# A WEB-BASED PLANNING PERMIT ASSESSMENT PROTOTYPE: ITWIN4PP

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**ABSTRACT:**

The current process of issuing planning permits mostly relies on checking Land-use Regulations (LuRs) against two-dimensional (2D) analogue or digital proposed development plans. Checking three-dimensional (3D) LuRs within 2D proposed development plans results in challenges for decision-makers to understand LuRs' limits and the impacts of the proposed developments on existing buildings in their surrounded proximity. Given the advancement of 3D geospatial technologies, to overcome such challenges and facilitate the process of issuing planning permits, 3D digital approaches should be developed for effective 3D storage, analysis, and visualisation of 3D LuRs and detection of their potential conflicts. This paper, as part of an internship project with Bentley systems, aims to design and develop a web-based 3D visualisation prototype called iTwin4PP for issuing planning permits using Bentley iTwin platform. This prototype first demonstrates how 3D LuRs related to planning approval can be modelled automatically in 3D and combined with an integrated BIM-GIS environment including BIM designs of the proposed developments and GIS models of planning/city-data. Then, the prototype considers the possibility of 3D spatial analyses (especially proximity analysis) for verifying 3D LuRs automatically to detect potential spatio-semantic conflicts that may arise between modelled LuRs and physical/planning objects. Five LuRs subject to planning approval in Victorian jurisdiction, in Australia, including height limits, energy efficiency protection, overshadowing open space, noise impacts, and overlooking are highlighted. While these LuRs are specific to Melbourne's planning scheme ordinance, we believe that the prototype and encountered challenges in integrating different sources of information especially BIM and GIS, modelling 3D LuRs, and detecting their potential conflicts are common and can be applied in other jurisdictions.

## 1. INTRODUCTION

### 1.1 Context and Problematics

Mid-rise and high-rise development growth (including a combination of different types of residential and commercial buildings) especially in cities with a lack of available lands, challenges responsible authorities (e.g., city councils and planning ministry) in both statutory and strategic planning phases (Emamgholian et al., 2021a; Selmi et al., 2017). Land-use Regulations (LuRs), with their involvement in regulatory mechanisms and processes, play a significant role to restrict illegal activities and developments on lands that may not be obvious to residents (Cann, 2018; Durham Jr and Scharffs, 2019). One of such processes is issuing planning permits that currently, in many countries, is mostly two-dimensional (2D), manual, time-consuming, and subjective which might lead to decisions based on the knowledge and expertise of planners (Benner et al., 2010; Noardo et al., 2020c, 2020a; Olsson et al., 2018; Van Berlo et al., 2013). Additionally, issuing planning permits comprises diversity and multiplicity in 1) documents (e.g., documents of direct legislation like planning scheme ordinance and complementary documents like decision guidelines), 2) institutions (e.g., city councils, planning ministry, and referral authorities), and 3) sources of information (e.g., IFC, RVT, SKP, DGN, SHP, CityGML) (Guler and Yomralioglu, 2021; Noardo et al., 2020a; Plazza et al., 2019).
With advances in three-dimensional (3D) digital information technologies, especially regarding the design of proposed developments with Building Information Modelling (BIM), 3D digital approaches and prototypes can be designed and developed for effective 3D analyses and visualisation of geospatial information (Atazadeh et al., 2017; Noardo et al., 2022b; Pouliot et al., 2018, 2016; Rajabifard et al., 2019; Shojaei et al., 2018). However, required data processing and prototypes to enable modelling LuRs in 3D and consequently, detecting their potential conflicts is still lacking (Emamgholian et al., 2021a; Kitsakis et al., 2022; Kitsakis and Dimopoulou, 2017; Noardo et al., 2022a).
Enabling 3D visualisation and verification of LuRs supports decision-making tasks and mitigates misunderstandings in interpreting and checking LuRs (Barzegar et al., 2021; Emamgholian et al., 2021b, 2020; Noardo et al., 2020b). Moreover, it is economically beneficial for both government and citizens (Grimmer, 2007). To have a better impression of the economic benefits related to the building permit process, Table 1 summarises the total number and value of issued building permits in 2021 in Canada based on two variables (i.e., number of permits and value of permits).

| Type of Building | Total No. | Value (millions of CAD) |
|---|---|---|
| Residential | 407,841 | $87,230.4 |
| Non-residential | 67,524 | $39,629.9 |
| Sum | 475,365 | $126,860.3 |

**Table 1**. Total number and value of issued building permits in 2021 in Canada extracted from Statistics Canada[1]

The value of permits, including materials, labour, profit, and overhead, proves how costly it can be to revoke a mistakenly issued permit during/after construction.

[1] https://www.statcan.gc.ca/

### 1.2 Objectives

This study is part of a research project focusing on the design and development of a three-stage conceptual framework for 1) modelling 3D LuRs geometrically, 2) combining them with 3D city models, and 3) detecting their potential conflicts based on users' needs (Emamgholian et al., in review, 2021a, 2021b, 2020). As the last phase of this research project, this study presents the outcomes of an internship project in collaboration with Bentley Systems with a focus on showcasing the feasibility of the proposed conceptual framework.

As a proof of feasibility, the general objective of this study is to design and develop a web-based planning permit assessment prototype (called iTwin4PP) for issuing planning permits automatically within Bentley iTwin platform. This prototype first demonstrates how 3D LuRs subject to planning approval can be modelled in 3D and combined with an integrated BIM-GIS environment including BIM design of the proposed developments and city-data. Then, it verifies the possibility of verifying the LuRs using 3D spatial analysis (especially proximity analysis) for detecting potential conflicts that may arise between modelled LuRs and physical objects like building elements.

### 1.3 Methodology

The methodology of this research follows an engineering type of approach to design and develop a web-based planning permit assessment prototype for issuing planning permits automatically. This prototype is developed by coding within the iTwin platform using JavaScript and ReactJS to address specific requirements as follows:

- Loading different data sources (e.g., zoning base map and BIM design of a high-rise building as a proposed building in IFC format or RVT) into iTwin,
- Modelling and visualising selected 3D LuRs geometrically,
- Combining the LuRs with the proposed and adjoining buildings,
- Verifying the LuRs by a set of analytical rules based on required geometric and semantic information,
- Detecting and locating the potential conflicts among LuRs and physical objects like building elements, and
- Visualising the conflicts (e.g., a complete report of validation checks).

The feasibility of the prototype is assessed based on a specific use-case of issuing planning permits in the city of Melbourne in Victoria, Australia, as a case study. The tests are performed on a high-rise building by assessing five specific regulations including height limits, energy efficiency protection, overshadowing open space, noise impacts, and overlooking. The next section reviews the iTwin functionalities underlying this study. Section 3 summarises the procedures for two developed functionalities focusing on modelling and verifying the 3D LuRs automatically that will be followed by a showcase of the tests were performed and the evaluation (section 4). Finally, the conclusions derived through this study are addressed by discussing issues that require further research (section 5).

## 2. REVIEWING ITWIN FUNCTIONALITIES UNDERLYING THIS STUDY

Bentley's iTwin platform[2], as a starter kit for developing web applications for infrastructure digital twins, enables the integration of heterogeneous 3D geospatial information. This section briefly reviews the iTwin components prior to presenting the developed planning permit assessment prototype. It should be noted this section only covers the components underlying this study including iModel, Base Infrastructure Schema (BIS), iModel console, iTwin Synchroniser, iTwin viewer, and iTwin clash detection API.

- iModel: An iModel is a cloud-ready format for all the datasets that need to be added to the iTwin platform. Via several built-in iModel connectors[3] (e.g., GIS, IFC, and MicroStation connectors) different file formats can be converted to the cloud-ready format in iModelHub which keeps the track of datasets and any changes within the iTwin platform.
- Base Infrastructure Schema (BIS): BIS[4] defines a set of base classes (e.g., 3D geometry) for capturing the core commonality of all the datasets with different formats as well as a set of specialised classes (e.g., descriptions and labels). It utilises a hierarchical structure containing different schemas in which there are several classes for which there are various properties. BIS enables the users to write queries for different/disparate data sources.
- iModel console: iModel console is another component of the iTwin platform that will be used to write queries within iModel. The queries should be in ECSQL[5] language which is based on SQL. As an example, all elements in BIS have a unique identifier ID (i.e., ECInstanceId) than can be retrieved within queries in the iModel console.
- iTwin Synchroniser: Synchronisation aims to translate and aggregate different data formats (e.g., Revit, IFC, DGN, SHP) into an aggregated dataset using iTwin synchroniser[6]. Via iTwin synchroniser, the iModel connectors can be enabled for aggregating all the required data formats. It should be noted that synchronisation should not be confused with the data federation concept which is used for connecting data from external sources such as JSON and databases.
- iTwin viewer: An iTwin viewer[7] is an open-source application written in TypeScript for being connected to the iTwin platform for visualising the datasets. It handles authentication process and contains different built-in functionalities like zoom and rotation as well as user interface tools such as decorators, markers, colorise, and show/hide tools.
- Clash detection API: iTwin contains several APIs like clash detection API[8] that mainly focuses on finding those physical objects/elements colliding or coming under clearance limits geometrically with other physical objects/elements in the digital twin application. As an example, it can be used for finding soft/hard clashes in BIMs.

Besides being open source, the main reason for selecting the iTwin platform is that it allows the integration of a variety of common 3D formats like IFC and RVT as a common format that many architects are working with to design proposed developments. It should be noted that the IFC/Revit connector can read/store the building geometries/semantics required for automating the process of issuing planning permits. In addition to its visualisation functionalities for BIM and GIS data, it enables writing different spatio-semantic queries. However, it does not include a CityGML connector for integrating the CityGML data format.

[2] https://www.itwinjs.org/

[3] https://www.itwinjs.org/learning/imodel-connectors/
[4] https://www.itwinjs.org/bis/
[5] https://www.itwinjs.org/learning/ecsqltutorial/
[6] https://www.bentley.com/en/resources/itwin-synchronizer
[7] https://developer.bentley.com/apis/visualization/
[8] https://developer.bentley.com/apis/clash-detection/

## 3. PLANNING PERMIT ASSESSMENT PROTOTYPE - ITWIN4PP

The planning permit assessment prototype, called iTwin4PP, is a web-based prototype that was designed and developed in this research project for issuing planning permits using Bentley iTwin platform. The iTwin4PP consists of different developed tools to facilitate the process of issuing planning permits. Two main capabilities are developed focusing on modelling first LuRs in 3D and second verifying 3D LuRs to detect potential conflicts between modelled LuRs and physical (e.g., building elements) or planning (e.g., public open spaces) objects.

### 3.1 iTwin4PP - Modelling Procedure

The iTwin4PP, as proof of feasibility, focuses on five specific LuRs subject to planning approval in Victorian jurisdiction including height limits, energy efficiency protection, overshadowing open space, noise impacts, and overlooking. The selection is in a way that proves the applicability of the prototype for modelling LuRs by utilising different geometric modelling approaches such as extrusion (for height limits), sweeping (for noise impacts), Boundary Representation (B-Rep) (for overshadowing), and Constructive Solid Geometry (CSG) by the union of a quadrant and a cube plus extrusion (for overlooking). To model the LuRs automatically, the prototype utilises the modelling parameters identified and proposed by Emamgholian et al. (in review, 2021a).

- **Height limits:** This LuR focuses on checking the proposed development regarding the maximum allowed height. For modelling this LuR, iTwing4PP first, makes a query in the BIS by using iModel console to retrieve the centre coordinates of the proposed development. Second, it creates a rectangle with a predefined length and width surrounding the proposed building. Then, by considering the maximum allowed height in the zone where the proposed development is located and using a linear extrusion approach, it geometrically models the height limits (Figure 1).

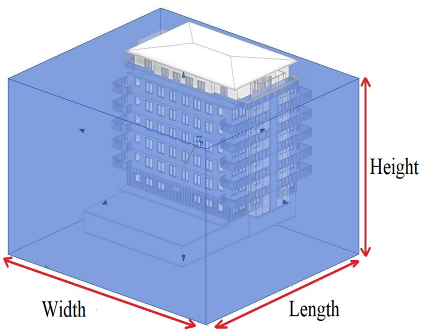



**Figure 1**. Height limits modelled by using linear extrusion.

- **Energy efficiency protection and overshadowing open space:** For both LuRs, a volumetric shadow is required. The prototype utilises the reverse engineering method proposed by Emamgholian et al. (2021a) to model the volumetric shadow using B-Rep (Figure 2). The iTwin4PP first gets the 2D shadow corner points on the terrain or shadow points with a pre-defined threshold in more complex shadows (i.e., blue multiplication signs in Figure 2). Second, it reads the centre coordinates of the proposed development and calculates the distance (Di) between each shadow point and the centre coordinates of the proposed development. Third, by defining the Di as the sweeping distance, it sweeps the shadow points on the terrain along the sun direction (α) to obtain the top points approximately (i.e., red multiplication signs in Figure 2). Then, by creating points with the zero height (or the first-floor height) for the obtained top points, corresponding points on the terrain are created. Finally, by having access to all points the energy efficiency protection and overshadowing open space LuRs are modelled using the B-Rep approach.

It should be noted that the extraction of 2D shadow points on the terrain is not part of this prototype. In addition, the proposed approach for obtaining top shadow points might overlap/cause a gap with the proposed development. But since here the proposed development should be checked with surrounding buildings and open spaces, it meets users' requirements in the process of issuing planning permit. Moreover, it facilitates the modelling phase extensively since there is no need to extract the proposed developments' geometries to obtain the top shadow points.

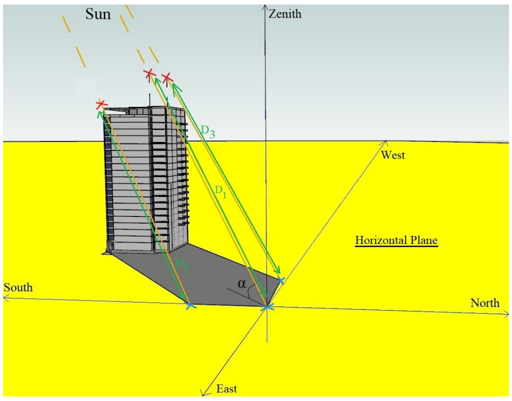



**Figure 2**. Energy efficiency protection and overshadowing open space points extraction in order to model it using B-Rep (adapted from Emamgholian et al. (2021a)).

- **Noise impacts:** This LuR checks the proposed developments' habitable room windows against roads, railway lines, and industry points closer than a specified distance (e.g., 300 meters for freeways carrying 40,000 Annual Average Daily Traffic Volume). The iTwin4PP first gets the roads/railway lines' width and centre points coordinates. Second, it creates a semi-circle with the specified radius based on the planning scheme and guidelines. Finally, to model the noise impacts geometrically, the semi-circle is swept along the road path. It should be noted that since the road direction might change, both translation and rotation of the semi-circle along the Z-axis (Rz) based on the road's direction at every two points are considered (Figure 3).

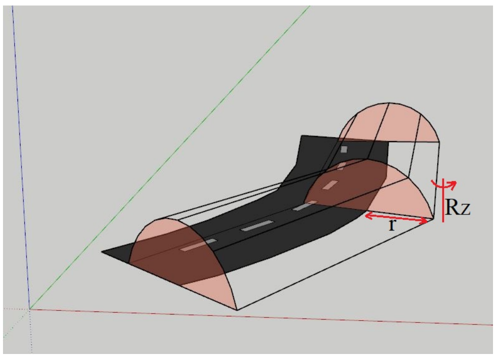



**Figure 3**. Noise impacts modelled by using sweeping approach.

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-4-W4-2022-37-2022  

- **Overlooking:** This LuR checks the direct line of sight of the proposed developments' habitable room window, balcony, terrace, and deck or patio into existing buildings' habitable room windows and secluded private open spaces. The iTwin4PP only focuses on habitable room windows. But the process is almost the same for other building entities such as the balcony, terrace, and deck or patio.
  To model the overlooking LuR, the prototype first retrieves the proposed development's habitable room windows coordinates and width by querying the iModel datasets with the BIS schema using the iModel console. Second, based on the window width, forms the union of a triangle (coloured in red in Figure 4) and arc (coloured in yellow in Figure 4) by using the union operator of the CSG modelling approach. Third, the iTwin4PP translates and rotates the unionised form along the Z-axis based on the location and true north angle of the proposed building's windows that are retrieved from the iModel. Finally, by extruding the unionised form to 1.7 meters from the window's floor level (based on Melbourne's planning scheme and guidelines), the overlooking can be modelled geometrically as illustrated in Figure 4.

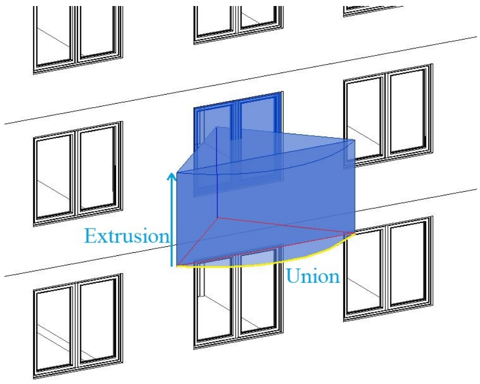



**Figure 4**. Overlooking modelled by using CSG and extrusion modelling approaches.

### 3.2 iTwin4PP - Clash Detection Procedure

This phase focuses on verifying 3D LuRs automatically using clash detection API by defining a set of geometric and semantic rules inside the iTwin4PP's iModel. The clash detection API needs two sets of model/category IDs referring to elements that are needed to be checked regarding collision. It can be a model (e.g., the proposed building) or a category (e.g., walls/windows) ID. This enables the prototype to detect spatio-semantic conflicts between modelled LuRs and physical/planning objects like building elements/public open spaces.
For example, Figure 5 shows the defined rules structure/components for detecting height limit conflicts. While the values might change for different LuRs, the procedure is the same for all other LuRs. For defining height limit conflict detection rule, the proposed building is the first element and the modelled height limits should be set as the second element. The defined rules include:

- ModelIds and categoryIds: All models and categories have a unique ID that can be retrieved by querying the iModel. Category IDs should be specified whenever specific building elements (e.g., windows) need to be checked.
- selfCheck: When selfCheck is false, the clashes will only be checked against elements in the opposing set.
- Clearance: When clearance is set above 0, any elements within this distance will be reported as a clash.
- SuppressTouching and touchingTolerance: When suppress touching is true, the results will not include elements that are touching, or whose clash overlap falls within the touching tolerance limits.
- IncludeSubModels: When it is true, any sub-models under the specified model will be included.

```
"test": {
    "id": "(iModel ID)",
    "displayName": "Height Conflicts",
    "description": "Detecting Height Conflicts",
    "setA": {
        "modelIds": ["(Proposed Building's ID)"],
        "categoryIds": [],
        "selfCheck": false,
        "clearance": 0
    },
    "setB": {
        "modelIds": ["(Modelled Height Limits)"],
        "categoryIds": [],
        "selfCheck": false,
        "clearance": 99mm
    },
    "suppressTouching": false,
    "touchingTolerance": 0,
    "includeSubModels": false,
    "suppressionRules": [],
}
```

**Figure 5**. Defined rule for detecting height limit conflicts.

## 4. RESULTS AND EVALUATION

The iTwin4PP loads the BIM file and models the selected LuRs (i.e., height limits, energy efficiency protection, overshadowing open space, noise impacts, and overlooking) automatically. Then, it detects and locates the LuRs' potential conflicts automatically by the defined geometric-semantics rules using the iTwin clash detection API.
The tests were performed on a complex BIM design in RVT format. Via iTwin synchroniser, planning scheme zones[9] and overlays[10] related to Fishermans Bend area in the city of Melbourne are added to the iModel in SHP format (coloured blue in Figure 6). Planning scheme zones/overlays are required to retrieve the zone and the assigned LuRs' restrictions where the proposed building is located. In addition, the digital terrain model, Bing Maps with labels, and OSM buildings of existing buildings are added to the iTwin viewer. To enhance the visualisation aspects, for all the datasets a show/hide toggle button is added to the viewer as illustrated in Figure 6.

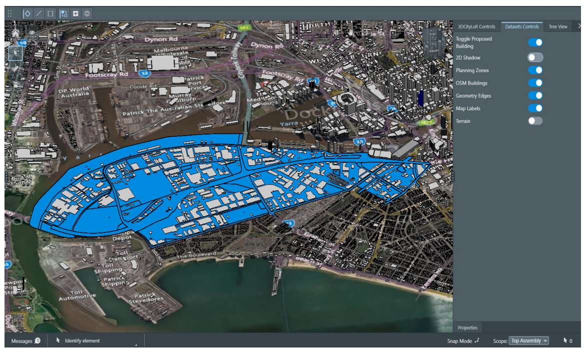


**Figure 6**. Added datasets in iTwin4PP.

[9] https://discover.data.vic.gov.au/dataset/planning-scheme-zones-vicmap-planning
[10] https://discover.data.vic.gov.au/dataset/planning-scheme-overlay-vicmap-planning

The prototype is developed by coding based on JavaScript and ReactJS using the iTwin library[11] in Visual Studio Code. It should be noted that the planning authorities (e.g., councils and planning ministry) are the target users of this prototype.

### 4.1 Modelling LuRs in 3D

Figure 7 illustrates the modelling control tools in the iTwin4PP. For height limits, an option for selecting the planning zones/overlays with an initial height limits value (if any) is added. In addition, as the height limit LuR might not be the same for the entire zone/overlay, it can also be changed interactively. For overshadowing LuRs, since it should be checked in specific dates (e.g., 22nd of September) and times (e.g., 11:00 or 13:00), the prototype includes an option for changing the date and time to retrieve the required sun direction and 2D shadow on the terrain.

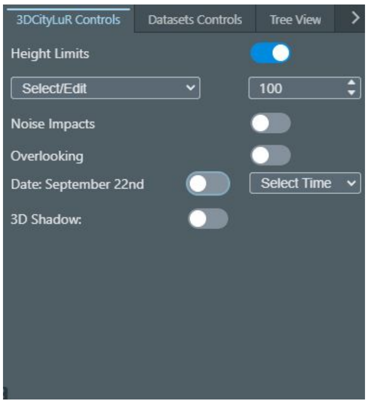
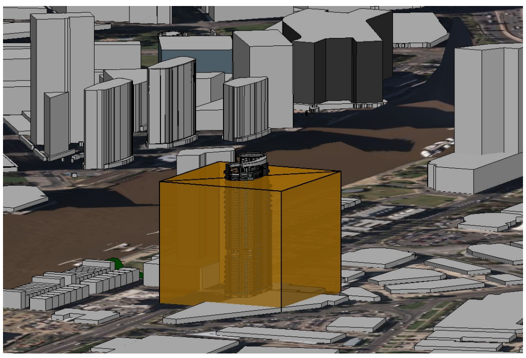
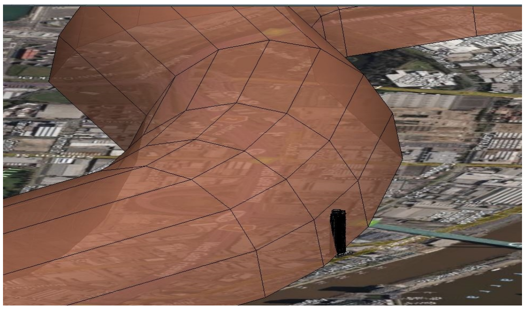



**Figure 7**. Modelling control tools in iTwin4PP.

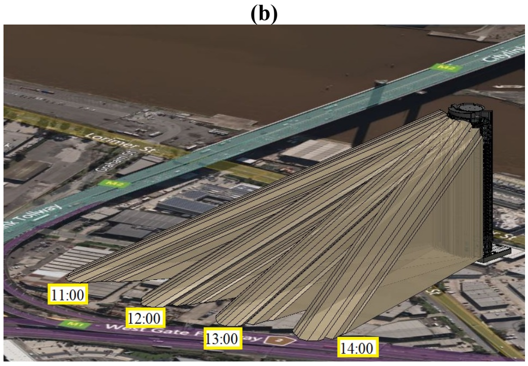
Figure 8 shows the results of the modelled height limits, noise impacts, and overshadowing LuRs. The noise impacts LuR is modelled for part of Lorimer St and the overshadowing is modelled considering four specific times (i.e., 11:00, 12:00, 13:00, 14:00) of the 22nd of September considering the Melbourne planning scheme ordinance. For modelling noise impacts, centre line coordinates of the highway and for overshadowing, the 2D shadow coordinates were retrieved from a JSON file. While the modelling procedure is automatic, some tools still need to be developed to extract the required geometries (i.e., roads/railway lines' centre points or 2D shadows on the terrain).



**(a)**



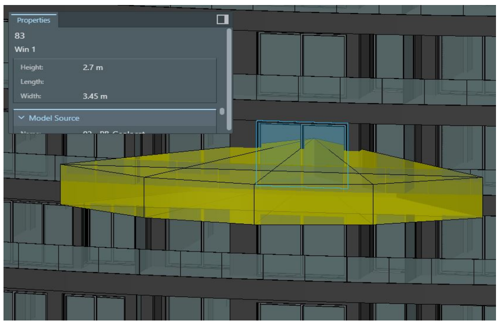
**(b)**



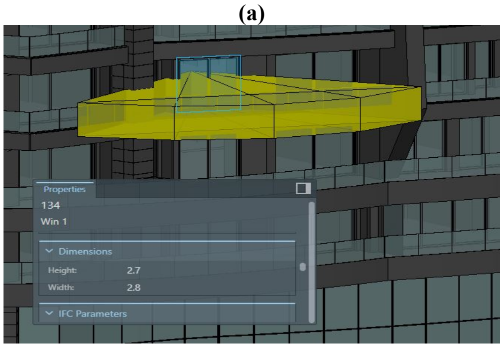

**(c)**

**Figure 8**. Modelled LuRs; **a)** height limits, **b)** noise impacts, and **c)** volumetric shadow in four specified times.

Overlooking regulation was modelled for different windows of the proposed development with varied widths and true north angles to show the applicability of the prototype for any habitable room windows in the proposed building (Figure 9). It should be noted that the windows' floor height, width, and true north angles were retrieved automatically by querying the iModel. Figure 9 illustrates the modelled overlooking LuR for three windows with different properties.

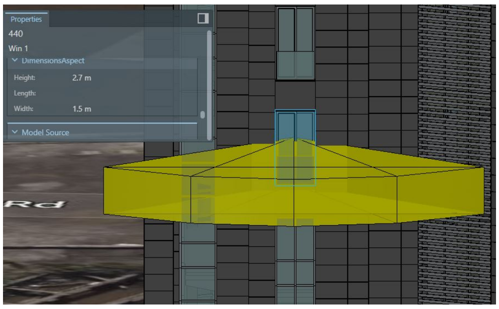



**(a)**




**(b)**

[11] https://www.itwinjs.org/learning/



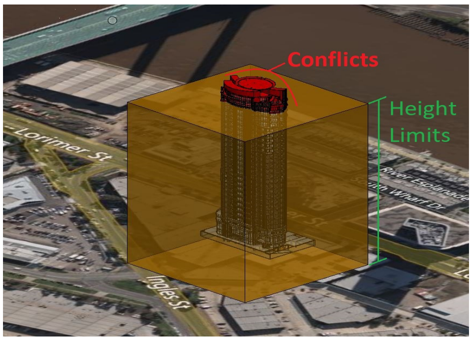

**(c)**

**Figure 9**. Modelled overlooking LuR for a window with a width of **a)** 3.45 meters, **b)** 2.8 meters, and **c)** 1.5 meters.

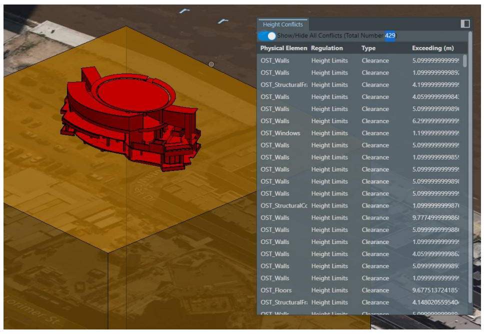
### 4.2 Detecting 3D LuR conflicts

In this stage, potential conflicts between the modelled LuRs and planning/physical objects are detected by taking the advantage of the iTwin clash detection API and defining analytical rules (e.g., based on proximity analysis) by considering both required geometric/semantic information. The clash detection API needs two sets of elements for each test.

- **Height limit conflicts:** For detecting height limit conflicts the proposed development should be set as one of the elements that should be checked against modelled height limits LuR as another element. In this case, since the building elements that are not geometrically colliding with the modelled height limits matter, the prototype considers a clearance vertical distance (i.e., 1 cm) to detect those buildings' elements that are above the height limit (see Figure 5). This clarifies that the detected elements are not respecting the height limits LuR. It should be noted that the defined rule here only needs to consider the geometric characteristics of the conflict. Figure 10 (a) shows the detected height conflicts of the proposed building that can also get filtered and reported as illustrated in Figure 10 (b). In addition, the maximum vertical exceeding distance (i.e., ~10 meters) can be identified by checking the exceeding tab in the results. Finally, the conflicts can be grouped or filtered individually by clicking on the table.




**(a)**



**(b)**

**Figure 10**. Detected height limits conflicts (coloured in red) with **a)** a full view and **b)** a zoomed view in which the conflicts got filtered.

- **Energy efficiency protection and overshadowing open space:** For detecting overshadowing conflicts, the public open spaces in planning scheme zones/overlays play as one of the elements, and the modelled overshadowing in specified times/dates is the other element in the clash detection API. Public open spaces IDs can be retrieved by querying the iModel regarding the planning scheme zones/overlays category IDs. The iTwin4PP only checks these LuRs against surrounding public open spaces. However, by having access to the 3D city model with a sufficient level of information, private open spaces and roof-top solar energy panels of the surrounding buildings can also be verified against the modelled overshadowing LuR. Figure 11 illustrates the detected overshadowing conflicts against surrounding public open spaces (coloured in red).

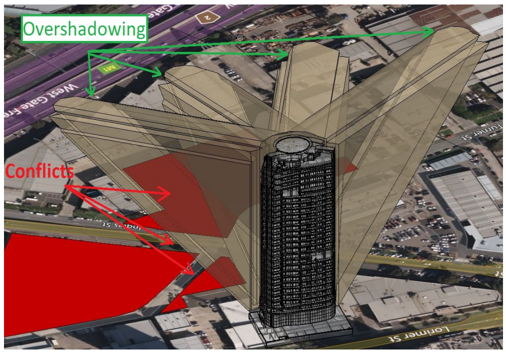
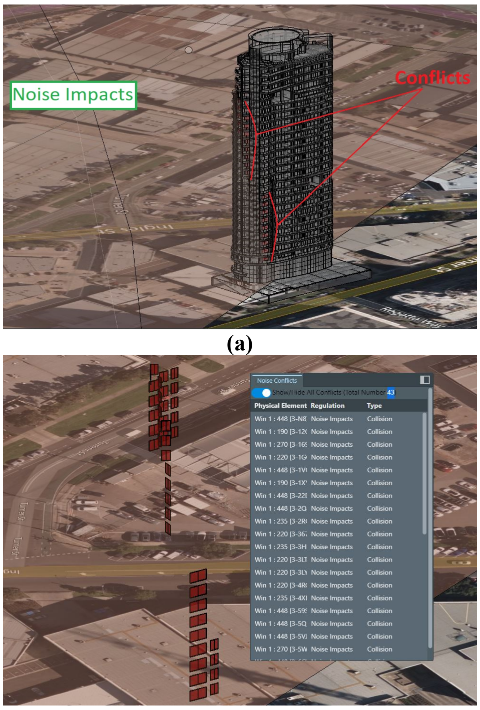



**Figure 11**. Detected overshadowing conflicts against public open spaces for the four specified times.

- **Noise impacts:** For detecting noise impacts conflicts, the habitable room windows in the proposed development are set as the first element and the modelled noise impacts LuR as the other element. Habitable room windows IDs are retrieved automatically from the iModel by querying the proposed development's models and categories. The habitable room windows were defined in the BIM design manually using Revit. Since the habitable room windows are the target elements, here a geometric rule cannot guarantee the conflicts can be detected properly and both geometric and semantic aspects should be considered in the defined rule. Figure 12 (a) shows the detected noise impacts conflicts that can also get filtered and reported as presented in Figure 12 (b).




(a)

(b)

**Figure 12**. Detected noise impacts conflicts (coloured in red) with **a)** a full view and **b)** a zoomed view in which the conflicts got filtered.

- **Overlooking:** Since the iTwin4PP does not include surrounding buildings with a sufficient level of information (i.e., existing buildings including habitable room windows and private open spaces), in this stage, the modelled overlooking LuR could not be verified to see if the conflicts exist. However, as mentioned before, by having access to surrounding buildings with the required information, it can be automatically verified.

In the last stage, to check and evaluate the performance of the prototype as an internal validation process, the results of the detected conflicts (Table 2) were compared in a manual manner by exploring the 3D model visually. For height limits, all 429 building elements above the modelled height limit LuR were detected. For height limit conflicts, the vertical exceeding distance also matters that can be identified from the reported conflicts (Figure 9b). For verifying overshadowing LuR, 7 conflicts between the modelled LuR and public open spaces were detected as expected. Finally, 43 habitable room windows were detected as noise impacts LuR conflicts for which special material should be considered during the construction to mitigate noise impacts in habitable rooms. The results proves that the developed prototype, as a proof of feasibility, can be utilised to facilitate the decision-making process for the responsible authorities (e.g., councils and planning ministry).

| LuR | No. of Conflicts | Detected by iTwin4PP |
|---|---|---|
| Height Limits | 429 | 429 |
| Overshadowing Open Space | 7 | 7 |
| Noise impacts | 43 | 43 |

**Table 2**. Evaluation results specifying the number of conflicts that were expected to be detected.

## 5. CONCLUSION AND FUTURE STEPS

This paper presented an original web-based planning permit assessment prototype, called iTwin4PP, for issuing planning permits by using the iTwin open-source platform with the potential for future developments. To our knowledge, this is the first web-based prototype enabling the automation of modelling LuRs in 3D and verifying them to detect the potential conflicts in issuing planning permits. In our opinion, this work opens the door to new market and technology development applied to land administration and land planning domains.

iTwin4PP and the underlying procedure show a number of advantages. First it enables the 3D visualisation of LuRs and consequently improves the understanding of their horizontal but mostly vertical extents. Moreover, it allows detecting potential conflicts between 3D LuRs and existing/proposed buildings. Our development reveals how 3D spatial analyses, as well as both geometric and semantic checks, jointly are necessary to detect the arisen conflicts automatically.

Planning authorities (e.g., councils and planning ministry) can be the main beneficiary of the prototype and procedures. The manual process of evaluating the results showed that the conflicts are detected correctly, and the developed prototype, as a proof of feasibility, can be utilised for the early decision-making process for issuing planning permits.

However, although we have received positive feedback on the developed prototype from DELWP[12], for now, this prototype is not fully validated nor confronted with a concrete decision-making process, and this is part of upcoming work. In addition, this research showed that for having a fully automated process, how important can be having access to the 3D city model containing existing buildings including required geometries and semantics (e.g., habitable room windows or private open spaces). Since most cities can have such challenges, AI capabilities to extract the required information from existing buildings can be a solution to overcome this issue.

While the selected LuRs are specific to Melbourne's planning scheme ordinance, we believe that the developed prototype and encountered challenges (e.g., integrating different sources of information, modelling/verifying 3D LuRs) are common among different jurisdictions and can be utilised as a source of inspiration for similar research studies and projects.

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[12] DELWP is the responsible authority for assessing development applications containing a total gross floor area of more than 25,000 square metres in the state of Victoria

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