BIM as a tool for setting and infrastructure management

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Abstract. Based on the consistent background and knowledge that the University of Minho (UMinho) has in 'Building Information Modelling', a practical roadmap towards the full BIM digitalization of the infrastructure management process has been recently set-up. After an initial diagnosis stage, the process of BIM implementation formally involves four stages related to the definition of modelling rules/requisites (Stage 1), the preparation of prototype buildings to test the concepts (Stage 2), the enlargement/ generalization of the process towards the Campuses of the UMinho (Stage 3) and a final stage of consolidation and improvements (Stage 4). This paper briefly describes the implementation of the two first steps, with a particular emphasis to the description of the two selected case studies.

1 Introduction

Building Information Modelling (BIM) is a methodology for information sharing and communication amongst all the stakeholders and during all the stages of the lifecycle of a given construction. It is normally supported by a digital model containing data about the geometrical features of the elements that compose the construction, as well as their properties and attributes, regardless of their nature, including physical properties, cost, construction timing, among others.

Even though BIM covers all stages of the lifecycle of construction, the scope of concern in this paper is the stage of operations and infrastructure management, normally termed as BIM-FM (Facilities Management) [1]. BIM-FM takes advantage of the extensive quantity and quality of information available in an as-built BIM model in order to assist operations and maintenance management of the building throughout its entire service life.

In the former UI Green Metric Conference was presented the strategic roadmap that the University of Minho has established towards a more effective and sustainable process of infrastructure management, through the implementation of BIM techniques [2].

Taking into account the lack of dedicated personnel to the preparation of the BIM models of the Campuses of UMinho, the staff involved in the present paper started an engagement of undergraduate students, within the Integrated Master in Civil Engineering, as to use real examples of buildings.

This paper briefly describes the definition of modelling rules/requisites and the simulation of two case studies to test the main concepts.

2 Training of human resources

An important adaptation that was made to the initial plan presented in the former UI Green Metric Conference [2] pertains to the anticipation of the training of a group of people that will be involved in the process of implementation of BIM-FM into the University of Minho. The reason for this anticipation is mostly related to the possibility of accelerating the implementation process, by making the potential users understand the possibilities and jargon associated to BIM. In this sense, a group of four members of the staff of the Facilities Management Services of the University of Minho has enrolled to the National Course in BIM, which is led and managed by Miguel Azenha, co-author of this paper. The course is targeted for practitioners of Architecture and Engineering, had a duration of 90 hours. Together with the theoretical background provided, the course challenged participants towards an actual practical application of BIM in a small project, focusing on the individual learning objectives of each participant, which are often diverse (participants include Architects and Engineers). For more information, the reader is directed to the website of this course, or to references [3, 4].

The members of the Facilities Management team that participated in this course were therefore quickly elevated from a low level of knowledge in BIM at the beginning of the learning process (October 2018), to a very reasonable level of proficiency by February 2019. A couple of examples of the models prepared during such assignment are shown in Figures 1 and 2 for illustrative purposes. The staff members were able to simulate a BIM process, from design up to facility management, hence obtaining the necessary know-how to support the implementation procedure.

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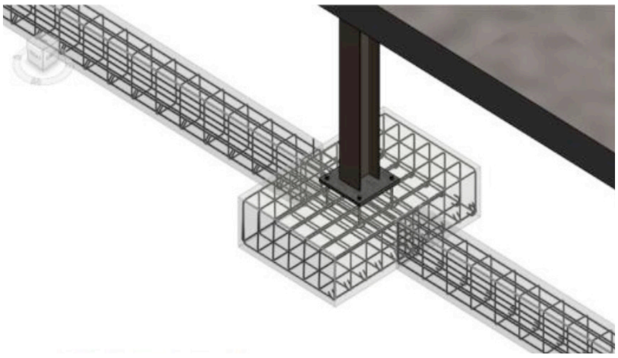

Fig. 1. Detailing of concrete reinforcement at foundation level.

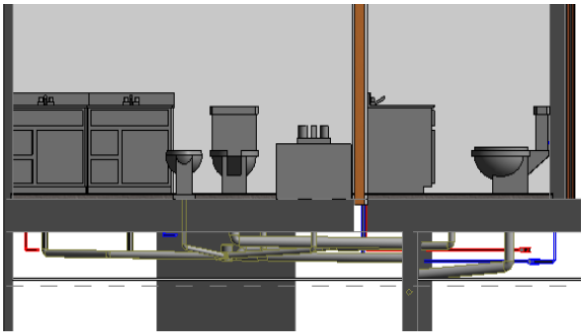

Fig. 2. Clash detection for plumbing performed within a suspended ceiling.

The process of training allowed more insights to be brought into possible frameworks to adopt in regard to the choice of software, the processes of surveying and modelling, the levels of detail/development/information and the relevant definitions towards an integrated 'Common Data Environment'. To some extent, this can be considered to match the initial plan devised in [2] towards the creation of a small pilot demonstrating model to show to all potential users, with a workshop to be held at M6 (indeed the presentations at the end of the training process were public, with participation of further members of UMinho).

3 The IB-S building in Guimarães

3.1 Description of IB-S

The Institute of Science and Innovation for Bio-Sustainability (IB-S) develops multidisciplinary research to provide new materials, methodologies and strategies, to support the rehabilitation of built environment.

One of the buildings of IB-S was built at the Azurém Campus of the University of Minho (Guimarães). It was designed by Architect Cláudio Vilarinho and built in 2016. The building, illustrated in Figure 3, has a total area of 2.676 m2, distributed in 5 floors.

The facade is covered with prefabricated panels of a cementitious matrix material reinforced with micro-fibres, without any conventional steel reinforcement, and consequently not prone to corrosion. The inclusion of pigmentation reduces the maintenance.

Fig. 3. Institute of Science and Innovation for Bio-Sustainability (IB-S).

3.2 BIM Model of IB-S

IB-S was selected due to its recent construction and good availability of data. Within the Curricular Unit of 'BIM in Civil Engineering: Design and Construction', groups of students were challenged towards the preparation of BIM Models, as an instrument for their learning and evaluation. In line with the above reasoning, the building of IB-S in the Campus of Azurém was selected for a group of 6 students [5], whereas other groups were focused in constructions outside the Campus, which are not of relevance for the present article. The curricular unit was active in the period between February 2018 and July 2018, and supervision/support was ensured directly by co-authors Miguel Azenha and Ricardo Mateus.

Students were given access to the construction drawings of Architectural design, Structural design (mostly reinforced concrete) and MEP design (mechanical, electrical and plumbing). They were requested to produce the 'as-built' model, following several specifications, namely the necessity of adequately classifying objects and spaces, as well as testing the building for use in a simulated 'Facilities Management' context.

The availability of the actual building and its users within 300 m of the classroom allowed the construction of the models to be supported by actual site visits and the 'Facilities Management' implementation to target the actual needs of this specific building, particularly through observation of its use, and interviews with the users.

Students were given full freedom of choice in regard to software, while being encouraged to use solutions of distinct software houses in order to be subjected to interoperability challenges that are often encountered in practice. Therefore, the choices of software for each purpose, also conditioned by the availability of student licensing, are signalled in Table 1.

Some highlights in regard to the models of IB-S are now given, with particular focus on FM-related matters. The Architecture model, performed in Archicad 21 is shown individually in Figures 4 and 5, as viewed in BIMVision (IFC).

Table. 1. Software used in the IB-S case study

Purpose	Software
Model quality assurance and clash detection	Solibri Model Checker 9.8
Architectural modelling	Archicad 21
Structural modelling	Tekla Structures 2017i
MEP Modelling	REVIT 2018
4D/5D	Vico Office R6.5; Navisworks
Facilities Management	REVIT 2018 linked with Archibus v23.2

The model includes all the partitions and outer shell of the building to an adequate level of graphical detail that allows users to clearly identify the building and its rooms. In Figure 5 it is seen that the architecture model was initially populated with some furniture, which was further enhanced when the model for FM was fine tuned.

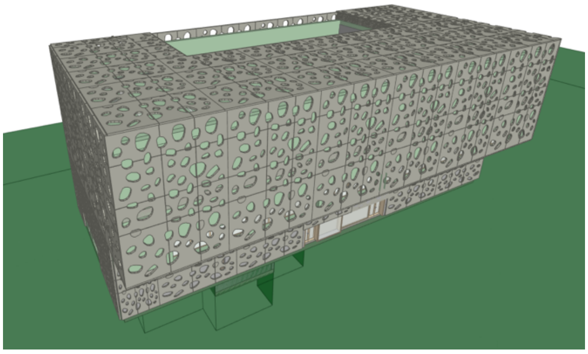

Fig. 4. Architecture model of IB-S (IFC Viewer: BIM Vision)

The structural model (developed in Tekla Structures) and MEP model (developed in REVIT) were federated together with the architecture model, as to produce the global integrated information, as shown in Figures 6 and 7, where the three specialties can be recognized (e.g. toilet seats, piping, structural piles below the building). It is noted that for non-graphical information, strong focus has been given to the adequate tagging of rooms and equipment, following the nomenclature currently adopted at UMinho. The Omniclass classification system was further used for the structure and MEP elements.

Initially, goals for the implementation of facility management in the building were defined. They were: definition of spaces, properties of spaces, maintenance reports, work schedules, work hours, space occupation and utilization, and discretization of one of the floors at the level of equipment and furniture (the third floor was chosen for this). The tools selected for the accomplishment of this work were Revit as the BIM software and Archibus as the FM software (CAFM - Computer Aided Facility Management).

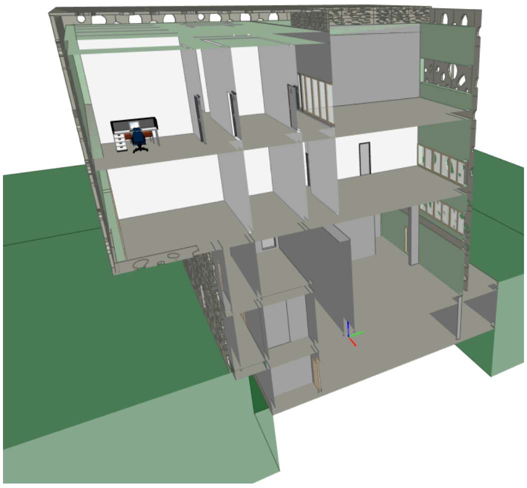

Fig. 5. Vertical cut-out view of the Architecture model (IFC Viewer: BIM Vision)

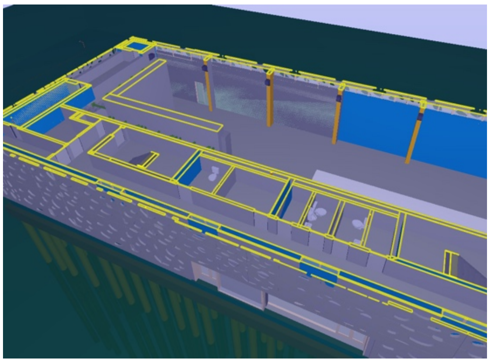

Fig. 6. Horizontal cut-out view of the federated model (IFC Viewer: Solibri)

REVIT was used with the intent of preparing the information related to the IB-S building, which would be later transferred to the Archibus Web platform. The latter allows the integration and editing of information, in a bidirectional way, regarding the space utilization, properties of spaces, creation of work schedules, maintenance reports, discretization of equipment, among others. The following paragraphs provide specific information on the achieved developments.

3.2.1. Space and occupancy

Firstly, in the Archibus application for REVIT, the building properties and delimitation of spaces that were attributed in REVIT, were catalogued so that they could be transferred to the Web platform. Then, information regarding the different spaces were added, including department, division, room and floor codes, room and floor numbers, room categories and types. Area and perimeter were automatically catalogued. This allowed the 2D and 3D models of the building to be published on the Archibus online platform, as shown in the example of Figure 8, where the 3D model of spaces is shown.

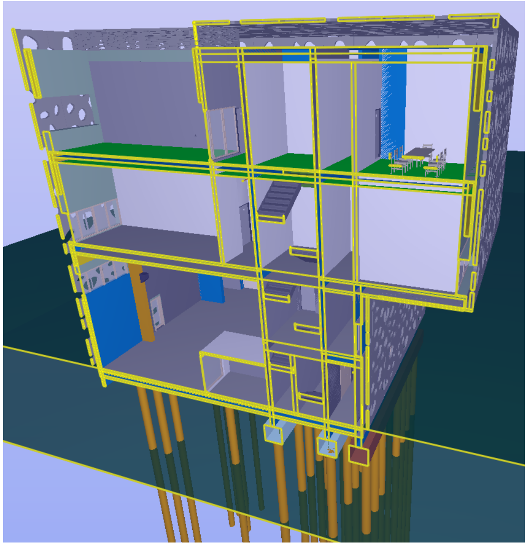

Fig. 7. Vertical cut-out view of the federated model (IFC Viewer: Solibri)

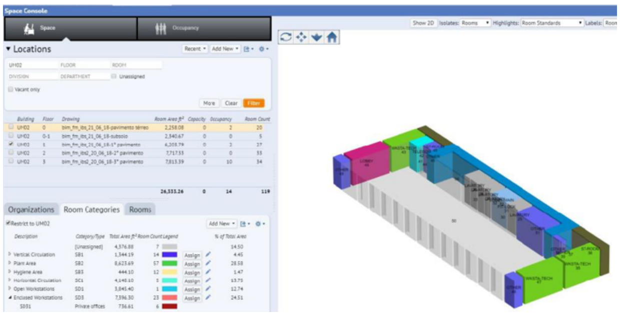

Fig. 8. 3D representation of spaces in floor 1, as shown in Archibus [5]

After the spaces were defined, it was possible to define their occupation. The occupants would be the workers, such as the researchers and people responsible for equipment and space maintenance. Several properties were inserted for testing purposes in such concern: shcedule, employee name, company to which he/she belongs, electronic address, phone number, photography with description, building and floor to which he/she belongs, space requested or occupied by him/her, date he/she was hired, who is in charge for him/her, among other additional information. This allows the recognition of the building users in the drawings available in the platform.

The use of BIM sourced data for space management facilitates the identification of individual spaces, hence assisting optimization of space usage. It can also allow for several other useful tasks such as: view and compare inventory and occupancy of multiple floor plans, edit room attributes (such as category, type, department, capacity, area); move or add employees to rooms; use virtual waiting room for employees waiting to be moved; reserve a room for meetings or a laboratory area for tests; identify underutilized areas; speed up decision-making for managers and executives with customizable, easily accessible reports; gain fast access to target information with the extensive filtering options; among others.

3.2.2. Equipment and furniture

One of the floors of IB-S (3rd) was chosen to be populated with all the equipment and furniture elements for testing of the features of equipment/furniture management. Firstly, it was necessary to add the equipment and furniture to the REVIT model, in order to have a schematic representation of them in the Web platform. Similarly to the space categorization, the characteristics of furniture were attributed, for instance, to tables and chairs, and to equipment and HVAC systems. This included furniture code and standard; and floor, room and building codes to which each furniture belongs. After that, the model was ready to export the data to Archibus. The physical representation of a 2D view in the FM software, including furniture, is shown in Figure 9.

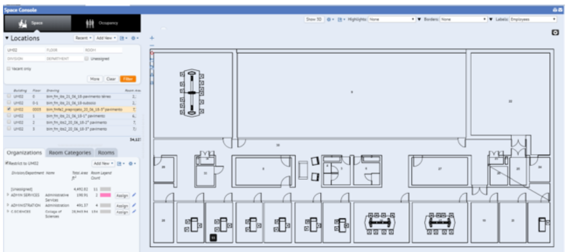

Fig. 9. 2D representation of furniture in floor 3, as shown in Archibus [5]

The graphical representation of the asset with the attached data in an integrated manner can assist decision-making, improve answers in emergency situations and equipment failure, and assist the planning of maintenance activities. The registers can improve the use of existing equipment, maintain detailed technical information in a unique place, provide reports with asset distribution to the university and avoid unnecessary purchases of equipment. Additionally, it gives the facility manager more control about the assets, allowing the maintenance team to find them quickly and precisely.

3.2.3. Maintenance

Maintenance and problem reports provide knowledge about issues such as water leakage, lamp failures, damaged equipment, among others that may arise during the building life cycle. Thus, to address any issue that may appear, it is necessary to have all the data related to the building assets stored in the FM Software database. These data encompass price, installation date, model, technical specifications, size, warranty, manuals, activity history, etc. An example of a work report tested in the scope of this work is shown in Figure 10.

With the integration of BIM and FM software it is possible to: create new work requests; identify work request location on a floor plan; review work request details; estimate, schedule and issue work to a crafts person; produce customized reports for executive and line managers; monitor preventative, corrective and reactive maintenance; monitor depreciation of assets; monitor performance evaluation of building systems.

Work Request Code	*1150001127* *1150001127*	Problem Type	LAB EQUIPMENT
Service Request Code	11311	Work Order	2015000158
Requested by	PROF	Priority	1
Date Requested	6/23/2018	Time Requested	11:13 AM
Building Code	UM02	Floor Code	0
Room Code	6	Equipment Code	DESKT
Division Code		Department Code	
Account Code		Status	Assigned to Work Order
Description	Computador avariado		

Step Responded By	On	Workflow Step	Status	Step Status After
PROF	6/23/2018	Basic	Requested	None
Comments				
SYSTEM	6/23/2018	Basic	Approved	None
Comments				
SYSTEM	6/23/2018	Basic	Assigned to Work Order	None
Comments				

Estimated Cost of Labor	$0.00	Cost of Labor	$0.00
Estimated Cost of Parts	$0.00	Cost of Parts	$0.00
Estimated Cost of Tools	$0.00	Cost of Tools	$0.00
Estimated Other Costs	$0.00	Other Costs	$0.00
Estimated Total Cost	$0.00	Total Cost	$0.00
Other Costs Description			

Fig. 10. Example of the type of information included in a work request issued on the FM software [5].

3.3 Towards BIM-based Building Sustainability Assessment

The availability of the BIM model of IB-S created the necessary conditions for its further use towards conceptual improvements in Facility Management context, but also in understanding how it can be used to support life cycle assessment. This opportunity has been taken through a recently started MSc thesis work within the scope of the "Master in Sustainable Construction and Rehabilitation" (co-author Tais Magalhães, supervised by Miguel Azenha and Ricardo Mateus). The thesis work builds upon the existing model and information richness towards exclusive dedication to the preparation of feasible frameworks to apply at the University of Minho. Particularly, the goal is to analyse the BIM model in order to identify the information that is still needed to be gathered by the BIM model in order to allow a comprehensive life cycle assessment of the building, based on the SBTool^{PT}-H building sustainability assessment (BSA) method and by other internationally recognized BSA methods, such as BREEAM and LEED.

A building project can be regarded as sustainable only when all the different dimensions of sustainability – environmental, social and economic – are taken into account. The various issues of sustainability are interrelated, and the interaction of a building with its surroundings has also important ramifications. Common concerns include those of reducing the use of non-renewable materials and water, as well as the production of emissions, waste and pollutants.

As an example, SBTool^{PT}-H covers 25 sustainability criteria that allow evaluating the performance of a building at the level of the most relevant sustainability targets in Portugal, considering the approach of the EN standards in the field of sustainable construction. These criteria are organized in nine sustainability categories (macro indicators) [6]: C1 – Climate change and outdoor air quality; C2 – Land use and biodiversity; C3 – Energy Efficiency; C4 – Materials and waste management; C5 – Water efficiency; C6 – Occupant's health and comfort; C7 – Accessibilities; C8 – Education and awareness of sustainability; and C9 – Life-cycle costs. During the operation stage of a building, different data is needed to allow controlling the building performance in light of the SBTool^{PT}-H method. For the C1 sustainability category, it is necessary to collect the maintenance intervals, the quantity of materials used and related embodied impacts. C2 allows to access the impact of the building in the surrounding environment and parameters such as the control of the storm water runoff and heat island effect, are needed. To assess the performance of the building at the level of energy efficiency (C3) it is necessary to have data connected to the energy consumed in the building for acclimatization (cooling and heating), preparation of hot water and energy consumed in the building integrated systems (e.g. artificial lighting and elevators) and each energy vector used. C4 concerns the type of materials used in the maintenance and renovation of the building (e.g. recycling content of building materials used), green procurement (e.g. type of consumables bought) and the implemented waste policy. For the water efficiency (C5) it is necessary to monitor the amount of water it is consumed in the different uses and to control the volume of grey water that it is recycled and the volume of rainwater it is used. To assess the performance at the level of the C6 (occupant's health and comfort) it is necessary to collect data related to indoor contaminants and hourly operative temperatures in the main building's indoor areas. Regarding the accessibilities (C6) updated information about the distance to public transportation and frequency and distance to other main urban amenities are needed. C8 is related to the building users' awareness and education in the context of sustainability and the availability and content of a user manual and adequate summarized information at the level of each indoor space is of utmost importance. To assess the life cycle costs category (C9) it is necessary to collect the energy and water bills and the costs related to building maintenance and renovation.

BSA methods are based on a set of different and multidisciplinary sustainability criteria. Therefore, although BIM was not developed with the focus of promoting more sustainable buildings, since it allows better information sharing between different stakeholders, it can play an important role to straightforward the assessment of the life cycle performance of buildings. For many sustainability criteria, BIM models can be adapted to provide the necessary data for assessment, even if external software is necessary, reducing the time necessary to assess sustainability. For other criteria, complementary plug-ins are needed to automate the building sustainability assessment process.

4 The School of Engineering

4.1 Introduction

Following the very positive experience of allowing students to participate in the endeavour of digitizing the Campuses of UMinho, the team decided to go one step further in the school year of 2018/2019. On the same

Curricular Unit 'BIM in Civil Engineering' mentioned above in Section 3.2, all the students were challenged to produce FM-oriented models of Buildings #1 and #2 of the School of Engineering, as described next.

4.2 School of Engineering - #1 and #2

Fig. 11. School of Engineering.

The Preliminary Study, completed in March 1983, although specifically directed to the installations of the 1st Phase presented a solution for the general plan of the campus. The ceremony of launching and blessing of the 1st stone of the campus of Azurém happened in November 1985. In 1989, after four years, its first buildings were officially inaugurated, housing the School of Engineering and several support services.

Designed GPA – Grupo de Planeamento e Arquitectura, under the coordination of Architect Bartolomeu Costa Cabral, three extensive parallel bodies were installed with great topographic acuity on platforms at different heights, apparently mimetizing the traditional agricultural terraces .

By joining two of these blocks, a wide glass roof forms the reception atrium in a gesture that, together with several foot-bridges that articulate and physically link it, enhancing the perception of the whole as a unique building. The northern body, at its highest elevation, extends along a street and according to a regular alignment that suggests its future expansion. The south front, on the other hand, fixes the limit of the building in this sense, being discontinuous and open on the park and the hill of the castle.

The second phase of the Pedagogical Complex, if on the one hand confirms this implicit possibility of growth, also marks its limit, by physically and formally enclosing the building. Completed in 1993 and including a group of auditoriums – one of them with a capacity for about five hundred people, which for a significant period served the city lacking of a similar equipment – the work was executed according to a project that gave continuity to the previous architectural solution, Allowing us to read today the whole as a whole, complete and complete.

4.3 The BIM assignments

The endeavour in the current semester (2nd semester of 2018/2019), that spans February to July 2019, is including all the students enrolled to the BIM Curricular Unit (33 students so far). They are forming a total of 7 groups (of 4-5 each), and Buildings #1 and #2 are attributed in parts to 6 of the groups, whereas the 7th Group is focusing on the adjacent laboratory Building #3. The plan view of the division of the assignments can be seen in Figure 12.

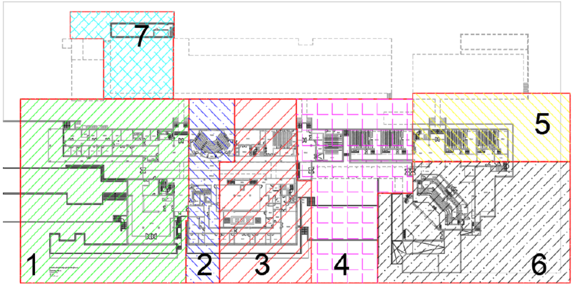

Fig. 12. Division of Buildings #1, #2 and #3 in 7 group assignments.

It is seen that groups with simpler stretches of the buildings need to cover wider areas as opposed to groups with more complicated parts (e.g. the main auditorium) are given smaller areas to cover. This should keep the work force relatively well balanced in between groups (except for the case of group 5, addressed later).

Table. 2. Assignment of classes of objects to individual work groups.

Group	Classes of objects to create/manage
1	Surface finishes for floors in general (e.g. tiles). All doors (fire-safety and normal doors)
2	Toilet equipment in general (toilet seat, sink, urinal, etc)
3	Electro-mechanical equipment (e.g. chillers, network hubs, etc)
4	Classroom equipment (chairs, tables, projectors, closets,…)
5	Windows, skylights, etc
6	Handrails and elevators
7	Light fixtures, false ceilings, technical railings

As all students are focused in buildings that use the same building techniques, materials and products, it made sense to create a collaborative framework for the production of classes of objects for the model. Therefore, during the first half of the semester in which all the students are dedicated to the preparation of coherent Architectural models (that support the additional models to be modelled afterwards), specific task forces have been setup for each group to model a set of classes of objects that will be used by all groups. In this way, a higher degree of care and time dedication can be given to each class of objects (e.g. doors, equipment) that will be used throughout the entire building. Table 2 shows the distribution proposed to the students.

The buildings to model have a great variety of windows, complex windows and façades, which complicates the work of Group 5. That is the reason why such group has a smaller area to model, as mentioned before, and indicated in Figure 12.

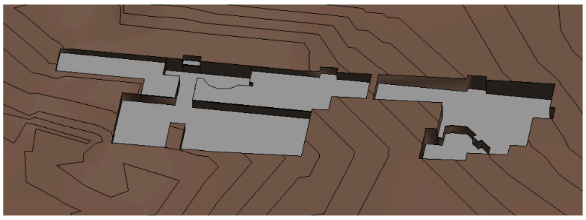

Fig. 13. Terrain in which all buildings will be implemented

To keep coherence in the modelling, facilitate a common learning curve, and ease interoperability aspects (particularly in sharing newly created common classes of objects), students were invited to use Autodesk REVIT. Furthermore, specific software training is given to student during classes. A common terrain platform has been given to students in digital form since the beginning, with basis on existing topographic information of the Campus of Azurém (Fig. 13) as to better ensure compatibility of placement of all models, and also contribute towards quicker attaining of results and stronger focus of the students of the engineering modelling/simulation tasks to be done later.

After the completion of the Architectural models towards half of the semester (March), each group of students was divided according to specific targets (and depending on the number of students per group): BIM Management; Structural Engineering; MEP Engineering (potentially sub-divided according to the number of networks); Construction management, Quantity take off and cost estimation; Facilities Management. Particular support and supervision efforts will be made in tailoring facility management scenarios that are feasible for practical implementation at UMinho.

5 Conclusions

BIM can be an essential tool for the architecture, engineering and construction industry to optimise building performance and reduce the environmental impacts of the industry in the future.

The paper provides specific information on the implementation of facility management. The developed models of the IB-S building include the definition of spaces, properties of spaces, maintenance reports, work schedules, work hours, space occupation and utilization, and discretization of one of the floors at the level of equipment and furniture. The Architecture model of the IBS building includes all the partitions with an adequate level of graphical detail that allows users to clearly identify the building and its rooms. The model was also populated with some furniture. The structural model and MEP model were federated together with the architecture model, as to produce the global integrated information.

Given the demand for more sustainable buildings and the amount of data produced during the operation stage of a sustainable building, it is important to create ways to integrate and automate the Building Sustainability Assessment (BSA) methods within the BIM context. In this context, project teams will be able to identify differences between the expected and real performance levels and compare different operation scenarios, without spending too much time, money and other resources.

Acknowledgments

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