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Definition of BIM and 3DCitymodel information requirements for digital building permits

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To start the construction phase of a building, it is necessary to have a building permit. This is a permit issued by the public authorities after careful verification that the project complies with the building regulations valid at both building and city level [1]. The development and linking of methods for issuing building permits, supported by digital tools, could improve the current manual procedures for processing regulatory information requirements and related compliance processes. With the increasing adoption of Building Information Models (BIM) in building design processes, several municipalities are investing in the semi-automation of these checks both by using BIM methods and tools, but also by increasingly integrating them with geographical datasets [2]. Research on the adoption of BIM and neutral building data schemes such as Industry Foundation Classes (IFC) aimed at verifying project compliance with building regulations is not recent. However, in recent years, research has been focusing on the integration of BIM and Geographic Information System (GIS) model data [3]. Furthermore, in order to be able to run a compliance check, it is necessary to prepare building information models and 3D city models according to the appropriate information requirements [4].

The interaction between BIM and GIS for the issuing of building permits is analysed in the CHEK project. CHEK project is a larger project that aims to remove barriers that, to date, prevent municipalities from adopting digital processes for building permits by developing, linking and aligning scalable solutions for the regulatory and policy environment, open standards and interoperability (geospatial and BIM).

The research described in this paper focused on the application of a methodology for the interpretation of the building regulations of municipalities belonging to the European Union with the aim of extracting the BIM and GeoBIM information requirements (entities, attributes and relationships) needed to apply for a building permit. An empirical approach was adopted for this research in order to obtain results as close as possible to the real needs of the municipalities. The research activities were carried out in close cooperation with four municipalities between 45.000 and 1.300.000 inhabitants (i.e., in ascending order of size, Municipality of Ascoli Piceno - Italy, Municipality of Vila Nova de Gaia - Portugal, Municipality of Lisbon - Portugal, Municipality of Prague - Czech Republic) in three European countries.

To this end, the five-step process for identifying the entities and attributes required to perform the conformity check is briefly described.

- Identification of relevant building permit checks: provision of a list of the most frequently performed checks, focusing on the checks carried out directly by municipalities, rather than by external checking authorities. The list was validated and approved by the municipalities themselves, who identified and provided the related regulatory articles accordingly;
- Interpretation of the rules: interpretation of the articles of the building and national regulations using the sentence-centred method and semantic mark-up RASE methodology [5;6] to define the Requirement, the Applicability, the Selection and Exception within the

regulatory articles. Subsequently, each element (Requirement, Applicability, Selection, Exception) was detailed to identify the data type (alphanumeric, numeric, boolean), the comparison operators (e.g., ≤, ≥, =), the value (e.g., float number, integer number, classification) to be compared and the unit of measurement (e.g., m, m2, m3), if necessary [7]. The doubts that emerged from the analysis were resolved in dedicated meetings involving the municipalities.

- Definition of conceptual models: the analysis of the regulations in the previous step was preliminary to the identification of information requirements for the preparation of the building and city models. These requirements were then represented in the form of a conceptual model using the Unified Modelling Language (UML) [8].
- Validation: the conceptual models representing the identified information requirements were validated by experts, such as municipal officials and planners and regulatory bodies.
- Comparison of results: the conceptual models and information requirements of the municipalities were compared with each other to highlight any needs for flexibility and scalability of the results obtained.

The controls relevant to building permits that emerged from the analysis can be divided into 5 sections: (1) urban indices, (2) distances, (3) parking standards, (4) building space requirements for usability and, finally, (5) accessibility. The priority that emerged during the meetings with the municipalities relates to issues on the interaction between the building and its context. Therefore, the methodology was validated on the building indexes of the parcels and the maximum building height, two issues related to section (1), on distances (between existing building-building subject of the building permit; building and street; building and parcel boundary and balcony and parcel boundary), section (2) and finally on the minimum area of spaces and dwellings, related to section (3). 80 normative sentences were analysed as follows: 32 normative articles for Ascoli Piceno, 14 normative articles for Vila Nova de Gaia, 17 normative articles for Lisbon and, finally, 17 normative articles for Prague.

In the case of distance, 38 entities were identified, of which 21 related to the 3Dcitymodel and 17 related to the BIM model, objects necessary for verification. A total of 44 attributes were identified for 3Dcitymodel entities and 29 attributes for BIM model entities were identified. This attributes will need to be included in the information model and control rules. The attribute that characterises each entity is the ID code, an alphanumeric attribute that allows the entity to be uniquely identified. In addition to this, there are boolean attributes (e.g., 'is external' for walls), alphanumeric attributes derived from a code list (e.g., 'intended use' for spaces) and numeric attributes (e.g., 'height' for building).

The development of the CHEK list of regulations and the interpretation of the first sets of regulations were the first steps towards defining a methodology and framework for assessing the overall body of regulations of the municipalities according to the automation potential of the regulations (i.e., how automated the control of a regulation can be) and the preparation of the regulations for formalisation (i.e., how much information can be extracted from the regulations). By comparing the results obtained in four municipalities differing in location and size, it was possible to analyse the scalability of the approach, assessing similarities and differences, as well as proposing recommendations for the drafting of effective and unambiguous regulations. Although the municipalities work on different scales (number of inhabitants), the regulations are very similar, in fact, they regulate the same urban planning and building issues. The ambiguities that emerged relate both to the words chosen for writing the regulations and to the identification of construction elements, as they are not adequately detailed in the regulatory articles. An example of ambiguity for the municipality of Prague case, Annex 1 – Chapter 2 of building

regulations [9] “The spacing angle is fulfilled if no obstacle infringes upon the open space demarcated above a vertical angle of 45°”. The word “obstacle” means any object interfering with the building view, such as a wall, a column, a ground etc. However, it could be not obvious to understand it for someone who is external to the municipality practice. The interpretation process required significant input from civil servants to resolve ambiguities due to, for example, references to other legal texts, or tacit knowledge difficult to interpret by those who do not work with the process on a daily basis. Furthermore, it proved essential to interpret not only the selected normative phrases, but also the definitions contained in building regulations and other normative texts. All this was made even more complicated by the need to translate the regulatory references of the four municipalities from three European countries and thus three different languages into English, in order to be able to compare the results obtained, for an evaluation of the scalability of the method and the proposed solutions. The translation into English, although performed with European tools [10], resulted in errors and consequently incorrect analyses of the normative article, which was later resolved by discussion with municipal officials. The analysis of building regulations in the original language would avoid this problem, although in some cases the need for translation could force the definition of specific meanings for some of the terms used in the regulation.

In conclusion, the current results show how, despite the fascinating narrative of automated technical solutions, the obstacles to be faced and overcome involve understanding many multifaceted meanings. The work led to the identification of the entities and their attributes that must be present in the model submitted for the building permit. After a standardisation of the data in neutral formats, it will be possible to verify the compliance of the information model with the regulations. The research developed shows some limitations in terms of potential scalability of results, due to so high diversity, at this stage. The case studies are location- and regulation-specific, for example. However, the type of problems found is an example generally applicable to the whole building permit use case. To extend the analysis to a larger number of regulations among those indicated as relevant for the BP release, other types of controls be considered, for example the accessibility. This research shows the need for a comprehensive and systematic approach to the analysis of regulations to identify the actual level of information needs for the digital building permit use case. It also means understanding how a consolidated approach to the methodology that emerged from this research can be implemented in practice to enable each municipality to effectively define its own set of standards and related information requirements.

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