EVALUATING URBAN INTENSITY THROUGH A CITY INFORMATION MODEL - INTERMEDIATE RESULTS FROM AN ACTION RESEARCH PROJECT

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ABSTRACT:

Urban planning is a very complex task, especially considering the many challenges it faces, including an increasing need for housing in response to demographic growth and a need to limit abusive land artificialisation. As part of an interdisciplinary action-research project focused on experimenting with various uses of an existing City Information Model (CIM) for urban design, we are developing a new indicator to characterize urban intensity and a method to quantify it through the City Information Model (CIM) of a French eco-district. Our project is ongoing, and, in this paper, we present intermediate results on the potential of this CIM to support the automated quantification of our urban intensity indicator. We also describe the solutions currently implemented so that our experimental CIM can provide the necessary information for a more complete and automated urban intensity analysis. Finally, we shed light on key issues regarding the use of CIM, specifically CIM made up of various BIM models (of buildings lots and public spaces) for urban analysis at the district scale during the design phase. These issues include the need to generalize BIM entities and to manage property sets and nomenclatures to allow automation of analyses at the district scale, as long as there is no BIM+ data model allowing for urban analysis.

1. INTRODUCTION

In this article, we propose a contribution to the assessment of potential uses of City Information Models (CIM) for urban analysis at the district scale. We focus specifically on CIM composed of Building information models (BIM) of buildings and of public spaces. We explore how this specific type of CIM can play a key role in the urban analysis process used by architects and urban planners to meet their planning goals and requirements, especially during the design phase.

Current demographic growth and environmental realities call for innovative ways to ensure respectful, sustainable and resilient urban management (Véron, 2008; Beaudet, 2014; Vezzoni, 2020). Urban analysis performed by urban planners and architects is key to achieve the objectives set for a given urban project (Ayeni, 2017), as it helps to understand the inherent dynamics of places. Due to the multifaceted reality of urbanisation, urban analyses based on traditional static, mono-criteria indicators are insufficient and researchers are turning to dynamic notions such as urban intensity (Fouchier, 1997; Da Cunha and Kaiser, 2009; Sevtsuk et al., 2013; Guan and Rowe, 2016; Chadee and Stoute, 2018; Stonor, 2019). This notion includes a set of characteristics which contribute to the understanding of complex urban systems. Urban analysis methods and tools must be adapted to dynamic notions such as urban intensity (Panerai et al., 1999). Although geographical information systems (GIS) have been used for many years for urban analyses (Longley et al.,2005, Goodschild, 2012), the rapidly increasing production of CIM is an opportunity for current urban practitioners, provided they can identify precisely what CIM can provide to urban design and management and how to produce and use them efficiently.

In the construction industry, the CIM notion is often used to designate BIM representing buildings and public spaces. Nevertheless, the use of BIM software and formats to model public spaces raises many issues, including modelling requirements for public space specific entities. Indeed, the openBIM standard Industry Foundation Classes (IFC) has not been initially designed for such a purpose. To tackle some of these issues, we adopt a use-centered experimental approach. The work presented here is based on intermediate results from an interdisciplinary action-research project. This multidisciplinary action brings together geoinformation and urban planning researchers working on an experimental CIM. Together, we propose a new urban intensity indicator and an assessment of this indicator through a CIM.

In this paper, we start by synthetically positioning our work in both considered fields, namely CIM for urban design and management and urban intensity characterisation for sustainable planning. We subsequently describe our ongoing project and methodology. We then present our results so far, i.e., which parameters of our intensity indicator can be measured through the existing version of the CIM and what is currently being done to modify the CIM to enable a more comprehensive and automated urban intensity analysis. Finally, we discuss those preliminary findings and link them to ongoing challenges in the field of CIM.

2. STATE OF THE ART

2.1 City Information Models and BIM+ approaches for district-scale analyses

First used by Khemlani (2005), the CIM notion still needs to be precisely defined, as it is used to label very heterogeneous models from a technical standpoint. Moreover, other denominations (digital twins, urban information model, spatial decision support systems, planning support system) are currently used to name similar models and/or processes (Gil, 2020). CIM being more of an ideal than a strictly delimited field, studies on CIM need to specify, at least for the moment, which technical realities their notion of CIM encompasses.

From a technical standpoint, the CIM notion inevitably points to the challenge of BIM and GIS integration, or at least their use in a common framework. The conversion between BIM and GIS standards (namely IFC and CityGML) is a much-studied aspect. As stated by Arroyo Ohori et al. (2018), BIM-GIS integration methods can be developed at the data, application or process level or through a unified model encompassing - or defining relations between - the two standards. Nevertheless, a completely lossless conversion between BIM and GIS open standard formats is not yet feasible in practice, due to differences between the concerned formats, to variability in the possible ways of creating and managing information in these standards (especially IFC) and to professional practices in the architecture, engineering and construction (AEC) domain (Stouffs et al., 2018, Noardo et al., 2020a, Salheb et al., 2019, Tauscher 2020). In current professional practices, joint use of BIM and GIS data remains a challenge and specific methods have to be developed for most use cases.

Despite these technical difficulties, several uses of GeoBIM, defined as the integration of 3D GIS city models with BIM data (Noardo et al., 2020a) are developed in practice, relying on various data extraction or data conversion processes and use of these data either in a GIS, BIM or third-party data environment (i.e., tools designed for specific tasks: simulation, asset management or digital twin management for instance). The building permit processing through GeoBIM is today both a relevant subject for many practitioners and the subject of many scientific works, which rely on the joint use of GIS and BIM data (Noardo et al., 2020b). Facility and asset management is another investigated topic, where data from GIS, BIM, and, from time to time, both types of datasets, are mobilized (Garramone et al., 2020). Other uses include design support system, sustainability analysis through simulation and visualization of one or more scenarios (Gil, 2020).
Finally, there is a growing field of uses at a “CIM-like” scale (from the scale of a public space to the district scale) relying mostly, if not only, on BIM data, whether representing a singular (but sometimes large) construction project or a project and its surroundings, in a BIM format (Correa, 2015, Chen et al., 2018). From a CIM perspective, this can be considered as a BIM+ approach, as proposed by Gil (2020). In this context, technical challenges include georeferencing BIM, extracting or converting information from BIM, realizing district-scale analysis in BIM tools and organizing data in BIM so as to be able to use them for various purposes at the district scale.
Most of the BIM+ use cases focus on engineering analyses and simulations, taking advantage of BIM precise urban morphologic data (precise geometry and information on materials and construction composition in general). Sirakova (2018) studies the microclimate around a metro station, Delval et al. (2018) perform acoustic, solar comfort and aeraulic simulations, as well as life-cycle assessment (LCA) analyses. However, larger scale urban analysis is rarely performed with BIM-like models extended at the district or city scale. Delval et al. (2018) do propose a biotope area factor (BAF) based on a typology of surfaces in a district of La Défense (sealed, partially sealed, semi-open and with vegetation), but do not go beyond the calculation of surfaces areas, which are then considered in the BAF with a specific weight.

In this paper, we propose to extend the BIM+ approach to perform a broader urban analysis, which has until now been relying mostly on less detailed GIS data (Longley et al., 2005, Goodschild, 2012).

2.2 Intensity analysis: CIM as a thinking support tool for urban planners

Visual and digital techniques (drawings, maps, physical and digital models) have been used by architects and urban planners for centuries for urban analysis and design (Soderström 2000, Longley et al., 2005, Goodschild, 2012, Jacquinod 2014). In this respect, City Information Modeling is one of several contemporary ways of using data and visualization to support urban planning.
Traditional urban analyses are based on diagnosis, mostly using indicators such as compactness and density, which are closely related. Many researchers and planners promote the dense and compact city model (Frank and Pivo, 1994; Jenks, 2019; Lehmann, 2010; Boussauw et al., 2011). Teller and Fontaine (2018) criticize the overuse of such indicators, stating that they can become counterproductive, if used as a universally prescriptive measurement of how to create and manage public spaces. Rerat's (2012) work criticises compact models by showing their limits in terms of feasibility, social cleavage and also lack of compatibility with sustainable development. Other authors point out that compactness or density does not seem ideal since users of these spaces mostly have a negative perception of them (Pelegrin-Genel and Pelegrin, 2008; Rodriguez, 2015; Teller and Fontaine, 2018).
Moreover, Stonor (2019) claims that mono-criteria indicators (such as density or compactness) are useful technical tools but fail to meet societal expectations in terms of sustainability. Richard Florida (2012) states that the primary function of a city is to enable and ensure exchanges and combinations between ideas and people. He adds that spaces designed with density alone in mind can inhibit these exchanges. Other authors state that urban systems are complex patterns, overlapping various dimensions that cannot be measured by a simple criterion (Batty, 2008; Solecki et al., 2013; Billen et al., 2015). The concept of urban intensity has been introduced by a number of authors to transcend traditional and frequently used indicators (Amphoux, 2003; Da Cunha and Kaiser, 2009; Darley et al., 2009; Lavadinho, 2009; Paquot, 2009; Zunino, 2009; Fouchier, 2010; Barretto et al., 2012; Sevtsuk et al., 2013; Guan and Rowe, 2016). However, this concept remains broad, unclear, undefined and there is currently no reliable and widely accepted method to operationalise the qualification and/or quantification of urban intensity for urban analyses.

In terms of digital models used for urban analysis, the use of CIM has already been considered by several authors, although never used in practice to realise an analysis on a specific district. More than a decade ago, authors such as Hamilton et al (2005) already recommended that urban analysis tools take into consideration both the physical structure of the city and the multiple dimensions of the urban system (social, economic, environmental, cultural). For Stojanovski (2013, 2018), there is a need to move towards urban analysis tools that capture the spatio-temporal convergences of the city, covering connectivity and flows. Gil (2020) defends that CIM can play several roles in urban analysis during the various project phases, taking into account temporality. Indeed, as Dall’O et al. (2020) state, urban planning becomes more complex because of the fast-paced evolution of urban spaces, the services offered by a given city as well as the city inhabitants’ needs. According to this perspective, several authors consider CIM as a suitable platform to support urban analysis processes aiming at better sustainability and integration of information (Amorim, 2015; Billen et al, 2015; Correa and Santos, 2015; Amorim, 2016; Thompson et al, 2016; Almeida and Andrade, 2018; Dantas et al, 2019; Petrova-Antonova and Ilieva, 2019; Sielker and Sichel, 2019).

3. CONTEXT AND METHOD

This research is part of a broader interdisciplinary project focused on the design of a French eco-district, in the suburbs of Paris. This eco-district is currently under design and construction (phase 1 has entered the construction phase, while later phases are still in the design process). Several urban innovations are being experimented on the area, among which the exploration of potential uses of the district's CIM in various use cases. We focus here on the construction of an urban intensity indicator and its measurement through a (BIM+) CIM. Our goal is to assess which aspects of our proposed multifaceted intensity indicator can actually be measured through a BIM+ model, representing a whole district being rebuilt, where no up-to-date GIS data is therefore available. This research action is ongoing and halfway through.

Concretely, a CIM of the district is produced throughout the design and construction phases. The CIM represents both the buildings and the public spaces of the district (see figure 2). The available CIM is currently in its first version, which allows for various experiments that will lead to recommendations for the final version of the CIM. These recommendations will be transmitted to the stakeholders so they can produce a useful final version of the eco-district's CIM. The CIM is exported in IFC format, an open BIM standard, by the various BIM managers (architects, planners, etc.) and assembled by a CIM manager. It is georeferenced at LoGeoRef 20 level (see Christian and Hendrik, 2018).

Our methodology is illustrated in figure 1. First, we conducted a state of the art on urban intensity and CIM, a portion of which is presented here. Next, we developed a first version of the urban intensity indicator, while conducting interviews with different project stakeholders on their vision of CIM and intensity and testing the measurement of the main indicator with the current version of the CIM. We have regular contacts with the CIM management team and the project team, so that we can discuss potential uses and also experiment different ways of CIM modelling with the practitioners. Our method is iterative and interviews, experiments on the CIM and regular exchanges with stakeholders allow us to progress toward our goals.

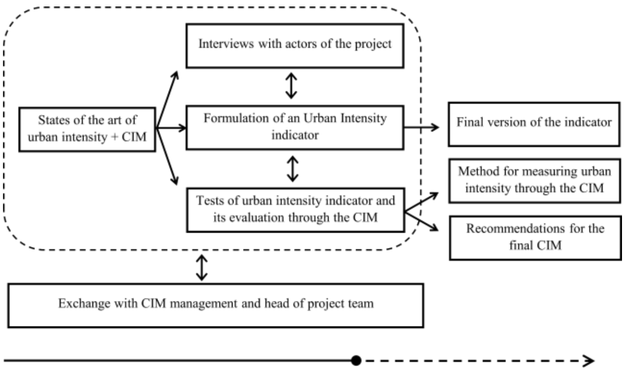

Figure 1. Our methodology and where we are in the process (●)

We aim to propose a useful and usable intensity indicator, methods for measuring at least some of its aspects using the CIM and recommendations for the final version of the CIM. We now have a first version of the intensity indicator, we have tested the measurement of some criteria through the CIM and we are still conducting interviews.

4. RESULTS: URBAN INDICATOR AND ITS QUANTIFICATION THROUGH A CIM

4.1 Proposed urban intensity indicator: intensity of use

We propose to approach the notion of intensity as an "intensity of use" of public spaces by anyone passing through these spaces. The "use" of space reflects the social reality of a place and refers to human activities taking place on it (Gérard, 2017), informing planners on the efficiency or dysfunctions of a public space design. By focusing on uses, we are placing users at the heart of the design or evolution process of cities. We therefore define the intensity of use as the volume of spatial, temporal and social interactions that a district can offer. This is a systemic approach, where users of a given space react to this space as part of the urban system. The intensity of use thus involves parameters related to both the spatial system and the societal system.
The district scale is optimal for capturing the various influencing factors of our intensity of use. Indeed, at this scale, a set of interacting elements such as the different urban functions, roads, networks, infrastructures and flows can be taken into account (Lotteau, 2017). Technical aspects and social dimensions can be included to question the inherent dynamics of the urban system and to deal with many issues such as quality of life, adaptation to changing needs or moderate use of resources (Delaître et al., 2016)

Our intensity of use indicator is based on a primary equation which is meant to assess the intensity of use for a given area. For our first tests, we measure it for a given city block, but it could also be measured for equal areas to form a grid or a heatmap:

$$I_{u,T} = \frac{P_U \cdot \Delta_{t,u}}{\Delta_{t,g}} \qquad (1)$$

where $I_{u,T}$ = intensity of use indicator
P_U = the use potential of a space
$\Delta_{t,u}$ = the average time of use
$\Delta_{t,g}$ = the time step studied

In this paper, we present a method to determine the P_U variable of the primary equation of our intensity. The use potential of a space (P_U) is, for us, influenced by various criteria which we have defined and grouped into thematic categories (table 1). Each criterion is composed of several parameters, which are to be individually quantified. Our indicator consists of 26 individual parameters. For each criterion and then each parameter composing it, we indicate those which are already automatically computable with the CIM (A), those which will be automatically computable in the future version of the CIM (B) and those for which we do not yet have data in the CIM (C) (see tables 1 and 2). As previously mentioned, we wish to achieve this task by using an existing CIM. Nevertheless, it should be noted that the CIM we use and our intensity indicator have been designed for different purposes and have not been coordinated. The aim of our results is to explore the potential new use of BIM + CIM for specific urban analyses.

Influence of use potential	Themes	Criteria
State and quality of the spatial environment	Typo - morphology	-Soil sealing (A) -Building blocks shape (B) -Urban ambiances (B)
Development, territorial interest and response to users' needs	District accessibility	-Mobility (B)
	Attractivity	-Functional diversity (B) -Visibility / interactivity (A) -Adaptability (B) -Temporal possibilities (A)
Demographic attributes	Social (C)	-Statics and dynamics densities -Population profile

Table 1. Influence of use potential, themes, and criteria

At this point, the public spaces (for all phases) as well as the building lots of the first phase are modelled in the CIM. For our demonstration, we focus here on one block of the district. This block includes all the elements we need to calculate our criteria (public spaces, building lots, street furniture, etc.).

4.2 Intensity of use measurement through the CIM

To demonstrate our quantification process, we focus on two themes: "Typo morphology" and "Public space accessibility". Table 2 shows the related criteria and their parameters.

Themes	Criteria	Parameters
Typo morphology	Soil sealing	-Impermeable surface (A) -Permeable surface (A) -Total surface (A)
	Building blocks shape	-Building volume (B) -Porosity of the building front (A)
	Urban atmosphere	-Uniformity of building ages (A) -Material types (A) -Artificial lighting (B) -Urban composition (A)
District accessibility	Mobility	-Public transport offer (B) -Allocated surface to cars, public transport, cyclists and walkers (A) -Car and bicycle parking facilities (A) -Other districts connections (A)

Table 2. Parameters detailed in these results, listed by criterion.

4.2.1 Soil sealing:

- *impermeable surface* is the total area of non-permeable surfaces whether from buildings or public spaces (roads, etc.). In the CIM we can add surfaces from buildings using related IfcSpace (from the ground floor level) to impermeable public space surfaces (filtered through the level of porosity of the material property set).

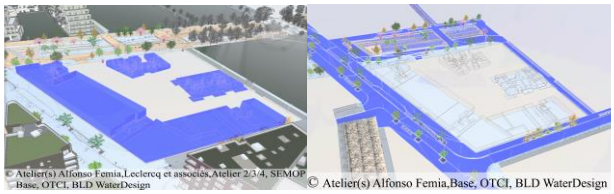

Figure 2. Impermeable surfaces (building lots (left) and impermeable public spaces (right))

- *permeable surface* is obtained thanks to the sum of the surfaces of the non-impermeable public spaces as well as the green spaces. The green spaces correspond to the common spaces within the building lots.
- *total surface* is the addition of the two previous areas.

Soil sealing criterion is the resulting ratio between the quantity of permeable and impermeable surfaces as a proportion of the total surface of the studied area.

4.2.2 Building blocks shape:

- *building volume* consists of both the ground floor level, measured by the corresponding IfcSpace (see 4.2.1), and the height of buildings. Currently, the height of each building is not directly available in the CIM but can be approximated by the number of storeys of each building or automatically calculated with a geometrical treatment in a third-party tool (bounding box creation).
- *porosity of the building front* is the ratio between the perimeter of the building front and the length of breaking spaces. The measurement is done by isolating the building facades (filtered as ground floor external walls facing the street). The length of this building front is computed, then subtracted to the perimeter of the area containing all the spaces.

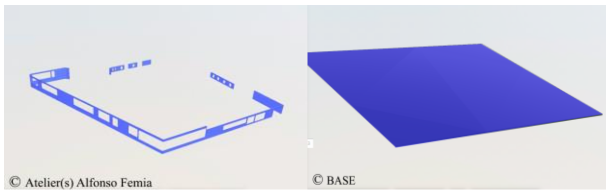

Figure 3. Street front (left) and breaking space (right)

4.2.3 Urban atmosphere:

- *uniformity of building ages*: building date will be in the future CIM, although not present at this time, the buildings being currently built.
- *material types*: materials of external shells are described in property sets and provide information on the materials durability and reusability.
-*artificial lighting* is a calculation of the illuminance area and is necessary to characterize the night-time urban atmosphere. To do this, several data are required such as:
  - the height of street lights,
  - the power of lighting,
  - the number of street lights in the area.

Currently, the CIM contains both the height and number of streetlights (Figure 4). However, we do not yet have data on the power of street lights. A precise calculation will be possible in the next version of the CIM.

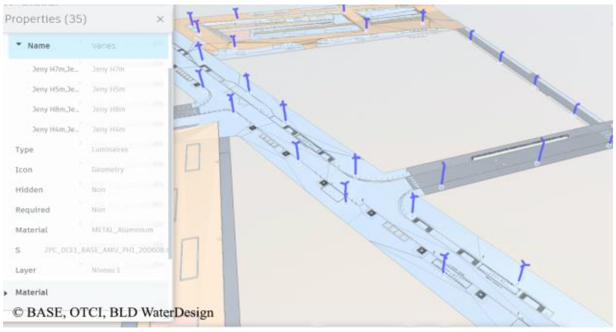

Figure 4. Number and height of streetlights of the work area

- *urban composition* depends on several variables: urban velum, and public space porosity.
-- *urban velum* is obtained thanks to height data (see 4.2.2),
-- *public space porosity* is the ratio between the "solids", which are represented by the impermeable surfaces of the building lots, and the "voids" (public), which are represented by the sum of the permeable and impermeable public spaces (see 4.2.1.).

4.2.4 Mobility:

- *public transport offer* is the number of public transport services in the area and their frequency. Our CIM does not yet list these properties and we are currently waiting for their modelling specifications.
- *surface allocated to each transport mode* can be deduced from road widths and public space surface properties. For example, the walker allocated surface is obtained by adding the surface of footpaths, pedestrian crossings and public walkable spaces.
- *parking facilities* can be determined from the modelled parking spaces. The CIM identifies "Permanent", "Drop-off", "PRM" and "Delivery" parking facilities. For bicycles, the parking offer can be calculated by isolating and counting the furniture intended for this use
- *connections to other districts* is the count of modelled entry and exit roads of the district.

4.3 CIM performance regarding urban analysis at the district scale

The CIM we are using for our experiment is not yet fully complete. Nonetheless, we can already assess which parameters and, which criteria can already be automatically calculated (A), which criteria would be automatically calculated thanks to some modifications to the current CIM (B) (see below), and which criteria may still not be easily calculated in the final version, as far as we know (the CIM is completed throughout the project and we do not have all the final specifications yet) (C). As shown in figure 5, 81 % of our parameters should be automatically calculable in later versions of the CIM. The remaining criteria are social criteria (C category) for which the unavailability of data is explained by the development phase of the project. Indeed, the data will be available when the district is inhabited. Moreover, real-time data informing on the exploitation of private and public spaces are currently missing. This would be especially important in the case of urban analysis performed on operational districts to assess and envision possible and /or desirable evolutions. In this case, data could be later provided by sensors connected to the CIM.
However, to perform urban analyses during the design phase, data could be simulated in order to carry out various prospective scenarios. Social parameters could thus be evaluated, provided simulated or projected data are produced.

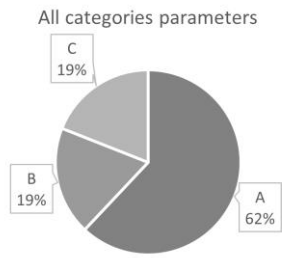

Figure 5. Percentage of parameters automatically calculable (A), manually calculable (B) and not calculable with CIM as it exists (C).

4.4 Proposed evolutions for the CIM

Our intermediate results show that some of the data usually contained in a BIM (impermeable soils, building shapes and materials) and in a BIM+ CIM (permeable surfaces, road surfaces, trees, street furniture, etc.) can be very useful for urban analyses at the district scale.
Nevertheless, some data are missing or not easily exploitable, especially if we want to be able to automate our calculations, which is needed for a usable indicator, i.e., an indicator that can be easily used by practitioners.
We have developed three main solutions to enrich our experimental CIM:
- for missing data that can be attached to existing objects in our BIM+ (i.e., to an existing IFC class), properties or property sets can be added.
- for missing data that are at a larger scale than what is modelled in our BIM+ (i.e., we would need a single object and would only have many sub-parts with no common properties), we resort to nomenclatures, so that object names contain specific codes allowing to select for instance all surfaces forming pedestrian ways or all surfaces with a specific material.
- for missing data that cannot be obtained through property sets or nomenclatures alone, we have defined simple entities with linked property sets that we asked the CIM and BIM managers to create.

5. DISCUSSION

From the standpoint of urban analysis, our first result is that a BIM+ CIM can be very useful, even if it was not intended to be used to perform analyses at the district scale. Indeed, since there is very little operational CIM, the anticipated uses for this CIM were defined before our action-research project and derived from BIM uses that seemed both useful and feasible at the district scale. They were identified as clash detection/technical coordination and visualisation with virtual and augmented reality devices.
From an operational standpoint, our proposed solutions were easy to implement for public spaces models, but is more difficult for the building lots since the BIM managers of building lots have the obligation to give a version of their model in IFC to the CIM managers, but have the latitude to impose some of their own modelling standards, corresponding to their firm's internal conventions. Therefore, we opted for solutions as light as possible, i.e., the creation of entities is limited to IfcSpace containing some entities (for instance building and parking lots access) and a few linked properties in a property set (for instance width of access or number of lanes).
From our use-centred perspective, the ability to perform urban analysis with a BIM+ CIM is key so that it can be done during the design process. As said, in order to achieve more sustainable

and comfortable private and public spaces, many analyses need to be performed on envisioned designs, so as to select the most suitable ones. In this perspective, in many situations, project managers might lack GIS data (new developments or significant district renewals) and will only be able to perform analyses and simulations on BIM + models.

Therefore, the LOD management and generalization in BIM and BIM+ models appear to be significant issues to tackle in order to develop analyses for the design phase (whether urban analyses, LCA analyses, district-scale environmental simulations, etc.). Indeed, our case study shows that for a given parameter or theme, objects in various LODs (with various precision) are needed. For instance, for mobility analysis at the district scale, we do need precise location and parameters for building and parking lots access, surface calculations for pedestrians' areas, road and bike lanes but also a linear description of users' routes for distance calculation in agent-based simulations (the lines being generalized from traffic surfaces in a GIS environment). The need for both surface and linear description of roads has also been taken into account in the latest development in CityGML (Beil et al., 2020). This need for entities in various LODs in the design phase raises issues for CIM modelling and calls for a precise description of needs for specific uses.

As far as interoperability is concerned, our proposed solutions limit the addition of specific entities in IFC, so that we can easily automate the translation to other formats. Without any BIM+ open data model and/or ontology designed at the urban scale, an operational choice was made together by researchers and practitioners. We do not convert IFC to CityGML but to simpler GIS compatible formats, when needed. Nevertheless, we do add specific IfcSpace that would not be taken into account in already developed conversion tools between BIM and GIS standards. In addition, we are faced with a common dilemma for IFC BIM + modellers for some objects that do not yet have specific classes in IFC (for example trees, street furniture, etc.). For these objects, generic IFC entities such as BuildingElementProxy are used and objects are named according to the CIM nomenclatures so as to be able to filter them for various purposes. This leads to reconsider the sometimes-linear vision of BIM level of details, which are often considered as progressing with a project's development phases, thus preventing many analyses to be performed during the design phase. Our exploratory study shows that with a few key data, urban analyses can be performed early in the process, without requiring many additions to a BIM+ CIM, but that, even for some analysis useful at the design stage, some detailed data can be needed for simulations or calculations.

6. CONCLUSION AND PERSPECTIVES

Our first results confirm the usefulness of BIM+ models for urban analyses at the district scale, provided this use is anticipated. From a technical standpoint, most of the parameters can be automatically evaluated if some modelling rules are taken into account (nomenclatures/property sets/objects). Given the diversity of analyses that one might want to conduct with the help of a CIM, it is necessary to document urban analysis' specific modelling needs so that useful CIM can be produced. One of our final results will be formalized recommendations for future CIM on the subject of urban analysis, listing the needed objects, properties and LOD.

Our experimental approach shed light on the diversity of objects and level of detail that are needed for a single analysis, whether for simulation (air quality simulation for instance, where our colleagues need simplified building shapes and more precise traffic surfaces) or for multi-criteria analysis like our proposed indicator and its 26 parameters.

As said, our project is ongoing, and exchanges with CIM managers and project stakeholders will continue in order to adapt the current CIM as much as possible so that it will be usable for as many uses as possible. Although we are already able to automatically evaluate 62% of our parameters with the CIM, we do have recommendations for the final version of the CIM, some of which will be implemented and tested during the second half of our project, to validate their operational use. This will require further work on translating the operational needs into modelling constraints on level of detail and level of information so that the intensity of use calculations can be automated as much as possible.

We will also continue to develop our intensity of use indicator, based on experimental measurement on our case study and on feedbacks from interviews with project stakeholders.

More broadly, beyond this particular case study, we believe our results can contribute to the definition of useful entities to be modelled in future CIM. As we have established that various entities, properties and levels of detail are needed to perform a given analysis, we think that it could be interesting to go beyond the level of detail specifications. A "CIM4 Value" procedure could be developed, like the "BIM4Value" strategy is developed for BIM and which consists of a list of anticipated uses that BIM managers can select to obtain the corresponding BIM modelling rules.

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