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APPLICATION OF BUILDING INFORMATION MODELLING METHODOLOGY IN A PROJECT BASED LEARNING SUBJECT

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Abstract. Building Information Modelling (BIM) could be understood as a collaborative work methodology that documents a building, plant or infrastructure, making use of computer tools in order to generate a unique repository (digital model) that contains all the information useful for all participating stakeholders (owners, promoters, constructors, designers, suppliers, manufacturers, administration, etc.) throughout its entire life cycle. Therefore it consists in the collaborative transmission of information for the development and execution of a constructive project through the elaboration of a unique 3D digital model.

The use of BIM produces multiple advantages in the quality of the projects, in terms of communication, efficiency, savings of cost and time, reduction of risks and environmental impacts, etc. For these reasons, BIM is called to become the standard for the development of infrastructure projects in public administrations and in the private sector. Nonetheless, in the architecture, engineering and construction (AEC) industries there is still room for its wider implementation. The industrialization in the AEC industry is one of its main challenges to improve the construction processes, since the traditional systems still have a great weight. In Spain, the compulsory use of BIM in the design and construction phases of public projects of buildings and infrastructures is due to 2018 and 2019, respectively, while it is expected to be also mandatory for the maintenance or rehabilitation works in 2020. However, the use of BIM is not very widespread in the Spanish AEC industry, and it is considered essential the teaching of the BIM methodology in Schools and Faculties for its implementation in the industry in the short and medium term.

With the above background, the School of Civil Engineers of Ciudad Real (Universidad de Castilla-La Mancha, Spain), a pioneer in the Project Based Learning teaching methodology, has recently embarked in a Teaching Innovation Project whose main objective is the implementation of the BIM methodology in the Project Work subjects. In this work we present the BIM-aided design of a Wastewater Treatment Plant developed by the students of the subject "Project Work: River and Water Management" (4th year, Degree in Civil and Territorial Engineering).

1 INTRODUCTION

Building Information Modelling (BIM) methodology still has no single, widely-accepted definition. It has been defined as *"the use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions*" [1]. Another possible definition of BIM would be *"a modeling technology and associated set of processes to produce, communicate, and analyze building models"* [2]. Therefore, BIM could be understood as a collaborative work methodology that documents a building, plant or infrastructure, making use of computer tools in order to generate a unique repository (digital model) that contains all the information useful for all participating stakeholders (owners, promoters, constructors, designers, suppliers, manufacturers, administration, etc.) throughout its entire life cycle.

The digital representation of both the physical and functional characteristics of a project allows users to transfer design data and specifications between different software applications and between members of a multidisciplinary work team. Since information is stored in a BIM database, whatever is necessary throughout the project life cycle - planning, design, construction, use, maintenance and deconstruction - can be properly planned and managed [3].

The origin of BIM can be found in the computer-aided design research from decades ago, and it has been used increasingly in several industries. Nonetheless, in the architecture, engineering and construction (AEC) industries there is still room for its wider implementation. The industrialization in the AEC industry is one of its main challenges to improve the construction processes, since the traditional systems still have a great weight. However, the large initial investment that it requires (e.g., training, software and resources) hinders its adoption in most construction companies.

BIM is one of the most promising developments in these industries, as it could facilitate a more integrated design and construction process that would result in better quality buildings or infrastructures at lower cost and reduced project duration [2]. This would in turn lead to a decrease in work accidents and a lower environmental impact. The concept of BIM was first introduced in the AEC industry in terms of increasing efficiency, reducing costs and serving as support for the different stages of execution of the work, although its extension to all levels of civil engineering is currently in process.

Some advantages of using BIM would be: i) it improves the quality of the projects, reducing the risks and saving costs and time in its elaboration; ii) it improves the final result of the work, as well as the estimation and fulfillment of construction deadlines and costs; iii) it facilitates real-time interoperability among all participating stakeholders throughout the construction life cycle; and iv) it can be applied to all types of projects, regardless of their size or complexity.

BIM is called to become the standard for the development of infrastructure projects in public administrations and in the private sector. The European Union has created in 2016 the EUBIM Task Group to promote the use of BIM in the public sector, because of its advantages for the public sector: *"from a public stakeholder perspective, BIM can provide significant efficiency benefits to public works, to public value for money and be a driver for growth and competitiveness"* [4].

In Spain, the compulsory use of BIM in the design and construction phases of public projects of buildings and infrastructures is due to 2018 and 2019, respectively, while it is expected to be also mandatory for the maintenance or rehabilitation works in 2020. However, the use of BIM

in Spanish construction companies is still limited: it is estimated that while 55% of the construction companies have implemented a BIM project, only 15% have implemented it in all their works [5]. Although the use of BIM is not very widespread in the Spanish AEC industry, since 2015 there is a commission whose main mission is the implementation of BIM in Spain, bringing together all the stakeholders involved in the industry [6]. One of its objectives is to promote the teaching of the BIM methodology in Schools and Faculties, which is considered essential for the implementation of this methodology in the industry.

Some Spanish Architecture and Building Engineering Schools are beginning to include the BIM methodology in their plans, but the implementation is much smaller in Schools of Civil Engineering. The main exception is the Universidad Europea de Madrid, which incorporates this methodology in various undergraduate subjects and has a postgraduate specialization in BIM [7]. Worldwide, the BIM methodology is being progressively incorporated in university teaching, allowing teachers to efficiently develop more realistic educational examples [8].

The implementation of the BIM methodology in university teaching will not only facilitate the incorporation of competent professionals that allow a greater development to the entire AEC industry, but will also provide new skills for students to face new challenges with greater efficiency [9]. Some studies [10] advocate the integration of the BIM methodology among the traditional disciplines, cooperating among them without isolating themselves, and collaborating with companies in real projects in the last years of the university studies.

The purpose of this work is to present the implementation of the BIM methodology in the teaching of a Project Work subject, related with Water Management, in the School of Civil Engineers of Ciudad Real (Universidad de Castilla-La Mancha, UCLM). Following the Project Based Learning (PBL) methodology, the students themselves had to carry out the BIM-aided design of a Wastewater Treatment Plant, as part of their group work of the subject (fourth year, Degree in Civil and Territorial Engineering).

2 MATERIALS AND METHODS

2.1 The UCLM's School of Civil Engineering and the PBL

The UCLM's School of Civil Engineering, which is located in Ciudad Real (Spain), was created in 1998, when only seven universities in Spain offered the 5-years degree ("Ingeniero de Caminos, Canales y Puertos"). From their beginnings, this School tried to implement a modern and high-quality training model with different teaching methodologies and specialization approaches than the existing schools [11], based on the following aspects: i) Adoption of PBL teaching method as a key differentiator element of the educational process; ii) Learning in small groups (about 50 students admitted per year), with emphasis on the development of communication and innovation skills; iii) Deepening in the territorial and environmental aspects of civil engineering; iv) Actions of internationalization and use of new technologies; and v) Promotion of study trips and visits to work sites as fundamental elements in the learning of civil engineering.

Nowadays, this School offers two degrees: a Bachelor´s Degree in Civil and Territorial Engineering (recognized in 2016 with the EUR-ACE® quality label) and a Master's Degree in Civil Engineering, being the PBL methodology the key difference of this School. This methodology, where students solve real (civil engineering) problems, was firstly implemented at McMaster University Medical School in the early 1970s. Since students have to deal with

real projects, they are involved in the design, problem solving, decision-making or researching activities during the whole duration of the subject. Additionally, students also get transversal skills such as management, communication, critical thinking, teamwork, leadership, innovative and entrepreneurial ability [12-16].

2.2 The Teaching Innovation Project on BIM

In 2017, the UCLM's School of Civil Engineering was granted by the Vice Chancellor of Teaching of the UCLM in the 10th Call for Teaching Innovation Projects (TIP) to develop the project "Application of the BIM Methodology to the subjects of Degree in Civil and Territorial Engineering". The main objective of this TIP was the introduction of BIM as a transversal tool in the training of the students, mainly through the Project Work subjects, optimizing the results of the Projects carried out by the students and increasing their professional skills. In addition, it is intended to lay the foundations for a future specialization in BIM of the School.

The first step in the project was to train the teachers of the School in BIM methodology. After that, the methodology would be applied in two pilot subjects: one Project Work in the specialization track in Transport and Territory, and another in the specialization track in Hydrology. Finally, the methodology would be extended to the rest of the subjects of the degree where it is pertinent and beneficial.

2.3 The Project Work: River and Water Management

The Degree in Civil and Territorial Engineering of the UCLM's School of Civil Engineering is developed over a span of 4 years; the first two are common and, from the third year, a specialization in Transport and Territory or in Hydrology must be chosen. All the students have to take 6 Project Works subjects (42 ECTS credits) during their studies: 3 common subjects during the second and third years (18 ECTS credits) and 3 specialization subjects during the third and fourth years (24 ECTS credits). This work presents the implementation of the BIM methodology in the Project Work subject "River and Water Management" (12 ECTS credits), which is in the fourth year of the Degree, in the specialization in Hydrology.

The main objective of this Project Work is the analysis, diagnosis and proposal of solutions for a real river basin. For this, teams of between 4 and 10 students are formed, which, in turn, are divided into groups of 2-4 members, which have a coordinator. The composition and coordinator of all the groups change in each of the 3 blocks in which the subject is structured. These 3 blocks, with a duration of 5 weeks each, are the following:

- Block 1: Analysis of the quality of water bodies and the risk of flooding.
- Block 2: Modelling of hydrological-hydraulic processes and pollutant flow.
- Block 3: Proposal and definition of structural and non-structural solutions to mitigate the problems detected.

The training activities include: i) Field work (Fig. 1); ii) Seminars and supervised work; iii) Resolution of practical cases; iv) Preparation of partial and final reports; and v) Exhibition and defence of their work.

Figure 1: Students measuring flows and dimensions in a river channel during the fieldwork

3 RESULTS

The implementation of the BIM methodology in the Project Work "River and Water Management" has been carried out for the first time in the 2017/18 academic year, as a pilot experience. The river basin studied has been that of the Guadalhorce River, in Andalucía, South Spain (Fig. 2).

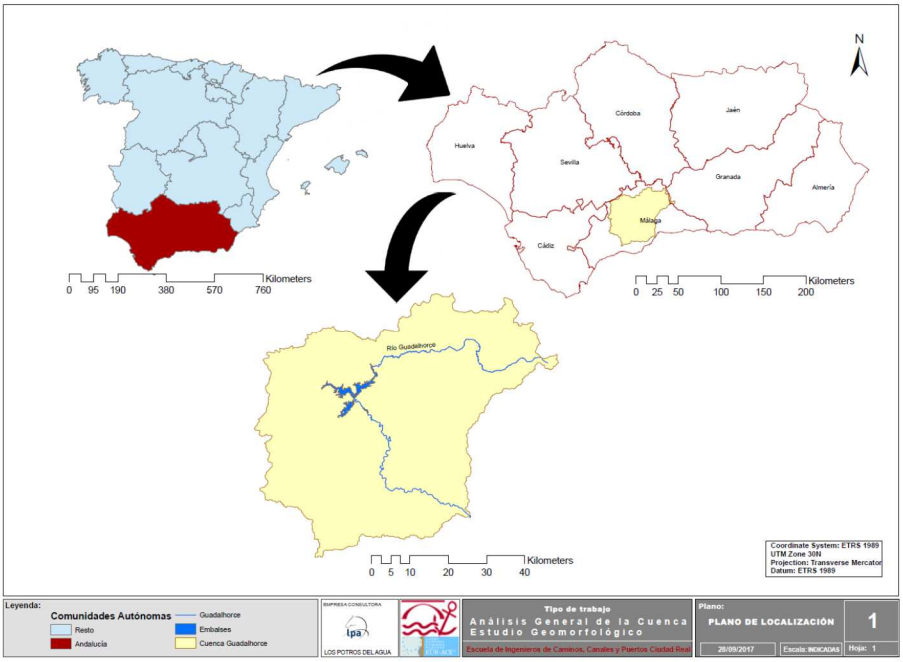

Figure 2: Location of the Guadalhorce River Basin, study area in the Project Work "River and Water Management" during the 2017/18 academic year

The implementation of the BIM methodology has consisted in the development of a 3D model of a Wastewater Treatment Plant (WWTP) proposed by the students for the town of Cártama (Málaga, 25317 inhabitants) and its implementation in the study area. For this, the following steps have been followed:

- Development of the digital model of the study area using Autodesk Infraworks as BIM software.
- Collection and import of raster and vector layers from several public websites: Digital Terrain Model, orthophotos, hydrography, transport network, land uses, etc.
- Simulation of floods for different return periods (T = 5, 100, 500 years) to obtain the flood inundation area.
- Design of the 3D model of the WWTP based on the drawings prepared in 2D by the students and using 3D modeling software (e.g., Civil 3D, ScratchUp, Revit) (Fig. 3).
- Import of the 3D model of the WWTP to Infraworks.
- Creation and incorporation of auxiliary elements in Infraworks (urban furniture, vegetation, urbanization, etc.)

Figure 3: Designed Wastewater Treatment Plant in 2D with AutoCad (left) and in 3D in Infraworks (right)

4 CONCLUSIONS

The introduction of the BIM methodology in Spain, and in the Civil Engineering industry in particular, is slow, although it seems that it is unstoppable and that it will bring multiple advantages to the industry. Therefore, higher education in civil engineering should be an example and leader in the integration of disciplines. An immediate action would involve the incorporation of technicians in the medium term who have assimilated this methodology of work with the consequent improvement of the design process of the works.

Furthermore, the BIM methodology would be a very useful tool in teaching the subjects of Civil Engineering since it would allow or facilitate:

- The collaborative work of different groups of students in the design of the same project.
- The interaction between the working groups and with the professor/s of the subject.
- The optimization of the work of each student and each group.
- The achievement of a greater degree of definition of the Project, with better quality and more realism than in the current ones.
- A differentiating competence of the students in view of their subsequent job placement.

The present work has shown a way of introducing this methodology in a School of Civil Engineering, without reducing the contents to be taught but complementing them with new training tools. Although it has not been possible to deepen in the BIM tools, the result has been positive and hopeful for future courses.

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