# "Enabling the City Information Modeling CIM for Urban Planning with OpenStreetMap OSM"

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**Abstract**

The 3D City Model 3DCM is essential for Urban Planning to enable the concept of City Information Modeling CIM, which is the implementation of Building Information Modeling BIM at the city scale. 3DCM is the Virtualization of the real-world. Moreover, it is one of the tools for Cloud and Spatio-Temporal Computing for Digital Twins of Smart City. The Geomatics are playing a significant role in the process of building the 3DCM. However, there are some limitations of remotely sensed datasets in the field of digitalization of cities and urban areas. Therefore, the Volunteered Geo-Information VGI and spatial datasets provided by the base map of OpenStreetMap OSM are widely employed for the reconstruction of the 3DCM. This paper presents the concept of CIM, Geo-BIM, and how participatory and collaborative mapping on OSM. Where the topographic map provides the building's footprint associated with various attributes about hights and geometric information to extrude the 3D of the building. Thence, provides a 3D City Model with a particular Level of Detail LoD. Which is supporting in return a wide range of applications and use cases during the whole life cycle of urban assets and the physical built environment by bridging the gap between the Geospatial and Construction industry.

**Keywords:** 3D City Model, Urban Planning, BIM, GIS, Geo-BIM, CIM, OSM, IFC, CityGML, Smart City

## 1. Introduction

The United Nations Sustainable Development Goals (UN-SDGs) consider city development as one of the primary or vital players to achieve sustainable development. Sustainable cities and urban development became a crucial research topic. Driven by urban sustainability strategies and motivated with significant challenges of the fast urbanization age [1]. Where cities face critical and severe concerns, e.g., rapid and high Population growth rates, urban sprawl, the limitation of urban infrastructure capacity, Ageing, and degradation of the built environment. Challenges related to the environment and natural resources, e.g., water and energy demand, pollution and its related issues, waste management, public health, security and socio-economic development concerns, the impacts of global climate change, and natural hazards,.etc. [2]. It is challenging to manage cities to face current circumstances based on traditional tools anymore. 50% of the population living in cities, the expected growth is going to reach 9.7 billion by 2050. [3]. Thence, 68 % of the world's population predicted to live in cities and urban areas; therefore, adaptative solutions have been provided to enable sustainable and smarter cities. The smart city concept could present a model for the resilient transformation of cities and sustainable urban development. Moreover, a comprehensive transformation process needs to be adopted to allow cities to meet urbanization strategies and goals. Many requirements have to be presented to enable such a transformation process[4]. Nevertheless, technologies are already there, and many systems have already beeing developed; still, the gap is widely seen concerning the transformation to sustainable and resilient urban development. The main reason is because of the lack of political and social awareness about city challenges and urban development plans and strategies. Also, the intention to change is a keyword for the adoption of sustainable urban development and comprehensive strategies. Technically, the transformation process starts with the adoption of the logic of life cycle thinking and the purposeful urban planning and design, where the impacts and interactions of all city components and elements are taken into consideration within the surrounding city environment. Therefore, cities need to be modeled, both spatially and temporally[5], within the City Information Modeling (CIM) approach, to provide Urban Planning digital tools for the city actors. Furthermore, compiling data into information and services, with a large matrix of applications and use cases, through web-based spatial and temporal computing, benefiting of city database and portals, for smart and resilient cities. This research focuses on the use of OpenStreetMap OSM as a Base Map to reconstruct the 3D City Model. OSM could fill the gap and provide ways to predict the Digital Height Model DHM for different feature extraction, which enables the CIM in the context of a smart city. The main outlines are represented as follows: I. Exploration of concepts and background, II. Case of study, and III. Discussion and Results.

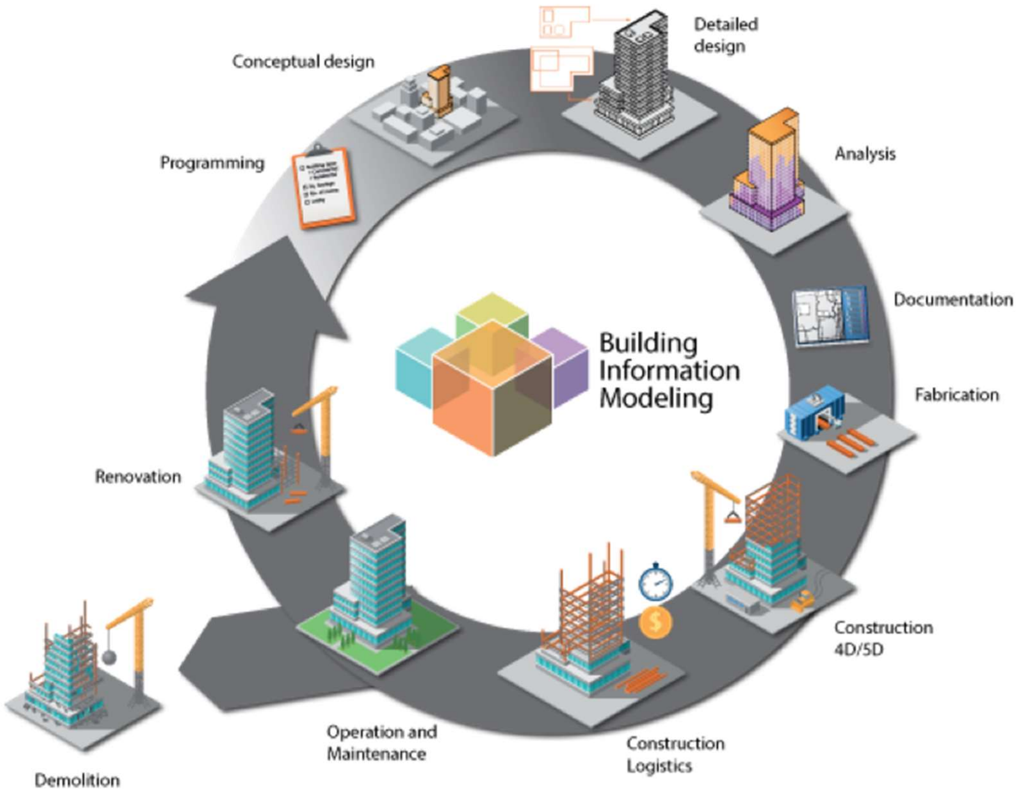
## 2. Concepts and Background

### 2.1 Building Information Modelling BIM

A Building Information Modelling/Management BIM is defined as a whole life cycle and purposeful management of information that drives the process of transition from a paper-based linear process to a digital, object-based, collaborative, and circular approach (figure 1). based on a set of coordinated processes for the design, management, and sharing of building and infrastructure information all through geospatial information description [14], which revolutionizing the Architecture, Construction, and Engineering industry ACE and providing supporting tools for Virtual Design and Construction VDC. Bringing together all stakeholders to work collaboratively during the entire life cycle of the asset. It depends on the adoption of the life cycle thinking and the digital representation of the building process to facilitate the exchange and the interoperability of information [15]. The implementation of BIM starts with the digitalization and automation in the construction industry.

Moreover, that is required a comprehensive virtual 3D model for building geometries with their associated attributes and semantics of the built environment and the surrounding natural and environmental conditions. This model is connected to all datasets, spatial relationships, and information with the related standards and rules. Every single object/element in this representation is related to a family of objects and referenced to a local coordinate system within a specific building's level/elevation. Objects are fully detailed and predefined according to the Industry Foundation Classes IFC. The BIM model is considered as a knowledge sharing tool [11] where the data and information of the building are shared within a unique/single collaborative model through the life cycle of the facility (Planning, conceptual design, analysis, detailed design, documentation, fabrication, construction and logistics, operation and maintenance, renovation, demolition and recycling, and environmental concerns, ..). This model has been structured for the multi-domain, multi-scale, and multi-filter approach, which allows users to select the only zone/part of the interest from the model with particular datasets and information for a specific use case. The BIM model could be extended, updated, shared, and reused for various Application Domain Extension ADE, such as Building Environment – Smoke Aire Heat Flames BE-SAHF and Facility Management FM models[13] where BIM maturity levels are extended to asset information management (figure 2). With such functionalities, the BIM model could be equated to web-based formatting for more collaborative activities and safe extensibility without losing the quality of the model. The Extensible Markup Language XML, which is both human-readable and machine-readable formatting, provides an open standard and XML-based formats called COLLAborative Design Activity COLLADA, the XML schemas format is one of the very efficient web-based BIM model formattings that allow Cloud and Spatio-Temporal Computing, which is required content sharing capabilities and BIM Collaboration Format BCF [12].

Furthermore, providing a tool for all stakeholders for better corroboration to facilitate the management of the building Information. Thence, enhancing the built environment performance and the quality of life for citizens. The digital transformation prosses, and it is implantation in the field of Architecture, Construction, and Engineering industry ACE contributes to sustainable urban development. Driven by the development in the Internet of Things IoT and Information Communication Technology ICT, which provides the link between the virtual and the real world, where smart sensors are collecting data and information form the real world, then send the collected datasets in the real-time into the virtual BIM model for real-time and instantly dynamic synchronization, which keeps the model updated with a continuous data flow about the urban systems and built environment — in return, enabling the real-time monitoring of urban systems, the early detection of undesirable events, the facility management, and the enhancing of the urban Planning Support System PSS[6]. CIM makes it easy to understand and to adapt the configurations of the city systems, and with the BIM for Infrastructure, significant savings could be achieved, where the model is shared on the cloud, and different design teams are working on the same model instantly, with such collaborative working method, there will be almost no interdisciplinary technical and design conflicts, teams




are aware of the latest design updates, phases and versions of the project design and reducing the rework.

*Figure 1: BIM circular approach*. Image source: https://www.france-charruyer.fr/

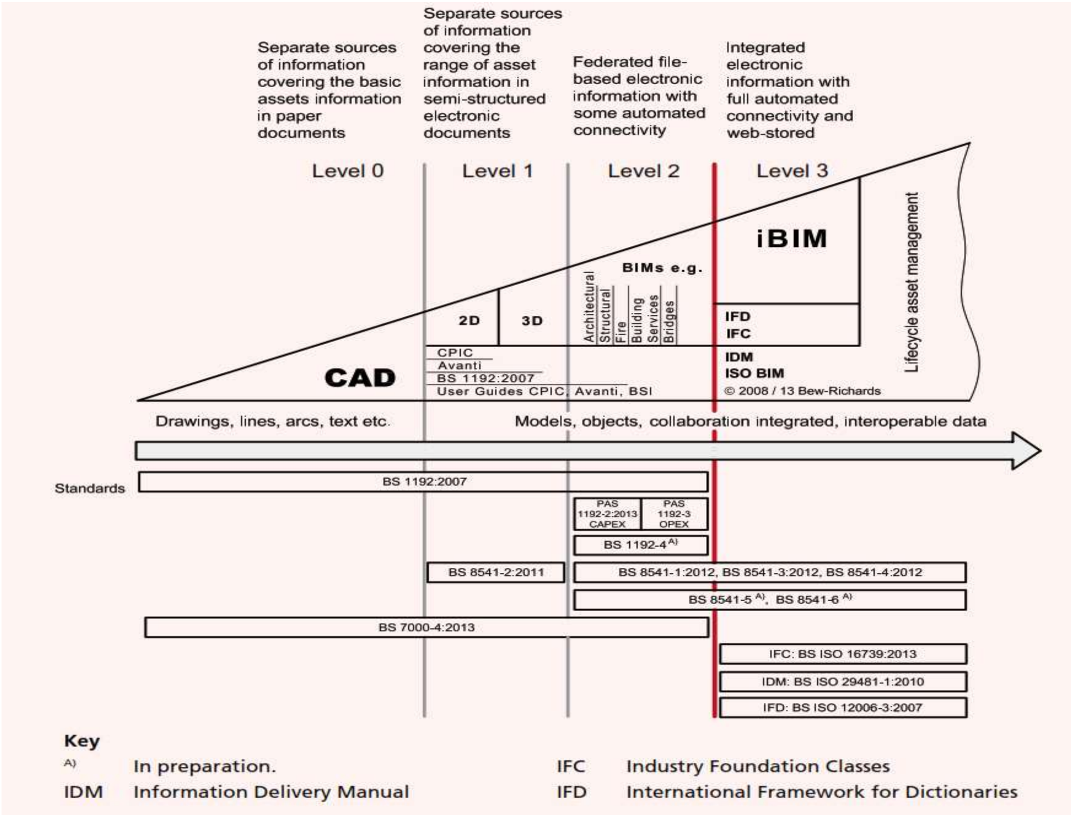



*Figure 2: BIM maturity levels extended to asset information management.*

Image source: PAS 1192-3:2014, Specification for information management for the operational phase of assets using building information modeling

### 2.1.1 Geo-BIM

BIM is not only about building and construction, but it is the context of building and constructing resiliently, and considering the Eco-Conception and Eco-Design, it could be about buildings or infrastructures and all human-made or built environments within their environmental and natural surrounding. So, at the macro level and from a geographic point view, it could be for a regional or national level when tackling horizontal infrastructure or linear projects which extended in kilometers. Eventhgouh, we have to keep in mind that we still dealing with a built environment that needs to be detailed in a multiscale representation that is sometimes varying from kilometers to millimeters, with a hyper complexity of systems and interoperability concerns. Therefore, the integration of Geographic Information System GIS and Building Information Modeling BIM provides the frame of indoor/outdoor interrelation and extends the concept of BIM from indoor to outdoor space and from vertical to horizontal projects. The generalization of the BIM concept from the buildings level to the city scale in parallel with GIS could allow for City Information Modeling CIM. At the city level, projects or physical built environments generally are varying in the scale, and they are vertically and horizontally expanded and composed of buildings, facilities, utilities, and different infrastructures and public spaces. Every component of the city built environment is interacting with and impacting the other components. Therefore the indoor/outdoor relationships and influences need to be considered; for example, the building's thermal performance and comfort configurations must be modeled and simulated with both BIM models and GIS. Where building façades and envelope characteristics are designed in respect to bothe; indoor configurations and outdoor natural and environmental conditions, as well as the energy systems, water, and sewage networks, fire fighting systems, rescue operations, and evacuation plans, waste management, such systems, are required the junction between the indoor and outdoor built environment to support the efficiency of buildings and infrastructure, thence, facilitate the Facility Management FM. A uniform system that allows the modeling and simulation of indoor/outdoor built environments within a Geo-BIM approach must be adopted for better urban planning workflows. This approach could be a data source for the 3DCity database and provide datasets for the reconstruction of 3D City Models paired with smart sensors to enable the Spatio-Temporal Computing and supports the data flow about the city.

Furthermore, it provides smart city knowledge and information sharing system via city portals and platforms (figure 7). Nevertheless, there are many challenges to integrate Geomatics (Geo) with BIM models, for example, the conversion of BIM semantics to map semantics, where in practice, IFC models are not structured to map use. Also, the vast number of IFC classes available with different modeling ways make it impossible to develop a uniform translation and conversion that works for any IFC model, thousands of constructional elements are modeled as volumes in BIM to define a building, while a single closed building object needs to be defined as a surface for geospatial analysis[15, 21].

Such challenges have been confirmed in the project of using the IFC and CityGML in Urban Planning by Open Geospatial Consortium OGC. Where inconsistencies in coding IFC elements which is complicating the transformation to CityGML, therefore, the processing of IFC files in compliance with a set of precise specifications must be conducted to enable the use of IFC in Urban Planning [16]. In addition to the errors contained in IFC models, the direct use of IFC models in spatial analysis is too hard; more knowledge, work processes, techniques, software, and standards need to be developed to enable the Geomatics and BIM Integration for Infrastructure, the outdoor built environment, and city physical systems. Finally, the processes of Geo-BIM integration need experts that are skilled and knowledgeable in both fields, Geomatics and BIM, which is rare at the time being. For example, in order to prepare the tunnel BIM model, various tools, applications, and software have to be used (figures 3,4,5,6), which imposes interoperability conflicts and elements translation and conversion problems from IFC classes to mapping schemas in CityGML representations and then affects the geospatial analysis. The FME Workbench from Safe software provides solutions for interoperability by connecting more than 450 applications with a straightforward visual interface.

Moreover, allowing the integration of location data and geospatial information for model georeferencing. Furthermore, it transforms data without losing the quality throughout the integration process, which performed by unique data processing task with a combination of more than 500 FME transformers. In return, saving time and automating the workflows by moving the manual tasks to repeatable or event-based activities, where integrated data are delivered to stakeholders on a real-time or scheduled basis [17]. Even with such solutions still, the challenge is widely seeing for the Geo-BIM integration, since many IFC classes are containing errors, so, they could not be extended to mapping and geospatial formats to allow BIMInfra to support Urban Planning.

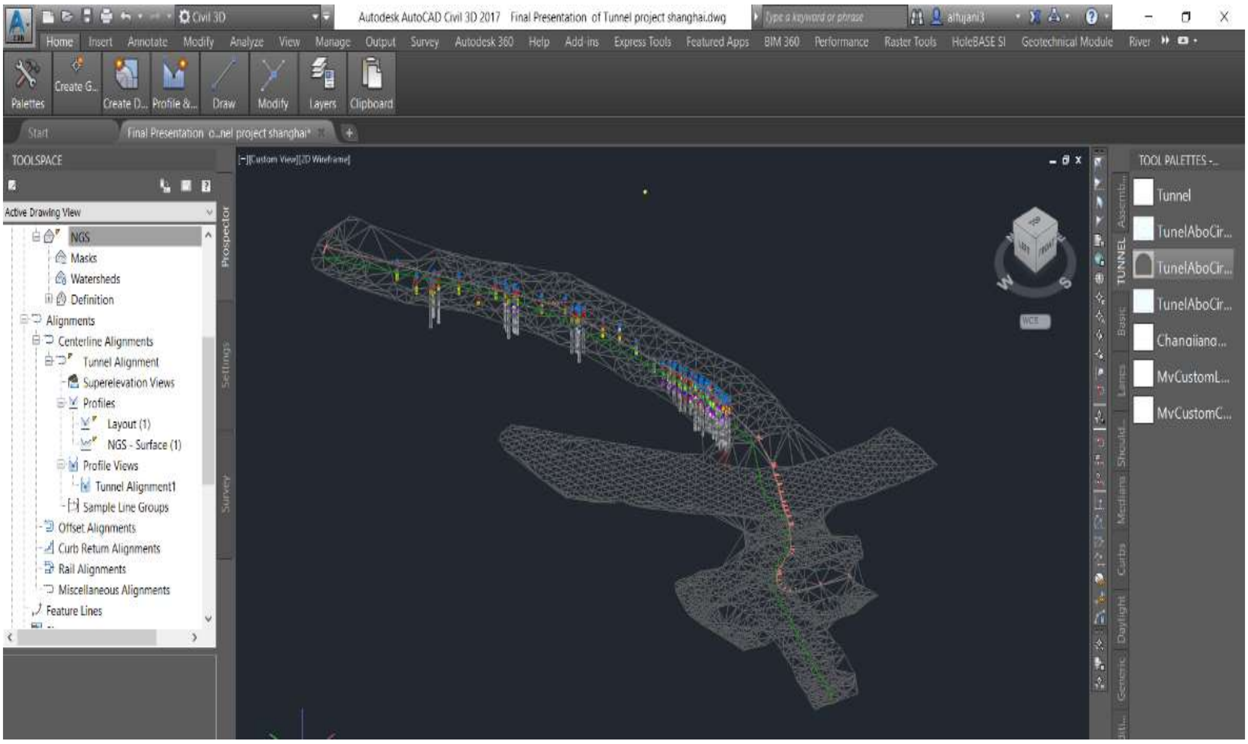



*Figure3, Building 3D points of point cloud imported from land surveying and geomatics data into Autocad Civil3D, creating the topographic surface and digital terrain model, representing the tunnel alignment, and providing 3D semantic representation of geotechnical data of boreholes according to georeferencing and global coordinate system.*

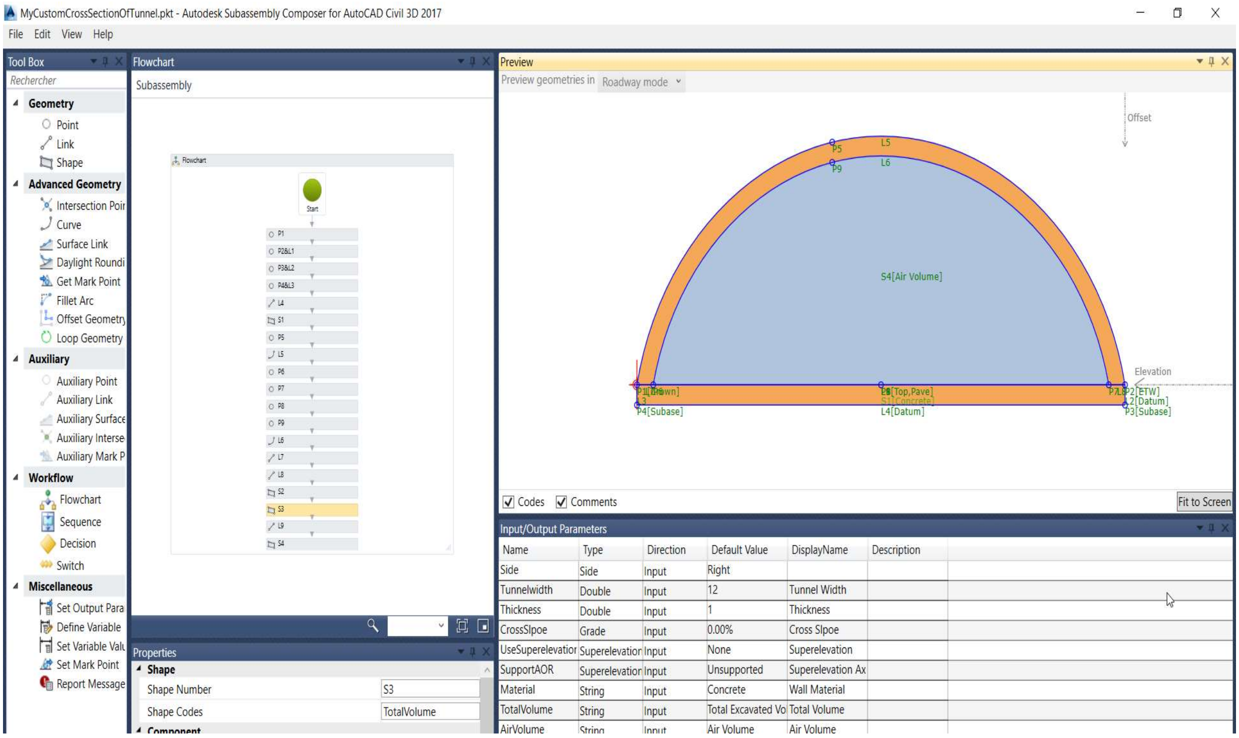



*Figure 4, using parametric modeling to design the tunnel profile in Autodesk Subassembly Composer with detailed geometries, materials, and semantics of predefined objects and adaptative tunnel cross-sections in compliance with the BIM concept requirements and IFC classes and standards.*

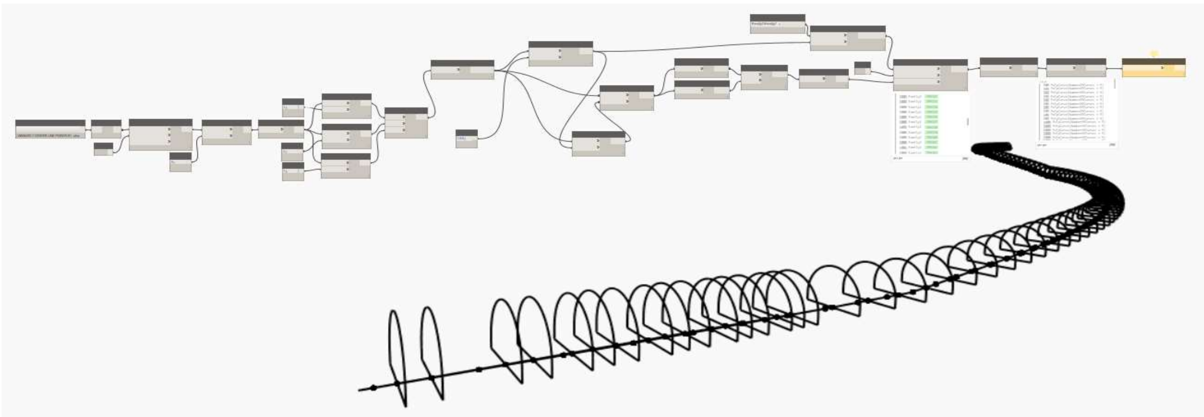


*Figure 5, with visual coding techniques in Dynamo open-source software, the profile of the tunnel is assigned to the tunnel alignment to be exported to the Revit software.*

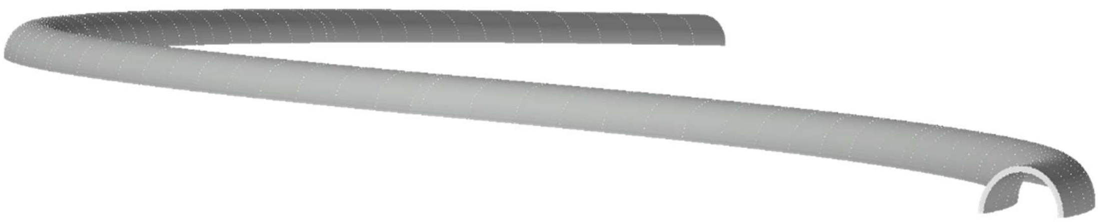


*Figure 6, tunnel model represented in Revit application.*

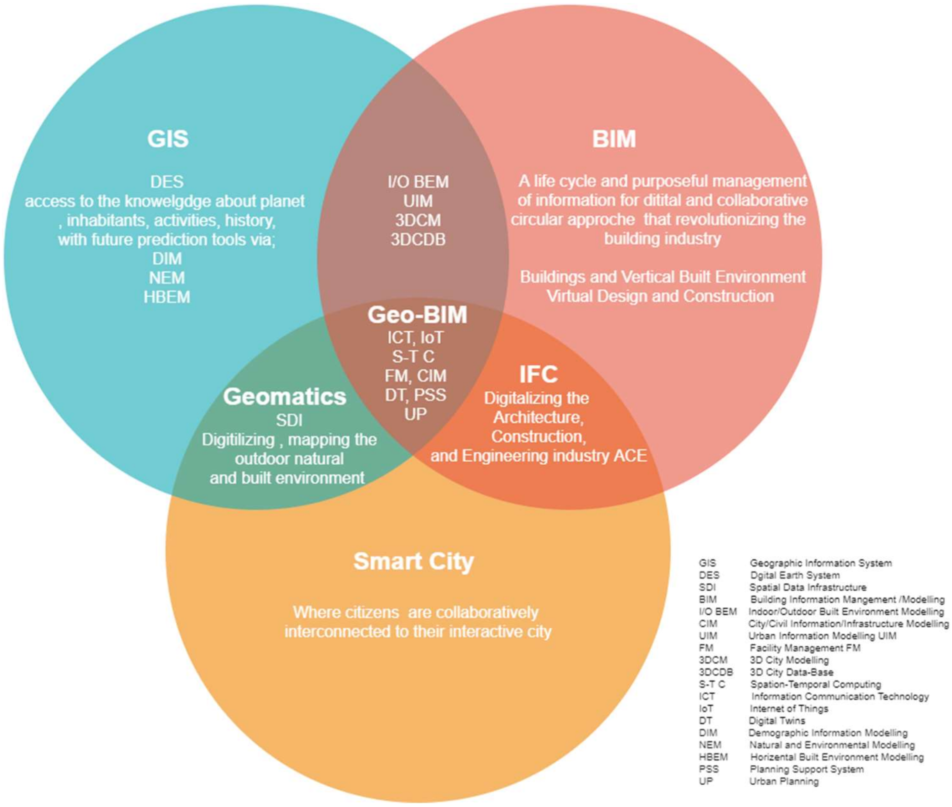



*Figure 7: The Geo-BIM Approach and implementation of the smart city concept*

## 2.2 City Information Modelling CIM

Recently, the abbreviation CIM is repeatedly used to describe City/Civil Information/ Infrastructure Modeling, While Common Information Model CIM in the computer industry used to refer to the standard that defining device applications and characteristics. CIM is the generalization of the Building Information Modeling BIM from the building's level to the city scale, nevertheless inheriting the semantics of the BIM process for digitizing the management and modeling of the building information during the whole life cycle of the built environment. The 3D City Model is one of the digital tools that include most of the required characteristics of digital representation, to enable City Information Modeling CIM. However, integrating different data sources, systems, and modeling tools leads to interoperability problems; also, the ambiguity and fuzziness of terms, topology and taxonomy affect the consistency of the 3D City Model. to overcome such challenges, the built environment has to be described within a standardized digital description models called Industry Foundation Classes IFC. Furthermore, using the Open Geospatial Consortium OGC standards, where OGC has improved the open standardized data model CityGML[19], to exchange and store 3D City Models based on the Geography Markup Language GML application schema. Using the 3D City Models for a wide variety of applications and use-cases needs the integration of different Application Domain Extensions ADE for better Spatio-temporal analysis [20]. Real-Time sensing allows better management of urban systems and environmental phenomena simulation. Integrating 3D City Models with real-time datasets communicated via various types of sensors could allow the simulation of different scenarios. Connected buildings and infrastructure powered by the Internet of Things (IoT) provide efficient support tools for city planning, management, governance, and regulations. These tools emphasize the enhancing of the decision-making process and improve the stakeholder's communication, which enables the smart city concept [2,4]. The digitalization in the field of urban planning and sustainable development reflects the fact that digitalizing the city equates it to the era of smart cities. The development in the field of Information Communication and Technology ICT and its applications in urban development seen in the approach of the fourth industrial revolution age. Where digital technologies are friendly integrated into everyday life [5], many tasks in the planning process could be supported by Planning Support Systems PSS through the integration of ICT and Geographic Information Systems GIS [6]. One of the digitalization phases is to provide approximated representation/virtualization of the physical or the real world. Virtualization could be varying from basic visualization in 2D Map or 3D City Model to a comprehensive digital representation or digital twin of the city [7,18]. Thanks to digitalization, many advantages can be provided, such as data integration and reusability, validation through simulation and transform data into value to enable the interaction between the physical and virtual information world [8,9,18]. The 3D City Model has to contain geometry data sets, attributes and information according to a specific level of detail. The Level of Detail LoD concept refers to the number/quantity of attributes and geometric content in the 3D City Model. The LoD depends on many issues such as the use/purpose of the model, sources of data-sets, techniques of data acquisition, investment/budget and the spatial scale of the model. Furthermore, The Level of Detail LoD used to describe, categorize and distinguish between different phases of 3D City Models creation. Moreover, to ensure quality control of the 3D City Model creation project during the whole life cycle of phases and project stages from scope definition to tendering and contracting process, delivery and exchange formats, extensions, materialization, and 3D printing, ending with the maintenance and updating of the models [10]. Therefore, a holistic 3D City Model must be provided to enable the process of virtualization/digitalization to enable the City Information Modeling CIM, which is required for the implementation of the smart city concept. Where all city components, environments, and inhabitants are interconnected and interacting together to run the city systems. For instance the main challenge that facing the utility management in the city is to have a digital model with semantically predefined Geo-referenced objects; such models could provide the accurate localization of network components and buried urban physical systems/facilities. That could lead to enhance the performance of the infrastructure/utility network and help to manage, operate, maintain and achieve important savings in time and cost[11]. In order to create a 3D City Model, various data sets and information will be needed, such as Geospatial data, CAD drawings or plans, and BIM models. Generally, data collection or acquisition depends on the scale or size of the model and the required LoD. At the city scale, the most suitable way for data acquisition is the remotely sensed data. Even though remote sensing techniques have many limitations and may be cost-prohibitive, but it is still the most efficient manner for data acquisition, especially for large scales with high LoD. For example, remote sensing provides the row data for GIS, and it is related to technologies. Where the high-resolution satellite and terrestrial images could provide photorealistic images for photogrammetry and digital terrain models. Furthermore, it provides many other sets of geospatial data and digital information models, such as elevation, surface, and heights. Also, the underground, remote sensing techniques like sonar and Ground Penetration Radar GPR could provide and collect data about the subsurface and buried networks/invisible infrastructure which facilitate the exploration of the underground urban spaces. Nowadays, more attention is paid to the subterranean and underground urban space, which contains the subsurface infrastructure, buried utilities/networks. Therefore, Digitalizing cities and underground urban space become one of the urban and planning support tools for city management and decision-making. Remote sensing plays a significant role in the process of building and developing digital representation/virtual models of the city. There is extensive use of many developed technologies for the reconstruction of the 3D City Model, like photogrammetry, Light Detection, and Ranging LIDAR, satellite, aerial, and terrestrial imagery. However, there are some limitations of remotely sensed datasets in the field of digitalization of cities and urban areas where there are many challenges during the phase of spatial data acquisition; for example, part or all of invisible built-environment in some cases is out of the range of sensors/cameras coverage. Therefore, participatory mapping activities contribute to the phase of spatial data acquisition for the reconstruction of the 3D City Model. Where Volunteered Geo-Information VGI and spatial data sets are extracted from open spatial data platforms and volunteered base maps like the case of OpenStreetMap OSM. This paper presents how OSM could be a source of Geo-spatial data sets to fill the gap and shortage of spatial data from remote sensing and provide alternative ways to predict the Digital Height Model DHM for feature extraction. Where the building footprint is provided by the topographic map with various associated attributes and hight data to extrude the 3D of building, thence the 3D City Model model of the city, which is supporting a wide range of applications and use cases during the whole life cycle of urban assets and the physical built environment of the city for sustainable development and smart city. Recently, many software and applications start to use OSM as a base map for the reconstruction of the 3D City Model in a straightforward way by importing the spatial data within the area of interest.

## 3. Case of study

For a better understanding of the impact of VGI, a comparison between the 3D City Model at the site of the SUNRISE smart city project on the campus of the University of Lille in France and the campus of the University of Tripoli in Libya (figure 8.,9.a,9.b) Both models have been created by using the OSM as a base map (figure 10). The Autodesk InfraWorks 360 uses the cloud and OSM as a base map and provides datasets and attributes of Barriers, Bridges, Buildings, City Furniture, Coverages, Culverts, Drainage End Structures, Easements, Land Areas, Parcels, Pipe Connectors, Pipelines, Railways, Right of ways, Roads, Streams, Trees, Water, and Watersheds. Then overlay collected dataset on the raster and topographic map to provide a combination of vectors or geometries, attributes and semantics, raster, and satellite image to start the construction and building of the 3D City Model based on predefined objects and libraries of features with rules and protocols for features extraction and 3D objects extrusion. Autodesk InfraWorks models provide a tool for Cloud collaboration where it can be shared on the cloud with BIM 360 using Document Management and Shared Views, with additional options for the local collaboration, Publish and synchronize online visual representation of models. Users can subscribe to Autodesk InfraWorks, where they can build, upload, and share models to collaborate with work teams and get comments and feedback throughout the web browser in real-time and remotely, which makes a significant saving [23].

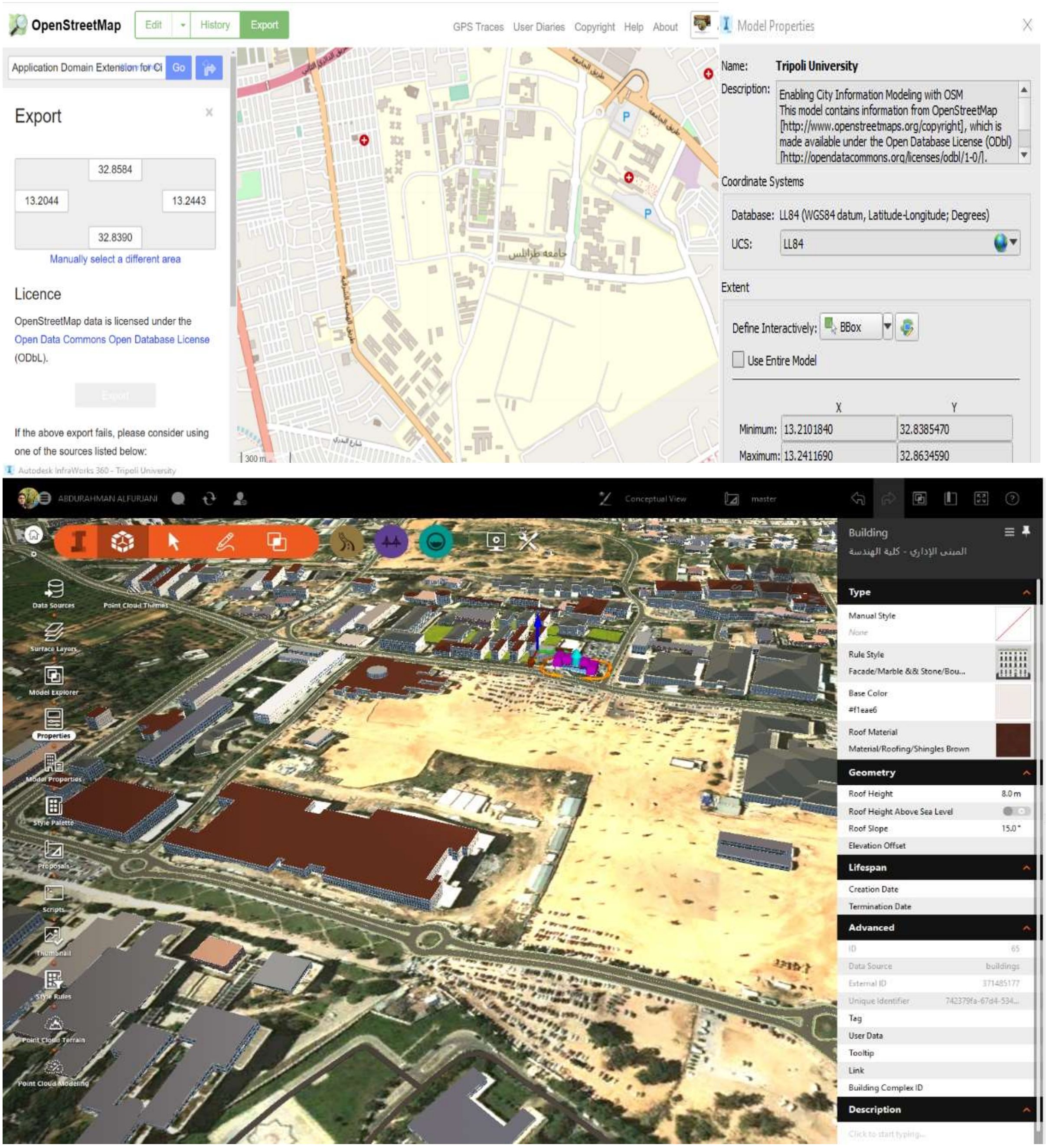



*Figure 8 Using the model builder in Autodesk InfraWorks 360 with OSM as a base map with georeferencing process for the location and project description, then the creation of the 3D City Model for the University of Tripoli- Libya*

After creating both models for the tow university campus sites, using the base map of OSM and the same modeling application which is Autodesk InfraWorks 360, many buildings and city features are missed in the University of Tripoli 3D City model, where some elements are not yet edited on OSM. That reflects the state of the map at specific regions and emphasizes the need to improve the socio-technical awareness about the importance of editing the OSM and encourage contributors to participate in the mapping activities of open spatial data platforms. While more accurate 3D City model has resulted in the site of the University of Lille, as a result of having the OSM with all buildings and infrastructure footprints with their associated attributes and semantics.

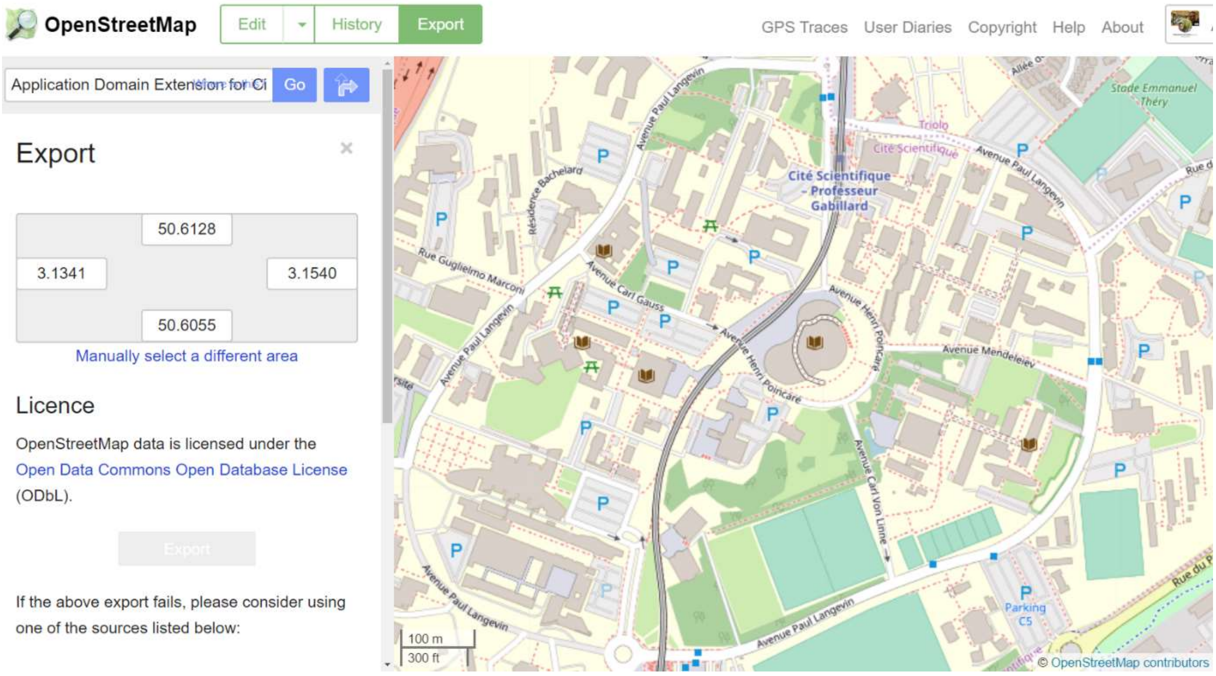



*Figure 9.a. The geographic location and topographic map of the SUNRISE project - smart campus at the University of Lille on the base map of OSM with buildings footprint edited by volunteers and contributors*

*Figure 9.b. SUNRISE project Using the base map of OSM and provides a 3D City Model with LoD2 - the smart campus at the University of Lille, this model has been prepared by with Autodesk InfraWorks 360*

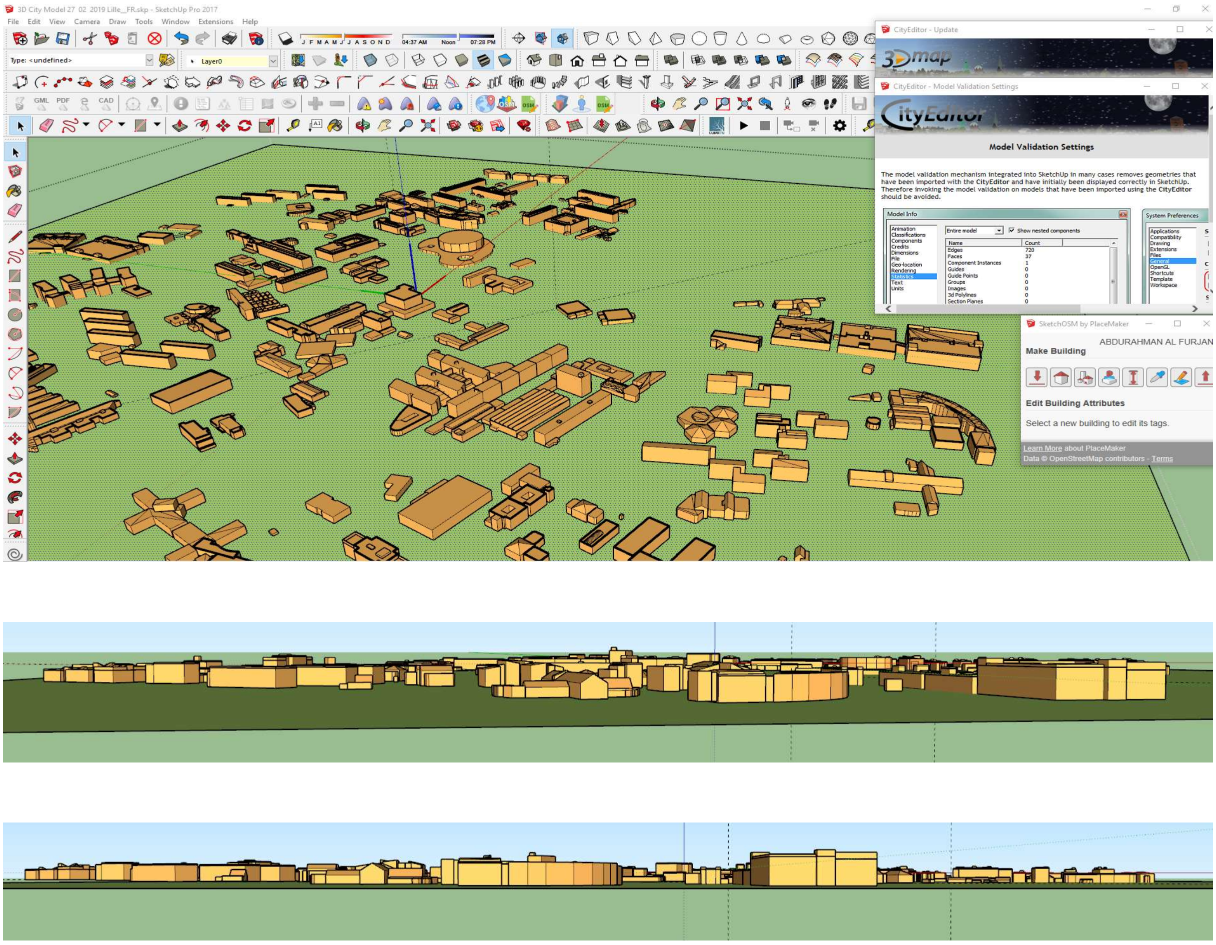



*Figure 10. The 3D City Model with LoD1 for the smart campus at the University of Lille, this model has been prepared by with SketchUp and OSM Add-in (PlaceMaker) with the real buildings hights*

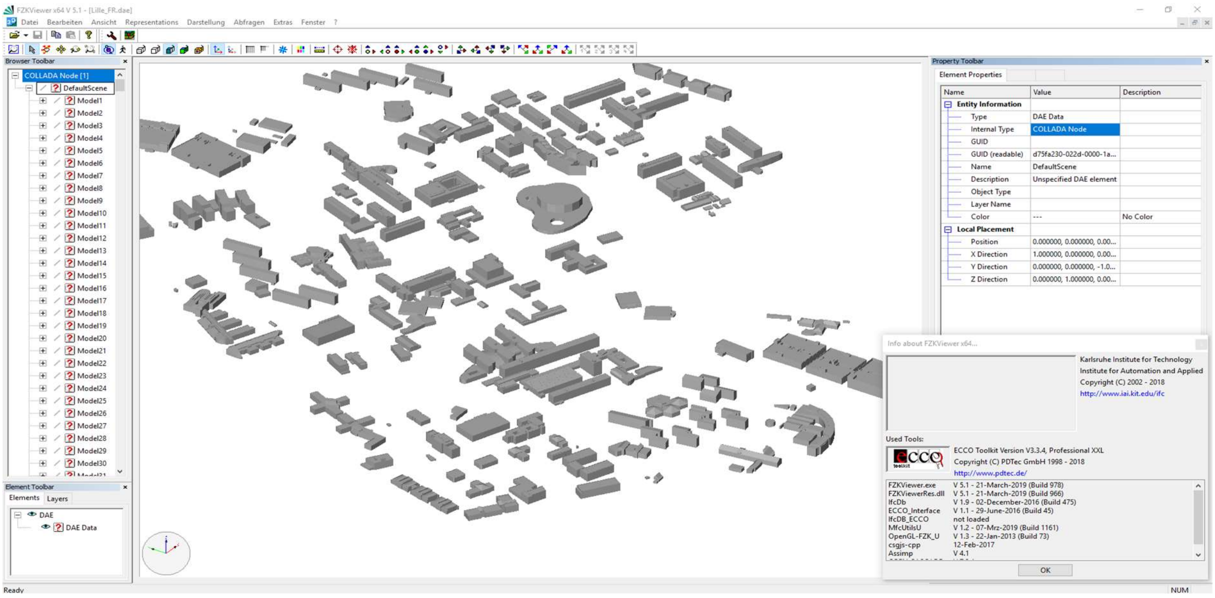



*Figure 11. The 3D City Model with LoD1 for the smart campus at the University of Lille, this model has been viewed and visualize with FZKViewer which is a free application for viewing/displaying semantic data models In this version the following data models are supported IFC (Industry Foundation Classes) CityGML (City Geography Markup Language) gbXML (Green Building XML) LandXML CIM (Common Information Model) and COLLAborative Design Activity COLLADA file formats.[22]*

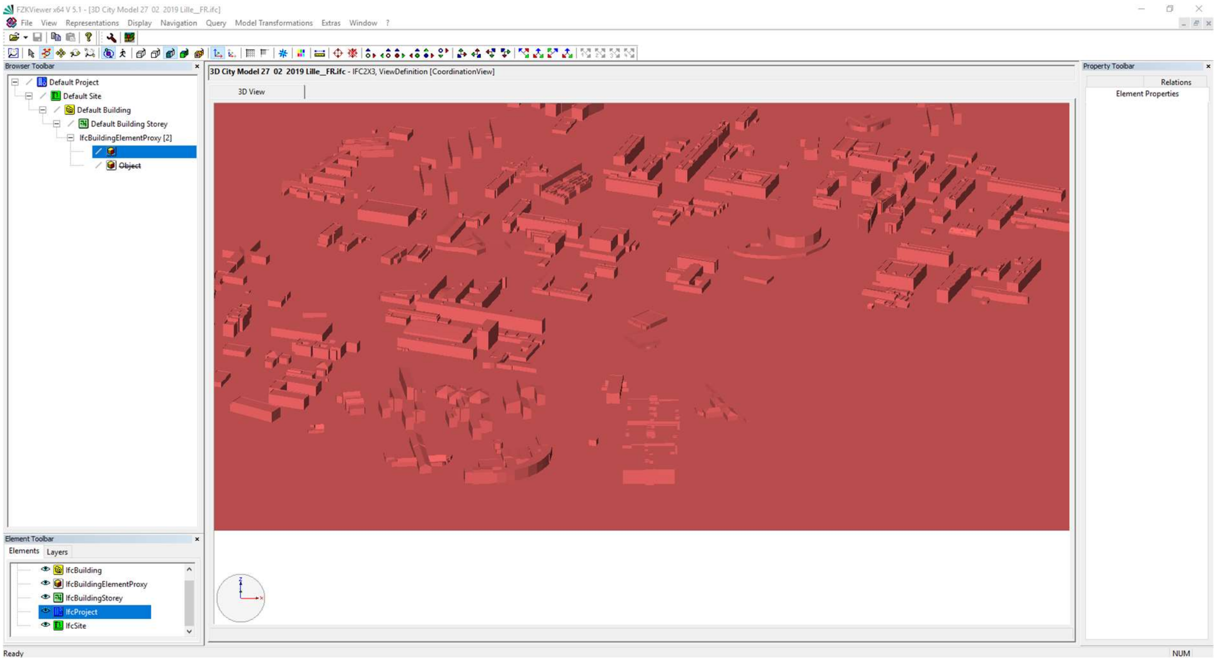



*Figure 12. IFC 3D City Model for the campus of the University of Lille has been developed within the SUNRISE smart city project for 3D Printing*

## 4. Results and discussion

The remote sensing plays a significant role in the process of data acquisition for building and developing an automated digital representation and virtual 3D City Models. Where provides 3D georeferenced data sets. There is extensive use of many developed technologies such as radar, Light Detection, and Ranging LIDAR, laser scanning, close-range sensing, terrestrial, and aerial imagery. Also, the Ground Penetration Radar is used for subsurface and underground 3D spatial data acquisition. Thence, the collected 3D Geoinformation is employed to construct a holistic 3D City Model and digital representation of the entire city and urban areas to provide one of the leading Urban Planning support tools. This tool could enable the City Information Modeling CIM and enhance city management and decision-making in return. Representing as maximum as possible of the surface and subsurface environment in the city is essential, but Researches still focus on the modeling and representation of buildings, surface infrastructure, and landscape with an apparent lack of underground environment, which is always omitted or not well digitally represented in 3D City Models.

Despite the importance of the underground environment in cities and urban spaces, researches on the topic are not yet adequately tackled. However, there are some limitations of remotely sensed data-sets acquisition in the field of digitalization of cities and urban areas. Where numerous challenges during the phase of spatial data acquisition. For example, it is difficult to collect data about the hidden or invisible physical built environment, buried networks, and utilities, and infrastructure embedded in the subsurface where they are out of the range of coverage of sensors, cameras, and scanners. Therefore, many techniques are used to provide a type of transparent layer between the city surface and subsurface to allow underground city visualization by using developed computer vision techniques and applications of Virtual, Extended and Mixed Augmented Reality, throughout the integration of several data- sets collected by remote sensing and other sources like government and open data form OpenStreetMap OMS.

The reconstruction of the 3D City Model Using the Volunteered Geographical Information VGI and spatial data sets from the base map of OSM could help to fill the gap and provide an open data sources to predict the Geomatics of the physical built environment. For the city surface, the 3D City Model is extruded based on the footprint of buildings with their associated attributes form the open data provided by VGI on the base map of OSM. On the other hand, still, the city subsurface and underground urban space not yet well represented on the open data maps and public city databases. Where many features and elements could be easily edited or entered by volunteers and contributors. This research aimed to explain that BIM could be generalized or extended for Infrastructure throughout the Geo-BIM integration. This challenge could not be faced without fitting the IFC classes of Infrastructure to the standards and specifications of OGC to provide a multi-scale and multi-domain 3D City Model (figure 11,12).

## 5. Conclusion

- The base map provided by contributors on the OpenStreetMap platform supports the reconstruction of the 3D City Model for any location (Figure 8 and Figure 9.a,b, as explained in the comparison of the Universities campus of Lille and Tripoli).
- The development of the Geo-BIM concept could support the implementation of the Smart City and digital transformation process throughout enhancing the Planning Support System PSS for better Urban Planning.
- Still, the challenge of generalizing IFC classes for outdoor built environment and Infrastructure is too hard to achieve due to the lack of IFC classes for infrastructure.
- The quality issues of Volunteered Geo-Information are not yet well defined.
- Remote sensing capabilities for spatial data acquisition in the urban planning field are cost-prohibitive and have some limitations.

## 6. Future research

- There is an apparent lack of knowledge about underground 3D City Modeling and digitalization of city subterranean or subsurface. Researches have to continue for reformalizing the concept of the Level of Detail LoD for the subterranean 3D City Model.
- Provide and develop the required algorithms and tools to the OpenStreetMap platform to allow contributors to edit underground spatial data and VGI for features extraction, visualization, and exchange.

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