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**Abstract–This paper describes the background to and execution of a postgraduate project undertaken by students on DIT's MSc in Geospatial Engineering (GeoEng) in support of a project on level 2 BIM being undertaken by students on the MSc in applied Building Information Modelling & Management (aBIMM) around the retrofit of and new build extension to the Grangegorman Clock Tower Building. In support of this requirement, an external and internal survey of the existing structure and its surrounding topography was required. The aBIMM students and staff acted as the Design Team who subcontracted the Geo Eng group who were organised into a survey team with a Topcon Ireland surveyor as team leader.**

**Students and staff, at the end of the project, recognised the need for significant upskilling of both Geospatial and Design professionals around the different requirements, time-scales and costs, associated with surveying for BIM versus traditional survey deliverables. The experience of this project showed that these design teams would be prepared to pay for a more value-added product than the basic point cloud.**

**The onus now is on Geospatial practitioners to take advantage of the opportunity afforded by collaborative BIM to engage early, often, and meaningfully in projects, and this will bring benefits to the geospatial profession as well as to the client, to the design team, and to the wider economy.**

*Keywords*– BIM Education, Collaboration, Geomatics, Surveying, Laser Scanning, Point Cloud.

## I Introduction

The interdependence of BIM and Geoscience is clearly articulated in this quote from two editors of the International Journal of 3-D Information Modelling, Sisi Zlatanova and Umit Isikdag: "BIM does not apply abstractions or simplifications; all components are represented with their true 3D shape" [1]. To capture this "true 3D shape", both accurate and precise geospatial measurement techniques are required.

While Geospatial Engineers have, for over 20 years, utilised geospatial databases to underpin graphical representations of reality via Geographic Information Systems (GIS), due to the scale of these systems, typically regional or national, some features are represented in generalised, simplified form. This is the digital equivalent of the simplified representations (symbols) used in medium- to small-scale mapping, e.g. at scales of larger than 1:10560. The new aspect of surveying for BIM is that the survey information can now be readily viewed by the client, in this case the designers, at 1:1 scale.

It is thus essential that Geospatial professionals communicate clearly and comprehensively with their clients about the quality of their data and its appropriate usage. No measurement is error free. All survey instrumentation is shipped with specification information that defines achievable accuracies and precisions in ideal situations. (A concise definition of the terms accuracy and precision, in the context of level 2 BIM, is given in [2]).

Instruments must be calibrated to both maintain the original specifications and to measure inherent errors (e.g. in lenses, lasers or levelling). Once instrumental errors are known, they can be minimised through the application of appropriate adjustments [3]. Errors in method are minimised through the utilisation of proper procedures and the implementation of checks during all workflows.

Although systematic methods are used to minimise errors, geospatial professionals must ensure that end-users are aware of the limitations of their data and that data is only utilised in the appropriate context.

The Survey4BIM (@Survey4BIM) working group of the UK BIM Task Group has produced a number of guides to assist with dissemination of this information to clients including ‘Survey and the Digital Plan of Works’ [4] and a ‘Client Guide to 3D Scanning & Data Capture’ [5]. Private companies such as Murphy Surveys and Ploughman Craven have also produced excellent Client Guides for this purpose. Currently, the Survey4BIM group, of which some of the authors are members on behalf of the Society of Chartered Surveyors Ireland’s (SCSI) Geomatics Professional Group, is working on the Big5 geospatial challenges to Geo-Enable successful BIM level 2 [6]: Accuracy, Geospatial Interoperability, Metadata, Level of Detail / Definition, and Generalisation. These have been chosen as the five items causing the most issues when integrating geospatial data and processes into BIM level 2, and were included as focus points for the project described in the following.

All of this work requires translation into industry, which is being achieved through widespread dissemination activities at conferences such as Geo Business and Survey Ireland, and in relevant publications such as the Civil Engineering Surveyor journal of the Chartered Institute of Civil Engineering Surveyors. The importance of appropriate use of geospatial data also needs to become embedded in the education and re-education of construction professionals around BIM.

This paper describes the progress made to date at the Dublin Institute of Technology in relation to creating a Geo-enabled BIM culture. In the next section, the context is described for a specific initiative where Geospatial Engineering (Geo) and applied Building Information Modelling & Management (aBIMM) postgraduate students jointly addressed a Client EIR in relation to the Clocktower Building at Grangegorman. Next the operation of the initiative is described, followed by lessons learned. The paper finishes with some conclusions about the future of Geo-enabled BIM education.

## II GEO-ENABLED BIM AT DIT

DIT has promoted the integration of BIM and Geoscience since as early as 2007 when the teaching of Autodesk Civil 3D was first incorporated into the BSc (Hons) in Geomatics in the School of Surveying & Construction Management. Since 2013, a full BIM module, focussing on the integration of geospatial data, such as point clouds, into BIM authoring software, has been operational on that programme [7].

Learnings gained on the DIT programme have been shared with Geomatics educators in other locations, such as HTW Dresden, University of Applied Sciences, and the outcomes have been published at FIG (International Federation of Surveyors) Working Week 2014 [8] & [9].

DIT has a unique position in the provision of BIM education in Ireland with a College of Engineering & Built Environment (CEBE) that is organised into seven Schools (Figure 1), all of which have current or potential links to full lifecycle BIM.

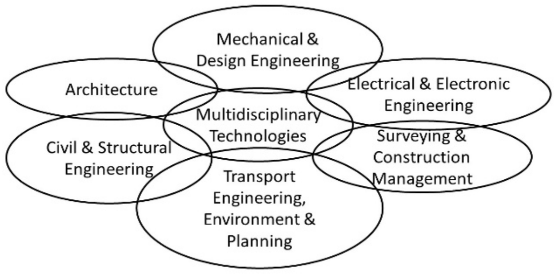


Fig. 1: Schools in the College of Engineering & Built Environment at DIT

These schools together created the multidisciplinary, collaborative MSc in applied Building Information Modelling & Management. The first stage of the MSc programme provides students with a solid foundation in discipline-specific technologies and workflows. The second stage, where this project is focussed, develops learners’ abilities to apply appropriate standards, workflows, and processes in the execution of multidisciplinary collaboration projects.

During this stage, the programme team also try to initiate as many interactions with students on other post- and under-graduate programmes, for example, with the MSc. in Geospatial Engineering. During the 2016/2017 academic session, students in the second stage of the MSc in aBIMM who took the Cross-Domain Geospatial Engineering elective (i.e. where professionals sample another discipline’s technologies and workflows) were taught jointly with all students on the MSc in Geospatial Engineering who were taking a core Geospatial Engineering for BIM module.

One of the goals of this integration was to develop deeper mutual understanding between professionals. The total cohort included students from the disciplines of Civil Engineering, Architectural Technology, and Building Services Engineering, in addition to the Geospatial Engineering group. The delivery of the module was designed to maximise the cross-pollination between disciplines by encouraging interaction and by requiring students to work in mixed groups to solve problems or to undertake tasks that required knowledge from both the Geoscience and BIM arenas.

During the 2nd stage of the aBIMM programme, students undertake an intensive Multidisciplinary Collaboration Project worth 15 ECTS credits (approximately 300 learning hours). Multidisciplinary teams of construction and design professionals receive a brief for a design project that must be produced, up to planning stage, including appropriate construction scheduling and adherence to sustainability and lean principles. A detailed description of the pedagogy unpinning the delivery of the module is given by Mathews in [10].

While previous collaboration projects on DIT's BIM programmes had been based entirely on new builds, in 2016/2017 the decision was made to base the project around the retrofit and extension of the Clocktower Building at Grangegorman, thus incorporating both new and as-built BIM. To complete the as-built surveying required to support this project, students on the Geospatial Engineering programme undertook Work Placement (one of their required modules) in a survey team.

## III CLOCKTOWER BUILDING, GRANGEGORMAN

*a) History*

Designed and built in 1816 by the architect Francis Johnston (1760-1829), the building's first function was as the Richmond Penitentiary [11]. Johnston was an architect for the Board of Works (predecessor of the Office of Public works (OPW)) and his work there included the Chapel Royal at Dublin Castle and the General Post Office. Among his other important Dublin buildings are Griffith's Barracks, St Andrew's Church, Royal Hibernian Academy, St George's Church, the former Central Bank in Foster Place and the former Houses of Parliament in College Green.

Fig 2: Clocktower Building, Grangegorman (DIT photo)

*b) The Hypothetical Design Brief*

The design brief provided to the MSc students was hypothetic and does not represent the actual plans for the building or the site. All updates on the development of the Grangegorman site are available for the Grangegorman Development Agency [12].

For this project the Client's brief specified:

1. Retention of the existing structure parallel to the road (running along the left side of the plan in Fig. 3) and refurbishment for use by administrative staff.
2. Buildings to the rear of the Clock Tower (Fig. 3) would be demolished and replaced by a fully serviced 300-seat auditorium with coffee shop, car parking and stage access.

Fig 3: Plan of Grangegorman building demonstrating the layout. To view in large format see [13]

To support the collaborative design work, the programme team were provided with plans, sections and elevations of the building by the Grangegorman Development Agency. However, the team designing the project wished to incorporate a wider range of surveying techniques, particularly, the use of point cloud measurement, to replicate the norms developing in industry.

*c) Response to the brief*

A group of five Geospatial engineering students were set up as a Survey Team with a Surveyor from Topcon Ireland as the Team Lead. Supports for the Survey Team were provided by a DIT Survey Equipment Specialist and by a number of Chartered Geomatics Surveyors who lecturer on both MSc programmes.

The students were provided with a verbal briefing on the Client's Requirements by the Multidisciplinary Collaboration Project's coordinator and a discourse followed to further explain the specific requirements. The Geospatial lecturers interpreted the client's verbal and brief and converted it into a Client Survey Specification (CSS). The CSS was defined with reference to national and international survey guidance documents [14], [15], and [16], and to the requirements for surveying identified in the BIM pillars documentation PAS1192-2 to 5 and BS 8536-1 to 2.

The students' first task was to interrogate the Client Survey Specification and to convert it into a survey plan. The plan encompassed equipment, software, and method specification, and as well as the production of a Method Statement and Risk Assessment for approval by the site owners. The students also applied standard project management principles to the organisation of people, equipment and time.

## IV SURVEYING FOR BIM

Much has been written about the ability of modern survey techniques to reduce the time taken for the survey of existing assets to assist with documentation, augmentation and reuse in BIM contexts, e.g. [17], [18], and associated.

### a) Control Network

While BIM in the design phase does not require geospatial location information (i.e. real world co-ordinates), both planning and construction phases do. This requirement was important to demonstrate to the aBIMM design teams, particularly because of the workflow implications of utilising point clouds and other survey data that are nationally or internationally geo-referenced (in this case Irish Transverse Mercator). Thus, the first task of the survey team was to establish co-ordination for the project in an ITM-based network that encompassed the relevant exterior and interior range of the project.

This portion of the survey took significantly longer than was planned for, mainly due to managing the logistics of surveying from interior-to-exterior and public realm-to-private property. The inexperience of the survey team was also a factor. Although the team lead and mentors could have stepped in and expedited the work, this would not have enabled the students to learn about the pitfalls and how to solve typical problems that arise.

### b) Topographic Survey

In a real world scenario, the topographic survey would be undertaken in parallel with the control checking but, to ensure that the students could clearly distinguish the requirements of different elements, these were carried out sequentially. Students utilised Topcon ES reflectorless total stations and downloaded their data directly to Magnet Office, where it was edited and tidied before delivery to the client.

### c) Point Cloud Survey

Once the control had been established internally and externally, the point cloud surveying was carried out using the Topcon GLS 2000. To achieve LOD 300 modelling, a point cloud spacing of ±10mm was selected.

Data was downloaded in Topcon Scan Master (Magnet Collage will be used in the future) and the point cloud was colourised and the geo-referencing checked to create a seamless point cloud from interior to exterior of the building. The data was moved into Trimble Realworks, because the students were more practised in its use, for segmentation and removal of unnecessary data point, e.g. people and vehicles moving through the scans. The final point cloud was delivered to the client in .e57 and .rcs formats, both as a full cloud and subdivided into different regions defined by the surveyors (see Lessons Learned).

## V MODELLING FROM THE POINT CLOUD

After delivery of the point cloud, associated photographs, and survey data, the aBIMM teams undertook modelling at LOD 300 for the retrofit requirements of the project. While a number of students attempted to model from the point cloud, most reverted to the plans, elevations and sections as this was the method with which they were most familiar and how they through that they could make the most rapid progress.

The models produced were not checked for validity. This has significant implications that are addressed in the Lessons Learned section.

## V LESSONS LEARNED

The Geospatial Engineering students undertook the survey with significant enthusiasm but the scale of the work was too large for the available time. The fieldwork took significantly longer than was intended (some of this was entirely unavoidable as one student of the five was taken ill on the second day of the survey).

The full engagement of Surveyors suggested by Survey4BIM's 'Survey and the Digital Plan of Work' document should be implemented between the two groups of students. This level of coordination is difficult to achieve in an academic setting where some students attend during daytime and some in the evenings, and where the sequence of learning of both students groups cannot be fully aligned because of other requirements. In this context, although the aBIMM group were entirely focussed upon the Grangegorman project, the Geo Engineering group also had requirements from four other modules to meet in parallel.

In future, the 100 learning hours of the Geo Engineering Work Placement module should be spread over a longer period. This would allow direct, face-to-face engagement between the two groups of students, acting as joint members of the BIM project team and utilising the direction of the Survey and the Digital Plan of Works document.

It would be strongly recommended that the delivery of all survey data should align with the Volume Strategy defined for the project, as per PAS 1192:2, which states that a volume is a "manageable spatial subdivision of a project, defined by the project team as a subdivision of the overall project that allows more than one person to work on the project models simultaneously and consistent with the analysis and design process" [17]. Early involvement of the survey team in the overall project team is essential to maximise the benefit of the volume strategy.

The validation of the model against the tolerances specified by the client is an essential element of the overall utilisation of point clouds. As the aBIMM students knew that their models would not be validated against any measured data, there was limited incentive to achieve geometric correctness. A validation requirement will be built into future projects to ensure better correspondence with real-world workflows and improved level 2 Geo-Enabled BIM compliance.

## X Conclusions & Recommendations

The Geo-enabled BIM project was partially successful in this educational context but it has the potential to be improved upon significantly in future iterations. The scale and complexity of the building / area being surveyed must be constrained to ensure that both the survey and modelling work are completed to the required standard, with appropriate validation.

The Geospatial Engineering students gained valuable experience of an in-demand set of skills and two of the five students chose to undertake dissertations on related topics; verifying how important they judged this area to be for their future careers.

The learning curve to enable students to competently measure for BIM using geo-referenced point cloud surveying is steep. Similarly, the challenge of modelling from point clouds is difficult when compared to the speed and expertise that some students have already gained in modelling from standard line and point measurements combined with plans, elevations and sections. However, the potential for error in a model produced from two-dimensional data is significant. As with so many other aspects of BIM, the temptation to return to the old ways when deadlines get tight is ever-present. While the value of the point cloud does not depend solely on the creation of models, it is necessary to undertake some modelling, particularly for energy simulation and meeting nZEB requirements in retrofit projects.

While software for modelling from point clouds has improved significantly and products such as ClearEdge3D's EdgeWise, Leica Geosystem's Cloudworx and Trimble's Realworks enable rapid fitting of regular shapes, complex buildings (such as the myriad public building requiring retrofit to nZEB standards within the next two years) require much more manual modelling. This is both expensive and time-consuming, and the expertise needed for this role must be built up over time. Thus, in future projects, students will be encouraged to upskill in and practise the area of modelling from point cloud data.

While a small number of companies have specialised in modelling from the point cloud, in the case of many project teams, there is a gap between the survey company who produce the point cloud (with appropriate accuracy and precision) and the (designer) client who would prefer to receive, and indeed pay for, a model rather than a raw point cloud. The opportunity for growth in this area of service provision is significant.

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