

Ensuring Compliance in Construction: A Deep Dive into BIM Model Checking and Automated Code Verification

Mohamed Helmy Ammar¹ and Merna Emara¹

¹Institute of Construction Informatics, Dresden University of Technology, Helmholtzstraße 10,
01069 Dresden, Germany

E-Mails: mohamed.ammar@mailbox.tu-dresden.de, merna.emara@tu-dresden.de

Abstract: The paper examines code compliance of energy efficiency in building design through (BIM) tools, particularly the BIMQ – Solibri rule plugin and a custom-created Solibri ruleset. It aims to simplify the validation of thermal transmittance (U-value) for architectural components such as doors, slabs, walls, and windows, ensuring these elements fulfil the established energy efficiency standards. The BIMQ plugin in Solibri Model Checker (SMC) effectively assigns and confirms thermal transmittance values across different components while identifying errors in the BIM model in Autodesk Revit. Furthermore, the model checking with the custom ruleset facilitates the assessment of components against energy efficiency rule criteria in the paper by pointing out the components that need adjustments to improve the whole building's performance and their exact locations. Using an Excel template to export the results from (SMC) makes analyzing the data simpler for stakeholders. The project highlights the significant importance of BIM in the construction sector especially in achieving energy efficiency objectives and it sets the foundational basis for future improvements in BIM technologies to further improve the consistency and efficiency with the AEC industry while acknowledging challenges and inaccuracies in component classification in the model that require further improvement.

Keywords: Code Compliance, Energy Efficiency, BIM, BIMQ, Solibri Model Checker, EIR



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1 Introduction

The construction industry faces the challenge of ensuring that buildings comply with strict standards, often slowed down by manual and error-prone compliance methods, leading to costly delays. Implementing a systematic and precise approach, particularly within Building Information Modeling (BIM), is crucial to enhance project outcomes, safety, and regulation. Despite both BIM's methods and processes efficiency, adapting to evolving compliance requirements remains a barrier. This

paper aims to address this by developing an Automated Code Compliance Checking (ACCC) solution to facilitate BIM model verification and code compliance. The main objective of the study is to establish an automated code checking focusing on construction projects. The primary objectives are to identify and locate the relevant rules from the standards and regulations that influence the thermal resistance of building components. Following this, the Employer's Information Requirements (EIR) are created using BIMQ and digitally transfer it into BIM software. The Revit model is then reviewed and adjusted according to these standards. Afterwards, the model is exported into an IFC file to facilitate its transformation into Solibri. Finally, the model is checked in Solibri to ensure that the information and values are accurate, thereby guaranteeing the building's energy efficiency. The methodology consists of seven steps: examining standards and regulations to extract energy efficiency rules, creating EIR using BIMQ, adjusting the model to comply with standards, conducting a compliance check on each building component, transferring EIR workflows to Solibri for further analysis, creating custom rules in Solibri to evaluate model compliance, and analyzing workflows and proposing enhancements for optimal outcomes. By bridging traditional gaps, the proposed ACCC solution promises safer, more efficient, and sustainable construction practices, essential for dealing with various requirements.

2 Literature Review

Automated code compliance checking within Building Information Modelling (BIM) has garnered significant attention in recent research. This rapidly expanding field delves into various aspects of rule-based checking systems, the integration of artificial intelligence (AI), and automation model verification to ensure compliance with building regulations, supported by an extensive literature review. [1] outlines the evolution of rule-based checking systems, highlighting the potential of advanced tools to support design and compliance tasks effectively. [2] underscored the pivotal role of AI in enhancing automated code compliance by minimizing human error and improving the accuracy of BIM models. Meanwhile, [3] proposed a methodological approach to automate code-checking processes within BIM frameworks, utilizing computer-readable language rules and software tools like Dynamo and Python scripting. Additionally, scholars like [4] and [5] contributed by providing conceptual frameworks and identifying inefficiencies in manual compliance procedures, highlighting the potential of BIM to streamline the process. [6] addressed the challenges inherent in automating rule checking, proposing a classification system to facilitate the process. [7] focused on automating model checking in building design, aiming to develop methods for specifying and evaluating building rules within BIM contexts. Collectively, these studies underscore the growing importance and potential of automated code compliance checking within BIM environments, offering valuable insights into its implementation, challenges, and future directions.

3 Methodology

This section outlines the plan for implementing automatic code compliance checking in a construction project in Germany. Based on the framework proposed by [1], the approach includes five main phases. The methodology involves a comprehensive approach to implementing automatic code compliance checking for energy efficiency in construction projects using Building Information Modeling (BIM). The process begins with rule interpretation, where relevant standards and regulations, particularly focusing on thermal transmittance (U-value), are extracted and formatted for software processing. Next, the Employer's Information Requirements (EIR) are prepared, detailing the necessary information and Level of Geometry (LOG) for various architectural components. The building model is then developed using Autodesk Revit 2023, incorporating essential elements like windows, doors, slabs, and walls, all selected for their compliance with energy efficiency standards. Following this, the compliance check is executed using the BIMQ – Solibri rule plugin and a custom-created Solibri ruleset, which identifies building components, that violate the energy efficiency criteria. The results are systematically reported, highlighting compliant components and those needing adjustments. This detailed reporting ensures compliance with energy efficiency standards, thereby enhancing the overall building performance and consistency. This structured approach not only simplifies the validation process but also highlights the significant role of BIM in achieving energy efficiency in the construction sector. Figure 1 below summarizes the whole process of code compliance checking.

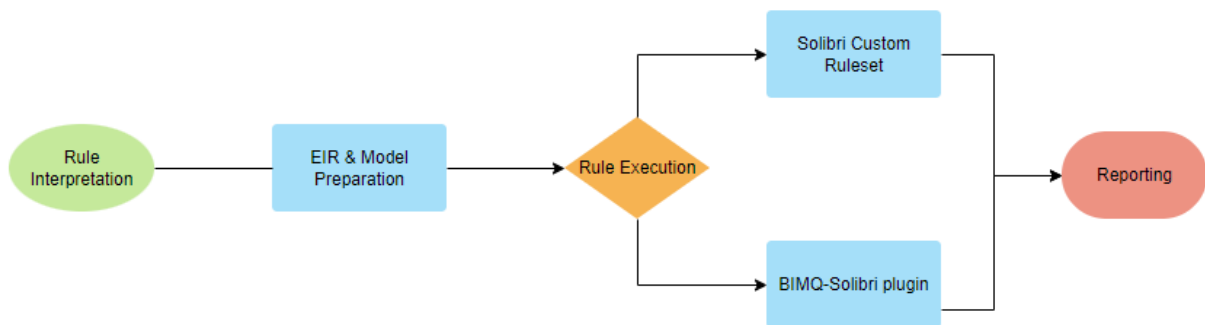


Figure 1: Process for Checking Compliance.

4 Implementation

This section details the practical application of the automatic code compliance checking framework, showcasing the operational phases and outcomes of the implemented methodology.

4.1 Rule Interpretation

This step begins by extracting and converting energy efficiency rules from relevant standards and regulations. By going through an in-depth examination of the Muster-Verwaltungsvorschrift Technische Baubestimmungen (MVV TB) that was published by the German Institute of Civil

Engineering [8]. The focus lies on thermal resistance and transmittance. Key rules extracted from DIN standards are summarized in Table 1.

Table 1: Extracted Rules from DIN Standards for Building Components

Standard	Reference	Element	Description
DIN 4108-2	Table (3) – Minimum values for thermal resistance of components, R-value	Walls	The Thermal Resistance of walls should be R-value ≥ 1.20 $m^2 \cdot K/W$, (or U-value ≤ 0.84 $W/m^2 \cdot K$)
DIN 4108-2	Table (3) – Minimum values for thermal resistance of components, R-value	Slabs	The Thermal Resistance of slabs should be R-value ≥ 0.90 $m^2 \cdot K/W$, (or U-value ≤ 1.2 $W/m^2 \cdot K$)
DIN 4108-4	Table (7) – Heat transfer coefficient of external doors, U-value Or Section (5.1.4) in DIN 4108-2	Doors	The Thermal Transmittance of doors should be U-value ≤ 2.90 $W/m^2 \cdot K$
DIN 4108-4	Table (10) – Heat transfer coefficient, U-value	Windows	The Thermal Transmittance of windows should be U-value ≤ 2.00 $W/m^2 \cdot K$

4.2 EIR Preparation

The next step involves creating the Employer's Information Requirements (EIR) using BIMQ, a crucial process that ensures the accuracy of the BIM model for subsequent energy efficiency evaluation. This process includes defining key actors, such as the architect and other stakeholders, assigning discipline models, and exporting the EIR report for further analysis. The EIR preparation process precisely defines the extracted rules from the standards to be included in the BIM model, ensuring that all project requirements are met. This includes specifying the Level of Geometry (LOG) for different architectural components, such as walls, slabs, doors, and windows. For instance, walls and slabs are assigned a LOG of 300, while doors and windows are assigned a LOG of 350, providing a high level of detail for precise compliance checking. Additionally, the EIR outlines the Level of Information (LOI) required, which includes data such as material specifications and thermal transmittance values (U-values). The process involves accurate checks to verify that each component meets the required standards. Once the EIR is prepared, it is exported as a detailed PDF report for further analysis. This report includes comprehensive information requirements for each component, ensuring that the BIM model includes all necessary data for compliance checking and

project execution. By using BIMQ, the process facilitates more efficient communication and collaboration among project stakeholders, ensuring that all parties are aligned with the project goals and requirements. This structured approach enhances the BIM model quality, ensuring compliance with energy efficiency standards.

4.3 Building Model Preparation

A school project (Förderschule) in Delitzsch, Germany, serves as the case study, prepared using Autodesk Revit 2023. Initially, the model lacked windows and doors, which were then integrated, as shown in Figure 2. Specifications for these elements were selected to comply with energy efficiency standards, focusing on materials with suitable thermal properties. Revit derives the R-value and U-value, ensuring compliance with DIN standards. According to [9], the building model data should be formatted to be compatible with the code-checking process. After modification, the model data was prepared for export to an IFC file to ensure compatibility with Solibri Model Checker (SMC). This required specific adjustments in Revit's export settings to guarantee accurate data transformation and inclusion for reliable code compliance checking.

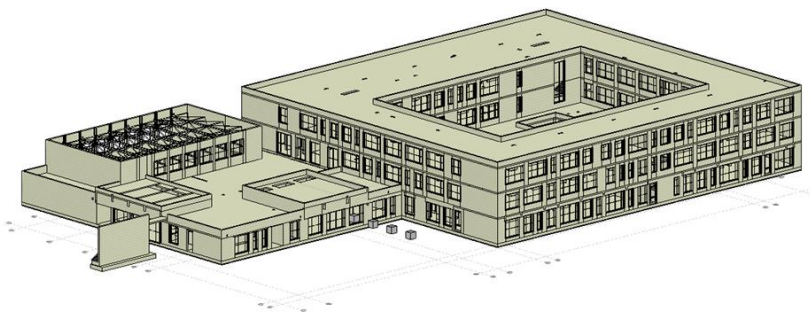


Figure 2: Model After Adding Windows and Doors.

4.4 Rule Execution Overview

The rule execution process is divided into two stages: the initial compliance check using the BIMQ-Solibri plugin, followed by a custom ruleset in Solibri for detailed evaluation.

4.4.1 BIMQ Plug-in Checking

The compliance checking process begins with the BIMQ-Solibri plugin within Solibri, which verifies that the thermal transmittance (U-value) was correctly assigned to all specified architectural components such as doors, slabs, windows, and walls in the Revit model, ensuring the fulfillment of energy efficiency standards. The plugin imports requirements from BIMQ and loads the IFC file from Revit into Solibri for verification. A new ruleset is created in Solibri based on BIMQ guidelines. During the check, a critical error is identified with the stair component, incorrectly defined as `IfcSlab` in Revit. This was corrected by redefining it as `IfcStairs` and re-exporting the model. Upon rechecking, all components had the correct U-values, and the model passed all compliance checks. Figure 3 shows the BIMQ requirements view and results of the BIMQ rule.

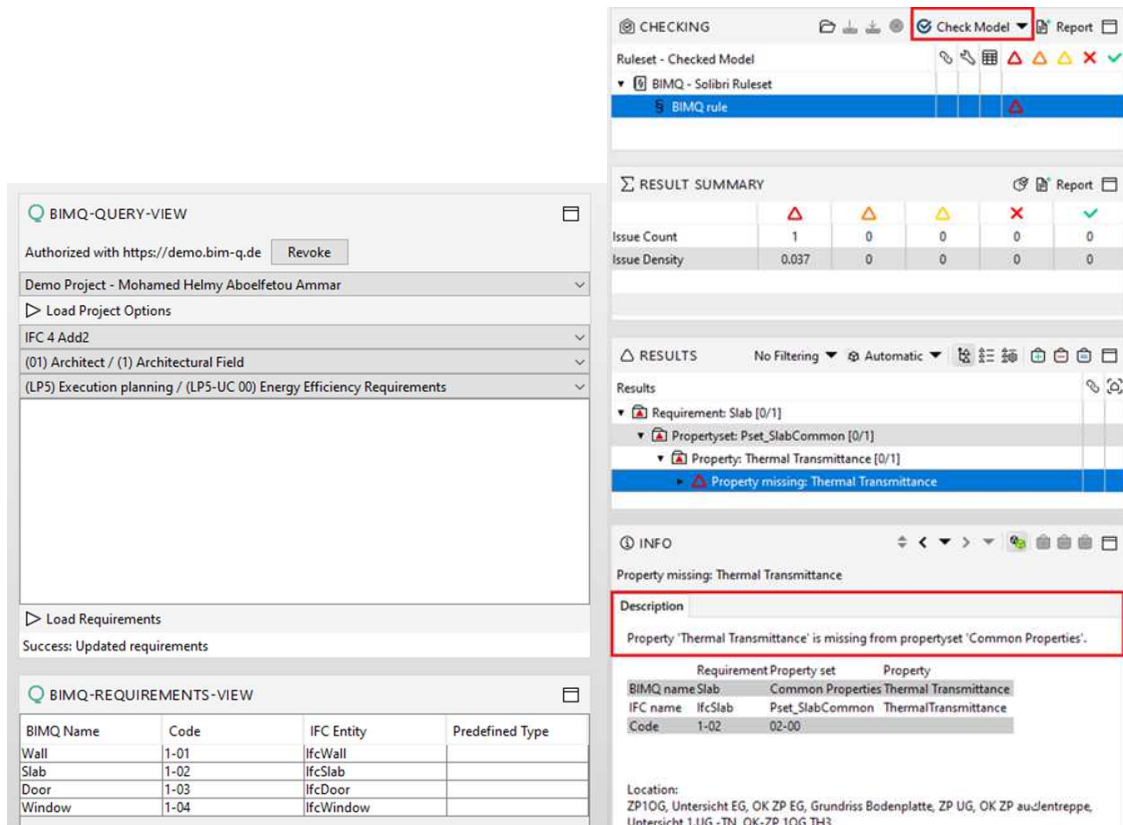


Figure 3: BIMQ Query and Requirements View, and Results of BIMQ Rule.

4.4.2 Solibri Created Ruleset

The compliance checking process with a custom Solibri ruleset involves exporting the Revit model as an IFC file to ensure compatibility. This ruleset assesses thermal transmittance values (U-values) for components like doors, slabs, walls, and windows against DIN standards. The ruleset checks if these components meet the U-value criteria: $\leq 2.90 \text{ W/m}^2\text{K}$ for doors, $\leq 1.20 \text{ W/m}^2\text{K}$ for slabs, $\leq 0.84 \text{ W/m}^2\text{K}$ for walls, and $\leq 2.0 \text{ W/m}^2\text{K}$ for windows. Components exceeding these limits are flagged as not energy efficient. The results highlight areas where the building design fails to meet energy efficiency standards, with detailed feedback highlighting issues as illustrated in Figure 4.

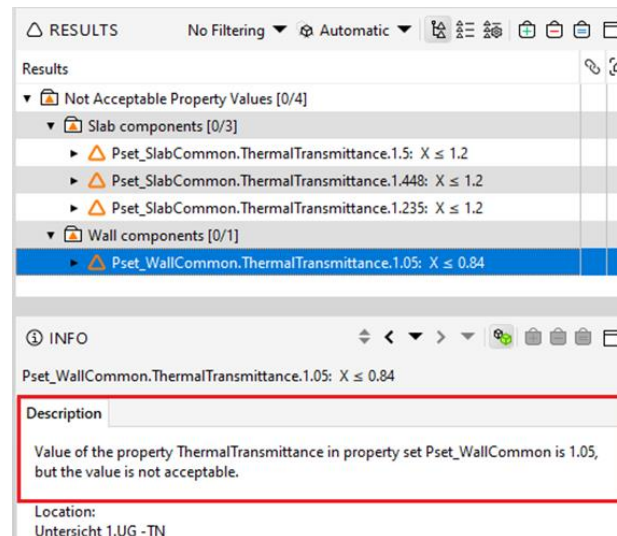


Figure 4: Detailed Results of Wall Components Exceeding U-value Limit.

4.5 Rule Checking Results

The rule-checking process utilized the BIMQ – Solibri plugin and a custom Solibri ruleset to validate that thermal transmittance values were correctly assigned, ensuring compliance with energy efficiency standards for architectural building components. The BIMQ plugin verified that doors, slabs, walls, and windows had assigned thermal transmittance (U-values), revealing an initial error with the misclassification of stair components in Revit, which is corrected by redefining it as IfcStairs. Subsequent checks confirmed component compliance. The customized ruleset checked these components against DIN standards, identifying areas where slabs and walls failed to meet the specified U-values. Detailed feedback from Solibri highlighted non-compliant components, allowing for precise adjustments. Reports summarizing these checks were exported to Excel for easier analysis and understanding.

5 Conclusion and Limitations

This research underscores the pivotal role of Building Information Modeling (BIM) tools, particularly the integration of the BIMQ – Solibri plugin and a custom Solibri ruleset, in improving the verification process for energy efficiency in building components. By effectively allocating and validating thermal transmittance values, these tools ensure compliance with energy efficiency standards by correcting inconsistencies within the BIM model. The custom ruleset offers specialized evaluations, identifying components that violate the standards and allowing for focused enhancements. Exporting results into an Excel template enhances data analysis accessibility, emphasizing BIM's critical importance in achieving energy efficiency objectives and facilitating future advancements in sustainable construction design. Due to BIMQ – Solibri plugin limitations in only checking for U-value assignments without verifying compliance with standards, a custom Solibri ruleset was developed

for component compliance, improving BIM-based compliance checking and promoting more sustainable building practices.

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