LOW CARBON LIVING CRC

Progressing Precinct Modelling on the UNSW Campus and Beyond: BIM/PIM and 3DGIS

Data Inventory

Acknowledgements

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- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

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Acronyms

BIM	Building Information Modelling
CAD	Computer Aided Design
DBMS	Database Management System
GML	Geographical Modelling Language
IFC	Industry Foundation Classes
OGC	Open Geospatial Consortium
SQL	Structured Query Language

Executive Summary

This report presents results of inventory of the administrative structure of UNSW Estate Management (EM), software used, datasets and their content. The study was completed via interviews with employees of EM, and by examination of several datasets provided by Facility Management (FM) department.

Introduction

The UNSW Kensington Campus lies at the heart of an extended precinct which is the subject of intensive strategic planning and assessment as part of both the Greater Sydney Commission Randwick Collaboration Area and an emerging living laboratory under Randwick City Council's Smart Cities Strategy.

UNSW Estate Management (EM) has an ambitious program to create a 'Smart Campus' which will see the campus area more effectively managed within its boundaries and better connected beyond them to the wider precinct. This provides a great opportunity to revisit some of the modelling and assessment challenges at precinct scale explored in previously funded CRC LCL project RP2011.

Recent advances in technology allow for a quick collection of 3D data and reconstruction of 3D realistic models. These come in addition to detailed 3D BIM models, which are becoming increasingly available as well. However, the integration and maintenance of these data with existing operational 2D datasets remains problematic. Data and models are scattered in different file formats and layers and maintained by different departments, institutions and companies. This complicates the update of data and the use and re-use of information. Despite international research efforts and developments, many issues related to structuring, semantic identification and management of 3D precinct information still requires further investigation.

This report is the first step of our project getting familiar with the administrative structure of UNSW EM, used software, datasets and their content. The study was completed via interviews with employees of UNSW EM, and by examination of several datasets provided by Facility Management (FM) department. The following two reports including data modelling (Li et al., 2019) and system visualisation (Aleksandrov et al., 2019).

The main goal of this report is to investigate the objects needed, their properties and relationships to be able to propose a unified data structure. Data inventory is guided by semantics (i.e. the meeting of the objects such as building, stair, grass area, tree, room, wall, roof), geometric descriptions (point, line, polygon, solid, point cloud, voxel) and their properties. This approach was followed because many of the objects (e.g. building) exist in different datasets, may have different geometries, attributes and naming. A much attention is given on the geometries of the objects as they can vary with respect to the used software. Information about needed queries, analysis and functions on these datasets are not investigated. The assumption is that commonly used queries on objects and their attributes should be available in a future information system. The need for spatial operations will be discussed on a later stage in the project.

The following major spatial datasets have been obtained by EM departments:

2D datasets:

- The most important datasets are about the indoors: floor plans of all UNSW building, electrical and mechanical maps (of the Library Building).
- Several outdoor datasets were provided including: cadastral map, building footprints, buildings above footprint, building basement, vegetation, walkways, gardens, carpark line markings, outdoor furniture, walls, waste trade, fences, bollards, survey marks, roads and sewer pipelines.

3D datasets:

The 3D data were newly designed or renovated BIM models: Library, Electrical Engineering building and Roundhouse.

Energy data:

The energy data provided to the project are in the form of spreadsheets and contain electricity use and gas consumption for four buildings in three months of 2018.

Geospatial Research, Innovation and Development (GRID) is a cluster of researchers at UNSW Faculty of Built Environment. Citydata is a data store of the City Futures Research Centre, which provides about 40 layers of datasets for the campus and Sydney. Land and Property Information (LPI) is currently known as NSW Land Registry Services. OpenStreetMap (OSM) provides crowdsourced, free, downloadable and editable geographic information. AAM is an Australian company that performs 3D scanning and modelling. Land Surveys is an Australia company that provides scanning and 3D data processing. UNSW IT is part of Strategy and Business Systems department of EM.

Several 2D and 3D datasets were obtained from GRID, CityData, LPI, Uni-Verse team and Land Surveys: Sensor indoor data (Myair data, CityData); BIM models of Red Centre building, Part of Quadrangle building, Webster building, Chemical Science building, Block house, Dalton building and Science theatre; 3D Point cloud data for the first floor of Red Centre Building and surrounding; 3D Airborne Lidar data (LPI); point clouds (Land Surveys); 2D data underpinning Uni-verse app (UNSW IT).

The report is organised as follows: the following section briefly outlines the structure of Estate management. afterwards the software packages are presented and these are followed by a discussion on the data and their properties. The conclusion of the study provides a list of the objects considered for the next steps of the project.

Administrative Structure of Estate Management

EM's main activities are related to support of planning, designing, building, maintaining and securing the campus. EM provides services and advice to the University Executive Team, Faculties and Divisions as well as logistic and associated services. EM's responsibilities can be subdivided into the following tasks: environmental and space management, infrastructure planning, campus master planning,

construction and development, refurbishment and maintenance. EM consists of seven departments: Asset Management, Development, Facilities Management, Strategy and Business Systems, Security and Traffic, Environmental Sustainability and Property Management.

Asset Management

The Asset Management department is responsible for space planning as the main goal is to ensure appropriate allocation and use of (working) space, as well as to keep track of user's occupancy of space. The Asset Management department uses space data in the form of 2D and recently 3D models (BIM) of the campus, outdoor and indoor buildings. Updating space data is central to the management as there are everyday changes from activities related to maintenance, renovation of facilities and so on.

Development Unit

This unit consists of three teams of Development, Delivery and Engineering. This unit manages creation of new physical real estate assets of university. The Development team leads early stages of the development process including suitable location of the asset, assessment of the commercial aspects, being in line with 2025 strategy as well as consistency with the Campus Design Masterplan Framework.

The Delivery team takes the project from the Development team and assesses the impact of the projects through consultation with the Faculties and departments of the University. It also manages mitigation of impacts caused by the construction works.

The Engineering team support the work of the Design and Delivery teams. It is specialised in the disciplines of building management systems, hydraulic and cold storage, mechanical and electrical fields. The engineering team consults for future buildings development, the design and planning of the open spaces and the flow of people among these areas.

Facilities Management

Facilities Management (FM) owns, operates and maintains the utility supply infrastructure on the campus. The infrastructure consists of in-ground 11kV high voltage electrical supply, aquifer bore and bore water systems, water treatment plants and pumping systems, combined drinking and fire water, and natural gas supply. FM manages metering, recoveries, the utility supply contracts, utility reduction programs and sustainability initiatives.

Since November 2017, a precinct map (demonstrated in Figure 1) has been used to distribute the responsibilities in EM for managing building maintenance, minor works and repairs. Each Facility Manager deals with one precinct and has a few Assistant Facilities Managers.
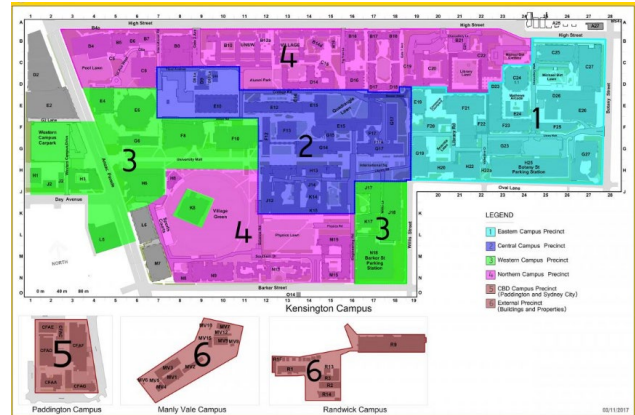
Figure 1 Map of EM precincts

The data generated and used in EM can be categorised to spatial and non-spatial data. Spatial data refers to the usage of location data directly in 2D maps and 3D building models. Spatial data are currently managed in AutoCAD, ARCHIBUS and Greensense software packages. Many of the data are now being migrated to ArcGIS software. Connections have been developed between different software packages as well as with DBMS.

The following sections explain specifications of data in these software packages.

Strategy & Business Systems

Strategic and operational planning, resourcing and management are main responsibilities of Strategy & Business Systems (SBS) and its major tasks include: Shared Services: Finance, HR, Procurement, IT, HSE; Compliance (risk, audit, procurement, finance, HR); Customer service (helpdesk); Corporate services support; Business improvement, change and continuity and Information & Systems.

As part of Information & Systems responsibility, SBS department leads EM's digital information, transformation, systems and systems opportunities.

Security & Traffic Management

Security & Traffic Management is responsible for provision of a safety and security in the campus in four areas of: Parking & Traffic Management, Emergency Management, Security Systems and Security Operations.

Environmental Sustainability

Environmental sustainability provides overall strategy and vision of environmental sustainability at UNSW. This department deals with impacts that UNSW could have on the environment.

Property Management

Property Management (PM) in Estate Management (EM) is responsible for working with project managers and planners to deliver projects on time. Effective service delivery and development of annual plans for Faculties or Divisions are other main tasks of this department.

As it can be seen, the structure of UNSW Estate management is quite complex. Many of the departments use their own data and much of this data has a spatial component. The intention is to reduce the management of individual spatial sources and have most of them obtained by FM. Therefore, this report concentrates on the data maintained by the FM department.

Software packages at FM

ARCHIBUS

ARCHIBUS is a package for management of space, planning and maintains information about space and assets, originally developed by Harvard University, USA 1980. The system was launched the first time in 1982, and later in 2008 ARCHIBUS company was founded.

ARCHIBUS has been used for space data management by many universities in Australia. The software is based on 2D floor plans and attribute information about the specified spaces. It provides opportunities of 2D space viewing, editing, extracting reports and downloading floor plans layouts.

ArcGIS

ArcGIS is a well-known and widely used software package, developed by ESRI, for management of GIS data. ArcGIS is a de-facto industry standard and is widely used in councils and institutions dealing with geospatial information. ArcGIS maintains limited set of geometries (point, line, polygon, multipatch) but provides many tools to check the validity (e.g. self-intersection) of individual objects and topology within layers. One of the strong features of ArcGIS is the possibility to perform many spatial and semantic operations. The operations are mostly 2D but many 3D operations have been progressively offered as well. The data can be maintained as files, in the ArcGIS database or on external databases as Oracle and PostGIS.

The well-known ESRI native file format, 'shapefile' (SHP), has been in existence for two decades (developed in 1998). It supports simple geometry (i.e. OGC point, multi-point, polygon, polyline and since ArcGIS 10 polyhedron), including vendor specific data types (i.e. multi-patches). SHP is binary file format and adapted for faster drawing speed and editing capabilities. The major advantage of this file format is that the objects are kept with their thematic attributes. The file format consists of three files: main file: *.shp; index file: *.shx and DBase file: *.dbf. Shapefile is the most commonly used format for GIS data. There are many tools and applications that can read and export SHP. SHP does not have a topological structure and the representation of textures is very basic.

FM do not have many GIS datasets. Datasets maintained in AutoCAD are being currently defined as objects and given attributes to be imported into ArcGIS by FM department. Some experiments have been done previously as well by other researchers. Several of these datasets are now maintained at the Citydata platform and can freely be downloaded by students and researchers. Citydata offers four georeferenced datasets, namely, the Red Centre building floor plans, 360 video data, UNSW building footprints and trees at UNSW campus.

AutoCAD

A large number of data at the FM department are currently maintained in AutoCAD.

AutoCAD is a computer-aided drawing software used in construction, architecture and manufacturing for making 2D and 3D plans and blueprints. Autodesk AutoCAD and Revit are currently the most used packages for design and construction. AutoCAD offers a range of drawing tools in 2D and 3D and is widely used not only by constructors and designers but also GIS specialists. The drawings are usually maintained in files on the cloud, although it is possible to make connection to DBMS systems such as Oracle and PostGIS (Autodesk 2005, 2009).

The two native and most recognised AutoCAD file formats are DWG and DXF. They have been created by Autodesk, December 1982 as part of AutoCAD 1.0, and have grown through the years as two of the most used formats for exchange of 2D and 3D CAD drawings. DWG (from DraWinG) is a binary file format and may also contain images, video or text, It can be opened by almost all drawing packages and many free viewers.

DXF (Drawing eXchange Format) is ASCII-based and has been used by researchers to read and process CAD files. Specifications for DXF from AutoCAD Release 14 (November 1998) to AutoCAD 2008 (March 2007) are available on the web site of AutoDesk. The file formats support many different geometries (simple and complex), layers and drawing attributes. Since it has been designed as drawing Interchange format, it does not support thematic attributes. DXF is not designed for web, but tools have been provided by some vendors for web-based visualisation.

The two native AutoCAD file formats are used to exchange data from one software package to another. Topology, texture, objects, level-of-details are not explicitly supported, although the user can apply some enhancements.

Revit

Revit is a software package, originally developed by Charles River Software (1997) and acquired by AutoDesk in 2002. The software is dedicated to 3D design and modelling, following strict object-oriented approach. Objects are defined with their attributes and materials and can be reused during the drawing process. Revit also provides tools to plan and track various stages of the building lifecycle. Revit has become the major software package for Building Information Modelling (BIM), which is 'a collaborative process which covers business drivers, automated process capabilities, and open information standards use for information sustainability and fidelity'.

Revit can maintain information either as Revit native binary file format, in DBMS (such as Oracle and PostGIS) and IFC. IFC (IFC, ISO16739) is the effort of BuildingSMART to specify a common language for technology to improve the communication, productivity,

delivery time, cost, and quality throughout the design, construction and maintenance life cycle of buildings.

IFC is a very complex model, which requires a thorough consideration during the design and construction process. In IFC, a building is modelled as a collection of objects (with properties and relationships) that represent parts of the building. In contrast to GIS topology, the relationships within IFC are hierarchical, i.e. the IFC model is a tree structure. The 3D geometry is one of the properties, at the same level as the name of the vendor, cost, etc. IFC objects may represent any building element such as walls, doors and windows but also the glass in the windows, window frames, materials in the walls, etc. BIM is used mainly in construction and is suitable for 3D modelling in a very detailed and precise manner. It is often used to model a limited site (e.g. a building or a precinct), but cannot handle large areas, as is typical in GIS applications. The immediate vicinity of the object of interest may be modelled in BIM for informative purposes (often at a much lower level of detail). Today, BIM also provides geo-referenced models and options to describe point clouds. IFC files can be viewed with many free viewers such as BIM Vision.

FM intends to maintain the BIM models of the newly renovated campus buildings and progressively increase the use of BIM in the management of the campus.

Greensense

Best Green Start-up winners of 2008, Derek Gerrard, Pete Tickler, Fabian Le Gay Brereton, from Australia launched Greensense View in 2008. This platform allows to harvest, process and present energy data near real time. The data is pushed to the Greensense from Energy Management system via an automatic FTP upload. Greensense then displays the data via a web server. Some additional analytics allow to analyse and eventually decrease the level of waste through monitoring energy and water consumption. The software highlights exactly where to focus for maximum savings.

Energy management unit, which is a part of the FM department, is working actively towards reduced comsumptions of gas, electricity and water in the UNSW campus. To stimulate staff, students and researchers to be conscious about their comsumption, the Energgy managemnt unit initiated the Greensense Live Energy Project, which allows to follow the consumption per each building. Examples of electricity and water consumption are given in Figure 2a and b, respectively. In addition, queries can be executed to prepare estimations of CO_2 emission based on electricity use and gas consumption.

a)
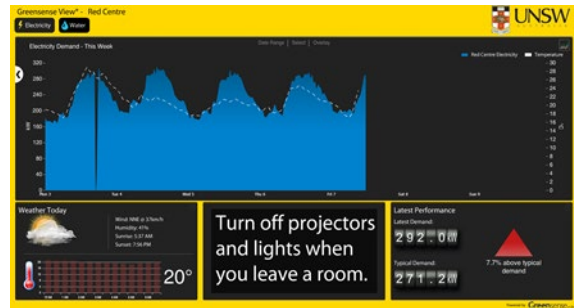
b)

Figure 2 Red Centre electricity usage (a) and water consumption (b)

Considering the systems used by UNSW EM, it should be realised that the digital representation of real-world objects and phenomena is guided by the different approaches and provided software packages. Each software package maintains its internal data structure to maintain the drawing, objects, attributes and relationships.

When data has to be exported for use in another software package, the data are recorded in a file. In this transformation from an internal data structure to a specific file format, data can be changed or even omitted to fit the data structure of the file. A typical example is the DWG/DXF which does not provide support for thematic properties. Even if properties can be assigned to objects in AutoCAD, they cannot be exported in a DWG/DXF files.

Indications of how 3D objects can be handled by different files formats are given below (Table 1):

Table 1 Comparison of 3D formats (from Zlatanova et al 2012)

	Standard/Criterion	VRML	X3D	KML	COLLADA	IFC	GML3	CityGML	DXF	SHP	3D PDF
1	Geometry	++	++	+	++	++	+	+	++	+	++
2	Topology	0	0	-	+	+	+	+	-	-	-
3	Texture	++	++	0	++	-	+	+		0	+
4	LOD	+				-	-	+	-	-	-
5	Objects	+	+	-	-	+	+	+	0	+	+
6	Semantic	0	0	0	0	++	0	++	+	+	+
7	Attributes	0	0	0	-	+	+	+		+	+
8	XML based	-	+	-	-	+	++	+	-	-	-
9	Web	+	++	++	+	-	-	+	-	-	0
10	Georeferencing	-	+	+	-	-	+	+	+	+	+
11	Acceptance	++	0	++	+	0	0	+	++	++	++

- not supported; 0 basic; + supported; ++ extended support

Data Maintained by Facility Management

In the following sections, we present data managed by Facility Management. This information is obtained from the provided file formats. As discussed in the previous section, some properties of objects are not presented as they have not been available.

Floorplans in ARCHIBUS

The UNSW ARCHIBUS database includes current attributes for floors and rooms with the intention identify individual working spaces/desks. A snapshot of a floor plan and its corresponding room attributes is given in Figure 3.
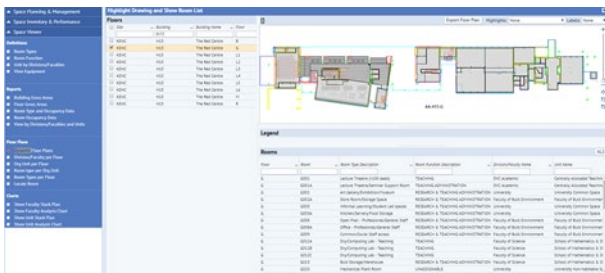

Figure 3 List of floorplans

Data in ArcGIS

As mentioned previously, these datasets do not exist yet. FM department is in process of creating GIS data. This includes manually identifying and creating valid objects, assigning names and attributes in ArcGIS based on information available in AutoCAD files. During this manual conversion, the original AutoCAD drawings are thoroughly investigated to create the objects of interest for FM. In most of the cases, the geometries of the objects must be re-drawn to form a correct geometric representation in ArcGIS. For example, gardens, and in some cases building footprints, are represented as a closed or open 'polylines' in AutoCAD (Figure 5, Figure 8). The geometry of these objects in ArcGIS should become 'polygon' as they are 2D objects. In this transformation from one type of data to another, some objects can be very challenging. For example, roads are represented as a set of 'polylines', which are disconnected. A manual intervention is needed to specify which lines belong to a polygon of a street or a street crossing. Another example are fences and walls, which might represent several individual objects (Figure 7).

The datasets listed in Table 2 are an example of some of the data that has already been converted to ArcGIS objects for other projects.

Table 2 Geometry of objects in available shape files

Objects	Geometry
Red Centre basement floor plan	Polygon
Building footprints	Polygon
Trees	Point

Data in AutoCAD

Indoor electrical and mechanical data

Table 3 includes the objects available in electrical and mechanical DWG files. The objects are organised in layers, which allows to identify the semantics of the objects. Snapshots of 2D and 3D data maintained in AutoCAD are shown in Figure 4.

Table 3 Geometry of objects in electrical and mechanical networks

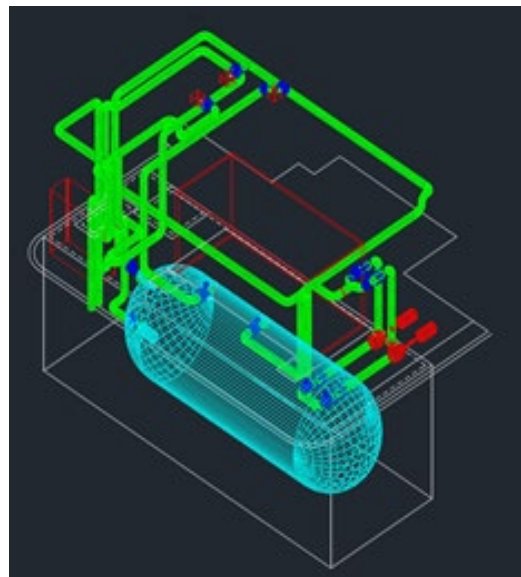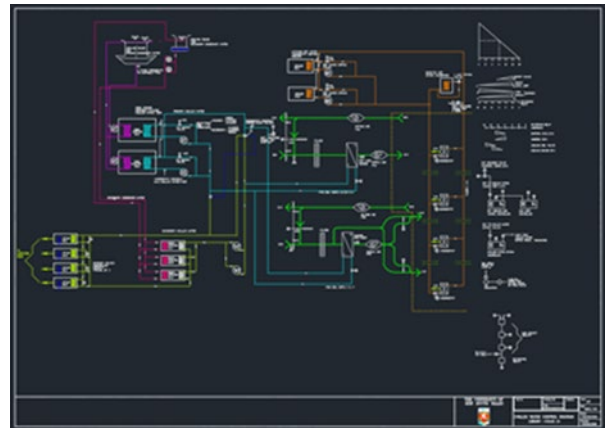| Network	Objects	Geometry
Electrical	Smoke Detector	symbol
	Building occupant warning speaker	
	Emergency exit lighting	
	Light Switch	
	Door alarm	
	Help point	
Mechanical	Pipeline	Line
	Valves	Symbol
	Tower	Mesh
	Ice tank	Mesh

Figure 4 Examples of electrical and mechanical data: 2D chilled water diagram- library stage 2 (up), main library ice storage in 3D (down)

Outdoor 2D data

Table 4 geometries and Figures 6-9 show types of objects and their geometries for the outdoor data within AutoCAD environment.

Table 4 Outdoor objects and their geometries

Objects	Geometries
Cadastre properties	Line
Buildings footprints	Polygon
Carpark line marking	Points, lines and polygons
Bollards	Polyline and circle
Fences	Line
Outdoor furniture (including seats, bins and ACs)	Polygon
Gardens	Lines
Survey marks	Circle
Building names and numbers	---
Roads	Polyline
Vegetations	Polyline
Outdoor Walls	Polygon
Handrailings	Line

Many attributes of the objects such as building names, numbers and attributes are stored in a separate text layer in AutoCAD. As a result, the attributes have not been specified for each individual object.
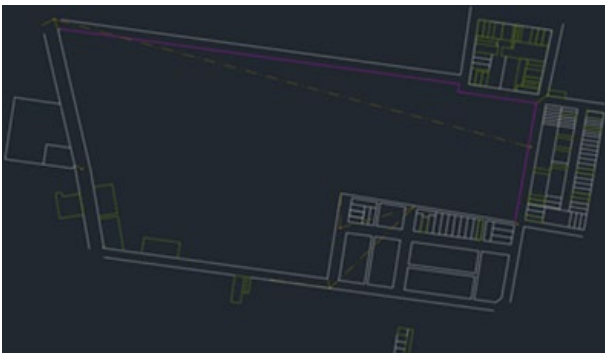
Figure 5 UNSW cadastre parcel

Figure 6 Footprint (in brown) and above footprint (in white) of buildings

Figure 7. UNSW walls and fences
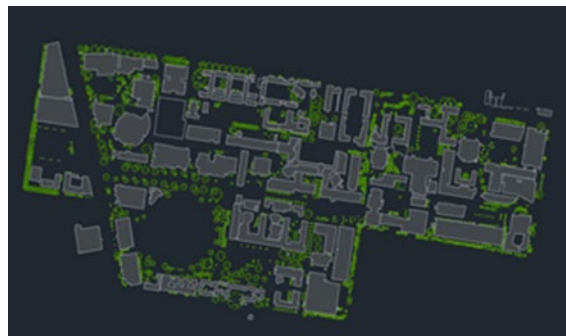
Figure 8 Gardens (a) and vegetation (b)

Underground utility network

The underground objects and their corresponding geometries can be seen in Table 5. A snapshot of the data for the sewer layer is provided in Figure 9.

Table 5 Underground sewer objects

Utility network	Objects	Geometries
Sewer	sewer pipe	Line
	sewer pit	Point
	sewer manhole	Point
	sewer inspection opening	Point

Figure 9 UNSW Kensington sewer layers in AutoCAD

BIM Models (Revit and IFC)

As mentioned before only a few BIM models are currently in the possession of the FM department. Most of the models listed below are created with the help of students within previous CRC LCL projects (e.g. CRC LCL project RP2011). Unfortunately, many of them are very simple and do not contain indoor information. Currently many Revit BIM models are available for the newly renovated buildings and they will be made available to FM by the construction company Multiplex. These models are now accessible to FM either as a simplified Revit file or via a viewer, which makes connection to the hosting Oracle DBMS (Figure 10). The BIM models, we have examined, are all available as IFC files.

The BIM model of Red Centre was built by researchers at GRID lab from existing pdfs of floor plans (Figure 11). These were digitised, augmented with sematic information about walls, slabs, doors, windows and stairs and updated to represent the present situation.

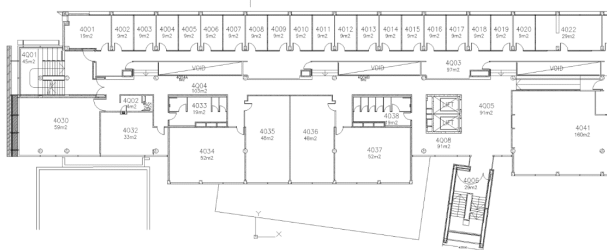Figure 10 BIM model in a BIM viewer extracted from ORACLE

Figure 11 Red Centre Building, 4th floor

For the scope of this project, BIMs of the following buildings were collected and examined: Red Centre and UNSW main library (Figure 12), Electrical Engineering building and Block house (Figure 13), Chemical Science and Dalton Building (Figure 14). Figure 15 displays an example of an indoor object in the Roundhouse BIM model. Figure 16 illustrates modelling of outdoor building elements. Some buildings undergoing renovation by Multiplex can be accessed for viewing.

The models of the Library, Electrical Engineering and Roundhouse building are more comprehensive. In some buildings semi-indoor objects attached to the buildings are modelled as well, such as two types of structural elements providing two covered walkways in the Science Theatre and Webster buildings, or an encircling structural element (Figure 16) for part of Quadrangle building model. The indoor objects are relatively simple repersenting only doors and windows. A chest of

drawers can be found in the Round House BIM model (see Figure 15 down).

All IFC files have a relatively limited number of objects as they have been not availble as design models, but created at a later stage manually. Most of the IFC files contain roofs, slabs, walls, walls, doors, stairs, stair flights, stair railings, stair slabs and windows. In some of the models columns, beams, curtain walls, curtain wall plate, covering, space, space proxies, space element furniture, space furniture type were present. Some of the internal infrastructure such ventilation, ventilation flow segment, electricity, electricity flow terminal, plumbing/drainage, plumbing flow controller and value type, sanitary and furniture elements were present.
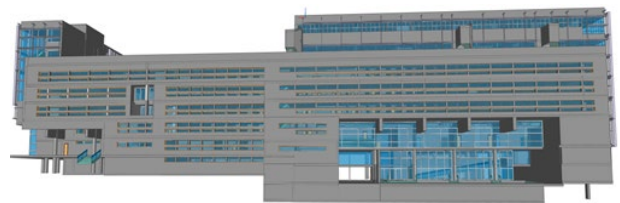
Figure 12 Red Centre BIM model front view (up) and UNSW Library BIM model (down)
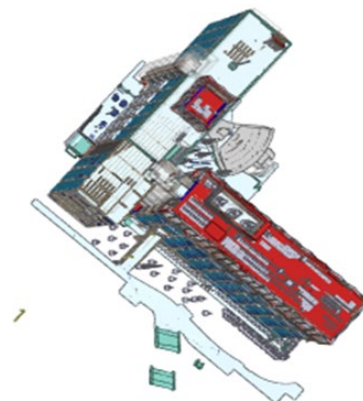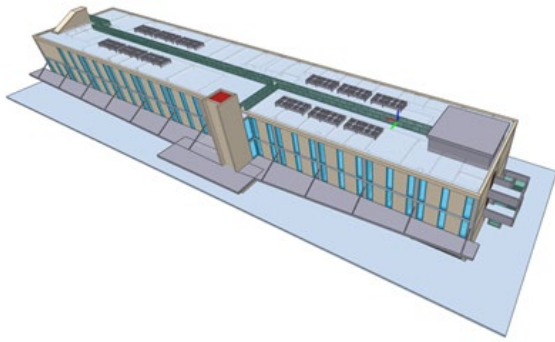
Figure 13 Electrical Engineering BIM model (up) and Blockhouse BIM model (down)

Figure 15 Roundhouse BIM model (up) and a furniture (cupboard) in Roundhouse BIM model (down)

Figure 14 Chemical Science Engineering BIM model (up) and Dalton Building BIM model (down)
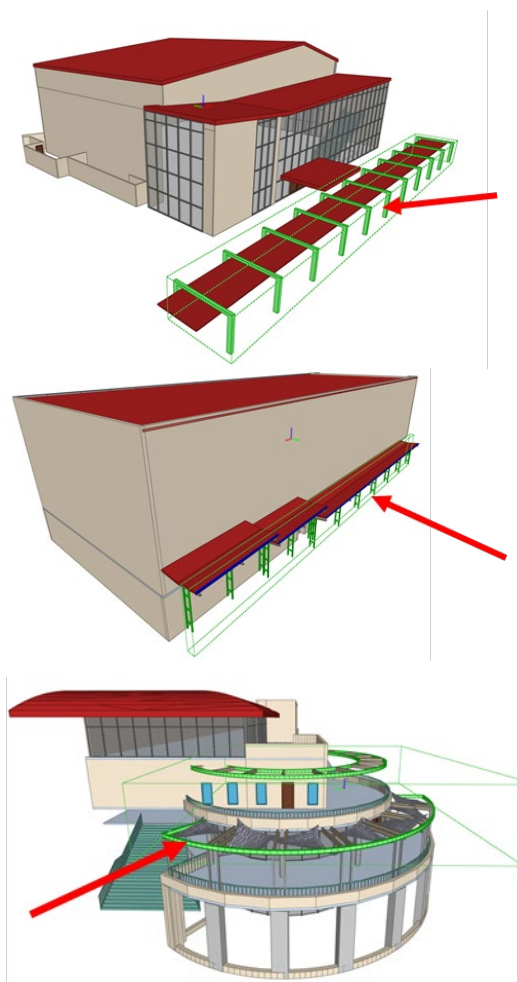
Figure 16 Illustration of element furniture in the models in three different buildings

Electricity Use and Gas Consumption (Greensense)

As mentioned before, these data are monitored through Greensense system. There are 650 smart meters in the

campus located in buildings. The data is attributed to the buildings and therefore there is no possibility to specify the level of energy consumption per room or as part of the building. Greensense data are continuously recorded and available in the form of spreadsheets under request. A web application gives access to the data and analytics (Figure 17). Figure 18 shows all UNSW buildings that are connected to Greensense system. The application allows to check the current (real-time) on 'click' on a building.
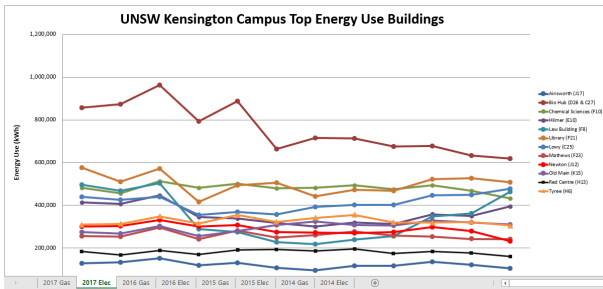
Figure 17 Electricity use for 2016

Figure 18 UNSW buildings included in Greensense

Other sources of spatial data

To be able to demonstrate the value of a 3D model for low-carbon living analysis, we have considered two more datasets: Point clouds and indoor sensor data. We have also investigated one of the most used campus apps to investigate what kind of information has been provided to students and visitors in the campus.

Point Clouds

Point clouds (airborne or terrestrial) can be collected in a very efficient and quick manner indoor and outdoor. Laser scanning is considered as one of the quickest ways to create 3D models as well as to detect changes. Airborne Lidar data for NSW can be obtained from many instances, most prominently Spatial Services NSW. For the purpose of this project a Lidar point cloud of 2013 will be used (Figure 19 and 20)
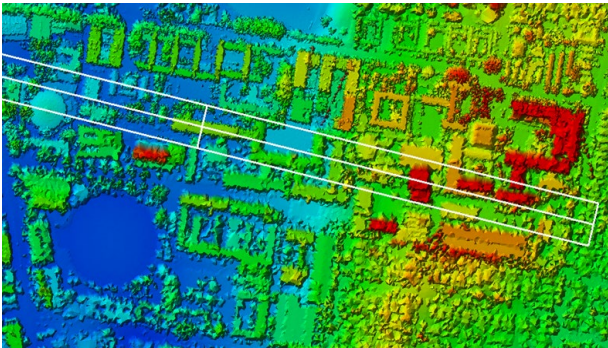
Figure 19 Top view of UNSW airborne Lidar DSM
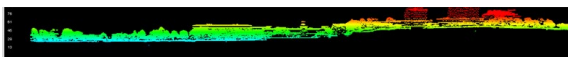
Figure 20 Profile view of the airborne Lidar over UNSW

A small area around the Red Centre building was scanned with Leica P40 to be able to record passages under building and overhanging parts of buildings. Example of the dataset is shown below in Figure 21:

Figure 21 Two snapshots of the point clouds around the Red Centre Building

Air Quality Data

This data is obtained from recently installed sensors within several rooms at the Red Centre. Indoor CO2, temperature, air quality and humidity data for several rooms at Red Centre are measured and maintained by the system Myair (see Figure 22). The sensor data is stored on CitySensors, which is an open source IoT platform running on Postgres. The data can be queried via Web-based interface. These data are quite interesting for the purpose of the project as they are recorded and maintained per room.

Figure 22 Representation of air quality data visualisation in Myair

Data used within Uni-verse app

One of interesting apps on the Campus is Uni-verse (https://student.unsw.edu.au/universe). It is designed by a team at IT UNSW to provide information about class and exam time tables, course content via moodle, library services. It has some navigation functions within UNSW campus and offers information about latest events or contact information in case of emergency.

The information about all objects used in this app was provided as spread sheets and is listed in Table 6. The geometry of all these objects is point level.

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Table 6 Categories of objects in Uni-verse app

Objects	Attributes
Buildings	Name, latitude and longitude, alternative name
Food and Retail	Name, latitude and longitude, building name,
Banks and ATMs	Name, latitude and longitude
Student Services	Name, latitude and longitude
Support Services	Name, latitude and longitude
Library	Name, latitude and longitude, building name and number
Parking	Name, address, latitude and longitude
Bus Stops	Address, latitude and longitude, bus numbers
Gates	building name and number gate number, latitude and longitude
Campus Safety & Emergency	latitude and longitude, address, building name and number
Museum & Art Galleries	Name, latitude and longitude, building name and number
Student Accommodation	Name, latitude and longitude, building name and number
Research Centres	Name, latitude and longitude, building name and number
Accessible amenities	building name and number, latitude and longitude, room number
Water bubblers	
	Address, closer building name
Charging station	Location on map
Bike rack	Lat and longitude, building name and number

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Discussion

We conducted this data inventory to understand the structure of EM, the software packages in use and the existing datasets. EM is a typical example of an institution taking care of a precinct. Precinct Information Model (PIM) is then a digital information platform developed on standards and protocols supporting the modelling at precinct scale (Newton et al 2013).

EM is a complex unit within UNSW with many responsibilities related to the management of the campus. The vision and goal of EM is to achieve centralised management of spatial data, which will be hosted by the FM department. The FM department is now in process of investigating the overall structuring of information, major software packages, approaches for data exchange between the different packages and procedures for update.

FM is conscious of the need for a 3D spatial information system to reflect the complex campus infrastructure but also appreciates the complexity of creating a 3D model. FM realises that the goal should be achieved in phases and the first very important phase to identify 2D objects and their properties and be able to host the newly created BIM models. It is also the intention to organise the data in a such a way that it will be available to three large groups of users with different rights and levels of access.

The first group consists of the EM departments. The employees should be able to get access to specific datasets to perform their campus management tasks. These would be the users with the most rights. They will be able to query, edit and delete data.

The second group of users will be external companies that perform services, maintenance and renovation on the area of the campus. They will be restricted only to a subset of the data that is related to their activities on the campus. For example, the garbage collectors should be provided data about streets and trash containers. Such users will receive either files to be used in their apps, or a very limited access to the some of the data of FM.

Another group of external users could be companies, which will develop applications for students, staff and researchers. For example, if it is a company developing navigation applications, data will be given only about buildings, floors, rooms and walking areas in the campus.

A very important group are the students and researchers. They might not only use data but also provide data. For example, many students are performing campus measurements for their studies and these measurements can be used to update information.

Councils and other organisations, responsible for the urban planning and development of the Kensington, can also request data.

A special attention is also paid on the possibility to maintain sensor information, be able to monitor occupancy of buildings and other dynamic events such as parking availability, temperature (outdoor and indoor) and be able to provide navigation services to parts of buildings for different types of users.

The discussions with FM have clearly shown that the FM is looking forward the development of an advanced, innovative, flexible and secure approach for management and exchange of data, which makes it a very good test case for the CRC LCL project.

Our data inventory has revealed many similarities with management of other precincts by large organisations (e.g. Falquet, et 2014, Zlatanova et al 2013, Zlatanova and Beetz 2012), which consist of many departments and responsible for large variety of tasks that are based on spatial information. The finding can be summarised and considered for PIM as follows:

• Different departments/institutions have their own preferred software package and are reluctant to shape the information with other departments/institutions. When needed information is shared via flies.

• The current spatial information is managed in several commercial packages without a unified data model. Each geospatial domain has its own description of information, even though many relate to the same physical entities or assets.

• The names, geometric representations, spatial dimensions (2D and 3D) and the attributes of the same physical objects vary between the different systems.

• Many of the datasets are in local coordinate systems (i.e. BIMs and Archibus floor plans), i.e. they are not geo-referenced

• The terrain is not considered in any of the software packages. Even when 3D objects are maintained, they are located on a horizontal plane. A terrain model when available is seen as one individual object. Streets, buildings, stairs, etc. are not integrated in the terrain. The depth of underground utility networks is relative to the surface, but is not maintained with x,y,z coordinates.

• Topology, or validity, of objects is not maintained in any of the datasets.

• There is no protocol for data exchange between different software packages. The exchange is based on files, which often leads to loss of data (e.g. attributes)

• There is no clear procedure for data update and management of temporal objects. Procedures, when exist, are manual and time-consuming.

The investigation of individual digital objects being a representation of physical objects, revealed many shortages, unclarities and duplications. The most import issues are summarised below:

• All objects do not have a unique identifier. It is up to the software package to define (or not) IDs. The objects are distinguished on the basis of names/numbers of buildings, floors and rooms and additional descriptive text. This complicates the digital management of objects as the descriptions can differ or can be error prone.

• Objects are organised in layers and often the geometric description of one object is scattered in several layers. While such approach does not disturb the

visual inspection, it poses challenges to the editing and update of information.

• Many of the objects are drawn with individual disconnected lines and do not form closed geometries. A typical example are roads and gardens. Besides maintenance, this disturbs spatial analyses such as area, length computation or overlays.

• The attributes of objects are organised with respect to the options provided by the software package, which makes it difficult and even impossible to exchange between software packages. A typical example is management of attributes in a separate text file in AutoCAD.

• Validity of object (intersections and gaps) is not maintained, which may complicate or even make impossible to compute lengths, distances, areas and thus resulting in wrong inventory and reporting.

Integrated 3D Data Model

The continuous development and maintenance of assets, infrastructure, facilities and logistics at the UNSW campus requires management of a broad spectrum of heterogeneous information. EM departments and stakeholders inside/outside the campus such as companies, councils, institutions, researchers and citizens are constantly involved in the use and exchange of critical information. Much of this information concerns infrastructural components that are embedded in a constantly changing environment. They are spatially distributed above ground (topography, cadastral parcels), underground (cables and pipes, soil, water and geological/geotechnical data) and indoor (buildings). Our data investigation, combined with discussions with FM experts, identified the following two important directions for improved information management: 3D data management and an integrated 3D model.

3D Data Management

The need for 3D data management is clearly imposed by two developments. On one hand many EM management processes need more accurate information about assets on the campus in the third dimension, on the other hand an increasing number of newly designed and renovated buildings are delivered as BIMs in 3D. The underground and indoor infrastructure (cable and pipe networks) is already very dense and complex. The granularity of maintained data is also increasing, e.g. there is clear intention to maintain data not only per room but also for parts of rooms or even desks. As mentioned above, a substantial part of the datasets consists of traditional 2D drawings (having limited records about z component as an attribute) in Archibus and/or AutoCAD and linking to and incorporating with 3D BIM models becomes a very challenging task. It requires clear procedures and workflows.

Generic Conceptual 3D Data Model

EM intends to improve the information management paradigm to better support all process and activities in the UNSW campus to be able to respond to the 2025 UNSW strategy of becoming a smart campus. Such a process-oriented approach poses higher requirements to the information management: an object needs to be defined only once in the system to avoid inconsistent and conflicting information.

Currently the information is managed by several applications with their own information models. This results in a large data diversity considering geometry, semantics, attributes, topology and resolution/accuracy. Geometric diversity refers to the geometric abstraction, e.g. point, line, surface/mesh, solid/polyhedron. Semantic diversity addresses the naming and the definitions of objects. Semantics is a very important component of digital abstraction of a physical entity as it allows for matching or integration between datasets, which contain information about the same physical objects (Oosterom and Zlatanova 2008). Semantically

rich data models (such as IFC, Table 1) are commonly converted to semantically-poor file formats for data exchange between different applications and software packages. As the data are managed in different systems the topologically correct datasets (when available) are often converted in non-topologically data structures, which influences the consistency of data. The last aspect, resolution & accuracy of different representations has a critical impact as well as it may disturb establishment of links between the data. For example, sensor measurements of Red Centre Building are now collected per room. In the current resolution of data, the measurements can still be related to the spatial representation of rooms. However, if outdoor sensors are mounted on roofs or outer walls of buildings, the current types of UNSW objects would not be enough, i.e. BIM models must be employed.
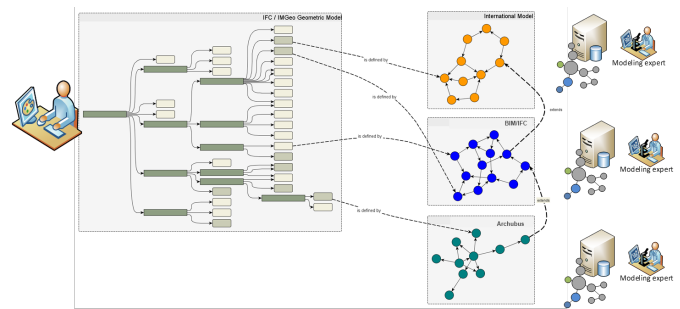

Figure 23 Conceptual 3D data model (extended from Beetz et al 2014)

A generic conceptual 3D data model (or a set of models) must be envisaged to allow integrated management of different data for the different departments, clients/partners and researchers (Figure 23, on the left). The conceptual model is a container of 'concepts' about campus assists, which will be used by all to specify what objects is modelled. This approach allows preservation of some 'concepts' and definitions that a specific domain is used to work with. They will be just mapped to the concepts in the generic data model.

This model should be the major part of all future developments with EM and clearly communicated to all commercial parties either maintaining information or developing applications for the purpose of the campus. This model would support the alignment, harmonization and integration of existing spatial data models (or file formats) as well as the development of additional umbrella meta-models to facilitate the understanding of data.

Two aspects related to the 3D spatial model require special attention: the set of objects and the data structure.

A thorough inventory and selection of all objects is required in the 3D data model. The objects must have well-defined semantics, geometry, topology, appearance, granularity or levels of detail (Zlatanova 2017). It should be taken into consideration that BIM provides very detailed information on the buildings. The BIMs collected for this study are very simplified and therefore not representative. Additional study is required to figure out whether all the information of BIM models is needed for the daily work of EM. Many components of

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BIM can be left for specialised use only. Some parts might be included in the generic model (e.g. walls, slabs, stairs, doors, windows, roofs), but many might be left only as a reference (e.g. furniture).

A suitable 3D data structure should be designed in such a way to follow some generic rules for data harmonisation: one object definition per physical entity and re-use of definitions and concepts already available in international standards such as IFC, CityGML, IndoorGML, LADM, etc. In this step a model-driven approach must be followed. This is to say that conceptual model should be readily implementable in different implementations such as database schemas (for SQL database management) or GML/JSON (for exchange of data).

System Architecture

Central data management will ensure consistency and re-use of information for UNSW EM. The data that are maintained by UNSW EM will be stored on in such a way that they can be accessed by all applications and users either for editing or query and visualisation (Figure 24). This mechanism will ensure that everyone has access to the last version of the data, without loss of information and allowing the specification of appropriate security levels.
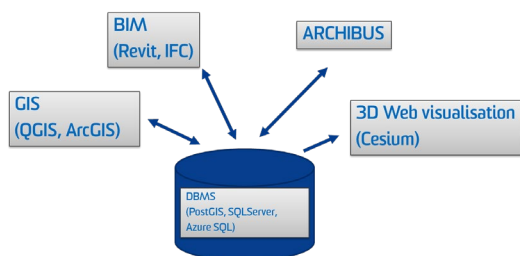

Figure 24 Generic System Architecture

The core component of such system architecture is the DataBase Management System (DBMS). DBMS have become some of the strongest media to maintain spatial information in the last decade (Zlatanova 2017). To date, all mainstream DBMS have spatial extensions (e.g. PostGIS, MySQL, Oracle Spatial, SQLServer, etc.) to maintain spatial data types, indexing and spatial operators. All of them are implemented according to the Simple Features Specification for SQL of OGC, which means that a spatial schema developed for one DBMS can be exported and readily imported in another DBMS. The implementations are based on the Abstract Data Types (ADTs) and support storage, retrieval, query and update of simple spatial features; namely points, lines and polygons, and a set of spatial operations built on top of them. Some of the DBMS (PostGIS, Oracle Spatial) maintain 3D data type, solid as well as special data types for point clouds. All data types are defined under specific rules and can be 'validated' with a function.

All DBMS provide spatial indexing mechanisms for quick search and query- one of the most prominent is R-tree.

Spatial functionality is related to operations and functions that can be performed on the data types. As known from GIS, spatial analysis can be grouped into topological, metric and proximity operations. Topological operations are considered most important. OCC has adopted three topological frameworks: Boolean set of operations, Edenhofer operators and Clementini operators. Using these frameworks, many operations are made available in current spatial DBMS (Zlatanova 2016). But it should be kept in mind that these operations are generic and have no intention to replace extended spatial operations as in QGIS and ArcGIS or some of the 3D operations available in AutoCAD and Revit. Further detail on 3D spatial DBMS can be found in (Janecka et al 2018, Breunig and Zlatanova 2011, Oosterom et al 2002)

In this project the focus is on object-relational DBMS that support SQL. SQL is a high-level language for relational database management and data manipulation. SQL consists of operators to query, insert, update and modify data. Most relational and object-relational databases support SQL, so scripts can be run on different platforms. Developed in the early 1970s at IBM, SQL was first released by Oracle Corporation. SQL is a standard and monitored by the American National Standards Institute (ANSI). Major vendors may also have extended proprietary versions (such as SQL Plus (Oracle), pgSQL (PostGIS and T-SQL (SQLServer). However, all are built on ANSI SQL. Such extended versions have additional operations to organise loops and if-then queries and thus integrate multiple SQL statements into one executable script. This opens many options to perform data processing at DBMS level (Zlatanova et al 2002).

In this project we will make an extensive use of PostGIS DBMS. It is the spatial extension of PostgreSQL. It is open project development released under GNU public licence. PostGIS brings several benefits to any research project: it is developed in compliance with OGC specifications, many freeware extensions are available for use and can be accessed easily by many applications. Many software packages amongst which QGIS, Revit, ArcGIS, AutoCAD provide direct connection to PostGIS

Selected Objects

Based on the investigations and considering previous experiences and knowledge, we have selected a set of objects and their attributes which will be considered in the following phases of the project (Table 7). The selection was led by the following considerations:

• To have a representative set of objects to deal with the issues discussed above

• To reduce as much as possible the manual drawing and re-drawing of objects

• To maintain geometric representation as in the original software packages, assuming they will still be kept operational.

The attributes are simplified and are only an indication that the objects should have some text, numeric or Boolean properties. The objects found in BIM models

are given separately with an indication as to which part
of the building they belong.

Table 7 Objects and their properties

Category	Object	Attributes	Geometry	Relationships
Building	Building footprint	Name, number, area, perimeter, height	Polygon	
	Buildings above footprint		Line	Part of building
	Floor/ Storey		Polygon	
	Roof	roof material, slabs, slab material	Solid/Mesh	Building storey
	Wall	wall type, wall material	Solid/Mesh	Building storey, building
	Slab	material	Solid/Mesh	Building storey, building
	Window	Window style	Polygon / Solid/Mesh	Room, building storey, building
	Door	Door style and material	Polygon / Solid/Mesh	Room, Building storey
	Stair	Type, Stair material	Solid/Mesh	Building storey
	Ramp	Flight	Solid/Mesh	Stairs, building storey, building
	Column	Type, column material	Solid/Mesh	Building storey
	Curtain walls	Type and material	Solid/Mesh	Building storey, building
	Room/ Space	Name, description	Polygon / Solid/Mesh	Building storey, building (Room)
	Beams	beam type and material	Solid/Mesh	Building storey, building
	Indoor furniture	Type	Polygon / Solid/Mesh	Building storey, building
	Ventilation (riser)	IFC entity, name, material	Solid/Mesh	Building storey, building
Indoor electricity	Smoke Detector	Type	Point, (Symbol)	
	Warning speakers	Type	Point (Symbol)	
	Emergency exit lighting	Type	Point (Symbol)	
	Light Switch	Type	Point (Symbol)	
City furniture	Bollards, survey marks, fences, walls, seats, bins and ACs	Height, width	Point, line	
Transportation	Roads, walkways, car park lot	Use, function	Line	
Vegetation	Garden and tree	Tree attributes: diameter, id, code, species	Point, Line	
Land use	Cadastre Parcels	owner	Polygon	
Sewer utility network	Sewer pipe	Type	Line	
	Sewer pit	Width, length	Point	
	Sewer manhole	Width, length	Point	
	Sewer inspection opening	Type	Point	

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