1	The main entrance / exit of the Public Building Building has an effective width of openings of at least 90 cm, and other doors have an effective width of openings of at least 80 cm.	Pass	Null	Null	Null	Pass
2.1.1.2	The 1-way swing door should be installed no more than 75 cm from the floor surface.	Failed	It can't apply in BIM This regulation cannot be found by BIM object but is applied to the door detail drawing in the plan document (Figure Number 21157)	Figure Number 21157.DWG	Pass	Pass

5. Conclusion

The scope of requirements can be managed by decomposition of work known as Work Breakdown Structure to produce a BIM component that will be subject to regulatory requirements checking. The ability of the BIM can produce building models that can be subject to inspection of regulatory requirements. Examination of regulatory requirements can be carried out at each stage of developing the BIM model according to the level of detail of the BIM object. Examination of regulatory requirements can be carried out independently by planners at each stage by using a Web-based Information System developed in the BIM format that has been validated by the Government. By grouping requirements based on the stages of developing the BIM model, it will maximize the fulfillment of the requirements at each stage so as to reduce the risk of redesign while at the same time increasing the technical requirements of the building.

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