Application of Software Testing Life Cycle into As-build Building Information Modelling.

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1. Introduction

ISTQB is well known certification in IT sector. Processes described in the “CTFL-2018-Syllabus” constitute best practices and establish the base of the knowledge for software testers.
Although those practices can be useful for another professions where testing represent significant role and output product quality product should be proved and analysed.
Objective of this project is to adapt good practices from Software Testing Life Cycle (STLC) in Building Information Modelling (BIM) as – build survey, in order to reduce costs and time of modelling, improve the process, create standards, improve standards, efficiency and deliver better quality product.

2.Testing in the terms of as-build modelling

2.1. What is BIM and as-build BIM

Building Information Modelling (BIM) - is the management of information through the whole life cycle of a built asset, from initial design all the way through to construction, maintaining and finally de-commissioning, through the use of digital modelling.

As-build BIM – building information model of an existing building. Shows exact location of geometry and dimensions of all visible elements at the time of the survey. Usually it contain structural, mechanical, plumbing members.

2.2. Main types of testing for as-build BIM

Component testing - verify if component/family type is assigned correctly according to reality, for instance that wall object is build as a wall not floor or roof. Components of the model should be modelled to real counterparts.

Integration testing – verify if components/families are correctly integrated. For instance: geometry of the wall is joined, floors and roofs are integrated with walls, voids are cutting geometry, information properties are this same for united group of elements etc.

System testing – verify if at least two systems/models does not have significant defects and works properly as a one system. In this case is urgent to coordinate properly in both models Project base point (X, Y, Z), Survey point, levels and in some cases of templates.

Acceptance testing – consult project with client in order to assure that model, objects and information are useful for the client and output meets with requirements and expectations of the client.

2.3. Test activities through as-build modelling

Test planning – outline of testing through all modelling process, divided by milestones which have to be achieved. Determinate objective of the project and propose techniques of testing.

Test monitoring and control – monitoring if the criteria for the project are fulfilled, control if project is developed according to attempted goals in each level. Creating reports and monitoring if techniques of test planning fulfil the purposes.

Test analysis – based on input information from the client analyse how goals can be achieved, determinates constrains of the project. Create risk reports, time and cost assessment. One of the document used for test analysis can be EIR – Employer Information Requirements, which is a fundamental document in the BIM process.

Test design – adaptation of testing techniques for each stage of the process of modelling. Prioritizing tests that should be done and determinate condition of each element/group of elements should pass, design tests tor extraordinary cases. In this test should be chosen tools used for geometry testing and information testing.

Test implementation and execution – verification if objects and systems meet with expectations according to designed tests. Run tests and monitor results. Initialize retesting and regression testing if its necessary. Create reports.

Test completion - gather all documentations, create new documentations, make sure that project closure was done properly before handover, collect data about time of modelling, testing and improvements for future analysis and in order to improve time estimation for the next projects.

2.4. BIM life-cycle based of norms PAS 1192

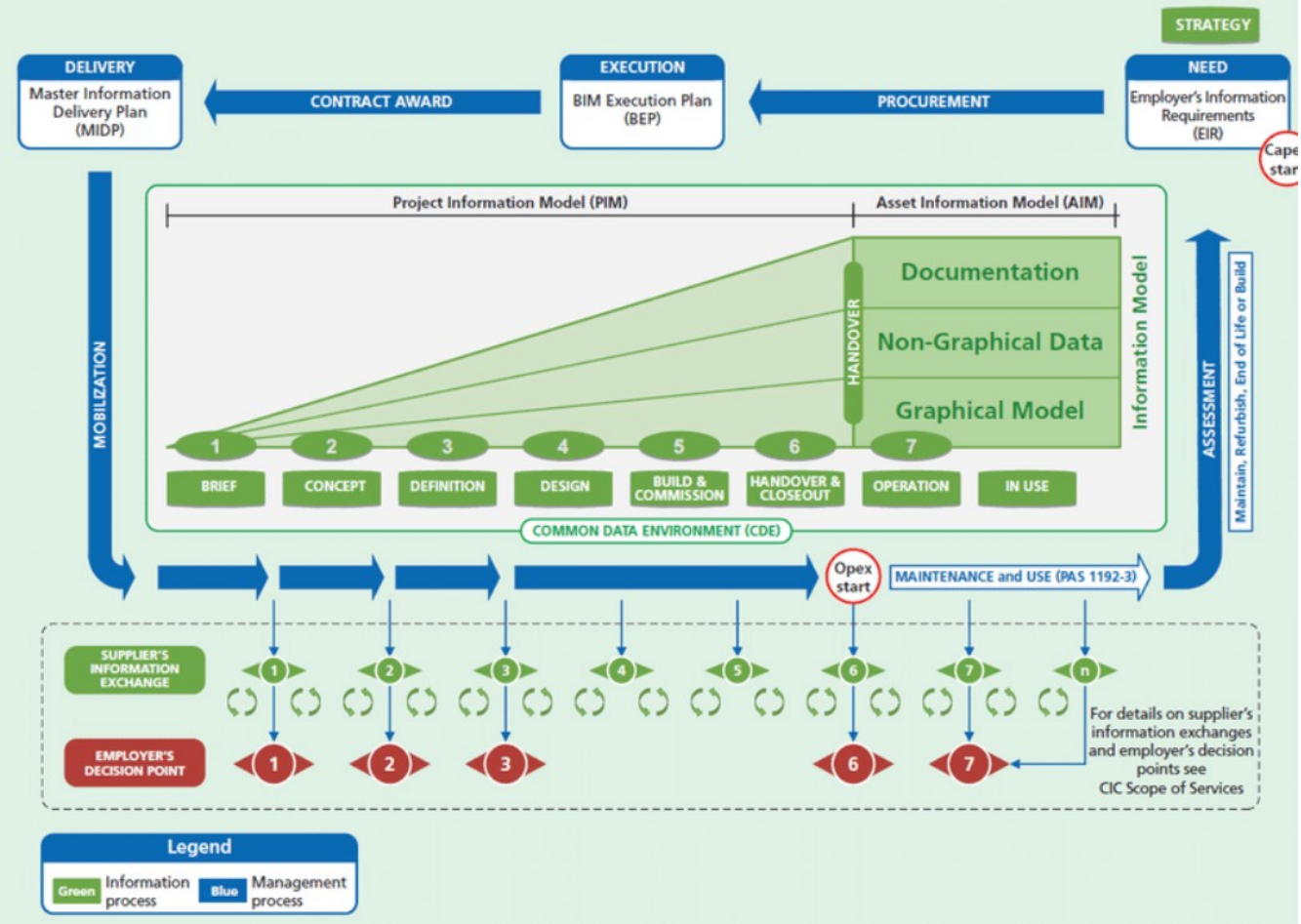

Image 1. Building Information modelling process based on PAS 1192.

3. BIM project objectives

- Understand client necessities,
- capture point cloud of the object,
- process point cloud and maintain accuracy (connection error < max. error),
- create 3D model based on point cloud with accuracy < 5 cm,
- maintain LOD – level of detail and LOI – Level of information according to client necessities,
- deliver the project to the client.

4. Main Project Levels

4.1. Gathering Information

- Gathering information (goals, budget, understating – BIM TABLE),
- Meeting with the client in order to understand project objectives. Gather information about location, type, size of the object. Fill Employer Information Requirements (EIR): accuracy, Level of Detail (LOD), Level of Information (LOI),
- analyse information – visit the site and object, point constrains, verify accessibility,
- goals which have to be achieved – special model representation, understand for what will be the model,
- tests (pass / fail) – check if the constraints can be omitted or solved e.g. access to the attic, access to the neighbour,
- return information to the client – talk with the client about constrains and try to solve it (get access to the rooms, covered elements),
- apply changes – add changes to the work plan.

4.2. Analyse information

- Capturing point cloud – Site visit, scanning in the scope of works,
- problems and solutions – no access to the ceiling and basement, another date with provided access,
- recapturing – return and capture point cloud with previous not accessible areas,
- testing point cloud accuracy and coverage – verify if the point cloud match with minimum connection by 3 faces (X, Y, Z) and if it is matching properly as a bundle. Process point cloud and check again alignment according to required accuracy.

4.3. Design, implementation and execution

- Choosing environment – and an environment was chosen Autodesk (Revit 2019 and Recap),
- planning, prioritizing process of modelling – Planning in plan toggle like a Trello (3 stages),
- execution of modelling process by stages – modelling walls, floors, roof etc.,
- test in the end of each stage (pass/fail) retest - goals to achieve, testing techniques like testing most important elements, defect clustering, better testing in high risk defect area, different testing techniques – plan cut, section cut etc.,
- modelling for the purpose of improvement,
- re testing / remodelling cycle.

4.4. Competition project and handover

- Handover v1 of model – feedback from the client,
- meeting with the client in order to confirm fit to use,
- regression testing and apply to the model improvements,
- handover v2.

4.5. Closure and competition of documentation

- Testing closure,
- gathering information about testing and process - which area were most vulnerable to defect, which testing technique was most efficient, which technique was less efficient, etc.,
- prepare testing documentation,
- create /change new steps in the process in order to improve it.

5. Execution of testing plan on the example of the as-build BIM project

5.1. Gathering Information

Subject: create parametric model of existing building close to Flower Street in Como in Italy.

Description: 2 floor family house with basement and attic. Plan of the main client is to extend usage area of the house, modify attic to storage and basement as a gym. Additionally extend area of 1st floor. Architects need to get information about walls, floors, columns, openings, windows and doors. Information was gathered in EIR table (attachment no. 1).
Accuracy error max. 5 cm on the element.
Level of details – LOD4 according to ISO 19650 BIM standard.

5.2. Analyse information

Building has prefabricated elements, doors and windows are in one similar type. Closets covers big part of the wall. No access to the attic – is necessary to create opening in the ceiling.
Testing of the requirements in order to eliminate errors in the early stage of the project.

Verification of the environmental condition:

- Revit version: 2019 – pass,
- attic access – fail – needs to be done opening,
- visibilities of columns – fail – needs to be provided access to the empty closets,
- approval of EIR – pass,
- approval of fee proposal – pass,
- required equipment for project – pass, all equipment is available.

5.3. Scanning and registration process

Report of the works status:

- Captured 92 scans,
- Opening of attic was not provided by client – is necessary to come back for recapturing date,
- Access to the basement was not provided by client – is necessary to come back for recapturing date,
- Captured 2 floors and outside area,
- Solution: set date with access to remaining areas provided by client.
- Coming back to the side on setted date and recapturing 24 scans stations more.

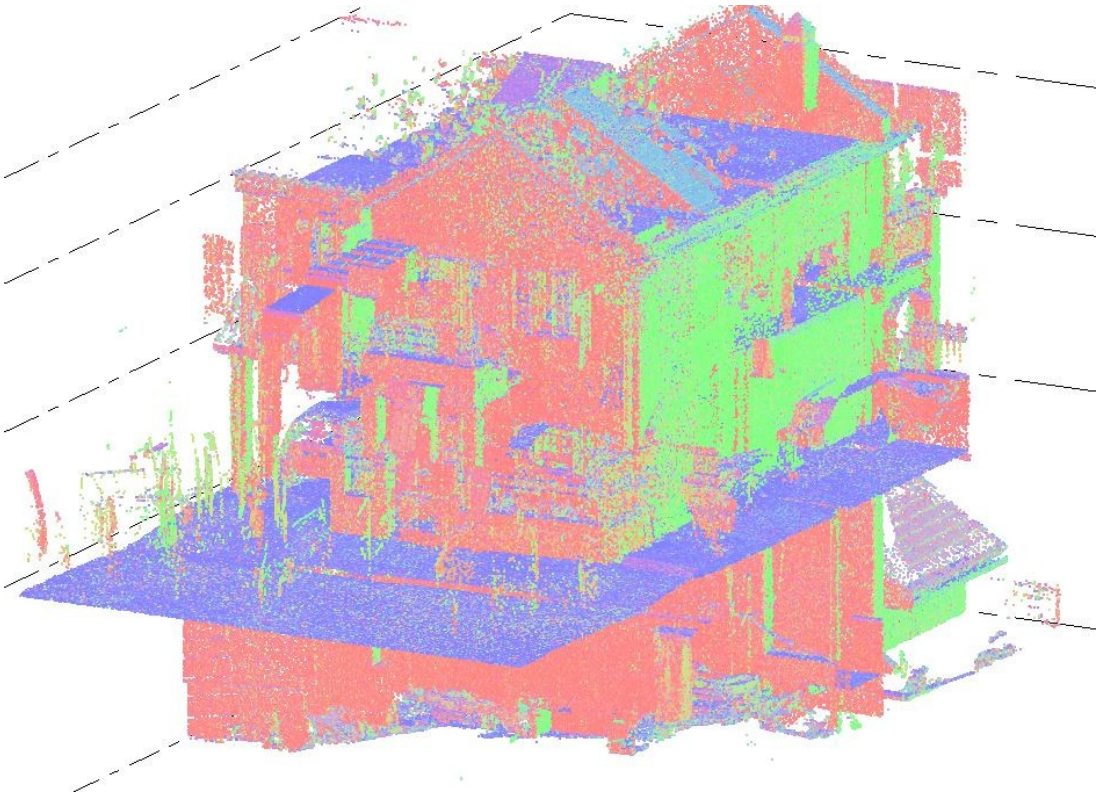

Image 2. Processed point cloud of the object.

Verification of point cloud registration:

- Pre alignment point cloud test: test – pass,
- Processing point cloud – alignment and removal of noise – test pass, alignment <1 cm accuracy.
- Test of connection min 2 each station = test pass.
- Test of coverage point cloud between stations 70 % - pass (is required min. 40% for alignment, all connections below need to be removed).

5.4. Planning of testing process and execution

In purpose of planning was used Trello application. Modelling was divided for 3 stages. Each stage characterize of level of importance. During first stage were modelled most important elements, which error on it can affect forward works. That means that First stage can affect Second and Second can affect of Third. Each stage is finished by testing of stage. This method allow minimizing errors on the high level stage which are provoked by low level stage. That can reduce time of fixing defects comparing to classical method (1 stage).

During testing, on each stage were used information from “CTFL-2018-Syllabus” converted to modelling testing.
Defect clustering – most errors of each stage of modelling are caused by wall defects. This area had the biggest importance of verification.

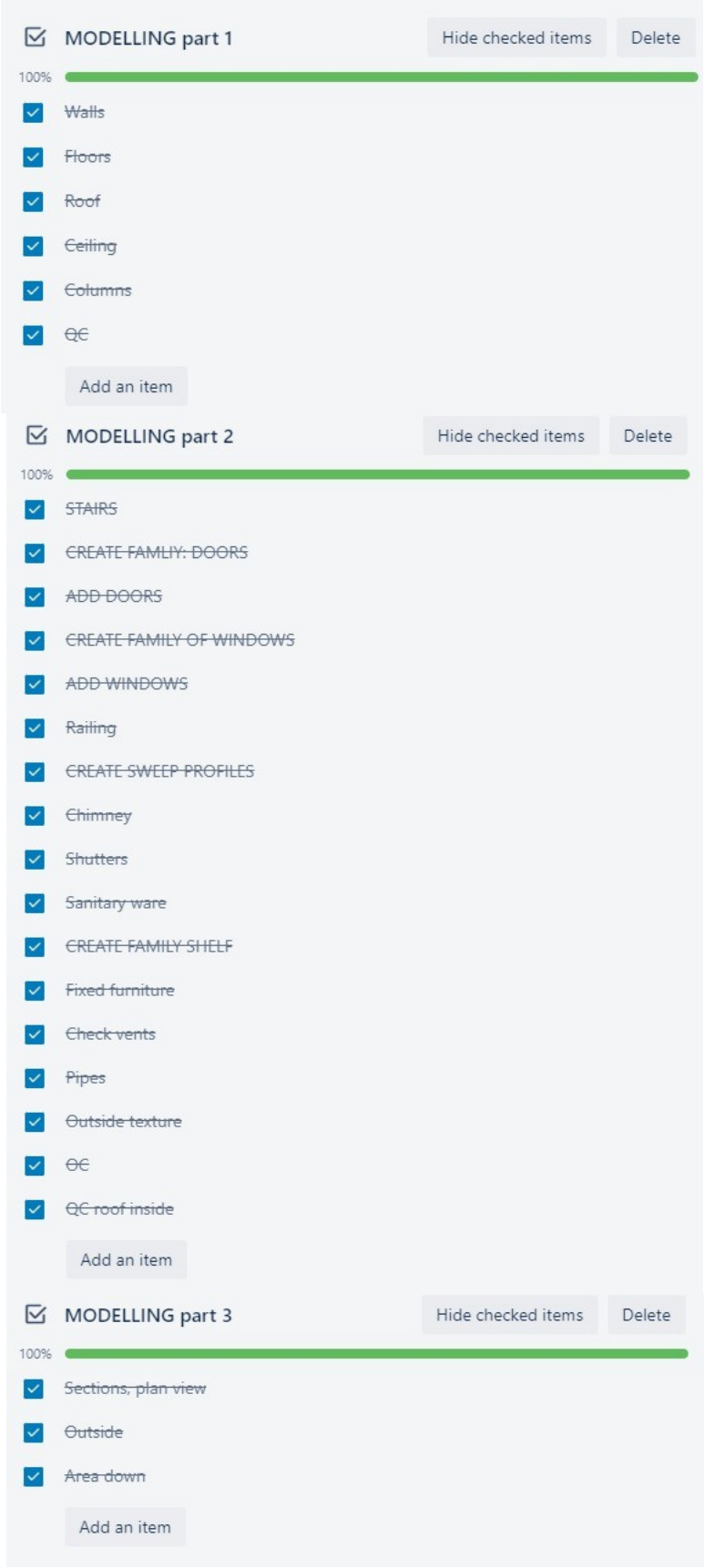

Image 3. Presented accomplished workflow on each stage in Trello app.

5.5. Project completion

While all necessary test cases are passed, project is ready for preparation to handover. On this phase, client is checking completeness of the model and if it is fit to use.

The model of the particular project was checked by client. In this case were found out defects related with fitting to use some particular elements which were not mentioned in EIR.

This particular client report and asked about changing families of some walls to columns based on previous construction plans. Information from laser scanning in not providing information about structures inside walls.

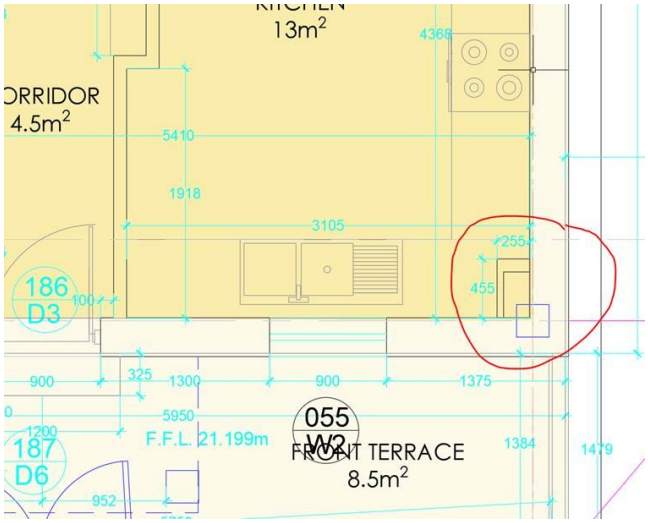

Image 3. Report of the error of column assignment.

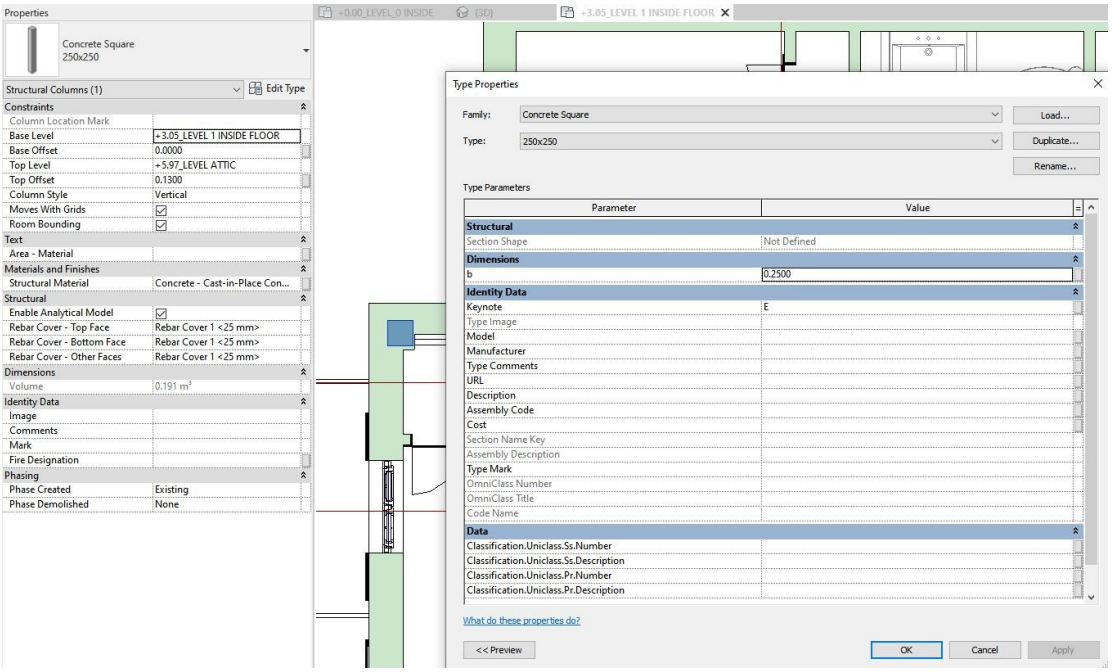

Image 4. Column properties.

Project has been updated, tested (passed tests – attachment 2 – Test case report) within required scope and handover again to the client passing acceptance of fit to use.

Image 5. 3D view of the model.

5.6. Gathering documentation and analyse post project data

Testing documentation has been collected (attachment 2) and analysed.

Following conclusion, were drowned:

- early testing helps to save time by reducing many defects on early phase of the project,
- walls geometry testing is one of the most important testing stages and has significant influence on all the project,
- early stage testing and assurance of understanding client necessities, has influence of final product quality and helps to pass acceptance testing. Revision by client on early stage can help to achieve goals of the project,
- testing of this particular as-build BIM project helped to reduce costs of the project about 34%,
- future project should be enriched about testing of accessibility to difficult areas, which can help to reduce time of measurements.

6. Attachments

- *Attachment 1 – BIM as build – Employer Information Requirements*
- *Attachment 2 – Test case report*
- *Attachment 3 – Image report*

7. References

- *ISO 19650-1:2018, Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles*
- *Foundation Level (CTFL) Syllabus,Version 2018 v3.1.1, International Software Testing Qualifications Board*
- *BS 1192:2007 Collaborative production of architectural, engineering and construction information. Code of practice.*