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DIGITAL BUILDING PERMIT: A STATE OF PLAY

I EUnet4DBP International workshop on Digital Building Permit

Organized by:
EUnet4DBP - EuroSDR - buildingSMART - EU-BIM

March 25th - 26th 2021 – Online Conference

Editors: Francesca Noardo, Giada Malacarne

Workshop Report

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Francesca Noardo, Giada Malacarne

“Digital Building Permit: a State of Play”

I EUnet4DBP International workshop on Digital Building Permit

Table of contents

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EUnet4DBP - EuroSDR - buildingSMART - EU-BIM

March 25th -26th 2021, On-Line Conference

Report and Abstracts

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Abstract

The digitalization and automation of building permit issuing processes are current interest of a huge and diverse community, including academia, municipalities, building designers, software developers and many other stakeholders that need to collaborate to find proper solutions. For this reason and with such a goal, the European network for digital building permit (EUnet4DBP) was initiated. On the 25th and 26th March 2021, a workshop was organized by the EUnet4DBP, together with EuroSDR, buildingSMART and the EU-BIM task group. The goal of the event was to gather presentations about some relevant works on the topic, as a ground of discussion for an international, intersectoral and multidisciplinary audience to raise awareness about the state of the art, relevant pilots and lead experiments, but also about the common challenges and current state of practice. Such a knowledge exchange is expected to lay the basis for the future developments.

In this report, after an introduction to the topic and the EUnet4DBP, the abstracts related to the presentations are collected. The highlights about lessons learnt and take-home messages are summarized in the end.

1 INTRODUCTION

1.1 Digital building permitting

Digitalization is an on-going process in many fields, including Architecture, Engineering and Construction (AEC). The ISO 19650 standards were developed in line with such a goal in order to guide the organization and management of digital information about buildings and infrastructure works. This would enable several advantages, among which the optimization of information and communication, information exchange and re-use. As a direct consequence, the design and construction processes would improve, as well as the use and monitoring of resources at a more central level, that would imply many virtuous effects.

Related to this change, the digitalization towards automation of the building permit process is a raising interest, intended to accelerate compliance checking, optimize resources and provide more objective checks, with advantage to the quality of the built environment and the city (e.g. Eastman et al., 2009; Lee et al., 2016, Noardo et al., 2020, Directive 2014/24/EU of the European Parliament and of the Council on public procurement.).

A building permit is the final authorisation, granted by public authorities, that gives permission to start the construction phase of a building project. The permit is part of a process of town planning with the aim of guaranteeing a sustainable and controlled development, benefiting communities, environment and economy (DCLG, 2015).

The issuing of a building permit is very complex: consists of several steps, a great number of stakeholders are involved, using many pieces of information. Moreover, in practice, the involved procedures and data are very heterogeneous and, in most cases relatively informal – e.g. decisions depend on the local knowledge and expertise of individuals. Addressing the several parts in a common framework is essential.

1.2 The EUnet4DBP

In order to address such a complexity, a number of researchers, stakeholders and organisations recently acknowledged the need to form a wider and more articulated international network, with strong components of intersectoral and interdisciplinary collaborations. Therefore, the European Network for Digital Building Permit (EUnet4DBP)[1] was initiated at the beginning of 2020.

The objective of the network is the definition of a common strategy to develop digital building permits tools and methods in a common effort, to be largely implemented and that support an interoperable environment for advantage of each part of the workflow (from the provision of information supporting a suitable building design, to the validation of the informative content by the municipality).

Its mission is to accelerate the digital transformation of the building permit process, within a vision towards the development of flexible, scalable and re-usable digital and automatic solutions by means of a common effort and under the umbrella of an open science framework, by sharing experiences and building-up knowledge.

In order for this to be effective, the objectives and activities need to address three main pillars, according to which the sessions of the workshop were designed:

1) *Process* - Including human practices and bureaucratical workflows to be taken into account and likely changed to adopt the new digital approach.

[1] https://3d.bk.tudelft.nl/projects/eunet4dbp/

2) *Rules and requirements* - As formulation of criteria and guidelines to be followed for the successful achievement of the objectives in all the steps and aspects of the use case, including rule interpretation and model preparation.
3) *Technology* - Regarding any aspect related and allowing the successful implementation of the previous ones.

In line with these, the three main goals of the network are formulated[2]:

Goal 1) Support the building permit process in becoming more efficient and automated.

Goal 2) Support to rule interpretation and information requirements in becoming as simple and as machine readable as possible in order to guarantee a certain level of automation.

Goal 3) Support the wide adoption of interoperable technologies based on open standards.

At the present status, several kinds of institutions and stakeholders coming from 18 different countries, converge within the network[3], including the research field, as both universities and other kinds of research centres; governmental institutions, related to ministries, municipalities and other public organisations, such as many National Mapping and Cadastral Agencies (NMCAs); and private companies and professionals, as BIM and construction counsellors and agencies, designers, software companies.

Multidisciplinary component is also a key of the network, because it's extremely relevant to involve several kinds of expertise to properly address the converging components of the topic with suitable skills and awareness. Therefore, the covered fields at the moment range from AEC, BIM, planning and regulations, to software development, geoinformation, geographical information systems and 3D city models, standardization and integration of 3D spatial data (GeoBIM).

In addition, three international organisations support the network: the EuroSDR, buildingSMART regulatory room and the EU-BIM task group. Their scopes and interests are wider than the digitalization of building permit, but all of them intersect with the EUnet4DBP scope, bringing an increased value derived from a wider coordination with related international organizations.

At the moment, the only rule to be part of the network is about the acceptance of its principles and commitments, which are intended to push towards fruitful and fair collaboration towards the common goals:

- *Commitment to share* - We share our knowledge, our experiences, our ideas with the other members of the network in order to turn our Vision into reality.
- *Commitment to openness* - We support the development of open formats, open standards and interoperable software. Our deliverables are open access resources, are published in open channels and all are freely to use them.
- *Commitment to be collaborative* - We voluntarily collaborate with others to grow the network impacts on the digital transformation of the built environment.
- *Commitment to be ethic* - We work together in a fair environment, giving credits correctly to single participants and to the network, and keeping as confidential any un-published shared material.
- *Commitment to be practical* - We develop tools and methods that address the real needs of current and future users.
- *Commitment to be innovative* - We believe in innovation as the only way to improve the quality of our present and future challenges. We aim at providing innovative solution of an innovative word.
- *Commitment to be competent* - We lead activities that require our competences.

[2] https://3d.bk.tudelft.nl/projects/eunet4dbp/about.html

[3] https://3d.bk.tudelft.nl/projects/eunet4dbp/network.html

1.3 The I EUnet4DBP international workshop on digital building permit

As one of the activities of the EUnet4DBP regards the dissemination and sharing of on-going works and projects about the topic of building permit compliance, a workshop event[4] was organized on the 25th and 26th March 2021, entirely held via a digital platform (airmeet.com).

The stated purposes were: to meet an intersectoral and multidisciplinary audience and not-only-scientific committee dealing with the digital building permit topic; present and describe valuable work about the digital building permit; getting and exchange constructive feedbacks from the reviewers and the audience.

An attempt made during this event was about gathering several kinds of contributions, including academic research, but without neglecting available implemented tools and current on-going projects, pilots, case studies and experiences relevant although without being developed within a scientific framework.

For this reason, several kinds of submissions were allowed, which were all reviewed by peers and received feedback and a different time-slot based on kind of work to be presented. First category (A) is 'study', including academic research, reports of completed projects and reviews about states of the art. Category B is about 'implementations', that can be either tools developed by companies, or proof of concepts and demonstrators resulting from different kinds of projects. Both initial implementations and complete working tools in a real-world environment could be represented within this category. Finally, any other on-going project, pilots and stories were welcome as a type C presentation, without the need of presenting complete works, documents and access to tools (that needed to be linked to the other submissions, instead) but only a more general short abstract. This system allowed to gather the outcomes coming from several sectors and disciplines in an effective way.

The presented works were reviewed by components of the not-only-scientific committee, in order to offer different perspectives and differentiated feedbacks with respect both to disciplinary aspects and application fields.

The event was a quite good success, with around 70 people participating each day, coming from several countries (in random order: Norway, Italy, Denmark, Spain, Germany, Belgium, The Netherlands, United Arab Emirates, Switzerland, Portugal, Finland, Turkey, Slovenia, United Kingdom, Sweden, Czechia, Latvia, Luxembourg, France, North Macedonia, Estonia, Lithuania, Croatia) and several visualizations of the videos streamed (and now stored) via youtube (see the links in the programme below).

In this report, the presented abstracts are collected, grouped according to the three network's pillars, as presented in the sessions. The links to the presented slides and to the youtube recordings are available.

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DCLG – Department for Communities and Local Government, 2015. Plain English Guide to the Planning System.

Eastman, J., Lee, Y., Jeong, L. Lee, 2009. Automatic rule-based checking of building designs, Autom. Constr., 18(8),1011–1033.

Lee, H., Lee, J.K., Park, S., Kim, I., 2016. Translating building legislation into a computer-executable format for evaluating building permit requirements, Automation in Construction. 71, 49–61. https://doi.org/10.1016/j.autcon.2016.04.008.

Noardo, F., Malacarne, G., Mastrolembo Ventura, S., Tagliabue, L. C., Ciribini, A. L. C., Ellul, C., Guler, D., Harrie, L., Senger, L., Waha, A., and Stoter, J.: integrating expertises and ambitions for data-driven digital building permits – the EUnet4DBP, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIV-4/W1-2020, 103–110, https://doi.org/10.5194/isprs-archives-XLIV-4-W1-2020-103-2020, 2020.

[4] https://3d.bk.tudelft.nl/projects/eunet4dbp/events.html#i-eunet4dbp-international-workshop-on-digital-building-permit

1.3.1 Organizing committee

- Francesca Noardo (Delft University of Technology, the Netherlands)
- Giada Malacarne (Fraunhofer, Italy)
- Miguel Azenha (University of Minho, Portugal)
- IJsbrand van Straalen (TNO, the Netherlands)
- Dogus Guler (Istanbul Technical University, Turkey)
- Lars Harrie (Lund University, Sweden)
- Fulvio Re Cecconi (Politecnico di Milano, Italy)
- Jernej Tekavec (University of Ljubljana, Slovenia)
- Alain Waha (Cogital, Burohapphold, United Kingdom)
- André Vonthron (Ruhr-University Bochum, Germany)

1.3.2 Not-only Scientific committee

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- Dogus Guler (Istanbul Technical University, Turkey)
- Lars Harrie (Lund University, Sweden)
- Fulvio Re Cecconi (Politecnico di Milano, Italy)
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- Jaan Saar (Estonian Ministry of Economic Affairs and Communications, Estonia)
- Gregorio Saura (SIA Architects, Belgium)
- Lennart Senger (Institute of Construction Management and Digital Engineering at the Leibniz Universität Hannover, Germany)
- Trajche Stojanov (ZWEI Consulting / SEMOS Education, North Macedonia)
- Stepanka Tomanova (Czech standardization agency, Czech Republic)
- Ophélie Vincendon (Etat de Genève, Switzerland)
- Thorsten Walter (Ministry of urban Development and housing – Hamburg, Germany)

1.3.3 Programme

25th March 2021 (CET)

8.30-9.00 – The platform is open and the network lounge accessible

9.00 - 9.30 – **Welcome and introduction**
chair: Francesca Noardo *youtube streaming*

9.00 - 9.05 *Francesca Noardo* - Intro/welcome
9.05 - 9.10 *Giada Malacarne* - EUnet4DBP ambitions and requirements
9.10 - 9.15 *Jantien Stoter* - The EuroSDR and its role in the EUnet4DBP
9.15 - 9.20 *Angelo Ciribini* - The EUnet4DBP and the European BIM Scenario
9.20 - 9.25 *Nicholas Nisbet* - buildingSMART and its role in the EUnet4DBP

9.35 - 10.30 – **Session 1: Empowerment of public officers**
chair: Miguel Azenha *youtube streaming*

9.35 - 9.55 *Eilif Hjelseth* - Hidden challenges in development of digital solutions for processing of building regulations
9.55 - 10.15 *Lennart Senger* - Development of an implementation strategy for municipalities to enhance computerized building permits
10.15 - 10.30 *Giada Malacarne* - Digital Building Permit Maturity Model: towards a GeoBIM integration

10.30 -10.45 – Coffee break

10.45 - 11.15 – **Keynote 1**
Andrea Fronk (Bimfactory Srl) - The challenges of Digital Building Permits *youtube streaming*

11.15 - 12.15 – **Session 2a - International experiences with digital building permit**
chair: IJsbrand van Straalen *youtube streaming*

11.15 - 11.35 *Ophélie Vincendon* - Digital Building Permit in the State of Geneva
11.35 - 11.55 *Ali Ismail* - Dubai BIM e-Submission Platform
11.55 - 12.15 *Christopher-Robin Raitviir* - BIM-based building permit developments in Estonia

12.15-13.00 – Lunch

13.00 - 13.30 – **Session 2b - International experiences with digital building permit**
chair: Francesca Noardo *youtube streaming*

13.00 - 13.15 *José Granja* - Concept for process towards automated building permits in Portugal
13.15 - 13.30 *Lars Harrie* - Exchange of digital information in the building permission process in Sweden – some previous and possible future studies

13.35-14.10 – **Session 3a - Process 1 –**
chair: Dogus Guler *youtube streaming*

13.35-13.50 *Manuel Garramone* - Analysis of the digital building permit requirements inside a BIM environment
13.50-14.05 *Giada Malacarne* - Combining BIM and GIS for the digitalization of the building permit process in small municipalities: the GEOBIMM project
14.05-14.25 *Judith Fauth* - About determination of building permitability

14.25-14.40 – Coffee break

14.40-15.35 – **Session 3b - Process 2**

chair: Lars Harrie *youtube streaming*

14.40-14.55 *Silvia Costa* - Digital Building Permit and Small Sized Local Authorities in Italy
14.55-15.15 *Dogus Guler* - A Workflow Containing Digital Building Permit for Turkey
15.15-15.35 *Giada Malacarne* - BIM for public authorities: Basic research for the standardized implementation of BIM in the building permit process

15.35-15.55 – **Interactive activity about maturity model - process**

chair: Giada Malacarne

15.55-16.00 – **Closing**

chair: Francesca Noardo

16.00-16.30 – Speed networking in the lounge

16.30-17.00 – The network lounge will remain open.

26th March 2021 CET

8.30-9.00 – The platform is open and the network lounge accessible

9.00-9.05 **Welcome and introduction**

chair: Francesca Noardo *youtube streaming*

9.05-10.15 – **Session 4 - Rules and requirements**

chair: Fulvio Re Cecconi

9.05-9.20 *André Vonthron* - Integration of Building Information Modelling into the process of building permits in Germany
9.20-9.35 *Nicholas Nisbet* - Normative, Definitive and Descriptive Knowledge
9.35-9.50 *Beidi Li* - The need for an integrating approach for developing digital building permit solutions
9.50-10.10 *Beidi Li* - A reasoning-based approach for checking performance-based codes in digital building permit processes

10.10-10.30 – **Interactive activity maturity model - Rules and requirements**

chair: Giada Malacarne

10.30-10.40 – Coffee break

10.40-12.30 – **Session 5 – Technology**

chair: Jernej Tekavec *youtube streaming*

10.40-11.00 *Francesca Noardo* - GeoBIM for the digitalization of building permit checks.
11.00-11.25 *Marco Rognoni* - Automated Code Checking in the Epermit BIM Process
11.25-11.45 *Matteo Mandrile* - BIM as multiscale facilitator for built environment analysis
11.45-12.10 *Ijsbrand van Straalen* - Development of a New Eco System for Automatic Code Checking based on BIM Bots Technology
12.10-12.25 *Franco Coin* - OpenBIM and DBP – the state of the art and future projects

12.25-12.45 – **Interactive activity maturity model - Technology**

chair: Giada Malacarne

12.45-13.30 – Lunch

13.30-14.30 – Panel session “protech disruption – the evolving context for Digital Permitting”
chair: Alain Waha *youtube streaming*

Panelists: Paul Oesten-Creasy (VU City) - Greg Demchak (Bentley Digital InnovationLab)

14.30-15.15 – **Concluding remarks**
chair: Francesca Noardo

14.30-14.45 *Giada Malacarne* - Results from interactive activites on maturity models
14.45-15.00 Closing

15.00-16.00 – The network lounge will remain open.

2 WORKSHOP CONTRIBUTIONS

2.1 Keynote

The challenges of Digital Building Permit

Andrea Fronk
Bimfactory Srl, Milan, Italy, Via Franco Russoli 6 - 20143, andrea.fronk@bimfactory.it

1 State of Art in Italy

The Construction sector is rapidly changing, in Italy and abroad; a digital transition scenario will involve all the stakeholders in the supply chain, from Clients to Facility Managers, Designers and Contractors. The actors who want to follow a strategic development, remaining protagonists in a sector strongly renovated, they will have to undertake a journey of renewal of business processes in a digital logic. The "Digital Prototype" will become a disrupter in every phase, from design to realization and lifecycle management.

In Italy, the Government has focused the topic and it has published regulamentations (D.M. n. 560/2017) and codes to make digitization mandatory. Since 2019 a Building Information Modeling (BIM) methodology is requested for all the complex works over 100 milions €. Starting from 2025, BIM will be mandatory for every kind of public work. The Public Administration is going to re-skilling staffs and acquiring retention plan for hardwares and softwares, but they are experiencing several problems.

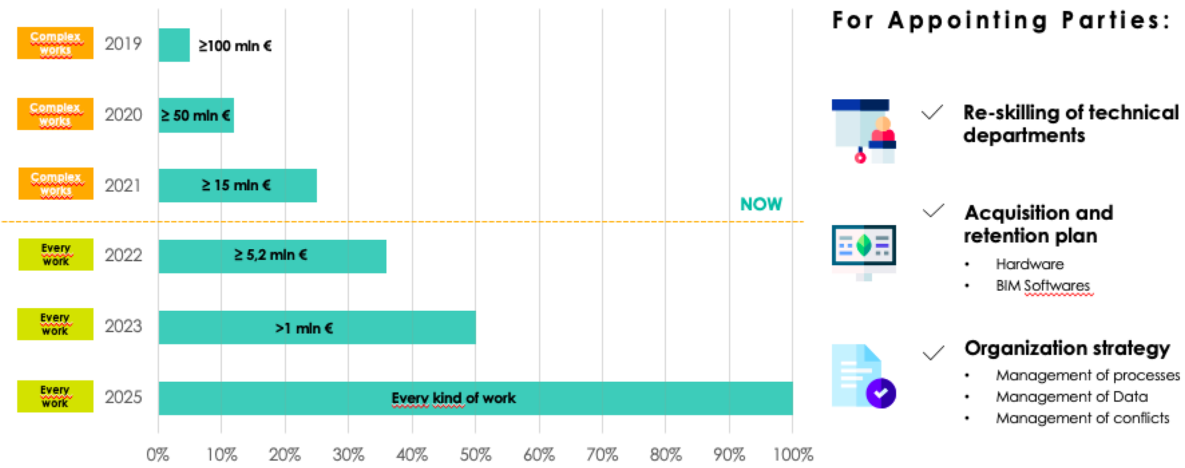

Figure 1. BIM in Public Sector

2 Critical Topics

First of all, the Public Administration is characterized by a fragmented ecosystem: in Italy, we have more than 5.500 small municipalities[1] (less than 5.000 people), which have different regulations and codes from each other (for example: air/light relation, buildable area…). Focusing on innovation targets, not always small and medium municipalities are ready for BIM and digital in general, because of the age of the staff and the cost of investment. Another critical topic is the digital culture of the Public Administration, focused on the virtualization of traditional workflows instead of re-design of processes. At the moment, a designer who wants to publish a Building Permit must analyze different regulations for every municipality, obtain information through non-structured data and communicate with the Public Administration in different channels, increasing the risk of loss in information.

Recently, the communication between Administration and citizens was re-designed with the adoption of digital platforms, but they are not able to solve completely the problem of communication. Every platform is designed as an answer to a specific task or function, so the user must publish the same

[1] http://www.anci.it/atlante-dei-piccoli-comuni/, Accessed 09 March 2021

information or data several times, spending a lot of time in low-value activities and generating possible mistakes. A Common Data Environment could facilitate the communications among the stakeholders, reducing the waste of time and mitigating the risk of loss of information creating a real accessible repository for all the data, documentation and information part of the public property.

3 Documentation vs Model

Although BIM and digital metodologies are mandatory for several works, the documentation on paper has to be considered legally binded more than data models. It means that designers are generating and submitting digital models, but their projects are evaluated on traditional 2D documentation. They are adding value to the process, but at the moment of the submission this added value is lost, spending a lot of time in editing of drawings or traditional demonstrations on calculations or cost quantification. In this process, the project contains structured data that will be de-structured during the submission, losing the main part of the added value. Considering BIM models as data-containers, the ability of Administration to obtain data and information by models could be an incredible step forward to align the scopes of public authorities and designers.

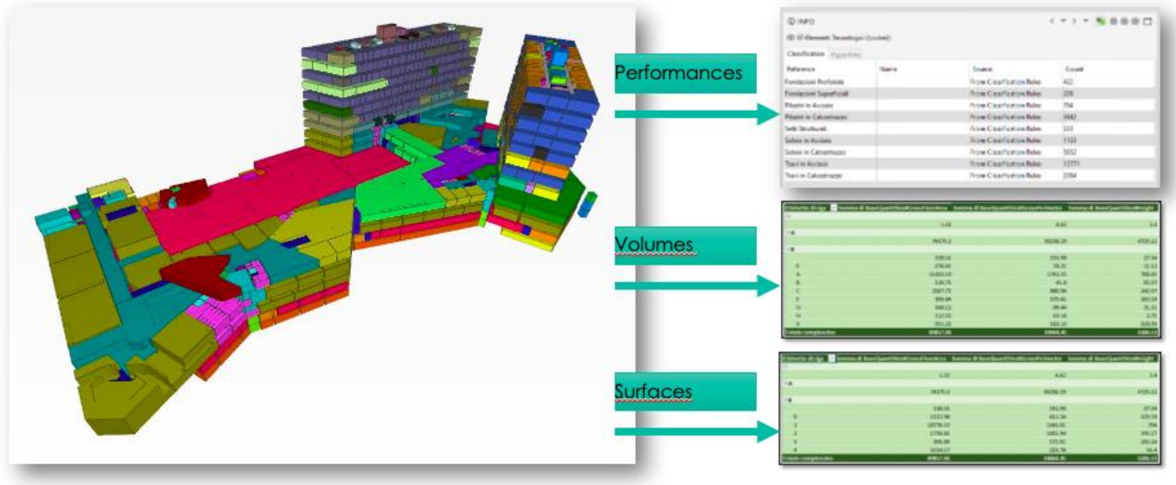

Figure 2. Digital query for project information

4 Validation of Data

The evaluation of the projects is linked to another important aspect, that is the validation of the project. The BIM tools are able not only to generate structured data, but also to automatize the process of checking. For example, it is possible to create automatic rulesets to find possible clashes with existing buildings (clash detection) or to check specific normative aspects (for example, minimum surfaces requested, volumes, height of the rooms, distances…). To support the designers to monitor these aspects, it is expected that Public Administration could publish common standards for the generation of data, sharing appropriate documentation as Information Requirements or Information Handbooks, according to an implementation of open standards as Industry Foundation Classes (IFC) by buildingSMART[2].

LINKS TO RELEVANT RESOURCES

OICE, Rapporto sulle gare BIM 2020 per opere pubbliche – Report 2020, Rome, February 2021, https://www.oice.it/688247/presentato-il-4-report-oice-sulle-gare-bim-2020-che-aumentano-del-17-e-rappresentano-l-8-7-del-totale-delle-gare

Assobim, BIM Report 2020, Turin, November 2020, https://www.assobim.it/pubblicato-il-bim-report-2020/

[2] https://www.buildingsmart.org/, Accessed 10 March 2021

2.2 Session 1 – Empowerment of public officers

Development of an implementation strategy for municipalities to enhance computerized building permits

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1 Targets

Digitalization is the most important process of change and affects all areas of our society in this century. In many economic sectors, digitization has already led to whole new processes and applications. In the construction and architectural industry these changes are still ongoing and are characterized by complex interactions and data management. Especially in the area of governmental points of interaction such as granting building permissions, analogue procedures and work methods are still widespread. This often affects all areas of interest from communication with builders or other stakeholders, plausibility and approval checks, file management and archiving. Furthermore, all process participants require both technical equipment (software, hardware, networks) as well as well trained personnel. In order to foster these processes, last but not least an open mindset for new forms of work and communication within organizations are as important as legal frameworks.

Digital methods, in particular Building Information Modeling (BIM), are increasingly being used in design phases and also in operations, yet only poorly in the areas of responsibility of the states and even less in the field of building permits. With the Onlinezugangsgesetz (OZG), the federal government has issued a directive to digitize all public administration services nationwide. This includes also services in the AEC sector and thus building permits. It has to be taken in account that the federal structure of Germany divides the country into 16 independent building supervisions. Each state respectively supervision area is further broken down into up to over 100 municipalities with specific regulations and aggravates a nationwide rollout such as in Estonia other countries. It has also led to a vast number of existing regulations, beginning with 16 different building codes and additionally regional regulations. This contradicts the approach and aims of standardization and harmonization, which are fundamental parts of the method building information modeling. Last but not least planning offices often not only provide their services in one region, so their personnel and their work has to follow and fulfill various regulations. Looking e.g. at the area of Bremen and Hamburg, three different state building Codes (Bremen, Hamburg and Lower-Saxony) and additional regulations have to be followed within a 120km radius.

Research at the Institute of Construction Management and Digital Engineering (ICoM) at Leibniz University Hannover investigates the concept for digitally supported building permissions in building supervisions on the municipal level with respect to harmonize the procedures and information requirements within a reference state (Lower-Saxony). The research is supported by three relevant state ministries (building, inner affairs and economics). Nine pilot municipalities participate actively with their building permit departments as well as the mentioned building ministry, being the statewide building supervision and the regulatory anchor.

A key to receive usable and practical results is the strong integration of the users, in this case the municipalities. This also ensures legal certainty in cooperation with the legislator, represented through the building ministry. The concept development includes 5 stages:

2 Methodology

Stage 1: Project development with mentioned stakeholders and a task force from other relevant groups (chamber of architects, chamber of engineers, planning offices, testing and surveying engineers, real estate industry etc.) Identification of main processes and linking to BIM respectively BIM-related data formats XPlanung and XBau, issued by the federal government and mandatory in 2022 (see Figure 1).

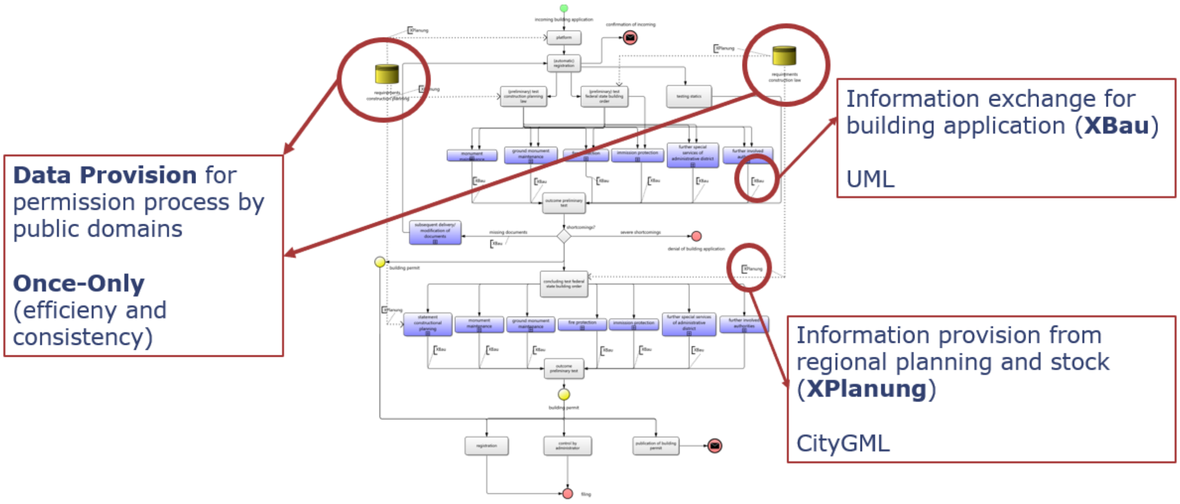

Figure 1. Digital Building Permission Process (BMPN 2.0) with Data Provision and Process Exchange Formats (XBau, XPlanung)

Stage 2: Base estimates and basic training for digital methods and especially BIM for the pilot municipalities. First level targets on digital workflows, machine readable data and 3D modeling. Second level includes model and code checking, linking of workflows and models and consequently digital administration services.

Stage 3: Development of a main concept for a strategic approach with key fields of action (e.g. IT landscape, qualification, regulations etc.) This includes a detailed survey and expert interviews (semi-structured approach) within all pilot municipalities as well as a larger survey within the whole state (all municipal supervisions).

Stage 4: Specification for the fields of action with the project partners. Validation with the partners and other stakeholders (especially the mentioned ones) such as the BIM-Cluster Lower Saxony or the European Network for Digital Building Permits (EUnet4DBP).

Stage 5: Matching with approaches from other states (North Rhine Westphalia, Bavaria etc.) and interface optimization with the central work partner regarding building permits, planning offices etc. Linking the strategy with other strategic approaches, e.g. federal or state building construction and masterplan digitalization.

3 *Status Quo*

Stages 1,2 and 3 have been completed and extensive result reports are available. They can be provided for other states, within the EU4DBP network or other non-commercial approaches.

Stage 4 is in process, including the development of holistic BIM models (buildings, terrain, stock, development plans) as well as setting up model checking in order to grant building permission. A side goal of the work is the setup of a model demonstrator to higher the acceptance of the approach in society, politics and users in general. The demonstrator consists of building models, terrain models and stock models. Open formats (IFC, CityGML etc.) have been used in the setup phase and first code checking has been processed suing model checking software (see Figure 2).

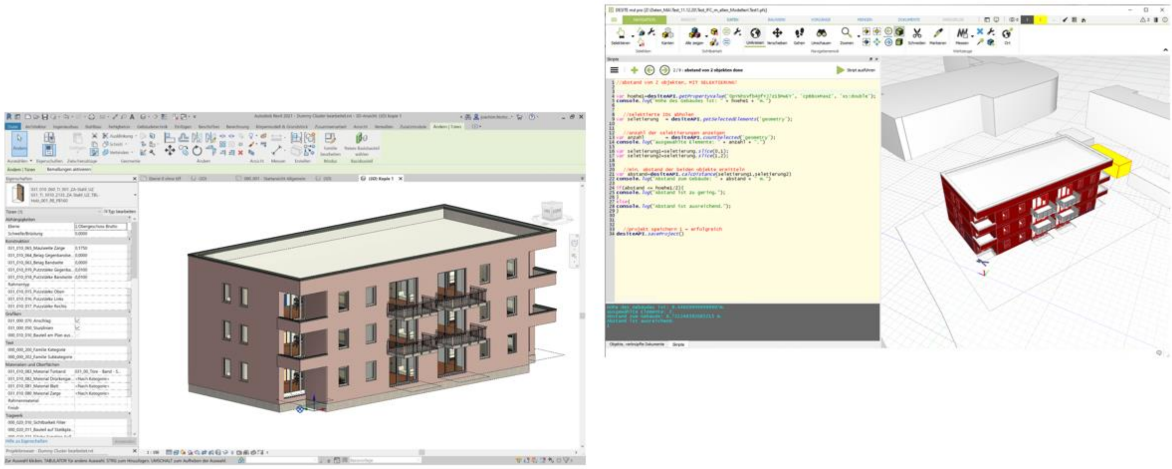

Figure 2. Building Model setup (left) and Code Checking in a holistic environment model (right)

A snapshot in time of the project is the fact that the municipalities do lack the existence of a strategy as well as sparring partners in order to move forward to the next milestone (implementation and use of platforms and model servers to fulfill their tasks in and advanced way. Therefore, measurable maturity levels are developed to compare and track progress. While the first two areas aim on digitalization of use cases in general, the last sections include the use of digital building and environment models in open data formats and paperless progressing.

Levels of Digitalization	0	1	2	3	4	5	6	7	8
Communication internal		x	x	x	x	x	x	x	x
Communication external			x	x	x	x	x	x	x
Submission				x	x	x	x	x	x
Digital Progress Tracking and Archiving					x	x	x	x	x
Digital Processing and Granting						x	x	x	x
Digital Signature							x	x	x
Use of open Formats								x	x
Model-based Work and Model-checking									x

paperless

IFC/GIS/BIM

IFC/GIS/BIM

Figure 3. Maturity Levels of Digitalization in Municipal Building Departments

4 *Expected Outcome*

The Work shall be embedded in a larger context, using building models throughout all life cycle bases, e.g. continuing in construction documentation and building operations. This also addresses the municipalities in their function as operators and planners, e.g. for public schools. The consistent use of building models e.g. for CAFM can be an additional benefit for municipalities.

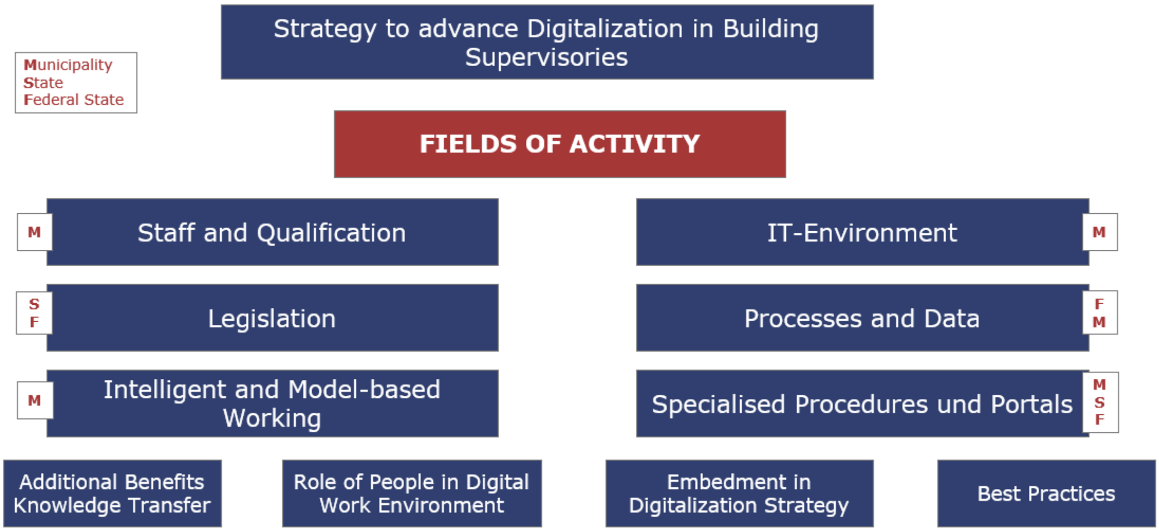

Figure 4. Draft of the Digitalization Strategy with the main fields of activity and relevant stakeholders

As a result, a coordinated concept for implementing digital methods within the municipal supervisions is seeked to shorten the gap between fully analogue procedures to model-based, object-oriented permission granting (see Figure 4). Methods und procedures shall be harmonized not only in between the municipal supervisions in the state, but also in between the states.

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Digital Building Permit Maturity Model: towards a GeoBIM integration

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1 Background and purpose of the presentation

The building permit process is still recognized as a manual, subjective, error-prone, and time-consuming activity that may lead to ambiguity, inconsistency in assessments and delays over the entire construction process (Malsane et al., 2015). For these reasons, its digitalization is seen as a priority in a wide part of the world. In 2020, members from several countries and including expertise in BIM, 3D City Modelling, building regulation, urban planning and software development initiated the European Network for Digital Building Permit – Eunet4DBP. Having defined the network vision for an automated and digital building permit (Noardo et al., 2020), the progress towards such ambition should be measurable, according to a Digital Building Permit Maturity Model (DBPMM). The aim of the DBPMM is to support Municipalities and other public authorities in assessing their level of maturity and in further developing an appropriate roadmap towards a fully digital building permit.

A Digital Building Permit Maturity Model is proposed, starting from the scales suggested by related disciplines and the results of related projects. During the I Eunet4dBP International Workshop the relevance, the accuracy and the clarity of the model has been validated with the attendants of the workshop, collecting feedbacks and identifying improvements for further developments. The results show that although the model is perceived as sufficiently relevant, accurate and clear, further efforts are needed to strengthen the accuracy, and in some parts also the clarity, of the model.

2 Methodology adopted for the development of the DBPMM

The DBPMM considers the Building Information Modelling Maturity Matrix developed by Succar (Succar, 2009) as a reference:

- The Succars´ fields of actions (Policy Field, Process Field, and the Technology Field) are herein replaced with the EUnet4DBP Pillars: Process, Technology, Rules and Requirements.
- The Succars´ Competency Areas are replaced with the list of requirements needed to achieve the EUnet4DBP vision.
- The Succars´ Capabilities stages (pre-BIM, object-based modelling, model-based collaboration, network-based integration, post-BIM) remain and we consider the Digital Building Permit application as part of the post-BIM Capability Stage.
- The Succars´ Maturity Levels (initial, defined, managed, integrated, optimized) are considered as the 5 levels of maturity also when assessing the level of digitalization of a building permit process.

The contents of each Maturity Level for each field of actions and each Competency area are currently proposed according to the authors´ experiences acquired in research projects on the topic. In particular, the following research projects provided knowledge for the definition of each maturity level:

- the “GEOBIMM” project. The project explored the building permit use case in close collaboration with the municipality of Merano (IT).
- the project “GeoBIM for Building Permit in Rotterdam”. The project explored the building permit use case in close collaboration with the municipality of Rotterdam (NL).

Fields of actions	Competency Areas	Level of Maturity					
		0	1	2	3	4	5
		Pre	Initial	Defined	Managed	Integrated	Optimized
PROCESS	Understand the necessary process steps						
	The process steps should contain different spatial and semantic data						
	Alligment at EU level						
	Standardization						
RULES AND REQUIREMENTS	Normative texts should be interpretable						
	Machine readable building codes						
TECHNOLOGY	An inclusiv system at whole level						
	A network platform as a unique repository of data across the whole life cycle						
	Technology for data analysis and visualization						
	Technology for data analysis						

Figure 1. Framework of the DBPMM

3 *Methodology for the evaluation of the DBPMM*

During the I EUnet4DBP International Workshop, held virtually on the 25th-26th March 2021, the DBPMM has been presented and evaluated. Three interactive sessions supported this evaluation process. Each interactive session lasted 20 minutes, during which the participants were asked to evaluate the relevance, the accuracy and the clarity of each part of the DBPMM, answering to a set of questions via the interactive tool Mentimeter[1]. Results of the three interactive sessions were presented during the "Closing and remarks" session at the end of the event.

4 *Results*

Up to date, the DBPMM is a Matrix between the Requirements of each Pillar in the framework of the EUnet4DBP Vision and the levels of maturity reachable for each requirement in the path towards a fully digital and automated building permit process. The definition of each Maturity Level is provided by the authors experiences gained in ongoing and past research projects. The proposed DBPMM has been evaluated by other experts of the sector during the I EUnet4DBP International Workshop. Results show that the DBPMM is perceived as sufficiently relevant, accurate and clear. However, while the relevance of each part of the model seems to be well perceived, to reach a "good" DBPMM, the accuracy of some parts of the model – especially the Process – needs to be improved. Further efforts are also required to improve the clarity of some parts of the model.

[1] www.mentimeter.com

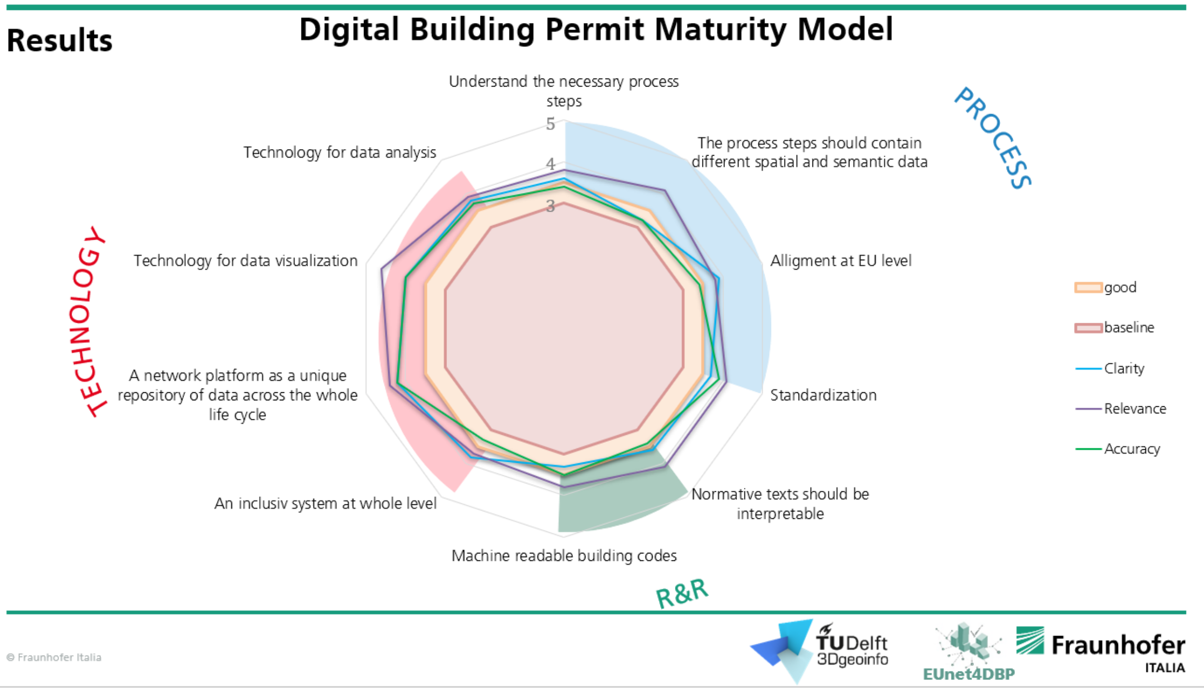

Figure 2. The results of the DBPMM evaluation presented during the “Closing and remarks” session of the I EUnet4DBP International Workshop.

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LINKS TO RELEVANT RESOURCES

DBPMM

https://zenodo.org/record/4630794#.YHAsc-gzZPa Accessed 09th April 2021.

EUnet4DBP Vision

https://3d.bk.tudelft.nl/projects/eunet4dbp/about.html Accessed 09th April 2021.

BIM Maturity Matrix by Succar

scholar.google.it/scholar_url?url=https://www.academia.edu/download/15751034/Building_Information_Modelling_Maturity_Matrix.pdf&hl=it&sa=X&ei=XNABYPOgAr2Dy9YPzo-qqA8&scisig=AAGBfm3mjl6ntqz6Lyw-sFW6DgMtlfJ1ew&nossl=1&oi=scholarr Accessed 09th April 2021.

Related projects

GeoBIM for Building Permit in Rotterdam (tudelft.nl) Accessed 09th April 2021.
GEOBIMM (fraunhofer.it) Accessed 09th April 2021.

The need for an integrating approach for developing digital building permit solutions

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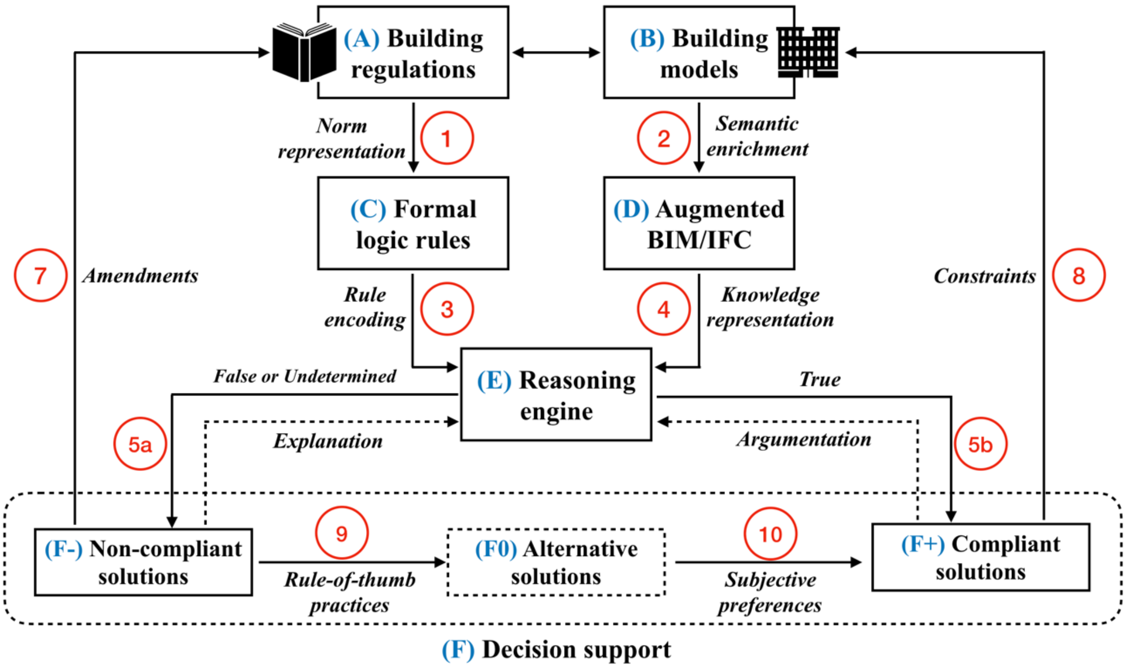
This study addresses the need for more collaboration to achieve an integrating approach for developing Digital Building Permit (DBP) solutions. As the overview developed in this study demonstrates, there are multiple methods – but they need to be integrated to enable a holistic solution.

A typical DBP workflow is presented in Figure 1. Regulation experts translate legislative texts into logical propositions (1), building experts deduce implicit attributes and properties from a building model (2), software programmers apply formalised rules and constraints to derived model parameters (E), and architects and engineers amend, refine, and improve design solutions [1], [2].



Fugure1. An example of DBP workflow, adapted from [3].

Digital Building Permit (DBP) integrates BIM-based code checking engines with decision support systems for:

- assessing the compliance of a building model (B) with respect to numerous, disparate building regulations (A), and
- proposing alternative design solutions while complying with normative and contractual requirements (F).

While a plethora of commercial tools is readily available for automated building code checking (Solibri, ePlanCheck), they rarely provide a uniform way to capture and encode expert knowledge that is needed for checking a natural language code against a large-scale building [4], [5]. As a result, the underlying methods are little accessible and difficult to re-implement, which heavily impedes knowledge sharing and transfer in the development process of DBP solutions.

In our review of existing approaches in BIM-based model checking, we identify the following key challenges in enabling a holistic DBP workflow:

- ***Transparent and traceable rule interpretation***. Ambiguous, domain-specific regulation terms give rise to various competing definitions [6]. Documenting the rationale for adopting a particular interpretation eases a clear division of legal responsibilities [7].
- ***Evidence-based semantic enrichment***. Ontological inferences about a building are contingent to a number of assumptions and hypotheses. Motivating this additional knowledge by research literature and rule-of-thumb practices provide verification and validation possibilities for semantic enrichment.
- ***Modifiable, maintainable rule encoding***. Continuous changes and updates to code provisions require a flexible, modular encoding that does not reply on a single algorithmic procedure which might run extremely fast but is arcane and brittle [8], [9].
- ***Verifiable, defeasible rule execution***. Compliance results are highly dependent on model quality, numerical precision, and subjective interpretations. Logic-based reasoning engines provide a way to explain, object, defeat, and verify rule execution with the best available information [10].
- ***Iterative decision support processes***. Reasoning about fuzzy rules and uncertain information produces inconclusive results, which should be used to improve regulation quality and to supplement physical models with design intentions, constraints, and concerns.

While numerous studies attempt to address above challenges, they are often limited to very specific use cases [11], [12]. Regarding rule encoding (3), building regulations should be interpreted and formalised in an evidence-based, transparent, and verifiable way. We argue that a logic-based reasoning engine with native spatial support will intuitively understand code semantics and intelligently check code compliance [13]. Regarding decision support, design solutions should include the rationales for their compliance (5b). We argue that maintaining these rationales in the form of constraints (8) will enable an integrated product delivery of physical models with design intentions. In the long run, this will enhance DBP with qualitative design principles (9) and architectural preferences (10).

Developing digital building permit solutions is resource and competency demanding process. This study demonstrates the impact of focusing on an integrating approach for developing digital building permit solutions. This requires multidisciplinary collaboration on larger projects aiming for complete and applicable solutions. In this regard the EUnet4DBP network can play an important role.

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2.3 Session 2 – International experiences with digital building permit

[Digital Building Permit in the State of Geneva]

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1 Development and implementation of the BIM-based digital building permit in the State of Geneva

In the Canton of Geneva, the State of Geneva has started its digital transition some time ago.

Two years ago, the State of Geneva launched a digital platform "AC Demat" for the building permits and delivers now around 80% of the building permits in a complete dematerialised way, based on online forms and 2D pdf plans.

At the same time, a BIM approach is in development. This approach concerns all the missions of the State, i.e. the State as a Regulation Authority, the State as a Built Asset Manager and the State as a Territory Manager.

Therefore, the State of Geneva initiated developments and researches on GeoBIM and open BIM standards. The final goal of this project is to have the possibility to submit a BIM project for a building permit. It will cover the whole chain of the building permit process: from the gathering and extraction of territorial data (Geographic Information System, GIS) in BIM format (openBIM standard, IFC) to the automated checking of the BIM model until the delivery of the building permit in BIM.

The first phase in the process is the data structuration: transformation of GIS data into IFC format and structuration of the BIM submission model. The second phase is the BIM data visualisation: integration of the BIM model in a 3D GIS Web scene and development of specific views to analyse a BIM model in a professional angle. The third phase is the data checking: identification of construction regulations translatable into programmable rules and implementation of rulesets for the structuration of a BIM model and for construction regulations checking. The fourth and last phase is the integration inside the global digital building permits platform in Geneva (AC Demat).

It is in the prototype phase now, but will be expanded in the next months and the two years to come, to have an operational system by the end of 2022.

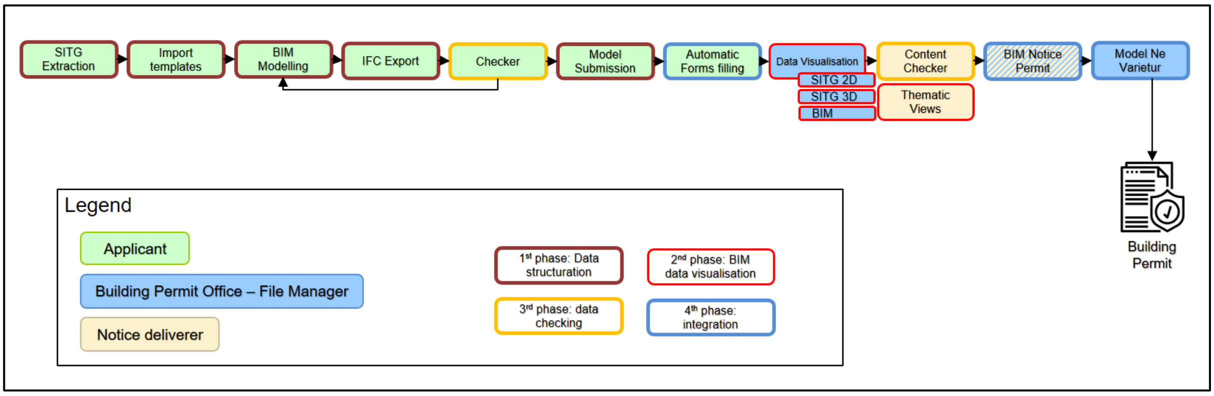

Figure 1. Steps of the building permit process in the State of Geneva

Dubai BIM e-Submission Platform and BIM-GIS integration

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1 Dubai BIM Roadmap project

Dubai BIM Roadmap project was funded and initiated in January 2020 by "Dubai Building Permit Development Committee" and managed by GIS center in Dubai Municipality. The project aims to improve the quality of building permit and GIS services. The main outcomes of this project are: (1) BIM roadmap for the building sector in Dubai, (2) unified BIM submission standards for building permit applications, (3) BIM e-Submission platform with automated code compliance checking engine and (4) Migration of building models into GIS.

Figure 1. Dubai BIM roadmap project, scope and stakeholders

2 State of building permit maturity in Dubai

United Arab Emirates represented by Dubai has consistently ranked by the World Bank report for Ease of doing business regarding the dealing with construction permit in the Top 5 in the last five years and in the third position worldwide in 2020[1]. The current permit system uses digital drawings and the review process is manual. With BIM adoption and integration with GIS services, the new e-Submission platform will allow summitting geo-located BIM models and enable partially automated review.

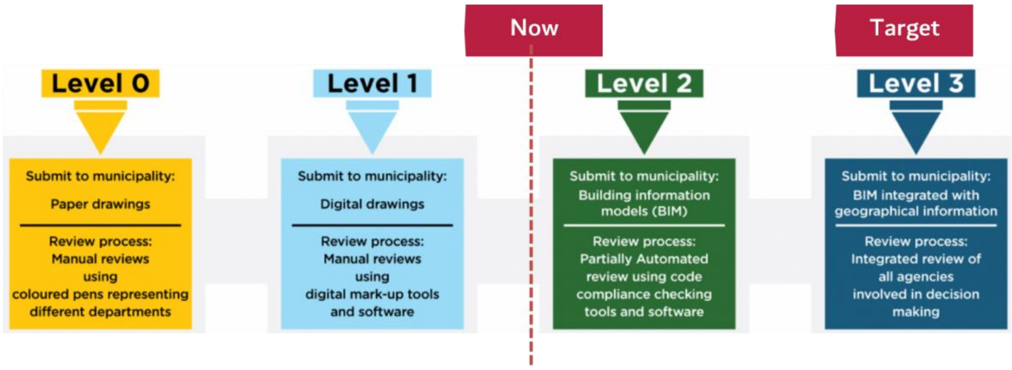

Figure 2. State and vision of building permit in Dubai

[1] https://www.doingbusiness.org/en/rankings

3 Dubai Digital Twin

GIS Center in Dubai Municipality aims to provide a digital twin of Dubai in the form of two-dimensional and three-dimensional maps containing all assets, structures and features, starting from the macro level of the land parcels master plans and reaching down to the micro level of building's unit level details. This digital replica provides all the information needed to plan and manage the Emirate and allows the government provides smart services.

The integration between submitted CAD and BIM models for building permit and GIS databases is very essential to achieve this target.

4 Dubai BIM e-Submission platform

Dubai BIM e-Submission platform[2] is based on Open BIM standards (IFC, BCF) and include various modules like: (1) user and project management, (2) online BIM viewer, (3) Code checking rules, (4) Issue management and (5) BIM-GIS conversion.

4.1 Workflow

Figure 3 shows a simplified workflow for pre-construction phase, which includes submission as IFC models, self-check of design rules by consultant, GIS and NOCs integration, export violations as BCF, building information extraction, and convert final design to GIS. For the construction phase, it includes in addition: updating construction progress by contractor, support VR, completion certificate and convert as-built BIM models to GIS.

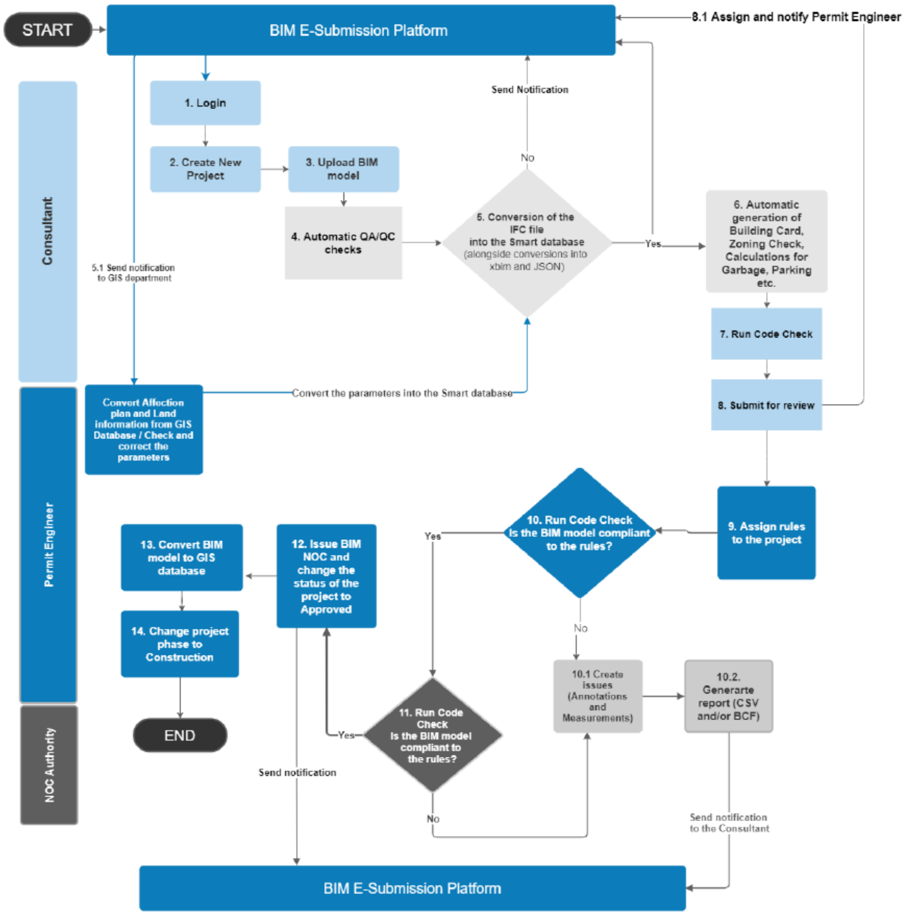

Figure 3. BIM based building permit workflow for pre-construction phase.

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[2] https://bim.geodubai.ae

4.2 Automatic code compliance checking

Dubai BIM e-Submission platform includes a powerful automated code compliance-checking engine with a user-friendly interface to add new rules by end users. The engine supports following kinds of rules:

- Attribute rules: to check any alphanumerical information attached to BIM objects
- Ratio rules: it adds the possibility to check ratios of two groups of filtered objects
- Geometry rules: to check geometry conditions (intersects, within distance of, etc.)
- SQL rules: to execute complex database queries which cannot be achieved through the user-friendly interface

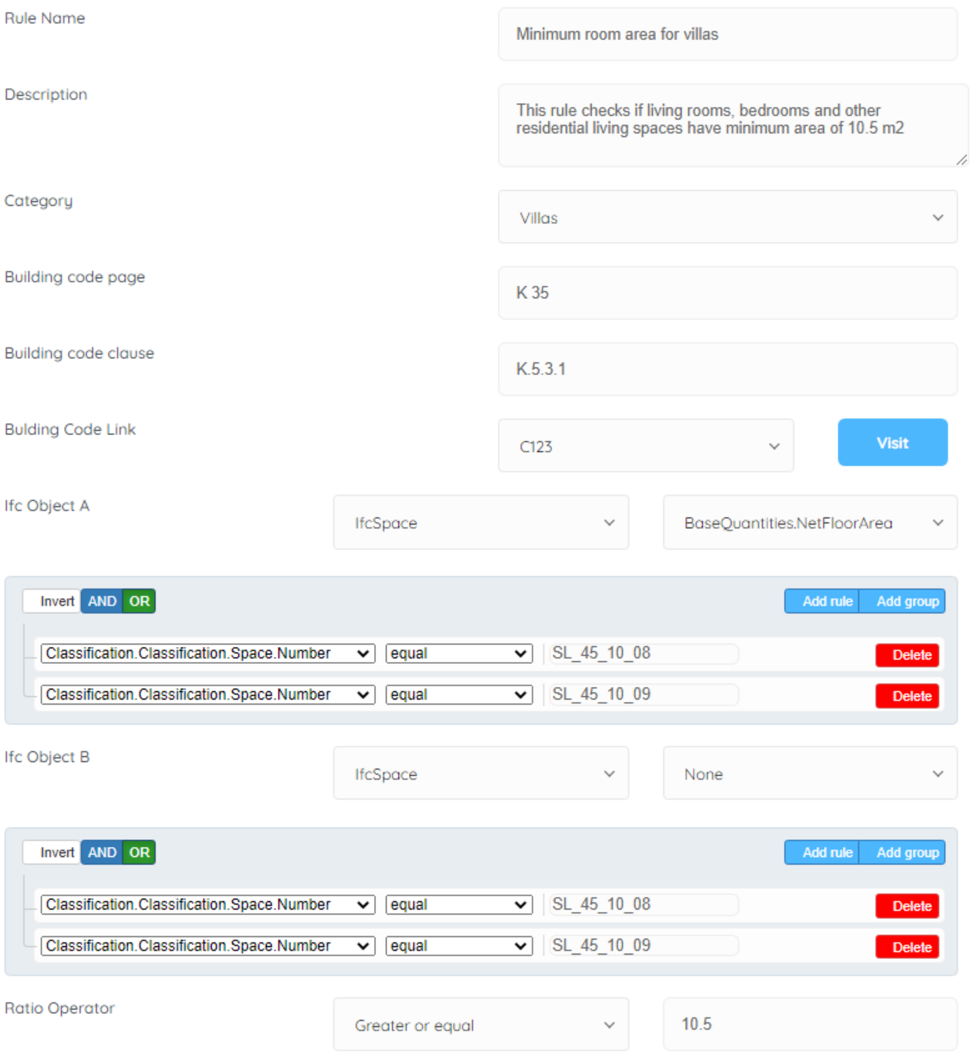

Figure 4. Example of ratio rule to check minimum room area.

4.3 BIM to GIS

Submitted BIM models in IFC format can be converted to a special 3D building GIS data model in order to embed building information with simplified 3D representation into GIS database.

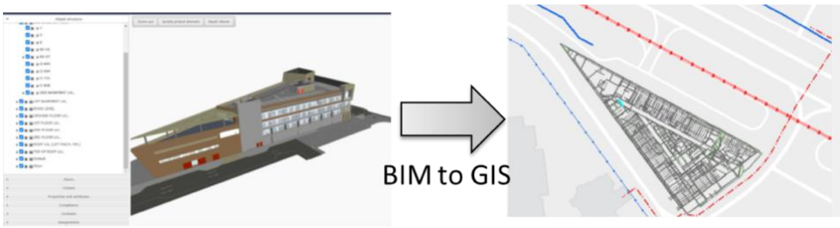

Figure 5. Example of BIM to GIS conversion.

BIM-based building permit developments in Estonia

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1 *BIM-based building permit software development project*

The aim of the project is to develop the software solution for BIM-based building permit processes in the Estonian Building Registry (EHR). The solution will enable the analysis of BIM models in IFC format based on today's best BIM practices and be able carry out automated building code checks.

The result of this software development project will simplify the permitting process by making it possible to submit BIM projects for building permits directly, without first converting them to "digital paper" (PDF). The BIM-based permit procedure makes it possible to shorten the building permit processing time by automating the technical inspection of construction designs. A more efficient building permit process will also increase the productivity of the AEC industry which is one of the key objectives of the Ministry of Economic Affairs and Communications.[1]

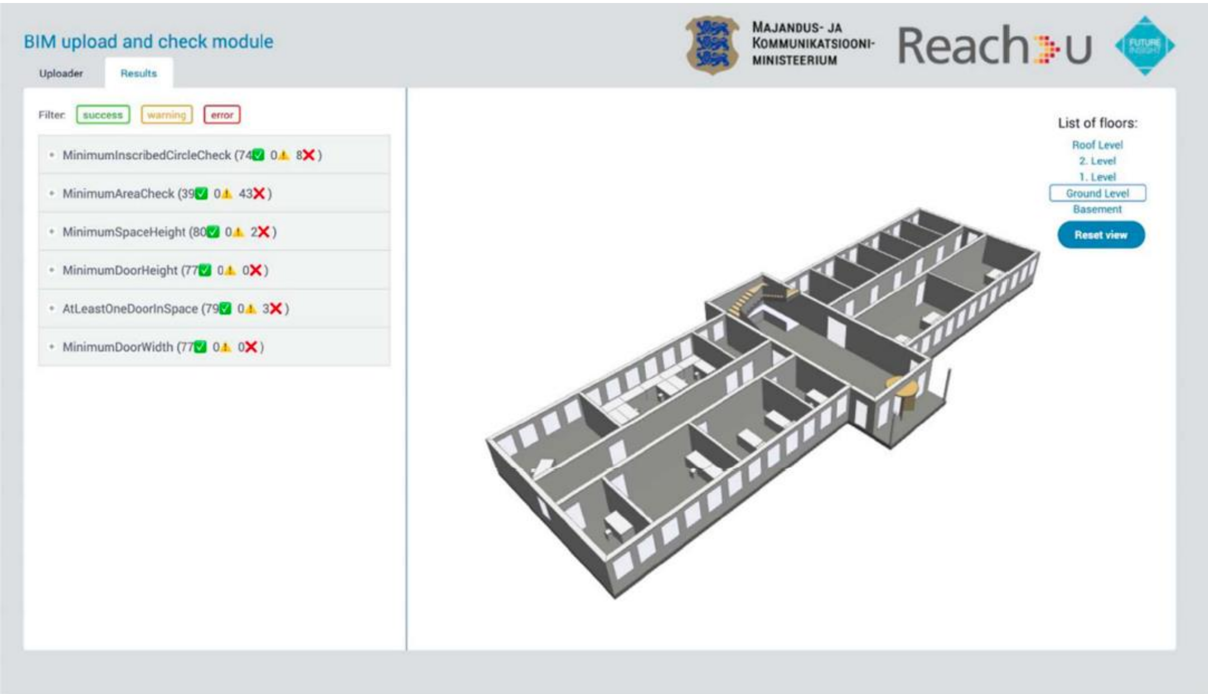

Figure 1. First demo of automated rule checking user interface

1.1 Common BIM requirements

To create software solution for automated rule checking (ARC) of building code, IFC schema by itself is not enough to ensure unambiguous information in BIM projects. This is the reason for introducing common BIM data requirements to architects and engineers. These requirements have structured data fields that need to be present in BIM project as user defined property sets. Requirements also provide information about IFC reference and data type that needs to be used for each data field. Software solution to validate IFC models according to these requirements is still in developing phase, but it should be ready by end of 2021.

[1] https://eehitus.ee/timeline-post/bim-based-building-permit-process/

	User defined property set: AR_Hoone										
	Omadus / Atribuut	***IFC Property Set***	***IFC reference***	***Data Type***	**Näide**	**ES**	**EP**	**PP**	**TP**	**TE**	**Selgitus**
AR	001_Nimetus	-	*IfcBuilding.LongName*	*IfcLabel*	Büroohoone						Hoone üldnimetus (kasutust iseloomustav)
	030_Hoone_aadress	-	*IfcBuilding.BuildingAddress*	*IfcLabel*	Lelle 24, Tallinn						Hoone postiaadress
	035_Sprinkler	*Pset_BuildingCommon*	*SprinklerProtection*	*IfcBoolean*	TRUE						Kas hoones on sprinkler kohustuslik?
	040_Kõrgus	*BaseQuantities*	*TotalHeight*	*IfcLengthMeasure*	25.1						Hoone kõrgus ümbritsevast maapinnast
	045_Hoonealune_pindala	*BaseQuantities*	*SiteCoverage*	*IfcAreaMeasure*	8000.1						Hoonealune pind (maapealne)
	050_Neto_pindala	*BaseQuantities*	*NetFloorArea*	*IfcAreaMeasure*	10284.8						Hoone netopindala
	055_Neto_ruumala	*BaseQuantities*	*NetVolume*	*IfcVolumeMeasure*	40054						Hoone netoruumala
	009_CCI-EE_klassifikaator	-	*IfcClassificationReference*	*IfcText*	<CE>+AHA						Kodeering lähtuvalt klassifikaatorist

Figure 2. User defined property set for IfcBuilding

1.2 Classification system

A common classification system must enable the creation of a common and comprehensible digital information space for all those involved in the life cycle of a building. The system must ensure a clear, transparent, and rational structure, as a result of which it is possible to apply BIM technology and work organization based on it, simplify information exchange, information processing and organization of activities, i.e. construction communication. CCI-EE classification system is being implemented in Estonia for ensuring quality of information in BIM projects. CCI-EE is national adaption based on CCI (Construction Classification International). CCI is further development of Danish classification system CCS.

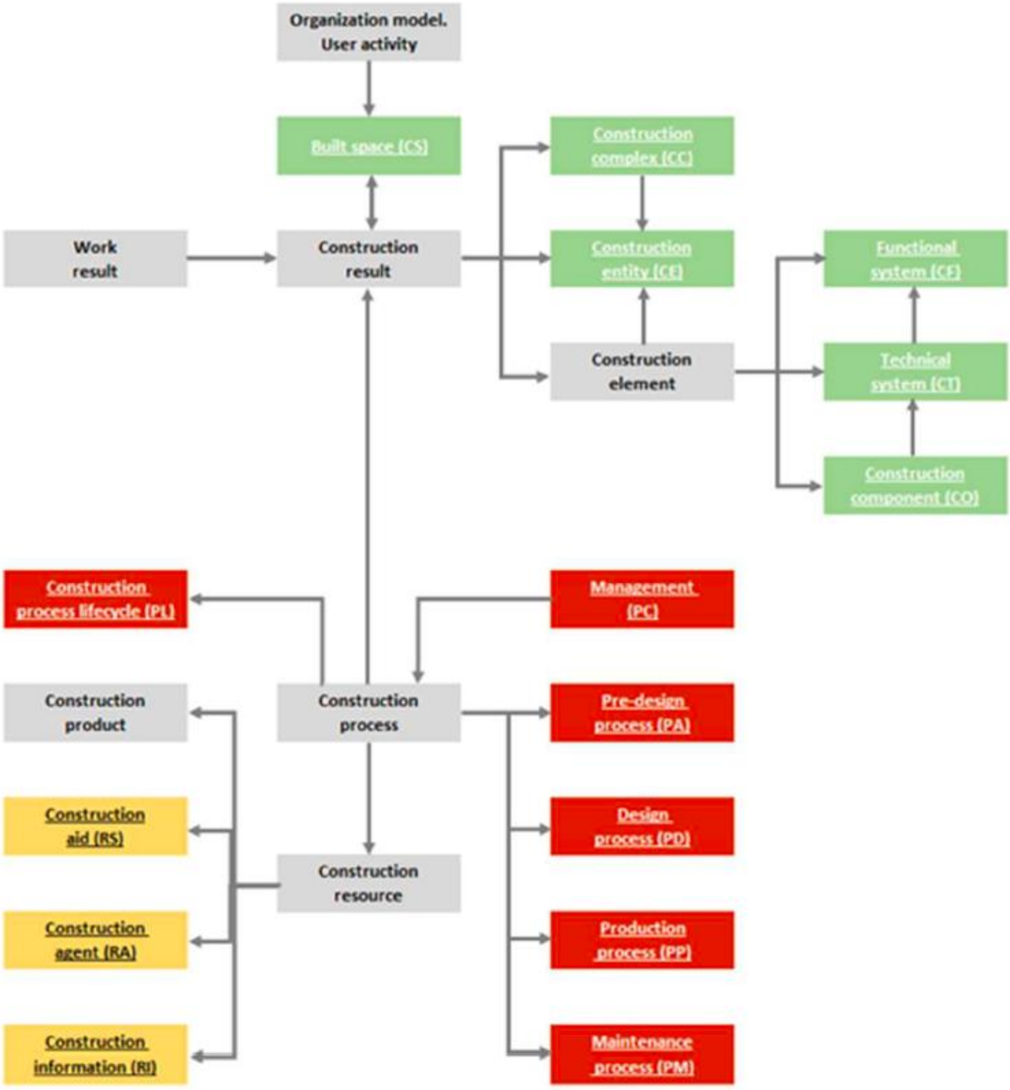

Figure 3. Schema of CCI-EE classification system

1.3 Communication to stakeholders

Another important issue is communication. By adapting new BIM requirements and classification system in the industry, a proper communication is necessary. Ministry of Economic Affairs and Communications are having continuous meetings with stakeholders to ensure adaption of new BIM requirements. These requirements will also be formalized into standard and used in public procurements. Additionally, there is cooperation with software vendors, who are also interested in common BIM requirements and can make trainings to end users for easier adaption. For adapting CCI-EE there will be government funded adaption project in 2021.

LINKS TO RELEVANT RESOURCES

Project website

https://eehitus.ee/timeline-post/bim-based-building-permit-process/

Interim work report of BIM based building permit development

https://eehitus.ee/wp-content/uploads/2021/01/Interim-work-report.pdf

Common BIM requirements

https://eehitus.ee/juhendid/bim/

CCI-EE classification system

https://eehitus.ee/timeline-post/cci-ee/

Concept for process towards automated building permits in Portugal

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1 Existing initiatives and expectations

Verification of rules within the scope of building permits is becoming increasingly sought by government agencies worldwide. Over the past few years, many countries have started to invest a considerable amount of effort in this area. Examples can be highlighted in this scope in the city of Vantaa in Finland (Virkamäki & Masjagutova, 2020), as well as the Estonian project to introduce a BIM-based process for building permits by 2021 (Future Insight Group et al., 2019). Several benefits make this topic attractive, with some of them being: (i) reduction of verification errors and of time spent for this task; (ii) profitable use of the information contained in the BIM model that would have been done regardless of the need to use it for licensing; (iii) ease and efficiency in reporting to applicants; and (iv) better perception of society in the public consultation phase.

Within the context of BIM use for building permits, a guide was recently developed in Portugal with the main goal of raising awareness among municipalities about the theme of BIM and to give guidelines to prepare for its implementation (Costa et al., 2020).

The research team at the University of Minho has already conducted a previous work together with the City Council of Vila Nova de Gaia, addressing the use of automated rule verification throughout the use of Solibri Model Checker (SMC) (Gualberto, 2019). The developed work classified the rules contained in the General Regulation of Urban Buildings - RGEU (Conselho Directivo Regional do Sul & Ordem dos Arquitectos, 2008) as to their possibility of being interpreted and verified through SMC, such as the rule interpretation to a machine-readable format, their insertion in a verification software and the BIM model information needs. A case study was developed to verify compliance with the rules contained in RGEU (254 rules in total). Many rules are not automatically verifiable because of the nature of their content. The RGEU rules that could be partially or fully verified totaled 140 (55% of all). From this number, only 55 could be verified using SMC. This is because some limitations were encountered, including restrictions in defining settings while using the templates in SMC. The existing rules in SMC did not allow the complete check of all the automatically verifiable rules, and the software does not allow the creation of new templates by the user. In some cases, the desired rule did not exist, and in others the parameters were not adjustable.

2 Proposed methodology

To broaden the scope of the rules and to make the process more flexible, automated and independent of a proprietary software, a new approach has been taken and a new venture is under development utilizing an algorithm-based technique. In the proposed methodology, still in the stage of proof of concept, the approach is to use an open API from an IFC viewer (free). At this stage, the selected viewer was the BIM Vision. It provides an SDK folder that the user can use to create their algorithm-based rules, through programming in C language or C# .NET., which will be shown in the viewer as plugins.

Four Portuguese codes were analyzed for the development of this research. One is a nationwide code (RGEU) and the others are local codes for the City Council of Vila Nova de Gaia. They are the Urbanization Plan for Avenida da República (Câmara Municipal de Vila Nova de Gaia & Gaiurb, 2019), the Municipal Master Plan for Vila Nova de Gaia (PDM) (Gaiurb & Município de Vila Nova de Gaia, 2009) and the Municipal Regulation for Urbanization and Building (Câmara Municipal de Vila Nova de Gaia, 2015). These codes are written in a non-machine interpretable language and define rules for the exterior and interior of the various categories of the built environment. Not all rules from the codes are automatically verifiable. The rules that are verifiable are mostly based on geometry from the building components and on their properties.

Once the rules are not machine-interpretable, it was necessary to interpret each rule from the selected codes and specify what types of verification would be needed, what IFC classes of objects would be used and the IFC properties and attributes that would be used to check the rules. Table 1 briefly shows some examples of rules and the methodology used for each presented case.

Table 1. Methodology used to verify rules from the local codes.

Code/Article	Rules	Rules and methodology used
RGEU/ Article 66º §1	The housing compartments may not be in number and area lower than those indicated in the code	All the IfcSpace must be named correctly (fractions and interior spaces). The interior spaces could be classified as SINGLE ROOM, DOUBLE ROOM, COUPLES ROOM, LIVING ROOM, LAUNDRY ROOM and KITCHEN. The number of rooms and typology of the fraction will be verified based on the area of the interior spaces
PDM/Article 38º §1	The full occupation of the building is not allowed, with constructions, even if in the basement, being the maximum deployment area, 75% of that area, not counting the areas of service to the domain for the purpose of calculating this percentage	The IfcSpace of both the implementation area and of the land parcel are needed. The percentage is calculated and checked for compliance
Urbanization Plan for Avenida da República/ Article 24º	§1: The maximum depth of construction at floor level 1 of buildings with two fronts cannot exceed 35m	The IfcBuildingStorey must be named correctly and the distances between the front and the back exterior walls will be measured
	§2: The maximum depth of construction of the levels above the floor level 1 cannot exceed 17,5m	

The rules from the codes were fragmented into methods of verification. Some of these methods that have already been performed in the proof of concept involve horizontal distances (e.g. distances between adjacent buildings), vertical distances (e.g. maximum building height), typology of fractions, including minimum number and area of internal compartments, external areas (e.g. maximum allowed implementation area), number of building storeys and spaces that belong to other spaces.

To better describe the process and tools used, two examples will be given in more detail. The first one is concerning the first article described in Table 1. The first challenge in this rule is to geometrically verify which interior spaces are inside each building fraction to classify the fractions according to their typology (number of bedrooms contained in it). For that purpose, a code was used to validate if all the points of each space were contained inside the polygon of the fraction, in a 2D environment. After that, the spaces inside a specific fraction were filtered, by name, and the property NetFloorArea was extracted from them. Each interior space was checked against their area and the algorithm verified if they had the minimum area indicated by fraction typology and by room typology (interior space name).

The second example is also the second article from Table 1. The property GrossFloorArea is extracted from both IfcSpace and the percentage of occupation is calculated based on a simple algorithm created.

To assure the quality of the IFC model and to enable the automated verification, the designer will need to follow IFC-based modelling and exporting guidelines, which will be kept to a minimum in order to avoid the input of additional effort during the modelling process.

The proposed platform will also include a system of pre-verification of the BIM model by the designer or applicant to allow errors to be anticipated and corrected before the project submission. Error checking in regard to the conformity of input of data were not considered yet, but they will be considered in the next phase of the project.

ACKNOWLEDGEMENTS

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Exchange of digital information in the building permission process in Sweden – some previous and possible future studies

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1 Background

Substantial resources are spent on data creation and management in the built environment process. National mapping agencies and municipalities provide geodata required in the planning and design phases of a building's life-cycle. The Architecture, Engineering and Construction (AEC) companies invest large resources on BIM data during the life-cycle of a building. However, even though there is an overlap between the GIS and BIM domains in the built environment, differences between the two domains currently prevent a smooth and fully automated integration; there is a need for methods and data exchange formats that enable integration of BIM and geodata for e.g. urban planning and 3D city modelling (e.g. Ohori et al. 2018). One area where this is apparent is in the building permission process. This paper is a summary of previous activities in Sweden related to information sharing in the building permit process as well as a description of possible future projects.

The building permit process is complex and contains several sub-processes and data deliveries between actors (for a comprehensive description, see Noardo et al. 2019). In this paper we concentrate on a subset of these processes and data deliveries illustrated in Figure 1.

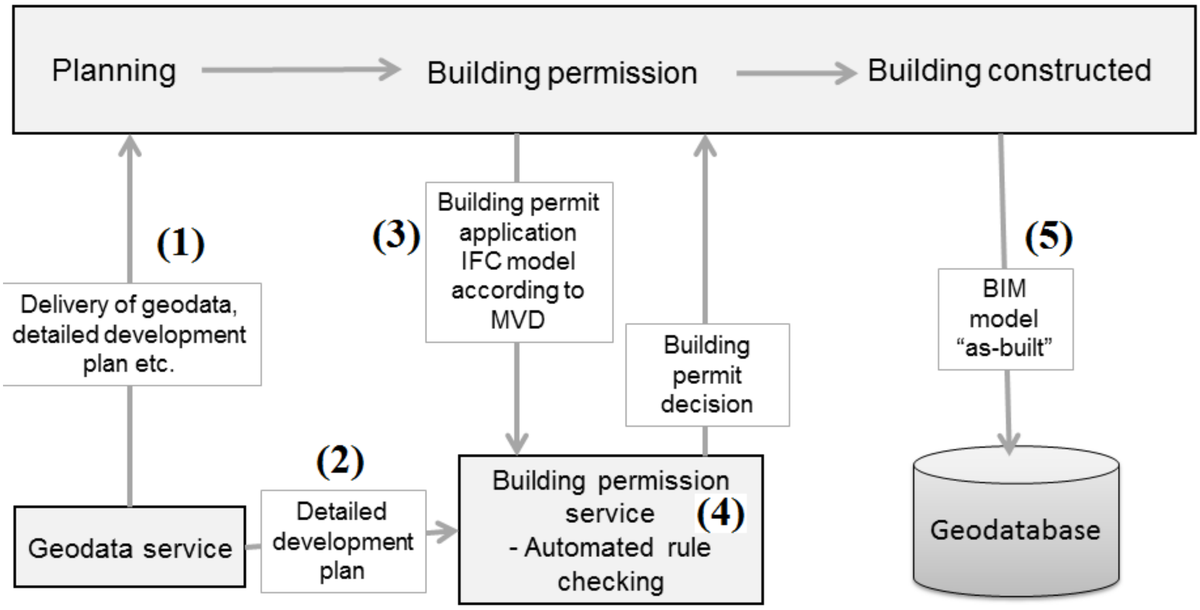

Figure 1. Processes and data delivery in a simplified building permit process.
In the top part are the AEC companies and in the bottom part the municipalities.

2 Current status in practice

In most practical work in Sweden the processes and data deliveries in Figure 1 are currently conducted as follows:

(1) The geodata (2D municipal base map) are delivered from the municipality in a proprietary format using a municipal information model (there is no well-established standard for municipality base maps). The base map is complemented with the legal detailed development plan and possibly other 2D geospatial data. The base maps are not in 3D, but the larger municipalities have 3D (presentation) city models that could be given to the AEC companies for use in their planning.

(2) The legal version of the detailed development plan has to be a paper document. But there are often digital versions in e.g. CAD format. This part is currently in a transition phase to more machine readable formats, see section 3 below.

(3) The building permit applications are most often consisting of a situation plan (municipality base map plus information about building footprint, changes in topography etc.) in e.g. CAD format as well as section drawings of the buildings (also in CAD, PDF or image formats). In some cases BIM models are appended, but there is no standard of how these BIM models should be structured.

(4) The automation level is low for checking the building permit applications against the national building rules and the detailed development plans.

(5) As built BIM models are sometimes given to the municipality when the building is constructed. But few municipalities are using these models for e.g. maintaining their geodatabases.

3 Swedish activities

In this section we describe some Swedish activities that have been addressing the five processes in Figure 1. The summary is both short and somewhat biased towards studies that the authors are aware of, no main literature search has been conducted.

The project *Får Jag Lov?* (FJL; coordinated by the National Board of Hosing, Building and Planning, 2016-2019) was targeting the building permit process[1]. The scope of this project was broad, and only parts concerned the issues mentioned here. Some results from FJL are reported below. There are also some projects, both finalized and ongoing, that concerns the building permit process under the umbrella program *Smart Built Environment*[2] (a 12 year national research and innovation program that concentrates on digitalisation in the planning and building processes). Within this program there were early projects devoted to identifying the key processes, and the exchange of digital data in the building permit processes was identified as one such key process. Technical solutions for the building permit processes were especially studied in the Smart Built project *Data delivery specification for geodata and BIM* [3] (denoted DDSGP below, coordinated by Lantmäteriet (the Swedish NMA), 2018-2019). This project made some progress in defining delivery specification (corresponding to 1, 3 and 5 in Figure 1) but did not succeed in creating production specifications.

Below follows a description of some Swedish activities by national agencies and some research studies for the five processes in Figure 1.

(1) In DDSGP studies were made for creating delivery specification for municipal data to the AEC companies. Especially one challenge was studied: converting the geometries in municipality base maps (which are often points and line geometries) to the CAD and BIM environment used by the AEC companies (normally requiring surface and volumetric geometries).

(2) As part of the governmental mission *Smartare Samhällsbyggnadsprocess*[4], Lantmäteriet and the National Board of Hosing, Building and Planning are working with the detailed development plans (the legal plans that regulates the new buildings). Linked to this (and in cooperation with the Swedish Standard Institute, SIS) a standard for machine readable detailed development plans was created (SS

[1] https://www.boverket.se/sv/samhallsplanering/digitalisering/far-jag-lov/
[2] https://smartbuilt.se/in-english/
[3] https://www.smartbuilt.se/projekt/informationsinfrastruktur/leveransspecifikationer/
[4] https://www.lantmateriet.se/sv/webb/smartare-samhallsbyggnadsprocess/

637040:2016). To guide the use of geodata in the detailed development plan Lantmäteriet launched recommendation in a handbook during 2020[5].

(3) In FJL studies were performed to identify the BIM elements that are of specific interest for the building permit application. And in DDSGP studies were conducted for creating delivery specification (based on BIM models) and how to validate an application according to these specifications. For the latter, only preliminary studies were conducted using Model View Definitions (MVD) validations[6].

(4) There have been several studies devoted to automated compliance checking of (fictitious) building permit applications (in form of both geodata and BIM models) against property criteria in the detailed development plan: Olsson et al. (2018) checked the building heights, Axelsson (2018) checked the building area, and Zhang (2019) checked the building placement and parking availability (these studies were linked to FJL). To our knowledge there has not been any Swedish studies of automated compliance checking against the national building rules (similar to e.g. IIal and Gunaydın 2017).

(5) Sun et al. (2019) studied the possibility to extract geometries from an as-built BIM model and use it in a (municipality) geodatabase. In the study comparisons were made about extracting 3D building information from BIM models and laser scanned data. However, this study did not consider the georeferencing issue, which was the topic in Uggla and Horemuz (2018). In their study they looked into the georeferencing capabilities of the open BIM format IFC as well as methodologies to handle the geometric differences in the BIM data and geodata (where BIM data is based on a Cartesian system while geodata is based on an ellipsoidal earth model).

4 Possible future studies

Even though earlier attempts of defining data delivery specifications have not been successful there are discussions to launch new projects with this aim. There have been several recent activities (and some are still ongoing) that facilitate a good ground for a new project:

- There is a new legislation that all detailed development plans must follow a certain model and that they should be delivered in accordance to the machine readable standard SS 637040:2016[7].
- During 2021 there will be a new national standard for building geodata information[8].
- There are new guidelines proposed about the information content in BIM models for buildings in the different phases (from planning to as-built models)[9].
- There is an ongoing work to standardise 3D city models (based on the international standard CityGML)[10]. This model could in the future be the base for a national standard for 3D base maps used in e.g. process 1 in Figure 1.
- The national board of hosing, building and planning have created a model library of permission processes and building process information[11].

[5] https://www.lantmateriet.se/sv/om-lantmateriet/samverkan-med-andra/handbok-i-mat--och-kartfragor-hmk/
[6] https://www.smartbuilt.se/library/5377/ap3_slutrapport.pdf
[7] https://www.sis.se/produkter/naturvetenskap-och-tillampad-vetenskap/astronomi-geodesi-geografi/ss6370402016/, https://www.boverket.se/sv/samhallsplanering/digitalisering/digitalisering-av-planeringsprocessen/digitala-detaljplaner/
[8] https://www.lantmateriet.se/sv/webb/smartare-samhallsbyggnadsprocess/nationella-specifikationer/
[9] http://www.nationella-riktlinjer.se/
[10] https://www.smartbuilt.se/projekt/informationsinfrastruktur/3cim/
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Uggla, G., Horemuz, M. (2018). Geographic capabilities and limitations of Industry Foundation Classes. *Automation in Construction*, 96, 554-566.

Zhang, M. Y., 2019. Automated building compliance checking: emphasis on building placement and parking availability. Master thesis, Lund University, https://lup.lub.lu.se/student-papers/search/publication/8954066.

LINKS TO RELEVANT RESOURCES

Related projects

Får Jag Lov: https://www.boverket.se/sv/samhallsplanering/digitalisering/far-jag-lov/ Accessed 10 March 2021.

Smart Built Environment: https://smartbuilt.se/in-english/ Accessed 10 March 2021.

Detailed delivery specifications for Geodata-BIM:
https://www.smartbuilt.se/projekt/informationsinfrastruktur/leveransspecifikationer/ Accessed 10 March 2021.

Related papers

Olsson P.O., Johansson T., Eriksson, H., Lithén T., Bengtsson, L.-H., Axelsson, J., Roos, U., Neland, K., Rydén, B., Harrie, L. (2019). Unbroken digital data flow in the built environment process - a case study in Sweden, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W13, 1347-1352*. https://doi.org/10.5194/isprs-archives-XLII-2-W13-1347-2019.

Eriksson, H., Johansson, T., Olsson, P.-O., Andersson, M., Engvall, J., Hast, I., Harrie, L. (2020). Requirements, development and evaluation of a national building standard – a Swedish case study. *ISPRS Int. J. Geo-Inf.*, Vol. 9, 78-106, doi: 10.3390/ijgi9020078.

Developed tool, with related instructions and documentation

https://github.com/TestbedLU/Testbed_BIM_GIS, Accessed 10 March 2021.

Data

https://github.com/TestbedLU/Testbed_BIM_GIS, Accessed 10 March 2021.

2.4 Session 3 - Process

Analysis of the digital building permit requirements inside a BIM environment in Italy

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1 Introduction

Digitisation has been a trending topic in Architecture, Engineering Construction and Operation (AECO) sector for at least five years. Many have been the efforts to digitalise lifecycle stages; however, few of them leverage new Information and Communications Tools (ICT) to ease the administrative process for a building permit (BP), a document granted by public authorities that legitimizes a building intervention. The possibility to streamline the digital transformation of the BP process codes can be triggered by translating existing codes into machine-readable rules and requirements. The redaction of this document is a time-consuming and error-prone activity that is still conducted manually with paperwork or, at best, PDF files (Noardo et al., 2020). Therefore, the building permit might represent an interesting case study to be processed with digital transformation (Plazza et al., 2019). The first step of this research involved the classification of Italian building regulations, as reported in Table 1.

Table 1. Classification of Italian building regulations.

	Process	Asset
National	"National Law of Building Regulations" (Testo Unico delle Norme per l'Edilizia) (*Decree of the President of the Republic no. 380/2001*) which includes: Building Permit standard form (*Official Gazette n. 119 dated 16/08/2017*)	"Hygiene and Health standards" (Regolamento di Igiene) (*Ministerial Decree n. 5/1975*) "Fire Prevention code" (Codice Prevenzione Incendi) (*DPR 151/2011*, 2011) …
Regional		"Territorial Government Plan" (Piano di Governo del Territorio) (*Lombardy Regional Law n. 12/2005*) "Building Code" (Regolamento Edilizio) (*Regolamento edilizio n.27/2014*)

This research is focused on what information is possible to retrieve from BIM and GIS models to promote this digitalization process. The next step evaluates what information is possible to include in the existing open, international standards such as Industry Foundation Classes (IFC) promoted by buildingSMART (*Buildingsmart*).

2 Methods and tools

The methodology is structured in the following parts: the analysis of the Italian building permit requirements, the classification of the information derivable from a BIM/GIS model, and the assessment of the available standard entities necessary for the document. The building permit standard form (*Official Gazette n. 119 dated 16/08/2017*) is analysed through XMLPad (*XMLpad*) to investigate the information required. These information are then classified according to the methodology proposed by (Hakim et al., 2017), as showed in Figure 1.

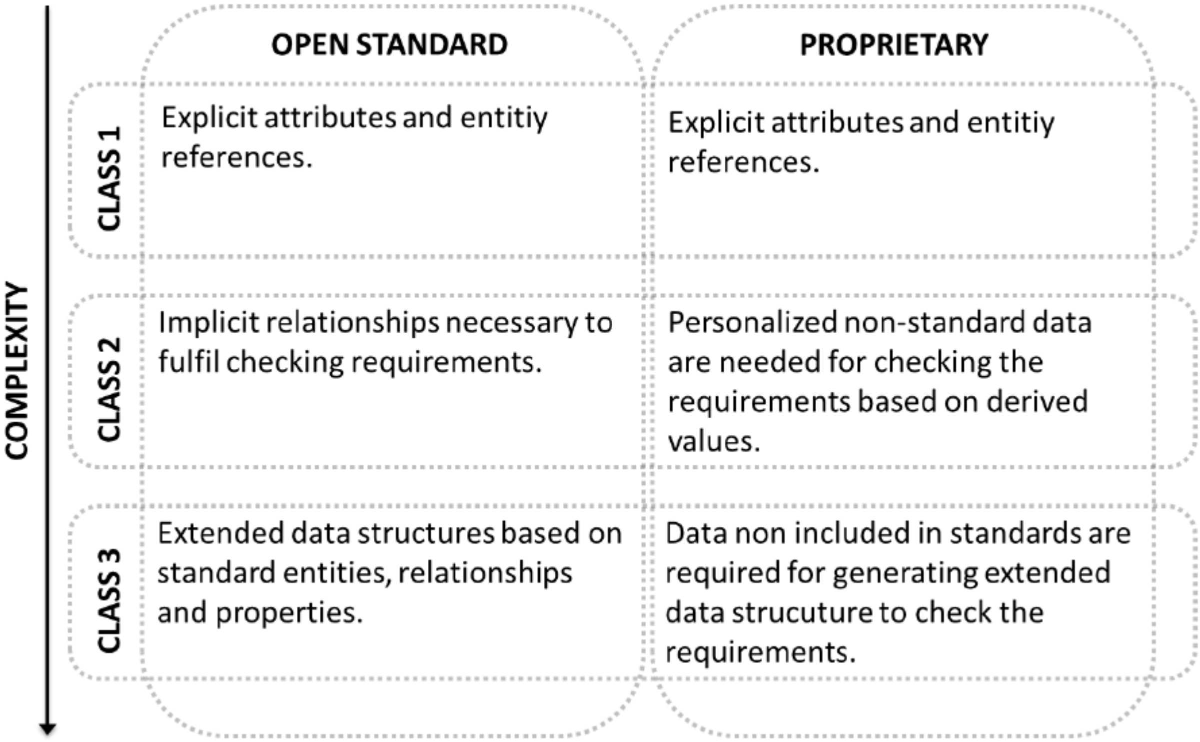

Figure 1. Classification of the required information's complexity.

3 *Results and conclusion*

Figure 2 shows the 14 main sub-categories that compose the building permit documentation. These include different specifications: the ones required by the building permit procedure itself (applicant, owner, designer, and contractor information) and the technical ones (specification of the building and the surrounding). The last element of this diagram includes all the 44 attachments: 5 are mandatory, and 39 depend on the intervention type. The proposed classification system considers two aspects: the complexity of the information required and the possibility to find the information inside an open standard or proprietary format. The general idea was to consider standards from both BIM model (IFC) and GIS systems (CityGML).

This study was focused on the investigation of the IFC standard. The IFC schema is defined by entities and related property sets (predefined and customized). This analysis considers only the match between building permit requirements and existing property sets. Considering that IFC4 (*IFC standard*) does not have entities dedicated to the building permit, suitable entities were used. The result of the analysis shows that, for instance, IfcPerson and IfcOrganization can be used to store some of the applicant, owner, designer, and contractor information; IfcBuilding is useful to extract dimensional information (IfcQuantityArea, IfcQuantityVolume and IfcBuildingStorey); IfcSite contains different information: address (IfcPostalAdress), object placement (RefLatitude, RefLongitude and RefElevation), land registration (LandID, IsPermanentID and LandTitleID) and site specification (BuildableArea, SiteCoverageRatio, FloorAreaRatio, BuildingHeightLimit and TotalArea).

In conclusion, two relevant causes hinder this transformation: i) the high number and the variety of information required, ii) the impossibility for the actual BIM environment to collect and manage all this information according to the IFC standard. Future developments will consider: i) the development of a case study to better understand the complexity of standard’s requirements, ii) the analysis of other standards using the proposed methodology, and iii) the evaluation of two different approaches, namely top-down approach, which considers the lawmaker intervention, and bottom-up, which includes all the best practices used during the design phase that could also be extended for the BP processes.

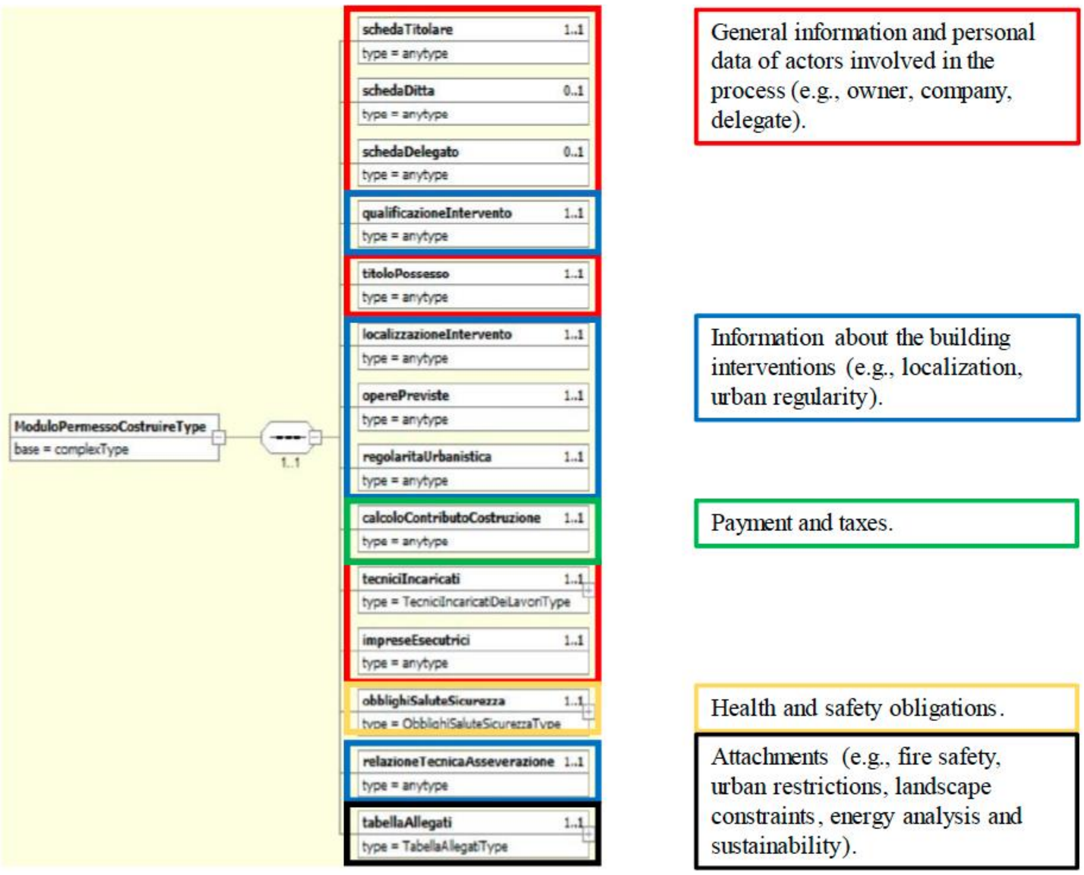

Figure 2. Italian Building Permit analysis (sub-categories)

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Combining BIM and GIS for the digitalization of the building permit process in small municipalities: the GEOBIMM project

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Approval processes have only recently begun to receive attention from the digital revolution. These are processes that, whatever they concern (town planning compliance, building permits, verification of user-defined requirements, etc.), to date are still carried out manually (with a high risk of human error) and that require high timeframes especially in smaller municipalities. In fact, a survey conducted by Fraunhofer Italia (Plazza et al. 2019) in collaboration with the South Tyrolean municipalities' consortium has shown that the duration of the verification process for a building permit takes 20% longer in a small municipality (less than 3,000 inhabitants) than in a large municipality (more than 10,000 inhabitants). In addition, 20% of building permits are submitted more than once due to non-conformities detected. All this highlights an inefficiency of administrative processes that could be minimized with the adoption of digital methods and technologies (e.g. BIM). In fact, the same survey highlighted that 40% of the requirements to obtain a building permit are quantifiable and computational, meaning they can be verified by machines (e.g., computers and software).

The GEOBIMM project aims at addressing the real needs of municipalities in digitizing their processes from a BIM perspective, but enhancing the information management systems already in use and consolidated internally (eg GIS). Thus, the GEOBIMM project has three main objectives:

- To make the process of managing a public work more efficient, reducing the execution time of technical processes for a faster, more transparent, and aware municipality.
- To support municipalities in facing the ongoing digital revolution by providing innovative software applications that are able to integrate with the data management systems already in use.
- To demonstrate the positive impact on the daily work of designers and companies that collaborate with municipalities.

The GEOBIMM[1] (Geographic Building Information Model Management) project (2020 – 2022) is funded by the European Regional Development Fund of the Autonomous Province of Bolzano - Investment for Growth and Jobs ERDF 2014 -2020 and it involves 5 interdisciplinary companies (R3GIS, Fraunhofer Italia, Ontopic, Erdbau, ASM Merano) and the Municipality of Merano.

1 The GEOBIMM app for code compliance checks

The GEOBIMM project will develop the GEOBIMM app for code compliance checks, a software prototype that will demonstrate the potential of the integration between BIM and GIS in making approval processes, such as the process of building permits and verification of urban conformity, more efficient.

Up to now, the project partners have defined the main functionalities of the prototype and are evaluating the opportunities for data exchange considering the use of open formats (i.e. IFC) and data formats already in use by the Municipality (i.e. shapefiles).

First observations regard:

1) The attitude of the Municipality against the GEOBIMM project.
2) The availability and readiness of data within BIM Models developed by planners, in order to perform compliance checks against the municipal building code and the municipal urban plan.

[1] https://www.linkedin.com/showcase/geobimm/?viewAsMember=true

2 First observations

- The attitude of the Municipality is positive. In fact, they see this kind of system as an opportunity for the Municipality to focus more on planning the city and on finding new ways to involve their citizen into the planning process. However, they see this kind of systems as tools to be used by designers before submitting a building permit rather than by technicians within the Municipality.
- The availability and readiness of data within BIM Models developed by planners is very low. There is a need for guidelines and MVD to support designers in implementing and exporting the appropriate information in .ifc.

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LINKS TO RELEVANT RESOURCES

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About determination of building permitability

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The proposed abstract presents an introduction from the author's PhD research (Fauth, 2021). The approach considers the building permitability determination from a project management perspective with focus on the building permit authority. Building permitability refers to the compliance of a construction project with legal requirements. It is used to ensure a legal condition in the building environment. Building permit determination involves the review and evaluation of information and documents submitted to the building permit authority by authority staff as the decision maker. Even the focus is on the authority, the approach equally offers benefits to applicants for building permitting.

Determining building permitability is essential to the success of any construction project (Plazza et al., 2019) but has received little attention in research to date. This concerns the authorities as well as the planners. Consequently, publications on the topic can be described as rare (Schleich, 2018; Schulte, 1996). However, there is a demand for optimization in building permit authorities (Ponnewitz & Schneider, 2019), especially with regard to digitalization (Noardo et al., 2020).

The high degree of interdisciplinarity makes the topic of building permits particularly complex. After all, numerous aspects from the disciplines of construction, architecture, public administration and jurisprudence must be taken into account. The fact to bundle these disciplines in one person or one authority is very special and poses a challenge for the involved parties.

A structuring and model development of the prevailing system for building permit determination form a valuable approach for the optimization and digitalization of building permit processes. The aim is to achieve transparency and intersubjectivity for all parties involved as well as to provide starting points for the implementation of digital methods.

From the construction project management point of view, processes are particularly significant and represent the main focus of the study. In this context, the building permit determination consists of many individual decisions to be made during the review of a building application.

Knowledge of the current state of aspects relevant to building permits is essential to the study. In addition to an international literature review on the current state of research, an empirical study was initiated. For this purpose, 100 interviews were conducted primarily in Germany and the USA in the form of qualitative expert interviews. The experts include employees in building permit authorities, planners, project developers and other experts such as lawyers. The study covers the period from October 2016 to February 2019, and the data material was subjected to software-based qualitative content analysis.

Various analyses were conducted to develop the model for building permit determination. Among others, the official organization, legislative objectives, processes, but also decision-making scope were considered.

Based on the decision-making theory, a model was developed that depicts the determination of building permitability. Therefore, relevant aspects such as processes, objectives and influencing factors are implemented. The approach provides a general system that can be adapted to a specific model according to an individual authority as well as to other countries. The model is divided into four subsystems: product system, objective system, actor system and process system, which is shown in figure 1.

The product system contains the project-specific information concerning the constructional facility, the plot of land and the surroundings. They represent the formal and material information required for the building permit determination.

All the objectives of the regulations are listed in the objective system. Especially in German planning and building law, the objectives are not explicitly stated in the legal texts, which is why making the objectives available is of significant value.

The actor system maps the factors that have an influence on the processes in the building permit determination. They are divided into organization and instruments. Organization refers to the individual internal structure of the authority. Instruments can be described as tools that plan reviewers can refer to. They can have a technical (e.g. BIM and GIS), legal (e.g. regulations and referred court decisions) or organizational (e.g. intra-authority checklists) background.

The process system describes the processes that are followed to determine building permitability. These are formal and material intentioned processes. They are distributed on different levels, depending on the level of detail. All processes lie between the submission of the building application documents and the determination of the building permit ability by the authority. A special characteristic is the inclusion of action alternatives, also under subjective influence. These were previously analyzed and typified from a project management perspective.

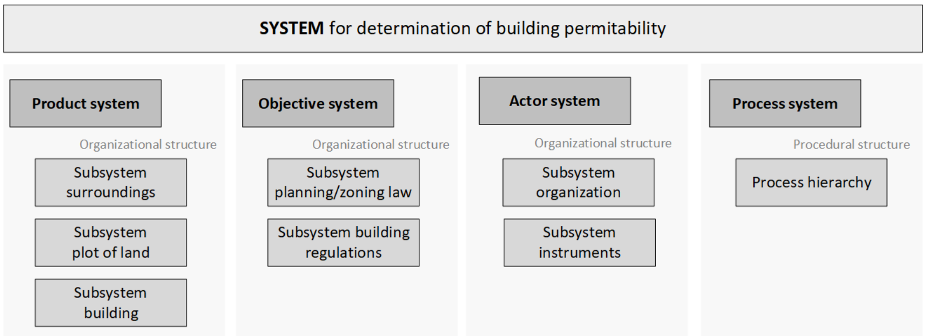

Figure 1. System of determination of building permitability

The theoretical model was transferred to practice and tested in the form of a prototype web application. [1] The prototype follows a process-based approach, provides decision-relevant information and connection to external data (e.g. BIM model and protocols).

The presented model is a decision support system for plan reviewers. In addition, it is an assistance for applicants to prepare their application documents and argumentation. The model serves as a basis for further automated, BIM-based and digital solutions, but provides also a foundation for comparison of building permit procedures in different countries.

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Digital Building Permit and Small Sized Local Authorities in Italy

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1 *Motivation for the research*

The current focus on digital innovation aims to support the reconfiguration of Architecture, Engineering and Construction (AEC)-related processes through the adoption of methods and tools of information modelling and management. Within such a context, as well as in accordance with the Italian Digital Administration Code (D.Lgs. 82/2005) and the European Directive on public procurement (2014/24/EU), the Italian government has initiated a plan to drive the digitalisation of public administrations. In this sense, in 2017 a Ministerial Decree was issued to regulate the gradual and mandatory implementation of BIM methods and tools in public procurement from January 1, 2019 (D.M. 560/2017). This transition is also affecting the context of private construction and building permits.

2 *Problem statement*

The building permit process is considered as a promising use case for automation via digital data about buildings and the built environment (Eastman et al., 2009; Lee et al., 2016). As the final authorisation granted by public authorities that gives permission to start the construction phase of a building project (Noardo et al., 2020), the building permit connects the public authority and the client during a process of town planning with the aim of guaranteeing a controlled development (Siew et al., 2013). However, the building permit process is still a manual and error prone activity, which often proves to be time-consuming and affected by subjective, leading to ambiguity and inconsistency in assessments that are mainly done by sample checks. (Malsane et al., 2015).

3 *Research background*

In Italy, first research works on the topic of code checking enabled by Building Information Modelling (BIM), which is considered one of the most demanding use case in terms of the effort-benefit ratio (AGC, 2010), are dated back to 2012, when tools like Solibri Model Checker started to be implemented in research activities and case studies (Bellomo, 2012; Tegon, 2013). The focus was first on large public clients and local authorities (e.g., Public Works authority of Lombardia and Emilia-Romagna) (Ciribini et al., 2016). However, the gradual and mandatory introduction of BIM implies the need to approach digitisation also for small-sized public administrations (Figure 1), which are of high interest since their capillarity on the national territory.

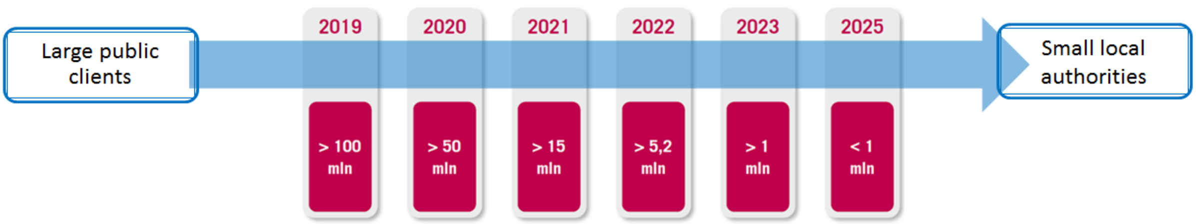

Figure 1. D.M. 560/2017 - Gradual and mandatory introduction of BIM in public procurements

4 *Methodology*

Within such a context, the authors are currently working on the evaluation of the needs for the effective implementation of the building permit use case, enabled by a BIM-based code checking approach, within small-sized local authorities from a process re-engineering perspective in terms of activities, stakeholders and data exchanges. A case study is currently under development in collaboration with the municipality of Lomazzo, a small-sized local authority in the north of Italy.

The methodology that has been adopted follows the scalable steps of the rule checking approach: rule interpretation, building model preparation, rule execution and rule reporting (Eastman et al., 2009). The research project is now focused on the rule interpretation stage: the aim is to understand what type of requirements, regardless of the specific source (local, regional, national) could be translated into computable parameters in order to reach the semi-automation of the procedure. It has been proved, for example, that a direct semantic interpretation of texts based on four mark-up operators can provide trustworthy rules and results (Hjelseth, 2009). These tags are the foundation for the so-called RASE methodology; once logically structured, regulations can be grouped into rulesets representing a validation domain (Mastrolembo Ventura et al., 2016).

Moreover, the research project aims to also adopt a process mapping approach in order to analyse how the building permit procedure could be affected by such a digital innovation. The current building permit process has been analysed using the Business Process Modelling Notation (Figure 2) and taking into account the national, as well as the regional, legal constraints which are featuring the processes. The map has already been validated in a meeting with the clerks of the municipality of Lomazzo.

Figure 2. Digital building permit process - main stages

Nowadays, compared to previous experiences, the authors want to move from the adoption of technological tools to the analysis of processes to support digital innovation even in small local authorities.

5 Discussion of the results

This research aims at understanding the level of automation that can be reached in the building permit process, which is a preliminary activity for structuring local regulation as machine readable rules. In the case study, using Solibri Model Checker, the regulations have been manually translated in order to be machine readable and to highlight the level of information need for the building permit of the study. The ruleset could be now adopted to validate building information models against Italian current regulations and the residential building code of Lomazzo. Moreover, the mapping approach is useful to understand the current as-is process and to evaluate the possibility of a reconfiguration in terms of digital transformation.

6 Conclusion

The definition of the appropriate level of information needs, the translation of codes and regulations into computable rules and the innovation of processes could support local authorities in increasing the efficiency of the process in terms of time management as well as objectivity of the evaluation.

Nevertheless it is necessary to specify this research develops in an investigation phase, this can be seen as a limit of research as well the resistance of officers to change.

Possible future works could be related to the comparison of the traditional workflow with a digital-enable one in order to analyse improvements in terms of time wasting adopting a lean perspective.

The ultimate intent to be achieved by means of the digitalisation of the digital building permit-related procedures stays with exploiting the engines proper to the BPMN 2.0 tools in order to establish a data-driven interactive and predictive process.

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A Workflow Containing Digital Building Permit for Turkey

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This abstract is based on the journal paper that was published recently by the authors (Guler and Yomralioglu 2021). The paper presents a reformative framework that aims to improve the building permit procedures, three-dimensional (3D) registration of property ownership, and update of the 3D city models in Turkey (Figure 1). The detailed description and evaluation of the reformative framework can be used in forward-looking plannings and policies. The present work puts forward a significant viewpoint that focuses on the efficient use of the 3D digital building models. Accordingly, this paper contributes to the body of knowledge by considering the building permit procedures, 3D registration of property ownership, and update of 3D urban models as an integrated concept.

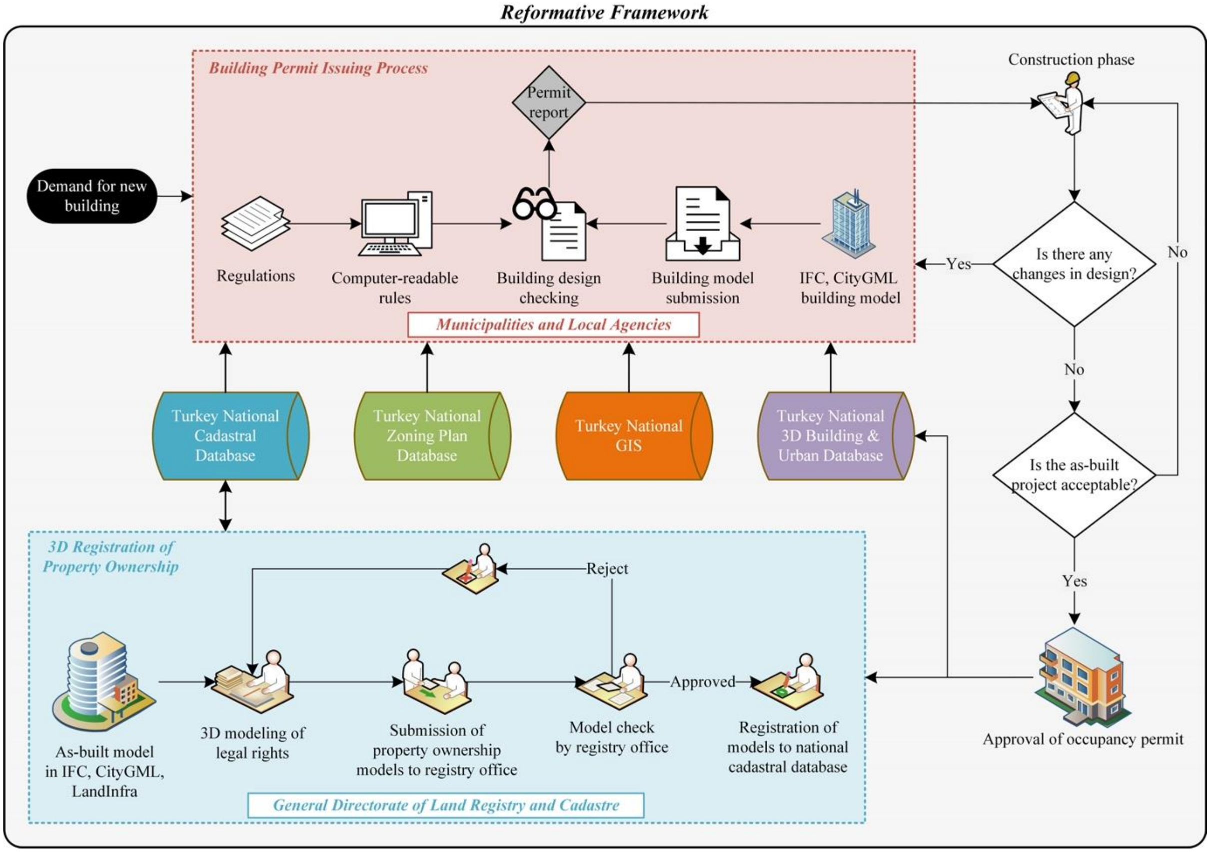

Figure 1. The reformative framework (Guler and Yomralioglu 2021)

The building permit procedures generally start with new building demand in the land parcel. This demand can be related to the renewal of the existing buildings or the construction of a new building. The building permit should be obtained from authorized agencies in both situations. The cadastral and built environment data are necessary to design new buildings realistically and conveniently. Architects benefit from underground and aboveground data during the design stage. Several restrictions about the surroundings of the buildings are able to be considered by using these data (Olsson et al. 2019). That’s why both 3D cadastral data and 3D urban models are of vital importance. For example, the spatial and ownership information related to infrastructure facilities can be obtained from the national cadastral database to be used in building design. Besides, architectural design is closely related to the built environment. The spatial data provide an advantage for multifaceted building design. Thus, the Turkey national 3D urban database and Turkey national cadastral database can be used in building design and compliance checking as well.

Furthermore, construction projects should be prepared in accordance with confirmed zoning plans (Chognard et al. 2018). Based on this, reaching the zoning plans electronically will be more useful because buildings can be evaluated in the design phase detailedly. The e-Plan project carried out in Turkey can contribute to the implementation of this notion by managing the works related to zoning plans electronically. As can be seen in Figure 1, the building permit issuing process is handled electronically by benefiting from digital building models. This is important because most of the buildings are being designed by using digital data models, for example, Building Information Model (BIM). Although the building permit procedures are being carried out with paper drawings or PDF files (Solihin and Eastman 2015), the use of BIM is increasing in Turkey and the rest of the world day by day (BIMgenius 2020; NBC 2020). The architects create much more 3D digital building models thanks to the common usage of data formats and standards. This is encouraging for enhancement and digitalization of building permit processes in Turkey. The reformative framework aims to conduct automatic compliance checking by exploiting digital building models and computer-readable rules. Many countries conduct projects to automate the compliance checking (Eastman et al. 2009; Noardo, Malacarne, et al. 2020), but the works related to the automation of building design checking in Turkey is very limited. Nevertheless, the use of digital building models for building permit is mentioned in the "2020-2023 National Smart Cities Strategy and Action Plan" for the first time. This positive action raises the importance of the reformative framework proposal for Turkey.

The building permit is prepared based on the created permit report. If the building design satisfies the conditions that are indicated in the relevant laws and regulations, the building permit is constituted. The construction can start after getting the building permit. The construction phase is important in Turkey because the buildings should be built according to the earthquake regulation. The country experienced a large number of earthquake disasters in the past and still experiences these days (DEMP 2020); therefore, earthquake regulation is prepared and published in order to strengthen the buildings and to ensure the required safety. Every building is audited by authorized building control firms during construction. Another important thing is that the design of the buildings might change in the construction phase. In that case, the new design of the building should be approved by the agencies that carried out the building permit procedures. By using digital building models, this process can be arranged more easily and accurately. At the same time, the as-built model of the building can be acquired. The as-built model of the building should be approved after completion of the construction to create the occupancy permit in Turkey. There is no strict guideline in the occupancy permit or building permit on how to control the as-built model of the building and relevant documents. For this reason, the evaluation of the occupancy permit can be conducted by using two-dimensional (2D) data in general. However, more realistic assessments can be practiced if the current as-built model of the building is used (Zhang and El-Gohary 2017).

After getting the occupancy permit, citizens can dwell in the new building and utilize various public services such as electricity and natural gas. Getting the occupancy permit finalizes the building permit procedures as such in several other countries (Noardo, Ellul, et al. 2020). Besides, the use type change of land parcel should be processed into the cadastral database in order to ensure effective land administration (UN-GGIM 2019). Currently, there is no obligation for stating the use type conversion of the parcel in Turkey. This might cause damage to the country financially because the taxation cannot be implemented realistically. In this connection, the condominium can be created for independent sections of the buildings pursuant to Property Ownership Law No. 634 in Turkey. There is a need for detailed building models to actualize rights, restrictions, and responsibilities (RRRs) with respect to property ownership since 2D representations fail to satisfy the requirements of the complex buildings (Oldfield et al. 2017). The 2D representations are used for the land registry in Turkey. The RRRs are registered to the cadastral database in writing even though there are initiatives regarding the 3D representation of property ownership. The reformative framework can contribute to these initiatives by providing as-built models of the buildings. Nowadays, various countries seek to use digital building models for registration of legal rights related to real properties and their physical counterparts (Rajabifard, Atazadeh, and Kalantari 2019). In this regard, the use of as-built building models that are obtained after building permit procedures can provide an advantage for panning out of projects in Turkey. These digital building models can be formatted as Industry Foundation Classes (IFC) or CityGML, which are state of the art open data formats for modeling of urban areas and buildings (Deng, Cheng, and Anumba 2016).

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LINKS TO RELEVANT RESOURCES

Related papers

The accepted manuscript version of the paper can be found in https://web.itu.edu.tr/gulerdo/papers/16.pdf Accessed 6th April 2021

BIM for public authorities: Basic research for the standardized implementation of BIM in the building permit process

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The building permit is an indispensable connection between the approval authority and the executive client within the construction process. Moreover, sustainability criteria do not have sufficient regard in the building permit process in the area of research. To lay the foundation for a state-of-the-art digitalization of the building permit process, the study identifies the information requirements relevant to implement the BIM methodology taking into consideration the available sustainability aspects relevant to the process. A detailed evaluation of the building permit process and the analysis of projects that have gained building permission in the last five years in the area of study of South Tyrol (Italy) gives us a better understanding of the organizational structure and responsibilities in the process. The authors use the data of in-depth process analysis to assess a defined catalogue of basic requirements for BIM methodology in the building permit process. As a result, the analyzed BIM-integrated approach enables an early-stage identification of approval compliance, which can be evaluated in the building permit process. A good understanding of the current process must be considered a key factor of a successful introduction of BIM for the building permit procedure.

LINKS TO RELEVANT RESOURCES

Related papers

Plazza, D., Röck, M., Malacarne, G., Passer, A., Marcher, C.and Matt, D., 2019. BIM for public authorities: Basic research for the standardized implementation of BIM in the building permit process. *IOP Conference Series: Earth and Environmental Science. 323(1),* IOP Publishing, p. 012102.

https://www.researchgate.net/publication/335664371_BIM_for_public_authorities_Basic_research_for_the_standardized_implementation_of_BIM_in_the_building_permit_process Accessed 9th April 2021

2.5 Session 4 – Rules and requirements

[Integration of Building Information Modelling into the process of building permits in Germany]

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While many architectural companies are already using 3D building information modelling (BIM) methods and even in other lifecycle phases, such as construction and maintenance, the advantages of using BIM are increasingly used, the step to apply a building permit usually means the fallback to conventional application methods. Although, some authorities allow the digital application of documents and plans by means of PDF format, the main advantage of significantly increasing the degree of automation are not exploited so far.

A concept for the integration of building information modelling into the general process of digital building permits was developed in a German research project[1] funded by Federal Office for Building and Regional Planning. It considers multiple aspects, which do not only include the use of a BIM-model, but also incorporates other sources and related technologies (Figure 1). Starting with the planning of a construction project on the applicant's side, the local restrictions for land-use and construction layout must be evaluated. That is defined in layout plans, that include the geometric layout of the construction site as well as restrictions to the construction design, such as building area, height, or number of stories. These plans should be centrally available and exchanged by a common data format, which is implemented with the XPlanung[2] standard for Germany. After the planning of the construction by an architect, typically application forms must be filled out and 2D-plans must be generated for submission. Here, a model-based approach introduces an alternative way. The contents of the original application forms are captured by a common data format, in this case XBau[2]. Many of the required parameters, especially in terms of quantities, can directly be extracted from the BIM-Model. The model itself is exchanged using the Industry Foundation Classes (IFC) standard. Together with the BIM-Model and the corresponding layout plan they represent the main documents to be submitted.

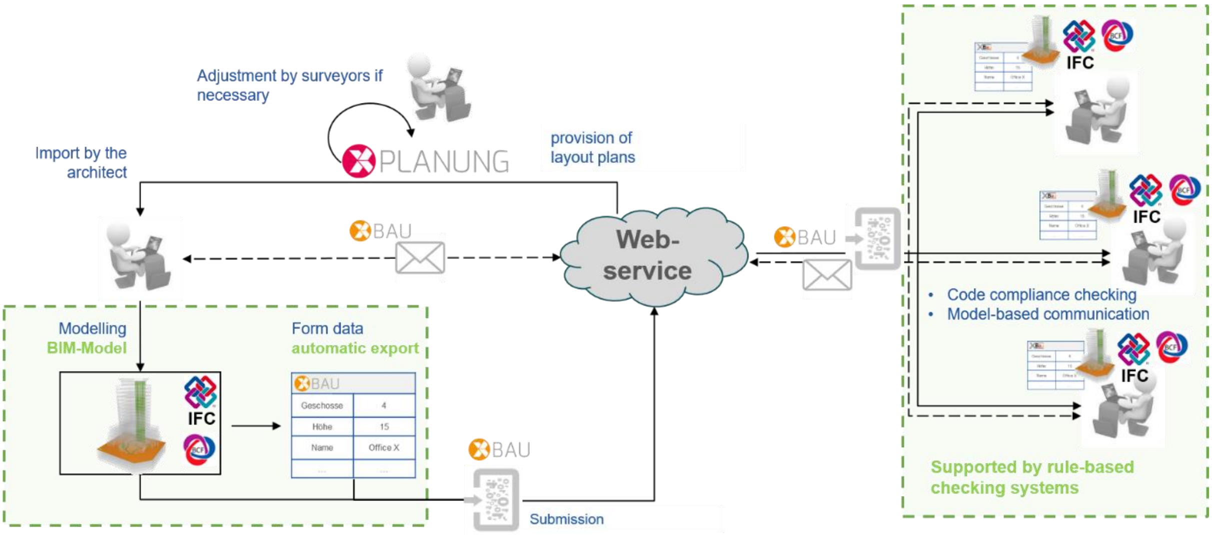

Figure 1. Overview of the concept for a BIM-based building permit application process

[1] https://www.bimbauantrag.de (only in German language). Accessed 19 January 2021
[2] XPlanung, XBau: https://www.xleitstelle.de/ (only in German language). Accessed 19 January 2021

Other important aspects, which are supported by the XBau format, are the consolidation of all documents related to the building permit into a container format and the ability to draw interdependent relationships between entities of different documents. This is especially important when communicating issues on the model such as so-called exceptional cases. These are not only captured by the classifications in the XBau format but are also supported by the BIM collaboration format (BCF), where each case is then linked to a specific BCF-Topic.

On the side of the authorities, the submitted BIM-model and layout plan can then be used to perform a direct and more automated analysis of the construction project. Here, the use of model checking tools provide the ability for automatic code compliance analyses. Especially when checking consolidated quantities, such as limits for total areas, these can significantly increase the efficiency of the overall process. Moreover, implementing this procedure additionally on the side of the applicant as a pre-check, time-delays through iterations of checking and correction can be reduced to a minimum.

The proposed methods present an integrated and intelligent way to implement a more efficient building permit process, but there also come lots of challenges to handle. The most important challenge is to ensure the information quality of the BIM-model. Automated processing of the model is only possible if the involved elements are properly modelled, and all necessary properties are assigned. Therefore, exchange requirements must be defined and considered. Many of them refer to the existence and correct format of properties, but also geometric requirements to the geolocation are important to synchronize against layout plans. Besides the consolidation in modelling guidelines for specific and local application process, these information are commonly captured by using open standards like property- and quantity set definitions (PSD, QSD) or IFC template properties. By translating these to model view definitions (MVDs), the model can be tested with existing frameworks.

There are also challenges which cannot directly be solved but require more future work. The quality of other incorporating resources, such as CityGML, are usually too inaccurate to rely on in automated model checking, such as for checking minimum distances to neighboring constructions. Also, there are challenges due to legal responsibilities in the modelling process, such as that specific modifications cannot properly be traced, i.e., when fire ratings must be assigned by another engineer within the overall process of the delivery of the BIM-Model by the architect. Other challenges, which are not specific to the building permit process, involve the correct authorization and authentication of the applicant party and the secure delivery of the involved data.

The proposed concept has been evaluated on both real references projects as well as demonstrators to show a fully implemented workflow and the implementation of the exchange requirements.

Normative, Definitive and Descriptive Knowledge

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Keywords

Regulation, Requirements, Dictionaries, Construction Knowledge, Compliance, RASE.

1 Concepts

This industrial presentation examined three kinds of construction knowledge. One kind of knowledge includes the social regulations and client requirements that represent the demand side for the construction sector. This knowledge is 'normative', describing expectations. A second kind of knowledge is found in dictionaries and thesauri that bridge between formal and informal language and technical representations. This knowledge is 'definitive', holding our shared understandings. A third kind of knowledge is found in the descriptions, narrative, databases and product models . This knowledge is descriptive of the current or intended state.

AEC3 Require1[1] is a knowledge workbench developed from the result of 20 years of experience in creating automated compliance checking systems that started in 2000 with the Singapore ePlanCheck system[2], and includes the ICC SmartCodes project[3] and several subsequent UK and US implementation projects.

2 Demonstration

The live demonstration showed AEC3 Require1 managing all three forms of knowledge. The use-case was to evaluate normative knowledge against descriptive knowledge, joined by the definitive knowledge. Starting with a complex clause from the UK Building Regulation Approved Document M[4], (figure1) the addition of RASE four-colour markup rendered it machine-readable. The application can use any regulation or requirement document containing normative knowledge as plain text, lists and tables in HTML[5]. There are no significant restrictions on language, grammar, complexity, style or structure. Currently figures and diagrams are not marked-up. The four-colour RASE[6] markup (Nisbet 2008) is added typically in a matter of minutes by a regulation domain expert. The mark-up consists of identifying the logical structure as boxing and logical metrics as underlining. The metrics are simple micro-queries, identifying a simple atomic test. The mark-up can be reviewed by others and is reported back as tables of metrics, as logical decision trees and as re-structured language. Other rules-languages such as DMN[7], Drools[8] or DataLex[9] can be generated.

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[1] http://www.aec3.eu/require1/AEC3_Require1.html Accessed 12 April 2021.)
[2] http://www.novacitynets.com/pdf/aecbytes_20052610.pdf Accessed 12 April 2021)
[3] http://www.iccsafe.org/uploads/news_release_links/1011smartcodes Accessed 12 April 2021)
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[5] https://www.w3.org/TR/html52/ Accessed 12 April 2021.)
[6] http://www.aec3.eu/require1/Help_en-GB/help_en-GB_200.html/ Accessed 12 April 2021)
[7] https://www.omg.org/dmn/ Accessed 12 April 2021)
[8] https://www.drools.org/ Accessed 12 April 2021.)
[9] http://www.datalex.org/dev/import/ Accessed 12 April 2021)

Provisions

2.13 Doors to accessible entrances will satisfy requirements M1 and M2 if:

a. where required to be self-closing, a power operated door opening system is used when through calculation and experience it appears that it will not be possible otherwise for a person to open the door using a force no greater than **20N** at the leading edge;
b. the effective clear width through a single leaf door or one leaf of a double door is in accordance with Table 2, and the rules for measurement are in accordance with Diagram 9;
c. unless it can be argued otherwise in the Access Statement, e.g. for reasons of security, door leaves and side panels towards the leading edge of the door whose vertical dimensions include at least the minimum zone or zones of visibility between 500mm and 1500mm from the floor, if necessary interrupted between 800mm and 1150mm above the floor, e.g. to accommodate an intermediate rail (see Diagram 9).

Table 2 Minimum effective clear widths of doors

Direction and width of approach	New buildings (mm)	Existing buildings (mm)
Straight On (without a turn or oblique approach) At right angles to an access route at least 1500mm wide	800mm	750mm
At right angles to an access route at least 1200mm wide	825mm	775mm
External doors to buildings used by general public	1000mm	

Note:
The effective clear width is the width of the opening measured at right angles to the wall in which the door is situated from the outside of the door stop on the door closing side to any obstruction on the hinge side, whether this be projecting door opening furniture, a weather board, the door or the door stop (see Diagram 9). For specific guidance on the effective clear width of doors in sports accommodation, refer to 'Access for Disabled People'

Diagram 9

Figure 1. Regulation with RASE markup

The application allows the collaboration to document any equivalences between terminology used in the document and terminology in the model. This dictionary is held locally but work is underway to also use the buildingSMART Data Dictionary[10] and other services.

A named ‘case’ is defined as a list of normative documents and a list of descriptive models.

The descriptive knowledge is held as IFC[11] models, but can be supplemented by other sources, such as user responses to specific requests for otherwise missing information. Work is underway to accept other descriptive sources such as specifications, GIS content, product data, construction schedules and algorithms alongside the IFC ontology, covering the spatial, physical and process aspects of the built environment. A BIM model of an office building in the City of London was tested to discover if its entrance had satisfactory geometric and non-geometric arrangements for accessibility. The user may elect to test the entirety or to test only as far as the first failure/unknown. The rule engine algorithm methodically checks every normative metric against every descriptive attribute but with logical heuristics that ensure that only the minimum number of checks are performed. The outcome is the overall logical outcome as true (pass), false (fail) or unknown (more information needed). This is summarized on-screen and as BCF messages. Result presentations and formats include results tabulated by entities (figure 2), results tabulated by clause and results with suggested remedial actions. Other presentations can be added if required.

Entities

Case MON_MAK

AEC3

Norm

False : UKBRAD_M_2_13M

Model

Entities

Model	Entity	Identifier	Result
	Project Project_1	0prj0000000000ID0EKSAG	True (True in log)
	Site Site_1	0sit0000000000ID0EKSAG	True (True in log)
	Building Building_1	0bui0000000000ID0EKSAG	True (True in log)
	Building Storey Level-0	0str0000000000ID0EKSAG	True (True in log)
	Space Bay-0	0spc0000000000ID0EKSAG	True (True in log)
	Door I1	0cmp0000000000ID0EKSAG	True (True in log)
	Door E1	0cmp0000000000ID0EVVAG	False (False in log)

AEC3 **AEC3 Require1 nn@aec3.com**
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Figure 2. Results by entity up to first failure.

[10] https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/ Accessed 12 April 2021)
[11] https://www.iso.org/standard/70303.html Accessed 12 April 2021)

3 Conclusions and implications

RASE and AEC3 Require1 address previous issues of scalability, accuracy and credibility. The RASE methodology and AEC3 Require1 are being used in the UK Government sponsored DCOM[12] projects which is specifying and creating a suite of standardized APIs and distributed servers and services for the UK Regulatory documents, the rule engine, the model servers and the case/results management.

There are three key ideas underlying this approach

1. The normative documents are the primary driver.
2. Domain experts already have in BIM and in other applications code-less interfaces to create human- and machine-readable descriptive content.
3. Domain experts now have a code-less interface to create human- and machine-readable normative content.

When we consider how we wish to manage our social and our built environment, The easy capture and evaluation of existing and future rules is a significant alternative to Explainable Artificial Intelligence (XAI), Natural Language Processing (NLP), Data Mining (DM) and Machine Learning (ML)

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A reasoning-based approach for checking performance-based codes in digital building permit processes

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Performance-based building codes provide qualitative descriptions for design goals rather than prescriptive dimensions for design solutions (see Figure 1). They reduce unnecessary costs of complying with a limited number of acceptable layouts by allowing novel, creative solutions to argue for compliance [1]. However, in traditional code checking approaches, performance-based building codes are the subject of extensive manual processing which is often laborious and error-prone [2].

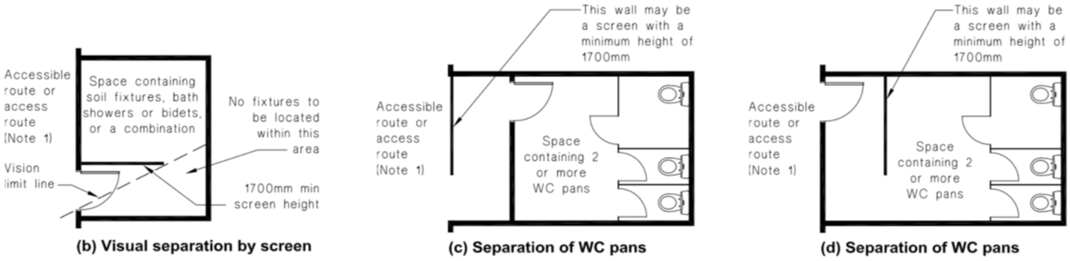

Figure 1. Examples of acceptable solutions satisfying the requirement "There shall be no direct line of sight between an access route or an accessible route and a WC, urinal, bath, shower, or bidet", taken directly from New Zealand Building Codes.

Figure 2 illustrates our proposed workflow for Digital Building Permit (DBP) processes: regulations are interpreted and encoded as logical propositions; building models are augmented with ***spatial artefacts*** [3]–[5] - fictive spaces induced by human-space interactions; formalised codes are checked against enhanced models in a logic-based reasoning engine; and checking results are iteratively refined and optimised based on design practices and guidelines [6], [7].

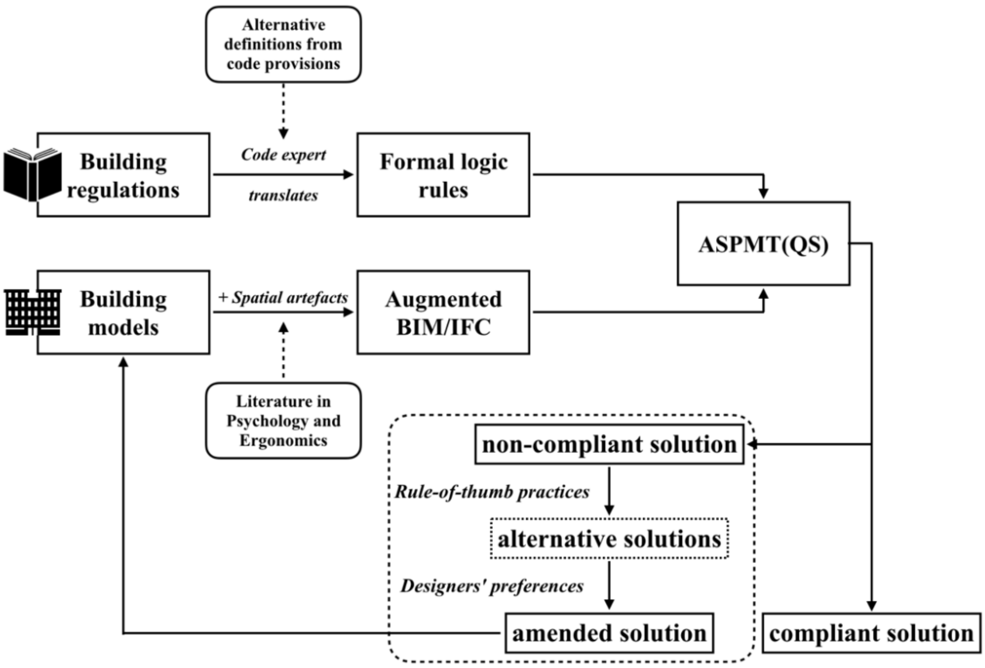

Figure 2. Proposed workflow for DBP processes, adapted from [8].

Automatically representing and reasoning about descriptive codes increases the amount of regulations that can be digitally processed [9]. However, qualitative codes raise several practical challenges as numerous, competing definitions exist for disambiguating vague, elusive regulation terms. This further leads to obscure checking methods (simulations, parametric tables, ad-hoc algorithms) and arbitrary checking results [10].

From a rule encoding perspective, descriptive codes elicit qualitative terms such as ***line-of-sight*** and elude to implicit spatial knowledge including form, orientation, topology, and hierarchy. Maintaining a large number of alternative definitions and their provenance in a procedural language is highly unpractical. Meanwhile, encoding incomplete, fallible commonsense knowledge naturally stipulates various forms of non-monotonic reasoning (belief revision, causal explanation, knowledge interpolation) that extend beyond the capabilities of rule-based languages with closed world assumptions[1].

From a model preparation perspective, qualitative codes evoke occupant experiences and behaviour such as ***visibility***, ***audibility***, ***egress***, ***wayfinding***, etc., but detailed parametrisation of these concepts vary greatly depending on the occupant, task, situation, and purpose. A simple compliance check thus consists in navigating a large number of combinations of anthropometric data, conditioned by subjective interpretations of code semantics and targeted user groups. This is distinct from typical model enrichment approaches that infer relatively objective attributes from metric and nominal properties of a building on a case-by-case basis [11].

From an implementation perspective, prominent rule checking approaches prove to be insufficient to tackle the logical intricacy, combinatorial complexity[2], and domain specificity embedded in qualitative regulations. Graph-based approaches such as BPMN and VCLL assume a perfect procedural clarity to execute interdependent rules, but are unfitting for modelling redundant, conflicting, and inconsistent information [12], [13]. Human-readable syntactic languages such as LegalRuleML and Gherkin are able to model deontic and defeasible logic in normative texts, but are not directly executable [14]. Query languages such as SHACL and GeoSPARQL provide native spatial support but offer limited customisation and verification possibilities [15], [16].

To negotiate the above limitations, we propose a novel, systematic approach based on the declarative logic programming language, Answer Set Programming (ASP), to support DBP processes. ASP is a three-valued logic system specifically designed for highly combinatorial problems. Our extension of ASP, ASPMT(QS) [17], [18], has built-in spatial ontologies and data structures for fast, robust query-answering and rule checking [19]. Combining the expressiveness of database languages and the verifiability of logic programming, ASPMT(QS) is well-suited for:

- (declaratively) representing alternative code definitions so they can be traced back to motivating literature in psychology and ergonomics for a uniform and coherent rule interpretation
- (dynamically) integrating numerical calculations with logic reasoning to define custom spatial functions such as ***visibility polygons*** for a modifiable, extensible rule encoding
- (natively) supporting spatial optimisations such as octrees so that they are applied automatically for a scalable and portable rule execution
- (transparently) encoding rules and constraints so checking results can be clearly explained and verified

We empirically evaluated ASPMT(QS) on a number of real-world BIMs in the context of checking qualitative codes pertaining to ***privacy***, ***accessibility***, ***wayfinding***, and ***construction safety*** and demonstrated promising results [20], [21].

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[1] Also known as non-monotonic logic, commonsense reasoning is never purely deductive, but rather abductive or explanatory. That is, humans tend to make default assumptions and plausible hypotheses to explain current observations based on their background knowledge. Such logics cannot be easily encoded in deductive databases or languages that consider knowledge as deterministic and infallible.

[2] Also known as NP-hardness, this complexity comes from a combination of different types of occupants, actions, and situations which generates a large search space, but also from the non-monotonicity of common queries such as multi-objective optimisations under constraints.

In the next step, we intend to integrate a building's physical manifestation with architectural rationales to preserve, transfer, and exchange high-level requirements and constraints. In the context of EUnet4DBP, this will enable a flexible, sustainable, and human-centric view to building compliance audits which focuses on the principles and intentions of performance-based building regulations.

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Hidden challenges in development of digital solutions for processing of building regulations

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Why do we not see more development of digital solutions for processing of building permit applications? The Norwegian Building Authority developed the "ByggSøk" (Building-Application) solution in 2007 [1]. This is a web-based solution for verification of filled-in application forms related to specific types of applications. The "CORENET" e-Submission System [2] from 1995 in Singapore is also well known. One should therefore assume that these solutions were used in other countries, but this is not the case. Even if these are used successfully in their separate, transfer to other countries has not been observed [3]. A study in 2013 [4] gives a very good overview of all development initiatives. On the other side, on a few have resulted in applicable solutions.

Solibri Model Checker [5] is a well know software for BIM based model checking. However, the is mostly used for clash detections and nor compliance checking according official building regulations. The gap in was demonstrated in a Norwegian study [6]. BIM based design processes enables a foundation for digital processed validation of content in the BIM related to defined criteria. In this respect we see proof of concept demonstration exemplified by studies of automated sustainability compliance checking [7] and BIM-based code checking for construction health and safety [8]. Use of parametric modelling is demonstrated in the PhD thesis by Gade [9]. This approach includes user-participation in of best practice-based rules.

This study explores the critical elements missing in this development process by use of integrated design and delivery solutions (IDDS) as framework [10]. IDDS focus the integration of Integrated Processes – Collaborative People – Interoperable Technology (PPT). Regarding assessment of implementation following elements are analyzed: Drivers for change – Enablers – Barriers – Opportunities. In this respect research overfocus on BIM / digital based technology and priority to enablers in relation to drivers for change [11].

Even if you can digitalize 95% or the requirements, this do not prove that 95 % of the processes can be digital processed. If the missing %-age is in the beginning of the process – use of an applicable solution stops up. It is therefore very important to identify and solve these challenges in front of the programming part of the project. The RASE framework developed by Hjelseth and Nisbet [12, 13, 14] demonstrate that there i a structured way to transform text and numeric requirements in building regulations (in principle all types of requirements) into computable rule. This transformation process is described as combination of legal interpretation, programming, and a multiciliary mix between legal an informatics [15]. The importance for this discipline combination is an important success factor to enable "Transformation" in the Tx3 taxonymy, see figure 1, developed by Hjelseth [16] as a supplement to the RASE framework.

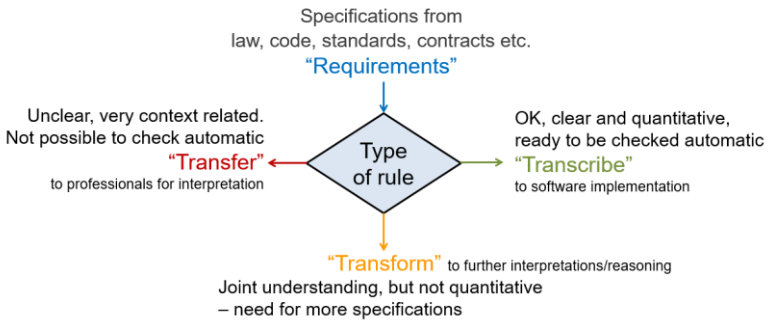

Figure 1. Taxonomy into type of rules, Tx3

It is very hard to find focus on this interpretation of transformation process within BIM based code checking in scientific literature and in industry magazine. From the authors point of view, it looks like this process is taken forgotten, due to use of prescriptive requirements as case for demonstrations of developed methods and digital solutions [17].

However, not all requirements are expressed as simple prescriptive rules. The challenge is both related to interpretation of performance-based requirements and prescriptive requirements where the need for specified is not direct accessible in BIM, GIS or external sources/registries [18]. It is therefore a gap between the positive results from proof-of-concept (PoC) studies addressing relatively simple prescriptive requirements. Another situation is that the case used in the PoC is relatively simple to solve manually. The cap between what is applicable in BIM based model checking – and what is the real need for practitioners was demonstrated in a study by Hjelseth [6].

Research focus on development of advanced methods / technology, while the practitioners wanted to validate compliance with a limited number of public requirements, in addition to assess if the designed building was in accord with own best practice. The IDDS framework [10] illustrate that the technological perspective is very well cowered, and do not appear to be a showstopper. The missing part was related to defragmented processes, where the first phase in interpreting the requirements in a way making them applicable for digital processing. This are a difficult task, even when done manually by professionals. This imply also that if the process can be supported by digital solutions – this itself will be an improvement for the stakeholder. The digital solution can vary from decision support by presenting relevant information (complete application) to automatic processing of decisions without human interference [16].

The challenges described above is possible to solved in a structured way, but this require stamina and dedicated effort to develop supporting methods, systems and frameworks [17]. Increased development of semantic and organizational interoperability is one example relevant to support a scaling up. Related to an integrating approach [17] the priority should be given to two improvement. Increased focus should be given to improvement of norm representation, where the RASE framework can be an appliable method. Another important improvement development of better rule encoding solution as input for the reasoning engine [19, 20]. In this way can performances-based regulations be included as a natural part in development of digital building permit solutions. Compared to communities within digitalization has the EUnet4DBP network priority to a holistic approach. This role can enable development and reuse of applicable digital solutions for all partners.

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2.6 Session 5 - Technology

GeoBIM for the digitalization of building permit checks.

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In line with the digitalization tendency of public administration processes and data, aimed at increasing efficiency and automation of processes, towards a final quality improvement, a study was developed[1] from October 2019 to July 2020, funded by the municipality of Rotterdam within their 'digital city' pilot.

The automation and digitalization of the building permit process has a relevant role for increasing the effectiveness of regulations checks, by reusing of data, optimization of processes, increase of objectivity in analysis. In addition, it would feed other related good practices, such as buildings digital logbooks, allowing reduction of waste, transparency and, finally, a higher environmental quality.

However, although several studies and pilots address the issue (e.g., Choi et al., 2015; Clayton et al., 2013; Eastman et al., 2009; Future Insight Group, 2019; Hirvensalo et al., 2009; Solihin et al., 2020), many of them mostly refer to conceptual approaches, often starting from the prescriptions of the Industry Foundation Classes (IFC) model by buildingSMART, leaving a gap with respect to the models that are actually provided by architects. In addition, as we know from previous experiences (e.g. Noardo 2021, Noardo 2020a,b) the use of open standard formats in data is a necessary condition but not sufficient to ensure a smooth interoperability of tools and information across different platforms and uses.

Because of this, we chose a bottom-up approach as most effective to reach solutions usable in practice: main objective was the use of data as they are provided from professionals to check two regulations involved in the building permit issuing process. Moreover, the focus was on the integration of the involved building information models (BIM), in IFC format, and geoinformation: the relationship of the newly designed building with their context is often at the center of several regulations, but few studies (van Berlo et al., 2013, Olsson et al., 2018) address it properly.

The two regulations were identified together with municipality officers, among the ones having advantage from the integration of BIM with geoinformation. The regulations about building dimensions and provision of additional parking places according to the new designed building were studied. We departed from the data as available (i.e., the IFC models provided by design firms, the regulations as they are written in the municipality codes, and the available geoinformation). This gave us the opportunity to tackle basic and common issues to most of models, regulations and integration efforts, which are often preventing a smooth automatic processing.

The initial part of the work was aimed at correctly interpreting and formalizing the two regulations, which was mainly a manual process, in close collaboration with the municipality officers (Noardo et al., 2020c).

Second (Noardo et al., 2020d), the available models were inspected and analysed (mainly by means of manual procedures within IFC viewers and text editors) in order to point out how such information could be most reliably used and which are the flaws that could instead hinder their use or produce unreliable results (Figure 1).

According to the findings of such preliminary steps, a tool[2] was developed, based on *IfcOpenShell*[3] to support the municipality in the check of the dimension regulation (Figure 2). In particular, the tool is able to extract the storeys profiles and use them as base to calculate, at first, their reciprocal overlap. This information can be used to detect two building parts foreseen by the considered regulation (a building base and a top tower). According to this, the rest of the regulation constraints can be checked:

[1] https://3d.bk.tudelft.nl/projects/rotterdamgeobim_bp/ Accessed on 07 April 2021
[2] https://github.com/twut/GEOBIM_Tool Accessed on 07 April 2021
[3] http://ifcopenshell.org Accessed on 07 April 2021

overlap of the two parts; maximum height of both the whole building and of the building part representing the base; overhang of the top part with respect to the base towards the two enclosing streets. A further development of such tool will aim at improving the integration with geoinformation, allowing the automatic retrieval of some useful parameters and references (such as the position of the two enclosing streets).

The regulation about parking places provision could not be completely checked through an algorithm because of the serious lacks in the models.

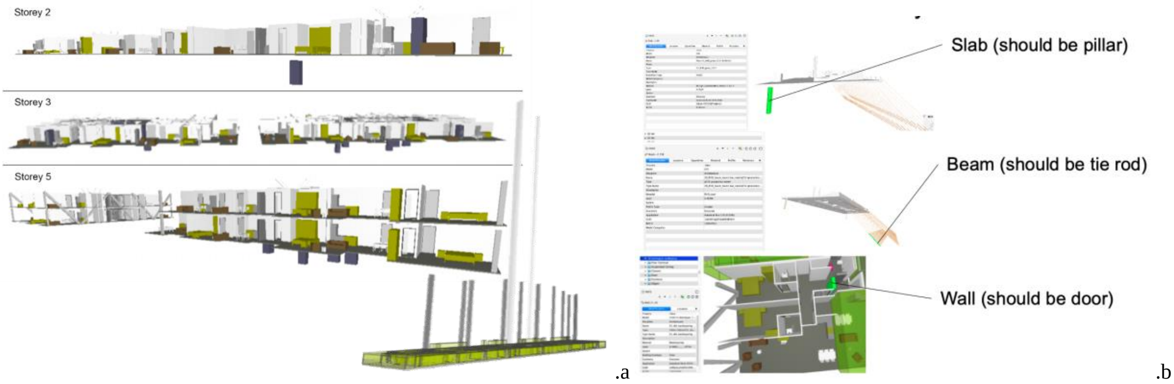

Figure 1. Example of IFC models inaccuracies: in grouping of IfcBuildingStoreys (a) and semantics (b).

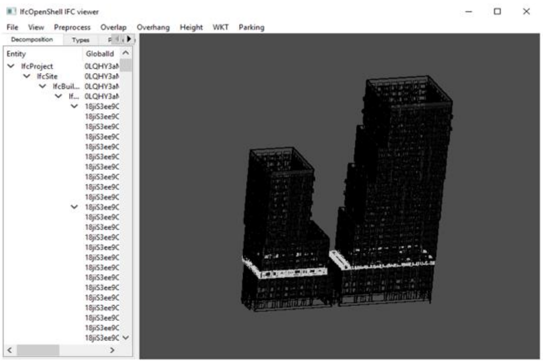

Figure 2. The interface of the developed tool.

Finally, some guidelines were provided about specific care to be followed when modelling the BIM or the geoinformation and when writing regulations. Such guidelines are a starting point to be developed more specifically and to be implemented in collaboration with professionals and modelers themselves and in accordance with software programmers.

Among such guidelines, georeferencing represents an important feature, essential premise to integration with geoinformation. A workflow was proposed together with options to store georeferencing information consistently and consciously, based on (Clement and Görne, 2019).

While the case study is specific in location, regulations and input models, the type of issues encountered is exemplary for automated code compliance checking in general.

Critical initial outcomes were achieved as a solid base to plan the following steps and on which to base the future work.

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LINKS TO RELEVANT RESOURCES

Project website

https://3d.bk.tudelft.nl/projects/rotterdamgeobim_bp/ Accessed 07 april 2021.

Related papers

Noardo, F., Malacarne, G., Mastrolembo Ventura, S., Tagliabue, L. C., Ciribini, A. L. C., Ellul, C., Guler, D., Harrie, L., Noardo, F., Wu, T., Arroyo Ohori, K., Krijnen, T., Tezerdi, H., & Stoter, J. (2020). GEOBIM FOR DIGITAL BUILDING PERMIT PROCESS: LEARNING FROM A CASE STUDY IN ROTTERDAM. *ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences*, 6. https://www.isprs-ann-photogramm-remote-sens-spatial-inf-sci.net/VI-4-W1-2020/151/2020/ Accessed 07 April 2021

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Developed tool, with related instructions and documentation

https://github.com/twut/GEOBIM_Tool Accessed 07 April 2021

Data

Any IFC data having a sufficient good quality (especially, the grouping of *IfcBuildingStoreys* should be accurate enough) can be used to test the tool.

Automated Code Checking in the Epermit BIM Process

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1 Intro

The purpose of our presentation is to allow participants, if wished, to an evaluation (through a test software on shared model) the progress on the BIM model checking tools and their user friendliness and customization.

We will focus on checking activity from:

- Public Administration side: once the BIM models have been implemented, P.A. has the responsibility to check compliance to local norms and standards.
- Designer side: once the BIM models have been developed, he's able to verify if all the design regulations have been correctly applied during BIM Authoring phase. If yes, the designer proceed with request for authoration working.

2 Current situation

First of all, let's make a point of the situation to the activity, to establish a common departure in relation to the Regulatory Control in BIM models from an Epermit perspective.

The verification activity plays a fundamental role within the authorization process of building and urban planning practices.

Once the project has been developed, the designer produces some documents aimed to achieving regulatory compliance of the project. The delivery of this file to public administrations initiates the authorization process to obtain the building permit or to request variations and additions to the proposed project.

P.A. technicians use to take several days to analyse a single practise via a manual control method. This affects the remaining building practices still to be checked, which very often accumulate. In addition to this, the checks are mainly related to those design aspects involved in the costs calculation that have to be paid to the Municipality. The lack of time and the need to respect the limits of law within which to provide a response to the user affects the quality of controls. As a result, some checks are carried out on a sample basis, allowing for a margin of error on each project analysed.

3 Automated code checking profits

Being able to automate these checks would ensure a better efficiency of the control and authorization process as well as a considerable reduction in the time required.

In the Epermit authorization process, it can be assumed that the Public Administrations provide a portal where all designers interested in an authorization request for a project can upload the BIM models produced and obtain their approval.

At this stage, the IFC format is of fundamental importance to ensure the impartiality of the procedures and therefore guarantee the concept of Open.

After the appropriate checks, the portal would respond to the professional automatically with a pre-acceptance of the case by delivering it via e-mail, attaching the reports of the problems highlighted by the check.

This automated flow hypothesis has been extensively covered in a series of tests that have underlined its feasibility. It is thanks to current technologies, provided by programs and web portals, that checks can be automated, reports created and authorization documents sent.

A specific example of this activity can be cited for the Solibri software, from the company of the same name, which deals with Model & Code Checking. Solibri Office allows you to automatically start a set of regulatory verification rules and then automatically save the result of this analysis in reports in traditional format (PDF, XLS), in OpenBIM format (BCF) or directly in 3D format (SMC)), without operator intervention.

Obviously, these checks are appropriately configured by the user before loading the set of rules into the automated system.

4 Checking with Solibri

With regard to verification checks, Solibri provides specific rules that can be customized for both geometric and informative checks, as well as regulatory ones. These rules automatically highlight the differences in the models, classifying them according to the seriousness of the problem. The ranges of values that identify low, medium and high discrepancy problems can be customized by the user, thus managing any limit situations.

In Solibri there are many basic rules (f.e. min distance between objects, min dimensions of the objects) that could be composed to apply a specific code checking, based on the norms.

The following are the main compliance checks to Italian legislations available by default in Solibri (however, in the standard installation there are other types of controls):

- Verification of compliance with hygiene and building regulations (room minimum height/area/ volume, window/floor surface ratio, minimum expected cleareance around a specific components, etc.);
- Verification of minimum geometric dimensions for stairs, windows, doors, etc;
- Verification of the minimum surfaces of the premises and accommodation in relation to their function (an hospital room must have a surface area more than *xxx* m2, etc);
- Verification of accessibility to stairs, ramps, spaces (to verify if a wheelchair is able to freely turn with a specific diameter into a space, etc.) and the presence of architectural barriers obstructing their access;
- Fire prevention checks (the presence of devices for fire detecting or extinguishing, the presence of a requested fire class resistance for specific components, free accessibility to fire extinguishers, hoses etc.);
- Evaluation of the escape routes (travel maximum distance, routing method used, starting point and exits, fire zone priorites to escape, minimun passageway height and widht, etc.);
- Safety checks (presence of properly designed protections, such as barriers and rails, against the risk of falling from above);
- Hospital regulatory and accreditation checks.

Once the checks have been carried out, any discrepancies in the model, with respect to the regulations applied, will be automatically grouped into a presentation: all the reports extracted will be represented by dynamic 3D images accompanied by the user's technical notes and the list of problematic components.

5 Issues communication

As anticipated in relation to the Epermit process, through a series of reports proposed by the software, it is then possible to communicate the differences to the various designers and sector specialists, to request their correction within their modeling software, where they generated the model checked.

These reports can be exported both as table files (XLS) and as text files (RTF, PDF).

In addition they can be generated as a 3D report, i.e. as an SMC and BCF file.

This last format is the acronym of the definition BIM Collaboration Format and, in the BIM modeling software, allows to:

- ✓ read the notes relating to the criticality highlighted;
- ✓ visualize/zoom directly the problem in 3D by way of an automatic link to the critical components;
- ✓ automatically highlight the elements that generate the problem to be corrected.

The last format is effective for the communication, and therefore the localization, of the problems between professionals participating in the BIM process, effectively completing the interoperability between the various disciplines.

The SMC format, on the other hand, can be viewed through the free Solibri Anywhere program which also allows you to access the rules applied for verification, having a preview of the reference values considered in the control.

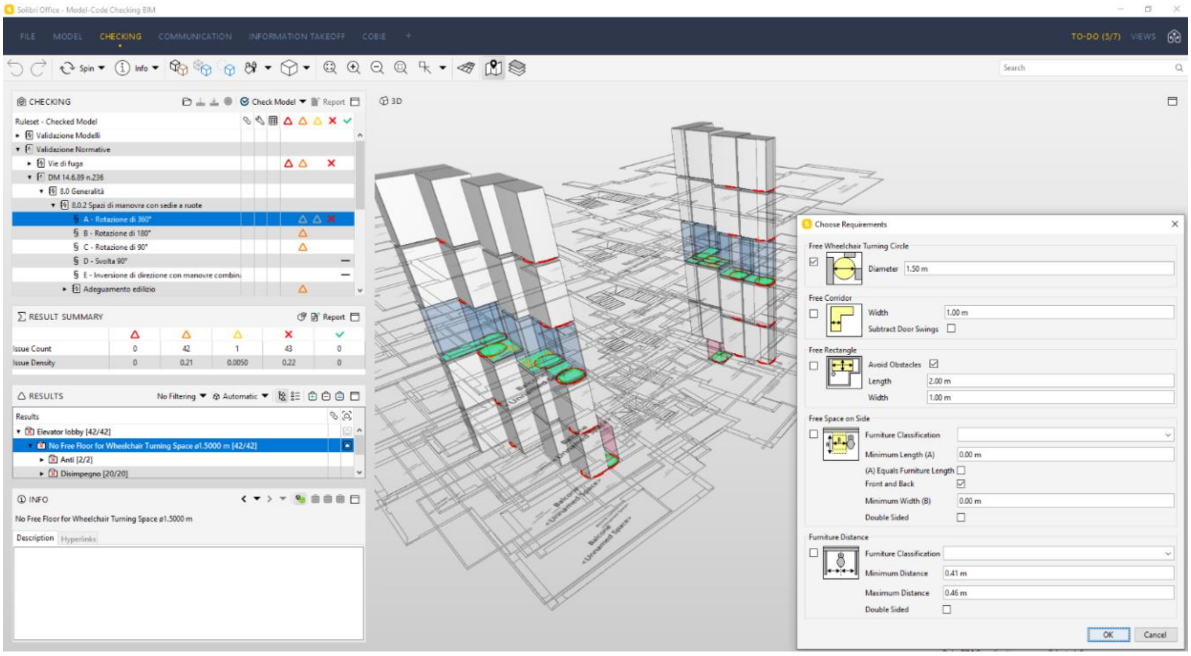


Figure 1. Example of application of rules and checks related to D.M.14/06/89 n.236.

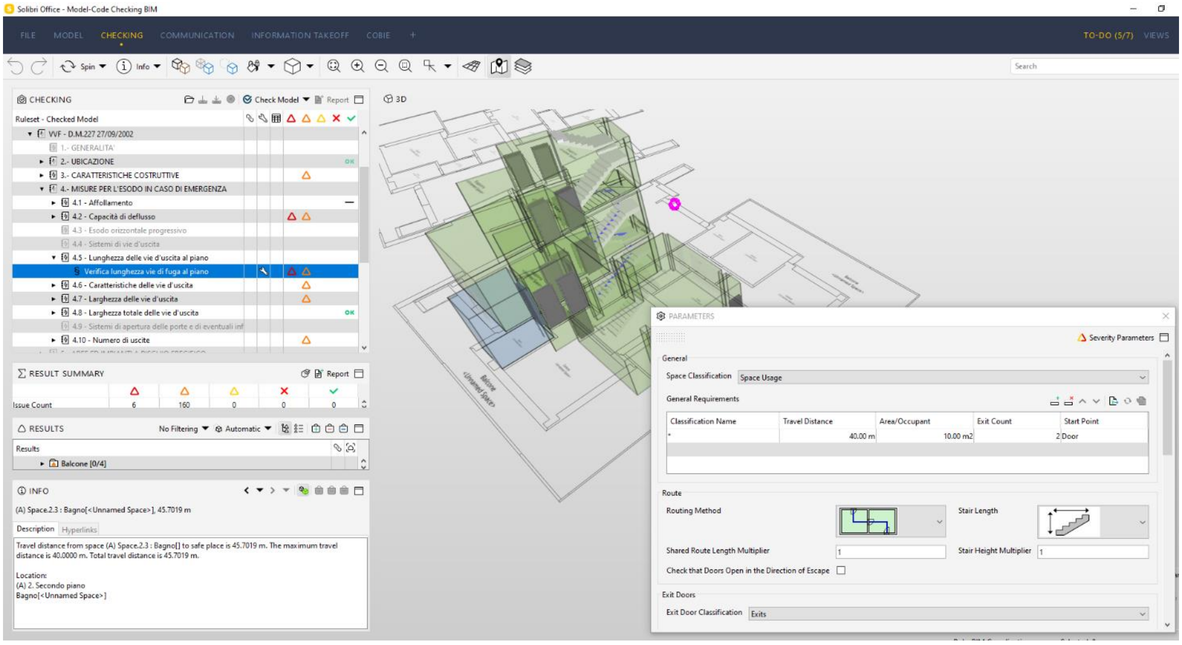


Figure 2. Example of application of rules and checks related to D.M.27/09/02 n.227.

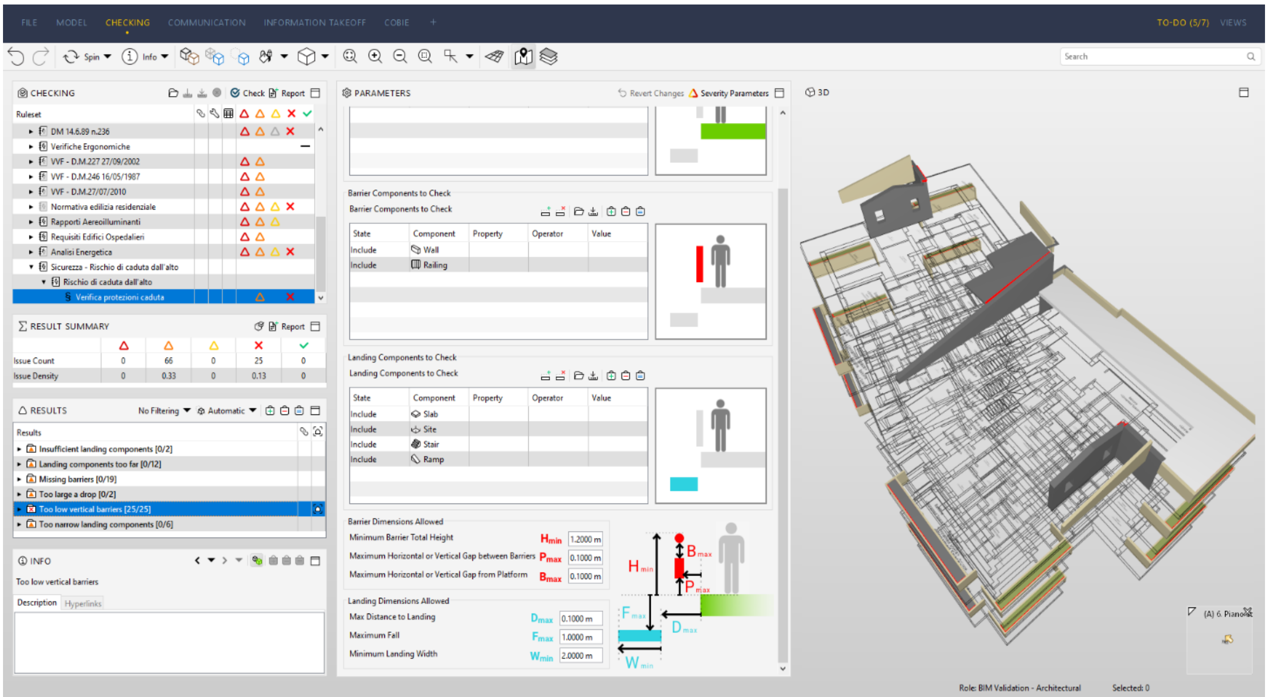


Figure 3. Example of application of rules and checks related to the safety of buildings and construction sites.

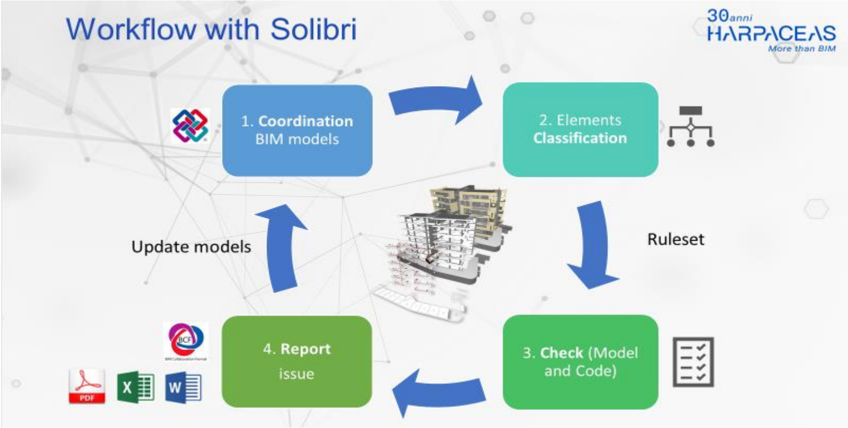


Figure 4. Code Checking workflow in Solibri.

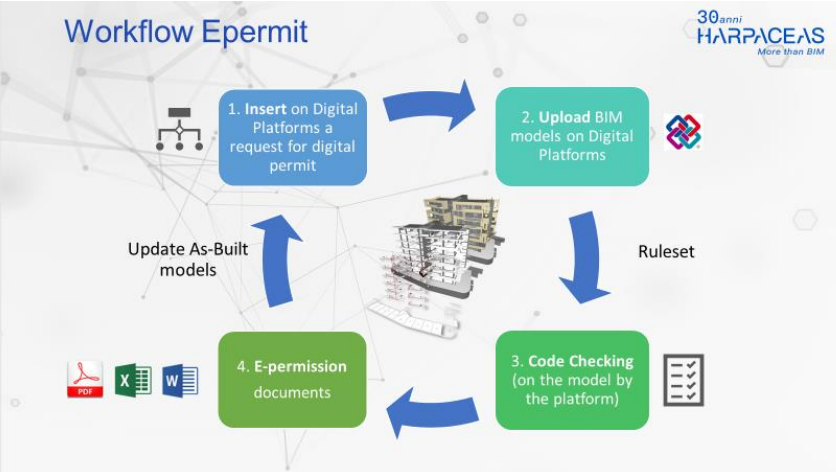


Figure 5. E permit workflow based on automatic checks.

LINKS TO RELEVANT RESOURCES

Epermit article published on Ingenio:

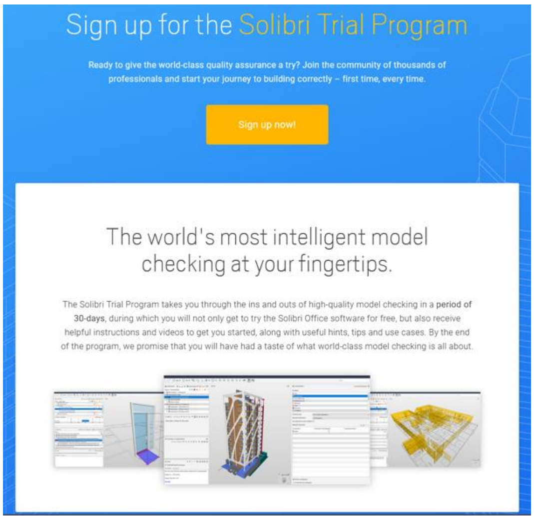
https://www.ingenio-web.it/24602-le-potenzialita-del-controllo-normativo-nei-modelli-bim-in-ottica-e-permit

System Requirements:

https://www.solibri.com/solibri-system-requirements

Trial version SolibriOffice version 9.12:

https://www.solibri.com/download-solibri-trial?step=1



The trial version Office is complete, without limitations compared to the paid version, and expires after 27 days. During the trial period, the user will be guided through a series of emails, managed by the Solibri company, with the help of a manual (Getting Started) and some educational videos, to allow the user to optimize the test independently.

At the end of the test the software remains installed and can be used as a viewer for IFC and SMC files. It will therefore allow during the workshop to reopen the smc file shared below.

Download Test model (smc file, open with Solibri):

https://harpaceasitaly-my.sharepoint.com/:u:/g/personal/alli_harpaceas_it/EVHxn3IPfJNGtQGr_Q315osBUFgw06bfjhytW8X2ciDRvQ?e=ye3u4u

BIM as a multiscale facilitator for built environment analysis

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1 Problem, goal and methodology

This research examines the use of digital data to understand better the relationship between buildings and cities. The problems addressed regard interoperability in the exchange of information among different spatial scales. The goal is to facilitate multiscale data exchange by leveraging BIM tools and processes through data integration strategies. The methodology adopts a literature review and a case study in collaboration with a Slovenian architecture firm.

2 Literature review

In 2019, the EU published the "Clean Energy for all Europeans Package" that revised the Energy Performance of Building Directive (European Parliament, 2018) to accelerate the shift toward cleaner energy. In 2020, the Integrated Digital Built Environment Group published a document comparing three standards covering different spatial scales (Gilbert et al., 2020). This research focuses on CityGML(Gröger, Kolbe, Nagel, & Häfele, 2012)[1] and IFC[2]. Looking at environmental assessments, researchers are developing Urban-Scale Energy Modelling platforms (Sola, Corchero, Salom, & Sanmarti, 2018), while at the building scale Building Energy Modelling is already well established.

A comparison between CityGML and IFC shows a similar structure composed of a core and additional components. For energy analysis, CityGML captures domain-specific information with the energy Application Domain Extension (Benner, 2018; Nouvel et al., 2015). Regarding IFC, work is ongoing to produce an Information Delivery Manual leading to an MVD for building energy analysis[3]. The two data schemas can both represent buildings, but their detailed structure is different.

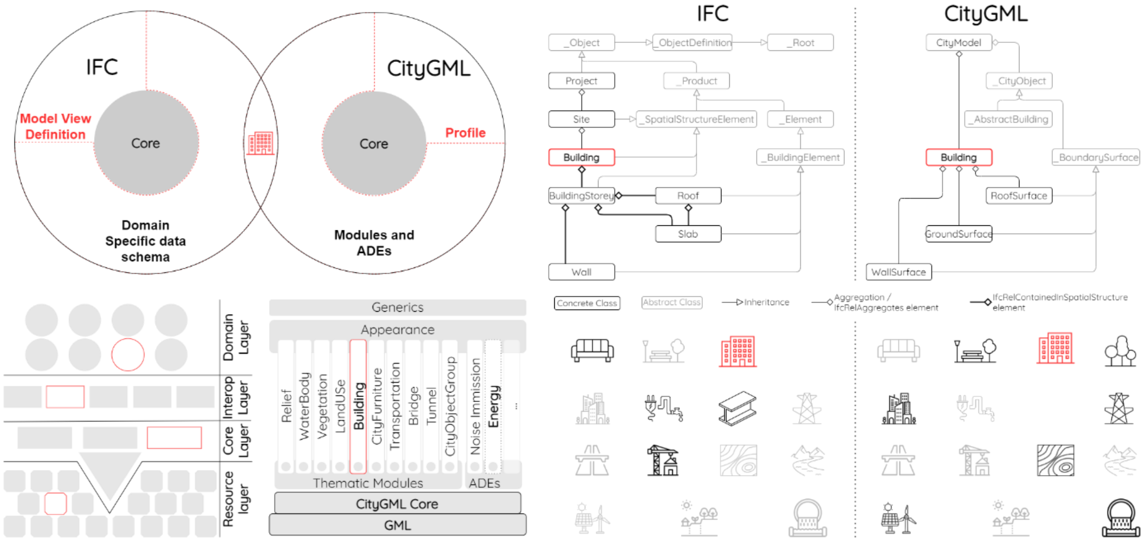

Figure 1. Modified from Gilbert et al., 2020

[1] https://www.ogc.org/standards/citygml
[2] https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/
[3] https://vimeo.com/483114055

Researchers have proposed a framework called City Information Modelling (Xu, Ding, Luo, & Ma, 2014) to integrate GIS and BIM. However, the schemas' different structures obstruct data integration (van Berlo & de Laat, 2010).

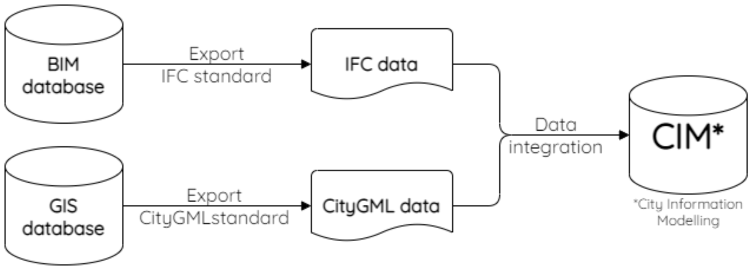

Figure 2. Modified from Xu, Ding, Luo, & Ma, 2014

This research proposes a workflow for multiscale information integration that requires exporting BIM data in IFC and then restructuring the data matching the CityGML schema. The output is stored in an urban database and used for different applications.

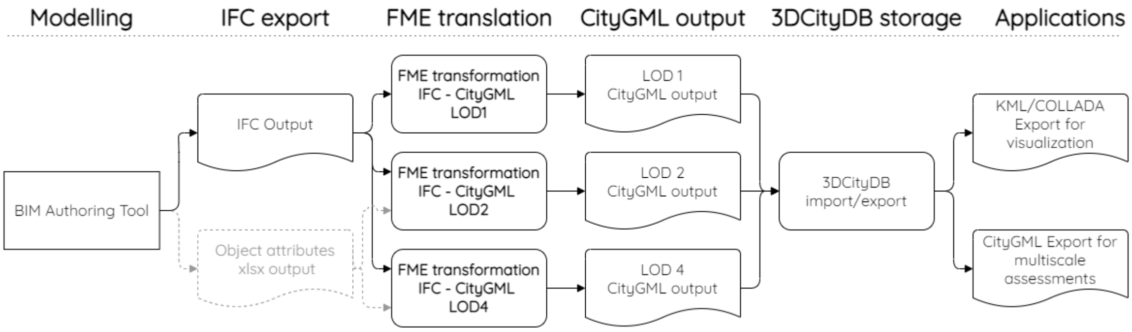

Figure 3. Modified from Jusuf, Mousseau, Godfroid, & Soh, 2017

3 *Top-down approach*

The top-down approach built a semantic 3D urban model for two districts of Ljubljana starting from institutional open-data, adopting a Service Oriented Architecture system to describe the creation and usage of the city model.

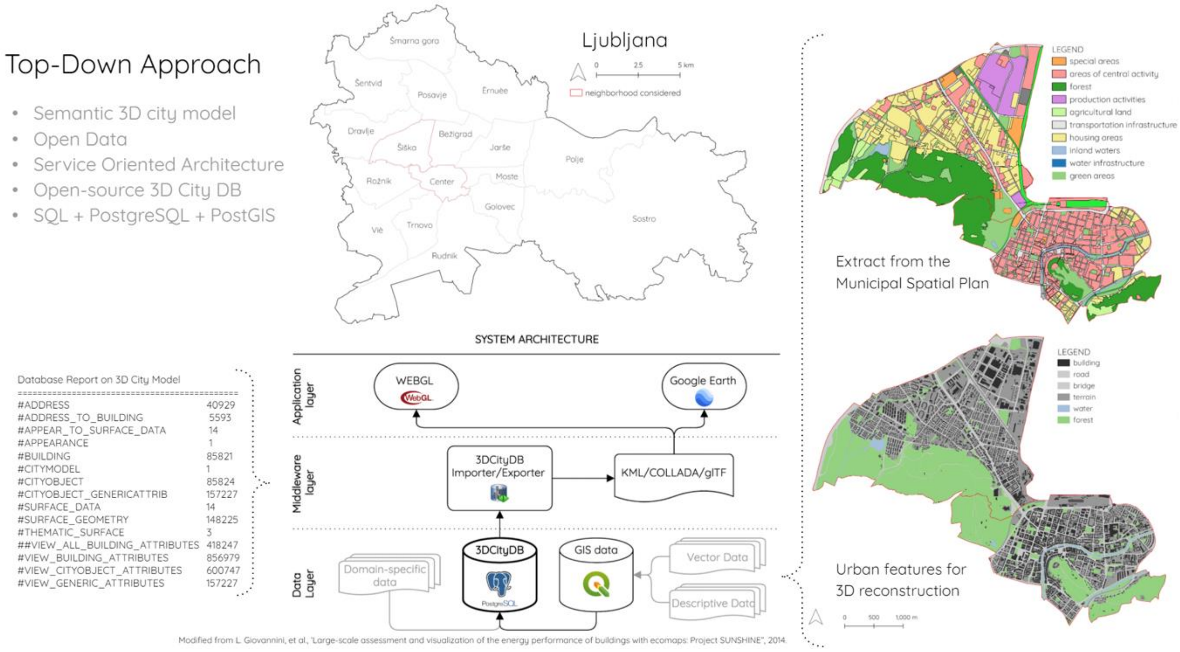

Figure 4. Top-Down approach. Service Oriented Architecture schema modified from Giovannini, Pezzi, Di Staso, Prandi, & De Amicis, 2014

The process comprises the modelling of geometric features and the enrichment with attributes. GIS shapefiles and Lidar data are combined to generate CityGML 3D geometry (Ledoux et al., 2021). The model is then imported into a database[4] and enriched with buildings attributes. Here, the data can be managed, queried, and exported for intended applications. Users can enrich the CityGML model for energy analysis using the Energy ADE (Agugiaro, 2016; Agugiaro, Benner, Cipriano, & Nouvel, 2018). However, energy data was either not available or distributed in PDF format.

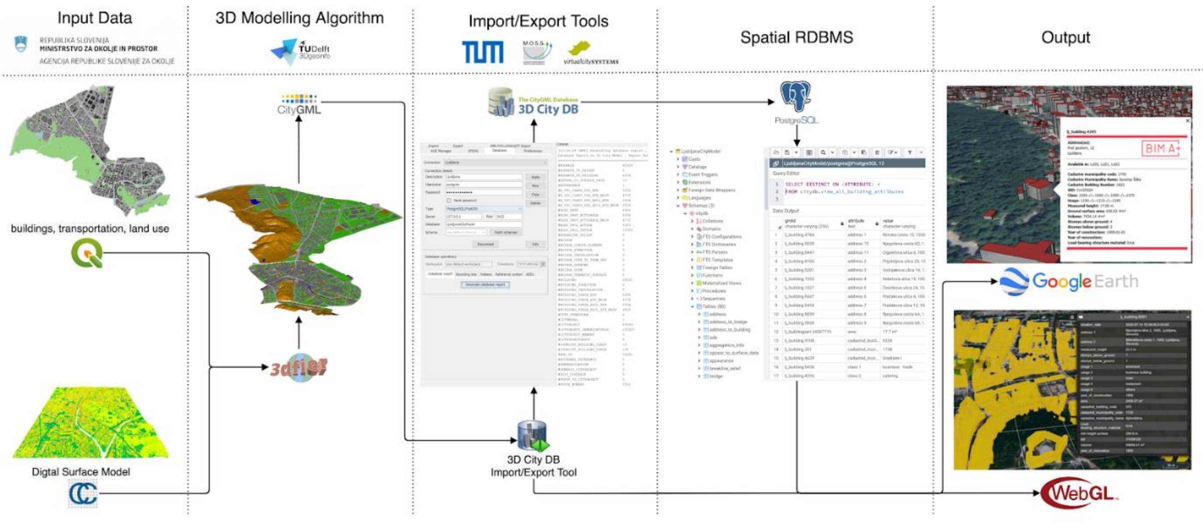

Figure 5. Semantic 3D City Model. Data and tools.

[4] https://www.3dcitydb.org/3dcitydb/

Figure 6. Output from the 3D modelling algorithm 3dfier5 visualized in Google Earth client

Figure 7. The output of the data enrichment process visualized in the 3DCityDB Web Map Client[6]

4 Bottom-up approach

The case study for bottom-up data integration involves the renovation of a historical Hotel in Ljubljana. It was built in 1909 and declared a cultural heritage in 2007. The building will be partly demolished and reconstructed with a new addition. The facility adopts energy-saving principles, heat conservation technologies and passive design strategies.

[5] https://3d.bk.tudelft.nl/code/
[6] https://www.3dcitydb.org/3dcitydb/3dwebclient/

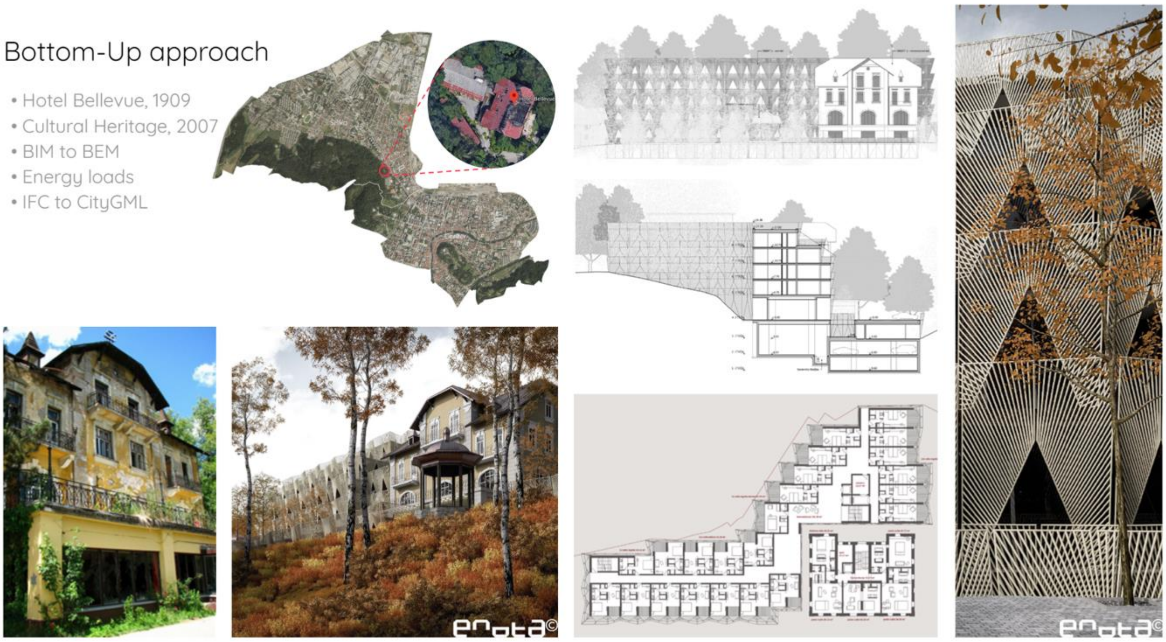

Figure 8. Bottom-up approach. Case study building location and proposed design

The process comprises three steps: the enrichment of the BIM model with the requirements for a Building Energy Model, the energy demand assessment, and the data integration in the CityGML database.

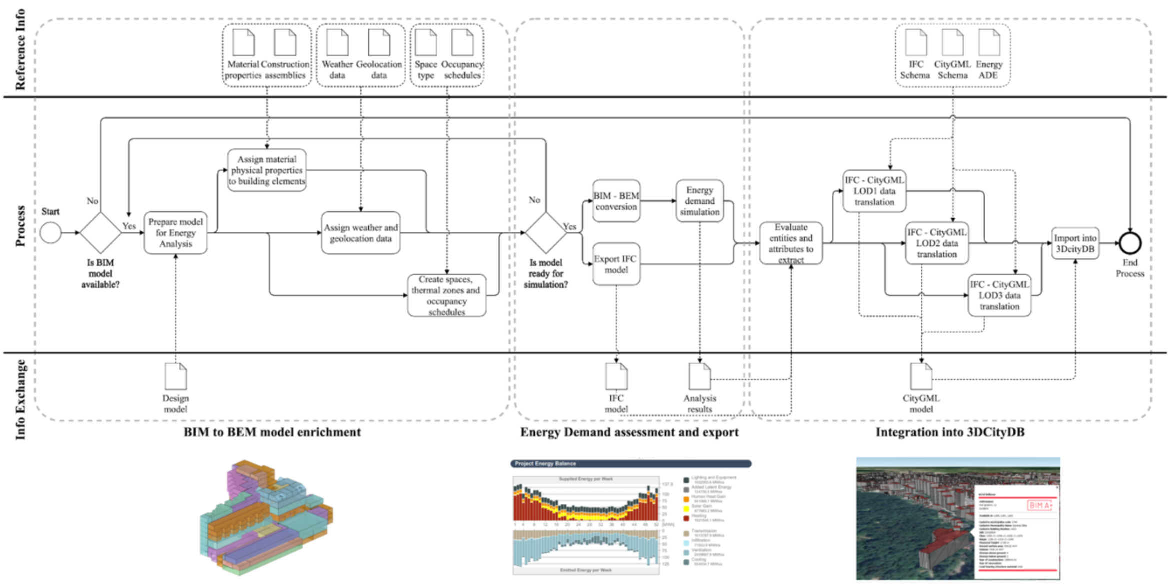

Figure 9. Process map describing the workflow, reference information and information exchange for IFC and CityGML data integration, including energy demand assessment data.

The process to Extract, Transform and Load (ETL) data from IFC according to the CityGML schema was applied using a tool for data integration[7]. The definition of LOD differs between CityGML and BIM. At CityGML LOD1-2, both require similar transformations, but the CityGML LOD4 conversion unveils how the IFC schema is more elaborate than CityGML (Jusuf et al., 2017). The process exported inconsistencies in some features because of the modelling process adopted to account for

[7] https://www.safe.com/

demolitions and reconstructions. While the whole process can be considered successful, more research is needed to assess the ability to handle domain-specific information.

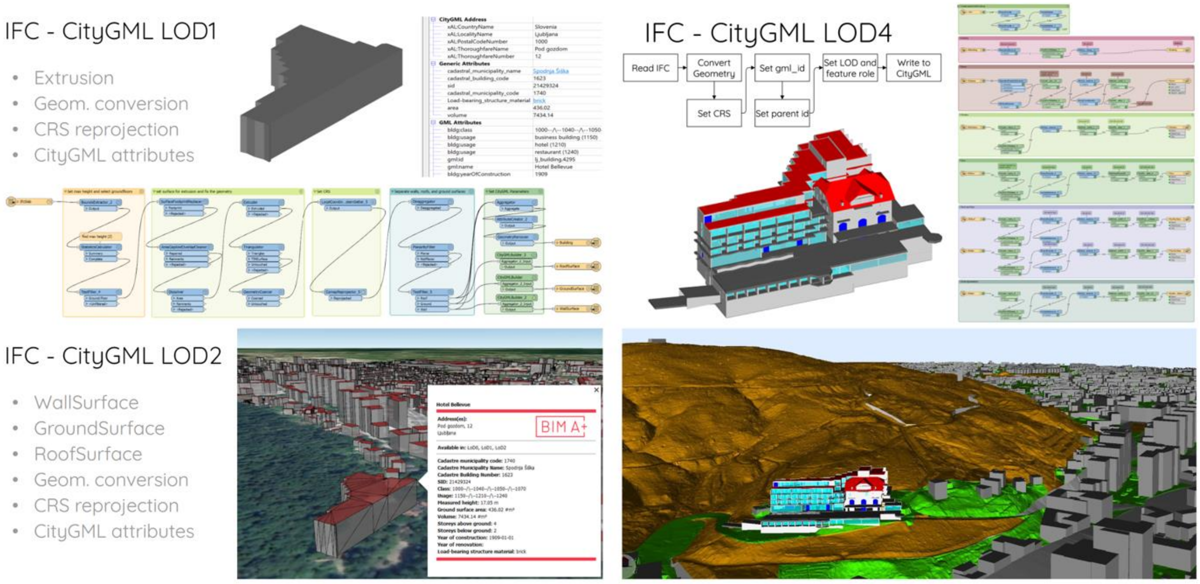

Figure 10. ETL process from IFC to CityGML using FME (Feature Manipulation Engine).

5 *Conclusion, lessons learned and future applications*

A multiscale analysis of the built environment is possible, with some limitation. Semantic modelling is helpful only if stakeholders agree on standard definitions. The process needs standardization and the definition of roles and responsibilities. For digital information exchange, understanding data schema is essential to avoid loss and misuse of data. The process is complex, but it can be repeated and scaled.

Further research is needed into the harmonization of data models and collaboration procedures. An effort in standardization for environmental analyses is required. Public bodies should work toward open energy data in a machine-readable format.

Some future applications of this work:

- The workflow could be integrated into the digital building permit process. For example, practitioners could acquire the 3d contextual data and semantic information from the city model. Public employees could verify the design against urban standards and update the model with the as-built model.
- A decision-making tool to assess new urban developments or
- An evaluation tool to verify the sustainability of urban energy policy.

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LINKS TO RELEVANT RESOURCES

Thesis website

BIM as a multiscale facilitator for built environment analysis:

https://repozitorij.uni-lj.si/IzpisGradiva.php?id=121115

Used tool

3DCityDB: https://github.com/3dcitydb

3dfier: https://github.com/tudelft3d/3dfier

FZKViewer: https://www.iai.kit.edu/english/1302.php

FME: https://www.safe.com/

Development of a New Eco System for Automatic Code Checking based on BIM Bots Technology

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1 Introduction

According to TNO[1], digitisation of the construction process and in particular the far-reaching adoption of BIM in the building sector allows for the implementation of automatic code checking. In the future, this will enable both engineering offices, contractors and building control to assess a building for various aspects of the building code upon completion. In this extended abstract, the authors discuss the development of a system for the automatic code checking of a BIM (model) against the requirements of the Dutch building code (the Environmental Structures Decree which will come into force 1st January 2022) as initiated by the Dutch Ministry of the Interior and Kingdom Relations and developed by TNO. According to the authors, future code checking will take place on the basis of digital robotisation, an ecosystem of autonomously operating BIM applications in the cloud called BIM Bots.

Key words: Automatic Code Checking, BIM, BIM Bots Technology, Environmental Performance Buildings

2 The Dutch Build Quality Assurance Act and Digitisation

The new Dutch Build Quality Assurance Act gives the contractor more responsibility in the construction process. The aim is to increase the quality of both the building process and the completed building. In order to be able to implement this, a contractor will have to check whether the design developed by engineering offices also fulfils the requirements of the building code. The contractor will also have to satisfy himself that when the design is realised and modified in various phases of the construction, the finalised building will still meet the requirements of the building code. The contractor is therefore obliged to carry out these checking independently. In addition, the Dutch Build Quality Assurance Act has created the new role of private building control. To this end, various control methods (instruments) have been developed which controllers use to check if the requirements are met. The code checking is manual work and requires the necessary professional knowledge, a great deal of experience, turnaround time and associated costs.

Both contractors and private building control companies are faced with the challenge that there is a shortage of experienced controllers. It would therefore be a welcome option if a large part of the actual testing is supported by tools that do this automatically. In that case, the controller can also focus much more on the assessment of the building in its context and on specific issues that arise in practice.

The dream of automatic testing has never come as close as it is now. Digitisation is a spearhead in construction and the increasing use of BIM in daily construction projects opens options for automatic code checking.

3 BIM Bot ecosystem

A BIM (model) of a building is a sum of the designs made by architects, constructors, engineers and suppliers, among others. In most cases, the main contractor also makes an implementation model in consultation with subcontractors. Each of these parties develops a so-called aspect (sub)-model and

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[1] TNO is an independent Dutch research organization. TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way.

uses specific applications for this purpose. Communication between information carriers (aspect models) is possible by using the open, internationally accepted BIM standards of buildingSMART, including IFC[2], the standard that forms the basis for automatic testing.

TNO has developed the principles of the so-called BIM Bots technology in recent years. “Robots" (the BIM Bots, see Figure 1) can autonomously read data from a BIM model, perform an analysis and send the result to the user and/or enrich the data from the BIM model. An important starting point is that the BIM Bots technology is based on open BIM standards. As a result, multiple parties will soon be able to develop and make BIM Bots available by their own and BIM Bots users will be able to use a set of Bots themselves and not be dependent on a particular software supplier. TNO has already demonstrated in several EU projects how the BIM Bots technology is used. By using the BIM Bots technology developed by TNO it is possible to have one or more BIM Bot(s) available for a specific requirement. BIM Bots might be available for checking of separations of floors, fire resistance of compartments, escape routes, soundproofing of rooms, accessibility of the building or the environmental performance of a building.

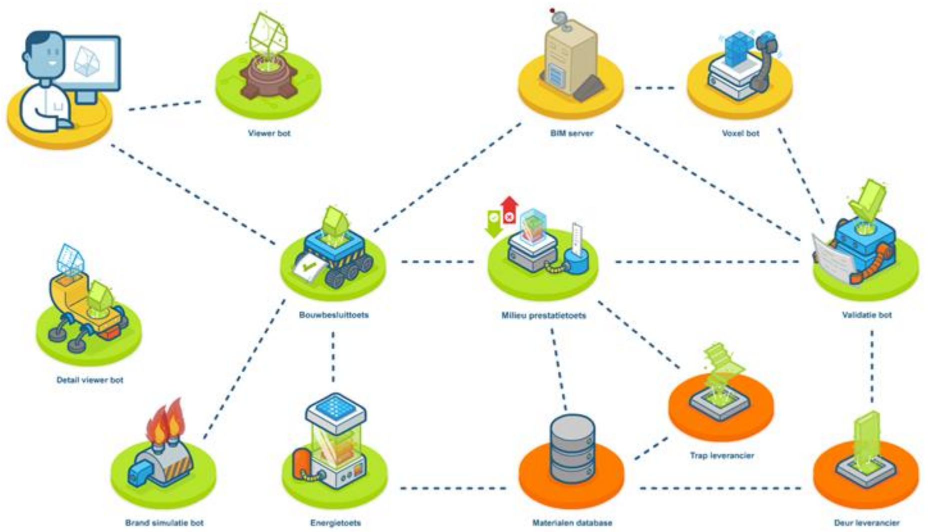

Figure 1. BIM Bots system with various “Robots”

In practice, it now appears that not all the necessary information for a checking is available in an information delivery specifications (IDS), partly because the BIM modeler does not have to enter all the data from their (design) perspective. A check of the BIM model on the basis of an Information Delivery Specification (IDS) could lead to an improvement, because in that case the BIM modeler would have to supply specific data. The downside of this is that the parties involved may feel under pressure to deliver a "perfect BIM model". This is where the BIM Bots environment provides a practical solution. By using specific BIM Bots, it is possible to interpret IFC and link external product properties. For example, there are smart routines that can determine the dimensions of walls, floors, doors, height differences and rooms, and technology is being developed that links IFC properties on the basis of interpretation with supplier product databases or generic material databases. This is being developed on the basis of machine learning.

The BIM Bots ecosystem, developed by TNO, offers space to build a community of software providers and users. A software provider can focus on a specific discipline (e.g. structural safety or energy efficiency) as is already the case today. And a user can make his own choice of applications that are useful for daily use. This prevents a vendor lock-in (forced shop tying at a specific supplier)

[2] IFC stands for Industry Foundation Classes. This is a standardized format for exchanging and sharing specific BIM information between software applications.

and creates a basis for further innovation that stimulates multiple (sometimes competing) parties to participate.

4 Challenge automation process keys

When the Dutch building code was written in the 1990s, the original authors made every effort to pursue a high degree of logic. For each functional requirement, as much detail as possible has been given in a number of operational performance requirements with associated verification methods. This legally technical elaboration still requires a certain degree of interpretation when applied in practice. For simple requirements such as, for example, the minimum allowable floor area of a toilet area (0.9 m x 1.2 m), the test is simple at first glance. It becomes more difficult if the toilet area is not rectangular; what can be assumed?

This is even more complex for more extended requirements. For example, when assessing structural safety, the structural engineer makes choices when schematising the structure, applying the load combinations and selecting a usable verification method to determine the resistance of elements. In order to proceed to automation, the choices made in practice must be made explicit in new additional logic. It is also important to include the various exceptions that occur in practice.

On the other hand, there is also a question of interpreting the data of an IFC. Simple things like thickness of a composite wall can be a problem if it is not included in the BIM model. In that case, how can the exact floor area of a toilet area be checked?

5 Automatic Environmental Performance Buildings

To perform a proof of concept of automatic code checking based on BIM Bots technology, TNO has developed a BIM Bot for code checking the required environmental performance of buildings. Software applications are currently available to assess the environmental performance of buildings. The engineer is in those cases forced to manually determine the elements present in the building, link them to a product card from the National Environmental Database[3] and calculate the total quantities. The software applications then carry out the calculation of the environmental performance. In order to be able to check this result against the requirement set, a controller will still have to go back to the drawings and bills of materials (randomly) in order to conclude. Despite the available software, the actions of both the engineer and the controller are labour intensive and prone to errors. Automating the checking process means that fewer actions are necessary and that the checking is carried out more clearly and transparently.

In the BIM Bots ecosystem developed by TNO, the BIM models of various parties in the cloud can be accessed. The 3D model of the structure becomes visible on a dashboard and after selecting the environmental performance requirement, the calculated value becomes visible automatically. The dashboard controls the BIM Bot, which uses IFC to determine which materials and products have been used and in what quantities. This step requires a number of intermediate steps, in particular to derive the quantities from available data. This also happens fully automatically. The next step is to link the various materials and products to the product maps of the National Environmental Database. For this purpose, a BIM Bot has been developed which establishes the correct link between material and object on the basis of selection criteria. Subsequently, the value of the environmental performance is determined on the basis of the Environmental Performance Buildings Method. This is compared with the requirement given by the Dutch building code. The dashboard also offers a number of additional functionalities for the user, such as indicating which materials and products could not be automatically linked to the National Environmental database and offering the user the possibility to do this interactively. This interaction serves as input for the machine learning procedure. In addition, this

[3] In the National Environmental Database, in accordance with the Determination Method Environmental Performance Buildings and Civil Engineering Works, the product properties are uniformly determined and available by means of product cards.

dashboard shows a 3D representation of the building with an overview of which materials and products have a major contribution to the value of the environmental performance and which only make a small contribution.

A demonstration of the BIM Bot application can be seen on https://youtu.be/emuthhlkW94.

6 Next steps

TNO has taken a first step in code checking of a building. The development of a BIM Bots ecosystem is crucial to create a community of software developers and users. TNO wants to take the necessary follow-up steps in the coming period. Both the technical basis and the organisation of the open ecosystem need to be developed further on.

OpenBIM and DBP – the state of the art and future projects

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1 Introduction

Building SMART International[1] is an open, neutral and international not-for-profit organization driving the digital transformation of the built asset industry.

The Regulatory Room[2] is a building SMART open group of specialists helping project owners and regulatory authorities benefit from the use of openBIM®[3] through an automated regulatory process, and therefore committed to the promotion and support to the Digital Building Permitting into the BuildingSMART organization.

Figure 1. What is openBIM®

This report would briefly introduce the Regulatory Room activities, projects, and achievements on application of OpenBIM in Digital Building Permitting.

2 Contents

2.1 BuildingSMART point of view on the international DBP state of the art.

Thanks to its global nature and connections to the Building SMART national chapters[4], the Regulatory Room can provide a wide international vision and compare the Digital Building Permit processes in many countries.

To map and classify such different states of the art in BIM adoption the Room adopt a 4 stages classification structure as in the following

[1] https://www.buildingsmart.org/
[2] https://www.buildingsmart.org/standards/rooms/regulatory/
[3] https://www.buildingsmart.org/about/openbim/
[4] https://www.buildingsmart.org/community/chapters/

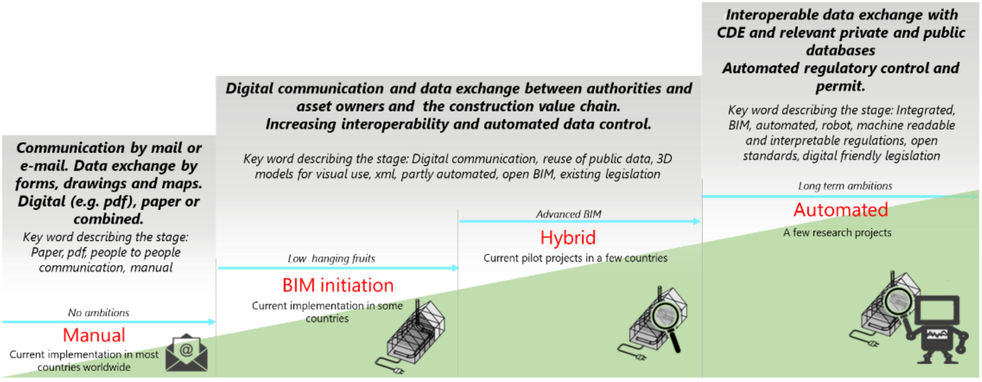

Figure 2. Digital Building Permitting maturity classification

To support and promote the DBP adoption process, the Regulatory Room put in place projects, studies and activities that has been published as on *e-submission common guidelines for introduce BIM to building process* (M.Muto), *Open Standards for Regulations, Requirements and Recommendations Content (RR group) and Case for Automated Rule Checking in AEC in the Era of Big Data (T. el Diraby)*

2.2 The Regulatory Room projects for digital standards improvements to support DBP projects.

On 2021 Regulatory Room started the project **Regulatory Information Requirements** [RIR]. The aim of this project is to ensure that the regulatory information requirements common across many jurisdictions have an appropriate representation in IFC[5], whilst leaving jurisdictions free to add local information requirements and implement their own checklists and rules.

The project is managed by Tomi Henttinen[6], the project scope focus on Concept and zonal approvals, Technical design and construction approvals and Approvals for occupation and use.

The project is in the early stages and still open to experts interested in collaborating (contact links in [b])

2.3 The out*comes of a BuildingSMART Regulatory Room global survey on perception and attitudes* in both Building industry and regulatory bodies about DBP adoption.

To better interpret the perception of BIM in Digital Building Permitting ecosystem, in March 2020 the Regulatory Room launched a global survey in 5 languages on "*The role of OpenBIM in the Regulatory Process"*. The Survey ended in March 2021, with more than 160 participants from 38 countries and from different industries as in the following

[5] https://technical.buildingsmart.org/standards/ifc/
[6] LinkedIn profile https://www.linkedin.com/in/tomi-henttinen-3b70596/

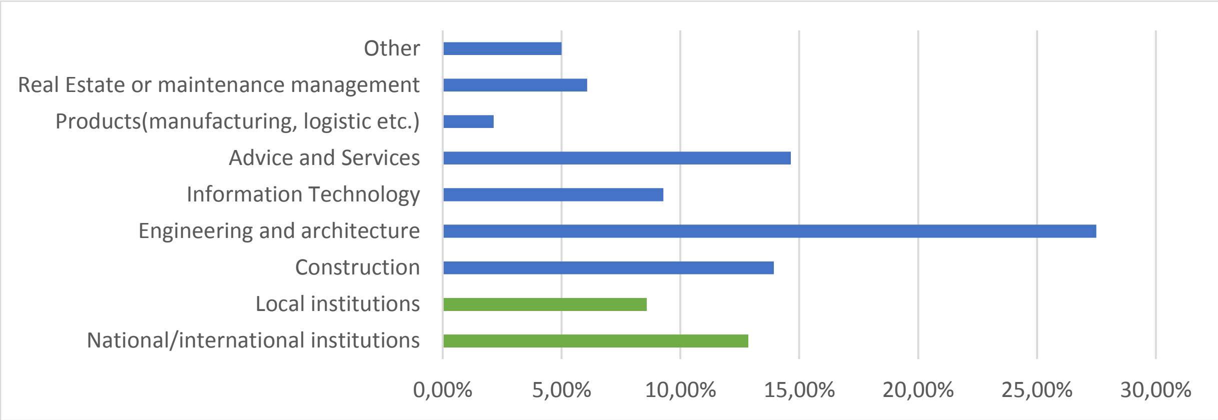

Figure 3. Survey Participants by job.

BIM adoption in regulatory looks to be an almost established and growing process, more than 70% of the attendants declared they are involved in regulatory activities including or going to include BIM in the process. 40 % of the panel is actually experiencing the use of BIM in regulatory, and 75 % of them are using openBIM®.

The perception looks prevalently positive, even though some worries are still braking a wider involvement of BIM in Regulatory; the complexity of adoption is the prevalent one.

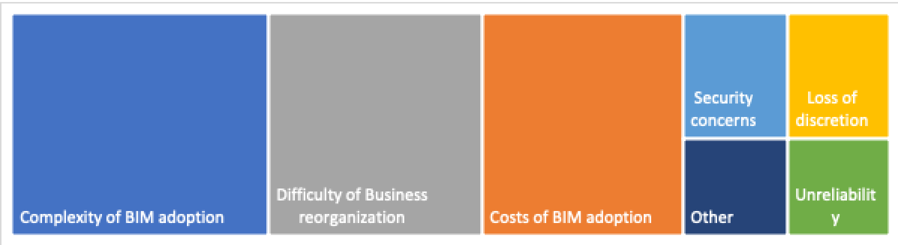

Figure 4. Perceived worries about BIM adoption in Regulatory

The survey revealed that attitude to BIM adoption in regulatory is not evenly distributed, in organizations it is more positive in technical roles than in managerial ones.

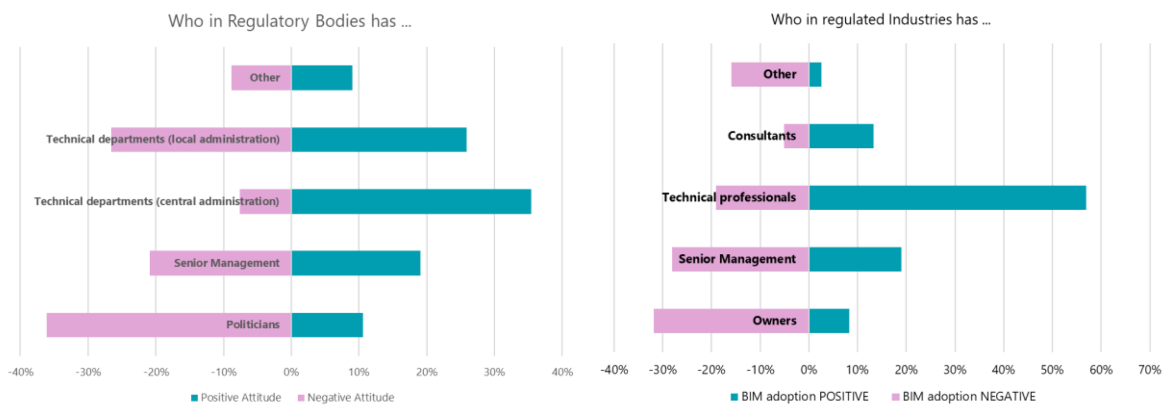

Figure 5. Positive/negative attitude to BIM by role in organizations

The survey finally indicated a "BIM in regulatory champion" profile, who should be a 30 to 40 years old person with an AEC background and with a technical/project-oriented attitude.

The survey data analysis conclusion is we have good foundation for the future of Open BIM in regulatory but some worries need to be solved.

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Tamer el Diraby - Technical Report No. TR 1012 (Dec 2019) : https://buildingsmart-1xbd3ajdayi.netdna-ssl.com/wp-content/uploads/2020/06/buildingSMART-RR-TR1012-Framing-the-Business-Case-for-Automated-Rule-Checking-v1.1-Final-Dec-2019.pdf

2.7 Panel Session

Proptech Disruption – the evolving context for Digital Permitting

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Buro Happold/ Cogital, London, United Kingdom (alain.waha@cogital.tech)

1. Background

The panel was animated by Cogital Ltd, which is active in the #proptech sector, advising both investors, and technology startup firms. The significance of the topic arises from increasing Venture Capital funding coming to the Property Technology (#proptech sector) – representing up to €165b of funding in the 2020-2025 timeframe. (Figure 1)

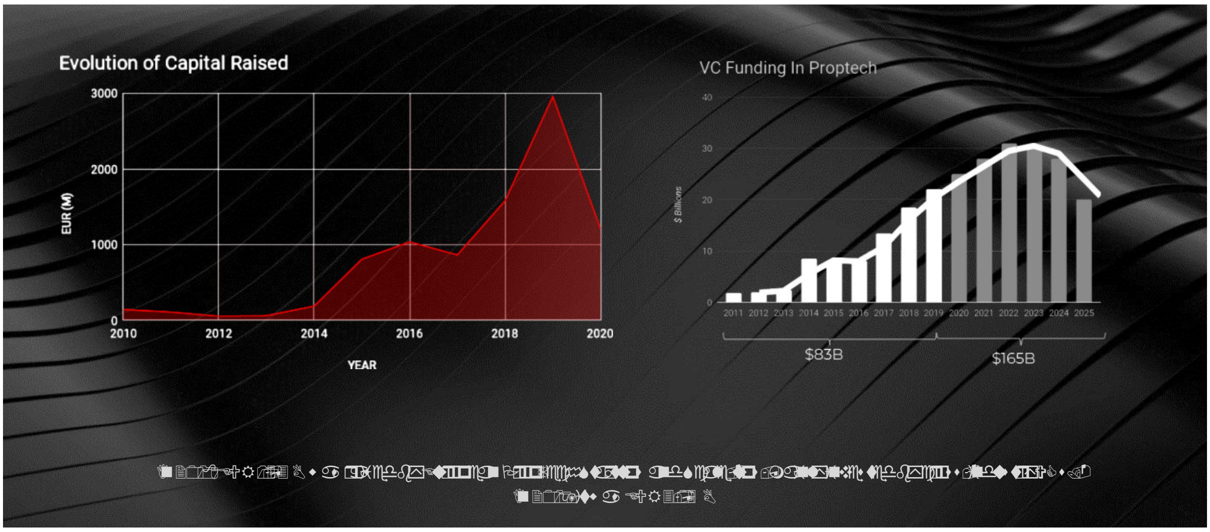

Figure 1. Source Relevation / PropTechLab Belgium

The hypothesis put forward as an introduction is that the "Digital Mirror" of the Built Environment, is establishing "the 3rd platform"; coming after the World Wide Web (the first platform) and the Social Web (the second platform).

The panel was made up of two technology leaders:

1. Paul Oesten-Creasy: CTO of VU City[1]

   Paul is a product designer by training, early proponent of CGI and Animation technology; which he applied to the Built Enviroment as part of VU.City

2. Greg Demchak: Director of Bentley Systems Digital Innovation Lab[2]

   Greg is a trained architect, alumni of MIT Design Computation team, the original Revit team which was acquired by AutoDesk Inc, the member of the Synchro team, acquired by Bentley Systems

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1 www.vu.city
2 www.bentley.com

2. Panelist Presentations

2.1. Introduction to iTwin platform approach by Greg Demchak– see here

Transition to platform technologies – which allows us to overcome the "Scale issues" and "peer to peer file exchanges" – and deliver the vision of Digital Twins. This platform approach is now being augmented by AE/VR and mixed reality approach to re-thing how we design and operate the built environment.

2.2. Introduction to the VU.City platform by Paul Oesten-Creasy here

The platform grew out of using Game Engines in the Real Estate industry to support planning. The platform now holds 3D representations of 20 key cities around the UK which is being used by 80% + of planning authorities to consider large schemes proposed for approval. "Planning is version control" for reality – which shapes the digital twins of the city.

3. Panel Discussion

Some key "take away" from the panel discussion" here

- The opening statement is that we are living through a technology breakthrough, which allows us to overcome resolution limitation through.
- Digital Twin is more than a model, as it is updated by reality at an agreed update frequency, with a defined latency. The model is therefore a edge case of Digital Twining: zero update frequency.
- The conversation is evolving from a technology question to a question about use cases and their value; solving new possibilities around popu
- Citizens will be at the heart of Digital Twins of cities
- At infrastructure level, Digital Twining will be the route to delivering measurable and measured outcomes
- The governance and ownership of Digital Twins is a key topic for policy makers, as we navigate towards the concept of a "Egalitarian Metaverse"

3 CONCLUSIONS AND TAKE-HOME MESSAGES

The results shown and presented could offer an interesting overview of the overall progress of many active groups working towards the digitalization of the building permit process.

It was interesting to see how the maturity level of the implementations related to the use case are progressing with respect to the past and how they are going in similar directions, mostly addressing the connection with practice and data readiness. Similar choices are made and the problems tackled are acknowledged from several parties. In the following subsections, relevant highlights arisen are summarized.

1. Development of new or adapted workflows

The current practice is being changed and therefore a new organization of information flows and procedures is necessary, having advantage of digital tools and information and often changing the roles and tasks of stakeholders.

It also implies that agreements with stakeholders need to be laid as well as their active participation in this change and new training for future operators.

2. Technology

There are amazing developments in the field of technology, which would enable many new opportunities. Some nice examples were presented during the panel session "Protech disruption – the evolving context for Digital Permitting" – organized and chaired by Alain Waha (recording available at: https://www.youtube.com/watch?v=BcHBFyFC5B4). During the Session 5, about technology, other interesting tools and applications were presented. The actual challenge remains the uptake of them in the current practice, but the current technological solutions are very promising.

3. Making regulations digital and machine readable

Such a necessity is being addressed by means of different approaches, such as changing regulations, write regulations differently, or developing tools able to interpret the natural language of regulations. In any case, the interpretation of codes and the way they will be used to check submissions are key.

4. Geodata to BIM (more than the other way around)

One of the issues for building permit automation is the gathering of information related to the context, from the location of the parcel to the reading of elements which are reference for the check of some regulations. For this reason, the conversion and import of geodata to BIM software (namely the most neglected side of GeoBIM so far) to support, guide and check the modelling and design is a topic being raised.

5. Requirements to modellers

Use of open standard (mainly IFC) is always acknowledged as the most effective way to proceed. In addition, requirements and specifications need to be respected by designers whether their models have to be effectively used within automatic tools. Different means are being proposed, such as excel sheets specifications or specific IFC Model View Definitions. The need of a validator to check the suitability of results is directly following.

6. Agreed classifications

The IFC model is vast, but also open to different interpretations in some parts or allowing several values. Therefore, the provision and use of stricter and more specific classifications (including aligned with the national ones) in models is another goal of several on-going projects.

7. Reporting

The kind of reporting of the checking results is one more open discussion: they need to be representative of the issues and allow inspection by officers (or designers, whether in a pre-check phase).

8. Convincing municipalities and stakeholders

One of the questions was: "you mention resistance to change by officers. Experience shows that digital transformation projects are 20% technology change and 80% people change, would you agree?".

The outreach work useful to convince most of governments to invest in digital building permits and municipalities to adopt it is a current issue for many. Although the development of the use case was started according to the demand of some (or part) of them, based on evidences of related savings and improvements, the majority of officers and stakeholders are still reluctant in changing their way of working and the skills required. Similar concerns are raised by designers, especially in case they are not big firms and big investments are needed, besides changes in internal procedures and used data.

9. Maturity model

Some references to assess the levels of maturity of the overall use case or the single parts involved in it is proposed within several projects. The maturity model as a tool to understand the direction for a development or awarding criteria is acknowledged as useful and it would be helpful to develop a proposal with agreement among several parties and groups. A roadmap based on it would be the following step.

10. Terms

Several disciplines are meeting together. For this reason, sometimes terms are used about similar concepts as perceived by different disciplines or with slightly different nuances. To agree on definitions could help the development and communications around the same topic.

11. Involved legal aspects

These are many and range from privacy and GDPR issues involved in the management of buildings and ownerships data to the use of data w.r.t transparency and recording to manage responsibilities towards higher quality and safety (e.g. fire safety https://www.bimacademy.global/insights/infrastructure/the-golden-thread-of-information-putting-the-hackitt-report-into-practice/). Not least, legal assistance should be taken into account to address possible disputes related to non-compliance cases and probably arguing against the automatic checking tools reliability. Future development will need to consider them.

12. Online events

Finally, we believe that some comments are deserved by the used digital environment: this event was held in a completely digital setting, by means of the airmeet.com platform, which also allows interactions between participants (via video meeting and chat) through virtual tables, available in-between the sessions. As an advantage of such a setting, we could count on the enhanced participation possible by people from far countries and without the need of available economic resources for traveling. The saving of time and pollution deriving from travelling is also relevant, especially because such kinds of conferences and events are very frequent. However, as a reflection for future events, we could notice that the chance of free interaction between participants, although allowed, was not very much exploited. Moreover, according to some feedback, a longer time for discussion would have been appreciated. The chance and challenge of organizing 100% digital events is still quite new, and probably to reach the same level of effectiveness of in-presence meetings it is necessary people to get used to the platforms and tools, as well as their pro-active participation in interactions. On the other hand, the timing of conferences could be organized differently, for example by dilute the event in smaller sessions over several days, to allow people managing other obligations. However, the interaction allowed by the common chat and questions and answers section allows all the questions to be raised and all the relevant resources and comments to be shared with everyone at the same time (including websites, external resources and so on), as is instead difficult in traditional in-presence events. The related best practices for the organization of (and participation to) such completely digital events are currently under construction and refinement. This was an interesting challenge as well.

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Tools provided for free were used to manage the conference submissions and reviews (https://easychair.org), the platform to host the two days conference (https://www.airmeet.com), the streaming of videos and storage of recordings (https://www.youtube.com).