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3D Zoning: A Missing Piece to Link Planning Regulations with 3D Cadastre

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Key words: 3D Land administration, Planning regulation, Spatial representation, 3D zoning, 3D Cadastre

SUMMARY

Interpreting planning regulations could be a challenging task for land surveyors when defining new ownership boundaries and for responsible authorities (e.g., city council) when assessing proposed developments. They need to be aware of the impacts of planning regulations on land parcels and vice versa since these regulations contain legally binding rules for all parties including government and citizens. There is a strong link between planning and cadastral regulations. For example, 3D zoning, with the capability of representing planning regulations in 3D, has a great potential to enable representing restricted and usable spaces for 3D cadastral purposes in a more visual way. This paper aims to offer a discussion about the advantages of enriching 3D zoning with the spatial representation of planning regulations in order to be integrated into a larger land-use information system called multipurpose cadastre to find better compliance between land use, urban planning, and citizen welfare. To this purpose, three groups of planning regulations (i.e., proposed design needed, 3D city model needed, and 3D zoning groups) are proposed in which 3D zoning group seems to be the most valuable one to achieve the overall objective. To support our discussion regarding mapping planning regulations for cadastral purposes, the paper results in a showcase for five planning regulations in the 3D zoning group including height limits, noise impacts, side and rear setbacks, street setbacks (side and front), and flooding limits. Victoria, Australia, was selected as a case study to illustrate some aspects of the discussion.

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1. INTRODUCTION

1.1 Context and Problematics

In urban planning, zoning is a regulatory mechanism that categorizes or divides land parcels into areas called zones (Selmi et al., 2017). In each zone, a set of regulations controls uses and developments on land with the purpose of mediating between social space and physical space for orderly urban growth and development (Salsich and Tryniecki, 1998; Selmi et al., 2017). Currently, most cities are using 2D zoning maps with a color-coded system in which clicking on a city zone will bring up general information about that zone. Based on this information, related planning regulations should be found in primary and secondary sources such as regulatory documents (Plazza et al., 2019). This method might cause significant shortcomings like in understanding restricted and usable spaces especially when most of the planning regulations contain 3D components (e.g., building height and setback limits). Usable spaces in this paper refer to spaces that are not restricted by planning regulations and can be used for defining new ownership boundaries.

Beyond visualization capacity, 3D zoning will gain value if they are integrated with the process of checking the compliance of land developments with planning and zoning regulations (Mayer and Somerville, 2000; Noardo et al., 2020a; Valencia et al., 2015; Van Berlo et al., 2013). In addition to preventing new uses and developments from interfering with existing uses and developments, it would be beneficial to use 3D zoning to control strategic planning rules and policies related to urban renewal and developments (Bracken, 2014; Brown et al., 2018; Cann, 2018; Durham Jr and Scharffs, 2019; Kochan, 2014). For instance, one of the difficult tasks for architects and land surveyors is to understand and identify regulations limits in city zones before designing and subdividing a multi-owned development when defining new ownership boundaries (Emamgholian et al., 2020a; Grimmer, 2007).

Due to the complexity and multi-dimensionality of zoning and planning regulations, identifying potential conflicts during designing and subdividing multi-owned buildings is not an easy task and requires lots of expertise, specialized knowledge, and analytical skills especially when 3D components are involved (Benner et al., 2010; Emamgholian et al., 2020a; Noardo et al., 2020b; Olsson et al., 2018; Plazza et al., 2019). In these situations, regulations limits must be accurately identified and considered when defining new ownership boundaries in cadastral plans. Enriching 3D zoning in which planning regulations are instantiated can significantly make the decision-making process faster and more communicable and improve the cognitive understanding of regulations limits for land administration and planning authorities (e.g., urban planners, architects, and land surveyors) (Emamgholian et al., 2021; Faucher and Nivet, 2000; Schaller et al., 2015; Schueren et al., 2016). Therefore, the benefits of enriching 3D zoning with the 3D representation of planning regulations can facilitate identification, validation, and registration of Rights, Responsibilities, and Restrictions (RRRs) for proposed developments in each precinct.

1.2 Objectives

This study offers a discussion mainly based on the findings in a research project started in 2019 in collaboration between Laval University (Centre for Research in Geospatial Data and Intelligence) and the University of Melbourne (Centre for SDIs and Land Administration) focusing on modeling 3D land-use regulations and detecting potential conflicts among regulations and physical objects. As the first phase of the project, Emamgholian et al. (2020a) proposed five variables to classify the potential conflicts as soft and hard conflicts. The variables were: number of 1) regulations and 2) physical objects involved in the conflicts, level of detail of the 3) proposed building and 4) surrounding buildings, and 5) spatial 3D spatial configuration of regulations. As the second phase of the project, Emamgholian et al. (2021) proposed a novel approach for modeling land-use regulations geometrically to validate proposed buildings against regulations in a later stage. From the modeling perspective, the key parameters, and a geometric modeling approach (e.g., extrusion, B-Rep, CSG, sweeping) that best fits with the identified parameters were proposed. Moreover, a level of information need for combining modelled regulations with 3D city models focusing on required planning information as well as physical objects was discussed considerably.

Based on our knowledge and experience, this paper aims to open a discussion about the advantages of enriching 3D zoning with a spatial representation of planning regulations that can be integrated into a larger land-use information system called multipurpose cadastre for 3D cadastral purposes in a later stage. To this purpose, the paper investigates 3D planning regulations and distinguishes the potential planning regulations that can be mapped or visualized into 3D zoning only based on planning information. In addition, for a case study (i.e., Victoria, Australia), this paper showcases an enriched 3D zoning for five identified planning regulations including height limits, noise impacts, side and rear setbacks, street setbacks (side and front), and flooding limits. The showcase aims to support our discussion regarding mapping planning regulations for cadastral purposes (e.g., a building subdivision and defining new ownership boundaries). Finally, the conclusions derived through this study were addressed by presenting issues that require further research.

2. BUILDING SUBDIVISION PROCESS IN VICTORIA, AUSTRALIA

To support our discussion and understand the current practices and existing issues and challenges, Victorian jurisdiction in Australia is selected as a case study. A building subdivision process in Victoria includes four main phases namely planning, certification, compliance, and registration phases (Atazadeh, 2017; Shojaei, 2014). In the planning phase, as the focus of this paper, the proposed design must be approved mainly based on the Victorian planning scheme. The planning scheme, as a legal document, is developed mainly based on Planning and Environment Act (1987). Generally, this planning system regulates “use” and “development” on land by zoning and planning regulations and includes different components such as zones, overlays, Local Planning Policy Framework (LPPF), State Planning Policy Framework (SPPF), general provisions, particular provisions, and schedules.

For a proposed development on a vacant land parcel, the process starts when an owner or a developer identifies an appropriate piece of land for the development. Accordingly, a land surveyor determines the boundaries of land by conducting a site survey and an architect designs the architectural model for the new "development" on the land parcel. The proposed development must be approved based on the Victorian planning scheme and the authority that administrates the planning scheme would be the responsible authority for granting/refusing the permit. In most cases, a city council is a responsible authority and the first point of contact for planning permit applications.

The decision-making stage starts when an application including plans, supporting information, and a copy of the title is submitted to the responsible authority (i.e., council) to get a planning permit or amend an existing permit. In summary, the decision-making stage mainly consists of three steps including referring an application to referral authority (e.g., utility suppliers such as water, electricity, and broadband network), asking for further information, and verifying the application mainly based on the planning scheme ordinance. The responsible authority needs to assess the planning permit application by verifying zoning and planning regulations. After verifying planning and zoning regulations, which usually takes 60 days (excluding additional information requests that can make a delay in the whole process), the responsible authority notifies owners about the potential zoning and planning regulations conflicts.

After receiving the planning permit, the land surveyor prepares subdivision plans based on the architectural design to apply for certifying subdivision plans (i.e., certification phase). This phase can be done concurrently with the planning phase. It should be noted that the certification phase verified by the Subdivision Act (1988) and Regulations (2011) is not the focus of this paper. It should also be noted that this paper only considers available planning regulations for building one, two or more dwellings on a lot, residential buildings, apartments with less than five storeys, and apartments containing five or more storeys.

3. 3D ZONING & 3D CADASTRE

Several software development companies (e.g., ESRI, Archistar[1], Gridics[2], MODELUR[3]) and cities (e.g., Toronto[4], Vancouver[5], Washington D.C[6], City of Miami) are launching their first version of 3D zoning mainly containing a 3D representation of some zoning and planning regulations such as height and setback limits (Quick et al., 2019; Schaller et al., 2015). However, in addition to not being fully operational and accessible, identifying potential zoning and planning regulations that can be represented in 3D zoning as well as its linkage with 3D cadastral purposes are still lacking and need further investigations.

[1] https://archistar.ai/
[2] https://gridics.com/zoning-data-api/
[3] https://modelur.com/
[4] https://map.toronto.ca/maps/map.jsp?app=TorontoMaps_v2
[5] https://www.reddit.com/r/MapPorn/comments/83g7i7/interactive_3d_zoning_map_of_vancouver_canada/
[6] https://maps.dcoz.dc.gov/3D/

Currently, in Victoria, Australia, checking the compliance of land with planning regulations before designing and defining new ownership boundaries when subdividing multi-owned buildings is not reachable unless surveyors lodge an application for a planning permit to a responsible authority (e.g., city council) (Atazadeh, 2017; Emamgholian et al., 2021, 2020a). However, to give an impression to the architects and land surveyors to design and subdivide proposed developments in accordance with the planning regulations, potential planning regulations can be mapped or represented in 3D by enriching 3D zoning. In this way, 3D zoning as the missing piece can link planning regulations with 3D cadastre by specifying usable and restricted spaces in the domain of land administration. In addition to being used for several cadastral purposes such as subdividing multi-owned buildings and defining new ownership boundaries, it can also be integrated into a larger land-use information system called multipurpose cadastre to find better compliance between land use, urban planning, and citizen welfare.

To this purpose, after exploring the characteristics of planning regulations, we propose three groups of 3D planning regulations to identify the potential planning regulations enriching 3D zoning. These groups include: **1)** proposed design needed, **2)** 3D city model needed, and **3)** 3D zoning groups. The main distinction between these groups is whether physical objects are required either in the new development proposal or in surrounding buildings to map or represent these regulations into 3D zoning. Each group with several examples is discussed in detail as follows. It should be considered that this paper focuses on city-scale 3D regulations and does not discuss internal restricted and usable spaces.

3.1 Proposed Design Needed

The first group as specified in table 1 includes 3D planning regulations (including their short description) for which the proposed development design model is required to map or visualize. Since the proposed design is required, these planning regulations cannot be represented in 3D zoning platforms unless we have access to the design model of the proposed development. However, they can be checked by architects and land surveyors after designing and subdividing multi-owned buildings whenever surrounding buildings are not required. This group is not the focus of this study and the importance of having the design model of new developments on modeling planning regulations (e.g., BIM data with sufficient Level Of Development (LOD)) is discussed in Emamgholian et al. (2021).

Table 1. Planning regulations in proposed design needed group

Group	Planning Regulations	Short Description	Design model of proposed developments	Surrounding buildings
Proposed design needed	**Overlooking**	A habitable room window, balcony, terrace, deck, or patio of a proposed building must not provide a direct line of sight into the secluded private open space and habitable room windows of existing buildings.	**Required**	Required
	Daylight to New Windows	Habitable room windows of proposed buildings should provide a light court (or outdoor space) with a minimum area of 3 square meters and a minimum dimension of 1 meter clear to the sky.		Required
	Internal Views	Windows and balconies should not cause an overlooking of more than 50 percent of the secluded private open space of a lower-level residential building directly below and within the same development.		Not required
	Energy Efficiency Protection	It considers the effects of overshadowing on an existing rooftop solar energy system on an adjoining lot.		Required
	Solar Access to Open Space	The southern boundary of secluded private open spaces of proposed buildings should be set back from all walls on the north, at least (2 + 0.9h) meters ('h' is the height of the wall).		Not required
	Overshadowing Open Space	In this case, overshadowing on existing secluded private open spaces will be checked.		Required

3.2 3D City Model Needed

The second group as specified in table 2 includes 3D planning regulations (including their short description) for which the design model of the proposed development is not required but 3D models of surrounding buildings are required. Although these regulations do not necessarily require a design model of the proposed development, for enriching 3D zoning platforms with them, the 3D models of surrounding buildings are required. This is where having 3D city models with existing buildings and city furniture matters. In this case, the planning regulations can be mapped in 3D zoning only if it is combined with the 3D city model. The approach and benefits of combining the 3D city model with planning regulations and a detailed discussion about the importance of having a 3D city model (e.g., CityGML data with a sufficient Level of Detail (LoD)) for mapping planning regulations can be found in Emamgholian et al. (2021). It can be concluded that for the planning regulations that require the 3D model of surrounding buildings, like those listed in table 2, it is possible to enrich the 3D zoning with them only if a 3D city model including existing buildings is accessible.

Table 2. Planning regulations in 3D city model needed group

Group	Planning Regulations	Short Description	Design model of proposed developments	Surrounding buildings
3D city model needed	**Daylight to Existing Windows**	Proposed buildings should provide a light court (or outdoor space) to the existing (adjoining) habitable room windows with a minimum area of 3 square meters and a minimum dimension of 1 meter clear to the sky.	Not required	**Required**
	Buildings Separation	It considers minimum distances between proposed buildings and existing buildings.	Not required	
	North-facing Windows	It considers if a north-facing habitable room window of an existing building is within 3 meters of a boundary on a proposed building's boundary, the proposed building should be setback from its boundary.	Not required	
	Depth Limitation[7]	It restricts any structure to be built over or near any of underground assets or easements.	Not required	

3.3 3D Zoning

The third group as specified in table 3 includes 3D planning regulations (including their short description) for which neither the design model of the proposed development nor surrounding buildings is required. This group with the capability of being mapped in 3D zoning seems to be the most valuable one to achieve the overall objective (i.e., enriching 3D zoning to enable visualizing restricted and usable spaces for cadastral purposes). In this case, 3D zoning potentially can be enriched with a 3D representation of the planning regulations to be linked with 3D cadastral purposes (e.g., subdividing multi-owned buildings and defining new ownership boundaries). It should be noted that this paper does not discuss the geometric modeling stage of specified planning regulations. The modeling parameters and geometric modeling approaches for representing 3D planning regulations are discussed thoroughly in Emamgholian et al. (2021).

[7] Although this regulation does not need the design model of surrounding buildings, it requires some underground assets (e.g., sewer pipes) in 3D city models.

Table 3. Planning regulations in 3D zoning group

<table>
<tr><th>Group</th><th>Planning Regulations</th><th>Short Description</th><th>Design model of proposed developments</th><th>Surrounding buildings</th></tr>
<tr><td rowspan="5">3D zoning</td><td>Height Limits</td><td>It considers the vertical distance between the ground level and the top of the proposed development.</td><td colspan="2" rowspan="5">Not Required</td></tr>
<tr><td>Side and Rear Setbacks</td><td>Proposed buildings should be set back from side or rear boundaries not less than the distance specified in the planning scheme or schedule.</td></tr>
<tr><td>Street Setbacks</td><td>Proposed buildings should be set back from side or front boundaries adjacent with streets not less than the distance specified in the planning scheme or schedule.</td></tr>
<tr><td>Noise Impacts</td><td>Residential buildings and dwellings close to busy roads, railway lines, or industry should be designed in a way that limits noise levels in habitable rooms.</td></tr>
<tr><td>Flooding Limits</td><td>Openings including doors, windows, and entrance level should be designed in an accordance with flooding limits.</td></tr>
</table>

4. SHOWCASE

To support our discussion regarding mapping planning regulations for cadastral purposes, this section presents a showcase for five planning regulations specified in the 3D zoning group (i.e., table 3) including height limits, side and rear setbacks, street setbacks, noise impacts, and flooding limits. In this showcase, land administration and planning authorities are the lead beneficiary of 3D zoning. In addition, 3D representation of planning regulations can give an impression to the land buyers/developers for their investment and it might affect the value of their property significantly (Calder, 2017; El Yamani et al., 2021; Emamgholian et al., 2020b). Please note that this paper does not discuss the geometric modeling aspects of planning regulations and this showcase is only a demonstration of an enriched 3D zoning.

This showcase consists of programming inside a web-based application (i.e., Cesium) using JavaScript. 2D zoning base map (in Shapefile format) for the city of Melbourne that is provided by the Department of Environment, Land, Water & Planning (DELWP)[8] was converted to GeoJSON and imported to Cesium ion (Figure 1(a)). To be more precise about mapping usable and restricted spaces, a land parcel (as an example) was selected located in Fishermans Bend precinct (Figure 1(b)). We assume that a multi-owned development is going to be constructed on this land parcel.

[8] https://www.delwp.vic.gov.au/

(a) (b)

Figure 1. a) Part of Melbourne zoning base map (color-coded based on different zones); b) The selected land parcel (colored in yellow)

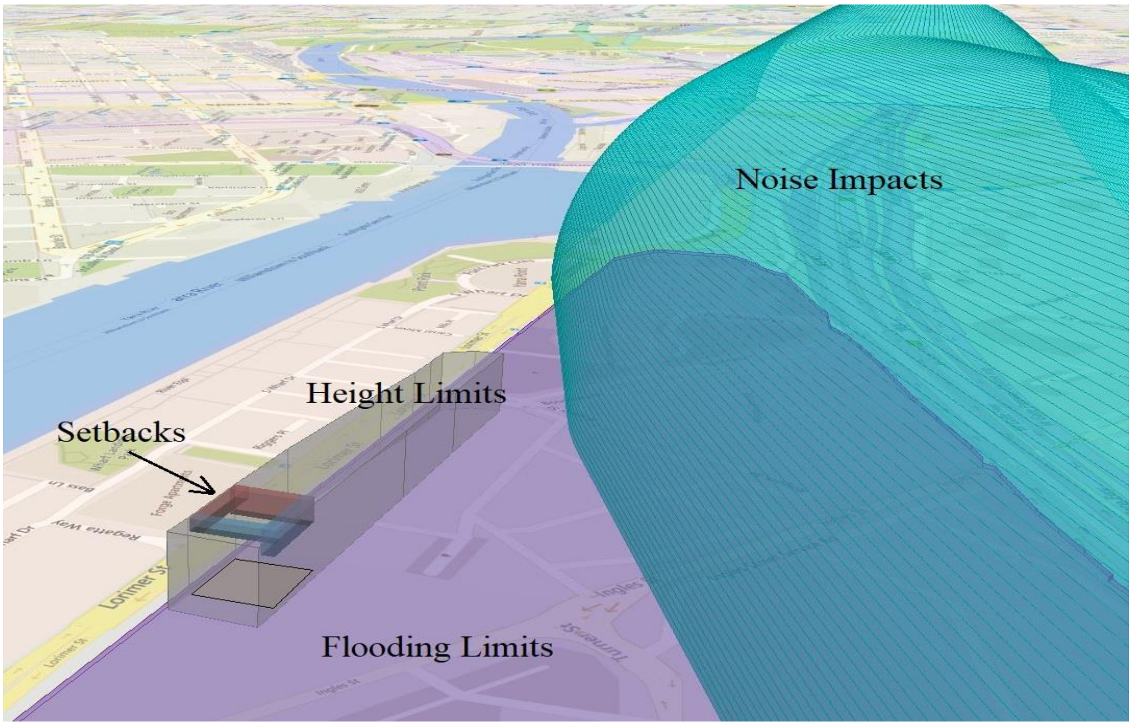
Based on the location of the land parcel and its assigned planning regulations summarized in the planning scheme ordinance[9] and complementary documents and guidelines (e.g., for flooding[10]), 3D zoning is enriched with the selected regulations as follows.

- **Height Limits:** According to schedule 67 to clause 43.02 design and development overlay related to Fishermans Bend - Lorimer Precinct (Melbourne Planning Scheme Ordinance, p. 907), a height limit of 36 meters applies to this land parcel.
- **Street Setbacks (front and side):** It is allowed to have a street wall type D (i.e., 8 storeys height) for its front street and type C (i.e., 6 storeys height) for its side street. From that level (i.e., street wall height) up to the height limits, a minimum street setback of 5 meters applies to front and side streets.
- **Side & Rear Setbacks:** If we assume that where the building below the maximum street wall height is built on the boundary, at least side and rear setbacks of 5 meters must be applied to both side and rear parts of the land parcel.
- **Noise Impacts:** For noise impacts, the proposed developments' construction materials need additional verifications if it is at less than 300 meters distance from the nearest lane of a freeway.
- **Flooding Limits:** By considering flooding limits, finished entrance and first floor levels should respect a minimum height limit (based on either predicted 2100 1% Annual Exceedance Probability (AEP) flood level or Nominal Flood Protection Level (NFPL)) to mitigate flooding concerns. Based on the location of this land parcel, 2.4 meters flooding limits are applicable.

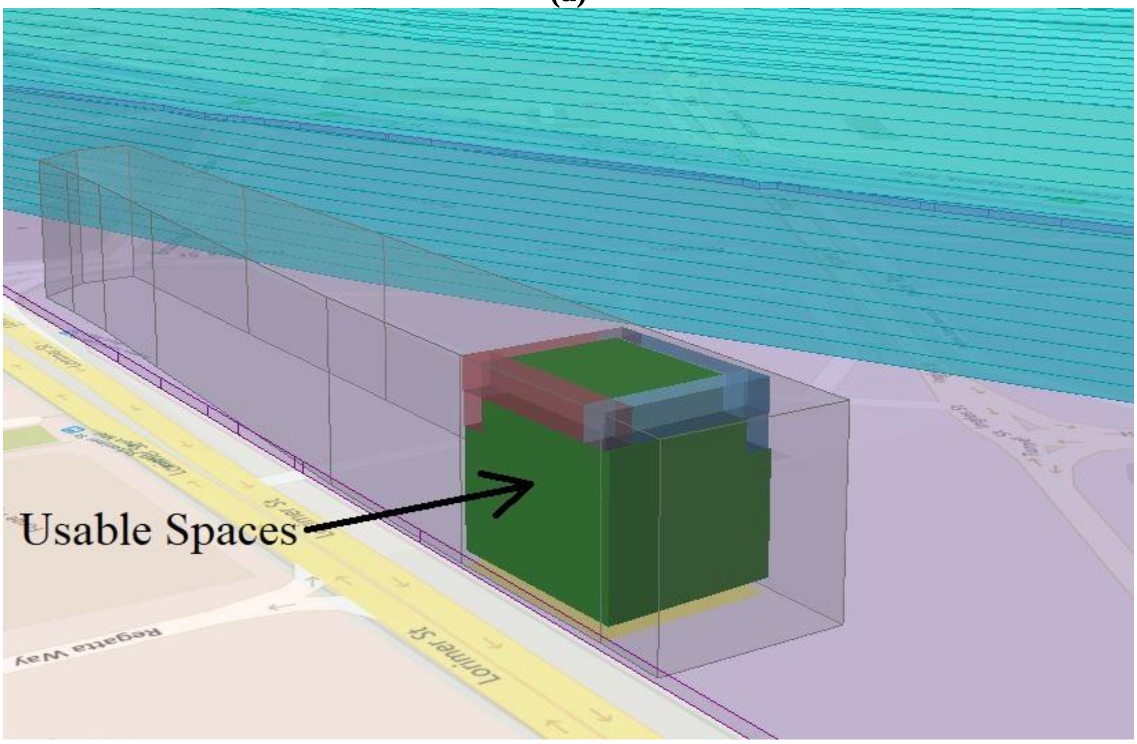
Figure 2(a) illustrates enriched 3D zoning specifying the restricted spaces applicable to the land parcel. Accordingly, Figure 2(b) illustrates both restricted and usable spaces for the land parcel.

[9] http://www.melbourne.vic.gov.au/building-and-development/urban-planning/melbourne-planning-scheme/Pages/melbourne-planning-scheme.aspx

[10] https://www.water.vic.gov.au/__data/assets/pdf_file/0025/409570/Guidelines-for-Development-in-Flood_finalAA.pdf



(a)



(b)

Figure 2. Mapping restricted spaces into 3D zoning by a) height limits (colored in grey), front and side street setbacks (colored in orange), side and rear setbacks (colored in blue), noise impacts (colored in cyan), and flooding limits (colored in purple); b) Usable spaces applicable in the land parcel (colored in green)

5. DISCUSSION & CONCLUSION

In this paper, we argued that to have a multipurpose cadastre, 3D zoning enriched with a 3D representation of 3D planning regulations has a great potential to be integrated into a larger land-use information system called a multipurpose cadastre system. Land administration and planning authorities can benefit from such a system by having access to the restricted and usable spaces in a literally more visual way. To this purpose, planning regulations were categorized into three groups including proposed design needed, 3D city model needed, and 3D zoning. Planning regulations in the 3D zoning group with the capability of being mapped by reaching only planning information was the most potential one to achieve the overall objective (i.e., integrating planning regulations with 3D cadastre in a larger system called multipurpose cadastre accessible to all parties). After identifying the potential planning regulations, with the purpose of supporting our discussion regarding mapping planning regulations for cadastral purposes, the paper resulted in a showcase for five regulations including height limits, noise impacts, side and rear setbacks, street setbacks (side and front), and flooding limits.

During this study, some important points can be highlighted as:

- Identifying more potential regulations: 3D zoning should be taken as a basis of a 3D representation of potential regulations depicting usable and restricted spaces in a multipurpose cadastral system. To this purpose, other potential planning regulations, sub-regulations, and other restrictions imposed on city precincts should be added to such a system.
- Qualitative reasoning: Since planning regulations can contain discretionary (e.g., noise impacts) or mandatory (e.g., minimum setbacks) rules, restricted spaces in the 3D zoning do not necessarily mean that they are not usable. This aspect reminds the importance of having qualitative reasoning in later stages.
- Reaching a generic approach: Planning regulations and their restrictions may not only be diverse in different jurisdictions but may also be distinct in different cities. Although the general rules may be the same, it is not straightforward to achieve a generic approach that maps/represents all the limited spaces applicable in all precincts. However, if the difference in the description of the rules is taken into account, the process can still be the same.
- Data linkage and accessibility: The required data (e.g., planning information, zoning base maps, related guidelines) is provided by different organizations with different levels of accessibility. To achieve having an integrated land-use information system including all required data further studies investigating data integration aspects like data quality and standardization are required.
- 3D city models and BIMs: This study shows that enriching 3D zoning has a great potential to be utilized in land administration systems. It can also facilitate the decision-making process for granting planning/building permits in a later stage. However, as the first step, only one group of planning regulations (i.e., 3D zoning group) could be mapped into 3D zoning. Hence, to represent all restricted spaces, 3D city models and BIMs should also be integrated with the enriched 3D zoning.
- Automatic enrichment: Planning regulations and their related information are mostly summarized in textual documents including lots of complexities that make the automation

process fail. It needs further research as well as collaborative work engaging all parties to facilitate the process of enriching 3D zoning automatically.

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BIOGRAPHICAL NOTES

Saeid Emamgholian is a Ph.D. student in Geomatics Science at Université Laval, where he is working to develop an approach for first, modeling land-use regulations as part of city objects and then, detecting spatio-semantic conflicts among land-use regulations, especially those that comprise 3D components. His research interests are mainly 3D spatial analysis, 3D GIS, 3D cadastre, 3D modeling, and 3D Geo-visualization.

Jacynthe Pouliot is a full professor at the Department of Geomatics Sciences (www.scg.ulaval.ca) and currently the vice dean of research of the Faculty of Forestry, Geography and Geomatics, Université Laval, Quebec, Canada. She is an active researcher at the Center for Research in Geospatial Data and Intelligence (https://crdig.ulaval.ca/) and received personal discovery grants from the Natural Sciences and Engineering Research Council of Canada. Her main research interests are the development of GIS systems, the application of 3D modeling techniques in the domain of cadastre, and the integration of spatial information and technologies. She has been a member of the Professional association of the Quebec land surveyors since 1988. She is also a member of the FIG working group on 3D Cadastres.

Davood Shojaei is a lecturer in the Department of Infrastructure Engineering at the University of Melbourne. Davood completed his PhD in 3D cadastre in the Centre for SDIs and Land Administration at the University of Melbourne in 2014. Previously, he was leading 3D digital cadastre research at Land Use Victoria, within the Department of Environment, Land, Water and Planning in Melbourne to modernize the current cadastre in Victoria and move towards a 3D digital cadastre. He has extensive experience working on various geospatial projects ranging from surveying and mapping, land administration, and GIS as well as designing and implementing a variety of research projects in spatial domain.

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