

# Teaching BIM to Geomatics Students

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**Key words:** Education, BIM, Geomatics, Ireland, Germany

## SUMMARY

The BIM method is changing the way Engineering Surveyors and Geomatics practitioners work. Universities are now developing new curricula for undergraduate students and for advanced vocational training. This paper will give a detailed outline on existing courses at Dublin Institute of Technology (DIT, Ireland) and at the University of Applied Sciences Dresden (HTW, Germany).

The main steps of BIM education are the following: First students have to recognise, that the model is a database – not a drawing. Then, they have to learn how to create a BIM-model from conventional sources, such as CAD floorplans. The next step is to understand how building elements are parameterised as types or families. For BIM terrestrial laserscanning (TLS) plays a dominant role as a data capture method. TLS methods and formats shall be discussed in the context of BIM. Georeferencing the project coordinate system is the next crucial part for the BIM process, which then leads to GIS/BIM integration. Engineering surveyors need to understand how to manage the setting-out of a BIM, typically model with total station.

It is important to convey that BIM is a method, not software. A proper methodological basis is very important. Working with their own BIM project, the students get to know both, BIM-software and general BIM methodologies.

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## BIM courses for geomatics students at DIT Dublin

Building Information Modelling (BIM) has been an important element, for a number of years, of programmes in the College of Engineering & Built Environment (CEBE), at the Dublin Institute of Technology (DIT), including the BSc (Hons) Geomatics. The development of a suite of cross-disciplinary, collaborative, postgraduate programmes in BIM from 2014 leveraged the skills that existed within the Schools that constitute the CEBE. From the outset, Geomatics was included as a stream within the programmes (McGovern, Behan and Furlong, 2014) and the distinct geomatics modules can also be taken as stand-alone modules. Furthermore, reflecting the importance of BIM to today's surveyor, a Geomatics for BIM module has been included in the MSc Geospatial Engineering.

### 1. BIM COURSES FOR GEOMATICS STUDENTS AT HTW DRESDEN

Eventually, BIM has been recognised by the surveying/geomatics industry in Germany. The federal state, especially the federal Ministry of Transport and Digital Infrastructure, the Ministries of Education and state level Universities and – last but not least – the construction industry have understood that business models, regulations and workflows will change in the near future. BIM changes also the way, engineering surveyors and geomatics work. Integrated in the European framework (CEN) our national standards (DIN) are now about to be modernised for BIM.

As one of the first German universities to adopt BIM, we are offering BIM methodologies to our students for Engineering Surveying and Geomatics.

#### 1.1 Requirements analysis and development of course content

In 2014, the faculty of spatial sciences established a new Bachelor (7 semester) program “Vermessung/Geoinformatik” for Surveying Engineers and Geomatics. This was a good time to introduce BIM to the curriculum. After intensive discussions we decided to place BIM education in the 6<sup>th</sup> term where students already know many things about surveying, CAD and GIS. The large module “3D Visualisation” (8 ECTS) consists of three parts: City models, building models and computational geometry.

In order to establish a high quality course, we adopted the interdisciplinary approach of BIM and started our investigations at our university. We liaised with lecturers from the civil engineering department and recognized that BIM was already taught there to a certain extent. In order to understand how BIM is thought to geomatics students, we visited the Dublin Institute of Technology

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FIG Working Week 2016  
Recovery from Disaster  
Christchurch, New Zealand, May 2–6, 2016

in February 2015. There we had the opportunity to attend several practical lessons and talked to the academic personnel as well as to the students.

Secondly, we evaluated our BIM projects with Beiersdorf (Clemen 2014) and Deutsche Bahn. Practically this had been done with student projects and several Bachelor/Master thesis. At the same time we brought the topic BIM to the working groups of the “German Association of Surveying” (DVW). We then invited well-established speakers to one-day seminars “Geodesy and BIM” in November 2014 and November 2015. These seminars had more than 70 attendees, from industry, administration and education sector.

As a university of applied sciences, we want to teach the BIM in theory and practice. Therefore, we had to choose the BIM software for our practicals. Due to technical reasons - Autodesk licenses and building suites are already installed in our faculty network – we decided to use Autodesk Revit as the main tool for the practicals in our computer lab.

## **1.2 Offering “off the job training” to professionals**

On September 8<sup>th</sup> to 10<sup>th</sup> 2015 and March 8<sup>th</sup> to 10<sup>th</sup> 2016, we offered the designed course as “off the job training” to professional engineers. The topic of the workshop was “Geodesy and BIM”. Each course was booked by 15 attendees who worked in both, small surveying offices and larger companies in different parts in Germany. The professional development of the participants went from surveying assistant to managing director. The workshop also offered two informal dinners to have enough time to establish professional BIM networks within the German surveying/geomatics community.

By offering an external learning module, we pursued three goals: Improving structure and content of the training course with the attendee’s feedback, evaluating whether the industry and future employers of our students recognise our course, and promoting the BIM method to SMEs in the field of engineering surveying and geomatics.

## **1.3 Course Content**

The main steps of BIM education are the following: First students have to recognise that the model is a database – not a drawing. Then, they have to learn how to create a BIM-model from conventional sources, such as CAD floorplans. The next step is to understand how building elements are parameterised as types or families. For BIM, terrestrial laser scanning (TLS) plays a dominant role as a data capture method. TLS methods and formats will be discussed in the context of BIM. Georeferencing the project coordinate system is the next crucial part for the BIM process, which then leads to GIS/BIM integration. Engineering surveyors need to understand how to manage the setting-out of a BIM, typically model with total station.

The BIM module for geomatics (surveying/cartography/GIS) at HTW Dresden consists of ten sections; each section takes 4 hours per week + additional time for self-study

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FIG Working Week 2016  
Recovery from Disaster  
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### 1.3.1 BIM basics

The first section of the learning module is a lecture that motivates the students. At first, current BIM projects are presented and analysed from a surveyor's point of view. Then, general BIM concepts are presented [Clemen 2014]: Level of maturity, Level of development, lifecycle approach, collaborative project management, semantic modelling, and parametric modelling. The lecture continues with data capturing for BIM and setting out.

### 1.3.2 BIM database queries

In the first practical lesson, the students recognise that the model is a database – not a drawing. The basic idea of this lesson is “reverse order”. The lesson starts with the existing model. After a short introduction, the students

- Add dimensions to the floor plan, which is to be exported from the BIM model.
- Add room names and numbers
- Create a bill of rooms and materials
- Calculate a standard conform (DIN277) rentable area calculation
- Create sections and views with proper dimension lines
- Configure the plan header with project meta data.

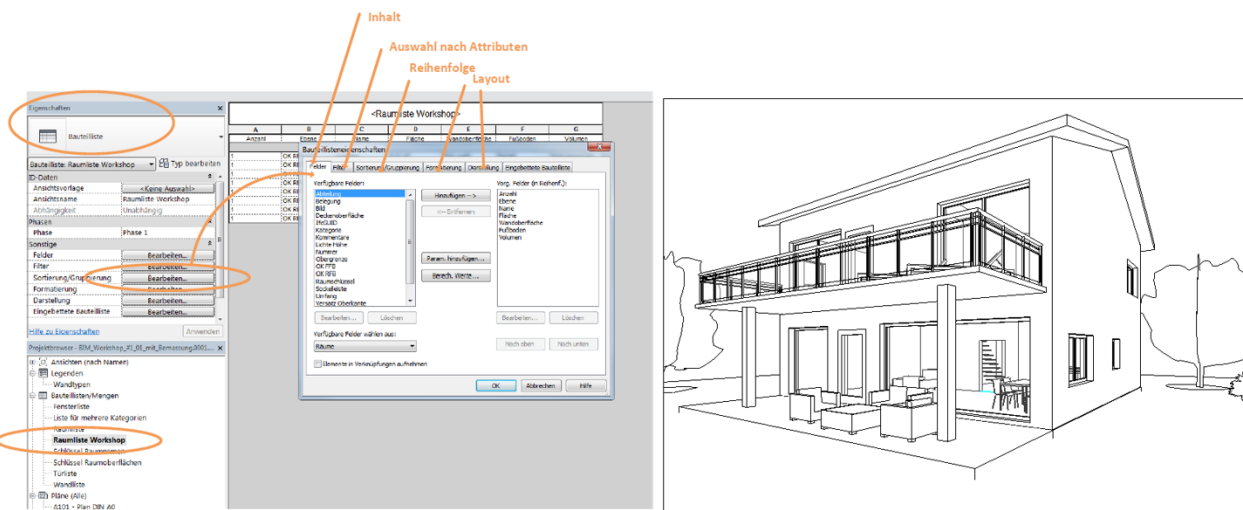


Fig. 1 A BIM model is a database - not a drawing

### 1.3.3 Basics of Modeling

In the second lesson, the students learn how to create a BIM model from a given CAD drawing, with measured dimensions from a survey. In detail, they get to know the necessary concepts and GUI elements from Autodesk Revit, get a first idea of building elements and parametric modelling,

and learn how to model floor plans, outer and inner walls, ground plate and ceilings, wall openings, doors and windows. The students then model a simple stairs and a standard roof with given dimensions.

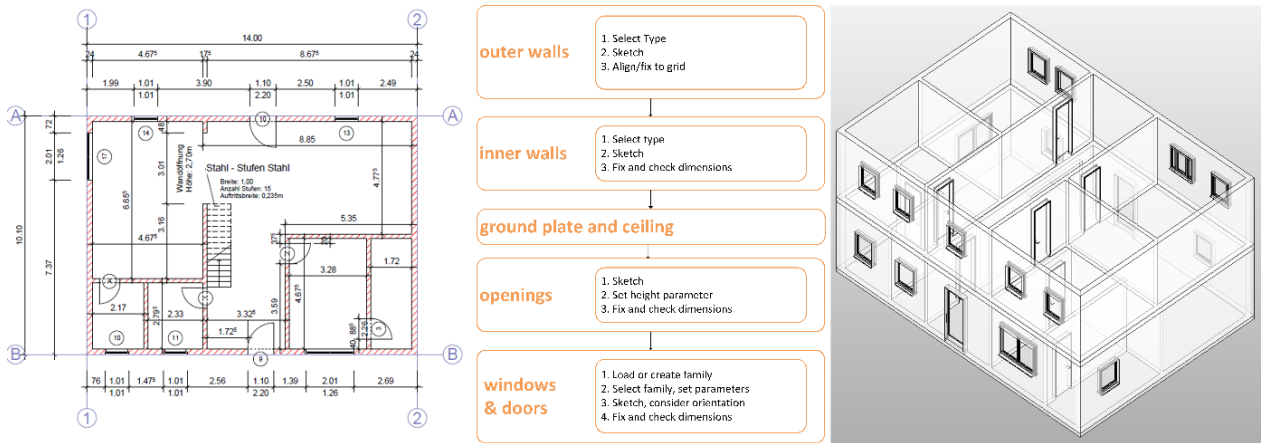


Fig. 2 Simple workflow from survey to BIM model

Autodesk Revit is mainly developed for the design of buildings, not for the examination of measured surveys. In contrast to online tutorials “from the internet”, this section of the learning module emphasises that accurate modelling is very important for the engineering surveyors work. Accurate modelling means: Proper dimensions, reasonable geometrical constraints and topologic relations of the building elements.

### 1.3.4 Modeling Building Elements

The next section focuses on creating and managing templates (types, families) for building elements. This step in the BIM workflow differs significantly from the well-known CAD process. As an example, a new window type has to be modelled.

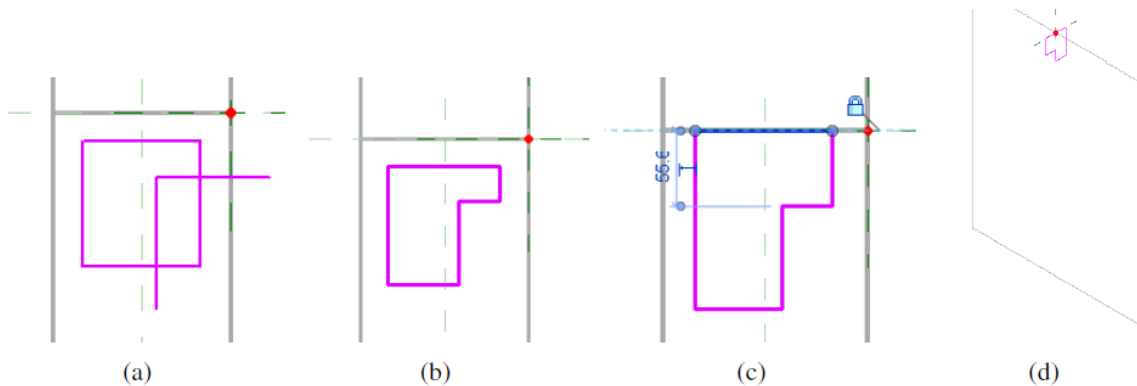


Fig.3 Modeling the window frame (sweep)

During the exercise, the following topics are covered: Reference planes and working planes, wall openings, EQ-measures, extrusion, sweep. The geometry and the material of the window is then parametrised. Eventually the students learn how to manage object libraries with Autodesk Revit.

This part of the course is not especially developed for surveying engineers. However, creating and managing building element libraries can be up 20% of the surveyors work.

### 1.3.5 TLS Point clouds – native support

For simple tasks, Autodesk Revit offers native point cloud tools. The exercise starts with a registered and filtered point cloud (pts format) from our computer laboratory. The first task is prepare the point cloud for Revit with the free software Autodesk Recap. Secondly, the point cloud is loaded to an empty Revit project. In order to use the cloud as reference for the digitalization of building elements, level and grid are adjusted to the cloud. For simple tasks, the built-in point cloud features of Autodesk Revit are sufficient (colouring of the point cloud, point and plane snapping, clipping). The students model several rooms, walls, columns, doors and windows.



Fig. 4 As-built survey with point cloud and BIM model

The third part of this teaching unit is an as-build comparison between an existing model of the building and the point cloud. Here, the proper alignment of the point cloud is crucial.

### 1.3.6 TLS Point clouds – professional approaches

In this section, the professional Revit plugin “PointSense for Revit” (Faro 3D Software, Dresden) is presented to the students. They learn how create complex building elements from point clouds, using 3D point cloud and 2D panoramic views. With a semi-automatic approach, the software automatically detect walls in the point cloud and links it to the BIM object library. After having constructed the building from the measured point cloud, the degree of generalization can be configured, matching the project needs.

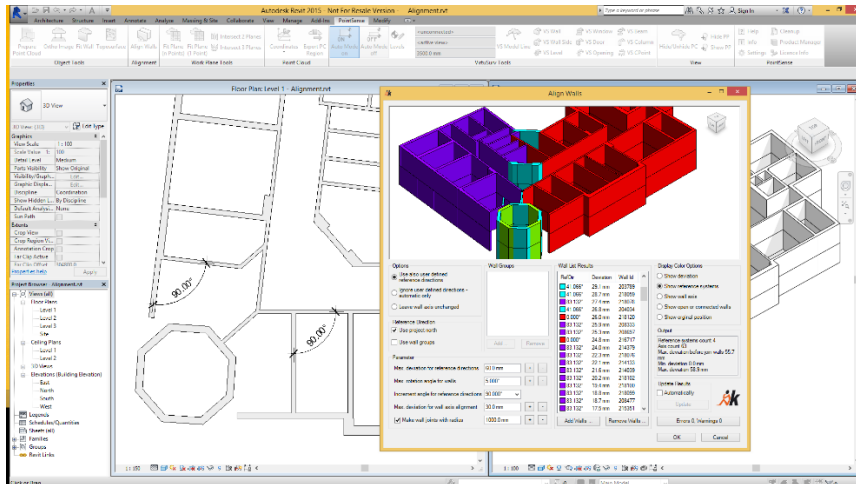


Fig. 5 Adjusting walls to (rectangular) constraints (Faro 3D Software GmbH).

### 1.3.7 Coordinate systems

Managing data sources with diverse coordinate systems is one of the surveyor's key skills. However, it is not so easy with BIM [Baldacchino 2013]. First, the three concepts for coordinate systems (internal, project, shared) are explained. The transformation parameters can be configured (position, azimuth, elevation) with the "project base point" and the "survey point". The students learn that BIM projects work in Cartesian coordinate systems with scale 1 and "short" coordinates, due to numerical reasons of the parametric 3D engine in the BIM software. The major axis should be parallel to the longest side of the building.

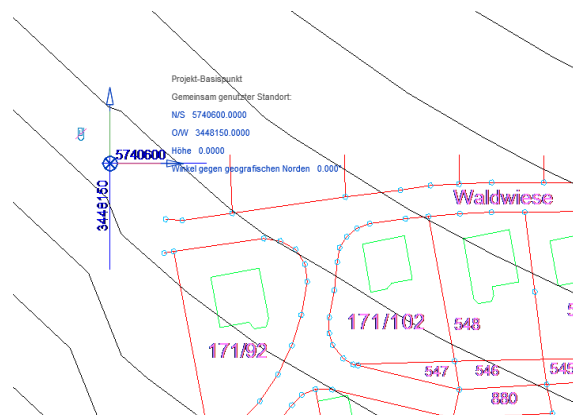


Fig. 6 Georeferencing the BIM project with an georeferenced CAD-plan

In the exercise, a BIM "master project" is georeferenced with a linked CAD site plan. Then the DTM and the Building Model (not georeferenced yet) are loaded to the master project. In this step of the process, the students consider constraints like distance spacing and alignment to parcel boundaries. In a last step, the "shared coordinate system" (georeferenced) is published to the building model. The workflow should be well-defined and documented. Changes between Autodesk Revit versions should be observed.

### 1.3.8 Setting out

A major task for surveyors is to set out points from a given model (plan) to the construction site (real world). The BIM method is based on parameterised building elements, which are positioned in several element coordinate systems. The world coordinate system (WCS) is not available at any point, as it is in CAD software. Due to the parametric modelling importing and exporting surveying and control points is not a trivial task.

In this section of the course, the students learn how to apply and configure the Autodesk Plugin PointLayout. With a simple file-based (CSV) interface, points with id, coordinates and codes can be managed for setting out and as-build survey. The software is able to compare design and measured points. Points can be created related to the grid and to building elements. The plugin should be used in the latest version which properly calculates with metric units.

### 1.3.9 BIM and GIS

BIM and GIS are equal in many things, such as geometric data structure in modern databases, computational geometry, and graphical representation. However, BIM represents buildings and construction sites while GIS represents topography, cities and utility networks. The theoretical part of the section “BIM and GIS” opposes the general approaches of CityGML and IFC. The basic data set for the exercise comes from Häfele [2012]. The different domains of the CityGML document (Building, DTM, tunnel, railway, vegetation, lake) had been georeferenced previously and then split into different files (\*.skp, \*.shp and \*.dwg).

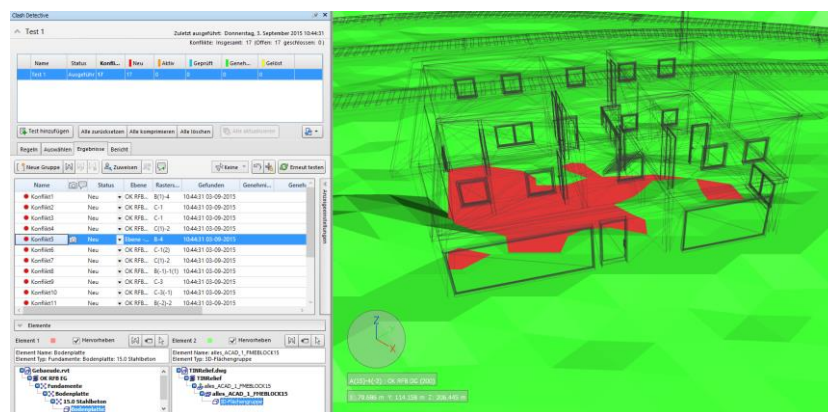


Fig. 7 BIM/DTM Collision detection with Autodesk Navisworks

The practical part of this section follows the workflow loading heterogeneous data sets into Autodesk Navisworks, setup a bidirectional interface to the earlier created Revit model, analysing the models together with clash detective, reporting conflicts and publishing the combined scene to a simple data viewer (KML, Google Earth). The workflow also shows, that changes in the Revit model are automatically reflected in the GIS/coordination model. Throughout the whole workflow, the coordinate system and semantic “richness” are considered intensively.



### 1.3.10 BIM Standards

The last section addresses both BIM standards and surveying standards. Open BIM standards are mainly developed by buildingSMART (f.k.a. IAI) and then overtaken by the International Organization for Standardization (ISO). The Industry Foundation Classes (IFC) define an open BIM standard for the exchange of building data. In the lecture, the data model (EXPRESS, XML), general structure (layer, resources), object oriented concepts (hierarchy, objectified relations), geometric features and georeferencing are covered in detail. As a practical exercise, the students examine an IFC file with a text editor. They have to find several items in the IFC file and investigate geometry, topology and semantics of walls and windows.

Furthermore, the lecture covers the basic ideas of Information Delivery Manual (IDM) and Model View Definition. As a practical example, the IDM Georeferencing [BuildingSMART Norway, 2010] is examined. The international standards (BS1192-x, ISO16739) are then discussed in the context of national surveying and GIS norms like DIN18710 (engineering surveying), VDI 25521 and the German regulations for land management.

## 1.4 Further developments

Of course, BIM is continuously changing the surveyor's world. Besides evaluating our course each semester, we are trying to establish a research group "Geodesy and BIM". We are pleased to have a postdoc position from May 2016 whose primary responsibility is to advance our BIM research activities. We will also continue to promote geomatics expertise to the large remaining part of the BIM world.

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## **BIOGRAPHICAL NOTES**

Prof. Dr. Christian Clemen, born 1976. Graduated in 2004 as a Dipl.-Ing. in Surveying from the Technical University of Berlin. From 2004 to 2010 he was an Assistant at the Department of Geodesy and Geoinformation, Technical University of Berlin. He then worked as a GNSS Software engineer for Alberding GmbH, Wildau. Since 2013 he is a full professor at HTW Dresden, University of Applied Sciences. Christian Clemen is DVW representative on FIG Commission 10.

Dr. Eugene McGovern is a chartered surveyor and lecturer at the Dublin Institute of Technology in the area of Geomatics. He previously worked internationally as a land surveyor before coming a director of a survey company in Ireland. He holds a PhD from University College Dublin in satellite image processing. He is a committee member of the Society of Chartered Surveyors Ireland Geomatics Professional Group and is the RICS representative on FIG Commission 5.

Dr. Avril Behan is a chartered surveyor and is Assistant Head of School of Multidisciplinary Technologies where she manages a range of programmes including the MSc in Applied Building Information Modelling & Management. She previously worked as a research assistant at Delft University of Technology and professionally as a photogrammetrist in Switzerland and Ireland. She holds a PhD from the University of Dublin, Trinity College in the application of Geomatics to architectural historical studies. She is a committee member of the Society of Chartered Surveyors Ireland Geomatics Professional Group and is chair of the Society's inter-professional group on BIM.

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FIG Working Week 2016  
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