INTEGRATED GEOBIM REQUIREMENTS DEFINITION FOR DIGITAL BUILDING PERMIT

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ABSTRACT: *The development of methods for building permit issuing supported by digital tools could improve the current mostly manual procedures for processing regulatory information and related compliance processes. Several studies are currently addressing the challenge of building permit digitalisation, mostly considering building information models as the source data for automating the regulations checks. However, many of the main checks, that usually represent the major bottlenecks of the compliance checking process, need a joint representation of the new proposed construction and its context, which could be effectively represented in a (3D) geographical information system. This study aims at supporting the automation of building permitting by addressing the rule interpretation as an input to model preparation and code checking. In particular, the regulations interpretation in this case is functional to the definition of data requirements and checking rules referring to a joint GIS and BIM (GeoBIM) framework. The approach is developed and tested in the case of an Italian municipality of 45.000 inhabitants. This paper describes the interpretation of distance-related regulations by adopting a semantic mark-up and sentence-centric approach. The resulting level of information need has been represented in conceptual models (object, attributes, relationships) as an essential input to city and building model preparation. While the case study is specific in location and regulations, the type of issues encountered are a generally applicable example for the building permit use case. Future works will extend the methodology to additional three European municipalities between 45.000 and 1.000.000 inhabitants, in three European countries, to address the need for a flexible and scalable approach.*

KEYWORDS: *Digital building permit; Rule interpretation; GeoBIM; Information requirements; Building-urban interaction.*

1. INTRODUCTION

A building permit is an authorisation required to start the construction phase of a building and it is granted by public authorities after verifying that the design proposal complies with construction regulations at building and urban levels (Noardo, *et al.* 2022). Building permit checks are traditionally a time-consuming and manual procedure for municipalities and the process is recognised as poorly effective due to multiple factors including, but not limited to, the technical knowledge of public officers in the assessment and the high demand for building permits to be inspected, troubled by the lack of adequate personnel (Fauth & Soibelman, 2022). Also, procedures for the issuance of the permit tend to be complex because of having to adapt to frequent legislative updates (Malsane, *et al.* 2015).

The development and connection of methods for building permit issuing supported by digital tools could improve the current as-is manual procedures for processing regulatory information and related compliance processes. With the increased adoption of Building Information Models (BIM) in building design processes, several municipalities are investing in automating these checks both by using BIM methods and tools, but also by increasingly integrating them with the geographic datasets at their disposal (Hobeika, *et al.* 2022). Research in the adoption of BIM to design verification for regulatory compliance is not recent - think of the discussion on BIM-based rule checking proposed by Eastman, *et al.* (2009). However, until a few years ago, research works were mainly focused on analysing building data, including their conversion in building-related neutral data schema as Industry Foundation Classes (IFC), rather than integrating BIM and Geographic Information System (GIS) (i.e., GeoBIM) (Hobeika, *et al.* 2022).

It is clear how important checks for the issuing of building permits require constant interaction between data on

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the building for which permission to proceed with the construction phase is sought – to be retrieved in the building information model - and information about the urban context in which it is located – to be retrieved in geo-data sets or 3D city models. This means that without adopting a GeoBIM approach some checks would require users to manually add information that should be instead automatically extracted from geo-data sets. For example, many urban parameters depend on urban zones, a new building must comply with minimum distance criteria from existing ones, interaction with existing public or private facilities must be considered, as well as public transport, parking standards and so on (Hobeika, *et al.* 2022). For this reason, according to recent studies on digital building permit (DBP), the automation of the checking of those kinds of regulations can only be effective if both geo-data and building data are considered. At present, the adoption of a GeoBIM approach represents a significant challenge of the DBP use case (Arroyo Ohori, *et al.* 2018). Recent literature, especially from 2016 (Noardo, *et al.* 2022), investigate the management of geo-data by available standards (e.g., CityGML) (Guler & Yomralioglu, 2021) and GeoBIM interoperability (e.g., conversion of 3D city models to BIM) (Nebras, *et al.* 2020) as essential steps for allowing designers to consider geoinformation as a suitable reference (Noardo, *et al.* 2022).

This paper focuses on rule interpretation, the process of conversion of the natural language of city and building regulations into computable parameters and constraints. Within the broader research framework, the methodology adopted for the interpretation of *distance-related* regulatory requirements and their formalisation is described in Section 2. Distance-related checks are one of the examples of regulatory checks that need the adoption of an integrated GeoBIM approach to be automated. Results from the interpretation of regulatory requirements from a specific case study are described in Section 3, including the formalisation of the relevant level of information need as a preliminary input to city and building model preparation and code checking (Section 4). Finally, limitations of the study, which is currently ongoing, are discussed along with future contributions (Section 5).

2. RESEARCH FRAMEWORK AND METHODOLOGY

The research considers the digitisation of the building permit use case for an Italian municipality of 45.000 inhabitants (i.e., Municipality of Ascoli Piceno). It has been explored in close collaboration with the municipality, and it is based on the field experience of its own officers. First, the list of checks to be digitised for effectively supporting the building permit process has been defined. Then, regulations among the ones that were deemed likely to have the best advantage from GeoBIM have been considered as a priority by municipality officers. They include: maximum buildable urban volume, buildability index, covered area, coverage ratio, maximum building height, building protrusions on public streets and squares, parcel's fence height, distance from other buildings (i.e., building-building distance), distance from the parcel boundaries (i.e., building-parcel boundaries distance), building-road distance, parking standards (dimensions/area and n. of parking spaces).

In this paper the results regarding *distance-related* regulations are described. Those regulations were selected, in consultation with municipality experts, because these were judged to be among the most important ones to be implemented. Distance-related regulations have been classified as follows: building-building distance, building-parcel boundaries distance and building-building distance if a road is interposed. The specific text of the regulation has been analysed with the aim of translating it into a set of information requirements for the DBP use case and, on the other hand, into a machine-readable format. The former objective lies within the scope of this paper, while the development of a pseudocode, developed based on this initial discussion, will be a future work of this research which is still ongoing.

2.1 Rule interpretation

Rule interpretation represents the first step of the DBP workflow (Figure 1) but it is also one of the main challenges in such a use case. The relevant information in documents such as public laws, codes and regulative standards should be captured in a time and cost-effective way to be able to adopt rule checking effectively (Noardo, *et al.* 2022). However, the complexity of the natural language used for regulatory requirements and its interpretation into data sets for supporting the adoption of a digital approach represents an open issue for automating and digitising design compliance checking and, specifically, building permitting. Malsane, *et al.* (2015) describe how knowledge formalisation of building codes could provide "suitable, significant and required data for the development of the building regulation-specific object modelling". They claimed how the formalisation of building regulations should include the classification of regulation clauses into "those which are computer-interpretable (declarative) and those which are not (informative)". The former provides a direct meaning to be interpreted (e.g., simple geometrical rules which when applied to an element can return true or false), while the latter contain data only partially suitable for interpretation into computer rules that can be processed (e.g., information is not obvious as checkable, needs human interpretation to understand the exact content and meaning). Finally, a remaining category of clauses exist that can be considered as unsuitable for automated compliance checking.

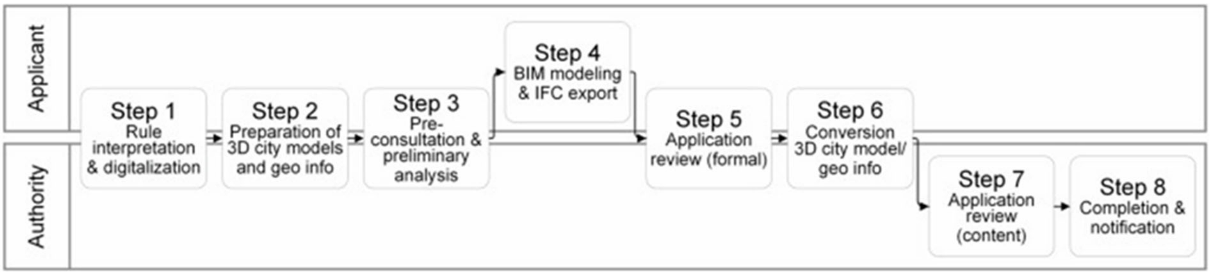


Fig. 1: Overview of considered DBP workflow steps assigned to involved parties (Noardo, *et al.* 2022)

Several rule interpretation processes are described in literature, both manual-based and automatically enabled, to create computable representations of normative data (Dimyadi, *et al.* 2017). Studies exist that propose methods to automatically interpret the natural language of regulations transforming them to code to check the proposed building design, as represented in building information models (e.g., Song, *et al.* 2018; Zhang & El-Gohary, 2017). However, challenges appear long before the conversion of this information from natural language to any formal language since even for human beings the interpretation of the text, tables and graphical contents of regulations can be open to different interpretations (Noardo, *et al.* 2020). According to Zhang, *et al.* (2023), the ambiguity of building requirements is one of the main issues since it could prevent their accurate interpretation and automated checking. They discussed how some ambiguous clauses in building requirements "reflect regulators' intention while others are unintentional, resulting from the use of language or tacit knowledge". Even if the rule interpretation process could rely on the programmer's interpretation and translation of the written rules into computer code (Eastman, *et al.* 2009), in most cases the logic of the human language statements is first formally interpreted and then translated. In fact, because of the complexity and subjectivity in nature of building regulations, as just mentioned, building regulation experts (e.g., municipality officers) need to be involved in their conversion to computer interpretable rules to ensure the correct interpretations (Malsane, *et al.* 2015).

In this study, a sentence-centric approach and a semantic mark-up procedure have been adopted for rule interpretation. Each regulatory article that municipality officers considered as significant for distance-related checks was interpreted (i.e., sentence-centric approach). To this end the *Requirement, Applicability, Selection, and Exception* (RASE) methodology has been adopted for deconstructing rule sentences and to extract semantics from building regulations for compliance checking (Hjelseth & Nisbet, 2011; Nisbet, *et al.* 2022). The content of regulatory requirements has been interpreted by dividing each sentence into these four basic components to support formalisation (i.e., semantic mark-up procedure). Such an approach to rule interpretation can be seen as a pre-processing step as in this case the result cannot be directly interpreted by the computer (Preidel & Borrmann, 2018).

Moreover, a relevant step to solve ambiguities has been performed by the organisation of a specific meeting with the involvement of municipality officers who usually check and then release or deny the building permits themselves. The details and meanings of the distance-related regulations were explained and agreed upon and specific questions were asked about ambiguous statements. Moreover, some more details arising during the following work towards implementation were asked later. That was the only way to have ambiguities about the regulation solved. This issue already showed how little the current state of regulations lends itself to automation (Noardo, *et al.* 2020).

After that, the regulation was formalised step by step. A table containing the metric phrases identified through the RASE labelling has been compiled and the following data set has been provided (Hjelseth & Nisbet, 2011; Tomczak, *et al.* 2022): the object to which the rule refers, the type of information to be verified (i.e., property), the data type (e.g., text, number, boolean) of the required properties, the comparison (e.g., ≤, ≥, contains), the value to be compared (i.e., target value), the unit of measurement that the value should have (i.e., for numerical values) and, if necessary, dependencies and application conditions. Plain text description could be added to support unambiguous definitions and information requirements could also demand a particular level of detailedness to support building and city model preparation, meaning what needs to be modelled and to what precision (i.e., geometrical data) (Tomczak, *et al.* 2022).

2.2 Information conceptual models

Based on the results from rule interpretation, information requirements have been identified and formalised in terms of information conceptual models (object, attributes, relationships) as an essential input to city and building model preparation (Zhang, *et al.* 2023). Both building and city models are sources of information involved in automated compliance audit processes if a GeoBIM approach is adopted. They respectively represent the building design to be audit - usually developed by the professional responsible for applying for a building permit on behalf of the applicant - and the urban context in which it is located. Another source in the automated compliance checking process is represented by normative clauses structured in machine-readable formats, which is not within the scope of this paper.

Conceptual models, in the practice of database design, are intended to formally represent the information to be stored in a database. The database design methodology defined by the ANSI/X3/SPARC standard defines four levels of data modelling: external model, representing a simple narration of requirements for information representation of the database; conceptual model, abstracting and formalising the information requirements in the external model into objects (i.e., entities or classes), the respective properties or characteristics (attributes) and reciprocal relationships; logical model, converting the conceptual model into rules more computing oriented; and finally the internal, or physical model, corresponding to the actual implementation format of the database (Laurini & Thompson, 1992).

In this study, the information about requirements was collected from the regulations, and the mark-up phase through the RASE methodology facilitating the formalisation of the regulatory contents was one intermediate step supporting the definition of data requirements as conceptual models, which were represented following the Unified Modelling Language (UML) (OMG, 2023). Objects and related attributes needed for distance-related checks in the DBP use case for the considered municipality have been identified. The representation includes data types and specifies if data are directly extractable from the model (e.g., the height of the object) or whether they need to be entered manually by the designer. For numerical value the type is specified (e.g., integer, real, float), while for textual data allowed classifications are specified from which data values can be chosen (e.g., the list of actual intended uses for the municipality's urban zone from which a designer has to choose before submitting its design to the building permit procedure. Depending on the type of intended use of the urban zone, in fact, some regulatory constraints will apply over others). The conceptual model representation also allows the type of relationship (aggregation relationship, composition relationship, etc.) to be specified.

Finally, the development of the conceptual models supports an easier comparison and harmonisation of the information requirements according to the same type of check (e.g., distance-related check) applied in different municipalities or according to different types of checks applied by the same municipality. This will facilitate the mapping to standards for representing BIM and GIS-related information consistently in future steps. To this end, as a preliminary step, for the objects in the conceptual model proposed in this paper it is specified whether they should belong to the BIM or GIS information representation.

3. RESULTS FROM THE INTERPRETATION OF REGULATORY REQUIREMENTS

The regulation considered here is the *Regolamento edilizio comunale (i.e., Building code) of the Municipality of Ascoli Piceno.* Municipality officers pointed out Article 61 of the text, reported here in paragraphs 2, 3, 4 and 6, as important for distance-related checks. The text translated into the English language is available in Table 1.

When considering this Article for formalisation, several examples of the complexity of the natural language of regulatory requirements emerges. For example, paragraph 2 refers to another regulatory text whose requirements, in relation to the one under analysis, are not made explicit. A reference to the "*urban planning instrument",* which could contain additional requirements, is also mentioned in the paragraph. The prescribed minimum distance between two buildings is implicit in the text – referring to the *"height of the tallest building"* - and refers to another regulatory aspect concerning the maximum building height, for the explication of which it is necessary to refer to further definitions or regulatory articles. The same happens for the distance of the building from the boundaries of the parcel in which it is located (i.e., "*the distance of a building from the parcel boundaries shall be equal to the half of the maximum permitted height"*). Paragraph 4 also refers to additional definitions, such as the one of the distances of a building from a road: what does the road should contain as an object in city or building information models?

It is therefore essential to interpret not only the regulatory requirements but also definitions contained in building regulations and other regulatory texts that are relevant to the inspection in question. In 2016, an agreement was reached between the Italian state, Regions and the National Association of Italian Municipalities to adopt the so-called Standardized Building Regulations to simplify and unify actions in building matters. To this end, a set of forty-two uniform building-urban definitions was also developed, which represents the common glossary valid throughout the country. However, the process of transposing the Standard Building Regulations and their homogeneous definitions is still in progress and it is currently not possible to proceed with an unambiguous interpretation of them that has generalised validity. In this case, the regulation considered here is the *Regolamento edilizio comunale of the Municipality of Ascoli Piceno – art. 13 (o, p, q).* The text of these definitions translated into the English language is contained in Table 2, which also contains the graphical interpretation of the definitions as proposed by the authors and validated by municipality officers. The definition of building height (art. 13, paragraph m and n) had to be considered as well and it is contained in Table 3.

Table 1: *Building code of the Municipality of Ascoli Piceno. Art. 61 (i.e., distance-related checks)*

Paragraph	Text of Normative Article
2	In (c) areas of expansion referred to in Article 2 of Ministerial Decree No 1444 of 2 April 1968, published in the Official Gazette of 16 April 1968, No 97 between windowed walls of facing buildings, a minimum distance is prescribed, equal to the height of the tallest building and no lower than 10 m; if the facing facades overlap for more than 12 meters, the rule applies also when only one of them has windows. In the same urban zones, the distance of a building from the parcel boundaries shall be equal to the half of the maximum permitted height and in any case not less than 5 m. Construction on parcel boundaries is allowed, where permitted by the urban planning instrument, by agreement between the neighboring owners
3	For all construction operations in other areas, the following minimum distances are prescribed: (building-building distance) (1) between windowed walls and walls of buildings in front of which at least one window: ml. 10; (building-parcel boundaries distance) (2) from the boundaries: ml.5 and unless otherwise prescribed by the general urban planning instrument.
4	Minimum distance between buildings with roads in-between, excluding cul-de-sac roads serving single buildings or settlements, must be equal to the road width plus: (1) 5.00 m per side, in case of streets width lower than 7.00 m, (2) 7.50 m per side, in case of streets width between 7.00 and 15.00 m, (3) 10.00 m per side, in case of streets width higher than 15.00 m
6	It will not be taken into account for the purposes of determining distances, overhang structures such as steps and open external stairs (maximum height 4), (1) gutter frames, open balconies and canopies, provided that the relative outline remains spaced from the boundaries at least by 1.50 m; (2) While account shall be taken of anybody closed in protrusion whatever is the adjective and at whatever height of the building it begins.

Several ambiguities and uncertainties also arise for human interpretation. Those were mainly solved with the help of municipality officers in a meeting organised on the 17th of May 2023. Later, further ambiguities have been solved thanks to the continuous collaboration with the municipality, which was critical for the success of this initial phase. For example, the *building-building distance* can be considered radially or perpendicularly to the new building. Through discussions with municipality officers, it was defined that the segment defining the distance is perpendicular to the line of the building (see Table 2, paragraph o). Considering the building-road distance check, doubts emerged in relation to the “road furniture areas”. Talking with the municipality officers it was possible to define the entity of “flowerbed” to which the normative text refers (see Table 2, paragraph q).

Results from rule interpretation have been formalised in a table containing the metric phrases identified through the RASE labelling as described in Section 2 (Figure 2). In Figure 2, the identified values for distances only apply to one urban zone, namely the c) areas of expansion. The first part of the article identifies the distance between two buildings with external windowed walls (art. 61(2) – case a), while in the second part, the overlap factor intervenes (x >12 m) (art. 61(2) – case b) and the distance is calculated between two walls of which at least one is windowed, so we have two cases, the existing building with a wall containing a window and the new building without windows or vice versa, the new building with a window and the existing building without (Figure 3).

Table 2: Distances-related definitions as defined in the *Building code of the Municipality of Ascoli Piceno, Art. 13*

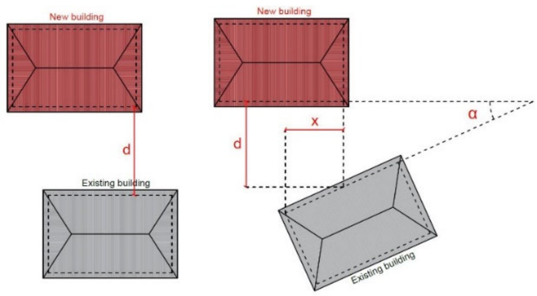
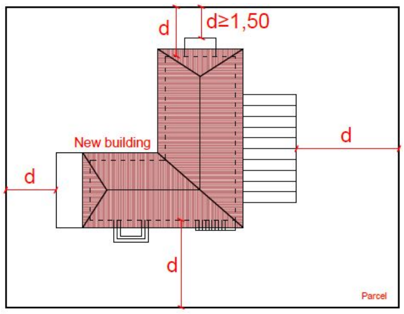
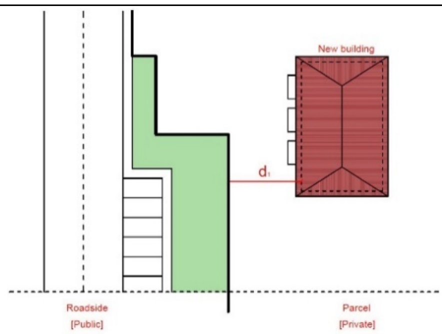
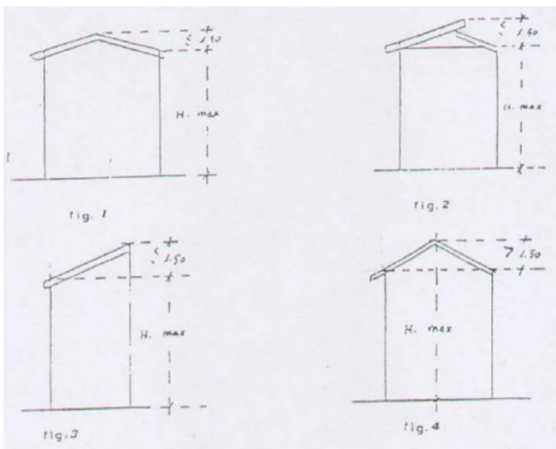
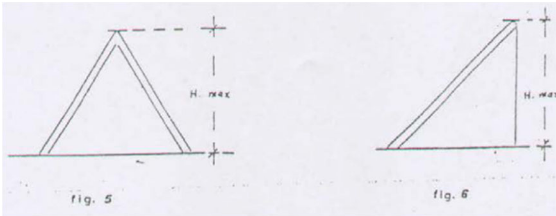
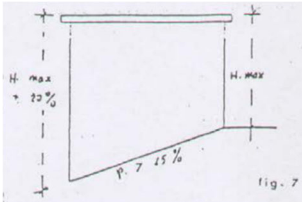
Regulatory requirement	Graphical interpretation
Paragraph o – Building-building distance. Is the distance (minimum) between the walls in front of the buildings, or buildings of the same, except for the walls on the interior spaces referred to in point (r) below, measured at the points of maximum protrusion. Two walls are considered to be facing when the angle formed by the extension of the same is less than 70 degrees sexagesimal and the overlap is greater than 1/4 of the minimum distance of the walls themselves. For graded buildings, the distance is measured at each setback.	
Paragraph p – Building-parcel boundaries distance. It is the distance between the vertical projection of the wall of the building and the boundary line, measured at the point of maximum protrusion. It is understood as a border beyond the separation line of the different existing properties or the line defining the different lots or compartments of the implementation plans, as well as the line of delimitation of public areas for services or equipment identified in urban planning instruments.	
Paragraph q - Building-building distance if a road is interposed. It is the distance between the vertical projection of the wall of the building and the edge of the road, including sidewalk and public parking and road furniture areas.	

Table 3: Building-height definitions as defined in the *Building code of the Municipality of Ascoli Piceno, Art. 13*

Regulatory requirement	Graphical interpretation
Paragraph m - Front height (H) - This is the height of any part of the elevation into which the building can be broken down, measured from the ground line to the roof line, taking into account the setback bodies if not included. The ground line is defined by the intersection of the wall of the elevation with the street level or the plane of the pavement or the plane of the ground at final settlement. The roof line is defined, in the case of a flat roof, by the intersection of the elevation wall with the plane corresponding to the extrados of the roof slab; in the case of a pitched roof, by the intersection of the elevation wall with the plane corresponding to the extrados of the roof pitch. Unless otherwise specifically prescribed by the individual town-planning instruments, the height measurement does not take into account stairwells, lifts and flues, nor the increases corresponding to basement window wells or external accesses, both vehicular and pedestrian, provided that the accesses themselves, built in a trench with respect to the ground line, are not more than 3 m wide.	
Paragraph n - Maximum height of buildings (HMAX) This is the maximum between the heights of the different parts of the elevation into which the building can be divided, measured as in letter m) above. In the	

case of elevations in which there are inclined roof pitches (gabled, staggered or single-pitched), the maximum height is considered to be that corresponding to the intersection of the elevation walls with the plane corresponding to the extrados of the roof pitch (1) as long as the ridge does not exceed the height measured in this way by more than 1.80 m, otherwise the maximum height is measured at the ridge line (see Figures 1,2,3 and 4). (2) If the roof slopes coincide with the sloping walls of the elevations, the maximum height must always be measured to the ridge line (see Figures 5 and 6). (3) For buildings on land with a natural slope of more than 15%, the maximum height permitted by the town planning instruments, unless more restrictive prescriptions of the same, may be exceeded by 20% in the downstream parts of the elevations, with an absolute maximum of 2.00 (see Figure 7).





Normative clause (*Regolamento edilizio comunale* – Art. 61.2)	Metric phrase	Mark-Up (RASE)	Object needed (building/city model)	Property	Data type	Comparison	Target	Unit	Dependency
In (c) areas of expansion referred to in Article 2 of Ministerial Decree No 1444 of 2 April 1968, published in the Official Gazette of 16 April 1968, No 97 between windowed walls of facing buildings, a minimum distance is prescribed, equal to the height of the tallest building and no lower than 10 m; if the facing facades overlap for more than 12 meters, the rule applies also when only one of them has windows. In the same urban zones the distance of a building from the parcel boundaries shall be equal to the half of the maximum permitted height and in any case not less than 5 m. Construction on parcel boundaries is allowed, where permitted by the urban planning instrument, by agreement between the neighboring owners.	minimum distance	Applicability	- New building - Existing building(s)			Exist			
	(c) areas of expansion	Selection	- Urban zone	Intended Use	Text	=	(c) areas of expansion		
	Between windowed walls of facing buildings	Selection	- New building			Contains	Wall; (which contains) window		If facing walls
			- Existing buidling(s)			Contains	Wall; (which contains) window		
	if facing facades overlap for more than 12 meters, the rule applies also when only one of them has windows	Selection	- New building - Existing building(s)			Contains	Wall; (which contains) window		If walls face each other for at least 12 m
	equal to the height of the tallest building	Requirement	- New building - Existing building(s)	Distance	Number	≥	Building height of the tallest building	m	If Building height of the tallest building is > 10 m
	and no lower than 10	Requirement	- New building - Existing building(s)	Distance	Number	≥	10	m	If Building height of the tallest building is < 10 m
	In the same urban zones, the minimum distance of a building	Applicability	- New building - Parcel			Exist			
	from the parcel boundaries	Selection	- Parcel			Contains	Parcel boundaries		
	shall be equal to the half of the maximum permitted height	Requirement	- New building - Parcel boundaries	Distance	Number	≥	½ of the allowed maximum building height		If ½ of the allowed maximum building height < 5
	and in any case not less than 5 m.	Requirement	- New building - Parcel boundaries	Distance	Number	≥	5	m	If ½ of the allowed maximum building height < 5
	Construction on parcel boundaries is allowed, where permitted by the urban planning instrument, by agreement between the neighboring owners	Exception	- New building - Parcel boundaries	Distance	Number	=	0	m	If a formal consent has been written between (or amongst) the involved parties and it is allowed by urbanistic regulations

Fig. 2: Resulting interpretation of Art. 61.2 based on a semantic mark-up and sentence-centric approach.

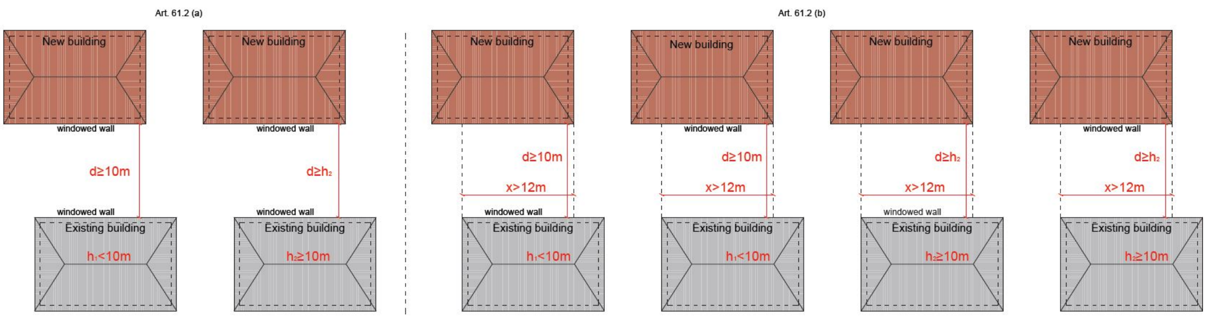


Fig. 3: Graphic Interpretation of Articles 61.2(a) (on the left) and 61.2(b) (on the right).

In the analysis of Article 61.3 shown in Figure 4, there are the values of the distances to be observed in '*other areas*'. This concept was the subject of discussion with the municipality as it does not specify in detail in which Urban Zones it applies. Unlike the previous article, the rule to be respected in this case is that the 3 areas emerged from the comparison: *Historic centre*, *Areas of completion* and *Areas of expansion*.

Normative clause (*Regolamento edilizio comunale* – Art. 61.3)	Metric phrase	Mark-Up (RASE)	Object needed (building/city model)	Property	Data type	Comparison	Target	Unit	Dependency
For all construction operations in other areas, the following minimum distances are prescribed: (1) between windowed walls and walls of buildings in front of which at least one window: ml. 10; (2) from the boundaries: ml.5 and unless otherwise prescribed by the general urban planning instrument.	minimum distance	Applicability	- New building - Existing building(s)			Exist			
	For all construction operations in other areas	Selection	Urban zone	Intended Use	Text	≠	- Historic centre - Areas of completion - Areas of expansion		
	between windowed walls and walls of buildings in front of which at least one window:	Selection	- New building			Contains	Wall; (which contains) window		If facing walls
			- Existing buidling(s)			Contains	Wall; (which contains) window		
	ml. 10	Requirement	- New building - Existing building(s)	Distance	Number	≥	10	m	
	minimum distance	Applicability	- New building - Existing building(s) - Parcel						
	from the boundaries	Selection	- Parcel			Contains	parcel boundaries		
	ml.5	Requirement	- New building - Parcel boundaries	Distance	Number	≥	5	m	
	unless otherwise prescribed by the general urban planning instrument.	Exception							

Fig. 4: Resulting interpretation of Art. 61.3 based on a semantic mark-up and sentence-centric approach.

Article 61.4 (Figure 5) deals with the distance that must be between the building and the road. First of all, it is necessary to identify the width of the road. In fact, the article refers to 3 brackets: less than 7 m (1), between 7 m and 15 m (2) and greater than 15 m (3). For these 3 cases it identifies the distance as the sum of the road width increased by a specific value: 5 m for the first case, 7.50 m for the second case and 10 m for the third case. Article 61.6 (Figure 6) deals with the distance between the projecting parts of the building and the parcel boundaries. A requirement emerges that has been identified by the authors as an '*implicit piece of the regulation*'. For the previous articles, the building line from which to calculate the distance referred to the external elevation understood as the external wall that must contain a window (Art.61.2a). In this article, the reference building line is moved from the outer wall to the reference overhang if the latter is less than 1.50 m away from the parcel boundaries. The projections referred to are precisely eaves cornices, open balconies and canopies.

Normative clause (*Regolamento edilizio comunale* – Art. 61.4)	Metric phrase	Mark-Up (RASE)	Object needed (building/city model)	Property	Data type	Comparison	Target	Unit	Dependency
Minimum distance between buildings with roads in-between, excluding cul-de-sac roads serving single buildings or settlements, must be equal to the road width plus: (1) 5.00 m per side, in case of streets width lower than 7.00 m, (2) 7.50 m per side, in case of streets width between 7.00 and 15.00 m, (3) 10.00 m per side, in case of streets width higher than 15.00 m	minimum distance	Applicability	- New building - Existing building(s)			Exist			
	between buildings with roads in-between	Selection	- Road			Exist			If the roads is interposed between New building and Existing building(s)
	excluding cul-de-sac roads serving single buildings or settlements	Exception	- Road	Type	Text	=	Cul-de-sac roads serving individual buildings or settlements		
	in case of streets width lower than 7.00 m	Selection	- Road	Width	Number	<	7	m	
	must be equal to the road width plus 5.00 m per side	Requirement	- New building - Existing building(s)	Distance	Number	≥	Road's width + buffer 5,00 m	m	
	in case of streets width between 7.00 and 15.00 m,	Selection	- Road	Width	Number	≥ ≤	7 15	m	
	must be equal to the road width plus 7.50 m per side	Requirement	- New building - Existing building(s)	Distance	Number	≥	Road's width + buffer 7,5 m	m	
	in case of streets width higher than 15.00 m	Selection	- Road	Width	Number	>	15	m	
	must be equal to the road width plus 10.00 m per side	Requirement	- New building - Existing building(s)	Distance	Number	≥	Road's width + buffer 10,00 m	m	

Fig. 5: Resulting interpretation of Art. 61.4 based on a semantic mark-up and sentence-centric approach.

Normative clause (*Regolamento edilizio comunale* **– Art. 61.6)**	**Metric phrase**	**Mark-Up (RASE)**	**Object needed (building/city model)**	**Property**	**Data type**	**Comparison**	**Target**	**Unit**	**Dependency**
It will not be taken into account for the purposes of determining distances, overhang structures such as steps and open external stairs (maximum height 4), (1) gutter frames, open balconies and canopies, provided that the relative outline remains spaced from the boundaries at least by 1.50 m; (2) While account shall be taken of any body closed in protrusion whatever is the adjective and at whatever height of the building it begins.	distances	Applicability	- New building						
			- Existing building(s)			Exist			
	overhang structures	Selection	- New building - Existing building(s)			Contains	Eave cornices, open balconies and canopies		
	(implicit piece of the regulation)	Requirement	- New building's eave cornices, open balconies and canopies - Existing building(s)	Distance		Must be verified			If not in the exception case (see below)
	It will not be taken into account for the purposes of determining distances, overhang structures such as steps and open external stairs (maximum height 4), (1) gutter frames, open balconies and canopies, provided that the relative outline remains spaced from the boundaries at least by 1.50 m;	Exception	- New building's eave cornices, open balconies and canopies - Existing building(s)	Distance	Number	≥	1,5	m	
	If closed bodies are present in protrusions	Selection	- New building			Contains	Closed building protrusions		
	While account shall be taken of any body closed in protrusion whatever is the adjective and at whatever height of the building it begins.	Requirement	- Building protrusions - Existing building(s)	Distance		Must be verified			

Fig. 6: Resulting interpretation of Art. 61.6 based on a semantic mark-up and sentence-centric approach.

4. INFORMATION REQUIREMENTS DEFINITION

As already mentioned in Section 2.2, Figure 7 shows the representation of the data required to verify the constraints specified in the *Regolamento edilizio comunale* of Ascoli Piceno. Each box represents an entity of building information models or city models, with its specific attributes. To facilitate the identification of entities belonging to the different models, colours were used, assigning a different colour depending on whether the entity should come from a BIM or city model. In particular, *green* was used to identify elements belonging to the building model (BIM) and *blue* to identify elements belonging to the city model (GIS). This distinction allows to have an immediate view of where the data should come from and highlights the necessary correlation between the data of the building and the geospatial data of the urban context in which it is located. This example makes it clear that the need to integrate BIM with GIS, and GIS with BIM, is increasingly essential. A grain size and tolerance must be defined to integrate these two types of data.

Building information models and city models for checking distance-related requirements in a digital building permit use case should contain:

- *urban zones* with an absolute location and for which the *intended use* (e.g., area of expansion; historic centre) is specified;
- *cadastral parcels* with an absolute location and for which *parcel boundaries* are modelled as well;
- *existing buildings*, meaning those that are already located in the urban context of the *buildings* for which the building permit is required. Existing buildings could be detailed with a simplified geometry that allows the extrapolation of the *building height* according to the relevant definition (e.g., a cube for a house with a flat roof that is not accessible). Existing buildings have to contain *windows* to allow building-building distance checks to be executed. Existing buildings have to be identified with their absolute location;
- *buildings*, meaning the ones for which the building permit is required. Buildings need to be detailed with their actual shape and size to identify the building outline. For this reason, buildings need to be modelled including overhangs as *balconies*, *canopies, roofs' eave cornices* and *closed building extrusions*. Appearance is not to be considered for this type of check. Moreover, *external walls* have to include *windows*. The *type of construction* could be a property to assign to buildings (e.g., new construction, renovation) for compliance checking;

- *roads* will have to be modelled including *streets, sidewalks*, *parking spaces* and *flowerbeds*. In fact, according to the definition in Table 2 (see paragraph q), the road is considered as the sum of several elements. The information content of *road* elements has to contain properties as *type of road* (e.g., cul-de-sac) and *width*.

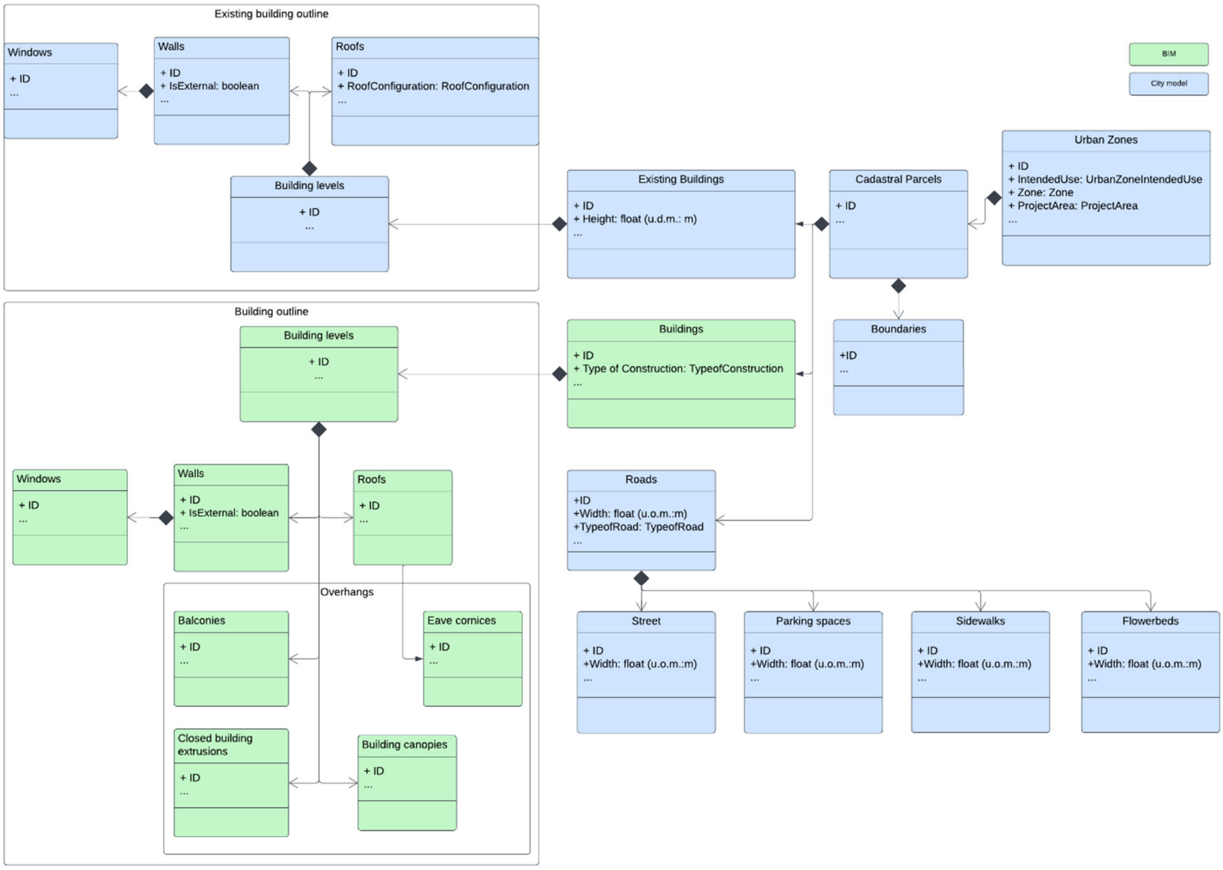


Fig. 7: Conceptual model representing the entities, attributes and relationships that must be present in the model to apply for a digital building permit.

5. CONCLUSIONS

5.1 Discussion of results

This paper describes the interpretation of distance-related regulations for the digitisation of the building permit use case for an Italian municipality of 45.000 inhabitants. Those regulations were selected as a priority by municipality officers, and they check the compliance of design proposal with regulatory requirements related to: building-building distance, building-parcel boundaries distance and building-building distance if a road is interposed. A semantic mark-up and sentence-centric approach has been adopted to extract normative constraints from the natural language of the regulatory text with the aim of translating it into a set of information requirements for the DBP use case. Information requirements have been defined as an essential input to city and building model preparation and they have been formalised in terms of information conceptual models. Domain-specific object types have been associated with required properties properly detailed. Moreover, object types have been matched with a preliminary categorisation into building-related and city-related objects. This could be the basis for the development of standard-oriented specifications for building and city information models.

The rule interpretation step revealed several difficulties, proving to be, as already described in the existing literature, probably the most critical phase in digitising design compliance checking and, specifically, building permitting. First, despite the fact that the municipality officers initially indicated only one regulatory article as necessary for distance verification based on urban zones (i.e., Art. 61 from *Regolamento edilizio comunale*), it was needed to add further regulatory references to this explicit request, either from the same regulatory text or from others normative codes. In addition, it was necessary to interpret not only the regulatory requirements but also the definitions to which they refer (e.g., the actual meaning of building-road distances and maximum building height). Moreover, to validate the extrapolated data and to remove ambiguities related to the complex regulatory textual form, a comparison with municipality officers was essential, which underlines, again confirming the literature, the interpretative subjectivity of building regulations that hardly fits with their digitisation.

5.2 Limitations and future works

Current outcomes show how, despite any fascinating narrative about the automated technical solutions, the hurdles to be tackled with and overcome imply to definitely understand a lot of multi-faceted meanings, unless a whole re-writing of the regulations might be figured out. While the case study is specific in location and regulations, the type of issues encountered are a generally applicable example for the building permit use case. Future works will extend the methodology to the analysis of distance-related regulations from additional three municipalities between 45.000 and 1.000.000 inhabitants, in other two European countries. The resultant level of information need will be formalised in terms of information conceptual models for the complete set of four municipalities and compared to point out the need for a flexible and scalable approach. To this end, the generated data set will be shared with professionals from municipalities, city modellers, and designers to allow the comparison and subsequent validation of the identified and analysed requirements.

Moreover, what is proposed in this article is a first step to proceed, in future works, with deeper analysis in relation to semantics, level of details, geometric representations and GeoBIM interoperability. As a future work, the representation of design and context information according to BIM and geospatial standards will be considered as well as standard definitions for the level of information need as the one proposed by the EN Standard 17412, to be soon re-shaped as a EN ISO Standard.

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