Geometry level of information needs for digital building permit regulations

El Yamani, S.; Stoter, J.; Noardo, F.; Hakim, A.; Arroyo Ohori, K.; van der Vaart, J.

Publication date
2024

Document Version
Final published version

Published in
Digital Building Permit Conference 2024 - Proceedings

EUnet4DBP

European Network for Digital Building Permit

EUnet4DBP Publication Series

DBP '24

Digital Building Permit Conference 2024

18-19 April 2024
Barcelona COAC

PROCEEDINGS

Editors: Francesca Noardo & Judith Fauth

Open Geospatial Consortium · BDTA Building Digital Twin Association · EUBIM Taskgroup · isprs · EuroSDR · buildingSMART International · ECTP-CEU · CEBC Consortium of European Building Control

EUnet4DBP Publication Series n.0

Doi: 10.5281/zenodo.12760551

https://eu4dbp.net

The present publication was peer-reviewed by EUnet4DBP members.

July 2024

Geometry level of information needs for digital building permit regulations

S. EL Yamani[a*], J. Stoter[a], F. Noardo[b], A.Hakim[a], K. Arroyo Ohori[a], J.van der Vaart[a]

[a] *3D Geoinformation, Delft University of Technology, Delft, the Netherlands.*
[b] *Open Geospatial Consortium Europe, Technologielaan 3, B - 3001 Heverlee, Belgium.*

Abstract

In the evolving landscape of digitalization, automating building permit processes are crucial for municipalities and other governmental bodies. Our research addresses the complexities of modeling digital building permit regulations, considering the level of the information needs (LoIN) for geometry-based regulations in four municipalities (Prague, Lisbon, Vila Nova de Gaia, and Ascoli Piceno) as case study. We propose a methodology and guidelines for geometrical building modeling, addressing challenges of integrating geoinformation with Building Information Modeling (BIM) for environmental based digital building permit (DBP) checks. This paper provides BIM-IFC geometrical interpretation choices, ensuring a seamless conversion into 3D city models. It offers insights for software companies, developers, and standardization organizations towards in implementing DBP checks, and preliminary results for a future scalable approach.

Key words*: Digital building permit, CHEK project, GEOBIM, BIM, IFC.*

Introduction

The increasing adoption of Building information models (BIM) in early urban design phases and developments in digital systems have highlighted the need for automating building permit processes worldwide. Current manual, 2D plan-based methods suffer from inaccuracies and inefficiencies, causing errors and delays in the construction pipeline. These outdated processes lack adaptability, leading to multiple resubmissions and significant financial setbacks for municipalities and the Architecture, Engineering, Construction, and Operation (AECO) Industry[1], [2].

To address these issues, (partly) automated DBP processes can be considered. Through digital processes it will be possible to avoid errors in regulations interpretations and improve consistency because the complexity of 3D geo-related regulations can be assessed and measured accurately (e.g., building height, distance building-building).

Despite prior attempts worldwide to digitize and automate building permit processes, including notable initiatives like the European network for Digital Building Permit (EUnet4DBP)[1], there remains a predominant focus on analyzing building data sets, often using Industry Foundation Classes (IFC), without adequately integrating BIM and 3D city models for comprehensive geometrical modeling in digital building permit checking [3], [4].

The Open GeoSpatial Consortium (OGC) offers standards like CityGML and CityJSON for integrating and digitizing 3D city models. These standards, including CityGML and CityJSON, employ the concept of Level of Detail (LoD) to define the granularity of both geometric and semantic information in building and city data models. Recently, CityGML has updated its LoD classification in version 3.0 to cater to various applications.

In the context of Building Information Modeling (BIM), concepts such as Level of Development, Level of Accuracy, and Level of Information have been introduced to extend the model framework. However, these concepts often lack standardization, resulting in diverse interpretations of the required level of detail, especially concerning geometric requirements.

To address this issue, BuildingSmart has introduced Level of Information Need (LoIN) as a new standard (EN 17412-1). LoIN emphasizes tailoring information granularity to suit specific needs for information exchange based on contextual use. The evolution of the Level of Development concept is progressing through the concept of Level of Information Need (LOIN), which serves as a necessary foundation for developing notions of Level of Geometry (LOG) and Level of Information (LOI).

While previous research has focused on specific aspects of digital building permit requirements, such as building height in Rotterdam or LoIN in Victoria, there remains a lack of a scalable approach for addressing the geometric information needed across different regulatory contexts. Our project addresses this gap by analyzing the geometric requirements of four municipalities across different European scales. We provide insights based on developed GEOBIM solutions for extracting envelope data and converting it to CityJSON format. This approach, which has been lacking in previous research, aims to address the challenge of scaling geometric information from BIM to geospatial data, offering a tested and feasible solution for the entire process.

This paper aims to harmonize the involved BIM and GEO information to provide the necessary geometrical information for digital building permit checking. This involves a methodology that considers the BIM and GEO connection, incorporating proper generalization techniques. The objective is to offer a comprehensive solution to interpret geometrical modeling requirements for effective digital building permit checking.

This research is carried out as part of the CHEK project. The ‘Change toolkit for DBP’ (CHEK)[2,3] project is a European initiative to develop digital tools and methods for DBP checks based on the integration of building and 3D city data.

This project combines multidisciplinary and multisectoral aspects, aiming to support municipalities in the transformation towards DBP.

This work aims to propose a scalable methodology detailed in the following section, to assist designers and software developers in modeling data requirements to support DBP processes. The goal is to facilitate optimal geometrical decisions for the conversion from BIM to 3D geoinformation, aligning with regulatory interpretations and supporting scalable building permit regulations for municipalities a shown in Figure 1. To ensure scalability and accessibility, we have chosen to use international open standards—specifically, CityGML/CityJSON by the Open Geospatial Consortium and Industry Foundation Classes (IFC) by BuildingSmart—as our reference data formats [5].

Methodology

The methodology focuses on implementing BIM guidelines to be able to extract the required geometry from BIM models, facilitating the conversion from IFC to CityJSON/CityGML to align with DBP regulations. The guidelines are tailored to the selected project regulations, encompassing BIM, 3D city models, legal requirements, and urban zones, each presenting unique complexities and data inputs.

The primary emphasis is on geometrical regulations, including Distance from other city objects, Maximum Building Height, Minimum Area, and Maximum Buildability Index. The goal is to comprehensively analyze these regulations across the four municipalities, offering suitable interpretations. Then, data requirements are identified based on LoINs and modeled to deliver a structured IFC with geometrical information, enabling designers and architects to convert it into a 3D city environment (CityGML/CityJSON), and to verify the specified regulations.

Regulations are chosen based on thorough investigations[4] conducted across the four municipalities.

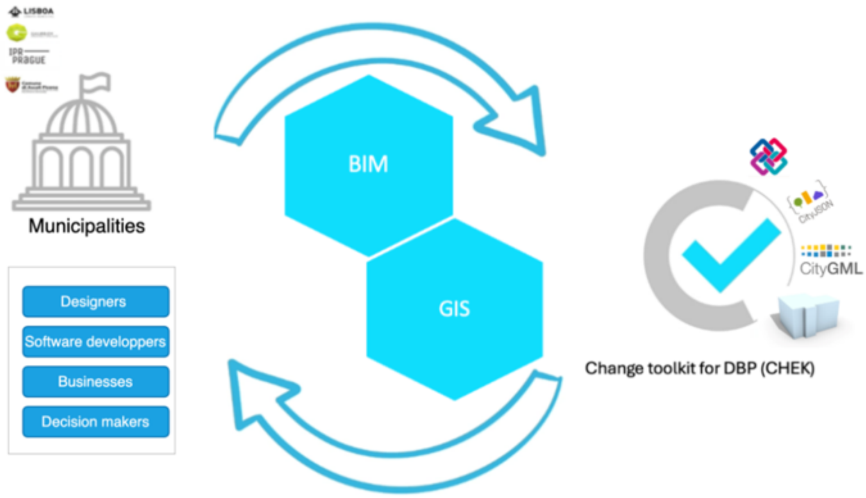

Fig. 1: Goal of a scalable approach to facilitate the implementation and integration of BIM with GEO data for municipalities and assist stakeholders in the process of digitalization.

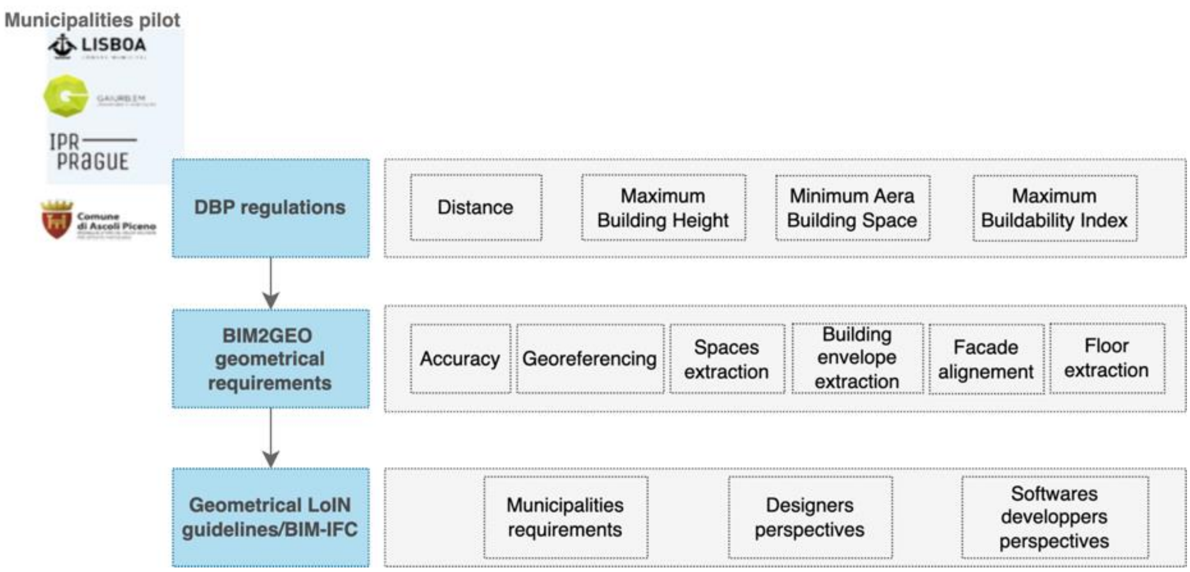

Fig. 2: methodology steps for BIM based regulations geometrical requirements.

Figure 2 outlines the methodology steps, emphasizing legal regulations chosen by the four municipalities as preliminary guidelines for the DBP process. The automation of these regulations involves identifying geometrical requirements for 3D building models, such as the building envelope, floors, façade, and georeferencing information. The outcome comprises geometrical LoIN guidelines to guide designers and software developers in meeting these requirements during the design phase. In the following, we will address the issues to be considered in the geometrical

LoIN guidelines as identified by the interpretation of the selected regulations in the four municipalities, which will be further elaborated in the proposed paper.

1. **Distance:**

Analyzing building permit issuance at the BIM level involves primarily assessing BIM requirements. In contrast, the BIM2Geo conversion incorporates the new design into a 3D city model, enabling distance checks in relation to its environment for four regulations: (1) distance building-building, (2) building-parcel boundaries distance, (3) building-road distance, and (4) balconies-road distance. BIM2Geo conversion enables accurate distance measurements by meeting the geometrical data needs, such as openings, façade details, balcony overhangs, footprint/ground floor extraction, and BIM georeferencing (Figure 3).

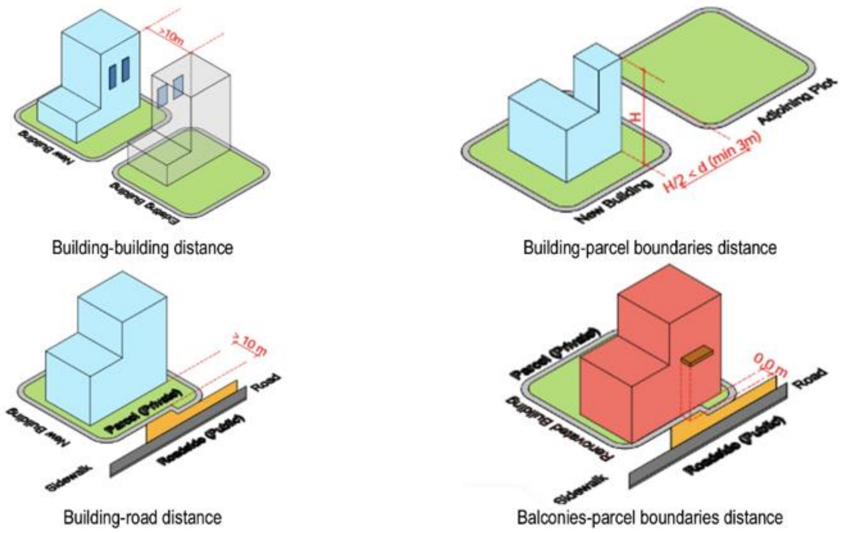

Fig. 3: illustrates Distance data requirements for the Municipality of Vila Nova de Gaia (reference: CHEK project Deliverable).

2. **Maximum Building Height:**

The building height is determined from the building's footprint at ground level to the roof's highest point. This calculation requires factors like facade details, extracted envelopes, and georeferencing (to refer the building to the height model of the surrounding terrain). Calculations use ground level as a baseline, excluding underground parts. Measurement starts from ground level, or the lowest vertex of the building as shown in Figure 4 as an example based on GAIA and LISBON municipalities national regulations definition of building height.

The maximum building height is defined differently depending on each municipality it can be either a maximum height number, or calculated based on the average surrounding building height and in some cases based on the maximum building floors as the case of Portuguese regulations.

1. **Minimum Area: Building Spaces**

Compliance with municipality regulations determining the minimum area requires extracting BIM spaces, encompassing area and volume determinations.

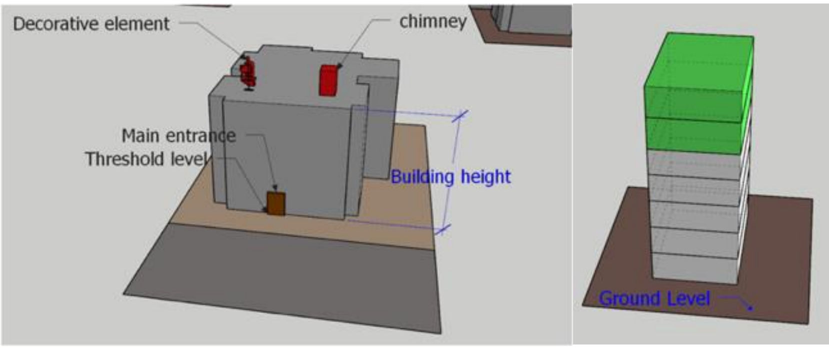

Fig. 4: illustrates Building height and maximum building height definitions for Lisbon and GAIA's regulations (illustrations credits to University of Minho).

2. **Maximum Buildability Index**:

Determining the buildability index of a parcel involves ground floor extraction for the built area, extruded to the building's height level.

The geometrical requirements that arise from the above-mentioned regulations, need to be further analyzed to make the optimal choices in terms of the most suitable level of information need to prepare the IFC to be converted, so that the output contains the accurate relevant geometries. In the final paper we will describe the results from our research on the correct interpretation of regulations in terms of geometrical requirements, addressing various aspects as presented in Figure 5:

- **Accuracy:** Our research covers identifying the minimum accuracy requirement for municipalities, understanding accepted tolerances in practice, and determining the Level of Detail (LOD) necessary for the conversion to 3D City models.
- **Georeferencing:** We will define the source and target coordinate reference systems, including their specifications, and ensure their proper storage within the BIM environment. Additionally, we will clarify the version of IFC used and ensure the accurate storage of georeferencing and conversion data within the IFC file. The relevant information is stored in IFC using IfcProjectedCRS and IfcMapConversion.

  To facilitate this process, we have developed a georeferencing tool called IfcGref, a web application designed for controlling, assigning, or modifying georeferencing information in IFC models, which are the standard format for exchanging BIM data. IfcGref allows users to visualize the roof outlines of IFC models on the target coordinate reference system (CRS) map. This Flask-based tool, accessible at https://ifcgref.bk.tudelft.nl, offers a comprehensive solution for designers, engineers, and software developers.

  It supports georeferencing operations from IFC 4 onwards, ensuring backward compatibility with earlier versions. By leveraging attributes like SourceCRS, TargetCRS, and other key parameters, IfcGref enables precise coordinate transformations. Its user-friendly interface simplifies file upload and verification processes.
- **Spaces extraction:** The feasibility of extracting rooms from BIM-IfcSpace is further analyzed and guidelines will be formulated for structuring spaces correctly. It is also considered whether to export areas as elements and spaces as complexes.

Voxelization appears to be the most reliable method for approximating spaces, despite its inherent inaccuracies in room shape and dimensions (height, area, and volume). A challenge arises from the fact that data stored in the IFC file may not always be entirely reliable. In BIM software like Revit, IfcSpaces are often invisible shapes that may not fully align with surrounding geometry (e.g., walls, floors), complicating detection of potential issues for BIM modelers. Furthermore, BIM software may alter geometry during export to IFC, posing challenges for resolution by modelers.

Even if room geometry is accurately extracted, there remains a concern regarding incorrect semantic classification. While IfcSpace can be categorized as "partial," "Element," or "Complex," they are typically labeled as elements, making it difficult to differentiate rooms from other building components.

Given these challenges, conducting a voxelization comparison by comparing the footprint's area and the room's volume with that of the voxelated shape can serve as a straightforward indicator of potential geometric inaccuracies. If significant discrepancies are observed, it could alert users to potential issues with specific rooms, indicating possible geometric inconsistencies.

- **Building envelope extraction:** The elements of the BIM to be considered are identified, exploring the use of specific IFC models within the BIM, and assessing spatial structure segmentations like storeys and bounding boxes for approximating the envelope. The references surface and criteria for generalizing the building envelope are also be determined.

  To accomplish this, we employ the IFC BuildingEnvExtractor, a tool developed by van der Vaart (2023), available at https://github.com/jaspervdv/IFC BuildingEnvExtractor. This tool extracts multiple abstracted Levels of Detail (LoD) shells from IFC files, aligning with the LoD specifications outlined by Biljecki et al. (2016). The number of extractable shells depends on the input model's quality. The tool defines three extraction levels, each with similar methods. Low-level shells (LoD0.0 & 1.0) are generated by approximating the smallest bounding box around the input model, applicable to any valid IFC file. Mid-level shells (LoD0.2, 1.2, 1.3 & 2.2) isolate the roof structure of the input model, projecting or downward extruding it. Accurate output depends on a well-modelled roof. High-level shells (LoD3.2) are derived from the surfaces of objects constructing the outer envelope, requiring well-constructed objects in the original BIM model for accurate extraction.

- **Façade alignment:** The right geometrical tolerance for façade details and overhangs are analyzed, including considerations for the Level of Detail (LOD) necessary to guarantee overhang accuracy.

  Overhangs require evaluation at LoD3.x to ensure precision; lower LoDs do not adequately support overhangs. However, for buildings with simpler shapes, LoD2.x may suffice. The choice between footprint-based or roof outline-based LoD2.x depends on the evaluation requirements.

  An intriguing option arises when considering larger tolerances. At LoD3.x, the shell extractor employs 1e-6 tolerances. Thus, a successful LoD3.x export likely accurately reflects the IFC shell geometry. However, at a city scale, this level of accuracy is often unnecessary. Utilizing a voxelized shape may suffice, particularly for slightly flawed models, providing satisfactory results for most evaluation purposes. Additionally, it supports overhangs, which LoD2.x does not.

- **Floor extraction:** A methodology for extracting floors based on IfcBuildingStorey and IfcSlab, the proper modeling of IfcBuildingStorey features, and exploring the potential for rule-based automation in floor extraction [6]

  While floor extraction seems straightforward in theory, it proves more challenging in practice.Our current approach, LoD0.2, involves:

  1. Retrieving IfcBuildingStorey objects.
  2. Obtaining IfcSlab objects associated with each IfcBuildingStorey.
  3. Generating outlines of these slabs.

  However, there are challenges. Sometimes IfcBuildingStorey objects are missing from the model, which can be rectified by notifying the BIM modeler. Additionally, not all objects are correctly linked to IfcBuildingStorey, though this issue is partially mitigated by analyzing a subset of related objects (specifically, the slabs). Nevertheless, incorrect slab associations may still pose challenges.

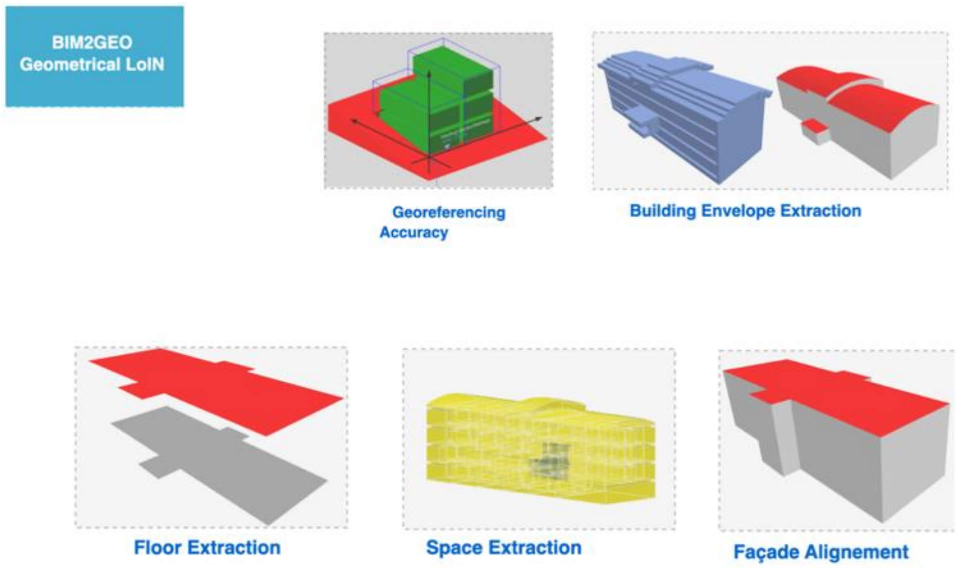

Fig. 5: BIM2GEO Geometrical LoIN approach

3. Case study

The case study of this research involves four municipalities, each defining their regulations differently. For instance, for maximum building height, the Prague municipality defines regulated building height as the distance from the lowest point of adjacent terrain to the level of the main cornice. One of the scenarios to be tested is the extraction based highest point roof until the level of footprint to assess the maximum building height of this specific case.

During the regulations data requirements interpretation, the information to be included in the data requirements, either for building or city information, or both are reported in the third and/or fourth columns, as well as any additional detail understandable from the regulations or reported by the municipality technician about their specification (level of detail, object to be represented, accuracy needed, semantic information and so on).

This information will be reviewed with developers of the checking software to clarify with them which software will check what regulations, and, consequently, how the information needs to be further specified and mapped to the reference standards (IFC and CityGML/CityJSON). Check the methodology illustration Figure 6.

From a broader perspective, the maximum building height complexities across the four municipalities can be categorized as follows (Figure 7):

1. Regulations' definitions regarding maximum building height may overlap and vary depending on national or municipal levels.
2. At the municipal level, the approach to computing building height can be based on either the number of building floors or vertical dimension calculation.
3. On sloped terrain, there may be varying tolerances in building height computation between municipalities (e.g., 1.5m for Portuguese regulations).
4. When existing roads are present near the building surroundings, the computation of building height from the lowest part may be based on either the nearest sidewalk elevation or the road elevation, with different road requirement levels, as depicted in the figure.

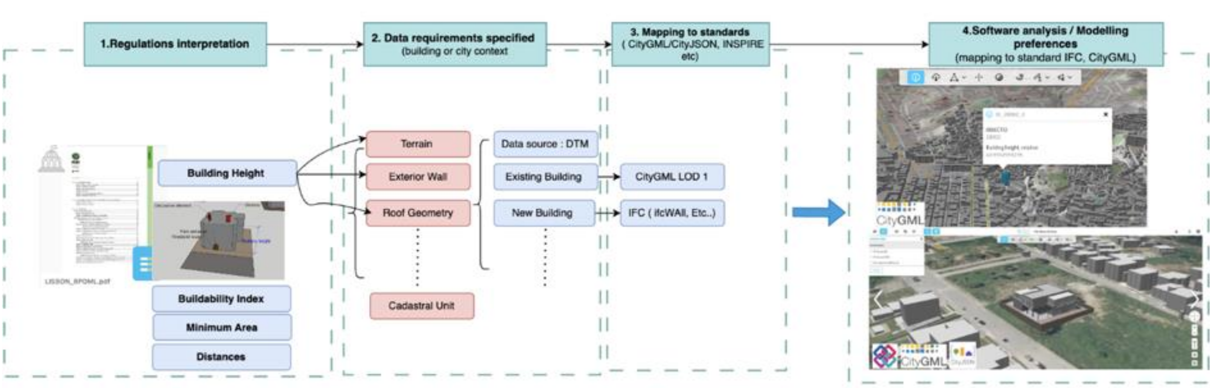

Fig. 6: Methodology followed for regulations interpretation and formalization for information need definition as an input to software's developers.

4. Results :

Apart from further detailing our methodology as well as further refining the geometrical LoINs based on the regulation analyses of the four municipalities, the final paper will include testing the feasibility of automating the selected regulations based on the developed extraction approach, aligning with municipalities' interpretations.

From these experiments, guidelines will be proposed to ensure stakeholders comply with these guidelines when modeling BIM for the DBP process.

Accurate georeferencing and precise extraction of building envelopes are paramount for conducting meticulous measurements, such as computing distances between buildings or determining building heights from ground level to the roof. Without precise georeferencing, these computations may lead to inaccuracies. An illustrative case study involving four municipalities with distinct regulatory frameworks showcases the importance of these processes. For instance, in Prague, regulated building height is defined as the distance from the lowest point of adjacent terrain to the main cornice level. To demonstrate, when assessing maximum building height in the Portuguese context using an IFC model from Vila Nova de Gaia (IFC4), the workflow involves validating IFC geometry, georeferencing the model using tools like the IFC Georeferencing solution, visualizing outcomes to ensure accuracy and compliance, extracting building envelopes through a voxelization approach like the extraction-based highest point roof method, and finally computing building heights based on regulatory requirements and the footprint elevation introduced in the tool (Figure 8).

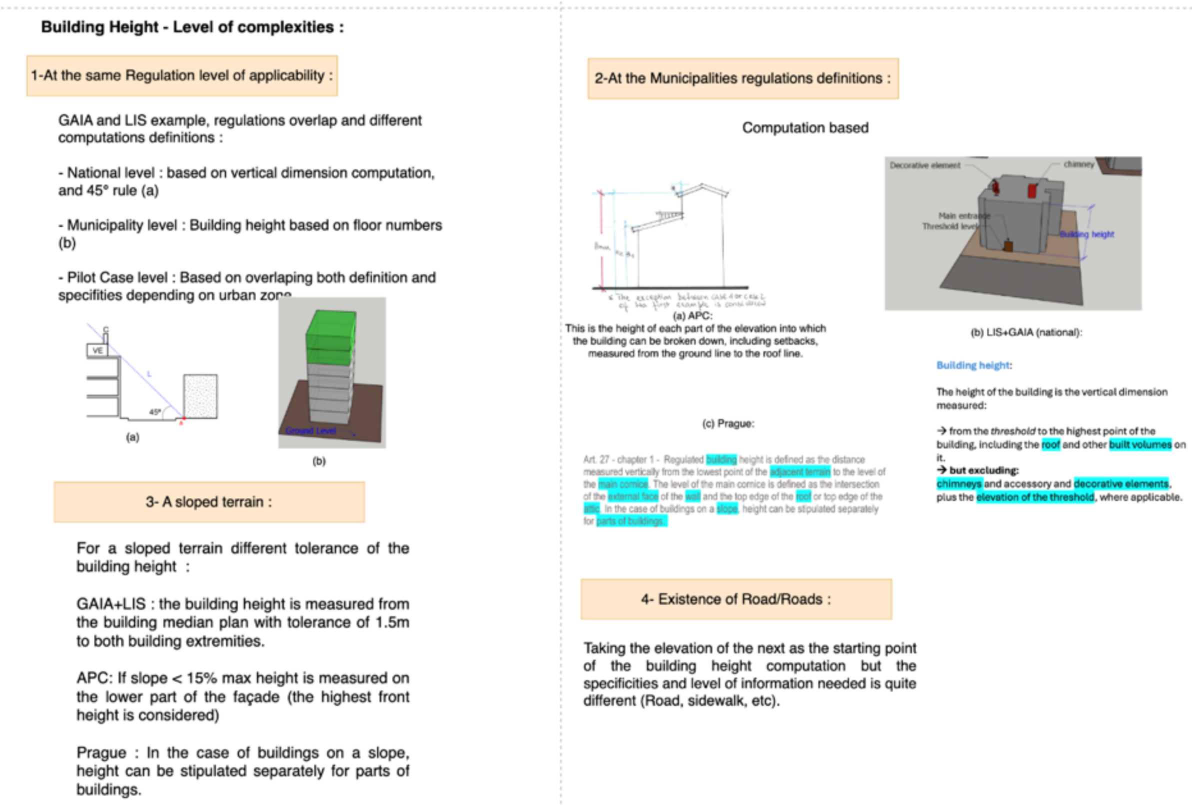

Fig. 7: complexities of building height and maximum building height 4 municipalities.

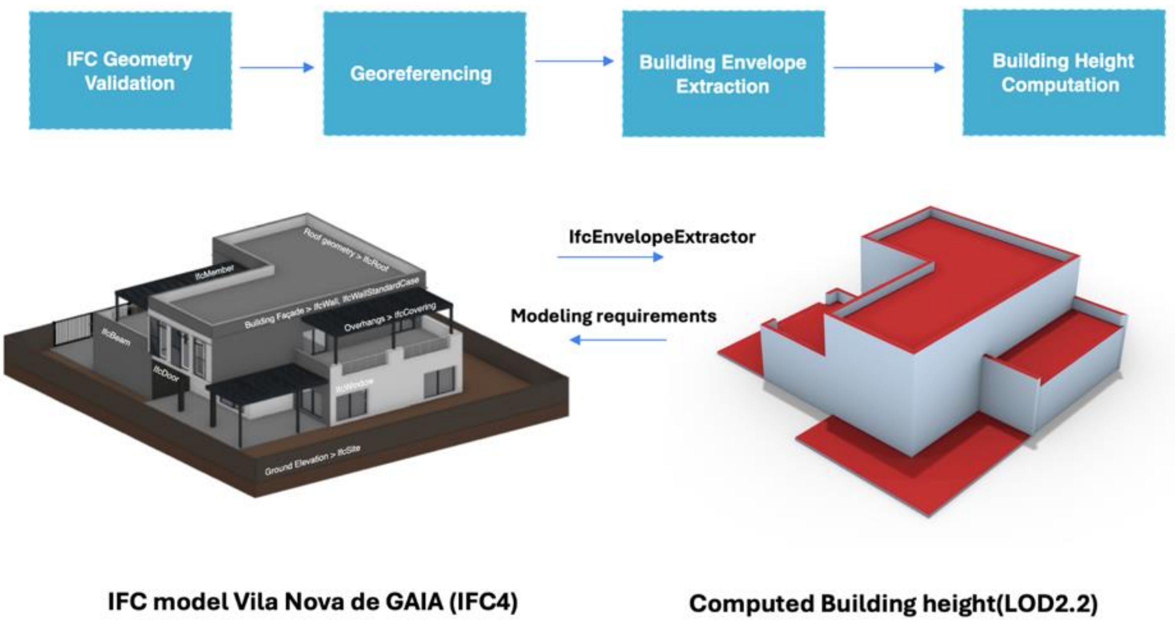

Fig. 8: Building height computation results based on the IfcEnvelopeExtractor and geometrical modeling requirements to be submitted to designers[6].

Conclusion

Our ongoing efforts involve finalizing geometrical information requirements based on regulations from four municipalities, upgrading the IfcEnvelopeExtractor tool, and aiding software developers in implementing regulation computations. However, we face challenges such as navigating regulatory complexities, structuring IFC models for designers, collecting municipal data for software developers, and coordinating pilot case demos.

From our endeavors, we've learned several valuable lessons. Flexibility is crucial in digitalizing building permit processes, and the true impact of implementation is best understood through practical use cases. Modeling guidelines must be iterative, and it's essential to consider differences in tolerances and accuracy between human and digital processes. These insights form a solid foundation for advancing digitalization efforts in building permit processes.

References

[1] S. El Yamani, R. Hajji, and R. Billen, "IFC-CityGML Data Integration for 3D Property Valuation," *ISPRS Int J Geoinf*, vol. 12, no. 9, Sep. 2023, doi: 10.3390/ijgi12090351.

[2] Hajji et al., "Building Information Modeling for a Smart and Sustainable Urban Space," *ISTE Ltd and John Wiley & Sons, Inc*, 2021.

[3] N. Hobeika, J. Van Liempt, F. Noardo, K. Arroyo Ohori, and J. Stoter, "Geobim Information To Check Digital Building Permit Regulations," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, vol. 43, no. B4-2022, pp. 529–535, 2022, doi: 10.5194/isprs-archives-XLIII-B4-2022-529-2022.

[4] F. Noardo, T. Wu, K. A. Ohori, T. Krijnen, and J. Stoter, "Automation in Construction IFC models for semi-automating common planning checks for building permits," *Autom Constr*, vol. 134, no. March 2021, p. 104097, 2022, doi: 10.1016/j.autcon.2021.104097.

[5] H. Ledoux, K. Arroyo Ohori, K. Kumar, B. Dukai, A. Labetski, and S. Vitalis, "CityJSON: a compact and easy-to-use encoding of the CityGML data model," *Open Geospatial Data, Software and Standards*, vol. 4, no. 1, pp. 1–19, 2019, doi: 10.1186/s40965-019-0064-0.

[6] J. Van Der Vaart, "Automatic building feature detection and reconstruction in IFC models," 2022.